Final Technical Report

Site Investigation and Evaluation of Remediation Alternatives for the Vernon Briggs Site, Matagorda County, Texas

(RRC Site No. 03-50218)

Volume I—Technical Report

by

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1.0 EXECUTIVE SUMMARY

The Bureau of Economic Geology (BEG) investigated the Vernon Briggs site (RRC Site Code 03-50218) in Matagorda County, Texas, between June 1996 and August 1997. Historical data indicate that the site was used for disposal of oil-field wastes including waste drilling fluids. Disposal operations at one large bermed disposal area on site continued from 1981 to 1993. Contaminants identified at the site by BEG include petroleum hydrocarbons, chloride, metals, and naturally occurring radioactive material (NORM). The scope of the BEG study was to determine the extent and composition of the waste materials, identify other impacted areas to determine the effects on ground-water quality, and evaluate risk-based options for site remediation. This report presents the results of that work and recommendations for Railroad Commission of Texas (RRC) action at the site.

Remedial standards used in this assessment include disposal criteria from the RRC and the Texas Natural Resource Conservation Commission (TNRCC) (1996); health-based standards (U.S. EPA, 1996a, b; TNRCC, 1998), and other guidance, such as secondary maximum contaminant levels (U.S. EPA, 1996b).

The waste materials are predominantly waste drilling fluids from oil-production sources. They are confined within berms at the site and are underlain by at least 5 ft of clay from the Beaumont Formation. Some surface outwash of the wastes has occurred, impacting soils in a bermed outwash area on site. Electromagnetic (EM) surveys at the site indicate that there is negligible impact to offsite soils or ground water from chlorides in the wastes. One exception is a zone of elevated conductivity immediately beneath the waste, which extends to a depth of at least 26 ft. Petroleum hydrocarbon concentrations in the waste averaged 0.92 percent. Chloride concentrations averaged 6,600 mg/kg. Metals detected at concentrations above action levels for landfill disposal were chromium and lead in the waste materials and in soils in a portion of the outwash area. The wastes exhibited low TCLP potentials for organic compounds and metals, indicating that they can be disposed of as nonhazardous wastes. Concentrations of these compounds in soils did not exceed health-based criteria.

Movement of constituents from the waste materials to surface and ground waters appears to be limited, judging from sampling results. The hydrologic gradient of shallow ground water at the site, which probably varies seasonally and with pumping of water from sand pits, differs from the historical, regional gradient in the deeper aquifer unit. The constituents detected above regulatory guidelines in onsite ground water were cadmium, lead, and chloride. No petroleum hydrocarbons were detected above MCL's or other regulatory guidelines in the onsite ground water. Although some constituents (TPH, cadmium, lead, and naphthalene) were detected at low levels in offsite ground-water samples, pathways to the offsite wells appear to be incomplete and the constituents most likely are related to offsite sources. Because of the depth of most local domestic supply wells and the presence of confining or semiconfining zones in the Chicot and Beaumont aquifers, the likelihood of the site having had an impact within the underlying aquifer at these locations appears to be low.

As a conservative approach a Plan B risk analysis was performed for constituents of concern at the site. The Plan B analysis allows for modeling of possible offsite ground-water impacts. Arsenic, cadmium, chromium (III and IV), ethylbenzene, xylenes, naphthalene, and fluorene were modeled as constituents of concern. No cumulative pathway (sum of all exposure paths) risks were found to exceed limits recommended by the TNRCC. A separate comparison of lead, selenium, and representative petroleum hydrocarbons with health-based criteria for soils and water indicated no excess risk from petroleum hydrocarbons for soil/waste exposure. Although lead in offsite wells is a concern, the source is potentially the plumbing systems of the residential wells and not oil and gas exploration or production activities.

Monitoring of existing and new onsite wells is recommended to determine whether remediation is justified to reduce the potential for ground-water and surface-water impacts associated with elevated chloride concentration in waste materials. If remediation is deemed necessary, capping of the waste materials may be a cost-effective alternative to excavation and disposal or other treatment options. Capping would also eliminate the physical hazard of the soft waste materials. Additional wells can be phased in and positioned on the basis of interim monitoring results.

2.0 INTRODUCTION

The Railroad Commission of Texas (RRC) has statutory responsibility under S.B. 1103 (72nd Legislature, 1991) for oversight of cleanup of abandoned oil-field sites throughout Texas. Since 1991, RRC personnel have identified and inventoried abandoned oil-field sites as candidates for cleanup. The RRC ranked sites by giving priority to contaminated sites that have had observable releases, occur in ground-water recharge zones with high soil permeability, lie near surface-water bodies or water-supply wells (or both), have high public profile and have received complaints, and lie near population centers.

The Bureau of Economic Geology (BEG) is providing extensive site investigations for the RRC under interagency contract 94-0423. The purpose of these investigations is to provide the required information for planning and executing the appropriate level of remediation at priority sites.

The Vernon Briggs site in Matagorda County (RRC Site Code 03-50218) was formerly used as a disposal pit for oil-field wastes such as salt water, drilling fluids, and oil-based drilling materials. Potential site contaminants include petroleum hydrocarbons, salts, metals associated with drilling practices such as barium, and unknown contaminants that may have been released while the site was uncontrolled, such as metals, PCB's, or pesticides. This report describes the investigation performed at the Vernon Briggs site and recommendations for remediating that site.

The principal tasks performed for this investigation were: (1) determination of the extent and composition of the solid waste materials present on each site; (2) identification of potentially impacted areas, such as surface soils or surface water, via sampling and geophysical survey methods; (3) installation of ground-water monitoring wells to determine the effects on ground-water quality as influenced by the site; (4) sampling of local domestic wells to determine potential influence by the site on local water quality; and (5) evaluation of risk-based options for site remediation and closure. A thorough review of the RRC case files was performed between June 1996 and March 1997. A site reconnaissance visit was made to the site by BEG personnel in March 1997. The site investigation was performed from April through August 1997.

An assessment of risk to human health and the environment as posed by the site is included in this report (Section 5.0). Although wastes from oil and gas production are exempt from most hazardous material assessment requirements, this section has been included to address possible concerns about local impacts from the site. Generally this assessment follows risk-based corrective action (RBCA) guidance from ASTM E-1739 and the proposed Texas Risk Reduction Program (TNRCC, 1998). This guidance was developed for petroleum release sites, such as leaking underground petroleum storage tanks (PST's) or pipelines, but was also found to be relevant to abandoned oil-field sites. The site was evaluated with a Plan B assessment (TNRCC, 1998), which includes evaluation of exposure to offsite ground-water receptors in the site-evaluation process and allows for adjustment of onsite worker exposures. This level of assessment is conservative and protective of human health and is intended to be used as guidance only for recommendations for site remediation and not as a detailed assessment of actual risks that may arise from this site. It is important to note that this abandoned oil-field cleanup site is not subject to regulation by the TNRCC.

The preceding work was performed specifically to address the presence of oil- and gas-industry-generated wastes at the Vernon Briggs site. Other wastes that may exist, including trash piles or scrap metal, were considered to be beyond the scope of this investigation and were not evaluated. This site investigation is intended to provide information pertinent only to recommendations for remediation of the site from any impacts of oil- and gas-industry wastes.

2.1 Site Description

The Vernon Briggs site is located 4.5 mi east of Bay City in Matagorda County, Texas, just west of FM 2540 (Live Oak Rd.). It is shown on the Bay City N.E. USGS 7.5-minute quadrangle, where it is located 0.75 mi south of the intersection of FM 2540 and FM 457 (fig. 2.1). The site is immediately adjacent to an operating sand quarry owned by Mr. Kenny Hales. The property was part of that operation under the former owner, Mr. Vernon Briggs. It includes an unvegetated raised pad, which was the waste disposal area, a vegetated outwash area to the south of the pad, and a vegetated low area to the south of the overflow area. There are no structures currently on the site, and the site is not fenced (fig. 2.2).

Regional topography within 1 mi of the site is nearly flat, typical of the coastal-plain setting. Manmade ditches, berms, ponds, and levees are the main topographic features. Approximate elevation of the site is 40 ft above mean sea level (msl). The sand quarry operation includes two deep pits, one to the east and one to the northeast of the site (fig. 2.2). Surface water stands in these pits at approximately 10 to 15 ft below typical site grade and is an expression of the shallow ground-water level.

Land use to the south of the site is agriculture (rice field). To the west is agricultural land currently used for cattle grazing. To the east are the quarry operation, grazing land, and some home sites. To the north and northeast are the quarry operation, ponds, grazing land, and home sites.

BEG personnel visited the Vernon Briggs site on March 6, 1997, to investigate the site conditions. The waste-disposal area, which is approximately 450 ft × 600 ft, was once a bermed pit but is now a pad with patchy vegetation and efflorescent salt deposits, elevated approximately 5 to 10 ft above the surrounding land surface to the north and east (fig. 2.2). The pad material is fairly soft, although it is firm enough when dry to support foot traffic but not vehicles. Drainage is to the south, toward the bermed area. Mr. Hales indicated that the pad is relatively isolated from human traffic now but that livestock occasionally have become mired in the softer areas. He also stated that Mr. Briggs is now deceased and that his estate owns the disposal-site property. Property

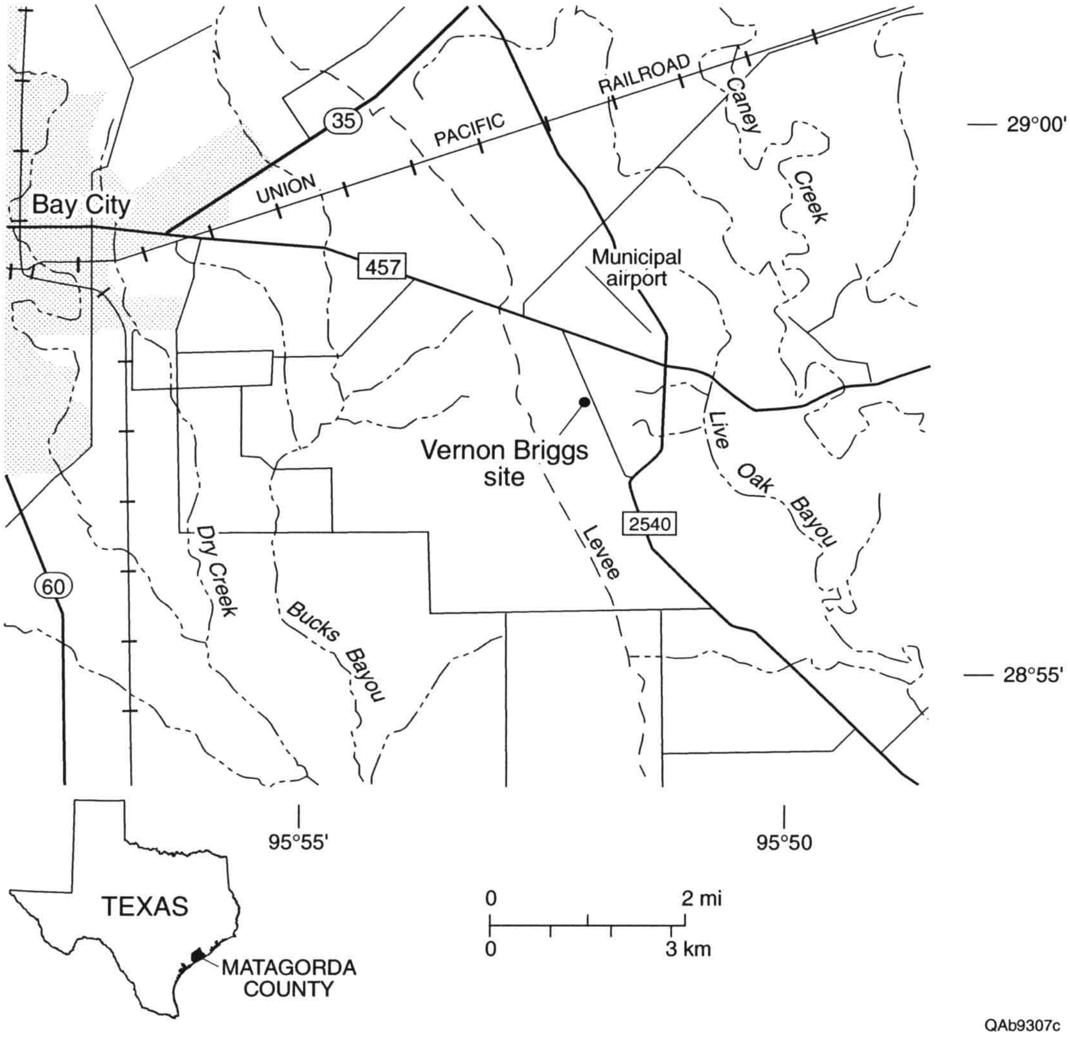


Figure 2.1. Location of the Vernon Briggs site, Matagorda County, Texas.

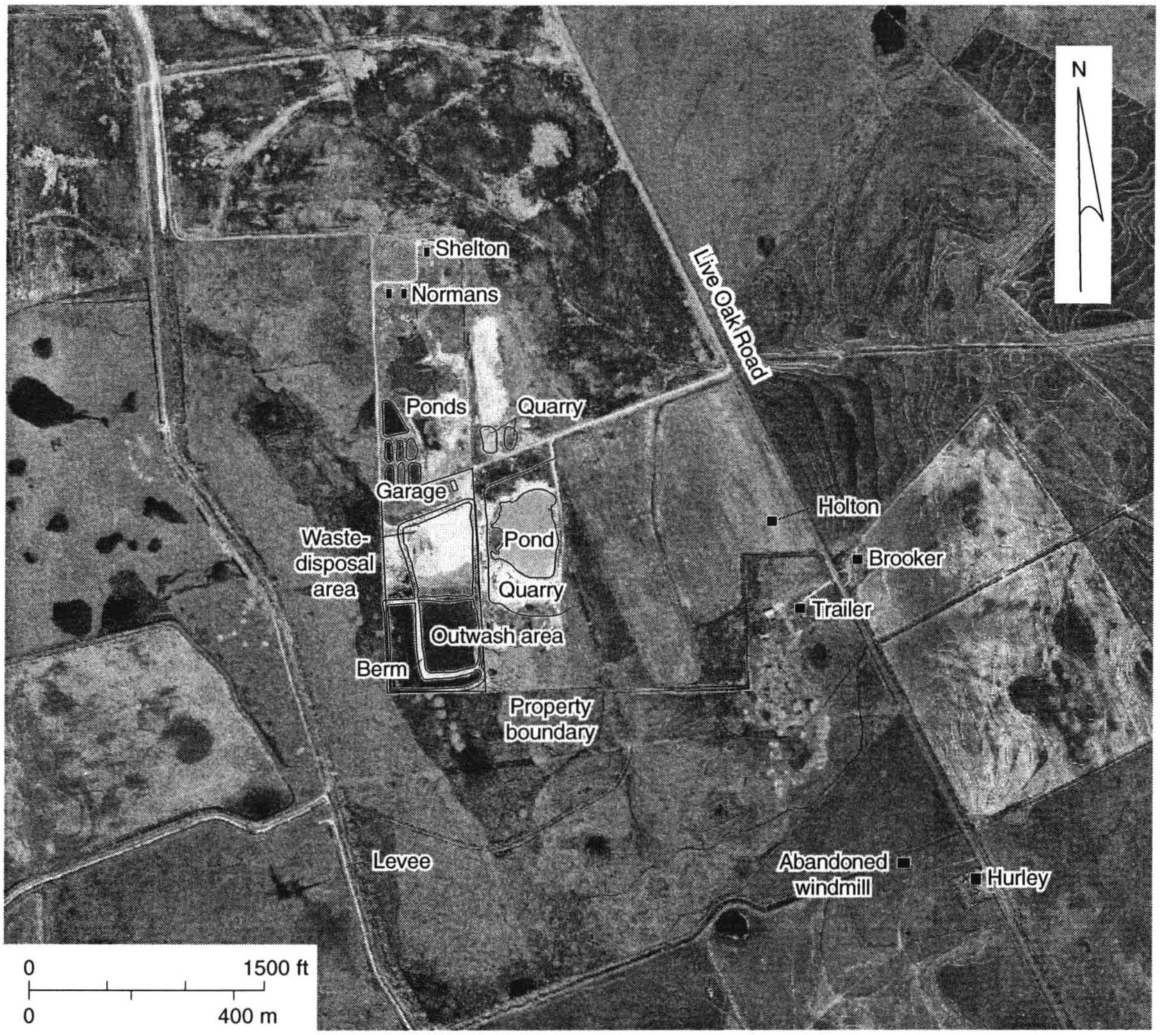


Figure 2.2. Layout of the Vernon Briggs site, showing surrounding property use, domestic wells, and property boundaries.

plat boundaries are shown in figure 2.2. Mr. Hales owns the adjacent garage and 20 acres for the quarry operation. According to Mr. Hales, the disposal operation was not closely supervised (Mr. Kenny Hales, personal communications, July 1997).

The pad material was inspected by BEG personnel. A brown soil-like material was noted on the surface, whereas gray drill mud-type material was noted about 4 inches below the surface. Minor oily zones and a petroleumlike odor were also observed in the below-surface material. There was no visible evidence of oil seepage in the quarry, although there were some small oil seepage areas on the east edge of the old disposal-area berm. The outwash area to the south is heavily vegetated, as is the marshland area beyond that. Runoff from the site flows to the outwash area, then to the marshland area and a ditch that runs from the east, around the south side, to a creek. There was no visible indication of oil, salt, or barren areas in either the outwash or marshland area. There were no areas of other types of wastes, such as trash or scrap metals, visible on the pad or in the outwash areas.

2.2 Site Geology

The Vernon Briggs site lies on the Pleistocene Beaumont Formation, which is composed of clay, silt, and sand deposited in various environments including fluvial meanderbelt flood basins, crevasse splays, levees, deltas, barrier bars, and lagoons (Aronow and others, 1975). A sand pit adjacent to the site confirms that this is an area of Beaumont fluvial sand and silt (McGowen and others, 1976). Abandoned channel facies and modern fluvial architecture appear to be extensive in this area (McGowen and others, 1976). The Beaumont Formation dips to the southeast toward the Gulf of Mexico at 1.5 to 5 ft per mi (0.3 to 0.95 m per km) (Solis, 1981). Near the site, the Beaumont forms an upland area between the abandoned valley of the Colorado River, now occupied by Caney Creek, and the modern Colorado River valley.

Soils in the area are mapped as the Telferner–Edna–Cieno assemblage. Telferner and Edna soils are fine sandy loams with moderate and somewhat poor drainage, respectively. Cieno soils are hydric, typically containing a perched water table at the surface.

Large oil fields in the area produce from reservoirs in and around piercement salt domes and from Oligocene-age Frio barrier-plain sandstones. Typical field-discovery dates in the area are between 1918 and 1946.

2.3 Site Hydrology

2.3.1 Surface Water

The nearest naturally occurring surface-water body to the site is Live Oak Bayou, which flows north to south and is located approximately 1 mi to the east. Less than 5 mi to the west is a canal that is also oriented north to south. Flow in the canal is toward the south. Surface water adjacent to the site occurs in a series of six manmade ponds approximately 200 ft to the north, in a quarry pit that lies approximately 50 ft to the east (dimensions of approximately 300 × 225 ft), and a quarry pit that lies approximately 200 ft to the northeast (dimensions of approximately 200 × 150 ft). The submerged area and water depth in the quarry ponds varies because of pumping, which is performed to uncover the sand unit below the water. The depth of water in the quarries, however, is usually shallow (about 1 ft or less). Water from the pumping is regularly discharged to the northern ponds, to roadside ditches, and to the outside of the berm on the south part of the site. The site operators have measured as much as 1 ft of elevation difference between the two quarry ponds during pumping (Mr. Kenny Hales, personal communication, July 1997).

Two berms enclose the south half of the site area. These berms retain site runoff water and keep irrigation water from adjacent fields outside the berms. Land within the berms supports wetland plants for part of the year and was partially submerged during the period of March through June of 1997, after which it was dry. The National Wetlands Inventory map for the area lists the site as an upland area with no delineated wetlands (Department of the Interior, 1995). The flood insurance rate map classifies the site area as an area of minimal flooding (FEMA, 1985).

2.3.2 Ground Water

The aquifer hosted by the Beaumont Formation and underlying units is described as the Gulf Coast aquifer and is part of the Coastal Lowlands aquifer system (Williamson and others, 1990). Dutton and Richter (1990) and Baker (1979) divided the upper portion of the Gulf Coast aquifer in this area into the Beaumont Formation, the upper Chicot, and the lower Chicot and Evangeline aquifers (fig. 2.3). Regional flow in the Chicot and Evangeline is from recharge zones in the northwest to discharge areas along the coast to the south and southeast. Predevelopment heads in the Chicot and Evangeline were estimated to be approximately 25 to 50 ft (~7.6 to 15.2 m) above msl, with vertical upward flow responsible for between one-third and one-half of the Beaumont Formation recharge. Hydraulic head declined to 0 ft msl in the area after 1980 (Williamson and others, 1990). Historically, most wells in the county have been screened at depths from 100 to 600 ft below ground surface (Hammond, 1969).

Dutton and Richter (1990) noted that although the Beaumont Formation is commonly considered an aquitard, the unit contains sand and silt and is locally a ground-water source. Sand percent in the site area is mapped as 20 to 40 percent (Dutton and Richter, 1990). A 10-to 12-ft-thick clay unit of the Beaumont exists at land surface at the site. Beneath this is a clean sand unit of the Beaumont, which is the unit mined locally for sand. Total sand thickness was not determined. Other major sand units exist locally at depths from 80 to 90 ft and at 250 and 300 ft, according to reports from local domestic well owners. The upper sand is the uppermost aquifer unit that is continuous beneath the site and is the focus of this study. It is likely that hydraulic heads in this aquifer unit are strongly influenced by quarry dewatering operations adjacent to the site. Other influences may arise from rice irrigation on the property to the south.

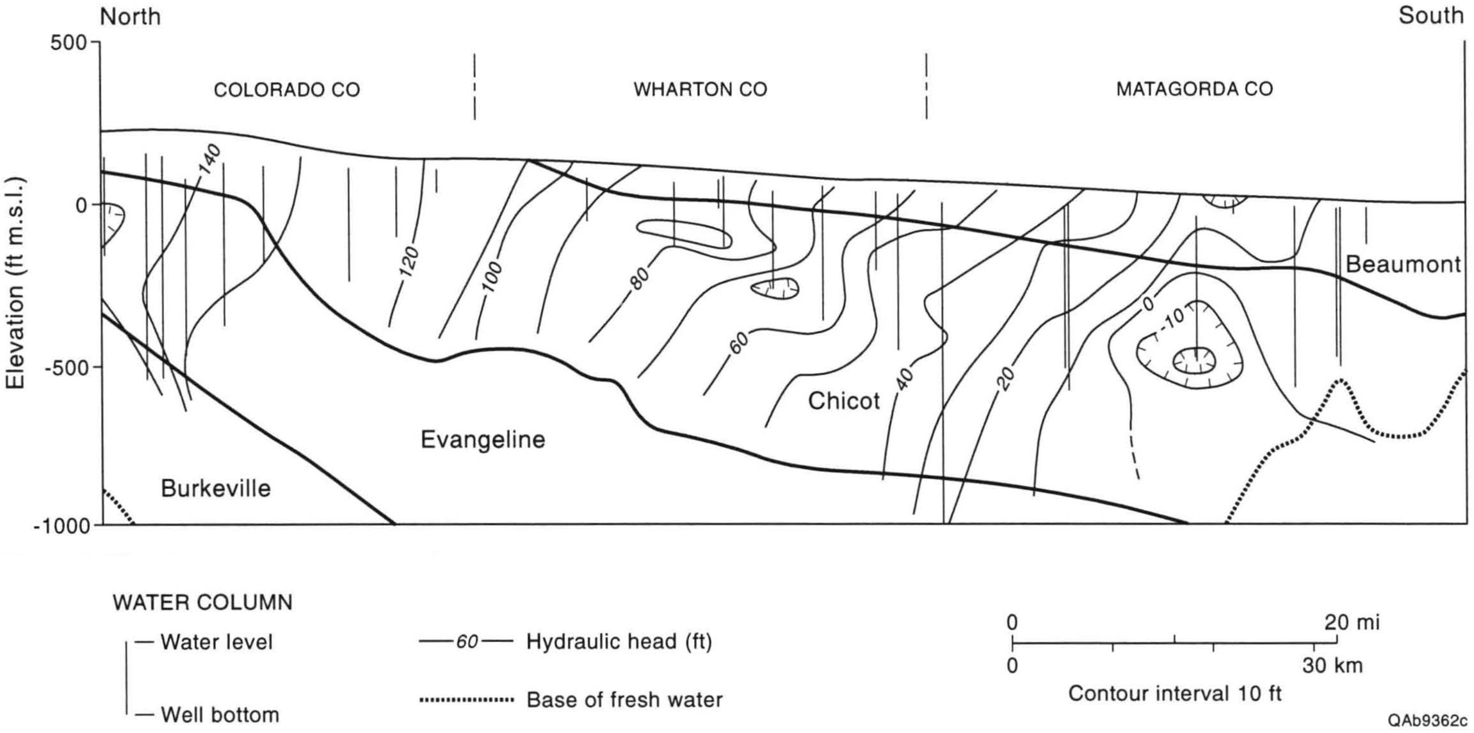


Figure 2.3. North-south dip cross section of the Gulf Coast aquifer section crossing Matagorda County.

