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REMEDIAL ACTION PLAN (RAP)/ INTERIM MEASURES WORK PLAN (IMWP) CHEVRON REFINERY AND BALLFIELDS PHILADELPHIA, PENNSYLVANIA

MARCH 15, 1993

DAMES & MOORE

DAMES & MOORE JOB NO. 16000-430

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1.0 INTRODUCTION

This Remedial Action Plan (RAP)/Interim Measures Work Plan (IMWP) provides a scope of activities to investigate areas containing free-phase hydrocarbon at Chevron's Philadelphia Refinery and evaluate remedial process options to address impacted soil at Area B and the Soil Gas Anomaly within the Ballfields Area. This RAP/IMWP was developed in response to a letter forwarded to Chevron from the Pennsylvania Department of Environmental Resources (PADER), dated September 4, 1992, requesting that Chevron address the removal of free-phase hydrocarbon from the water table in "affected areas." In this letter, the PADER also concurred with recommendations, presented in Dames & Moore's report *Addendum II: Environmental Investigation - Ballfields Area*, dated May 7, 1992, for the remediation of soils in potential source areas (Area B and the Soil Gas Anomaly) within the Ballfields.

A meeting was held on December 9, 1992 at the PADER offices in Norristown, Pennsylvania between representatives of the PADER, the United States Environmental Protection Agency (USEPA), Chevron, and Dames & Moore. The purpose of this meeting was to discuss the implementation of measures to define the extent of free-phase hydrocarbon at various locations within the Refinery and remediate impacted soil within the two identified areas at the Ballfields Area. As a result of this meeting, Chevron agreed to submit this RAP/IMWP to address areas within the Refinery containing free-phase hydrocarbon. In addition, the PADER/USEPA requested that Chevron refine the June 3, 1991 matrix that presented remedial process options and alternatives for soil within the Ballfields. Dames & Moore re-evaluated the remedial alternatives presented in this matrix, and the results of this study are presented in this RAP/IMWP.

During the December 9, 1992 meeting, Dames & Moore presented a map showing the areas within the Refinery containing free-phase hydrocarbon. A total of sixteen areas were identified by Dames & Moore. In addition, the PADER, in a January 19, 1993 letter to Chevron, requested that another area in the vicinity of the Main Office Building be addressed in this RAP/IMWP. The specific areas within the Refinery that require investigation with regard to free-phase hydrocarbon are:

- Area 1 - SWMU No. 101 (Monitoring Wells A4, A8, A20, A21, A39, A48)
- Area 2 - Lube Oil Area (Monitoring Wells A5, A7, A45)
- Area 3 - Building 512 Area (Monitoring Wells A13, A14R, A43)
- Area 4 - Pump House 1 Area (Monitoring Wells A46, A47)
- Area 5 - 22 Pump House Area (Monitoring Well A24)
- Area 6 - SWMU Nos. 11/12 (Monitoring Well A133)
- Area 7 - Platt Bridge Area (Monitoring Well A22)
- Area 8 - Tank T-145 Area (Monitoring Well B39)
- Area 9 - SWMU No. 95 (Monitoring Well B124)
- Area 10 - Tank 680 Area (Monitoring Well B43)
- Area 11 - SWMU No. 92 (Monitoring Wells B116, B117)
- Area 12 - SWMU No. 30 (Monitoring Wells B94, B129)
- Area 13 - SWMU No. 90 (Monitoring Well C50)
- Area 14 - SWMU No. 88 (Monitoring Wells C65, C107)
- Area 15 - SWMU No. 89 (Monitoring Wells C97)

- Area 16 - Main Building Office Area
- Area 17 - Unit No. 1333 Area (Monitoring Well B47)

The two areas within the Ballfields that require soil remediation are:

- Area B
- Soil Gas Anomaly

The remainder of this document is divided into six chapters. Chapter 2.0 reviews background information pertaining to both the Chevron Refinery and Ballfields Area. The scope of the RAP/IMWP to address free-phase hydrocarbon within the Refinery and impacted soil within the Ballfields Area is presented in Chapter 3.0. Remedial options for the recovery of free-phase hydrocarbon are discussed in Chapter 4.0. A planned format for the report detailing the results of the RAP/IMWP investigation and remediation is discussed in Chapter 5.0. The organizational structure for the project team is included in Chapter 6.0, and a schedule for the implementation of the RAP/IMWP is presented in Chapter 7.0.

2.0 BACKGROUND

2.1 PROJECT LOCATIONS

The Chevron Refinery and Ballfields Area are located in a heavily industrialized area (primarily petrochemical) approximately five miles southwest of the center of Philadelphia, Pennsylvania. The Refinery is situated adjacent to the eastern bank of the Schuylkill River. The Ballfields Area is located further east across Lanier Avenue. Figure 1 shows the locations of both the Refinery and Ballfields Area.

2.2 SITE USE

2.2.1 Chevron Refinery

The Refinery occupies approximately 350 acres along the Schuylkill River. For purposes of site evaluation, the Refinery has been divided into three areas, designated Areas A, B, and C, as shown on Figure 2.

Area A, which lies south of the George Platt Bridge, is the oldest area of the Refinery, dating back to the 1920s. This area, referred to as the "terminal," contains a gasoline tank truck loading rack (scheduled to be closed in May 1993), a petrochemicals tank truck and rail loading rack, a lube oils rail loading area (not in operation since the mid 1980s), a former package and grease plant, a marine loading dock, and associated piping and tankage.

Area B, which is located north of the George Platt Bridge and south of Pennypacker Avenue, contains the petrochemical process plants, wastewater-treatment system, maintenance and laydown yards, and associated piping and tankage. Area B formerly contained the original refining units, most of which have been removed except for their foundations. This area also includes office buildings and a laboratory.

Area C, which is located north of Pennypacker Avenue, contains the primary refining units, several separators, and associated piping and storage tanks. The refining units were constructed during the 1950s.

The Refinery appears to have been constructed by placing non-indigenous fill over a salt marsh. Typically, the marsh deposits are composed of plastic, low permeability clays. These clays often contain peat or seams high in organic content that may have higher permeabilities than the clay. Some permeable alluvial materials, sand or gravel, may also be interbedded with the marsh deposits. To Dames & Moore's knowledge, the origin and composition of the fill materials at the Refinery are not documented.

2.2.2 Ballfields Area

Immediately adjacent to, and east of, the Refinery Area C is an area designated as the Ballfields. This area, shown on Figure 2, is presently occupied by a parking lot, several large mounds of soil, and vacant land. This area formerly contained two baseball diamonds which were removed to facilitate a parking lot expansion in early 1992. From the 1940s to the 1970s, the Ballfields Area was owned by the Union Tank Car Company and contained nearly 100 sidings where tank cars were cleaned. The property was sold to Philadelphia Electric and then to Arco Oil Company, which traded property with Gulf Oil Company. In the mid-1980s, Chevron Oil Company purchased the entire Refinery from the Gulf Oil Company, including the Ballfields Area.

2.3 PROJECT HISTORY

This section presents a summary of the environmental activities performed at the Refinery and Ballfields Area with regard to soil and ground water conditions.

2.3.1 Site Assessment Investigation

Dames & Moore conducted an investigation of Chevron's Philadelphia Refinery and Ballfields Area in 1986 and 1987. A report entitled *Final Report - Site Assessment Investigation, Chevron-Gulf Refinery, Philadelphia, Pennsylvania,* dated May 18, 1987, and prepared by Dames & Moore, describes the activities, results, and conclusions of the investigation. The following conclusions were reached in this report with regard to the Chevron Refinery and Ballfields:

Refinery

- Free-phase hydrocarbon was detected in 17 monitoring wells at the Refinery. The extent of hydrocarbon at each area appeared to be localized. Extrapolation of free-phase hydrocarbon measurements between wells was tenuous in most cases. Multiple sources were suspected to exist.

- Bail tests performed on two wells (A24 and B39) within the Refinery indicated that product recovery rates ranged between 1.25 gallons per week (gpw) in A24 and 0.25 gpw in B39.

- A pilot test trench was installed in the vicinity of A24 and pumped at 3 to 5 gallons per minute (gpm). No free-phase hydrocarbon entered the well within the trench nor the soil used to backfill the trench.

- A pumping test indicated that free-phase hydrocarbon near A24 could be controlled and recovered by pumping a recovery well at approximately 0.26 gpm for an extended period of time. However, this action would result in pumping a substantial amount of ground water compared to free-phase hydrocarbon.

Ballfields

- Free-phase hydrocarbon was detected in one monitoring well (BF99) within the Ballfields.

- Priority pollutant and library search compounds were detected at varying concentrations in soil samples collected from six test pits. Total priority pollutant (PP) volatile organic compounds (VOCs) were detected at concentrations ranging from non-detect to 31.43 milligrams per kilogram (mg/kg). Total PP base/neutral extractable compounds (B/Ns) were detected at concentrations ranging from non-detect to 1,159 mg/kg. Priority pollutant acid extractable compounds were not detected. Total chromium concentrations ranged from 22 mg/kg to 4,650 mg/kg. Total lead concentrations ranged from 30 mg/kg to 1,860 mg/kg, and total zinc concentrations ranged from 44 mg/kg to 7,480 mg/kg. Other priority pollutant metals were also detected. Cyanide was detected at concentrations ranging from non-detect to 15 mg/kg. The vertical and lateral extent of the contamination was not defined.

2.3.2 Additional Investigation at the Refinery

2.3.2.1 Investigation Near City Sewer Line

In September 1991, the U.S. Coast Guard notified Chevron that hydrocarbon was being released intermittently from the Philadelphia Refinery into the City of Philadelphia's storm sewer and subsequently into the Schuylkill River. This storm sewer, which is approximately 9 feet wide, 8 feet tall, and 4 feet below ground surface (BGS), crosses Chevron's Philadelphia Refinery below the George Platt Bridge. An interim inspection of the rectangular storm sewer confirmed that it was cracked, thereby allowing free-phase hydrocarbon to seep into the sewer.

In September 1991, Chevron excavated test pits near Tank 228, in the area of the storm sewer. Free-phase hydrocarbon was found in each of the test pits. Subsequently, Chevron excavated a trench adjacent to the city storm sewer, exposing its southwestern wall, to evaluate where the hydrocarbon may be entering the storm sewer. The excavation was approximately 140 feet long, 4 feet wide, and 13 feet deep. Depth to ground water in the vicinity of the storm sewer is approximately 6 feet BGS.

The 140-foot-long trench remained open from September 1991 to February 1992. An attempt was made by Chevron to repair the sewer box and Dames & Moore prepared a preliminary design for a hydrocarbon monitoring/recovery system. During this period, Chevron continually dewatered the trench with a Godwin pump to prevent hydrocarbon from entering the city's storm sewer. Discharge from the dewatering system was pumped to Chevron's wastewater treatment system. From September 1991 through the construction of the hydrocarbon monitoring/recovery system (February 1992), Chevron recovered approximately 3,000 gallons of free-phase hydrocarbon and an undetermined amount of water from the trench. The construction of the monitoring/recovery system is detailed in a Dames & Moore document entitled *Construction Report, Construction of Ground Water Monitoring/Recovery System Adjacent to City Sewer Line Under the Platt Bridge, Chevron Refinery, Philadelphia, Pennsylvania,* dated May 4, 1992.

2.3.2.2 Main Office Building Investigation

Dames & Moore conducted an investigation to evaluate the thickness and extent of free-phase hydrocarbon in the vicinity of the Main Office Building at the Refinery between October 1992 and February 1993. The location of this investigation (Area 16) is shown on Figure 2. The results of this investigation are detailed in the report entitled *Final Report - Investigation to Evaluate Hydrocarbon Recovery Options, Main Office Building, Chevron Refinery, Philadelphia, Pennsylvania*, dated February 25, 1993. A copy of this report is included in Appendix A. Based on the results of this investigation, Dames & Moore concluded that:

- Subsurface soil in the vicinity of the Building consists of gray to brown to dark brown silty clay with some sand, cobbles, and sandy clay.
- Ground water forms a mound immediately south of the Building and flows radially away from the mound in all directions.
- Free-phase hydrocarbon is limited to a small area immediately south of the Building.
- Two different plumes of hydrocarbons are present in the vicinity of the Building. The first, defined by well points WPM-2, WPM-6, and WPM-8, consists primarily of gasoline. The second, defined by well points WPM-3 and WPM-9, consists primarily of gasoline with some heavier oil components. This hydrocarbon is more degraded than the hydrocarbon detected in WPM-2, WPM-6, and WPM-8.
- The rate of hydrocarbon accumulation in well points WPM-2, WPM-3, and WPM-9 was estimated to be approximately 0.12 gpd, 2.23 gpd, and 3.39 gpd, respectively.
- The hydrocarbon plume(s) may be migrating in a southwesterly direction through the subsurface.

- The Building foundation may prevent migration of hydrocarbon in a north/northeasterly direction, but the gravel subbase underlying the foundation may induce preferential flow beneath the Building.

- The upgradient and sidegradient extent of hydrocarbon has been established, but the downgradient extent has not been fully defined. Additional investigation will be necessary to gain a full understanding of the distribution of hydrocarbon downgradient of the Building.

Dames & Moore's recommendations for additional investigation and the installation of a hydrocarbon recovery system in the vicinity of the Main Office Building are:

- Install two or three well points downgradient of WPM-9 to further define the distribution of hydrocarbon downgradient from the Building.

2.3.3 Additional Investigation at the Ballfields Area

2.3.3.1 Investigation of Area B

Between February and August 1988, Dames & Moore conducted an investigation in the vicinity of Area B (Figure 2). The objectives of this investigation were to:

- Identify and quantify compounds present in Area B soil.

- Evaluate the horizontal and vertical extent of contaminated soil that required remedial action.