Regional information indicates that the horizontal gradient in hydraulic head in the lower aquifers is to the southeast (Dutton and Richter, 1990; Williamson and others, 1990; Dutton, 1994). The vertical gradient in the lower aquifers historically has been upward; however, this may be changed by pumping in the region around Bay City. Regional data indicate that the gradient in the Beaumont also is to the southeast. This appears to have been locally affected by pumping in the quarries and by rice-field irrigation near the site, however, and the measured gradient is now apparently to the northeast beneath the site (see Section 4.4.1). Water levels in the uppermost aquifer unit of the Beaumont do not extend above the bottom elevation of the uppermost clay unit in the area beneath the site, indicating that shallow ground water at this location is unconfined (see Section 4.4.2).

Water chemistry in the Beaumont Formation near the site is mapped as Na-Cl and mixed-cation-HCO_3 (Dutton, 1994). Total cations and anions were analyzed for all ground-water sampling points. Ion balance data were calculated for ground-water samples from the site and are shown in Section 4.4.

2.4 Site History

Mr. Vernon Briggs received a permit to maintain an unlined pit for the disposal of fresh-water-based drilling mud on August 17, 1981. RRC records (1993) indicate that more than one pit may have existed on the site at one time, although no evidence was found to verify this fact during the site investigation. Complaints about the site initiated RRC involvement (RRC Phase I environmental assessment, May 28, 1993). Although Mr. Briggs was directed on July 29, 1994, to initiate cleanup, none was performed and the site was listed for State-funded cleanup in December 1994 (Memorandum from Guy Grossman to Peggy Gray, RRC Legal Enforcement, December 21, 1994).

In 1993, oil and oil-stained soils were visible during site visits by RRC personnel. “Sludge” samples taken on May 17, 1993, by RRC indicated as much as 6.5 percent oil and grease, 4.5 percent TPH, and barium TCLP (Toxicity Characteristic Leaching Procedure) of 1.89 mg/L. The site was described in RRC records as abandoned and a candidate for cleanup. RRC noted that the site was very "accessible and could be used for illegal dumping" (RRC Phase I environmental site assessment, May 28, 1993). The current quarry owners monitor site access closely. Hearsay reports (RRC Phase I environmental site assessment, May 28, 1993) indicated a possibility of barge waste being dumped, which was corroborated by Mr. Robert Hurley (personal communication, July 1997), who noted that caustic barge-cleaning waste may have been dumped at the site. No other documentation referring to this waste was found in RRC records. No evidence of caustic or other anomalous waste, however, was found during this investigation.

3.0 METHODOLOGY

A combination of nonintrusive techniques, such as surface geophysical methods, and invasive techniques, such as monitoring well installation, were used to assess environmental media at the Vernon Briggs site. These methods, described later, were used to characterize both chemical and physical properties of these media and to determine the potential extent of contamination therein.

3.1 Geophysics

3.1.1 Surface Geophysics

Electromagnetic induction (EM) line surveys were used to delineate areas of potential salt contamination in soils surrounding the waste-disposal area and to determine lateral and vertical trends in conductivity related to salt water in subsurface soils and ground water. Survey lines were run at coil separations of 10, 20, and 40 m (32.8, 65.6, and 131.2 ft) between the transmitter and receiver coils and two coil orientations (horizontal and vertical dipole) using the Geonics EM 34-3 meter. The effective penetration depth was 19.7 to 82 ft (6 to 25 m) for the horizontal dipole orientation and 39.4 to 164 ft (12 to 50 m) for the vertical dipole orientation. Station spacing was 32.8 ft (10 m) for each of the coil separations.

Conductivity values represent “bulk” conductivities, or an average conductivity of the soil volume beneath the transmitter and receiver coils, and are plotted on profiles and on maps at the midpoint between the transmitter and receiver coils. Values obtained from the horizontal dipole orientation are weighted by the conductivity of the uppermost third of the exploration depth. The vertical dipole orientation has a deeper exploration depth, and the values are weighted by the conductivity of the middle third of the exploration depth. Inferences about potential leakage from the waste disposal area and transport in ground water can be made from any detected plume geometry and hydraulic gradient and are discussed in Section 4.1. Soil and ground-water sampling data (Sections 4.3 and 4.4), as well as borehole geophysical data (Section 3.1.2), were used to confirm results of the survey.

3.1.2 Borehole Geophysics

The Geonics EM 39 borehole logging tool was used to measure apparent ground conductivity surrounding the monitoring-well boreholes and a single borehole placed on the berm near the center of the site area. This instrument detects changes in apparent ground conductivity related to lithology (clay versus sand, for example) as well as changes due to salt contamination. It functions similarly to the EM 34-3, except that the transmitter and receiver are contained in a single probe for downhole use. Measurements are insensitive to the presence of PVC borehole casings, sand pack, and grout. The monitoring wells were located so that the EM 39 logs could be closely correlated with the surface EM 34 readings. Results are shown and discussed in Section 4.1.

3.2 Global Positioning System Survey

Global positioning survey (GPS) data, compass bearing and distance, and aerial photography data were combined to generate preliminary maps for the Vernon Briggs site. Positional data were organized, evaluated for accuracy, and then transferred to ArcView Geographic Information System (GIS) software. A GIS data base was then developed for the site. Computer-scanned vertical aerial photography of each site was georeferenced and mathematically corrected for distortion. These images were then imported into a layer in the GIS. The photographs serve as a backdrop to the site maps and allowed the on-screen digitizing of features not measured in the field, such as roads and buildings. When available, property boundaries from plat maps were added electronically to the GIS files. These plat data were not field checked and are provided for information only.

3.3 Sampling Methods

3.3.1 Probing/Hand Coring

The surface of the waste-disposal area within the surrounding berms was divided into 18 100- × 100-ft grid spaces, and samples were extracted from each grid point. Sample locations are shown in figure 3.1. A graduated steel probe was used to measure the penetrable thickness (approximately 8 ft) of the waste materials at each sampling point. Continuous cores were extracted from the surface to the base of the waste material using a clear polyvinyl chloride (PVC) piston (suction) corer. Each sample was extruded onto plastic sheeting, logged, and photographed. Cores were composited across the full core length of 7 ft or less, with the exception of the top foot of material, which was sampled separately because of differences in texture and apparent composition. No natural soil material samples were analyzed from beneath the waste because of insufficient sample recovery. Each sample was composited in a stainless steel bowl, placed in precleaned glass containers, and shipped on ice at 4°C. All samples were analyzed for total petroleum hydrocarbons (TPH), chloride, electrical conductance (EC), and moisture. Selected samples were analyzed for RCRA 8 metals. Two samples from the central part of the waste disposal area were selected for analysis of total organic halogens (TOX), semivolatile polynuclear aromatic hydrocarbons (PAHs), volatile organic compounds (VOC's), pesticides/PCB's, and

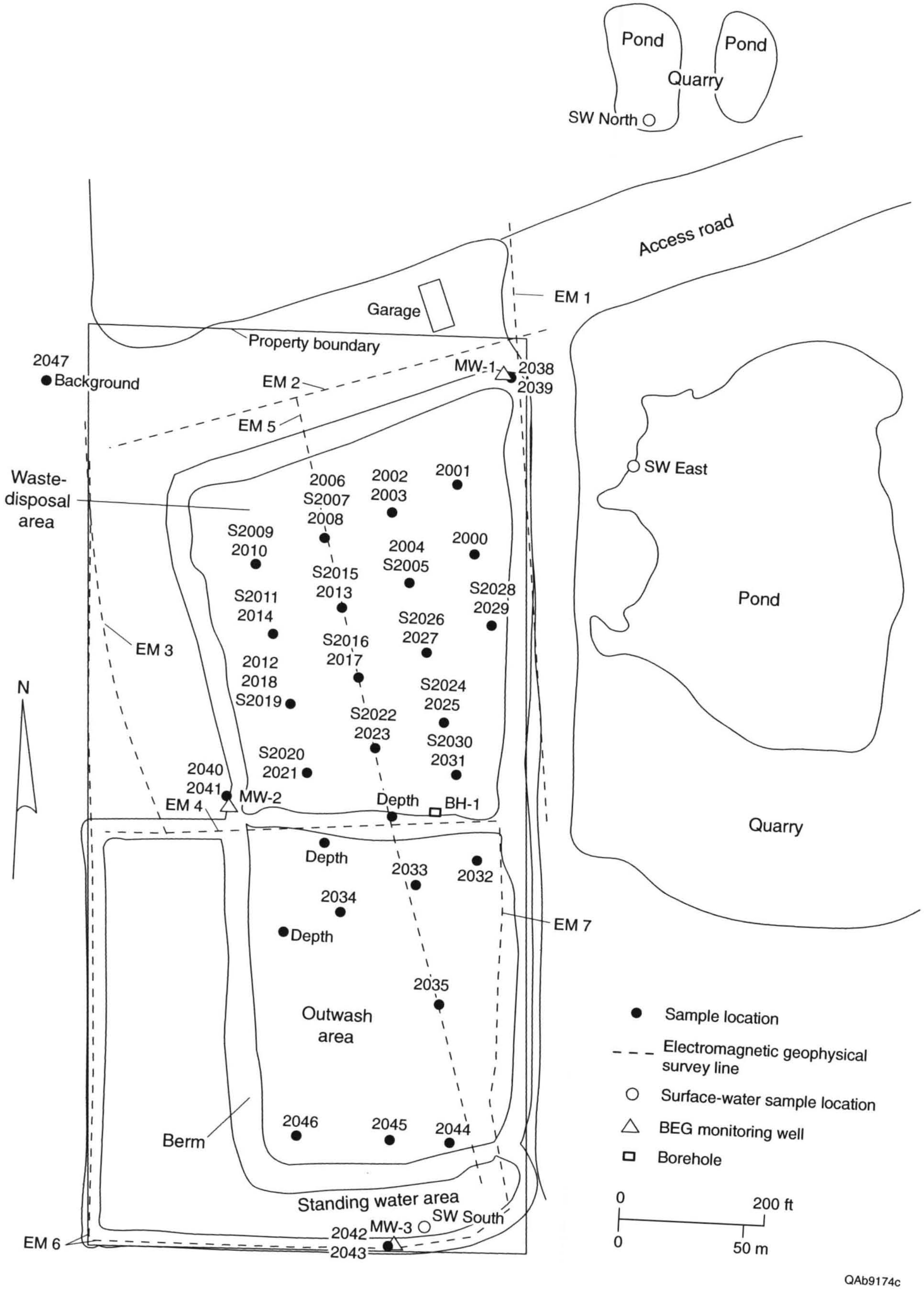


Figure 3.1. Sample locations, Vernon Briggs site.

toxicity characteristic leaching procedure analytes (TCLP), which include VOC's, semivolatile organic compounds (SVOC's), leachable metals, reactivity, corrosivity (pH), and ignitability. One sample was also analyzed for additional landfarm parameters, including potassium, zinc, copper, nickel, total nitrogen, nitrate, ammonia nitrogen, and phosphorous. The sample for VOC's was not composited but was extruded directly into the sample container. Samples were analyzed by either Chemsolve or the RRC Surface Mining and Reclamation Laboratory.

Eight surface-soil samples were taken in the outwash area on the south side of the site. A decontaminated shovel was used to excavate a soil column at 0 to 2-ft depth at each location. A soil sample from this column then was composited in a stainless steel bowl, placed in a precleaned glass container, and shipped on ice at 4°C for analysis of TPH, chloride, EC, and moisture. All samples were received and analyzed at the laboratories within maximum holding times.

3.3.2 Soil Borings and Monitoring-Well Installation

One deep soil boring and three monitoring-well borings were drilled by Master Monitoring Services, Inc., of Houston, Texas, using 7-inch hollow-stem augers on a "buggy"-mounted Mobil B-57 drilling rig. Cores were taken simultaneously by a 5-ft-long detachable rod-mounted core barrel. The drill rig, augers, and all drilling equipment were decontaminated before drilling and between boreholes by a high-pressure steam cleaner. The borehole (BH-1) was backfilled with a 2-percent bentonite-grout mixture after an EM 39 downhole log was completed. Monitoring wells were constructed of nominal 2-inch I.D. PVC casing with a 0.010-inch slotted screen, sand-packed using clean, 20/40 silica sand, and sealed with Hole-Plug brand 100-percent bentonite pellets and 2-percent bentonite-cement grout. Potable water was added to the hole during installation of the well casings. An analysis of this water for volatile organic compounds (BTEX and MTBE, sample number 2047, Appendix B) indicated no volatile compounds in the added water. Monitoring wells Nos. 1 and 2 (MW-1 and MW-2) were completed with a 4 inch × 4 inch × 4 ft long steel protector casing with a minimum 2-ft stick-up and a 4 ft × 4 ft × 4 inch concrete pad.

Well No. 3 (MW-3) was completed in a flush-mounted manhole cover with a similar pad, to allow for truck access along the berm road. All wells were equipped with a sealed internal cap and a protective padlock. Figure 3.2 illustrates the monitoring-well construction data. Wells were developed to visual clarity (1 h of pumping per well at approximately 5 gpm). Details of well-completion data are shown in table 3.1. Boring logs and well-completion diagrams are provided in appendix A. Results of the boring and monitoring-well sampling are discussed in Sections 4.2 and 4.3.

3.3.3 NORM Survey and Surface Sampling

A NORM scintillater survey for naturally occurring radioactive material (NORM) was performed on the waste-disposal area surface and waste cores by Mark Osterman of the RRC Houston office. Natural background at the site was 7 to 9 μR/hr. None of the waste core samples exhibited elevated readings. The surface contained an area that exhibited elevated NORM scintillator readings at twice the background level or greater. The highest surface readings were 100 μR/hr and 95 μR/hr in two locations. The area was delineated and fenced, and two grab samples (numbers 2036 and 2037) of the highest-reading material were submitted for analysis (American Radiation Laboratories, Baton Rouge, LA). Both samples were taken from the top 6 inches (15 cm) of the waste within a 6-inch radius. The samples were analyzed for isotopes of radium (Ra-226 and Ra-228) and lead (Pb-210) and for total activity. Results are discussed in Section 4.3, and sample locations are shown in figure 4.8.

In addition to samples collected from the highest NORM areas, two composite samples, one from the 150 ft × 100 ft rectangle surrounding this area (sample number 2200) and one from the entire site (sample number 2201), were also analyzed. Each composite was taken in accordance with Texas Department of Health guidance (C. Cardwell, personal communication, August 14, 1997; 25 TAC Sect. 289.127; TRCR Part 46; BRC regulating guide 5.10). The composites are made up of five equal-volume samples of material from the top 15 cm of soil, one sample from

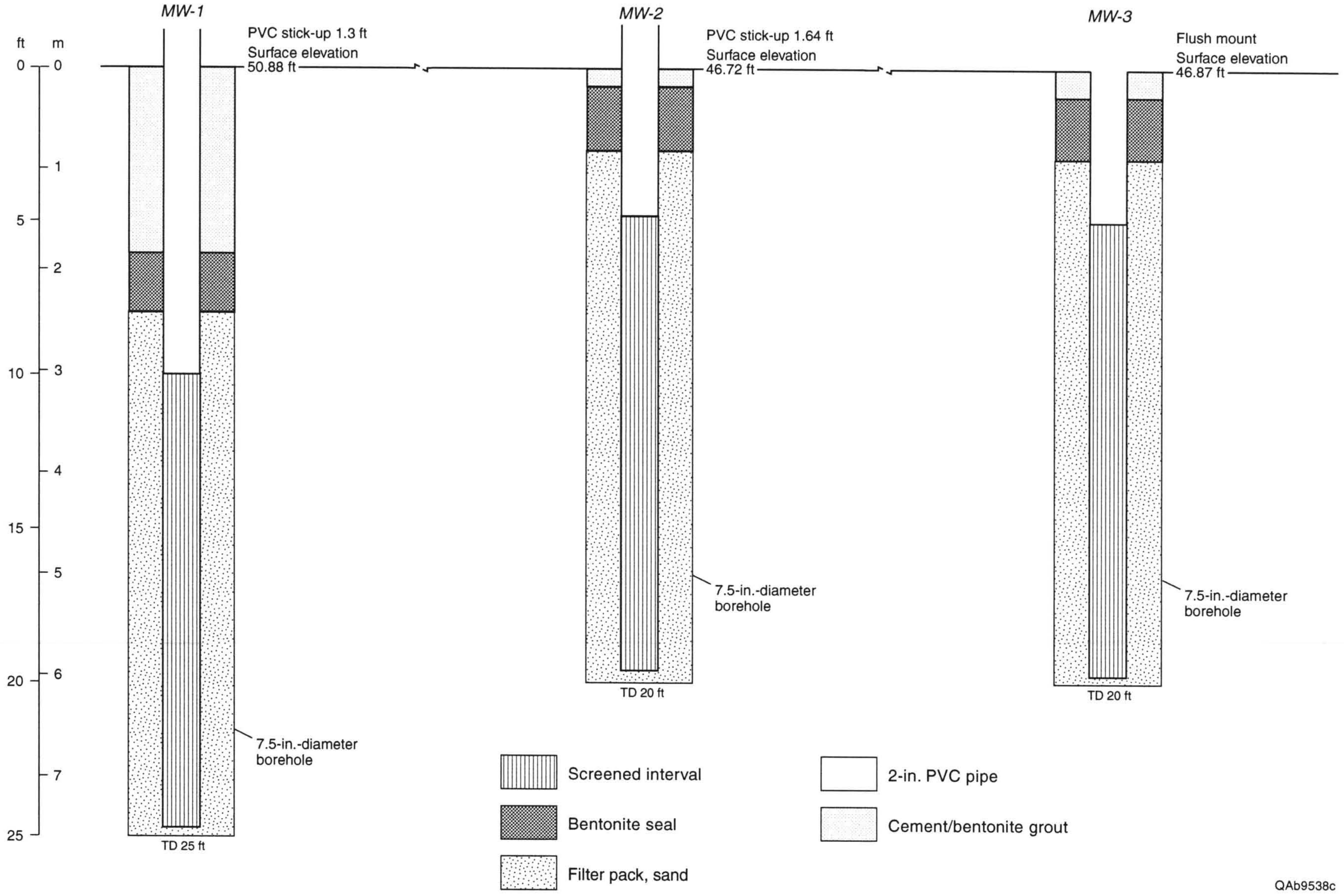


Figure 3.2. Monitoring-well construction information.

Table 3.1. Monitoring-well construction data. All data in feet from ground surface.

Well number	Total depth	Screened interval	Sand pack interval	Seal interval	Depth to water	Relative ground surface elevation[1]
MW-1	25	10-25	8-25	0-6 (grout) 6-8 (bentonite)	15.58	49.57
MW-2	20	5-20	3-20	0-1 (grout) 1-3 (bentonite)	8.49	45.08
MW-3	20	5-20	3-20	0-1 (grout) 1-3 (bentonite)	7.27	47.34
BH-1	30	N/A	N/A	0-30 (grout)	N/A	49.13

[1] All elevations relative to arbitrary 50-ft datum. Not surveyed into offsite grid.

each corner of the area of interest plus one sample from the center of that area. The same analysis was performed on the composites as on the grab samples. Sample locations are shown in figure 4.8. Results are discussed in Section 4.3.

3.3.4 Surface Impoundment (Pond) Sampling

Three surface-water samples were taken at the Vernon Briggs site to evaluate the influence of the site on local surface water. Sample locations are shown in figure 3.1. One sample was taken from shallow water collected in a low area enclosed by the south berm, and one sample was taken from each of the two quarry ponds. The samples were taken from the ponded water nearest the waste-disposal area by filling a bailer with a water column and sequentially filling the sample containers in the following order: VOC's, TPH, RCRA 8 metals, cations, anions, field parameters (pH and specific conductance). All samples were shipped on ice at 4°C to Chemsolve and were received and analyzed within maximum holding times.

3.3.5. Domestic Water Well Inventory

State well records of wells within a 0.5-mi radius of the site were found to be incomplete. These records, from the TNRCC and Texas Water Development Board, did not include records of several of the domestic wells noted near the site by BEG and RRC personnel. Therefore, a door-to-door domestic well inventory of the area surrounding the site was performed with the assistance of Mr. Larry Arrington of the Matagorda County Health Department. Each dwelling within a 0.5-mi radius of the site was identified by maps, visual identification, and information from the Health Department office. Residents were contacted on July 17 and 18, 1997. A total of five domestic wells were identified and sampled for VOC's, TPH, RCRA 8 metals, pH, specific conductance, major cations and anions, and total coliform. Sample containers were filled directly from either an inside or outside tap after flushing the lines for 10 min. The tap was sterilized with isopropyl alcohol prior to the coliform sample collection then thoroughly rinsed to remove all traces of alcohol. All samples were shipped on ice at 4°C to the Chemsolve Laboratory and were received and analyzed within maximum holding times. Well locations are shown in figure 2.2. Depth and ownership information is shown in table 3.2. Analytical results are shown and discussed in Section 4.4.3.

3.3.6. Ground-Water Sampling

Ground water was sampled at the three onsite monitoring wells on August 1, 1997. A Grundfos submersible pump was used to purge the wells and to conduct hydrologic tests. Ground-water samples were collected at the end of the drawdown periods of the hydrologic tests. More than 10 well-bore volumes of water were removed in each drawdown test prior to collection of water samples.

Temperature and pH were measured at the well sites. Alkalinity was measured at well sites by titration of unfiltered samples with a standard dilute (approximately 0.16 N) H_2SO_4 solution using a Hach digital titrator. Samples for RCRA 8 metals, total cations, and total anions were filtered by an inline 0.45-µm Geotech high-flow filter attached at a tee in the discharge line. Metals and cation samples were acidified with 1 mL of 6N HNO_3 in 125-mL polyallomer containers. Sample containers for PAH's and VOC's were filled from a disposable bailer after pumping had ceased, to prevent excess volatilization from the pump action. Temperature was measured from the pump outlet stream; pH and alkalinity were measured at the wellhead in an unfiltered sample. All samples were shipped on ice at 4°C to Chemsolve and were received and analyzed within maximum holding times. Results are shown and discussed in Section 4.4.

3.4. Ground-Water Pump Testing

Tests to determine transmissivity were conducted at the three monitoring wells in conjunction with collection of water samples for chemical analysis. The hydrologic tests consisted of unsteady-

Table 3.2. Domestic ground-water well survey data.

Owner	**Address**[1]	**Depth (ft)**	**Diameter (ft)**	**Treatment system**	**Sample location**	**Aquifer**
Gayle Holton	Rt. 3, Box 133B	270	0.3, steps down to 0.1	no	outside tap	lower Beaumont/ Upper Chicot
Raymond Brooker	Rt. 3, Box 133C	400	N/A	yes	outside tap	Upper Chicot
Bill Norman	Rt. 3 Box 133A	255	may be 0.3	no	outside tap	lower Beaumont/ Upper Chicot
Wesley Shelton	Rt. 3, Box 185D	340	0.3	no	outside tap	Upper Chicot
Robert Hurley	Rt. 3, Box 133K	80	N/A	no	kitchen tap	Beaumont

[1] All addresses are Bay City, Texas 77414.

N/A: not available

state drawdown and recovery tests, with water-level changes measured in the pumping well. The test at MW-1 was performed as a step-drawdown test to determine how great a pumping rate could be sustained, whereas the tests at MW-2 and MW-3 were performed as constant discharge tests. Discharge rate was measured using a 5-gal (18.93-L) bucket and stopwatch. In addition, water levels during tests were recorded using a pressure transducer and programmable data logger attached to a laptop computer. Pumped water was discharged to the waste-disposal area.

At completion of the drawdown phase of the test, ground-water samples were collected, and then the pump was turned off and water-level recovery was monitored. Data analysis focused on the drawdown period of the tests, which lasted from 27 to 60 min. Graphical inspection of the test data and information about subsurface stratigraphy indicated that the drawdown and recovery data should be analyzed by type-curve matching following the so-called delayed-yield (Boulton) method for unconfined and semiunconfined aquifers (Kruseman and De Ridder, 1983). Results are presented in Section 4.4.2.

4.0. RESULTS

4.1 Geophysical Survey

Seven surface geophysical survey lines were used to collect subsurface ground conductivity data at the site. Results from the surface geophysics were used to help select locations for the monitoring wells and the soil borings. Geophysical logs downhole from these locations were then used with soil chloride to compare with the surface/EM data (fig. 4.3). Figure 3.1 shows the locations of these lines. Data for the 10-, 20-, and 40-m spacings are shown in figures 4.1 (horizontal dipole) and 4.2 (vertical dipole).

Values of the horizontal dipole geophysical data are discussed later. These data tend to be weighted toward the surface, and, thus, were most indicative of the effects of the waste on soil and the shallow ground water to a depth of about 80 ft. EM line 1 showed conductivity values that

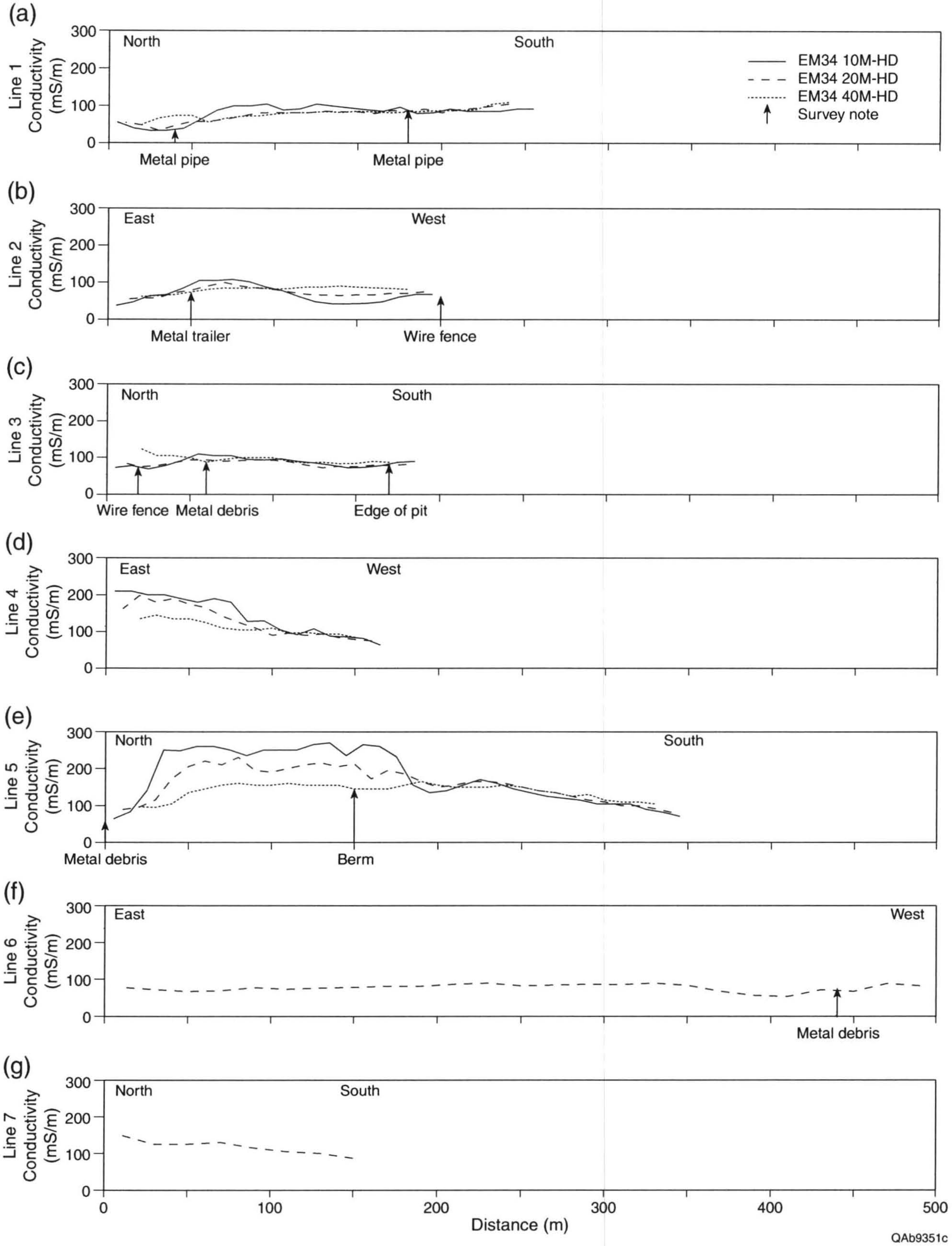


Figure 4.1. EM 34-3 electromagnetic geophysical survey data, horizontal dipole.

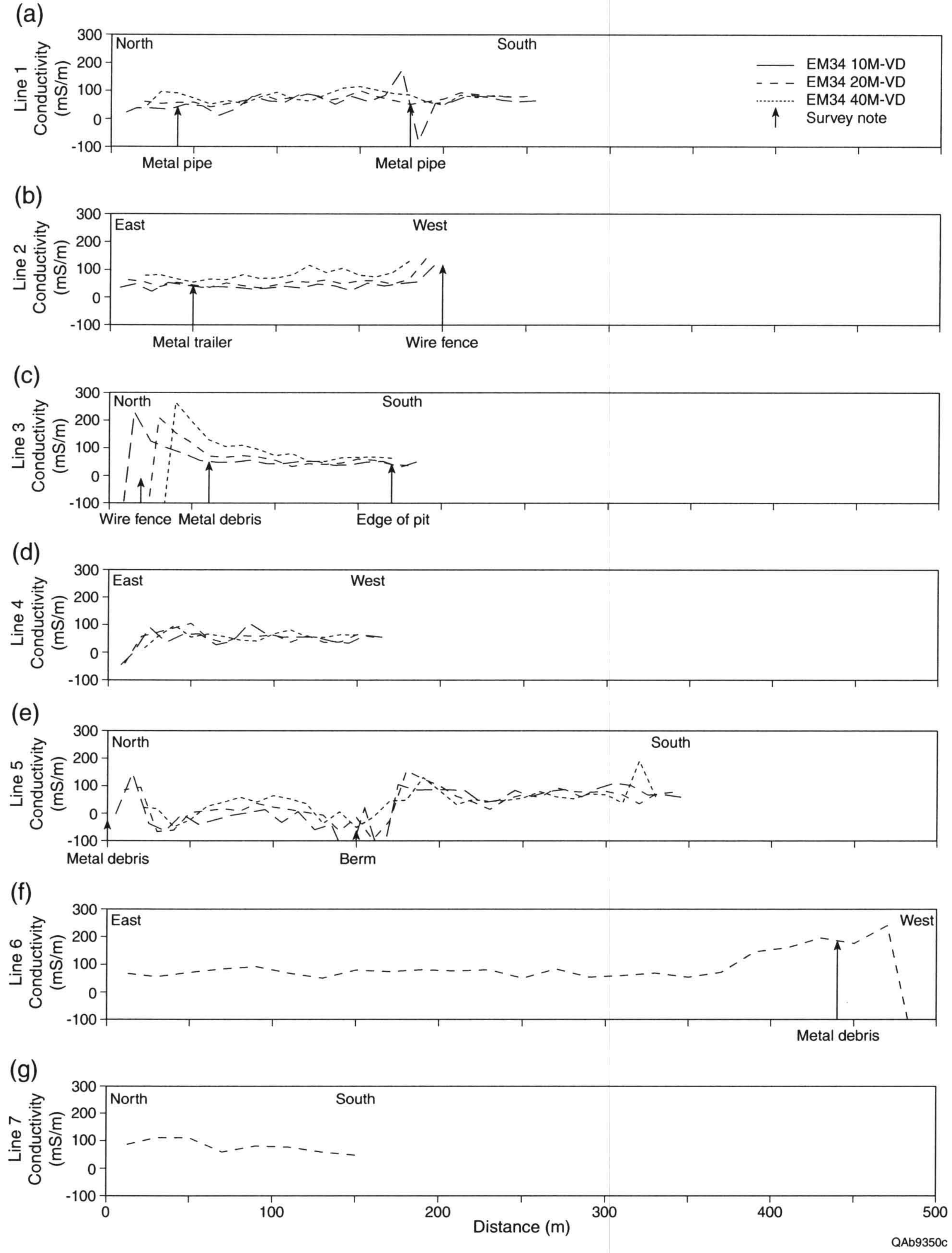


Figure 4.2. EM 34-3 electromagnetic geophysical survey data, vertical dipole.

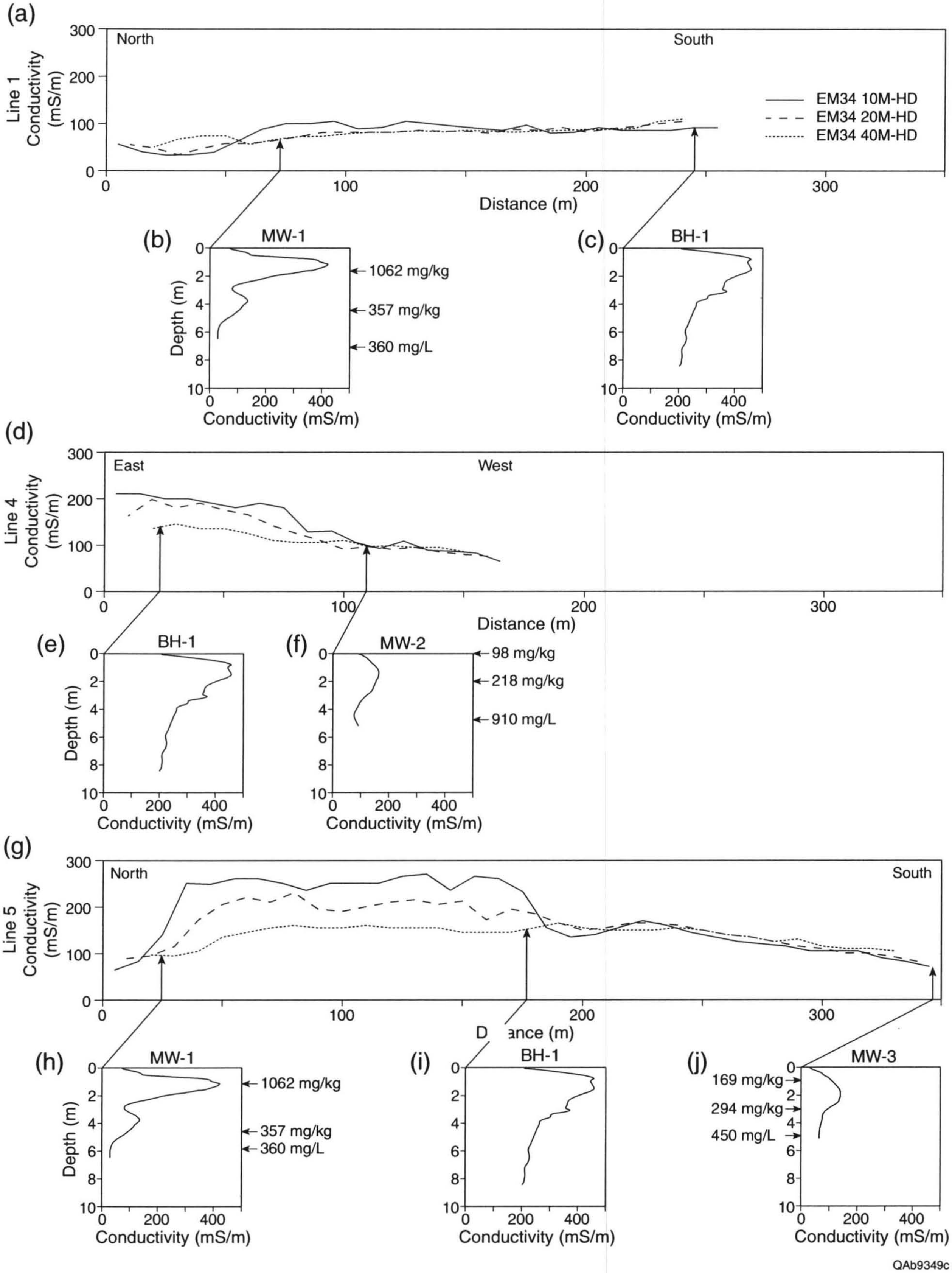


Figure 4.3. EM 34-3 and EM 39 combined electromagnetic geophysical survey data.

were well within normal ground conductivity levels (less than 100 mS/m). A slight increase from north to south was noted, as well as a moderate increase from the 10-m line parallel to the north edge of the waste-disposal area. The 20- and 40-m values became greater than the 10-m values along the south part of the line. These values corresponded well with the downhole log of monitoring well (MW) 1 and borehole (BH)1, which showed increased conductivity over MW 1 in the saturated zone below 3.5 m.

Line 2 ran from east to west along the north side of the pit and showed normal conductivities at all levels, with a slight increase in the 10-m-depth data adjacent to the pit. Line 3 ran north to south along the west edge of the pit and also showed normal levels at all depths. There was a slight elevation in the conductivity of the 40-m-depth data on the north side. These data at the south end of line 3, consistent with the normal conductivity results from MW 2, indicate no transport of chloride west of the waste area.

Line 4 ran from east to west across the south edge of the waste-disposal area on the central berm. As expected, conductivities were high on the east side and across the area, mostly at shallower depths. This line crosses the location of BH-1, and the data are consistent with the higher conductivities measured at 3 to 8 m in this borehole, particularly for the 20-m spacing data. Values dropped to near background levels on the west side, consistent with the data from MW 2.

Line 5 ran north to south on a transect of the waste area and onto the spillover area. Conductivities were high (200–250 mS/m) across the pit for the 10- and 20-m data, and elevated for the 40-m data. Values dropped sharply at the south berm crest and gradually decreased with distance south at all depths. This drop is consistent with BH 1 and MW 3 data and indicates that the conductivity is increased below the waste area at all depths. The vertical log of MW 3 showed normal conductivity ranging from 0 to 5 m.

Line 6 was performed for only the 20-m spacing. This line ran from east to west along the south berm, then turned and ran north along the west berm. Conductivities were normal except for an outlier that occurred at a pile of metallic debris along the southeast corner of the site. Line 7 also was run only for the 20-m spacing, along the east side of the south half of the site. Conductivities were slightly elevated to the north and decreased with distance south.

Data from the surface and borehole geophysical surveys and from the monitoring wells indicate a zone of salt-water influence around the waste that is probably limited in depth and lateral extent. Surface geophysical data on the waste-disposal area display elevated ground conductivity, indicating higher chloride both in the waste and in the soil immediately beneath the waste-disposal area (transects 4 and 5, fig. 4.3), Conductivity is elevated (>100 mS/m) more in the 10-m and 20-m surveys than in the 40-m survey, showing a decrease in conductivity with depth. Data from transect 5 (fig. 4.2) also show conductivity decreasing to the south of the waste-disposal pit.

Because conductivity values are normally weighted to shallow depths and zones of high conductivity, the slightly elevated 40-m values probably do not mean that there is a deep saline plume beneath the site. This inference is supported by the fact that conductivity was not elevated below a depth of about 10 ft in MW-1 to the north of the waste area nor in MW-2 and MW-3 to the west and south. BH-1 borehole data, however, show that conductivity remains well above 100 mS/m to a depth of at least 26 ft. Downward movement most likely is retarded by the clay layer that underlies the waste, such that only a moderate impact on ground-water quality has been detected at MW-2 and a low impact on MW-1 and MW-3. Chloride data relating to these conclusions are discussed in Section 4.4.

4.2. Waste

The waste materials appear to be predominantly oil contaminated, water-wet drilling muds, composed primarily of bentonite clay. The materials are very soft and have little or no compressive strength. The upper surface is characterized by a crust of tan, sandy clay material with roots, some salt encrustation, and evidence of pipe scale, fractured grout, and fine gravel in some areas. No oil or oil stains were observed on this surface crust, which is about 2 to 6 inches thick.

The horizontal extent of the waste materials is limited by the berms emplaced by Mr. Briggs on the north, east, and west sides of the disposal area (fig. 3.1). Figure 4.4 shows the contoured,

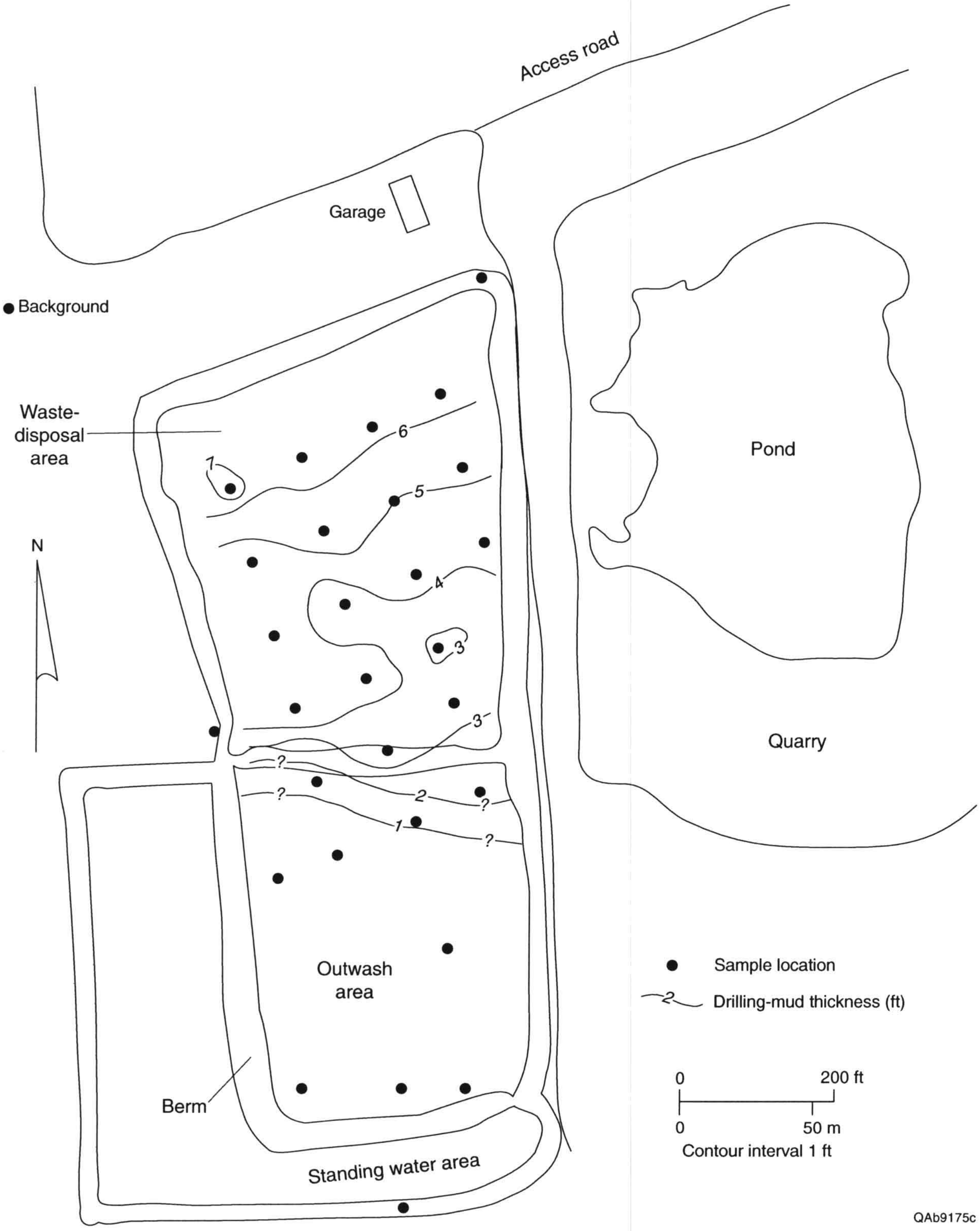


Figure 4.4. Sludge-thickness contours in the waste disposal area.

measured thickness of the wastes. To the south, some spillover of waste materials has occurred. Thicknesses measured in this outfall area are approximate, however, because the washed-over drill-mud wastes appear to grade into the saturated clay soils in this area. A better measure of the extent of wastes in this area may be from the concentrations of TPH and chloride (see figs. 4.6 and 4.7 and section 4.3). Total waste volume in the bermed disposal area was calculated to be 39,000 yd^3. Figure 4.5 shows a cross section of the waste, the underlying clay thickness, and the monitoring-well depths projected onto EM line 5. The waste lies on top of the Beaumont clay and well above the static water table.

The summary results of chemical analyses of the composite waste samples are shown in table 4.1. Sample numbers corresponding to the sample points are shown in figure 3.1. Sample numbers 2006 and 2012 were analyzed for TCLP parameters, VOC's, PAH's, and TOX in addition to RCRA 8 metals, TPH, chloride, conductivity, and moisture, which were analyzed for all subsurface waste sample composites. One sample, number 2018, was analyzed for landfarm parameters. These data are shown in table 4.2. Copies of the full analytical-data reports are provided in appendix B.

TPH values, although not compound-specific, indicate the presence of a range of petroleum-related volatile and semivolatile petroleum components. TPH concentrations from the composite subsurface samples are shown in figure 4.6. In past remediation cases (Jill Hybner, RRC, personal communication, 1997), the RRC has applied maximum soil values of 1 to 5 percent TPH as a requisite for cleanup in nonsensitive locations. Guidance from TNRCC suggests a maximum level of 1,500 mg/kg (0.15 percent) TPH in soil for disposal purposes (TNRCC, 1996). The maximum level of TPH detected in Vernon Briggs waste samples from below-surface composites was 21,000 mg/kg (2.1 percent), and the mean was 0.92 percent (standard deviation (s): ± 0.63 percent, 18 samples). Surface samples of the wastes from 0 to 0.5 ft below grade contained a maximum TPH concentration of 1.7 percent, with a mean value of 0.37 percent (s: ± 0.54, 14 samples).