These objectives were achieved through a series of tasks, including aerial photograph review and collection of soil samples from test pits excavated within Area B. The results of this investigation are detailed in a Dames & Moore report entitled *Final Report - Investigation of Area B, Ballfields, Chevron Refinery, Philadelphia, Pennsylvania,* dated August 30, 1988. Based on the results of the investigation, Dames & Moore concluded that:

- Based on historical aerial photographs, a railroad yard existed at the Ballfields from 1959 to 1970, and a relatively large building existed at the present Area B. In the early 1970s, the railroad yard and large building were dismantled. This process was complete by 1975, when the Ballfields were cleared of all railroad yard debris except for a concrete pad where the large building previously existed. By 1979, a mound of soil (Area B) was deposited on top of the concrete pad. The northern-half of the mound contained four areas of ponded liquid that reportedly received refinery wastes.

- The Area B soil mound can be divided into two areas: the northern three-quarters, which appeared to be contaminated; and the southern quarter, which did not appear to be contaminated.

- Most of the soil samples collected from the northern three-quarters contained elevated concentrations of VOCs, B/Ns, total petroleum hydrocarbons (TPH), and metals compared to PADER cleanup guidelines at the time of the investigation.

- The soil samples collected from the southern quarter did not contain elevated concentrations of VOCs, B/Ns, TPH, or metals.

- The concentrations of PCBs and cyanide detected in Area B soil were insignificant.

- Area B soil was considered non-hazardous, based on RCRA characterization analysis (EP Toxicity).

- A sample collected below the Area B soil from an asphalt-like material, believed to be an old railroad bed, contained a significant concentration of lead (637 mg/kg). No other parameters were detected at significant concentrations in this sample.

Dames & Moore recommended that a feasibility study be performed to evaluate the most cost-effective and environmentally sound remedial alternative to address Area B soil. Methods thought applicable included off-site disposal, bioremediation (landfarming), incineration (rotary-kiln), and stabilization.

2.3.3.2 Soil Gas Anomaly

Between May and July 1989, Dames & Moore conducted an investigation at the Ballfields Area. The objective of this investigation was to verify the presence and approximate extent of subsurface soil containing VOCs. This objective was achieved through a series of tasks, including soil gas survey and the excavation of test trenches. The results of this investigation are detailed in a Dames & Moore document entitled *Final Report - Soil Gas Survey, Ballfields, Chevron Refinery, Philadelphia, Pennsylvania,* dated July 28, 1989. Based on the results of this investigation, Dames & Moore concluded that:

- Several pockets of black, hydrocarbon-saturated soil were found to exist at a depth of approximately 2 to 4 feet below ground surface (BGS) in the northeast portion of the Ballfields. These pockets ranged in length from approximately 5 feet to 20 feet. The soil in these pockets produced a strong hydrocarbon odor. The depth, width, and number of these pockets could not be ascertained. Based on several assumptions presented in the report, the volume of the impacted soil was estimated to be 1,710 cubic yards.

- The pockets appeared to be more numerous closer to the eastern third of the northern property boundary.

- The pockets of impacted soil were sometimes associated with a gray, sand-like material that emitted a moderate gasoline odor.

- A mound of black soil (approximately 1,070 cubic yards) was also found to exist in the northeastern corner of the Ballfields.

- Laboratory analysis performed on a sample of the black soil collected during our Site Assessment Investigation (see Dames & Moore's report dated May 18, 1987) indicated that the soil contains the VOCs benzene and ethylbenzene, B/Ns, and other long-chain hydrocarbons.

- The soil gas in the vicinity of these pockets of black soil contained compounds typically found in refined petroleum products and wastes.

2.3.3.3 Environmental Investigation - Ballfields

Between August 1990 and May 1991, Dames & Moore conducted an Environmental Investigation at the Ballfields to address three concerns: Area B, the Soil Gas Anomaly Area, and the potential impact to ground water related to these two areas. The specific objectives of this investigation were to:

- Further characterize the degree and extent of soil contamination in Area B and the Soil Gas Anomaly Area.

- Confirm the understanding of the ground water flow system at the site and further evaluate ground water quality at the Ballfields.

- Identify and evaluate remedial alternatives for contaminated soil through analysis of treatability, disposal, and mobility characteristics.

These objectives were achieved through a series of tasks, including an expanded historical review, soil investigation, monitoring well installation, and ground water sampling and analyses. The results of this investigation are detailed in Dames & Moore's report entitled *Environmental Investigation - Ballfields, Chevron Refinery, Philadelphia, Pennsylvania,* dated May 24, 1991. Based on the results of this investigation, Dames & Moore concluded that:

- The volume of Area B soils was estimated to be 15,000 cubic yards, based on a topographic survey.

- The area that contains pockets of black soil covers approximately 46,150 square feet. The pockets of black soil (visible at the surface through stressed vegetation) comprise approximately 20 percent of the 46,150 square feet (9,230 square feet). Some of the pockets of black soil extend to ground water at a depth of 12 to 15 feet BGS. A soil mound containing approximately 1,070 cubic yards of black soil is present adjacent to the Soil Gas Anomaly. Given these conditions, there is approximately 5,175 cubic yards of black soil associated with the Soil Gas Anomaly. However, adjoining soils have been affected by these pockets. Therefore, the estimated contaminated soil volume in this area is 10,000 cubic yards.

- No fatal flaws eliminating biological remediation were identified. Biological treatability analyses indicated that the soil contained populations of hydrocarbon degrading bacteria, that toxicity due to metal and organic compounds should not limit biodegradation, and that levels of nitrogen and phosphorus must be elevated to accelerate bioremediation.

- Due to the physical characteristics of the Area B soil (i.e. high hydrocarbon content and tendency to aggregate), mixing was deemed necessary to ensure proper nutrient and oxygen circulation. Further biological treatability testing was recommended before selecting bioremediation as a remedial alternative.

- VOCs, semi-volatile compounds, and metals were present in soil at Area B and the Soil Gas Anomaly within the Ballfields Area. Selected VOCs and metals were impacting the shallow ground water beneath these areas.

- The elevated hydrocarbon concentrations detected in soil samples from Area B did not appear to be affecting ground water at that location.

- The elevated metals concentration in Area B, particularly chromium and lead, appeared to be affecting ground water in the area of BF-105.

- The elevated concentrations of aromatic hydrocarbons in soil samples from the Soil Gas Anomaly Area, particularly benzene, ethylbenzene, and xylenes, were affecting ground water.

- The elevated metals concentrations in soil samples from the Soil Gas Anomaly Area, particularly chromium and lead, were affecting ground water.

- Remediation of the source areas, Area B and the Soil Gas Anomaly, was recommended to minimize further migration of VOCs and metals to the upper aquifer ground water. The absence of the clay layer separating the upper aquifer from the lower aquifer presents a potential pathway for the migration of contaminants, although the analysis of water from wells screened in the lower aquifer did not indicate the presence of constituents of concern.

2.3.3.4 Evaluation of Remedial Process Options and Alternatives

Based on the results of previous investigations conducted at the Ballfields, Dames & Moore conducted an evaluation of remedial process options and alternatives for soil within Area B and the Soil Gas Anomaly. The results of this evaluation were presented in a letter, dated June 3, 1991, and titled *Evaluation of Remedial Process Options and Alternatives for Soil, Ballfields Area, Chevron Refinery, Philadelphia, Pennsylvania.*

Processes were assessed based on operational, monitoring, and effectiveness considerations, including completion time, worker protection, environmental impacts, long-term effectiveness, reliability, costs, and site-specific problems. Based on our examination, process options were categorized as "Prohibitively Expensive", "Technically Difficult", or "Feasible."

The feasible process option of on-site, ex-situ vapor extraction/bioremediation and low temperature (on-site or off-site) incineration followed by solidification/cementation (on-site or off-site) were preferred based on several factors. First, these processes can be completed within the shortest time frames (with the exception of off-site landfilling). Second, these options do not pose significant site-specific problems. Third, the effectiveness of these methods is easily assessed by post-excavation sampling and leaching tests on the treated material.

Dames & Moore recommended two remedial alternatives to address the areas of concern. Both alternatives consist of two process options. The first alternative consists of vacuum extraction/bioremediation to address organic compounds, followed by solidification/cementation to address the metals. The second alternative involves low temperature incineration (thermal screw) for organic compounds and solidification/cementation for metals.

In addition, Dames & Moore recommended that additional testing be conducted to further evaluate the feasibility of each alternative. Bench scale testing was recommended for the vacuum extraction/bioremediation technology to evaluate the time required for remediation. Pilot testing of the low temperature thermal screw was recommended to evaluate its effectiveness on the long-chain hydrocarbons present in the material. Subsequently, bench scale solidification/cementation and leachability testing was recommended to evaluate the degree of treatment necessary.

2.3.4 Routine Free-Phase Hydrocarbon Measurements

Between 1988 and 1992, Chevron conducted quarterly monitoring of free-phase hydrocarbon within monitoring wells A4, A5, A7, A8, A21, A22, A24, B39, B43, B47, C65, and C97, at the Refinery. Routine monitoring of free-phase hydrocarbon is not conducted at the Ballfields.

The thickness of free-phase hydrocarbon in well A4 has generally declined from approximately 2.37 feet (second quarter; 1988) to 0.01 feet (first quarter; 1992). The most notable decrease occurred between the third and fourth quarters of 1991 when the thickness decreased from 1.36 feet to 0.02 feet.

Well A5 contained free-phase hydrocarbon during all monitoring events. However, due to the high viscosity of the product, accurate measurements of the thickness of free-phase hydrocarbon could not be obtained.

The thickness of free-phase hydrocarbon in well A7 has fluctuated from quarter to quarter. The A7 thickness measurements ranged from between 0.29 feet (fourth quarter; 1988) to 2.04 feet (first quarter; 1990). Since the first quarter of 1990, the thickness of free-phase hydrocarbon has generally declined.

Free-phase hydrocarbon thickness measurements in well A8 have varied throughout the monitoring program. Generally, the measured thickness has been below 0.3 feet. However, between the first quarter 1990 and the first quarter 1991, the thickness increased to

1.4 feet (third quarter; 1990). Free-phase hydrocarbon has not been detected in A8 since the second quarter of 1991.

Well A21 contained free-phase hydrocarbon during all monitoring events. However, due to the high viscosity of the product, accurate measurements of the free-phase hydrocarbon thickness have not been obtained since the fourth quarter of 1989. The greatest thickness recorded prior to the fourth quarter of 1989 was 4.58 feet (first quarter; 1989).

The thickness of free-phase hydrocarbon in well A22 has generally declined from approximately 4.47 feet (second quarter; 1988) to 0.05 feet (first quarter; 1992). The majority of recorded measurements were below one foot.

The thickness of free-phase hydrocarbon in well A24 has generally declined from approximately 6.35 feet (first quarter; 1989) to 0.36 feet (fourth quarter; 1991). The majority of hydrocarbon thickness measurements were between one and four feet.

Well B39 has contained free-phase hydrocarbon during all monitoring events. The greatest measured thickness (3.48 feet) was recorded during the second quarter of 1988. The majority of the thickness measurements were between one and two feet.

Well B43 has contained free-phase hydrocarbon during all monitoring events. The greatest measured thickness (1.82 feet) was recorded during the third quarter of 1991. The majority of the thickness measurements were below one foot.

Free-phase hydrocarbon was consistently detected in well B47. However, during most of the monitoring events, the high viscosity of the hydrocarbon precluded accurate measurement of free-phase hydrocarbon. The greatest thickness recorded was 5.0 feet measured during the second quarter of 1990.

The thickness of free-phase hydrocarbon in well C65 has generally declined from approximately 6.11 feet (second quarter; 1988) to 0.25 foot (fourth quarter; 1991).

Free-phase hydrocarbon was consistently detected in well C97 prior to the fourth quarter of 1990. Since the fourth quarter of 1990, with the exception of the first quarter of 1992 (0.01 foot), free-phase hydrocarbon has not been detected in well C97. All of the recorded thicknesses were below one-half of a foot.

3.0 REMEDIAL ACTION PLAN/INTERIM MEASURES WORK PLAN

This section describes the actions that will be performed to determine the thickness and horizontal extent of free-phase hydrocarbon on the water table at the areas of concern within the Refinery. In addition, this section presents the selected remedial alternative for the remediation of impacted soil within the Ballfields Area.

3.1 CHEVRON REFINERY

Seventeen areas at the Refinery require investigation with regard to free-phase hydrocarbon. Investigation of these areas will involve well point installation followed by an evaluation of ground water flow and free-phase hydrocarbon as detailed in the following subsections. A total of approximately 120 well points are anticipated to be installed within the investigation areas. Table 1 lists each area of investigation and the number of well points to be installed.

3.1.1 Well Point Installation

Well points will be installed using a hollow-stem auger drill rig. Each well point will be screened to intersect the water table. Split-spoon samples will be collected on 5-foot centers from the ground surface to the bottom of each boring (estimated to be approximately 15 feet BGS). The split-spoon samples will be field-screened using a photoionization detector (PID) for the presence of volatile organic compounds. Soil will be logged and described from the split-spoon samples according to the Unified Soil Classification System (equivalent to ASTM D 2487-69). All data, including soil descriptions and qualitative observations regarding soil conditions, will be recorded by the on-site geologist in the daily field logbook.

Upon completion of drilling activities, a well point will be installed at each boring location. The well points will be screened above and below the water table to allow for detection of free-phase hydrocarbon, and will be constructed of 2-inch-diameter Schedule 40 PVC screen (0.020-inch slot size) and riser. The annular space between the borehole wall and the PVC casing will be filled with No. 2 sand from the bottom of the well to the ground surface. In areas that contain highly viscous free-phase hydrocarbon, a larger screen slot size and coarser filter pack may be used. A one-foot bentonite seal will be placed above the sand. The remainder of the borehole will be backfilled to the ground surface with drill cuttings or cement. These well points will be temporary installations, and will be removed upon completion of RAP activities.