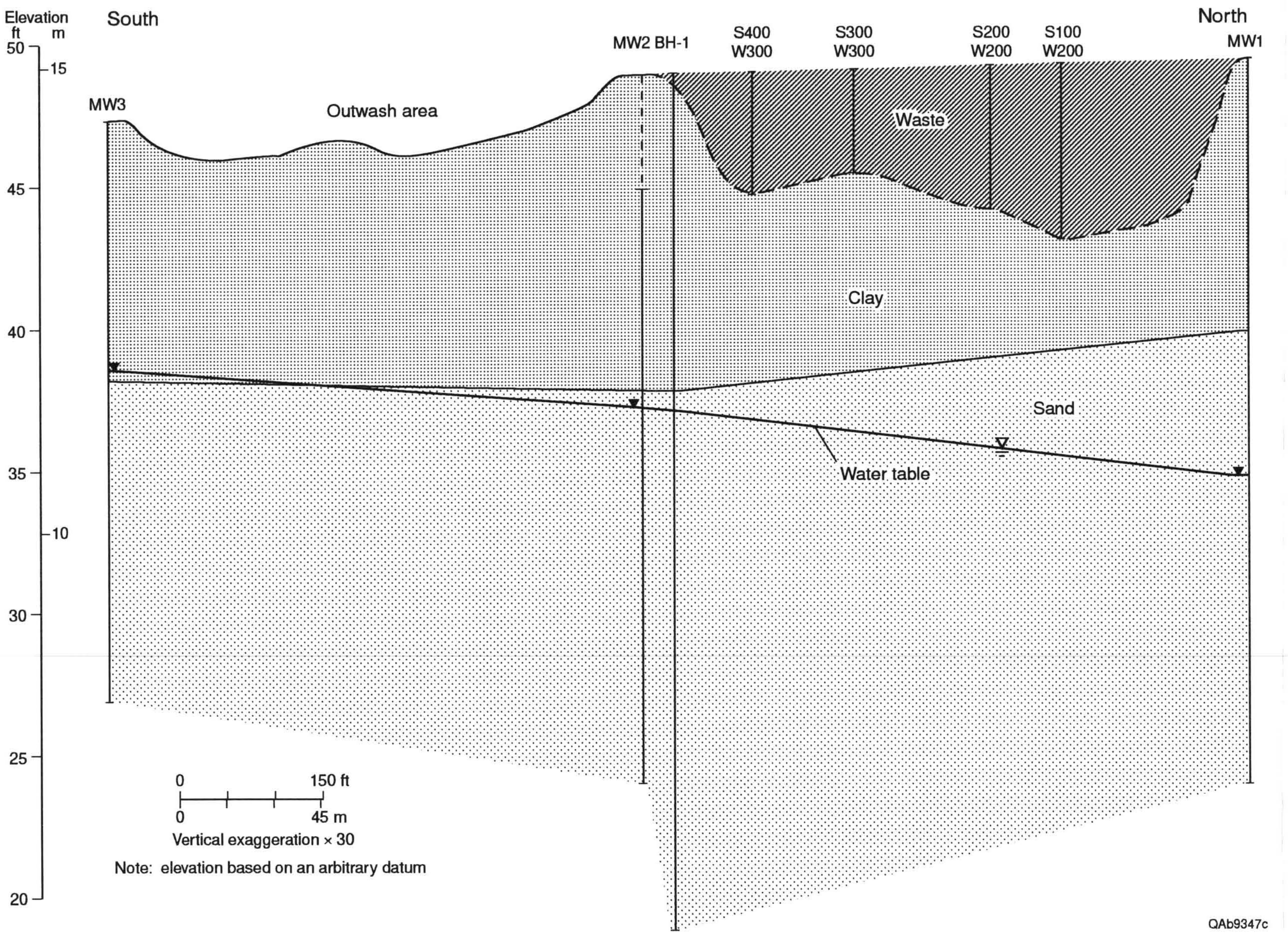


Figure 4.5. Cross section of the waste-disposal area and local stratigraphy. Also showing profile surface for the deeper, locally used aquifer.

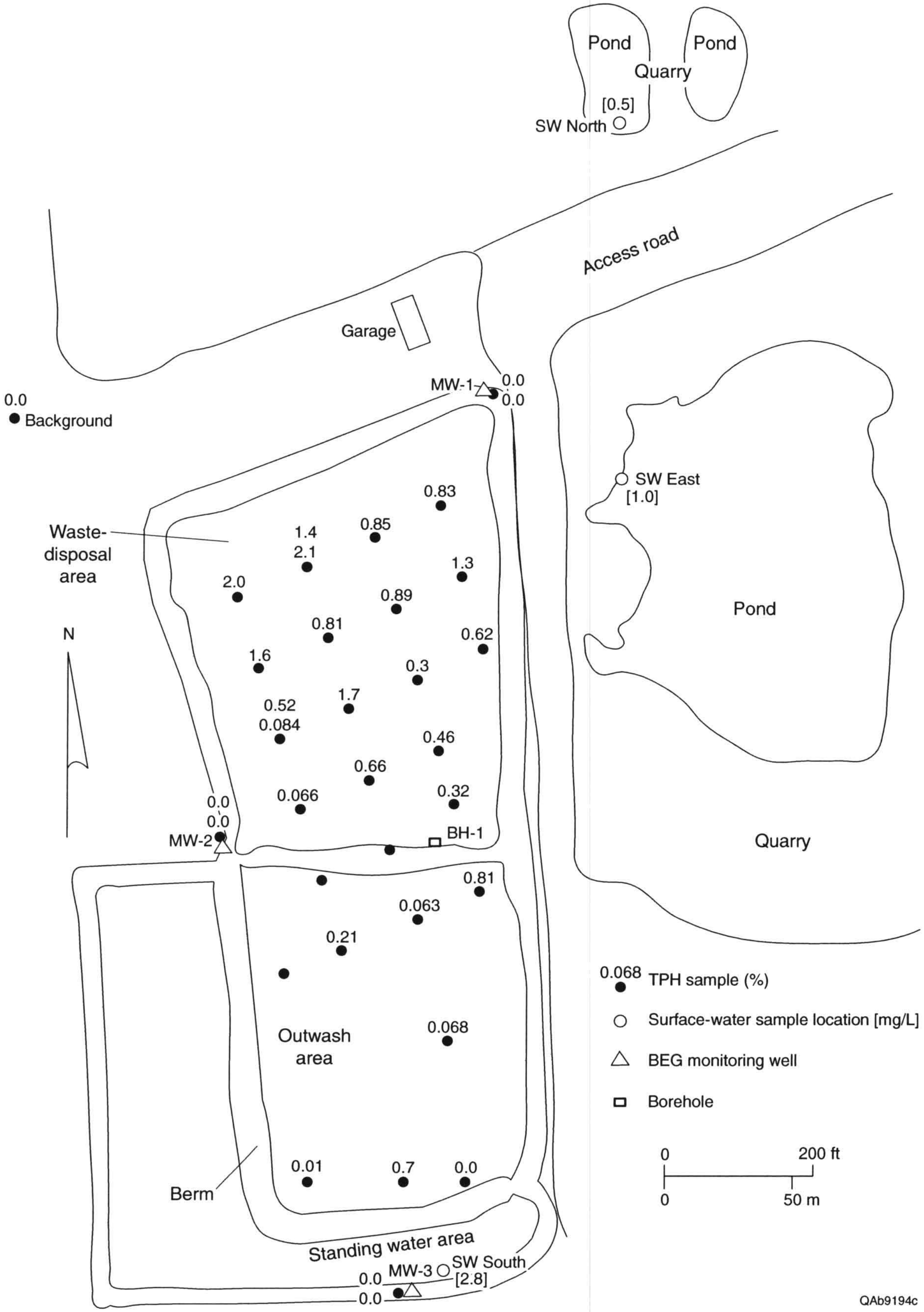


Figure 4.6. Total petroleum hydrocarbon (TPH) concentration data in soils, water, and the waste-disposal area.

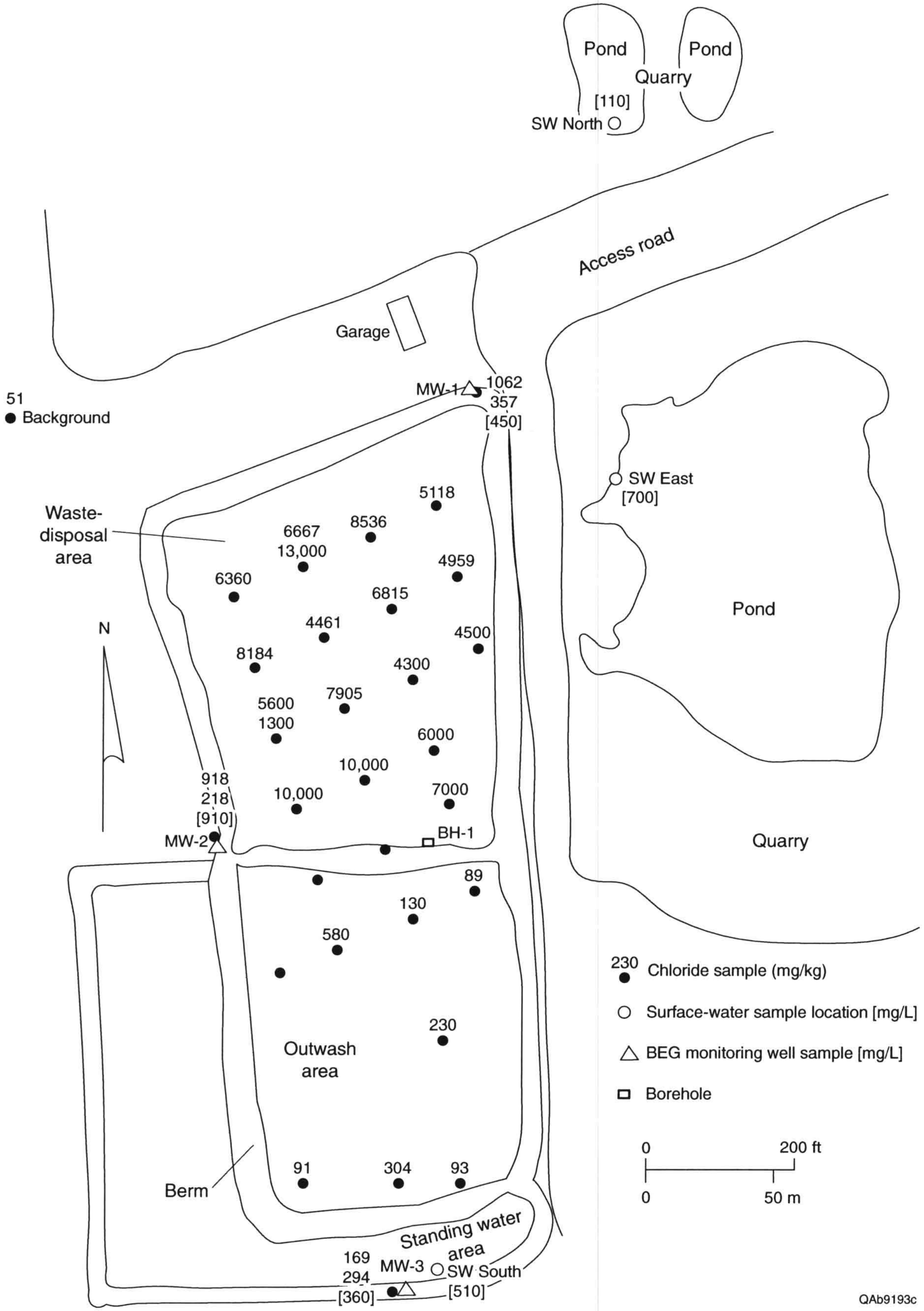


Figure 4.7. Chloride concentration data in soils, water, and the waste-disposal area.

Table 4.1. Summary of analyses of waste-material samples from Vernon Briggs waste-disposal area. Units are in mg/kg except where noted.

Location: **Sample number:** **Depth range (ft):**	**1-1** **2001** **0.5–6.5**	**1-2** **2000** **0.5–5.1**	**1-3** **2028** **0.0–0.5**	**1-3** **2029** **0.5–4.2**	**2-1** **2003** **0.0–0.5**	**2-1** **2002** **0.5–6.1**	**2-2** **2005** **0.0–0.5**	**2-2** **2004** **0.5–5.0**	**2-3** **2026** **0.0–0.5**	**2-3** **2027** **0.5–4.1**	**Regulatory or guidance limit[1]**
Arsenic	<0.5	<0.5	N/A	7.7	N/A	<0.5	N/A	<0.5	N/A	6.2	36
Barium	73	90	N/A	790	N/A	110	N/A	125	N/A	1300	2000
Cadmium	<0.5	<0.5	N/A	0.86	N/A	<0.5	N/A	<0.5	N/A	0.59	10
Chromium	138	145	N/A	250	N/A	144	N/A	161	N/A	200	100
Lead	<0.5	<0.5	N/A	61	N/A	<0.5	N/A	<0.5	N/A	50	30
Mercury	<0.1	<0.1	N/A	<0.02	N/A	<0.1	N/A	<0.1	N/A	<0.02	4
Selenium	<0.5	<0.5	N/A	<0.1	N/A	<0.5	N/A	<0.5	N/A	<0.1	20
Silver	<0.5	<0.5	N/A	<0.1	N/A	<0.5	N/A	<0.5	N/A	<0.1	100
Chloride	5118	4959	400	4,500	5412	8536	5712	6815	1,600	4,300	n/a
Conductivity (mS/cm)	17	16	4.53	15.75	18	26	10	22	7.3	15.2	n/a
TPH (%)	0.83	1.3	0.054	0.62	0.53	0.85	1.7	0.89	0.19	0.3	1
Oil and grease (%)	1.6	2.2	N/A	N/A	0.83	1.3	2.5	1.5	N/A	N/A	n/a
Moisture (%)	42	46	N/A	39	28	41	20	41		47.2	n/a

n/a: not applicable

N/A: not analyzed

[1] Metals limits are for a total analysis. If a total analysis exceeds the limits listed, then TCLP must be performed (TNRCC, 1996). Total limits are for MSW landfill disposal. TPH limit is from RRC Rule 91, 1-percent value used as guidance limit.

[2] Landfarm results for sample number 2018 (mg/Kg): ortho-phosphate <0.5; potassium 1300; total organic nitrogen: 328; zinc 610; copper 15; nitrate-N 20; ammonia-N <1.

Note: All samples analyzed by RRC lab, except 2006, 2012, and 2018 through 2035 (Chemsolve).

Table 4.1. Continued.

Location:	**2-4**	**2-4**	**2-5**	**2-5**	**3-1**	**3-1**	**3-1**	**3-2**	**3-2**	**3-3**	**3-3**	**Regulatory or guidance limit[1]**
Sample number:	**2024**	**2025**	**2030**	**2031**	**2007**	**2006**	**2008**	**2015**	**2013**	**2016**	**2017**	
Depth range (ft):	**0.0–0.5**	**0.5–3.0**	**0.0–0.5**	**0.5–3.9**	**0.0–0.5**	**5.0–6.0**	**0.5–6.5**	**0.0–0.5**	**0.5–5.3**	**0.0–0.5**	**0.5–3.6**	
Arsenic	N/A	5.7	N/A	3.7	N/A	N/A	<0.5	N/A	<0.5	N/A	<0.5	36
Barium	N/A	1200	N/A	1500	N/A	N/A	107	N/A	69	N/A	73	2000
Cadmium	N/A	0.67	N/A	0.45	N/A	N/A	<0.5	N/A	<0.5	N/A	<0.5	10
Chromium	N/A	270	N/A	190	N/A	N/A	188	N/A	147	N/A	289	100
Lead	N/A	64	N/A	34	N/A	N/A	<0.5	N/A	<0.5	N/A	<0.5	30
Mercury	N/A	<0.02	N/A	<0.02	N/A	N/A	<0.1	N/A	<0.1	N/A	<0.1	4
Selenium	N/A	<0.1	N/A	<0.1	N/A	N/A	<0.5	N/A	<0.5	N/A	<0.5	20
Silver	N/A	<0.1	N/A	<0.1	N/A	N/A	<0.5	N/A	<0.5	N/A	<0.5	100
Chloride	2,700	6,000	4000	7,000	575	13,000	6667	283	4461	3290	7905	n/a
Conductivity (mS/cm)	9	18.2	13.4	19.9	2.8	19	20	1.9	15	12	26	n/a
TPH (%)	0.008	0.46	<0.001	0.32	0.05	1.4	2.1	0.55	0.81	0.25	1.7	1
Oil and grease (%)	N/A	N/A	N/A	N/A	0.13	N/A	3.1	0.75	1.8	0.37	2.3	n/a
Moisture (%)	N/A	16.3	N/A	28.4	23	23.1	32	43	35	32	59	n/a

n/a: not applicable
N/A: not analyzed
[1] Metals limits are for a total analysis. If a total analysis exceeds the limits listed, then TCLP must be performed (TNRCC, 1996). Total limits are for MSW landfill disposal. TPH limit is from RRC Rule 91, 1-percent value used as guidance limit.
[2] Landfarm results for sample number 2018 (mg/Kg): ortho-phosphate <0.5; potassium 1300; total organic nitrogen: 328; zinc 610; copper 15; nitrate-N 20; ammonia-N <1.

Table 4.1. Continued.

Location:	**3-4**	**3-4**	**4-1**	**4-1**	**4-2**	**4-2**	**4-3**	**4-3**	**4-3**	**4-4**	**4-4**	**Regulatory or guidance limit[1]**
Sample number:	**2022**	**2023**	**2009**	**2010**	**2011**	**2014**	**2019**	**2012**	**2018[2]**	**2020**	**2021**	
Depth range (ft):	**0.0–0.5**	**0.5–4.1**	**0.0–0.5**	**0.5–7.0**	**0.0–0.5**	**0.5–4.7**	**0.0–0.5**	**2.0–3.0**	**0.5–4.7**	**0.0–0.5**	**0.5–4.8**	
Arsenic	N/A	6.4	N/A	<0.5	N/A	<0.5	N/A	N/A	5.4	N/A	5.7	36
Barium	N/A	1500	N/A	84	N/A	68	N/A	N/A	1200	N/A	1400	2000
Cadmium	N/A	0.53	N/A	<0.5	N/A	<0.5	N/A	N/A	0.54	N/A	0.86	10
Chromium	N/A	190	N/A	212	N/A	354	N/A	N/A	190	N/A	230	100
Lead	N/A	36	N/A	<0.5	N/A	<0.05	N/A	N/A	29	N/A	82	30
Mercury	N/A	<0.02	N/A	<0.1	N/A	<0.1	N/A	N/A	<0.02	N/A	<0.02	4
Selenium	N/A	<0.1	N/A	<0.5	N/A	<0.5	N/A	N/A	<0.1	N/A	<0.1	20
Silver	N/A	<0.1	N/A	<0.5	N/A	<0.5	N/A	N/A	<0.1	N/A	<0.1	100
Chloride	4,200	10,000	584	6360	340	8184	6,600	5,600	1,300	820	10,000	n/a
Conductivity (Ms/cm)	9	40.5	2.6	21	1.7	25	16.9	20.7	6.3	4.4	20.7	n/a
TPH (%)	0.043	0.66	0.04	2	0.21	1.6	1.4	0.52	0.084	0.089	0.066	1
Oil and grease (%)	N/A	N/A	0.09	3	0.34	2.7	N/A	N/A	N/A	N/A	N/A	
Moisture (%)	N/A	22.7	22	41	22	45	N/A	18.6	1.7	N/A	27.4	n/a

n/a: not applicable
N/A: not analyzed

[1] Metals limits are for a total analysis. If a total analysis exceeds the limits listed, then TCLP must be performed (TNRCC, 1996). Total limits are for MSW landfill disposal. TPH limit is from RRC Rule 91, 1-percent value used as guidance limit.

[2] Landfarm results for sample number 2018 (mg/Kg): ortho-phosphate <0.5; potassium 1300; total organic nitrogen: 328; zinc 610; copper 15; nitrate-N 20; ammonia-N <1.

Table 4.2 Summary of TCLP, TOX, and VOC results for waste samples 2006 and 2012. Units are as noted (mg/kg or mg/L).

	Result[1] 2006*	*Result*[1] 2012	*PQL*	*Method*	*Regulatory guideline or limit*	*Reference*
VOC's and SVOC's (mg/Kg)						
Ethylbenzene	<0.250	0.310	.25	8260	70	TNRCC[2]
m,p-Xylenes	<0.250	0.280	.25	8260	560	TNRCC[2]
Fluorene	1.3	<1	1	8270	247	TNRCC[2]
Naphthalene	3.8	2.5	.25	8260	389	TNRCC[2]
Petroleum hydrocarbons	14,000	5,200	2,250/150	418.1	1,500 1 percent	TNRCC[3] RRC
TCLP Parameters (mg/L)						
TC Arsenic	0.048	<0.005	0.005	6010	5	TNRCC[3]
TC Barium	7	9	0.005	6010	100	TNRCC[3]
TC Cadmium	<0.005	0.0057	0.005	6010	1	TNRCC[3]
TC Lead	0.019	<0.005	0.005	6010	5	TNRCC[3]
Reactivity cyanide (mg/Kg)	<10	<10	10	7.3.3.1	presence	EPA[4]
Reactivity sulfide (mg/Kg)	<10	<10	10	7.3.3.2	presence	EPA[4]
Ignitability (° F/Kg)	>150	>150	75	1010	<140	EPA[4]
pH	9.4	9.2	n/a	9045	<2 or >12	EPA[4]
Total organic halogens (mg/Kg)	<1	<1	1	9020	< 50	TNRCC[3]

[1] Shaded analyzed values are those above regulatory or guidance values.

[2] TNRCC: RG 17 Action Levels for LPST sites, fine-grained soils; October 1996.

[3] TNRCC: RG 03 Disposal of Special Wastes Associated with Development of Oil, Gas, and Geothermal Resources; September 1996.

[4] EPA: 40 CFR Sect. 261.21-24 Subpart C.

[5] PQL (quantitation limit) > regulatory guideline.

n/a: not applicable

*Sample number; samples analyzed by Chemsolve.

The presence of chloride is expected in oil-field wastes containing brines. Chloride can restrict soil biodegradation processes, harm vegetation, and degrade surface water and ground water via leaching and runoff. Composite chloride results are shown in figure 4.7. The maximum chloride concentration in the waste samples was 13,000 mg/kg in below-surface composites (mean: 6,689 mg/kg, s: ± 2,746, 18 samples). Surface waste samples contained a maximum of 6,600 mg/kg (mean: 2,608 mg/kg, s: ± 2,257, 14 samples).

Subsurface waste samples were submitted for RCRA 8 metals analysis. Arsenic, barium, cadmium, chromium, and lead were detected in several samples. Results are listed in table 4.1. None of the arsenic, barium, or cadmium values exceeded the TNRCC's total metals limit (TNRCC, 1996), which is used to indicate the need for follow-up TCLP analysis prior to landfill disposal. Chromium exceeded the limit in 19 (of 19) samples and lead exceeded the limit in 9 (of 11) samples. TCLP metals analysis results are discussed later.

Differences were noted between metals analyses performed by Chemsolve and those by the RRC laboratory. Patterns in detected metals were compared; most samples submitted to Chemsolve were from the southern area of the site; therefore, more low-level detections were recorded. Typical values were not significantly different from the samples analyzed by RRC. RRC detection limits were higher and, thus, resulted in a number of nondetectable results for metals, skewing the detection of some metals toward the south part of the waste-disposal area. Judging from observed distribution and similarities between detected values, it is likely that the north part of the disposal area contains a distribution of metals similar to that of the south part.

Volatile and semivolatile organic compounds were analyzed from two sample locations randomly selected from the disposal area, samples 2006 and 2012 (fig. 3.1). Table 4.2 shows the results obtained from these samples. Only fluorene and naphthalene were detected above the method detection limit (or PQL) for sample 2006. Only ethylbenzene, m- and p-xylenes, and naphthalene were measured above the detection limit for sample 2012. All of the measured values fall below the LPST soil action limits for fine-grained soils (TNRCC, 1996). Although higher than for typical soil samples, the detection limits for these waste analyses are one or more orders of magnitude less than the LPST soil action limits and the total limits for selected petroleum hydrocarbon compounds.

Samples 2006 and 2012 were also analyzed for pesticides and polychlorinated biphenyl compounds (Aroclor PCB's). Results are provided in appendix B. None of these analyzed compounds was measured above method detection limits. Total organic halogen (TOX) analysis on these samples was below the method detection limit of 1 mg/kg (table 4.2). Sample pH of 9.2 to 9.4 did not exceed the guidance level of 12 pH units. These pH values were higher than typical drilling-mud values (pH 8 to 8.5, Leuterman and others, 1988) but well within the range of pH of drilling fluids (pH of 8 to 13, American Petroleum Institute [API], 1969). No physical or chemical characteristics were noted that would indicate that the wastes are anything other than oil- and gas-production wastes.

Summary results also are listed of the TCLP extraction values for these two samples (table 4.2). No TCLP VOC's or SVOC's were detected above method detection limits for these two samples in the TCLP extract. Again, detection limits for VOC's were less than TNRCC landfill-disposal TCLP requirements. Arsenic, barium, cadmium, and lead were detected above method detection limits, but they did not exceed TNRCC disposal limits for hazardous materials (TNRCC, 1996).

The location of all the samples for the NORM radionuclide analysis, analytical results, and an outline of the elevated reading area are shown in figure 4.8. Original data reports are provided in appendix B. The NORM analyses of the two grab samples showed the presence of Ra-226, Ra-228, and Pb-210. Total activity exceeded the sum of activity for all these samples, suggesting that there may be other species present, such as uranium (Don Brown, Texas Department of Health, personal communication, July 7, 1997). The Texas Department of Health exemption limit is 30 pCi/gm of Ra 226 or 228 averaged over any 100 m^2 and the first 15 cm below the surface for materials other than soils. The composite samples, however, indicated values well below this limit for both the large sampled areas, including a nondetect value for Pb-210 in the sample from sample number 2201. Implications for remedial measures at this area are discussed in Section 6.0.

In general, the results of the waste sampling indicate nonhazardous waste material that has relatively low levels of TPH either below or slightly above guidance levels and moderate to high concentrations of chloride. TCLP results indicate that leaching of organic or metal constituents from this waste is minimal and below regulatory limits for TNRCC MCW landfill disposal. The presence of NORM appears to be confined to one area of the surface and is exempt from disposal restrictions.

4.3. Soils

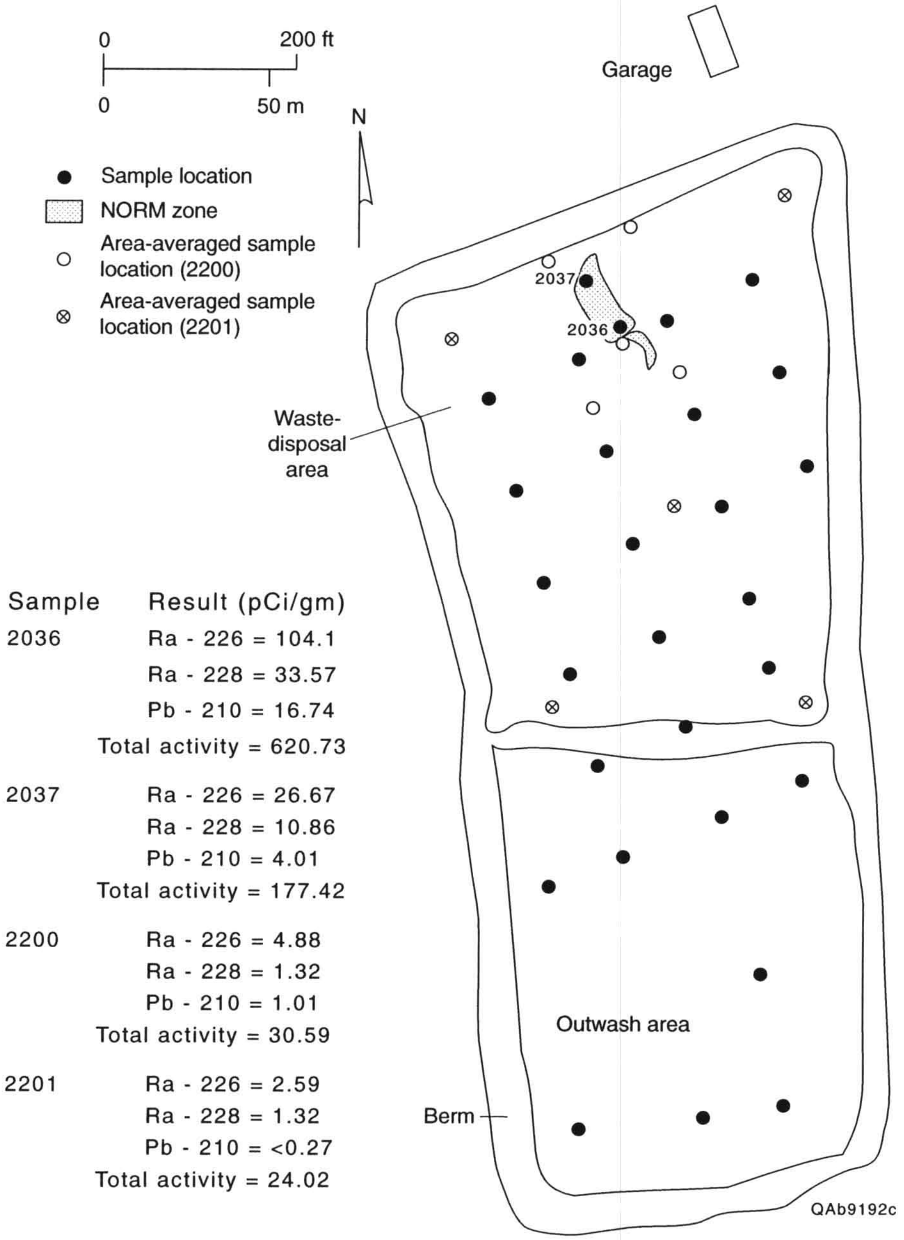
One background soil and nine soil samples from the outfall area were analyzed for TPH, chloride, RCRA 8 metals, EC, and moisture. Selected samples were analyzed for PAH's. Locations are shown in figures 3.1, 4.6, and 4.8, and results are provided in table 4.3.

Outwash area surface samples averaged 0.18 percent TPH (s: ±0.29, seven samples), with a noticeable decrease in values with distance from the disposal area. These values are well below the RRC minimum guidance of 1 percent for TPH in soil materials but above the TNRCC guidance of 1,500 mg/kg.

The background sample was taken from a location north of the waste-disposal area in an area considered to have had minimal disturbance from site-related operations. The background chloride value was 51 mg/kg. No TPH was detected above method detection limits in the background sample. In addition, no TPH was detected in any of the soil samples from the monitoring-well borings.

Chloride values for the outwash area varied from 89 to 580 mg/kg. Electrical conductivity values in the outwash soils analyses were lower than in the waste materials but slightly higher than background. These values for the outwash area are moderate to low when compared with both RRC and TNRCC guidance levels and onsite waste concentrations.

Chloride in soils from MW-1 were elevated over MW-2 and MW-3, and verify the shallow elevated-conductivity zone found in the EM downhole survey. In soil samples from the monitoring-well borings, shallow vadose zone soils exhibited lower chloride than did soils at or



Sample	Result (pCi/gm)
2036	Ra - 226 = 104.1
	Ra - 228 = 33.57
	Pb - 210 = 16.74
	Total activity = 620.73
2037	Ra - 226 = 26.67
	Ra - 228 = 10.86
	Pb - 210 = 4.01
	Total activity = 177.42
2200	Ra - 226 = 4.88
	Ra - 228 = 1.32
	Pb - 210 = 1.01
	Total activity = 30.59
2201	Ra - 226 = 2.59
	Ra - 228 = 1.32
	Pb - 210 = <0.27
	Total activity = 24.02

Figure 4.8. Location of NORM samples and NORM analytical results within the waste-disposal area, top 15 cm.

Table 4.3. Summary of soil-sample analyses from the Vernon Briggs site. Units are mg/kg except where noted.

Location:	Regulatory or guidance limit[1,3]	Outwash area							MW-1	MW-1	MW-2	MW-2	MW-3	MW-3	Background
Sample number:		2032[2]	2033	2034[2]	2035[2]	2044	2045	2046	2038	2039	2040	2041	2042	2043	2047
Depth range (ft):		0–1	0–1	0–1	0–1	0–1	0–1	0–1	5–5.5	14–14.5	0.5–1.0	7–7.5	4–4.5	9.5–10	0–1
Arsenic	36	4.8	6	3.9	4	<0.5	<0.5	<0.5	N/A	N/A	N/A	N/A	N/A	N/A	<0.5
Barium	2000	1400	1500	1200	1800	637	979	542	N/A	N/A	N/A	N/A	N/A	N/A	367
Cadmium	10	0.68	0.53	0.39	0.26	<0.5	<0.5	<0.5	N/A	N/A	N/A	N/A	N/A	N/A	<0.5
Chromium	100	450	390	230	240	29	49	25	N/A	N/A	N/A	N/A	N/A	N/A	30
Lead	30	47	49	40	27	<0.5	<0.5	<0.5	N/A	N/A	N/A	N/A	N/A	N/A	<0.5
Mercury	4	<0.02	<0.02	<0.02	<0.02	<0.1	<0.1	<0.1	N/A	N/A	N/A	N/A	N/A	N/A	<0.1
Selenium	20	<0.1	<0.1	<0.1	<0.1	<0.5	<0.5	<0.5	N/A	N/A	N/A	N/A	N/A	N/A	<0.5
Silver	100	<0.1	<0.1	<0.1	<0.1	<0.5	<0.5	<0.5	N/A	N/A	N/A	N/A	N/A	N/A	<0.5
Chloride	n/a	89	130	580	230	93	304	91	1062	357	98	218	169	294	51
Conductivity (mS/cm)	n/a	3.11	9.9	4.02	2.78	0.7	1.5	0.6	3.59	1.29	0.61	1.08	0.86	1.23	0.39
TPH (%)	1	0.81	0.063	0.21	0.068	0	0.07	0.01	0	0	0	0	0	0	0
Oil and grease (%)	n/a	N/A	N/A	N/A	N/A	0	0.07	0.01	0	0	0	0	0	0	0
Moisture (%)	n/a	1.5	22.9	20.9	6.4	13	22	17	N/A	N/A	N/A	N/A	N/A	N/A	N/A
pH	n/a	N/A	N/A	N/A	N/A	N/A	N/A	N/A	7.2	6.51	7.71	7.5	6.91	7.53	N/A

n/a: not applicable
N/A: not analyzed
[1] Shaded analyzed values are above totals limits.
[2] Additional PAH analysis performed. No analytes detected above method detection limits. See appendix B for results.
[3] TNRCC: RG 03 Disposal of Special Wastes Associated with Development of Oil, Gas, and Geothermal Resources; September 1996.
Note: samples 2032 through 2047 analyzed by Chemsolve; 2038 through 2043 analyzed by RRC lab.

just above the water table. This difference indicates a moderate influence from chloride in the wastes.

RCRA 8 metals detected above method detection limits in the outwash area include arsenic, barium, cadmium, chromium, and lead. Of these, barium and chromium were also detected in the background sample. There was a distinct trend in concentrations for all these metals, which decreased in concentration toward the south away from the waste-disposal area. In particular, barium was elevated close to the waste area but did not exceed the TNRCC total limit guidance level to trigger TCLP analysis. Chromium and lead, however, did exceed this limit close to the waste area. Values were similar to those detected in the waste material, and the waste material TCLP results are likely comparable to what would be expected from these clay-rich soils.

In summary, the wastes appear to have a small effect on the outwash area soils. Runoff from the site drains to this area and may carry dissolved and particulate matter to these soils. No impact on vegetation in the outwash area was observed, however. Levels of constituents in this area were mostly lower than in the wastes themselves and are reduced with distance from the waste area. Concentrations of the compounds detected did not exceed health-based criteria for the protection of human health.

4.4. Ground Water

4.4.1. Water Levels and Hydrologic Properties

Depths to ground water were measured at the site on July 18, August 1, and August 18, 1997. Ground-water elevations (hydraulic head) from July 18 are shown graphically in figure 4.9. All of the data are shown in table 4.4. The gradient measured is consistently to the northeast in the uppermost aquifer and varied from 0.0027 to 0.0035. The first and second set of elevations were measured when no pumping was occurring in the quarries; however, the third set of measurements was taken during pumping of the north quarry pit. It is possible that quarry pumping exerts a localized transient influence on the ground-water levels in the uppermost aquifer that could not be

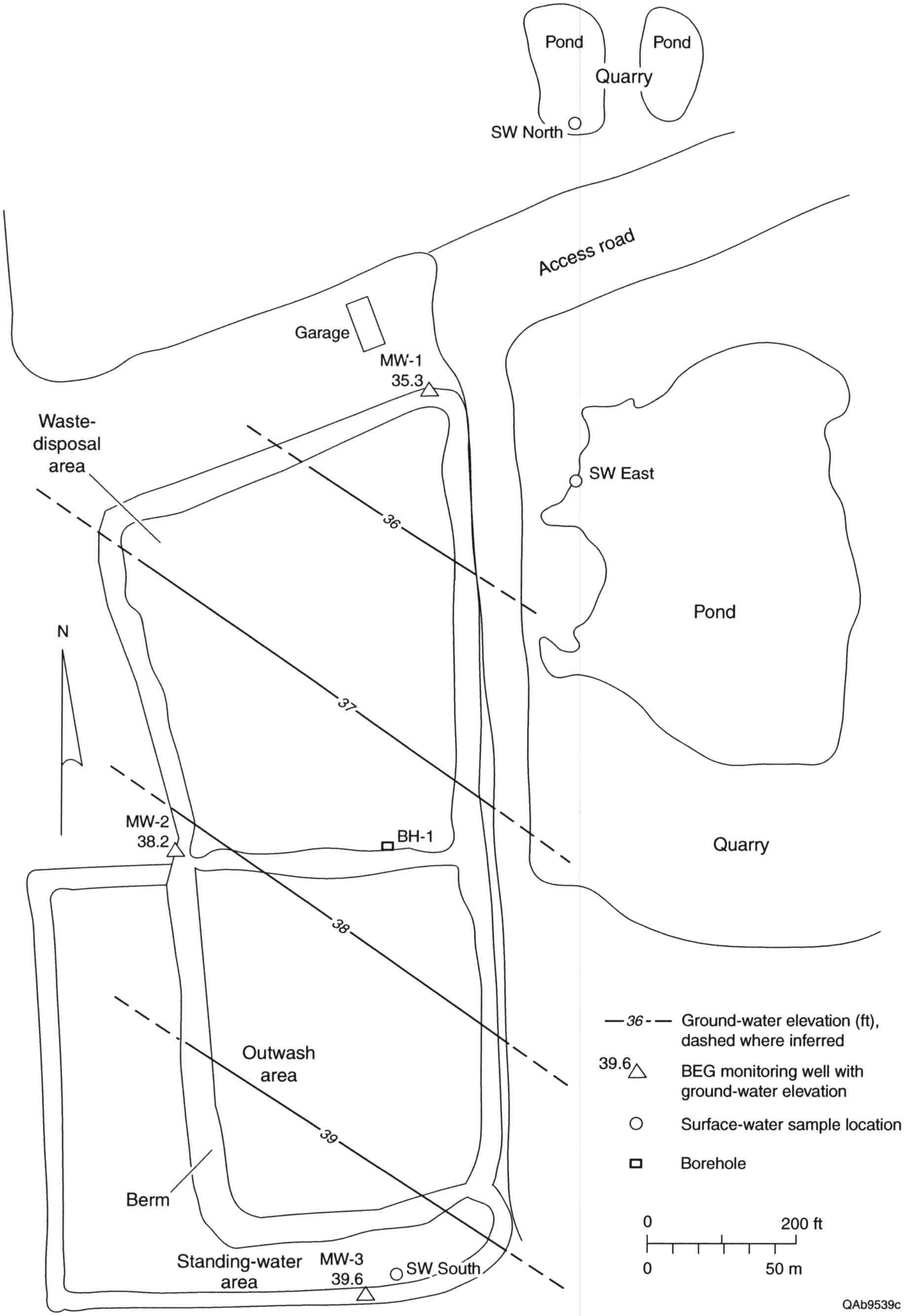


Figure 4.9. Ground-water elevation data from the uppermost aquifer beneath the Vernon Briggs site, July 18, 1997.

Table 4.4. Ground-water elevation and gradient data.

	Elevation[1], top of casing[2]	Ground-water elevation[1] 7/18/97	Ground-water elevation[1] 8/1/97	Ground-water elevation[1] 8/18/97
MW-1	50.88	35.30	35.28	34.98
MW-2	46.72	38.23	37.97	37.52
MW-3	46.87	39.60	39.34	38.3
Gradient (MW-3 to MW-1)	--	0.0035	0.0033	0.0027

[1] All elevations based on arbitrary datum

[2] Top of PVC casing

completely mapped in this study. The potentiometric surface in this aquifer should therefore be considered a transient feature in which the gradient can change, not only seasonally with natural recharge, but also by events such as pumping from either of the surface ponds. Gradient directions discussed in the following sections are in relation to the data shown in fig. 4.9, for the purposes of discussion of conditions at the time of sampling only.

Results of drawdown tests are depicted in figure 4.10 a through d. Analysis of water-level changes during the hydrologic tests and information about subsurface stratigraphy and hydrologic setting suggest that the aquifer material at the Vernon Briggs site is semiconfined; that is, the aquifer material is covered by another layer that is less permeable than the aquifer and in which horizontal flow is not negligible. This cover layer most likely corresponds to the surficial 10- to 12-ft-thick clay layer described in Section 2.3.2. Vertical leakage from this less-permeable layer affected the results of hydrologic tests, with drawdown less than that predicted from the Theis equation (fig. 4.10c).

Transmissivity estimated by matching drawdown data from the MW-3 test to the Boulton delayed-yield type curves was 12 ft^2/d (table 4.5). Transmissivities of 130 to 219 ft^2/d derived from specific capacity tests at MW-1 and MW-2 overestimate actual transmissivities because of the delayed yield. Note that the transmissivity derived from specific capacity for the test at MW-3 is as much as 14 times greater than the more reliable estimate based on matching the type curve (table 4.5). The specific capacities (amount of discharge obtained per unit amount of drawdown), however, were similar at the three test wells. The transmissivities do not differ greatly, therefore, between the three test wells, and 12 ft^2/d is a reasonable estimate of average transmissivity at the Vernon Briggs site.

4.4.2. Onsite Ground Water

Three monitoring wells were sampled on August 1, 1997. Well locations are shown in figure 3.1, and summary tables of chemistry results are shown in table 4.6. Detection-limit data

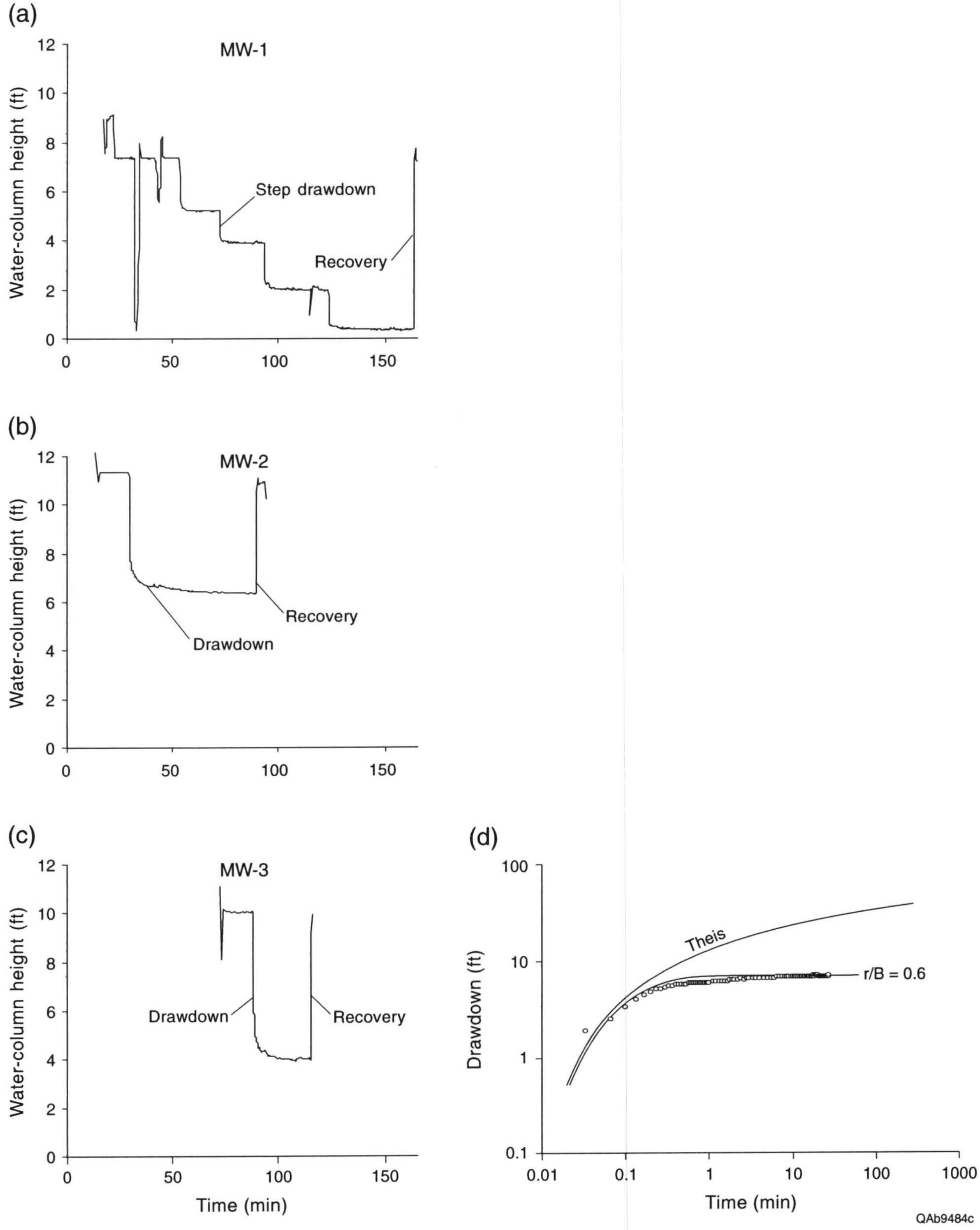


Figure 4.10. Graphical results of drawdown tests.

Table 4.5. Data on hydrologic properties estimated from tests at monitoring wells at the Vernon Briggs site.

Well	Test period	Discharge (ft^3/d)	r/B value	Specific capacity (ft^2/d)	T^1 (ft^2/d)	T^2 (ft^2/d)	T^3 (ft^2/d)
MW-1	Drawdown	956[4]	nd	212	nd	174.5	130.8
MW-2	Drawdown	1,376	nd	276	nd	219	162
MW-3	Drawdown	1,465	1.0	241	12	172	121

[1] Transmissivity determined from type-curve matching.

[2] Transmissivity determined from specific capacity assuming storativity of 0.01.

[3] Transmissivity determined from specific capacity assuming storativity of 0.1.

[4] Weighted average of multiple-rate discharge; maximum rate of 1290 ft^3/d.

nd = not determined

Note: ft^3/d can be converted to gallons per minute by multiplying by 5.2×10^{-3}.

Table 4.6. Onsite ground-water chemical-analysis summary. Units are in mg/L unless otherwise noted.

	MW-1 ***Result***[1]	**MW-2** ***Result***[1]	**MW-3** ***Result***	***PQL***	***Method***	***Regulatory guideline or limit***	***Reference***[3]
	2100*	2090	2095				
Arsenic	0.013	<0.005	<0.005	0.005	6010	0.05	EPA-1°MCL
Barium	0.50	0.65	0.93	0.001	6010	2.0	EPA-1°MCL
Cadmium	0.016	0.027	0.021	0.005	6010	0.005	EPA-1°MCL
Chromium	<0.005	<0.005	<0.005	0.005	6010	0.1	EPA-1°MCL
Lead	0.020	<0.005	0.039	0.005	6010	0.015	EPA-action level
Mercury	0.0010	0.00030	<0.0002	0.0002	7470	0.002	EPA-1°MCL
Selenium	<0.005	<0.1[2]	<0.005	0.005/0.1	6010	0.05	EPA-1°MCL
Silver	<0.005	<0.005	<0.005	0.005	6010	0.1	EPA-2°MCL
	2096*	2086	2091				
Barium	0.25	0.31	0.31	0.0050	6010	2.0	EPA-1°MCL
Calcium	42	170	70	0.050	6010	n/a	
Magnesium	16	65	26	0.050	6010	n/a	
Potassium	2.4	4.7	2.7	0.050	6010	n/a	
Sodium	150	550	280	0.050	6010	n/a	
Strontium	0.19	0.84	0.36	0.0050	6010	n/a	
	2097*	2087	2092				
Total Alkalinity	171	510	754	10	310.1	n/a	
Bromide	<1	220	82	0.1/1	300.1	n/a	
Chloride	360	910	450	0.5	300.1	250	EPA-2°MCL
Sulfate	18	110	33	0.5	300.1	500	EPA-1°MCL
Ion balance error (%)	–14.3	–1.5	+17.3				
pH	5.94	6.39	6.74			6.5-8.5	EPA-2°MCL
TDS[4]	760	2541	1699			n/a	
Specific Conductance (mS/cm)[4]	1.2	3.8	2.2			n/a	

[1] Shaded values are those above guidance or regulatory limit.
[2] Detection limit is above regulatory limit.
[3] EPA Drinking-Water Regulations and Health Advisories; EPA 822-B-96-002; October 1996.
[4] Calculated from chemical analysis.
*Sample number; all samples analyzed by Chemsolve.
n/a: not applicable

and analytical results are provided in appendix B. No VOC's or PAH's were detected above method detection limits in any of the onsite ground-water samples.