3.1.2 Ground Water Flow and Free-Phase Hydrocarbon Evaluation

After installation, the top of PVC casing at each well point location will be surveyed to allow for the construction of a ground water flow map. The well points will be left undisturbed for a period to allow for equilibration of ground water and free-phase hydrocarbon within the well points. Approximately two weeks after well point installation, the depth to ground water and free-phase hydrocarbon will be measured with an Oil Recovery System interface probe in each of the well points and the existing on-site monitoring wells. The elevation of ground water at each monitoring point will be calculated (and corrected to account for free-phase hydrocarbon, if necessary), and a ground water flow map will be constructed. In addition, an isopach map showing the thickness of free-phase hydrocarbon will be completed based on the interface probe measurements.

Bail tests will be performed in monitoring wells/well points containing significant (greater than 0.5 foot) accumulations of free-phase hydrocarbon. By conducting these bailing tests at the monitoring points, a more realistic evaluation of the free-phase hydrocarbon thickness can be made. Free-phase hydrocarbon thicknesses calculated by this method will result in a more realistic evaluation of the free-phase hydrocarbon floating on the water table, and will not be altered by the effects of free-phase hydrocarbon held by the capillary fringe in the unsaturated zone, or mounding of hydrocarbon caused by lesser subsurface pressure in the monitoring point casing. These factors commonly cause unrepresentative free-phase hydrocarbon measurements from monitoring wells.

Prior to the bail test at each location, static ground water and free-phase hydrocarbon levels will be measured with an ORS interface probe. After the static levels have been obtained, free-phase hydrocarbon will be bailed out of each well/well point until all but a small amount of floating hydrocarbon remains.

Following the removal of free-phase hydrocarbon at each location, the recovery rate of hydrocarbon accumulation will be recorded with an ORS interface probe. The following schedule will be used when recording hydrocarbon recovery rates on the first day:

TIME INTERVAL (minutes)	ITERATIONS	TOTAL TIME
30 seconds	10	5 minutes
1	5	10 minutes
2	10	30 minutes
5	6	60 minutes
10	12	180 minutes

After the early time data (first day) is recorded, free-phase hydrocarbon thicknesses will be measured approximately every 24 hours for a period of one week. The data will then be plotted on a time versus recovery graph and extrapolated to evaluate the true free-phase hydrocarbon thickness at each point. Once the thickness of free-phase hydrocarbon has been calculated at each point, an isopach map showing the thickness of free-phase hydrocarbon will be constructed based on the bail test data and analysis.

During the hydrocarbon bail tests, samples will be collected to evaluate the nature and relative viscosity of the hydrocarbon. This information will aid in the evaluation of potential sources and the development of recovery options. In addition, samples of both hydrocarbon and water will be collected and analyzed for Total Benzene by USEPA Method No. 624. The benzene data will be used to ensure compliance with the USEPA Benzene Waste NESHAP regulations.

3.2 BALLFIELDS

As discussed in Section 2.3, Dames & Moore performed an evaluation of potentially feasible alternatives for the remediation of the soils currently in place at the Soil Gas Anomaly Area and Area B within the Ballfields Area. Approximately 25,000 cubic yards of material containing hydrocarbon are present at these two locations. The Soil Gas Anomaly contain discrete waste pits situated throughout the area of concern. The "pockets" contain an organic waste material that contains elevated levels of metals and VOCs. Based on existing data, this area contains an estimated 10,000 cubic yards of material requiring treatment. Area B contains approximately 15,000 cubic yards of soil containing volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs), heavy petroleum-based material, inorganic constituents, and debris from refinery operations.

The results of the preliminary evaluation concluded that two remedial approaches were potentially viable for the handling of this material:

- Ex situ vacuum extraction/bioventing of the material of concern at the site
- Ex situ removal of the organic constituents using low temperature thermal desorption

Based on a further evaluation of potentially applicable technologies, Dames & Moore concluded that recycling of the waste material at the site may be potentially feasible. Based on existing data, the waste does not exhibit the characteristics of a hazardous waste, as defined under 40 CFR Part 261, nor does the Toxicity Characteristic Leachate Procedure (TCLP) extract obtained from selected samples exceed the promulgated criteria. Therefore, the recycling of the waste soils/material into bricks may be potentially feasible, pending regulatory and facility approval of this option.

3.2.1 Evaluation of Technologies

The three options presented in this section were subjected to a more detailed evaluation to determine the most viable approach to use at the site. A summary of this evaluation is presented in Table 2.

3.2.1.1 Ex Situ Vacuum Extraction/Bioventing

The first option, ex situ vacuum extraction (VE)/bioventing, involves the physical removal of VOCs from the material of concern, followed by biological degradation of the heavier SVOCs. VE operates by inducing a vacuum through the area of concern using horizontal or vertical air extraction wells placed at strategic locations. A vacuum pump is attached to the extraction well(s) and air is withdrawn through the material. A zone of lower than ambient air pressure is generated in the area around the extraction well, which increases the apparent volatility of the organic constituents. As the contaminants partition into the vapor phase, they are drawn into the extraction well and discharge to the surface. Typical VE systems employ offgas treatment, such as a catalytic incinerator or granular activated carbon (GAC) to treat the offgas prior to discharge to the ambient air.

Active VE units typically operate 24 hours a day for the duration of the cleanup. The offgas is periodically monitored to evaluate the effectiveness of remedial operations, and as the contaminant concentrations reach an asymptotic level, the system is cycled on and off to determine if the endpoint of remediation has been achieved. If contaminant concentrations in the offgas remain at a constant level after cycling, operation is assumed to be complete and confirmatory sampling is performed. However, as stated previously, VE is typically most effective for VOCs, and less effective for SVOCs. Therefore, in order to reduce the SVOC concentrations in the impacted soils, a second approach, bioventing, will be used.

Bioventing involves the enhancement of the existing microbial population to metabolize and degrade organic compounds present in the subsurface into simpler compounds and ultimately to carbon dioxide and water. Preliminary studies at the site have indicated that the constituents of interest in the soils are not inhibitory to biological growth, and may be effectively degraded using a biological approach. Bioventing uses the same process units as VE, but the cycle of operation is modified. Rather than being used to actively remove organic constituents, the VE unit is used to introduce fresh air to the microbes and to remove excess carbon dioxide generated during degradation. Recirculation does not have to be performed continuously, but only at periodic intervals (i.e., 3 hours per day) to ensure that an adequate supply of oxygen is present for the microbes. Nutrients and moisture may also be necessary to facilitate degradation of the contaminants.

A combined VE/bioventing option can effectively reduce concentrations of VOCs and SVOCs. If performed on the surface, horizontal extraction piping can be installed in an engineered biocell and attached to a VE unit. The biocell can also be covered with an impermeable material to increase the vacuum generated in the pile by eliminating preferential short-circuiting, and to allow the pile to generate and retain heat more efficiently during the colder winter months. VE/bioventing is not effective for inorganic constituents, and the treated soils may require further processing, such as solidification, after remedial operations to remove organic compounds are complete. A pilot study may also be necessary to refine the operating parameters of the system. Typically, a VE pilot study can be completed within 3 to 6 weeks after implementation; however, a pilot-scale bioventing study may require 3 to 6 months of operation to determine operating parameters, such as reaction kinetics, nutrient requirements and other variables.

3.2.1.2 Low Temperature Thermal Desorption

Low temperature thermal desorption, or LTTD, utilizes a rotary kiln to heat impacted soils and partition the contaminants into the vapor phase for treatment or destruction. Typically, the primary combustion chamber of these units operate in the range of 700 to 800° Fahrenheit (° F), and the secondary chamber operates at a temperature of 1,000 to 1,500 °F. The primary combustion chamber is where desorption occurs, whereas the secondary chamber is used to combust the vapor-phase contaminants prior to discharge. Additional offgas controls, such as a caustic scrubber (to reduce acid emission) or a particulate scrubber, may also be necessary prior to discharge.

The operating temperature of an LTTD unit makes it very effective for the removal of VOCs and SVOCs to very low levels, but this technology is not effective on inorganic constituents. The type of unit considered appropriate for this site is a screw conveyor system, capable of handling over-sized solids with minimal processing. Material to be treated would be introduced into the unit via a conveyor belt, and transported through the unit. As the material is treated, the offgas is continuously withdrawn into the secondary chamber for destruction. After treatment, the material is quenched and allowed to cool prior to post-treatment sampling. Treated soils can then be replaced or further processed if necessary.

A preliminary treatability study would be necessary to evaluate the effectiveness of this technology. A trailer-mounted mobile unit could be brought to the site, and a preliminary study could be performed. Typically, adequate results can be obtained using only 500 tons of material; however, the heterogeneity of the material at the site may require a larger quantity of test material. The unit under consideration is capable of a throughput of 150 tons per operating day (8 hours, with an additional 4 hours required for start-up and cool-down), although higher throughputs are possible with less contaminated soils.

3.2.1.3 Recycling

A third option potentially applicable to this site would be transport of the impact material to a recycler for processing into an innocuous material. Cement and brick manufacturers use kilns which operate in excess of 1,700° F, and provide an extended residence time on the order of hours. These conditions are effective for the destruction of even the least volatile compounds, and transforms the waste material into a useable product. The material would have to be classified as a non-hazardous waste before acceptance, and would have to approved by the receiving facility prior to shipment.

Treatability studies would have to be performed to determine if:

1. The material is acceptable for shipment, based on the waste characteristics, and
2. The material is capable of making an acceptable product (i.e., it passes the "Brick Test")

Both of these criteria would have to be met prior to acceptance. This option would be effective for both the organic and inorganic constituents found at the site.

3.2.2 Summary and Conclusions

Based on the results of the detailed evaluation of potential alternatives, each of the options appear to viable for the treatment of the organic constituents in the site soils. VE would be effective for the VOCs present in the soils, while SVOC concentrations would be effectively reduced using bioventing. A pilot study would be necessary to implement this alternative in order to refine the operating parameters of the VE system, and determine nutrient requirements and reaction kinetics for the bioventing phase of operation. This option would be more effective for the material in Area B rather than the viscous organic material at the Soil Gas Anomaly Area. If this approach is used for the Soil Gas Anomaly Area, excavated material would have to be mixed with a bulking agent (such as sawdust) to increase permeability, and allow for more efficient air exchange and better workability. This alternative would not be effective for the metals present in site soils. The treatment of these constituents would require additional remediation (solidification/ cementation).

Low temperature thermal desorption is also considered a viable option for the impacted material at the site, but the effectiveness of this approach would be dependent on the results of a field pilot test. Desorption should remediate both the VOCs and SVOCs, but would not be effective for removal of metals. Additional remediation (solidification/ cementation) would be required to treat the inorganic constituents.

Recycling is considered the most viable and cost-effective option because it permanently removes the impacted material from the site, and provides source control for the impacted ground water. The acceptability of this material by the facility will determine whether or not this option is feasible. This option will permanently reduce the concentrations of VOCs, SVOCs and metals in the contaminated soils at the site.

In summary, we recommend that treatability tests be performed to determine the most appropriate alternative or combination of alternative(s) for the site. These treatability studies should be conducted using a phased approach. Because recycling is considered to be the most viable option for the materials at the site, the most cost-effective way to conduct these treatability studies would be to evaluate the recycling option first. Thus, the first phase of the treatability studies will consist of:

- Collecting appropriate samples and analyzing them for RCRA characteristics and TCLP constituents to classify the material as hazardous or non-hazardous.

- Submitting representative samples of the Area B and the Soil Gas Anomaly waste material to a recycler for approval and Brick Testing.

Should the first phase treatability tests indicate that recycling is not a feasible option, a second phase of treatability studies will be performed to evaluate VE/bioventing and LTTD. The second phase of treatability studies will consist of:

- Installing pilot-scale biocell(s) at the site to evaluate the effectiveness of VE/bioventing on the material in Area B, the Soil Gas Anomaly, and a mixture of the two. These tests will take three to six months to complete after the biocells are constructed.

- Performing a pilot LTTD test to determine the effectiveness of this approach on the Area B material, and the Soil Gas Anomaly material. A pilot-scale unit can be mobilized to the site within two months after approval.

4.0 REMEDIAL OPTIONS FOR RECOVERY OF HYDROCARBON

There are several types of remedial technologies that could be implemented to recover free-phase hydrocarbon at the various locations within the Refinery. Depending on hydrogeologic conditions in the area of concern and the characteristics of the hydrocarbon, any one of these recovery options may be the appropriate selection. The types of remedial systems that could be potentially selected for recovery of free-phase hydrocarbon are:

- Construction of a recovery trench or series of trenches.
- Installation of a strategically located recovery well.
- Installation of filter canisters in existing monitoring wells and well points that contain hydrocarbon.
- Installation of automatic bailer system in existing monitoring wells and well points.

The recovery of free-phase hydrocarbon by options 1 or 2 above would require the use of a dual pump to pump both hydrocarbon and water or a scavenger system that would essentially skim hydrocarbon off the water table and pump the hydrocarbon to a storage tank or into the wastewater system at the Refinery.

5.0 REPORTING

Upon completion of the RAP discussed in Chapter 3.0, Dames & Moore will prepare a report detailing the findings of the investigation. This report will include a detailed evaluation of ground water flow at the Refinery that will concentrate on the areas of concern. In addition, the recovery rates and extent of free-phase hydrocarbon will be discussed with regard to the applicability and implementation of remedial alternatives. Finally, remedial alternatives will be selected for the recovery of free-phase hydrocarbon at the various locations within the Refinery, based on information obtained during this investigation and during previous investigations. Factors that will aid in the evaluation of remedial alternatives include site geology, site hydrology, and the characteristics of the free-phase hydrocarbon encountered. The recovery of free-phase hydrocarbon will be considered complete when all monitoring points indicate no measurable accumulations of free-phase hydrocarbon.