Cadmium was detected above the EPA primary maximum contaminant level (MCL) in all three wells. Lead was detected above the EPA action level in MW-1 and MW-3. The detection limit for selenium in MW-2 was higher than the MCL, but selenium has not been detected in any other media on site and thus is unlikely a concern. There were no obvious site-related trends in the detected levels of RCRA 8 metals in the ground water.

Chloride and specific conductance were higher for MW-2 and MW-3 than for MW-1. Flow directions can be influenced by the presence of recharge zones and the quarry pumping and may complicate the distribution of chloride and other ions around the site.

Ground water sampled beneath the site is from the uppermost aquifer unit within the Beaumont. This highly permeable sand unit lies approximately 10 to 15 ft below ground surface and 5 ft or more below the base of the waste-disposal area. Above the sand unit is a dense, stiff, blocky clay that might retard the downward movement of water from the wastes to the aquifer. The chloride data and the results of the EM survey suggest, however, the possibility that saline pore water has moved downward to some extent, at least in the vicinity of MW-2 and BH-1. No impact was noted, however, in MW-1, indicating no northward movement of saline water.

4.4.3. Offsite Ground Water

Five ground-water wells at residential locations were sampled for inorganic and organic constituents. No water-level data were obtainable because of restricted well access (pump in well or closed well cover). Because few well-construction data were available (see Section 3), evaluating screened interval locations or the depth and quality of the well seals was not possible. Negative coliform bacteria results (appendix B) show no contamination from septic sources—one indicator of proper seal construction. A summary of results is shown in table 4.7. All results and method detection limits are shown in appendix B. The well locations are shown in figure 2.2.

Table 4.7. Residential well ground-water chemical-analysis summary. All values in mg/L unless otherwise noted.[1]

Well name:	Brooker	Normans	Shelton	Holton	Hurley			Regulatory guideline or limit	
Sample No.:	2066	2071	2076	2061	2081				
Sample No.:	2067	2072	2077	2062	2082	PQL	Method		Reference[2,3]
Naphthalene	<0.005	0.026	<0.005	<0.005	<0.005	0.005	8260	0.01	TNRCC
Petroleum hydrocarbons	0.97	0.9	0.25	0.63	<0.2	0.2	418.1	5	TNRCC
	2069**	2073	2078	2063	2083				
Arsenic	0.0082	<0.005	0.012	0.007	0.015	0.005	6010	0.05	EPA-1°MCL
Barium	0.5	0.59	0.42	0.43	0.69	0.005	6010	2	EPA-1°MCL
Cadmium	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	6010	0.005	EPA-1°MCL
Chromium	0.0092	<0.005	<0.005	0.0092	<0.005	0.005	6010	0.1	EPA-1°MCL
Lead	0.037	0.048	0.041	0.064	0.032	0.005	6010	0.015	EPA-action level
Mercury	<0.0002	0.0003	<0.0002	<0.0002	<0.0002	0.0002	7470	0.002	EPA-1°MCL
Selenium	<0.005	<0.005	<0.005	<0.005	<0.005	0.005	6010	0.05	EPA-1°MCL
Silver	<0.005	0.018	<0.01	0.056	<0.01	0.005/0.01	6010	0.1	EPA-2°MCL
	2068**	2074	2079	2064	2084				
Barium	0.35	0.35	0.31	0.24	0.29	0.005	6010	2	EPA-1°MCL
Calcium	120	110	51	78	110	0.05	6010	n/a	N/A
Magnesium	17	21	9.7	20	12	0.05	6010	n/a	N/A
Potassium	3.3	2	1.4	10	2	0.05	6010	n/a	N/A
Sodium	88	73	100	68	85	0.05	6010	n/a	N/A
Strontium	1.1	1.1	0.67	0.36	0.63	0.005	6010	n/a	N/A
Total alkalinity	240	280	230	270	180	10	310.1	n/a	
Bromide	<0.1	290	<0.1	<0.1	<0.1	0.05	300.1	n/a	N/A
Chloride/duplicate	120/130	120/470	130/130	120/120	100/98	0.05	300.1	250	EPA-2°MCL
Sulfate	18	45	2.4	20	4.8	0.5	300.1	500	EPA-1°MCL
Coliform	absent	absent	absent	absent	absent			absent	
pH	6.69	6.71	7.12	6.51	7.03			6.5-8.5	EPA-2°MCL
TDS	480	476	448	456	461			500	N/A
Specific conductance (mS/cm)	0.958	0.95	0.894	0.911	0.929			n/a	N/A

[1] All shaded values above regulatory or guidance limits.

[2] TNRCC: RG-17, Action Levels for LPST Sites, October 1996.

[3] EPA: Drinking-Water Regulations and Health Advisories; EPA 822-B-96-002.

n/a = not applicable

**Sample number; all samples analyzed by Chemsolve.

Depth and aquifer information for these wells is given in table 3.2. The Norman and Shelton wells are located northeast of the site in the Lower Beaumont and/or the Upper Chicot aquifers, and the Brooker and Holton wells are east in the Chicot and Upper Chicot. The Hurley well is screened in the Beaumont and is located to the southeast of the site. According to regional data (Dutton and Richter, 1990; Williamson and others, 1990), the gradient is to the southeast; judging from short-term, site-specific data (Section 4.4.1), it appears to be toward the northeast in the shallow aquifer zone onsite.

One organic compound, naphthalene, was detected above method detection limits in the Norman well at a level of 0.026 mg/L. This is slightly above the TNRCC action level of 0.01 mg/L for leaking underground petroleum storage tank sites. This level is used by TNRCC to determine the need for further evaluation. There is no Federal MCL or MCLG (guidance MCL) for naphthalene. No other volatile or semivolatile organic compounds were detected in the wells above method detection limits (appendix B). Naphthalene was not detected above the method detection limit of 0.005 mg/L in the onsite wells, suggesting that this compound in this well may be unrelated to the site.

Low levels of TPH were detected in all wells with the exception of the Hurley well. All values were near the method detection limit and less than 1 mg/L. These levels are well below the TNRCC screening level of 5 mg/L in ground water. There was no clear trend in these data other than the low level; however, no TPH was detected in the onsite wells. Thurman (1985) reported ranges of dissolved organic carbon from 0.2 to 15 mg/L, the majority having levels of about 2 mg/L. The values in the domestic wells are probably a result of low regional background levels of organic carbon in the aquifers.

Arsenic, barium, chromium, lead, mercury, and silver were detected in one or more wells above the method detection limits. None of these was detected above EPA primary MCL's or action levels with the exception of lead, which varied from 0.032 to 0.048 mg/L and was detected in all of the wells. The EPA action level for lead is 0.015 mg/L in drinking water. There were no clear trends in the levels of the metals or locations of the detected compounds with respect to the site. Lead is, however, a common contaminant in residential water that contacts lead-soldered piping. It thus can be related to another source (Hem, 1989; DeZuane, 1990, and others cited therein).

Analysis of the cation:anion ratios for the wells indicated that all of the waters were of a Na-HCO_3, Na-Cl, or Na-mixed anion type. No trends signifying major differences in water quality were found between wells. Chloride levels in the ground water were within normal ranges, as were the values for specific conductance and other cations and anions, with the exception of a slightly elevated level of bromide in the Norman well.

4.5. Surface Water

Three surface-water samples were collected at the site on July 17, 1997. Sample locations are shown in figure 3.1. No flowing surface water was found near or on the site; the closest locations of potential impact were judged to be the east quarry pit (sample SW-east), the north quarry pit (SW-north), and an area of surface-water runoff collection inside the southernmost berm (SW-south). The two quarries are pumped regularly by the quarry operators, the north pond more frequently during the course of the investigation, and are therefore likely discharge points for shallow ground water, which exists beneath the site. The southern area containing surface water may be impacted by site runoff. In this low-lying area surface water collects during winter and spring but is ephemeral in summer and fall. This area was dry during the July sampling event.

Results of surface-water analyses are shown in table 4.8. Chloride was found at levels greater than EPA secondary MCL's in both SW-south and SW-east samples. This may be caused by runoff from the site pad, recharge from site-related ground water, evaporation, or a combination of these factors. Duplicate analyses of chloride were more consistent for SW-south than for SW-east or SW-north samples. Levels of TPH were below the TNRCC screening level of 5 mg/L in all three samples. Barium in SW-south was at or slightly above the primary MCL maximum level of 2.0 mg/L (duplicate: 3.2 mg/L), whereas all other RCRA 8 metals were below the MCL or MCLG

Table 4.8. Surface-water chemical-analysis summary. All units in mg/L.

	SW-south result	SW-east result	SW-north result	PQL	Method	Regulatory guideline or limit (mg/L)[1]	Reference[2,3]
	2057*	2053	2048				
Petroleum hydrocarbons	2.8	1.0	0.5	0.2	418.1	5	TNRCC
Chloride	510	700	110	0.5	300.1	250	EPA-2°MCL
pH	8.5	7.8	N/A			6.5-8.5	EPA-2°MCL
TDS	711	1090	N/A			n/a	
Specific conductance (mS/cm)	1.41	2.18	N/A			n/a	
	2058*	2055	2049				
Arsenic	0.027	0.019	0.02	0.005	6010	0.05	EPA-1°MCL
Barium	2.0	0.34	0.31	0.001	6010	2.0	EPA-1°MCL
Cadmium	<0.005	<0.005	<0.005	0.005	6010	0.005	EPA-1°MCL
Chromium	<0.005	<0.005	<0.005	0.005	6010	0.1	EPA-1°MCL
Lead	<0.005	<0.005	0.016	0.005	6010	0.015	EPA-action level
Mercury	0.00020	<0.0002	0.0010	0.0002	7470	0.002	EPA-1°MCL
Selenium	<0.005	<0.005	<0.005	0.005	6010	0.05	EPA-1°MCL
Silver	<0.01	0.023	0.014	0.01	6010	0.1	EPA-2°MCL
	2059*	2054	2050				
Barium	3.2	0.79	0.37	0.0050	6010	2.0	EPA-1°MCL
Calcium	100	160	140	0.050	6010	n/a	
Magnesium	13	25	24	0.050	6010	n/a	
Potassium	22	11	5.6	0.050	6010	n/a	
Sodium	240	210	210	0.050	6010	n/a	
Strontium	0.85	0.44	0.96	0.0050	6010	n/a	
Total alkalinity	170	15	180	10	310.1	n/a	
Bromide	56	57	16	0.1	300.1	n/a	
Chloride	530	1000	130	0.05	300.1	250	EPA-2°MCL
Sulfate	36	370	140	0.05	300.1	500	EPA-1°MCL
Ion balance	–5.7	–30.9	+30.5				

Note: EPA secondary MCL for total dissolved solids is 500 mg/L.

[1] Shaded values are those above regulatory or guidance limit.

[2] TNRCC: RG-17, Action Levels for LPST Sites, October 1996.

[3] EPA: Drinking Water Regulations and Health Advisories; EPA 822-B-96-002.

n/a - not applicable; N/A - not analyzed.

*Sample number; all samples analyzed by Chemsolve.

levels (table 4.6). Barium is a common additive in drilling mud (Deuel and Holliday, 1994). From these results, it appears that impact of the site on the surface water is low.

5.0. RISK EVALUATION

This section presents an assessment of potential human health risks that may be associated with the wastes disposed at the Vernon Briggs site. Information presented here will be used along with other factors, such as feasibility, for selection of the appropriate remediation option for the site. This assessment used risk-based corrective action (RBCA) modeling software developed by Groundwater Services, Inc., for the TNRCC Petroleum Storage Tank (PST) Division. The software is based on guidance provided in "Risk-Based Corrective Action for Leaking Storage Tank Sites (RG-36)" (TNRCC, 1994) and was selected because of the similarities in constituents between those detected at the site and those found at PST sites.

5.1. Site Summary and Classification

Potentially impacted environmental media include soils directly beneath the waste-disposal area and the area of soils in the outwash area within the site berms. No other soils in the vicinity appear to be impacted on the basis of EM and sample results. Ground water was considered on the basis of EM and sample results onsite. Volatile and particulate emissions from the waste material to air were also considered.

One important difference between the Vernon Briggs site and a typical leaking PST site is that the constituents of concern (COC's) are found primarily mixed in disposed drilling mud. Another important difference is that no free petroleum product was found in the soils or ground water at the Vernon Briggs site. The presence of the drilling mud is likely to increase sorption, decrease permeability, and decrease mobility of petroleum-related constituents when compared with typical soil properties.

Current land usage immediately surrounding the site is agricultural, including rice fields and livestock grazing land, and commercial–industrial, with a sand quarry operating on the east and northeast sides of the waste-disposal area (fig. 2.2). The south part of the property is unused; this outfall area receives runoff from the waste-area surface and is seasonally wet or partly submerged. Residential areas exist within 0.5 mi of the site.

Exposure of humans to impacted media appears to be minimal. There is little foot traffic on the waste pad and the outfall area. About two or three people work at the adjacent quarry, their time at the quarry is normally less than 8 h per day, and the quarry operation inherently limits access of unauthorized persons to the waste-disposal area. Some exposure to dusts in dry times of the year or vaporization from the waste-disposal area may occur for short periods. There is no water-supply well at the site. Residential wells used for water supply near the site are described in Sections 3.3.4 and 4.4.2. The closest well is the Norman well, which is approximately 1,800 ft (548 m) north of the site boundary. The local (near-site) gradient is toward this well; regional gradients may differ. Because of this potential effect from near-site ground water, and because no screened interval data were available for the local wells, this well was used as the nearest exposure point for potential offsite impacts from ground-water pathways.

A surface crust covers the waste materials and decreases the likelihood of direct exposure to the buried materials. The crust has lower concentrations of TPH and chloride than do deeper materials. Entrapment in the soft waste material is a potentially acute physical hazard at the site. There are anecdotal reports of cattle becoming mired in the pad area (Mr. Kenny Hales, personal communication, 1997).

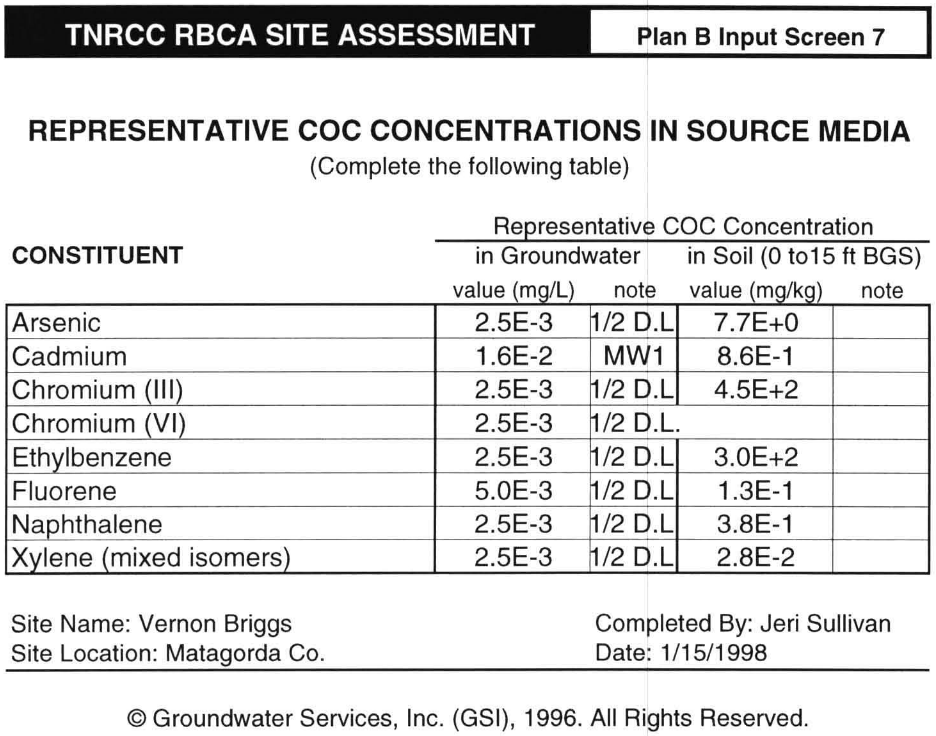
5.2. Constituents of Concern

Risk evaluation models the possiblity of hazard or danger associated with selected constituents of concern (COC's). Organic and inorganic compounds detected above method detection limits in the waste-package samples include arsenic, cadmium, chromium, ethylbenzene, fluorene, naphthalene, and xylenes. Arsenic was included because it was detected in the soil, waste package, and ground water. We were conservative in our assumption because the levels of arsenic in the soil or waste package were well below accepted cleanup levels of arsenic in soil (20 mg/kg for residential areas) determined by the Texas Natural Resource Conservation Commission (1999) and the Agency for Toxic Substances and Disease Registry. In addition, the levels of arsenic in water were below the drinking-water standard or Maximum Contaminant Level (MCL). Lead was excluded from the model because the health-risk values are under review by TNRCC. Lead and other COC's not included in the model or evaluated separately are discussed in Section 5.5. Representative concentrations are shown in table 5.1. Physical properties of the COC's are given in appendix C.

The RBCA assessment software requires a representative concentration for each parameter evaluated. As a conservative estimate, the maximum concentrations detected were input as representative soil concentrations. The same constituents present in the waste material were selected for the ground-water assessment, regardless of the detection rate in ground water. The maximum concentrations detected in ground water or one-half of the detection limit, whichever was higher, was used in the model.

The speciation of chromate in the ground water is not known, and the differences in mobility and toxicity between chromium (VI) and chromium (III) are large. Because of these factors, chromium (VI) and chromium (III) were each added to the list of ground-water COC's at one-half of the detection limit. This assumption allows calculation of the potential health effects as if the total chromium concentration is chromium (VI), a worst-case assumption. It is unlikely that this is truly the case, because both species may coexist depending upon redox and pH conditions in the ground water.

Table 5.1. Representative concentrations for constituents of concern.



TNRCC RBCA SITE ASSESSMENT | **Plan B Input Screen 7**

REPRESENTATIVE COC CONCENTRATIONS IN SOURCE MEDIA

(Complete the following table)

CONSTITUENT	Representative COC Concentration in Groundwater value (mg/L)	note	Representative COC Concentration in Soil (0 to15 ft BGS) value (mg/kg)	note
Arsenic	2.5E-3	1/2 D.L	7.7E+0	
Cadmium	1.6E-2	MW1	8.6E-1	
Chromium (III)	2.5E-3	1/2 D.L	4.5E+2	
Chromium (VI)	2.5E-3	1/2 D.L.		
Ethylbenzene	2.5E-3	1/2 D.L	3.0E+2	
Fluorene	5.0E-3	1/2 D.L	1.3E-1	
Naphthalene	2.5E-3	1/2 D.L	3.8E-1	
Xylene (mixed isomers)	2.5E-3	1/2 D.L	2.8E-2	

Site Name: Vernon Briggs
Site Location: Matagorda Co.
Completed By: Jeri Sullivan
Date: 1/15/1998

5.3. Potential Receptors and Migration Pathways

Potential receptors at the site include site workers at the adjacent quarry and trespassers who might walk across the site. Potential offsite receptors include persons residing within approximately 0.5 mi of the site who use ground water as their drinking-water supply. Seven residences were identified within this radius; five wells supplying these residences were sampled (see Section 4.3). There is no water-supply well at the quarry site.

The baseline risk-assessment pathways that are significant to this site are:

- soil/air exposure, including soil ingestion and dermal contact for onsite workers and trespassers,
- inhalation of volatiles and particulates for offsite residents and workers,
- ground-water ingestion for offsite residents, and
- ground-water dermal contact for offsite residents.

These pathways are detailed in table 5.2, along with exposure parameters and target risks. Indoor air pathways were not considered. The inclusion of the offsite ground-water ingestion and dermal contact pathways necessitated the use of a limited Plan B assessment model.

5.4. Assessment Assumptions

The Plan B process involves comparison of known onsite or calculated offsite constituent concentrations to risk-based exposure limits (RBEL's) at selected points of exposure. Target concentrations are generated by the software in accordance with the TNRCC RBCA guidance. Exposure points are located at some stated distance from the site for the various applicable pathways. For soils, the distance was set at 100 ft for airborne exposure for onsite (quarry) workers. For ground water, the nearest well, regardless of gradient, (Norman well) was chosen as the point of exposure. This is a conservative estimate that also provides a contingency for increased residential development at this distance from the site. The ground-water gradient was input as

Table 5.2. Target health-risk values and RBCA model input data.

STATE OF TEXAS - TNRCC RBCA SITE ASSESSMENT

Plan B Output Table 1

Site Name: Vernon Briggs
Site Location: Matagorda Co.

Job Identification: RRC Vernon
Date Completed: 1/15/98
Completed By: Jeri Sullivan

Software: Texas RBCA
Version: 1.0

NOTE: values which differ from default values are shown in bold italics and underlined.