In addition, the report will include a discussion of the results of the treatability studies. This will aid in the final selection of the most appropriate alternative(s) for the soil at Area B and the Soil Gas Anomaly Area within the Ballfields.

6.0 PROJECT ORGANIZATION

This section provides the organization of the project team for this investigation. The project team that Chevron and Dames & Moore will utilize during this investigation will include:

• John Harris (Chevron)	Project Coordinator
• Ralph T. Golia (D&M)	Project Director
• Thomas J. Glancey (D&M)	Project Manager
• Eric H. Tartler (D&M)	Senior Engineer

The key personnel will be assisted by other professionals of appropriate disciplines from Dames & Moore's Philadelphia and other offices on an as-needed basis.

7.0 SCHEDULE

The project will be initiated within two weeks from PADER and USEPA approval of this RAP. The drilling and installation of well points should be completed in six to eight weeks. As discussed in Subsection 3.1.1.2, subsequent to installation, the well points will be left undisturbed for a period of two weeks. The free-phase hydrocarbon evaluation at the Refinery will be completed in four weeks. The compilation of data and the writing of the investigative report will commence immediately upon completion of field activities, and should be completed in four to six weeks. Thus, the final report should be delivered to the PADER approximately 16 to 22 weeks following approval of the RAP.

This RAP was prepared by:

Ralph T. Golia

Ralph T. Golia
Managing Associate, Geosciences

Thomas J. Glancey
Project Manager

Eric H. Tartler
Senior Engineer

TABLE 1

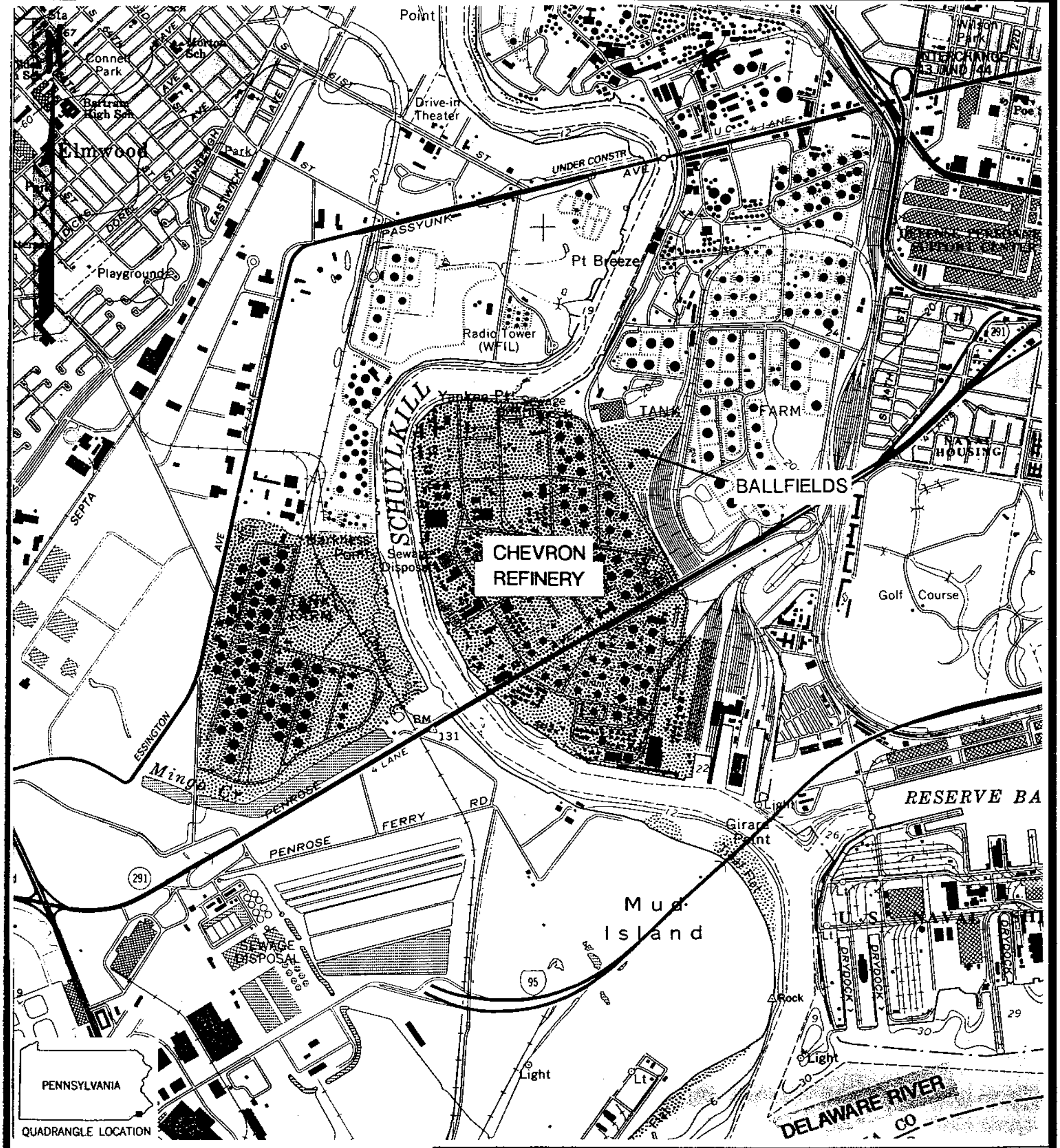
SUMMARY OF PROPOSED WELL POINT INSTALLATIONS
RAP/IMWP AREAS OF CONCERN

CHEVRON REFINERY
PHILADELPHIA, PENNSYLVANIA

AREA NO.	AREA DESCRIPTION	NUMBER OF WELL POINTS
1	SWMU No. 101	26
2	Lube Oil Area	4
3	Building 512 Area	12
4	Pump House Area	9
5	22 Pump House Area	5
6	SWMU Nos. 11/12	4
7	Platt Bridge Area	5
8	Tank T-145 Area	5
9	SWMU No. 95	5
10	Tank 680	5
11	SWMU No. 92	8
12	SWMU No. 30	9
13	SWMU No. 90	5
14	SWMU No. 88	6
15	SWMU No. 89	5
16	Main Office Building Area	3
17	Unit No. 1333 Area	5
	TOTAL	121

Table 2
Soil Remedial Process Option Evaluation Summary
Ballfield Area
Chevron Refinery
Philadelphia, Pennsylvania

Process Option	***Vapor Extraction/Bioremediation***	***Low Temperature Incineration using Thermal Screw Unit***	***Recycling***
Location	Onsite–Ex Situ	Onsite–Ex Situ	Offsite
Project Completion Timeframe	24 – 36 months, depending on effectiveness of bioventing depending on effectiveness of bioventing	12 months	Dependent on quantity that can be transported daily to treatment facility
Worker Protection Requirements	Dermal Contact and Inhalation hazards during construction and material handling operations. Can be minimized with PPE. Physical hazards associated with field operations can be minimized using good field practices and experienced personnel.	Dermal Contact and Inhalation hazards during excavation, material handling and treatment. Can be minimized with PPE. Physical hazards associated with field operations can be minimized using good field practices and experienced personnel.	Dermal Contact and Inhalation hazards during excavation, material handling and transport. Can be minimized with PPE. Physical hazards associated with field operations can be minimized using good field practices and experienced personnel.
Environmental Impacts	Potential atmospheric releases during excavation, material handling and treatment. Offsite impacts to flora/fauna can be minimized using erosion/sediment controls. Potential ground water impacts could occur during disturbance of waste.	Potential atmospheric releases during excavation, material handling and treatment. Offsite impacts to flora/fauna can be minimized using erosion/sediment controls. Potential ground water impacts could occur during disturbance of waste.	Potential atmospheric releases during excavation, material handling and transport. Offsite impacts to flora/fauna can be minimized using erosion/sediment controls. Potential ground water impacts could occur during disturbance of waste.
Long–Term Effectiveness	Minimum weekly maintenance during operation. Effectively reduces soil VOC contamination by permanent removal and offgas treatment. Effectiveness on SVOCs enhanced by bioremediation. Not effective for metals.	Regular weekly maintenance during operation. Effectively reduces soil VOCs and SVOCs through destruction and offgas treatment. Not effective for metals.	Contaminants permanently removed from site. Source area(s) of ground water contamination removed.
Residual Risk	Not effective on metallic constituents. SVOC reductions dependent on soil and contaminant characteristics.	Not effective on metallic constituents. Heavy asphaltenes may remain after treatment.	Residual risk associated with soil significantly reduced through elimination of exposure pathway.
Long–Term Management Requirements	Regular maintenance required during remediation. Additional containment may be required if treated soil is to be replaced after treatment. Ground water monitoring required.	Regular maintenance required during remediation. Additional containment may be required if treated soil is to be replaced after treatment. Ground water monitoring required.	Ground water monitoring required for existing conditions. No long–term soil monitoring required.
Reliability of Technology	VE proven on variety of VOCs. Bioremediation proven for VOCs and SVOCs, but effectiveness may be limited by contaminant and soil characteristics. Pilot study required.	Incineration proven effective on both VOCs and SVOCs. Heavy molecular weight compounds (asphaltenes) may remain after treatment. Pilot study recommended.	Effective if material classified as non–hazardous. Brick kiln can handle up to 80,000 ppm TPH with minimal impacts. Bulk soils crushed before processing. Pilot test required.
Ease of Monitoring Effectiveness	Pre–remediation testing required for baseline conditions. Periodic monitoring required to ensure appropriate operating parameters are maintained during treatment.	Post–treatment sampling of treated soil can easily be performed on batches, but sufficient area must be established to segregate piles until receipt of analytical results.	Post–excavation sampling required to confirm removal of areas of concern.
Relative Cost	**Without Solidification:** $60 – 75/cubic yard $1 875,000 **With Solidification:** $135 – 150/cubic yard $3,765,000	**Without Solidification:** $146.81/ton $5,158,900 **With Solidification:** $234.81/ton $8,251,223	**Without Solidification:** $143.71/ton $5,050,000 **With Solidification:** Solidification not required under this option.
Effectiveness on Contaminants	VE proven on variety of VOCs. Bioremediation proven for VOCs and SVOCs, but effectiveness may be limited by contaminant and soil characteristics. Pilot study required.	Incineration proven effective on both VOCs and SVOCs. Heavy molecular weight compounds (asphaltenes) may remain after treatment. Pilot study recommended.	Effective if material classified as non–hazardous. Brick kiln can handle up to 80,000 ppm TPH with minimal impacts. Bulk soils crushed before processing. Pilot test required.
Additional Remediation Steps Required	Solidification/stabilization may be required for metals.	Solidification/stabilization may be required for metals.	None
Site–Specific Problems	May require mixing or bulking to enhance permeability and homogeneity. Excavation and material handling logistics. Open areas must be protected prior to receipt of post–excavation sampling results.	Establishment of treatment, storage and material handling areas onsite. Bulky materials can be processed but should be removed before treatment. Excavation and material handling logistics. Open areas must be protected prior to receipt of post–excavation sampling results.	Excavation and material handling logistics. Open areas must be protected prior to receipt of post–excavation sampling results.
Advantages	On–site, permanent reduction of toxicity, mobility and volume of VOCs and SVOCs. Required treatment and handling areas readily available.	On–site, permanent reduction of toxicity, mobility and volume of VOCs and SVOCs. Required treatment and handling areas readily available.	Permanent removal of contaminants from site. Soil must be classified as non–hazardous before acceptance.



0 1000 2000 3000 FEET

GRAPHIC SCALE

CONTOUR INTERVAL = 20 FEET

REFERENCE:
A PORTION OF USGS 7.5 MINUTE TOPOGRAPHIC
MAP; PHILADELPHIA QUADRANGLE, PENNSYLVANIA 1967
PHOTOREVISED 1985

TITLE	SITE VICINITY MAP
PROJECT	CHEVRON REFINERY PHILADELPHIA, PENNSYLVANIA
	Dames & Moore WILLOW GROVE, PENNSYLVANIA

SCALE	AS SHOWN	DWN. BY	EM²	JOB NO.	16000-422
DATE	2/17/92	APPR. BY	TJG	FIG. NO.	1

APPENDIX A

MAIN OFFICE BUILDING AREA INVESTIGATION REPORT

REPORT
INVESTIGATION TO EVALUATE HYDROCARBON RECOVERY OPTIONS
MAIN OFFICE BUILDING

CHEVRON REFINERY
PHILADELPHIA, PENNSYLVANIA
MARCH 15, 1993

DAMES & MOORE

DAMES & MOORE JOB NO. 16000-422

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Appendix

1.0 INTRODUCTION

Chevron USA, Inc. (Chevron) retained Dames & Moore to conduct an investigation to obtain information for the development of a hydrocarbon recovery system in the vicinity of the Main Office Building (Building) within the Chevron Refinery in Philadelphia, Pennsylvania (Figure 1). This report presents the results of Dames & Moore's investigation.

The remainder of this report is divided into seven chapters. Chapter 2.0 outlines background information relating to the presence of free-phase hydrocarbon in this area. Chapter 3.0 presents the objectives of the investigation. Chapter 4.0 summarizes the scope of work implemented during the investigation; and Chapter 5.0 contains a discussion of the investigation results. Chapter 6.0 discusses remedial options for the recovery of free-phase hydrocarbon. Chapter 7.0 includes Dames & Moore's conclusions regarding the hydrogeologic conditions and extent of free-phase hydrocarbon, and recommendations for remedial alternatives for the recovery of the free-phase hydrocarbon. Chapter 8.0 lists the references used to prepare this report.

2.0 BACKGROUND

In September 1992, Chevron detected free-phase hydrocarbon in a sump located in the basement of the northwest corner of the Main Office Building at the Chevron Refinery in Philadelphia, Pennsylvania. Dames & Moore, under contract to Chevron, installed a carbon adsorption system to address vapors emitting from the free-phase hydrocarbon contained in the sump.

Chevron found an area of stressed vegetation in front of the Building (to the southeast). Based on visual observations during excavation activities, Chevron established that a leak was present in a jet fuel line that ran underneath this area of stressed vegetation. The line was subsequently decommissioned by Chevron.

3.0 PROJECT OBJECTIVES

The objectives of this phase of the project were to:

- Evaluate the thickness and horizontal extent of free-phase hydrocarbon on the water table in the vicinity of the Building.
- Identify the source of the free-phase hydrocarbon (if possible).
- Obtain hydrogeologic/hydrocarbon recovery data for the development of a remedial alternative to address the free-phase hydrocarbon.

4.0 FIELD INVESTIGATION

In order to achieve the objectives of this study, Dames & Moore implemented a field investigation that consisted of three tasks:

- Installation of eleven well points near the Building.
- Collection of depth to water/free-phase hydrocarbon measurements, and free-phase hydrocarbon samples for simulated distillation analysis.
- Evaluation of hydrocarbon recovery rates using product bail tests.

4.1 TASK 1 - WELL POINT INSTALLATION

MARCOR of Pennsylvania (a Pennsylvania-licensed well driller) installed eleven well points at the locations shown on Figure 2 using a hollow-stem auger drill rig. The well points were installed in two phases. Phase I well points (WPM-1 through WPM-5) were installed on November 9, 1992. Phase II well points (WPM-6 through WPM-11) were installed on January 6, 1993.

The well points were installed to intercept the water table. Dames & Moore personnel logged the soil from drill cuttings and described the soil according to the Unified Soil Classification System (equivalent to ASTM D 2487-69). The on-site geologist recorded data acquired during drilling activities, including soil descriptions and qualitative observations regarding soil conditions, in the daily field logbook.

Upon completion of drilling activities, a well point was installed at each boring location. The well points screen the interval above and below the water table to allow for detection of free-phase hydrocarbon, and are constructed of 2-inch-diameter Schedule 40 PVC screen (0.020-inch slot size) and riser. The annular space between the borehole wall and the PVC casing was backfilled with No. 2 sand from the bottom of the well to approximately 1 foot below ground surface; the remainder of the annular space at each location was backfilled with bentonite pellets.

After installation, Dames & Moore contracted Pennoni Associates to survey the top of PVC casing at each well point location. Based on this data, Dames & Moore was able to construct ground water contour maps. The elevation of the top of PVC casing for each of the well points was surveyed relative to the National Geodetic Vertical Datum.

4.2 TASK 2 - WATER LEVEL AND FREE-PHASE HYDROCARBON EVALUATION

The Phase I well points were left undisturbed for approximately ten days to allow for equilibration of ground water and free-phase hydrocarbon within the well points. On November 19, 1992, Dames & Moore measured the depth to ground water and free-phase hydrocarbon with an ORS interface probe in the five Phase I well points. The depths to ground water and free-phase hydrocarbon were also measured on December 7, 1992. Tables 1 and 2 present the water measurements collected on November 19, 1992, and December 7, 1992, respectively.

Dames & Moore calculated the elevation of ground water at each monitoring point (and corrected the elevations to account for free-phase hydrocarbon, if necessary), and constructed a ground water flow map, based on the November 19, 1992 data. In addition, from these data, Dames & Moore completed an isopach map showing the thickness of free-phase hydrocarbon in the vicinity of the Building.

Based on the ground water flow and distribution of hydrocarbon derived from analysis of the November 19, 1992 data, Dames & Moore selected the location of six additional well points (Phase II) in order to further define the extent of free-phase hydrocarbon in the vicinity of the Building. These Phase II well points were installed on January 6, 1992. Dames & Moore measured depth to water/free-phase hydrocarbon on two different dates (February 3 and February 11, 1993) in each of the eleven well points and six area monitoring wells. Tables 3 and 4 present the water level and free-phase hydrocarbon measurements collected on February 3 and 11, 1992, respectively. Dames & Moore constructed a more refined isopach map and ground water flow map for the area based on the measurements collected on February 11, 1993.

Dames & Moore collected free-phase hydrocarbon samples from two of the well points (WPM-2 and WPM-3) and submitted the samples to Caleb Brett Laboratories of Houston, Texas for simulated distillation analysis. The results of the analyses on the free-phase hydrocarbon samples were used to evaluate the type(s) of free-phase hydrocarbon that exist on the water table in the vicinity of the Building. The laboratory report containing the results of the simulated distillation analysis on the free-phase hydrocarbon samples is included in Appendix A.

4.3 TASK 3 - EVALUATION OF HYDROCARBON RECOVERY RATES

Dames & Moore performed hydrocarbon recovery tests on February 11, 1993, at three well points (WPM-2, WPM-3, and WPM-9) that contained greater than 0.5-foot of free-phase hydrocarbon. These recovery tests were conducted to evaluate the actual thickness of free-phase hydrocarbon in these well points and estimate hydrocarbon recovery rates in the area.

Initially, Dames & Moore measured and recorded stabilized ground water and hydrocarbon levels. Once the depth to water/hydrocarbon in each of the well and well points was measured and recorded, free-phase hydrocarbon/water was bailed from well points WPM-2, WPM-3, and WPM-9 until all the hydrocarbon was removed from the well casing or until the thickness of the hydrocarbon remained constant after numerous bailer volumes were removed.

When each well point was sufficiently bailed out, the rising depth to hydrocarbon and water/hydrocarbon interface levels were recorded with time. The following schedule was used to record hydrocarbon recovery rates:

Time Interval (Minutes)	Measurement Frequency (Minutes)
0-5	30 seconds
5-10	1
10-30	2
30-60	5
60-180	10

After the data was obtained, both the depth to hydrocarbon and water/hydrocarbon interface levels were plotted versus time. According to Gruszczenski (1987), there are two different types of curves that result from plotting the depth to hydrocarbon and water/hydrocarbon interface. Type one curves are observed in wells with only a few inches of hydrocarbon accumulation. This type of curve indicates a one to one correspondence between the measured and actual formation hydrocarbon thickness. Type two curves are observed in wells containing greater than one foot of hydrocarbon accumulation. This type of graph indicates an inflection point at the depth to water/hydrocarbon interface curve prior to stabilization of water and hydrocarbon levels. This inflection point is the actual equilibration point of water/hydrocarbon levels during their accumulation. Dames & Moore plotted the slope of the water/hydrocarbon interface line and identified the inflection point (the point where the water level starts to fall) on each of the curves. The difference between the hydrocarbon line and the water/hydrocarbon interface line at the inflection point was measured to evaluate the actual hydrocarbon thickness.

5.0 INVESTIGATION RESULTS

5.1 WELL POINT INSTALLATION/SOIL DESCRIPTION

Dames & Moore installed eleven well points in the vicinity of the Building to intercept the ground water table and potential free-phase hydrocarbon floating on the water table. These well points were installed in two phases. Phase I well points (WPM-1 through WPM-5) were installed on November 9, 1992. Phase II well points (WPM-6 through WPM-11) were installed on January 6, 1993. Dames & Moore installed each of the Phase I and II well points with ten feet of 2-inch-diameter Schedule 40 PVC screen connected to PVC riser pipe to total depths between 10 and 11 feet BGS.

During the installation of the well points, the soil encountered from the ground surface to 6 inches in each boring was generally topsoil consisting of dark-brown silt and sand. Below this topsoil, the soil at the majority of the well point locations consisted of gray to brown to dark brown silty clay. Some sand, cobbles, and sandy clay were also noted in a few borings.

5.2 GROUND WATER FLOW/THICKNESS AND EXTENT OF HYDROCARBON IN PHASE I WELL POINTS

Based on ground water elevations calculated from depth to water/hydrocarbon measurements collected on November 19, 1992 from the Phase I well points (Table 1), Dames & Moore constructed a ground water flow map for the area. Ground water appeared to form a mound, defined by well points WPM-1 and WPM-4, in the vicinity of the Building. Ground water flows radially away from the building in all directions. Figure 3 shows the ground water flow in the vicinity of the Building based on the November 19, 1992 measurements.

Dames & Moore also constructed an isopach map based on depth to water/hydrocarbon measurements collected on November 19, 1992. This map, shown on Figure 4, shows the thickness and extent of free-phase hydrocarbon in the vicinity of the Building based on measurements collected from the Phase I well points. This map indicates that free-phase hydrocarbon is limited to a small area immediately south of the Building. Free-phase hydrocarbon was detected in WPM-2 (2.61 feet) and WPM-3 (0.26 foot), but not in well points WPM-1, WPM-4, or WPM-5. The hydrocarbon detected in WPM-2 appeared fresh, was light brown in color, and contained a strong hydrocarbon odor. The hydrocarbon in WPM-3 appeared more degraded, was dark brown to black in color, and did not exhibit as strong an odor as the WPM-2 sample. Both the WPM-2 and WPM-3 samples had viscosities similar to that of gasoline.

Dames & Moore reviewed preliminary drafts of Figures 3 and 4 to select the Phase II well point locations. Based on these maps, free-phase hydrocarbon appeared to be limited to a small area immediately south of the Building and ground water appeared to form a mound directly under the Building and flow radially in all directions away from the Building. It appeared that, in the vicinity of well points WPM-2 and WPM-3, the direction of ground water flow was from north/northeast to south/southwest. Thus, Dames & Moore selected a well point upgradient of these two well points (WPM-6), two upgradient/sidegradient well points (WPM-7 and WPM-11), and three downgradient well points (WPM-8, WPM-9, and WPM-10) to further define the shape of the plume of free-phase hydrocarbon floating on the water table near the Building.

5.3 GROUND WATER FLOW/THICKNESS AND EXTENT OF HYDROCARBON IN PHASE I AND II WELL POINTS AND EXISTING MONITORING WELLS

After the Phase II well points (WPM-6 and WPM-11) were installed, a second round of ground water measurements were collected on February 11, 1993, in the Phase I and Phase II well points and existing monitoring wells in the vicinity of the Building (Table 2). Dames & Moore constructed revised ground water flow map based on the February 11, 1993 measurements. This map indicates that a ground water mound exists immediately south of the Building. This mound is defined by well points WPM-6, WPM-7, and WPM-11. Ground water flows radially away from this mound in all directions, but eventually follows the site-wide flow patterns for the Refinery defined by the existing monitoring wells. Figure 5 shows the ground water flow in the vicinity of the Building based on the February 11, 1993 measurements.

Dames & Moore constructed an isopach map showing the thickness and extent of free-phase hydrocarbon, based on depth to water/hydrocarbon measurements collected on

February 11, 1993. This map, shown on Figure 6, indicates that free-phase hydrocarbon is limited to a small area immediately south of the building. Free-phase hydrocarbon was detected in well points WPM-2 (0.63 foot), WPM-3 (6.86 feet), WPM-6 (0.20 foot), WPM-8 (0.35 foot), and WPM-9 (3.84 feet), but not in well points WPM-1, WPM-4, WPM-5, WPM-7, WPM-10, or WPM-11 or existing monitoring wells A16, A25, A26, B48, or B113. The hydrocarbon detected in WPM-2, WPM-6, and WPM-8 appeared fresh, was light brown in color, and contained a strong hydrocarbon odor. The hydrocarbon in WPM-3 and WPM-9 appeared more degraded, was dark brown to black in color, and did not exhibit as strong an odor as the other, less-degraded hydrocarbon. Both types of hydrocarbons were similar in viscosity to gasoline.

Free-phase hydrocarbon was detected in monitoring well B47, but the hydrocarbon was of much greater viscosity than the hydrocarbon detected immediately south of the Building. In addition, this monitoring well is upgradient of the Main Office Building Area. Thus, the free phase hydrocarbon detected in B47 is not considered to originate from the same source as the hydrocarbon detected in the Phase I and II well points immediately south of the building.

5.4 HYDROCARBON RECOVERY TESTS

On February 11, 1993, Dames & Moore conducted bail tests on well points WPM-2, WPM-3, and WPM-9. Figures 7, 8, and 9 show graphs of depth to hydrocarbon and depth to water over time (during the bail tests) for well points WPM-2, WPM-3, and WPM-9, respectively.

5.4.1 Bail Test Results

WPM-2 contained approximately 0.63 foot of hydrocarbon prior to the bail test. The curve on Figure 7 indicates that the depth to hydrocarbon and depth to water decreased at approximately the same rate, similar to that defined as a type one curve. This scenario is typical of wells containing only a few inches of free-phase hydrocarbon. The greatest measured thickness of hydrocarbon during the WPM-2 bail test (5 minutes) was 0.17 foot.

The bail tests conducted in well points WPM-3 and WPM-9 produced hydrocarbon recovery graphs that resembled type two curves. The thicknesses of free-phase hydrocarbon in WPM-3 and WPM-9 prior to the bail tests were 6.86 feet and 3.84 feet, respectively. As shown on Figures 8 and 9, the water and hydrocarbon levels rose at approximately the same rate until, at some point, an inflection point occurred where the water level began to fall. The hydrocarbon thickness measurement recorded at the time where this inflection point occurs on the curve is considered to represent a more realistic thickness of hydrocarbon.

Figure 8 shows that the inflection point for the WPM-3 curve occurs at approximately 2 minutes, and the thickness of hydrocarbon measured in WPM-3 at this time was 0.42 foot. Figure 9 indicates an inflection point at approximately 5 minutes on the WPM-9 curve. The thickness of hydrocarbon measured in WPM-9 at this time was 1.42 feet.