Exposure Parameter	Definition (Units)	RME (Current Exposure) Res.	Child	Comm.	MLE (Future Exposure) Res.	Child	Comm.	Const.
ATc	Averaging time for carcinogens (yr)	70			70			
ATn	Aver. time for non-carcin. - soil/air exp. (yr)	30	6	25	9	6	25	0.25
ATn.GW	Aver. time for non-carcin. - GW ing. (yr)	30		25	9		25	
ATn.GWd	Aver. time for non-carcin. - GW dermal (yr)	33			33			0.25
BW	Body weight (kg)	70	15	70	70	15	70	70
ED	Soil/Air exposure duration (yr)	30	6	25	9	6	25	0.25
t	Exposure interval (s)	9.5E+8		7.9E+8	--		--	7.9E+6
ED.GW	Groundwater ing. exposure duration (yr)	30			9		25	
ED.GWd	Groundwater dermal exposure duration (yr)	33			33			0.25
EF	Soil/Air exposure frequency (d/yr)	350		***125***	235		250	250
EF.D	Soil dermal exposure frequency (d/yr)	350		***125***	40		40	40
EF.GW	Groundwater ing. exposure frequency (d/yr)	350		***125***	235		250	
EF.GWd	Groundwater dermal exposure freq. (d/yr)	5			5			250
IRw	Ingestion Rate of Water (L/day)	2			1.4		1	
IRs	Ingestion Rate of Soil (mg/day)	100	200	50	100	200	50	480
AAFs	Use age adjustment on soil ingestion?	TRUE			TRUE			
IRadj	Age adjusted soil ing. rate (mg•yr/kg•d)	114			84			
IRa.I	Inhalation rate indoor (m^3/day)	15		20	15		20	
IRa.O	Inhalation rate outdoor (m^3/day)	15		20	15		20	20
SA	Skin surface area (soil dermal) (cm^2)	5.8E+3		5.8E+3	5.0E+3		5.0E+3	5.0E+3
M	Soil to skin adherence factor	1			0.2			0.12
SA.GWd	Skin surface area (GW dermal) (cm^2)	6.2E+3			6.2E+3			6.2E+3
ET.GWd	Duration of GW dermal exposure (hr/day)	3			3			4

Matrix of Exposed Persons to Complete Exposure Pathways		On-Site Current	On-Site Future	Off-Site Current	Const. Future
Groundwater Pathways:					
GW.i	Groundwater Ingestion	FALSE	TRUE	TRUE	--
GW.d	Groundwater Dermal Contact	FALSE	FALSE	TRUE	TRUE
Soil Pathways:					
S.i	Direct Ingestion and Dermal Contact	TRUE	FALSE	--	TRUE
Outdoor Air Pathways:					
S.v	Volatilization and Particulates from Soil	TRUE	FALSE	TRUE	TRUE
GW.v	Volatilization from Groundwater	FALSE	TRUE	TRUE	TRUE
Indoor Air Pathways:					
S.b	Vapor Intrusion to Buildings from Soil	FALSE	TRUE	--	--
GW.b	Vapor Intrusion to Buildings from GW	FALSE	TRUE	--	--

Distance to Off-Site Receptor		
GWdist	Distance to groundwater receptor (m)	5.5E+02
Sdist	Distance to inhalation receptor (m)	3.0E+01

		On-Site Current All Off-Site			On-Site Future		
		Individual		Cum.	Individual		Cum.
Target Risks		Soil/Air	GW		Soil/Air	GW	
TRab	Target Risk (class A&B carcinogens)	1.0E-6	1.0E-6	1.0E-4	1.0E-4	1.0E-4	1.0E-4
TRc	Target Risk (class C carcinogens)	1.0E-5	1.0E-5		1.0E-4	1.0E-4	
THQ	Target Hazard Quotient	1.0E+0	1.0E+0	1.0E+0	1.0E+0	1.0E+0	1.0E+0

Calculation Options		
LU_opt	On-site land use	Commercial
LU_opt.off	Off-site land use	Residential
tox	Use PEL as industrial exposure limit in air?	FALSE
gwMCL?	Use MCL as exposure limit in groundwater?	TRUE
SPLP_opt	Use site-specific soil to leachate partitioning?	FALSE

Surface Parameters	Definition (Units)	Res.	Const.
A	Contaminated soil area (m^2)	1.5E+2	1.5E+2
W	Width of affected soil perpendicular to wind (m)	2.1E+1	2.1E+1
W.gw	Length of affected soil parallel to GW flow (m)		
Uair	Ambient air velocity in mixing zone (m/s)	2.3E+0	
delta	Air mixing zone height (m)	2.0E+0	
Pe	Particulate areal emission rate (g/cm^2/s)	2.2E-12	

Groundwater Parameters	Definition (Units)	Value
Ugw	Groundwater Darcy velocity (cm/yr)	1.2E+4
Ugw.tr	Groundwater seepage velocity (cm/yr)	3.7E+4
Ks	Saturated Hydraulic Conductivity(cm/s)	1.0E-1
grad	Groundwater Gradient (cm/cm)	3.7E-3
phi.eff	Effective Porosity in Water-Bearing Unit	3.2E-1
foc.sat	Fraction organic carbon in water-bearing unit	2.0E-3
Sw	Width of groundwater source zone (m)	1.5E+2
Sd	Depth of groundwater source zone (m)	1.0E+1
LDF	Leachate dilution factor (unitless)	1.0E+2
delta.gw	Groundwater mixing zone depth (m)	
I	Groundwater infiltration rate (cm/yr)	
BC	Biodegradation Capacity (mg/L)	
BIO?	Is Bioattenuation Considered	FALSE

Soil	Definition (Units)	Value
hc	Capillary zone thickness (cm)	5.0E+0
hv	Vadose zone thickness (cm)	3.0E+2
Lgw	Depth to groundwater (cm)	3.0E+2
Ls	Depth to top of affected soil (cm)	6.0E+1
ds	Thickness of affected soil zone (cm)	6.0E+1
rho	Soil density (g/cm^3)	1.8E+0
phi	Soil porosity in vadose zone	3.2E-1
foc	Fraction of organic carbon in vadose zone	2.0E-3
pH	Soil/groundwater pH	6.9E+0

		cap.	vadose	fndtn.
phi.w	Volumetric water content	2.9E-1	1.0E-1	1.2E-1
phi.a	Volumetric air content	3.2E-2	2.2E-1	2.6E-1

Building	Definition (Units)	Res.	Comm.
Lb	Building volume/area ratio (cm)	2.0E+2	3.0E+2
ER	Building air exchange rate (s^-1)	1.4E-4	2.3E-4
Lcrk	Foundation crack thickness (cm)	1.5E+1	
eta	Foundation crack fraction	1.0E-2	

Dispersive Transport Parameters	Definition (Units)	
Groundwater		
ax	Longitudinal dispersion coefficient (m)	9.5E+00
ay	Transverse dispersion coefficient (m)	9.5E-01
az	Vertical dispersion coefficient (m)	9.5E-02
Vapor		
dcy	Transverse dispersion coefficient (m)	3.4E+00
dcz	Vertical dispersion coefficient (m)	2.3E+00

0.0037, and the hydraulic conductivity was estimated to be 10^{-2} cm/s. The onsite land use was entered as commercial use. It is unlikely that noncommercial uses will be feasible in the future in the quarry area. The ground-water use category was classified as category II (beneficial use and TDS <10,000 mg/L). Default soil parameters were also used. Table 5.2 lists the assumptions and input parameters.

Model calculations are based on standard exposure factors, such as an 8-h day of exposure for site workers and standard intake values for ground-water consumption (TNRCC, 1998). These factors are listed in table 5.2 and appendix C. One change was made to the default parameters to evaluate onsite worker exposure more accurately. Because the quarry workers are at the site no more than 4 h per day, the total number of days of exposure was reduced by one-half, to 125 d/yr.

Target health-risk values are shown in table 5.2. Individual values are for an individual exposure route, whereas cumulative values are for the combined routes. The cumulative cancer risks and hazard indices should be summed over various exposure pathways when the same individual or subpopulation is subject to the exposure over the same period (TNRCC, 1998). Typically if cumulative values fall below the target values for a site, the exposure limits may be assumed to be protective of human health. A cumulative hazard index greater than 1 or a cumulative carcinogenic risk greater than 1×10^{-4} is unacceptable and necessitates remediation or appropriate control measures, or both, according to the TNRCC (1998). If individual values simultaneously fall above the target values, however, then these particular pathways may be of concern and may be addressed if the responsible party concludes that it is necessary or appropriate. This assumption is based on the reasonable maximum exposure expected under current and future land use (TNRCC, 1998). Protective concentration limits (PCL's) can then be established as goal concentrations for the remedial process, and remedial actions can target particular pathways of concern.

5.5 Assessment Results

5.5.1 RBCA Model Results

Table 5.3 lists the summary results of the base-line RBCA risk model. No cumulative COC risk levels were exceeded, according to the assumptions outlined above. No hazard indices were exceeded for the COC's evaluated in the model, indicating that the hazard risk from the site is acceptable under model conditions. This means that the cumulative carcinogenic and toxic risks modeled for the listed COC's are acceptable at the site, judging from input data and assumptions. A discussion of other compounds not included in the model or evaluated separately because of special circumstances, such as PAH's, lead, and selenium, follows in section 5.5.2.

Calculations for risk associated with arsenic are illustrative of the findings that no individual-pathway risks meet or exceed individual-pathway limits. First, arsenic dominates the calculated risk associated with the ground-water exposure pathway. Arsenic was detected in ground water but at levels below the EPA MCL (0.05 mg/L). RBCA guidance (TNRCC, 1996) indicates that the MCL standard should be used as the risk-based exposure limit (RBEL) for this site. Because none of the detected arsenic concentrations, however, exceeded the EPA MCL, the calculated individual-pathway risk is found to be acceptable. Likewise, whereas arsenic dominates the calculated risk associated with the onsite-soil dermal-contact and the soil–air combined exposure pathways, these levels of risk are also acceptable. Measured arsenic in soil did not exceed the accepted cleanup target level (20 mg/kg for residential areas). Printouts of individual-pathway risk spreadsheets are given in appendix C.

The calculated hazard index for the ground-water exposure pathway (0.99) was close to the applicable limit of 1.0. The hazard index was dominated by the presence of cadmium, ethylbenzene, and arsenic in offsite ground water. All three COC's were detected in waste materials on site, which is the potential soil-leaching source. The hazard-index values for cadmium were dominated by ingestion rates from ground-water sources. Cadmium was detected in all three onsite wells above the MCL, but not above method detection limits or the MCL in any offsite

Table 5.3. Summary RBCA model results.

STATE OF TEXAS - TNRCC RBCA SITE ASSESSMENT | **Plan B Output Table 4**

Site Name: Vernon Briggs
Site Location: Matagorda Co.

Completed By: Jeri Sullivan
Date Completed: 1/15/1998

1 of 1

PLAN B BASELINE RISK SUMMARY TABLE

	BASELINE CARCINOGENIC RISK					BASELINE TOXIC EFFECTS				
	Individual COC Risk		Cumulative COC Risk		Risk Limit(s) Exceeded?	Hazard Quotient		Hazard Index		Toxicity Limit(s) Exceeded?
EXPOSURE PATHWAY	Maximum Value	Target Risk	Total Value	Target Risk		Maximum Value	Applicable Limit	Total Value	Applicable Limit	
OUTDOOR AIR EXPOSURE PATHWAYS										
On-Site:	1.4E-10	1.0E-6	1.5E-10	1.0E-4	☐	2.6E-3	1.0E+0	3.3E-3	1.0E+0	☐
Off-Site:	3.5E-10	1.0E-6	3.7E-10	1.0E-4	☐	5.6E-3	1.0E+0	6.8E-3	1.0E+0	☐
INDOOR AIR EXPOSURE PATHWAYS										
On-Site:	0.0E+0	1.0E-4	0.0E+0	1.0E-4	☐	1.2E-1	1.0E+0	1.2E-1	1.0E+0	☐
SOIL EXPOSURE PATHWAYS										
On-Site:	1.0E-6	1.0E-6	1.0E-6	1.0E-4	■	4.5E-2	1.0E+0	5.1E-2	1.0E+0	☐
COMBINED SOIL/AIR EXPOSURE PATHWAY										
On-Site:	1.0E-6	1.0E-6	1.0E-6	1.0E-4	■	4.5E-2	1.0E+0	5.5E-2	1.0E+0	☐
GROUNDWATER EXPOSURE PATHWAYS										
On-Site:	1.4E-5	1.0E-4	1.4E-5	1.0E-4	☐	3.1E-1	1.0E+0	5.3E-1	1.0E+0	☐
Off-Site:	3.1E-5	1.0E-6	3.1E-5	1.0E-4	■	5.8E-1	1.0E+0	9.9E-1	1.0E+0	☐

CRITICAL EXPOSURE PATHWAY (Select Maximum Values From Applicable Pathways)										
On-Site:	1.4E-5	1.0E-4	1.4E-5	1.0E-4	☐	3.1E-1	1.0E+0	5.3E-1	1.0E+0	☐
Off-Site:	3.1E-5	1.0E-6	3.1E-5	1.0E-4	■	5.8E-1	1.0E+0	9.9E-1	1.0E+0	☐

Software: Texas RBCA
Version: 1.0

Serial: G-437-SNX-750

wells. The hazard indices for ethylbenzene and arsenic were dominated by ingestion from groundwater soil-leaching sources. Ethylbenzene was not detected above the method detection limit in onsite ground water. Cadmium and ethylbenzene were not found above the method detection limits or MCL's in the offsite wells, indicating no exceedence of the RBEL's (MCL's) at these locations and an acceptable hazard risk in this case. Arsenic was found in four of five offsite wells at low levels, below the MCL. The consistent low levels of arsenic (below MCL) in several wells, independent of local and regional gradients, indicates that arsenic might be present regionally at low levels. No excess risk was therefore associated with these concentrations at the time of sampling.

5.5.2 Additional Risk-Assessment Comparisons

Five COC's, or COC groups, required specific approaches outside the RBCA model, including TPH's (benzene and alkyl benzene compounds), naphthalene in offsite ground water, lead, and selenium. TPH compounds were included separately because the method for assessing potential health risks from complex mixtures of hydrocarbons is under development (TNRCC, 1998). Total petroleum hydrocarbons were detected above method detection limits in the waste materials, although not in onsite ground water. Although overall TPH concentrations in the waste materials are moderate, the volume of waste is large and is, thus, a concern as a possible low-level TPH source. One current methodology for assessing the impact of petroleum hydrocarbons includes breaking the mixture of compounds into representative classes on the basis of the number of carbons and the chemical form (Gustafson, 1996). Benzene, commonly found in TPH mixtures, tends to drive human health risk in assessments. This compound is a conservative representative of the alkyl-benzene group of compounds found in crude oil (API, 1993). Although benzene was below method detection limits, and, thus, MCL's in onsite ground water, it was chosen as a means of conservatively evaluating any health risks from TPH that might arise from the waste materials themselves. Evaluation of the detection limits for these compounds is a way to help explain the relative risks posed by the groups of compounds that they represent. Table 5.4 compares the detection limits in the wastes with health-based criteria, in order to provide a conservative assessment of the adequacy of detection limits for protecting human health with respect to these classes of compounds, until better assessment methods can be developed.

Also included in table 5.4 is a comparison of health-based values of naphthalene in ground water. Naphthalene was detected in one offsite residential well above the TNRCC LPST guidelines for further evaluation, although it was not detected in onsite ground water, indicating that this detection may not be site related. There is no MCL for naphthalene, hence the risk-based value comparison here, which is a conservative means of evaluation.

Lead was not included in the RBCA model because the model for lead is still in review by TNRCC. Selenium was also not included in the model because it was not detected above method detection limits on site. The detection limit for selenium in one sample, however, was noted to be above the MCL, and so it is included in this analysis for completeness. Comparison levels of lead in ground water and soils and selenium in ground water are also included in table 5.4.

The detection limits of alkyl benzene and PAH compounds in onsite soil and waste were evaluated for their adequacy as measures of risk. According to the data, the detection limit of benzene falls below the guidance values available. The detection limit of benzene thus allows for protection of human health from benzene and related alkyl benzene compounds. These values should be taken into consideration with other risk-model results and site-specific knowledge when further site-monitoring or remediation plans are being developed. Benzene does not appear to present any excess risk via potential ground-water pathways and, on the basis of currently available data for ground water, neither do related alkyl-benzene nor PAH compounds.

Table 5.4. Concentrations, soil-screening levels, and PCL values of constituents of concern not included in RBCA modeling.

Constituent	Medium	Concentration[1]	Screening or regulatory limit[1]	Source of limit
Lead (inorganic)	Ground water	0.039 (on site) 0.064 (off site)	0.015	EPA[4] (action level)
			.015	TNRCC PCL[2]
Selenium	Ground water	0.1*	0.05	EPA MCL[4]
			0.05	TNRCC PCL[2]
Naphthalene	Ground water	0.026	1	TNRCC PCL[2]
			0.4–1.0	EPA[3]
Lead (inorganic)	Soil/waste	64	30 (total)**	TNRCC[5]
			400–130#	EPA[3]
			500	TNRCC PCL[2]
TPH (benzene)	Soil/waste	0.25*	20	TNRCC PCL[2]
			0.5	TNRCC[5]
			0.63	EPA[3]

[1] for ground water, mg/L. For soil or waste, mg/kg.

[2] TNRCC, 1998, Draft Appendix V, mandatory pathways. Ground-water PCL's (permissible concentration limits) are the lowest mandatory individual (ingestion) PCL for residential sites. Soil PCL's are the lowest mandatory PCL (combined) for residential sites, 30-acre source area.

[3] U.S. EPA, 1998, Region 9 preliminary remediation goals (PRG's) for residential soil, derived from U.S. EPA Soil Screening Guidance, July 1996, Publication 9355.4-23.

[4] U.S. EPA, 1996, Drinking water regulations and health advisories, EPA 822-B-96-002.

[5] TNRCC, 1996, Guidelines for the disposal of special wastes associated with development of oil, gas, and geothermal resources.

*detection limit

**not a human health or risk-based level

#varies with model selected. First value is uptake biokinetic model; second is CAL-modified value. See U.S. EPA, 1996a.

The presence of naphthalene in an offsite well was addressed in table 5.4. Because naphthalene was not found in onsite ground water, it was inappropriate to include this concentration in the risk model. The detected value, while exceeding the TNRCC's guideline for further evaluation at LPST sites, did not exceed the currently available health-based guidelines from TNRCC and EPA. There is no MCL for naphthalene at this time. The calculated risk from exposure to naphthalene from this offsite well, regardless of its source, is acceptable according to currently available data.

Concentrations of lead in two onsite wells exceeded EPA's action level for lead in drinking water in public supply systems. These data suggest that the waste materials might be of concern as a source of lead to shallow, onsite ground water. Background concentration of lead in shallow soil near the site, however, has not been statistically determined.

Although the concentration of lead in offsite residential wells exceeded the EPA Action Level, these wells are drilled into a different and deeper aquifer than that monitored onsite. Lead in the water from these wells may be due to plumbing and not past onsite activities. The results of these analyses have been forwarded to residents, the local health department, and the Texas Department of Health for appropriate follow-up.

The results of waste and outwash-area soil testing indicate that lead in these media does not pose a health issue at the Vernon Briggs site. Lead in the wastes did not exceed the currently available range of health-based concentration goals for soils from EPA and TNRCC. Although lead did exceed total analysis limits in six of the seven waste samples and three of the outwash-area soils where it was detected, it was not detected in the background soil sample. The total limit is not a risk-based level but is a TNRCC limit for landfill disposal. The results of TCLP analysis of the wastes were below regulatory limits for landfill disposal. These results indicate that lead in wastes does not pose a waste-disposal issue at the Vernon Briggs site.

Finally, the detection limit for selenium should be maintained at the MCL level to provide appropriate protective limits (the MCL) for ground water. Any future analytical work should be monitored to maintain this detection limit.

6.0 REMEDIAL EVALUATION

Results of the site investigation and risk assessment were considered when various site-remediation alternatives for the Vernon Briggs site were evaluated. These remediation options were evaluated with respect to effectiveness in addressing the waste components and effectiveness of mitigating potential environmental impacts. In addition, site-specific constraints that may affect the viability of remedial options were considered.

6.1 General Regulatory Requirements

The Vernon Briggs site is not located in a floodplain or floodway, according to the Flood Insurance Rate Map (FEMA,1985). Because the site is located in Matagorda County, it is not within the Houston–Galveston ozone nonattainment area.

The site location within Matagorda County, however, is not currently within the Coastal Management Zone, according to the Texas General Land Office (1998). Certain activities within the Coastal Management Zone require interaction with the Coastal Coordination Council. Actions that must be consistent with the Coastal Management Program (CMP) goals and policies include wastewater discharge permitting, waste-disposal or storage-pit permitting, and certification of a Federal permit for the discharge of dredge or fill material [see 31 TAC 505.11 (a)(3)] (Carman, 1995). The RRC should contact the Coastal Coordination Council for verification before performing any of these activities at the site. The waste-pit area at Vernon Briggs is approximately 6 acres. Railroad Commission Rule 3.8(j) states that oil and gas waste pits that occupy 5 acres or more of a coastal natural resource area exceed the referral threshold for the purpose of the CMP rules [16 TAC 3.8 (j)(3)(A)].

No wetlands are indicated at the Vernon Briggs site on the Bay City NE wetlands map prepared by the U.S. Department Of Interior, Fish, and Wildlife Service, 1992 draft version. Wetland maps, however, are not definitive authority as to the presence or absence of wetlands at a particular site. The Army Corps of Engineers administers permitting under Section 404 of the

Clean Water Act, including wetland activities. Three wetlands indicators are used by the Corps of Engineers when making wetland determinations: hydrophytic vegetation, hydric soil, and hydrology that supports water at or above the soil surface for a sufficient part of the year. Except in unusual circumstances, all three characteristics must be present during some portion of the growing season for an area to be a wetland. When one or more of the wetlands indicators are observed, assistance should be obtained from either the local Corps of Engineers office or a wetlands expert. The final determination of whether an area is a wetlands and whether the activity requires a permit must be made by the appropriate Corps of Engineers District Office.

At the Vernon Briggs site, the waste area does not display any of the characteristics used to determine the presence of wetlands. The overflow area does contain some hydrophytic vegetation, although other types of vegetation are also present. Some hydrophytic vegetation is also present in the ditches and swales surrounding the site. It is recommended that, prior to disturbing areas beyond the waste-disposal area, the Galveston District of the Corps of Engineers be contacted to confirm the lack of jurisdictional wetlands at the sites. Areas that may be classified as a wetlands but that have a cumulative extent of less than 1 acre are generally considered not jurisdictional.

A national pollutant discharge elimination system (NPDES) permit is required for point-source discharges to waters of the United States (US). These permits may be individual, group, or general and may be for industrial activities or storm-water discharges from industrial facilities. In Texas, the RRC, in addition to the U.S. EPA, regulates point-source discharges from oil and gas exploration and production activities under Rule 3.75. The RRC also provides water-quality certification of Federal permits under Rule 93.

In addition to any permit requirements associated with oil and gas exploration and production activities, the NPDES General Permit for Storm-Water Discharges Associated with Construction Sites covers construction activities that involve 5 acres or more of construction area. Because the Vernon Briggs waste-disposal area is approximately 6 acres, remedial activities that encompass the site may require that a notice of intent (NOI) to be filed for coverage under this general construction site permit. In conjunction with this NOI, an erosion-control and sedimentation plan may be required.

6.2 Summary of Site-Investigation Results

Steps in site assessment include determining the contaminant source and its status, determining the types and concentrations of contaminants present and any existing environmental impact, assessing the risks presented by these contaminants, analyzing the potential for future risks and environmental impact, and evaluating remedial alternatives. The following summarizes the points from the assessment that are pertinent to the remediation-selection process.

6.2.1 Waste Pit

The oil and gas waste-disposal pit, containing primarily drilling muds, covers approximately 6 acres. No free liquids exist in the waste-disposal package at Vernon Briggs. Measurements of waste thickness in the pit ranged from 3 to 7 ft. Estimated in situ volume is 39,000 yd^3. The materials are very soft and have little compressive strength; an upper surface crust about 2 to 6 inches deep is present over the waste materials.

The mean level of TPH detected in subsurface waste samples was 0.92 percent (2.1 percent maximum), and the mean level of TPH in surface waste samples was 0.37 percent (1.7 percent maximum). In past cases (personal communication, Jill Hybner, RRC, 1997), the RRC has applied maximum soil values of 1 to 5 percent TPH as a requisite for cleanup. Guidance from TNRCC sets a maximum level of 1500 mg/kg (0.15 percent) TPH in soil for disposal as municipal solid waste (TNRCC, 1996).

The maximum chloride concentration in the waste samples was 13,000 mg/kg in below-surface composites. Railroad Commission Rule 8 limits chloride concentrations to 3,000 mg/L for onsite landfarming or burial of drilling fluids without a permit. Elevated chlorides can restrict biodegradation processes and inhibit vegetative growth. They may also degrade surface water and ground water via runoff and leaching.

Arsenic, barium, and cadmium were detected in waste samples; none of the levels, however, exceeded the TNRCC's total limit used to indicate the need for follow-up TCLP analysis prior to landfill disposal (TNRCC, 1996). Chromium and lead levels were also detected and exceeded the TNRCC total limit. A TCLP analysis was performed, and no constituent exceeded the regulatory limit for nonhazardous waste disposal. Risk modeling indicated that the health risk from arsenic, cadmium, and chromium in soil (waste) exposure pathways is acceptable, judging from site sampling data. Comparisons of lead levels with currently available health-risk-based guidance indicate that lead is not a concern in the wastes.

Two waste samples were tested for volatile and semivolatile organic compounds. Fluorene and naphthalene were detected in one sample, and ethylbenzene, m- and p-xylenes, and naphthalene were detected in the other. All of the measured values fall below soil action limits for fine-grained soils used by the TNRCC to trigger further evaluation at LPST sites (TNRCC, 1996). No TCLP VOC's or SVOC's were detected above method detection limits.

Two grab samples showed the potential for NORM by detecting the presence of two species of radium (Ra-226 and Ra-228) and lead (Pb-210). An area containing NORM was delineated and composite samples taken per the Texas Department of Health regulations. Composite NORM samples over the delineated area indicated values well below regulatory limits.

6.2.2 Outwash Area

The pit wastes are contained by berms to the north, west, and east; to the south, some spillover of waste materials has occurred into an outwash area. Surface soil samples in this area averaged 0.18 percent TPH. Chloride values for the outwash area varied from 89 to 580 mg/kg, compared with a background chloride value of 51 mg/kg. Arsenic, barium, cadmium, chromium, and lead were detected in the outwash area; barium and chromium were also detected in the background soil sample. Chromium and lead exceeded the TNRCC total limit guidance level to trigger TCLP analysis. TCLP results of the waste area, which indicated no exceedance of TCLP regional levels, are considered to be representative of the outwash area as well. Heath-risk modeling and comparison results of metals and petroleum hydrocarbons in the waste materials showed little or no excess risk (see Section 6.2.1) and are considered a worst-case scenario for the outwash area soils.

6.2.3 Ground Water

Near-site, shallow ground water was characterized by three onsite wells. The gradient, to the northeast, differs from historical measurements of the hydrologic gradient in deeper layers, which follows the regional trend to the southeast. Pumping from the nearby quarry probably induces temporal changes in the gradient at the site, along with seasonal fluctuations, and can complicate expected patterns in the ground-water chemistry.

No VOC's or PAH's were detected in the three ground-water monitoring wells onsite. Cadmium was detected above the EPA MCL in all three wells, and lead was detected above the EPA action level and the TNRCC PCL in MW-1 and MW-3. Risk modeling of cadmium, however, indicated no unacceptable risks via the ground-water pathway. A separate comparison of lead by means of concentrations and action levels indicated a possibility of excess risk from lead in the ground-water pathway.

Chloride levels in soils from MW-1 were higher than in soils from MW-2 and MW-3. In all the monitoring-well borings, soil chloride concentrations decreased with depth. EM data, however, indicated the potential presence of an isolated zone of chloride in the saturated zone, which may be moving downward toward the uppermost aquifer. The rate of vertical movement remains unknown. Chloride levels in ground-water samples were higher for MW-2 and MW-3 than for MW-1.

Five offsite ground-water wells at residential locations were sampled. These wells are completed deeper (as much as 400 ft below surface) than the near-site wells. Screened intervals of these wells are unknown, although negative coliform data indicate the likelihood of intact surface seals, and, thus, a low probability of connection with shallow ground water. One organic compound, naphthalene, was detected above method detection limits in the Norman well at a level of 0.026 mg/L. No other volatile or semivolatile organic compounds were detected in the offsite wells. This detection, which is above the TNRCC action level, is used by TNRCC to designate further site evaluation of LPST sites (0.01 mg/L). There is no Federal MCL or MCLG for naphthalene. Because naphthalene was not detected in the onsite wells, this detection most likely bears no connection to the site. Risk-based comparisons indicate no excess risk from naphthalene in this well, according to current health-based data.

Low levels of TPH were detected in four of the offsite wells. These four off-site wells are up-gradient and side-gradient from the site. TPH was not detected in one potentially down-gradient well. All values were near the method detection limit and less than 1 mg/L; these levels are well below the TNRCC screening level of 5 mg/L in ground water. No petroleum hydrocarbons (as VOC's and SVOC's) were detected in the onsite wells. These low levels of TPH are typical of naturally occurring organic carbon.

Arsenic, barium, chromium, lead, mercury, and silver were detected in one or more of the offsite wells. Lead was detected in all of the offsite wells, and levels ranged from 0.032 to 0.048 mg/L; the EPA action level for lead is 0.015 mg/L in drinking water. None of the other metals exceeded EPA primary MCL's or action levels. Although the concentration of lead in offsite residential wells exceeded the EPA Action Level, these wells are drilled into a different and deeper aquifer than that monitored onsite. Lead in the water from these wells may be due to plumbing and not past onsite activities.

Chloride levels in the ground water were within normal ranges (100 to 130 mg/L), well below the secondary MCL of 250 mg/L.

6.2.4 Surface Water

TPH levels in surface-water samples were below the TNRCC screening level of 5 mg/L in all three samples. Chloride was high, greater than EPA primary MCL levels for total dissolved solids in both SW-south and SW-east samples. The barium level in SW-south was near the primary MCL; the other metals were below the MCL or MCLG levels.

6.3 Considerations for Site Remediation

6.3.1 Waste Pit

The top of the waste material, consisting of low-strength drilling muds, is exposed at ground surface. A thin weathered crust layer is present, and the materials are contained by berms on three sides. Based on site observations, the current configuration of the waste pit itself appears to be stable; with the exception of some outwash from surface waste erosion, release of waste material from the pit area is not anticipated. The low compressive strength of the waste does pose physical concerns. During the site investigation, the waste materials supported foot traffic but would not support vehicular traffic. During times of heavy precipitation, the waste materials did not readily support foot traffic. The current surface condition is therefore considered unacceptable because of the potential physical hazard, and remedial steps are recommended to address the exposed waste surface and to provide for foot traffic, at a minimum.

The presence and quantity of TPH in the drilling-mud waste material are important factors in evaluating remedial alternatives. Risk analysis indicated no excess risk via the ground-water pathway or soil pathway. On the basis of current TPH levels near the cleanup standard, measured reduction in TPH concentrations over the past 4 yr, and the results of VOC and SVOC testing, no organic-directed remediation is recommended. Treatment of TPH, as a measure of the organic constituents in the waste, is not considered necessary at this time.

The elevated chlorides in the waste at Vernon Briggs, however, require remedial attention. Elevated chloride levels inhibit vegetation and may degrade surface water and ground water via leaching and runoff. The impact of elevated chlorides in the waste materials is evidenced by the barren surface of the waste pit, the elevated chloride levels in two of three surface-water samples and in soils from the outwash area, and the elevated chlorides in onsite monitoring-well soils and ground-water samples. No offsite impacts have been detected. The chloride levels in the waste exceed the concentrations for which the RRC authorizes onsite disposal by landfarming or burial without a permit.

Some metals (totals) and five volatile or semivolatile compounds were detected in the waste materials. None of the constituents detected was unexpected. None of the constituents' total concentrations exceeded TNRCC action levels, although some levels did trigger TCLP testing. TCLP tests were performed and any TCLP constituents that were detected were at levels significantly below disposal thresholds. Because Texas evaluates drilling-mud sites on a case-by-case basis, total concentrations were compared with levels deemed acceptable in Louisiana for drilling mud pits (Louisiana Administrative Code 43: xix.129(B)(7c), 1997). All concentrations were below acceptable limits. Risk modeling indicated acceptable risk levels from arsenic, cadmium, and chromium. Lead was shown to be of low concern on the basis of another risk-based comparison. On the basis of these data and the risk analysis, no remediation directed at these constituents is recommended.

6.3.2 Outwash Area

Some metals, chlorides, and TPH were detected in the outwash area. Chloride levels were all less than 600 mg/kg, well below regulatory constraint. All TPH levels in the outwash area were below the 1-percent TPH cleanup criteria; most results were significantly below 1 percent. Chromium and lead were detected above guidance levels in four outwash soil samples near the waste-disposal area. Risk evaluation indicates no excess risk from these levels. Waste thicknesses in these areas are all less than 2 ft and generally less than 1 ft. These data indicate that no remedial action is necessary for this area at this time.

6.3.3 Ground Water

Judging from available site data, cadmium, lead, and chloride are the constituents of concern at the site, which would most likely be mobile in ground water. Because naphthalene and total petroleum hydrocarbons detected off site were not detected on site, there is no evidence that the site is a source of these constituents. In addition, the source of lead in the offsite residential wells cannot be assigned to oil and gas activities on site because of the potential presence of lead in the residential well plumbing. At this time, direct remediation of the ground water is not recommended because of the absence of evidence to indicate that the site is impacting local ground-water quality beyond the site boundaries, the low level of impact detected at onsite wells, and because of the limited use of the uppermost aquifer. Total risk for current and future use of ground water in the area was found to be within acceptable risk levels on the basis of the Plan B assessment and other risk comparisons. Remedial actions to eliminate leaching from waste materials (for example, removing or capping the waste area) would most likely reduce the concentrations of the above-mentioned COC's in site ground water.

A period of monitoring the onsite wells and strategically placed offsite wells is recommended in place of any ground-water remediation at this time. This will define more clearly the ground-water-flow directions, background water quality, and the potential extent of COC's near the site. Additional offsite monitoring wells could include wells in both the uppermost water-bearing zone on the north side of the quarry property and in a deeper aquifer zone. These would provide more information on horizontal and vertical gradients. A staged approach can be implemented for well installation. An additional onsite well is recommended for the lower portion of the uppermost aquifer, on the east side of the site near the berm and BH-1. Information from this well could be used to determine vertical gradients beneath the site and the effectiveness of any remediation procedures, if any, implemented in the future. Continued sampling will produce a data base to support future decisions regarding remediation needs or site closure.

6.3.4 Surface Water

Surface-water results indicate TPH in low levels (less than 3 mg/L), chlorides (as much as 700 mg/L) and some metals. Surface-water samples were taken from adjacent quarry pits or surface-water ditches. The constituents detected in the surface water are consistent with the constituents detected in the wastes. These surface-water constituents are best addressed by remediating the source of the contamination. If the waste is removed or the waste-disposal area is capped, precipitation will neither contact the waste material nor carry waste constituents to surface waters. Remediation of surface water itself is not recommended because of the limited use, the high volumes, and the low levels of constituents detected.

6.4 Remedial Alternatives

At the Vernon Briggs site, areas of concern include the exposed waste materials and associated physical hazards, the elevated chlorides at the surface inhibiting vegetation, the potential for ground-water and surface-water contamination from the waste material, (most notably, from chloride) and the potential for surface-sediment chloride contamination beyond the waste-disposal areas. Types of remedial activities and methods of addressing contaminant sources fall within one of three categories: destruction, immobilization, or extraction. Destruction techniques are used to degrade contamination to an acceptable level and include technologies such as bioremediation, soil flushing, and treatment systems. Immobilization techniques seek to reduce potential threat by containing, isolating, or fixing contamination. Immobilization methods include stabilization/ solidification, capping, and slurry or cutoff walls. Extraction techniques remove the contamination from its location. Once extracted, the contaminated media may be managed on or off site and disposal, treatment, or destruction processes may be used to remediate the contaminated media.

Common extraction and remediation techniques include excavation of contaminated material and removal for offsite treatment or disposal and vertical and horizontal wells for fluid contaminant removal.

Ground-water monitoring is an essential component of any remedial action where the potential for ground-water contamination is a concern. Monitoring of gradient changes and COC's in ground water provides evidence of the effectiveness of remedial actions in meeting risk-reduction goals. Other constituents or parameters, such as total dissolved solids or conductivity, are monitored as indicators of potential plume movement or degradation. Monitoring can be accomplished through a combination of on- and offsite wells, which are sampled for selected constituents of concern. Previously installed monitoring wells and new wells sited to assess some particular aspect of the remediation design may be incorporated into the remedial monitoring network. Installation of any new off-site wells will require landowner approval. In addition, we recommend resampling of the residential wells for lead, using improved flushing techniques, appropriate replication, and, if possible, avoidance of the plumbing system, including the pump and tank. Doing so will help determine the actual source of lead in the residential wells.

For the reasons outlined in Sections 6.3.3 and 6.3.4, remediation of the ground water and surface water at the Vernon Briggs site is not recommended. Continued ground-water monitoring is recommended. Ground-water samples should be analyzed for the following analytes: TPH, benzene, toluene, ethylbenzene, and xylenes (BTEX), naphthalene, chloride, arsenic, cadmium, lead, specific conductance, pH, and total dissolved solids. These data should be compared with previous sample results.

The primary reasons for implementing remedial actions at the site include the physical hazard posed by the soft sediments and the leaching of chloride to shallow ground water and surface water. Options that were considered for managing the waste include onsite land treatment, solidification, soil flushing, dilution burial, capping, excavation, and offsite management. These methods are described later, along with cost estimates provided for the most feasible methods. On the basis of feasibility, cost effectiveness, and the simultaneous reduction of physical hazards, capping is recommended as the most effective technique for reducing chloride movement and physical hazards associated with waste material at the site.

6.4.1 No Action

The no-action alternative means taking no action to remediate the site and leaving the site in its present condition, with natural processes controlling the fate of waste and rate of remediation. Under a no-action alternative, the waste materials would remain at or near the surface, water runoff would continue to carry waste constituents into the overflow area, and the potential for ground-water contamination from the waste would not be reduced. Some impact to onsite media (soils and ground water) was found, although no offsite migration of contaminants in ground water was. It is possible under the no-action alternative for this problem to develop in the future. Because of this possibility, and because of the physical site hazards, the no-action alternative is not considered appropriate for the Vernon Briggs site.

6.4.2 Long-Term Monitoring

Monitoring of potential migration pathways such as ground water is essential to evaluate both no-action alternatives and specific remedial actions. At the Vernon Briggs site, monitoring is recommended to define the direction of ground-water flow near the site in more detail and the extent and direction of any possible movement of constituents of concern in the onsite shallow ground water.

Quarterly monitoring allows documentation of seasonal changes in ground-water gradients and provides a statistically significant number of points to determine change in chemistry data. Statistical tests such as a students t-test are used to document the significance of changes in water-quality data. Specific goals of the monitoring process, such as implementation of a remedial action or ending the monitoring process, are based on the results of the tests.

Additional testing to determine the source of lead in local water-supply wells is needed. The analyses made in this study have been forwarded to residents, the local health department, and the Texas Department of Health for follow-up. No additional testing of these wells by RRC is recommended at this time.

6.4.3 Land Treatment

Land treatment is a standard technology used in treatment and disposal of drilling muds. The predominant constituents in drilling-mud fluids are bentonite and barite, substances that are natural earth materials (Deuel and Holliday, 1994). Land treatment involves dilution and biodegradation to reduce constituents to an acceptable contaminant level. In land treatment, the drilling-fluid solids are spread upon the land surface to a designated thickness, the solids are mixed with soil, amendments are added as necessary, and adequate time is allowed for biodegradation of organics to occur. Nutrients and/or microbial cultures may be added as supplements to speed up the rate of bioremediation (U.S. EPA, 1991).

Bioremediation involves the destruction of organic waste by microbial activity. The organic content, as measured by TPH, of the waste at Vernon Briggs averages 0.92 percent (maximum 2.1 percent) as compared with an RRC cleanup criteria of 1.0 percent. There is little need for bioremediation of the Vernon Briggs waste. Second, the waste volume is estimated to be approximately 39,000 yd^3. Thickness applications for land treatment are recommended to be less than 6 inches. Approximately 48.4 acres (2,106,000 ft^2) of surface area would be required for land treatment of the waste volume at the Vernon Briggs in a single lift. The Vernon Briggs property is not large enough to permit land treatment on site without staging waste applications. Third, the waste has high chloride content that exceeds the 3,000-mg/L concentration considered acceptable for land treatment. Calcium amendments, such as calcium nitrate or agricultural gypsum, may be used to reduce the effects of high chloride contents. These amendments, however, are used primarily as a means to reduce chloride content to a level where it no longer inhibits bioremediation, not as a primary treatment for large waste masses with elevated chlorides (Deuel and Holliday, 1994). A high level of treatment or dilution with clean soil would be required to reduce the chloride level from a mean 6,700 mg/kg to below 3,000 mg/kg.

6.4.4 Soil Flushing

Soil flushing is a technique that may be used to remove organic and inorganic materials, including the elevated chlorides at Vernon Briggs, from soils in the unsaturated zone. A fluid, generally water, is used to saturate the waste, flushing the contaminants from the waste and recovering the flushed contaminants. Soil flushing may be conducted in situ in conjunction with ground-water recovery or may be performed ex situ with fluid recovery through an underdrain system. The benefit of soil flushing is that contaminants are removed from the waste materials; disadvantages include the costs associated with the required recovery and treatment of the flushing fluid. Ex situ soil flushing has the advantage of a controlled fluid-recovery system but has the disadvantage of the necessity of moving the waste material. In situ soil flushing requires a thorough understanding of the site hydrogeology and a high level of confidence that the flushed fluids are recovered (U.S. EPA, 1991). The effectiveness of soil flushing in removing contaminants decreases rapidly with decreasing permeability, and the wastes at the Vernon Briggs site are low-permeability materials. In addition, designing a ground-water recovery system at this location is complex and not cost effective.

6.4.5 Solidification and Stabilization

Solidification and stabilization processes use additives physically or chemically to immobilize certain constituents of concern in the contaminated material. These processes do not destroy the contaminants but stabilize and reduce the mobility of the constituents. Stabilization processes are not recommended at the Vernon Briggs site because the constituents are relatively immobile in the drilling mud. Solidification processes should be considered at Vernon Briggs only as a means to increase the strength of the waste material in place. Solidification would increase the waste volume, and the excess materials would need to be managed or disposed. Considering current land use in the area, it is anticipated that future land use at the Vernon Briggs site will not require high compressive strengths to support structures. In addition, with proper notice about subsurface conditions, structures may be designed to accommodate low compressive strengths.

6.4.6 Dilution Burial

Dilution burial is another technique frequently used for treatment or disposal of drilling muds. In dilution burial, the waste is mixed with soil, thus diluting the concentration below an acceptable contaminant level, and the resulting mixture is buried in trenches. Dilution burial is not recommended when the depth to ground water from the base of the buried waste–soil mixture is less than 5 ft. In addition, it is recommended that a minimum of 5 ft of soil cover be placed above the waste–soil mixture (Deuel and Holliday, 1994). Because of the anaerobic conditions that occur in dilution burial, it is recommended that the oil and grease concentration of the waste–soil mixture should not exceed 3 percent by weight. RRC Rule 8 permits onsite disposal, such as dilution burial, of dewatered drilling fluids with chloride concentrations in excess of 3,000 mg/L without a permit.

The waste-disposal pit at Vernon Briggs is elevated above natural grade and surrounded on three sides by berms. Although constituent concentrations in the waste are near or below guideline limits, the configuration of the Vernon Briggs site does not promote dilution burial. Either an excavation would be required and the waste placed in the excavation to no more than 5 ft from surface grade, or a minimum of 5 ft of fill material would have to be placed over the waste-disposal area.

6.4.7 Capping

Capping is a containment technique that reduces risk of (1) erosion and surface transport of waste material, as well as (2) water infiltration and subsurface leaching of pore water to ground water. Capping removes the risk of casual surface contact with waste and prevents surface water from contacting the waste mass. By providing a low-permeability layer in the cap, precipitation infiltration is reduced to nominal levels, thereby eliminating percolation of fluids through the waste mass and subsequent leaching of constituents into the ground water. Capping also provides a stable surface that reduces the physical hazard at the site, which is necessary when unstable materials are to be left in place. Capping is frequently performed in conjunction with other remedial techniques (U.S. EPA, 1991).

Capping is an established technology that addresses the areas of concern at this site. A cap profile could consist of a clean soil cover layer, a geomembrane cover, and a vegetative layer. The clean soil layer performs a separation and support function. The soil layer covers the waste material, provides a means for establishing grades with positive drainage away from the waste area, and serves as a stable base for the geomembrane installation. The geomembrane provides an essentially impermeable layer above the waste mass. This layer restricts infiltration into the waste, thereby reducing risk of ground-water impact due to surface-water percolation through the waste mass. This layer also provides an effective barrier that prevents surface water from contacting the waste, reducing the potential for erosion, contaminated surface-water runoff, or contaminated sediment outwash. Finally, the vegetative layer consists of clean top soil that is seeded and fertilized. This layer allows for the establishment of vegetation over the waste area, in spite of the high chloride concentration in the waste material, and prevents erosion.

Capping provides excellent separation of the waste from the surface environment. Whereas capping would address the potential for ground-water contamination via vertical infiltration through the waste surface, it does not address the potential for ground-water chloride contamination via horizontal subsurface infiltration. At Vernon Briggs, the waste mass is contained within above-grade berms. As discussed in Section 4.2, the ground-water level is more than 5 ft below the base of the waste material and there is essentially no potential for horizontal subsurface infiltration into the waste mass. Capping can therefore effectively remove the potential for ground-water chloride contamination via vertical infiltration through the waste mass.

6.4.8 Excavation and Offsite Disposal

Excavation of the waste material at Vernon Briggs and disposal of the material at an offsite facility is a technically viable option. Once the waste is removed from the site, surface grading would be required to establish drainage. As the waste disposal area is elevated and surrounded by soil berms on three sides, it is anticipated that little or no offsite fill would be required and that acceptable surface grades could be established using onsite materials.

The advantage to excavation and removal of the waste material is that the source of potential contamination has been removed from the site and the potential for future exposure or contamination is eliminated. The disadvantages to excavation and removal of waste materials are the steps necessary in handling the waste materials and the transfer of the waste to another location. Monitoring of the waste materials for NORM during excavation would be required. One reason for monitoring is worker safety. Another disadvantage to excavation and removal is that although the NORM encountered at Vernon Briggs was at a level exempted from TDH regulation while in situ, the material may not be exempt when disturbed or partitioned into excavated loads.

The volume of waste materials in the disposal area is estimated to be 39,000 yd^3 and the volume of contaminated sediments in the outwash area is estimated at 3,500 yd^3 for a total excavation volume of 42,500 yd^3. When disturbance of the materials is also accounted for, the final estimated disposal volume is 48,875 yd^3.

No RRC-permitted commercial disposal facility exists in Matagorda County, although several RRC-permitted facilities located in nearby counties accept drilling muds. These facilities, however, have permit restrictions that limit waste chloride concentrations to 3,000 mg/kg, and the chloride concentration of the Vernon Briggs waste is consistently above 3,000 mg/kg. Another facility located in Victoria County accepts tank bottoms and contaminated soils but is not explicitly permitted for drilling muds. Some disposal facilities in Zapata County are permitted to accept drilling fluids with chloride concentrations up to 6,000 mg/kg. Explicit chloride limits are not stated for permitted disposal facilities that accept drilling fluids in Jim Wells, Bexar, or Starr Counties.

As an alternative to RRC-permitted facilities, the Vernon Briggs waste may be considered for disposal at TNRCC-permitted facilities. Generally TPH is limited to 600 mg/kg (0.06 percent) for waste disposed of in municipal solid waste (MSW) landfills; select MSW landfills accept waste with TPH as much as 1,500 mg/kg (0.15 percent). In addition to MSW, the TNRCC regulates industrial wastes. Class 1 industrial waste is a classification used for nonhazardous wastes whose constituents exceed levels acceptable for MSW or lower waste classifications. Class 1 wastes require waste-specific approvals from the TNRCC prior to disposal at an authorized landfill. Some Class 1 permitted facilities are located in the Houston area; in addition, several MSW facilities have approval to receive Class 1 waste on a case-by-case basis.

7.0 CONCLUSIONS

This assessment of the Vernon Briggs site included a one-time characterization of disposed drilling-mud materials, surface and subsurface soils, surface water adjacent to the site, and on- and offsite (residential) ground water. Constituents of concern detected in media at the site were petroleum hydrocarbons and metals, including arsenic, cadmium, chromium, lead, and chloride. Naturally occurring radioactive material (NORM) was also detected at low levels in surface wastes at the site. The waste materials have mixed with a limited area of onsite soils and have had a moderate effect on surface water adjacent to the site and onsite ground water. Although constituents of concern were detected in offsite ground water, the pathways from the site are incomplete, or alternate sources may exist for these constituents. A preliminary assessment made on the basis of the one set of samples indicated little or no excess risk to onsite workers or offsite residents resulting from wastes at the site. Other site issues include physical hazards at the disposal area owing to the soft waste material, elevated levels of chloride in the waste materials, and elevated levels of chloride in near-site surface water.

Monitoring is recommended at the Vernon Briggs site to provide additional data as a basis for determining the cost effectiveness of remediation. The one-time measurement of waste, soil, and water constituents in this study supports preliminary findings that remediation of waste materials is not justified on the basis of exposure risk. Whether elevated levels of chloride in waste materials and near-site surface water indicate the need for remediation of waste materials can be better determined with additional monitoring data. Monitoring should include new wells in addition to the three installed in this study.

If additional monitoring data support a finding that remediation of waste materials is needed, a preferred approach may be capping of the waste material. Benefits of capping include closure of the individual pathways of concern, removal of the physical entrapment hazard at the site, elimination of runoff to onsite soils and offsite surface water, reduction or elimination of leaching of chloride and other constituents to ground water. Drawbacks include leaving the wastes in place onsite and the need for a long-term monitoring commitment to prove the effectiveness of remediation.

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