5.4.2 Estimated Hydrocarbon Thickness and Extent

Using the information obtained from the bail tests and other hydrocarbon thickness measurements collected with an interface probe on February 11, 1993, Dames & Moore constructed an isopach map showing the thickness of hydrocarbon in the vicinity of the Building. This map, shown on Figure 10, indicates that a small plume of free-phase hydrocarbon, with a thickness of generally less than one foot, exists immediately south of the building.

5.4.3 Estimation of Hydrocarbon Accumulation Rates

During the WPM-2 bail tests (duration of 3 hours), approximately 0.09 foot of hydrocarbon entered the well point. Using a factor for the interior volume of the well point, the rate of hydrocarbon accumulation for a period of one day was calculated to be 0.1 gallons per day (gpd). Approximately 1.64 feet of hydrocarbon entered well point WPM-3 during the bail test (duration of 3 hours). The rate of hydrocarbon accumulation in WPM-3 is estimated to be 2.2 gpd. In well point WPM-9 approximately 1.66 feet of hydrocarbon accumulated in the casing in a two-hour period. The rate of accumulation in WPM-9 is expected to be approximately 3.4 gpd.

5.5 SIMULATED DISTILLATION ANALYSIS OF FREE-PHASE HYDROCARBON SAMPLES

The chromatograms generated as a result of the simulated distillation analyses on the free-phase hydrocarbon samples collected from well points WPM-2 and WPM-3 indicate that the hydrocarbon present in each of these well points is somewhat similar in character. Upon review of the gas chromatograms from analysis of samples collected from WPM-2 and WPM-3, it appears that the hydrocarbon present in well point WPM-2 is gasoline. Well point WPM-3 contains a mixture of several types of product including gasoline and heavier hydrocarbons. The laboratory report containing the gas chromatograms is included as Appendix A.

5.6 SUMMARY AND DISCUSSION OF INVESTIGATION RESULTS

During drilling activities conducted as part of the well point installation, the soil encountered in each borehole from the ground surface to 6 inches BGS generally consisted of topsoil composed of dark brown silt and sand. Below this topsoil, the soil at the majority of well point locations consisted of gray to brown to dark-brown silty clay. Some sand, cobbles and sandy clay were also noted in some of the borings.

Based on depth to water/hydrocarbon measurements collected on February 11, 1993, a ground water mound, defined by well points WPM-1, WPM-7, and WPM-11, exists immediately south of the Building. Ground water flows radially away from this mound in all directions. In addition, free-phase hydrocarbon is limited to a small area immediately south of the Building.

Hydrocarbon was detected in well points WPM-2, WPM-3, WPM-6, WPM-8, and WPM-9. The hydrocarbon detected in well point WPM-2, WPM-6, and WPM-8 appeared fresh, was light brown in color, and contained a strong hydrocarbon odor. The hydrocarbon detected in well points WPM-3 and WPM-9 was degraded and dark brown to black in color, but did not have as strong an odor. Both types of hydrocarbons had viscosities similar to that of gasoline.

The hydrocarbon bail tests, conducted in well points WPM-2, WPM-3, and WPM-9 indicated that the actual thickness of free-phase hydrocarbon in these well points are approximately 0.17 foot, 0.42 foot, and 1.42 feet, respectively. In addition, the rate of hydrocarbon accumulation in each of these well points was evaluated. The rate of hydrocarbon accumulation in WPM-2 was approximately 0.1 gpd. The approximate rate of accumulation for well points WPM-2 and WPM-9 were calculated to be approximately 2.2 gpd and 3.4 gpd, respectively.

Based on simulated distillation analyses conducted on samples collected from well points WPM-2 and WPM-3, it appears that two different types of hydrocarbon are present in the vicinity of the Building. The first, detected in WPM-2, consists primarily of gasoline. The second, detected in WPM-3, consists primarily of gasoline but also contains heavier hydrocarbons.

Dames & Moore used the information derived from simulated distillation analysis and field observations recorded during sampling activities to evaluate the distribution of free-phase hydrocarbon in the vicinity of the Building. Based on this evaluation, it appears that two plumes of free-phase hydrocarbon exist in the vicinity of the Building. The first, consisting primarily of fresh gasoline exists in the vicinity of well points WPM-2, WPM-6, and WPM-8. The second, consisting of gasoline with some heavier hydrocarbons, exists in the vicinity of well points WPM-3 and WPM-9. Both of these plumes are oblong with their long axes oriented north/northeast which is approximately equivalent to the direction of ground water flow in the area. The extent of both of the hydrocarbon plumes are shown on Figure 5.

Based on the depth to water/hydrocarbon measurements collected in the well points, it appears that the plume(s) may be moving in a southwesterly direction. As the thickness of hydrocarbon continues to wane in WPM-2 during each successive monitoring event, the thickness of free-phase hydrocarbon in WPM-3 continues to increase.

At this point, we have defined the upgradient and sidegradient extent of the hydrocarbon plume(s) in the vicinity of the building. It appears that, in the upgradient direction (north), the thickness of hydrocarbon becomes lesser toward the Building. Hydrocarbon was detected in WPM-6 which is close to the southern side of the Building, but not in WPM-1 which is adjacent to the western side of the Building. The thickness also decreases to the east and west (sidegradient). The downgradient (southern) extent of free-phase hydrocarbon has not been adequately defined. Additional investigation will be necessary to fully understand the distribution of free-phase hydrocarbon downgradient of the Building.

6.0 REMEDIAL OPTIONS

There are several types of remedial technologies that could be implemented to recover free-phase hydrocarbon on the water table in the vicinity of the Main Building. These remedial technologies are discussed in the Remedial Action Plan (RAP) for this area prepared by Dames & Moore and dated February 25, 1993. The RAP also presents the additional scope of work necessary to further define the extent of the free-phase hydrocarbon and to select an appropriate remedial alternative.

7.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this, and previous, investigations, Dames & Moore's conclusions and recommendations are:

- Subsurface soil in the vicinity of the Building consists of gray to brown to dark-brown silty clay with some sand, cobbles, and sandy clay.
- Ground water forms a mound immediately south of the Building and flows radially away from the mound in all directions.
- Free-phase hydrocarbon is limited to a small area immediately south of the Building.
- Two different plumes of hydrocarbons are present in the vicinity of the Building. The first, defined by well points WPM-2, WPM-6, and WPM-8, consists primarily of gasoline. The second, defined by well points WPM-3 and WPM-9, consists primarily of gasoline with some heavier hydrocarbons. This hydrocarbon is more degraded than the hydrocarbon detected in WPM-2, WPM-6, and WPM-8.
- The rate of hydrocarbon accumulation in well points WPM-2, WPM-3, and WPM-9 was estimated to be approximately 0.1 gpd, 2.2 gpd, and 3.4 gpd, respectively.
- The hydrocarbon plume(s) may be migrating in a southwesterly direction through the subsurface.
- The extent of hydrocarbon to the north, east, and west has been established, but the downgradient extent (to the south) has not been fully defined. Additional investigation will be necessary to gain a full understanding of the distribution of hydrocarbon downgradient of the Building. Recovery of hydrocarbon in the center of the plume can begin immediately using a portable hydrocarbon-only recovery system. However, more investigation will be conducted as part of the RAP for this area to further define the downgradient extent of hydrocarbon in this area. This information will be necessary to select the final recovery system.

8.0 REFERENCES

Gruszczenski, T.S., 1987. Determination of a Realistic Estimate for the Actual Formation Product Thickness Using Monitor Wells: A Field Bailout Test, In 1987 Proceedings of: Petroleum Hydrocarbons and Organic Chemicals in Ground Water, Houston, Texas

This Report was prepared by:

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AAW03187

TABLE 1

WATER LEVEL/FREE-PHASE HYDROCARBON MEASUREMENTS
PHASE I WELL POINTS - NOVEMBER 19, 1992
VICINITY OF MAIN OFFICE BUILDING

CHEVRON REFINERY
PHILADELPHIA, PENNSYLVANIA

WELL POINT DESIGNATION	TOP OF PVC ELEVATION (FEET)[1]	DEPTH TO GROUND WATER (FEET)[2]	DEPTH TO FREE-PHASE HYDROCARBON (FEET)[2]	THICKNESS OF FREE-PHASE HYDROCARBON (FEET)	CORRECTED GROUND WATER ELEVATION (FEET)[3]
WPM-1	14.85	8.25	ND	ND	6.60
WPM-2	15.02	10.99	8.85	2.14	5.85
WPM-3	14.81	10.21	8.86	1.45	5.83
WPM-4	14.06	7.61	ND	ND	6.45
WPM-5	14.18	8.37	ND	ND	5.81

Explanation:

ND = Not detected

Notes:

(1) Surveyed elevations referenced to the National Geodetic Vertical Datum 1929.

(2) All depths to ground water/free-phase hydrocarbon were measured from the top of the PVC casing in each monitoring well/well point using an Oil Recovery Systems interface probe.

(3) Ground water elevations (GWE) are in feet relative to mean sea level. Ground water elevations have been corrected for free hydrocarbon influences by the equation Corrected GWE = Measured GWE + (0.85 x Measured Product Thickness). This assumes a product density of 0.85.

TABLE 2

WATER LEVEL/FREE-PHASE HYDROCARBON MEASUREMENTS
PHASE I WELL POINTS - DECEMBER 7, 1992
VICINITY OF MAIN OFFICE BUILDING

CHEVRON REFINERY
PHILADELPHIA, PENNSYLVANIA

WELL POINT DESIGNATION	TOP OF PVC ELEVATION (FEET)[1]	DEPTH TO GROUND WATER (FEET)[2]	DEPTH TO FREE-PHASE HYDROCARBON (FEET)[2]	THICKNESS OF FREE-PHASE HYDROCARBON (FEET)	CORRECTED GROUND WATER ELEVATION (FEET)[3]
WPM-1	14.85	7.73	ND	ND	7.12
WPM-2	15.02	10.25	8.29	1.96	8.40
WPM-3	14.81	12.43	8.23	4.20	10.09
WPM-4	14.06	7.36	ND	ND	6.30
WPM-5	14.18	8.14	ND	ND	6.04

Explanation:

ND = Not detected

Notes:

(1) Surveyed elevations referenced to the National Geodetic Vertical Datum 1929.

(2) All depths to ground water/free-phase hydrocarbon were measured from the top of the PVC casing in each monitoring well/well point using an Oil Recovery Systems interface probe.

(3) Ground water elevations (GWE) are in feet relative to mean sea level. Ground water elevations have been corrected for free hydrocarbon influences by the equation Corrected GWE = Measured GWE + (0.85 x Measured Product Thickness). This assumes a product density of 0.85.

TABLE 3

WATER LEVEL/FREE-PHASE HYDROCARBON MEASUREMENTS
MONITORING WELLS/WELL POINTS - FEBRUARY 3, 1993
VICINITY OF MAIN OFFICE BUILDING

CHEVRON REFINERY
PHILADELPHIA, PENNSYLVANIA

MONITORING WELL/ WELL POINT DESIGNATION	TOP OF PVC ELEVATION (FEET)[1]	DEPTH TO GROUND WATER (FEET)[2]	DEPTH TO FREE-PHASE HYDROCARBON (FEET)[2]	THICKNESS OF FREE-PHASE HYDROCARBON (FEET)	CORRECTED GROUND WATER ELEVATION (FEET)[3]	APPEARANCE OF HYDROCARBON
WPM-1	14.85	7.90	ND	ND	6.95	--
WPM-2	15.02	7.67	8.29	0.77	6.61	Light brown; fresh strong odor
WPM-3	14.81	1.96	7.75	6.81	6.04	Dark brown to black; degraded
WPM-4	14.06	7.34	ND	ND	6.72	--
WPM-5	14.18	7.84	ND	ND	6.34	--
WPM-6	14.35	8.72	7.12	0.22	7.20	Light brown; fresh strong odor
WPM-7	15.73	8.45	ND	ND	7.28	--
WPM-8	14.99	7.48	8.97	0.25	5.98	Light brown; fresh strong odor
WPM-9	16.50	3.84	10.31	4.06	5.58	Dark brown to black; degraded
WPM-10	13.73	6.61	ND	ND	7.12	--
WPM-11	14.65	7.07	ND	ND	7.58	--
A16	11.85	4.85	ND	ND	7.00	--
A25	10.46	6.37	ND	ND	4.09	--
A26	11.38	7.02	ND	ND	4.36	--
B47	10.56	--	3.25	--	--	Black; high viscosity
B48	8.90	1.12	ND	ND	7.78	--
B117	11.65	6.52	ND	ND	5.13	--

Explanation:

ND = Not detected.
NR = Not recorded.

Notes:

(1) Surveyed elevations referenced to the National Geodetic Vertical Datum 1929.

(2) All depths to ground water/free-phase hydrocarbon were measured from the top of the PVC casing in each monitoring well using an Oil Recovery Systems interface probe.

(3) Ground water elevations (GWE) are in feet relative to mean sea level. Ground water elevations have been corrected for free hydrocarbon influences by the equation Corrected GWE = Measured GWE + (0.85 x Measured Product Thickness). This assumes a product density of 0.85.

TABLE 4

WATER LEVEL/FREE-PHASE HYDROCARBON MEASUREMENTS
MONITORING WELLS/WELL POINTS - FEBRUARY 11, 1993
VICINITY OF MAIN OFFICE BUILDING

CHEVRON REFINERY
PHILADELPHIA, PENNSYLVANIA

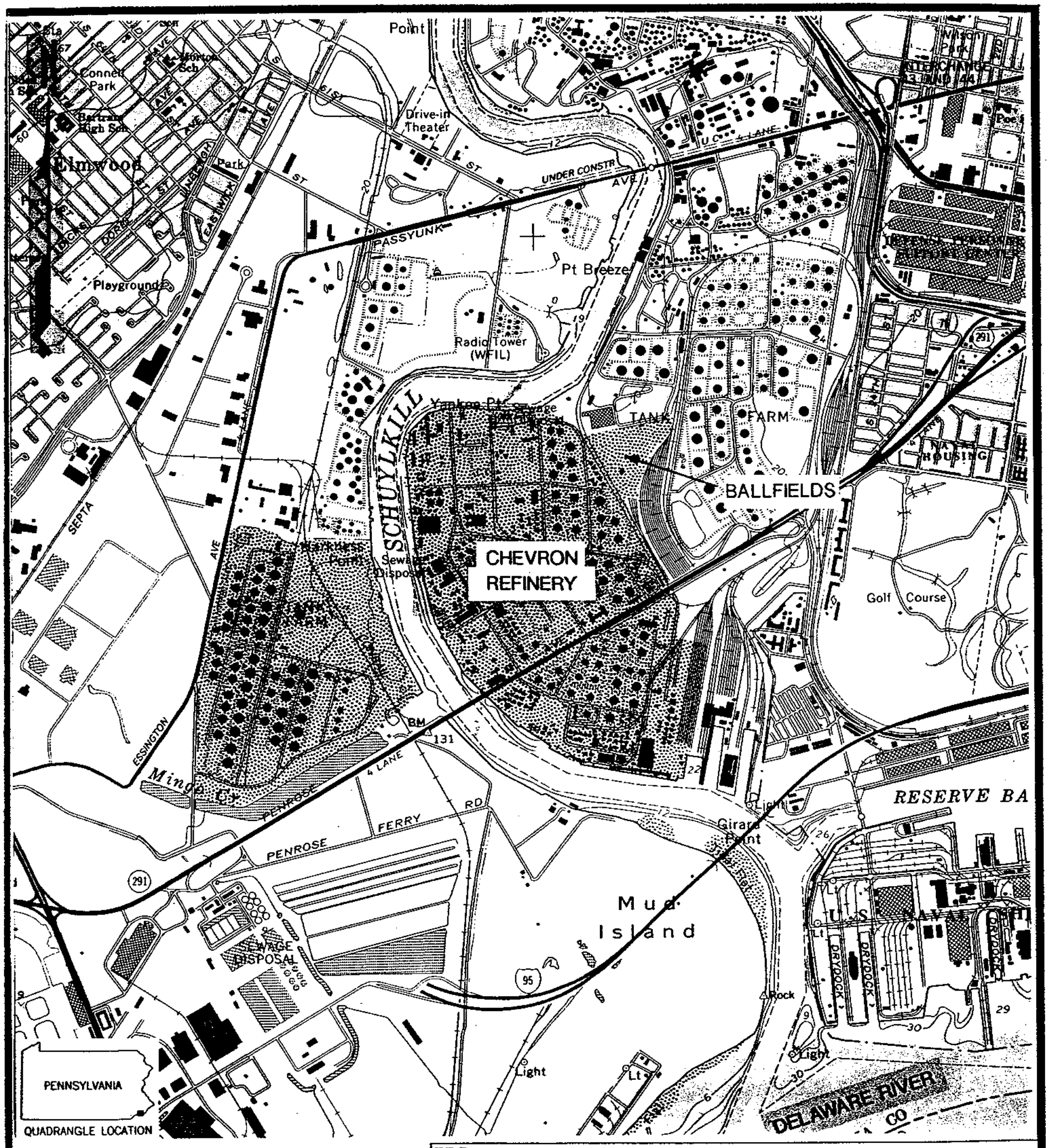
MONITORING WELL/ WELL POINT DESIGNATION	TOP OF PVC ELEVATION (FEET)[1]	DEPTH TO GROUND WATER (FEET)[2]	DEPTH TO FREE-PHASE HYDROCARBON (FEET)[2]	MEASURED THICKNESS OF FREE-PHASE HYDROCARBON (FEET)	ESTIMATED THICKNESS OF FREE-PHASE HYDROCARBON (FEET)[4]	CORRECTED GROUND WATER ELEVATION (FEET)[3]	APPEARANCE OF HYDROCARBON
WPM-1	14.85	8.01	ND	ND	NA	6.84	--
WPM-2	15.02	9.13	8.50	0.63	0.17	6.43	Light brown; fresh strong odor
WPM-3	14.81	14.73	7.87	6.86	0.42	5.91	Dark brown to black; degraded
WPM-4	14.06	7.47	ND	ND	NA	6.59	--
WPM-5	14.18	8.14	ND	ND	NA	6.04	--
WPM-6	14.35	7.49	7.29	0.20	NA	7.03	Light brown; fresh strong odor
WPM-7	15.73	8.68	ND	ND	NA	7.05	--
WPM-8	14.99	9.41	9.06	0.35	NA	5.88	Light brown; fresh strong odor
WPM-9	16.50	14.35	10.51	3.84	1.42	5.41	Dark brown to black; degraded
WPM-10	13.73	6.76	ND	ND	NA	6.97	--
WPM-11	14.65	7.06	ND	ND	NA	7.59	--
A16	11.85	5.04	ND	ND	NA	6.81	--
A25	10.46	6.55	ND	ND	NA	3.91	--
A26	11.38	6.96	ND	ND	NA	4.42	--
B47	10.56	--	3.59	--	--	--	Black; high viscosity
B48	8.90	1.01	ND	ND	NA	7.89	--
B117	11.65	6.38	ND	ND	NA	5.27	--

Explanation:

ND = Not detected.
NR = Not recorded.
NA = Not applicable. Bail test not conducted at this well point location.

Notes:

(1) Surveyed elevations referenced to the National Geodetic Vertical Datum 1929.
(2) All depths to ground water/free-phase hydrocarbon were measured from the top of the PVC casing in each monitoring well using an Oil Recovery Systems interface probe.
(3) Ground water elevations (GWE) are in feet relative to mean sea level. Ground water elevations have been corrected for free hydrocarbon influences by the equation Corrected GWE = Measured GWE + (0.85 x Measured Product Thickness). This assumes a product density of 0.85.
(4) Thickness estimated from results of bail tests conducted at well points WPM-2, -3, and -9, on February 11, 1993.



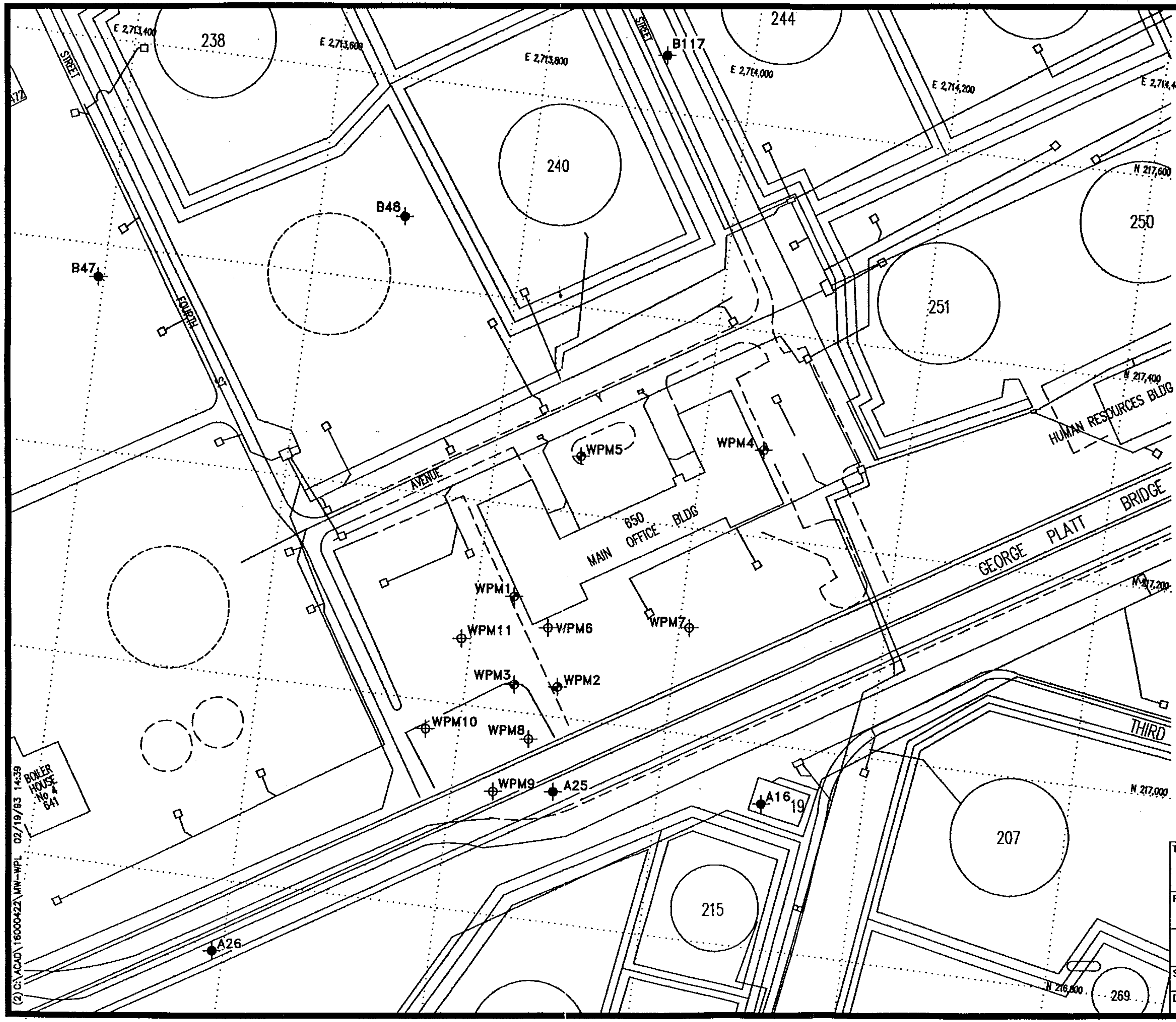
0 1000 2000 3000 FEET

GRAPHIC SCALE

CONTOUR INTERVAL = 20 FEET

REFERENCE:
A PORTION OF USGS 7.5 MINUTE TOPOGRAPHIC MAP; PHILADELPHIA QUADRANGLE, PENNSYLVANIA 1967 PHOTOREVISED 1985

TITLE SITE VICINITY MAP			
PROJECT CHEVRON REFINERY PHILADELPHIA, PENNSYLVANIA			
Dames & Moore WILLOW GROVE, PENNSYLVANIA			
SCALE AS SHOWN	DWN. BY EM²	JOB NO. 16000-422	
DATE 2/17/92	APPR. BY TJG	FIG. NO. 1	



N

EXPLANATION:

B48 ● EXISTING MONITORING WELL LOCATION

WPM1 ⌖ PHASE I WELL POINT LOCATION

WPM6 ⌖ PHASE II WELL POINT LOCATION

NOTE:

WELL POINT LOCATIONS BASED ON FIELD MEASUREMENTS CONDUCTED BY DAMES & MOORE PERSONNEL.

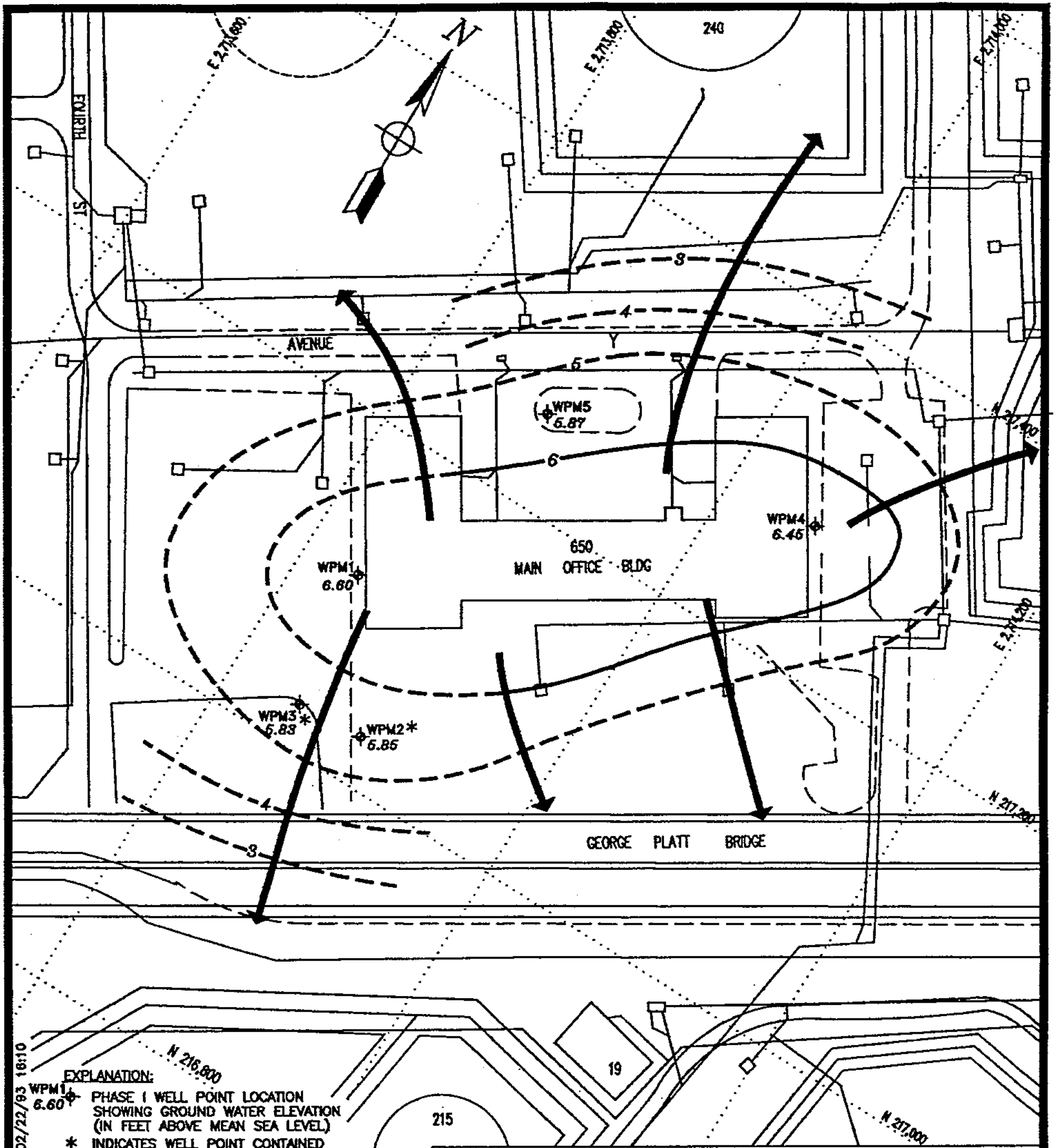
0 50 100 FEET

GRAPHIC SCALE

TITLE	MONITORING WELL/WELL POINT LOCATIONS MAIN BUILDING INVESTIGATION
PROJECT	CHEVRON REFINERY PHILADELPHIA, PENNSYLVANIA

DAMES & MOORE
WILLOW GROVE, PENNSYLVANIA

SCALE	AS SHOWN	DWN. BY	R.G.B.	JOB NO.	16000–422
DATE	2–19–93	APPR. BY	T.J.G.	FIG. NO.	2



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EXPLANATION:

WPM1 ⊕ 6.60 PHASE I WELL POINT LOCATION SHOWING GROUND WATER ELEVATION (IN FEET ABOVE MEAN SEA LEVEL)

* INDICATES WELL POINT CONTAINED FREE-PHASE HYDROCARBON. THE GROUND WATER ELEVATION PRESENTED ON THIS FIGURE HAS BEEN CORRECTED TO ACCOUNT FOR THE HYDROCARBON.

3 — LINE OF EQUAL GROUND WATER ELEVATION (DASHED WHERE INFERRED)

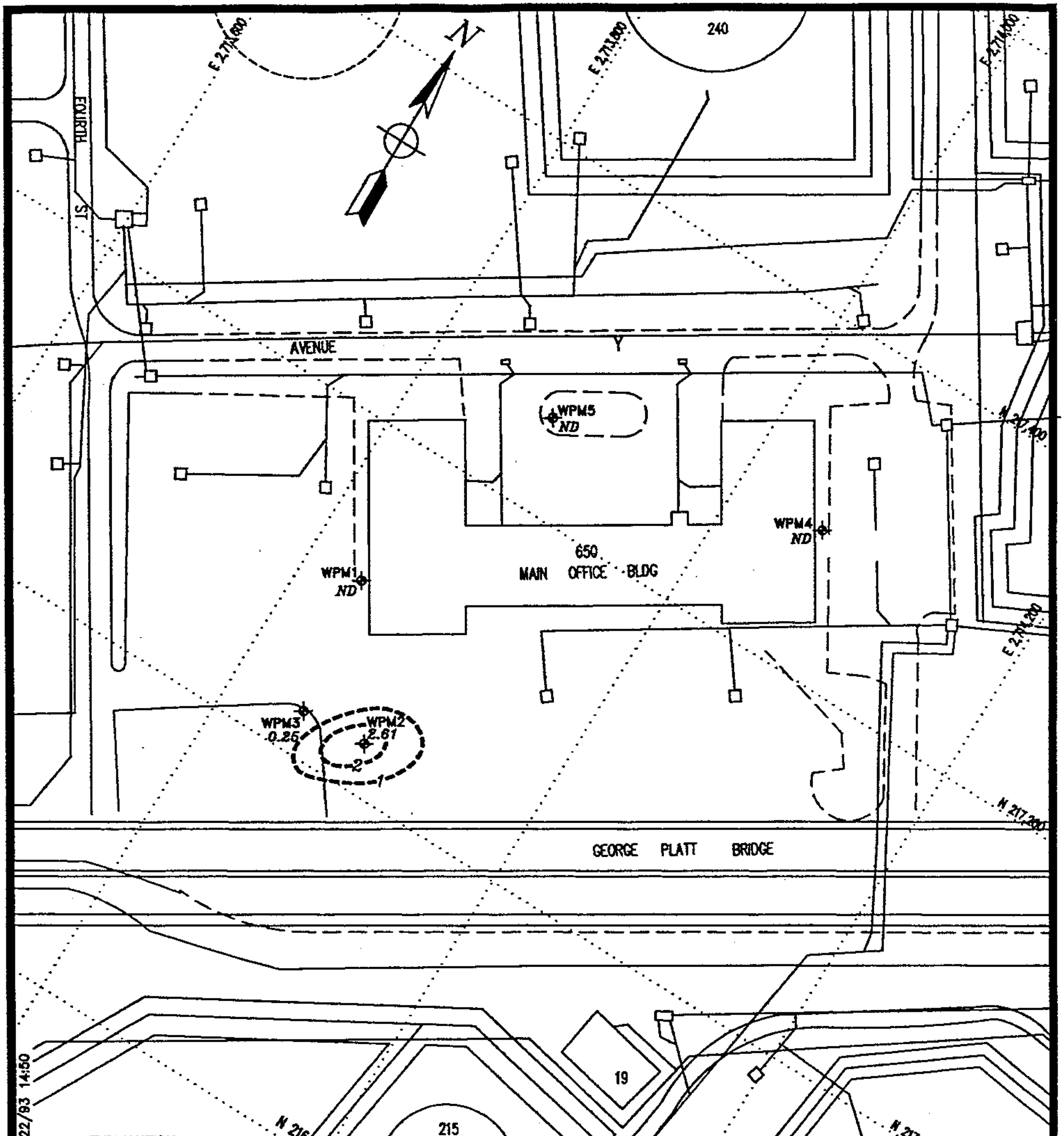
← APPROXIMATE DIRECTION OF GROUND WATER FLOW

NOTE:
WELL POINT LOCATIONS BASED ON FIELD MEASUREMENTS CONDUCTED BY DAMES & MOORE PERSONNEL.

0 50 100 FEET

GRAPHIC SCALE

TITLE	GROUND WATER FLOW MAP NOVEMBER 19, 1992 MAIN BUILDING INVESTIGATION	
PROJECT	CHEVRON REFINERY PHILADELPHIA, PENNSYLVANIA	
DAMES & MOORE WILLOW GROVE, PENNSYLVANIA		
SCALE AS SHOWN	DWN. BY R.G.B.	JOB NO. 16000-422
DATE 2-22-93	APPR. BY T.J.G.	FIG. NO. 3



(3) C:\ACAD\16000422\FPH-1192 02/22/93 14:50

EXPLANATION:

WPM2 2.61 — PHASE I WELL POINT LOCATION SHOWING THICKNESS OF FREE-PHASE HYDROCARBON (IN FEET)

ND — HYDROCARBON NOT DETECTED

1 — LINE OF EQUAL HYDROCARBON THICKNESS

NOTE:
WELL POINT LOCATIONS BASED ON FIELD MEASUREMENTS CONDUCTED BY DAMES & MOORE PERSONNEL.

0 50 100 FEET

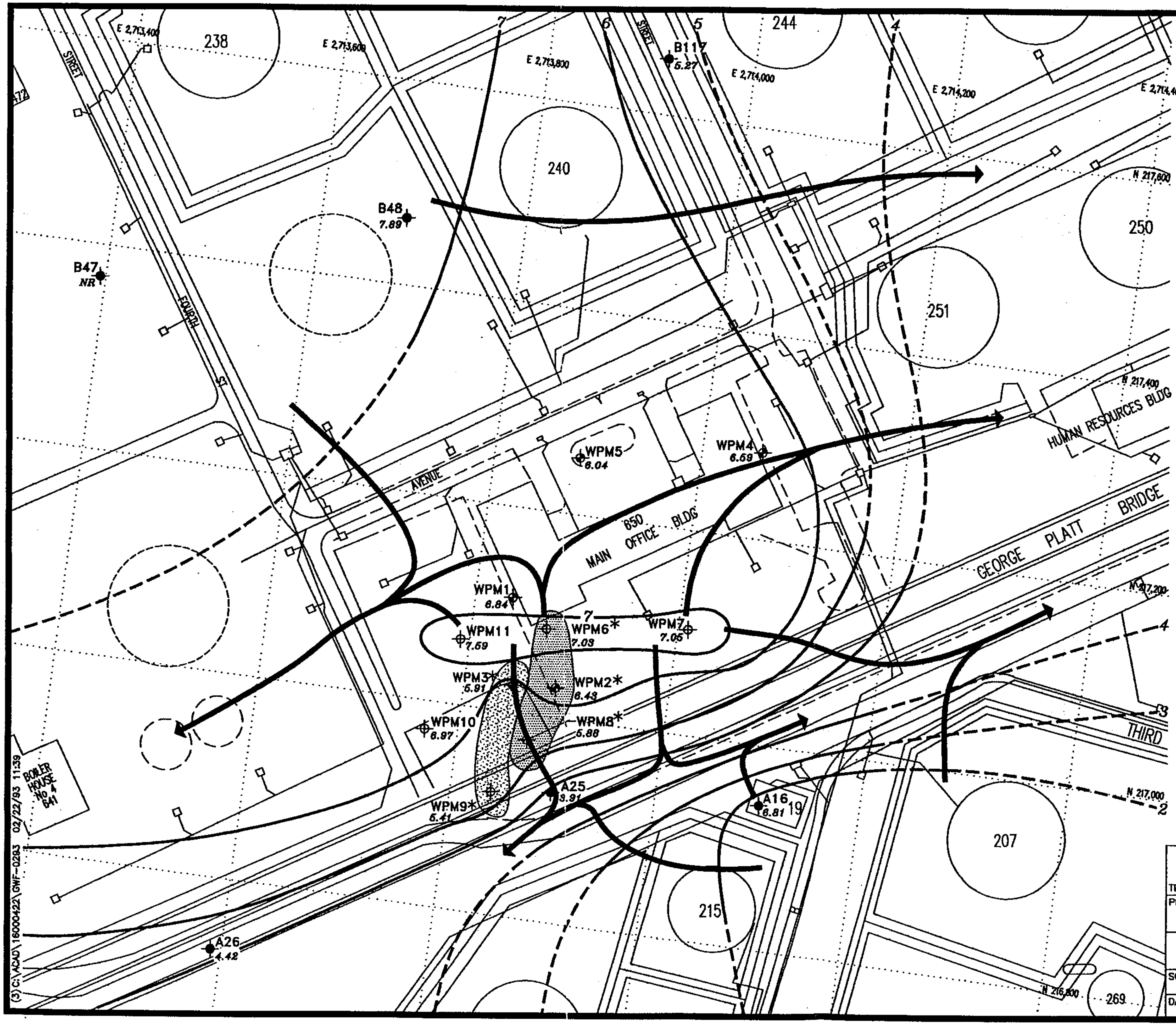
GRAPHIC SCALE

TITLE THICKNESS/EXTENT OF FREE-PHASE HYDROCARBON
NOVEMBER 19, 1992
MAIN BUILDING INVESTIGATION

PROJECT CHEVRON REFINERY
PHILADELPHIA, PENNSYLVANIA

DAMES & MOORE
WILLOW GROVE, PENNSYLVANIA

SCALE AS SHOWN	DWN. BY R.G.B.	JOB NO. 16000-422
DATE 2-25-93	APPR. BY T.J.G.	FIG. NO. 4



EXPLANATION:

B48 7.89	EXISTING MONITORING WELL LOCATION SHOWING GROUND WATER ELEVATION (IN FEET ABOVE MEAN SEA LEVEL)
WPM1 6.84	PHASE I WELL POINT LOCATION SHOWING GROUND WATER ELEVATION (IN FEET ABOVE MEAN SEA LEVEL)
WPM6 7.03	PHASE II WELL POINT LOCATION SHOWING GROUND WATER ELEVATION (IN FEET ABOVE MEAN SEA LEVEL)
NR	NOT RECORDED. HYDROCARBON TOO VISCOUS TO OBTAIN ACCURATE THICKNESS MEASUREMENT.
*	INDICATES WELL POINT CONTAINED FREE-PHASE HYDROCARBON. THE GROUND WATER ELEVATION PRESENTED ON THIS FIGURE HAS BEEN CORRECTED TO ACCOUNT FOR THE HYDROCARBON.
▨	APPROXIMATE EXTENT OF PLUME No. 1 (PIMARILY GASOLINE)
▨	APPROXIMATE EXTENT OF PLUME No. 2 (GASOLINE WITH HEAVIER HYDROCARBONS)
4	LINE OF EQUAL GROUND WATER ELEVATION (DASHED WHERE INFERRED)
←	APPROXIMATE DIRECTION OF GROUND WATER FLOW

NOTE:

WELL POINT LOCATIONS BASED ON FIELD MEASUREMENTS CONDUCTED BY DAMES & MOORE PERSONNEL.

0 50 100 FEET

GRAPHIC SCALE

TITLE	GROUNDWATER FLOW MAP–FEBRUARY 11,1993 MAIN BUILDING INVESTIGATION
PROJECT	CHEVRON REFINERY PHILADELPHIA, PENNSYLVANIA

DAMES & MOORE
WILLOW GROVE, PENNSYLVANIA

SCALE AS SHOWN	DWN. BY R.G.B.	JOB NO. 16000-422	
DATE 2-25-93	APPR. BY T.J.G.	FIG. NO. 5	

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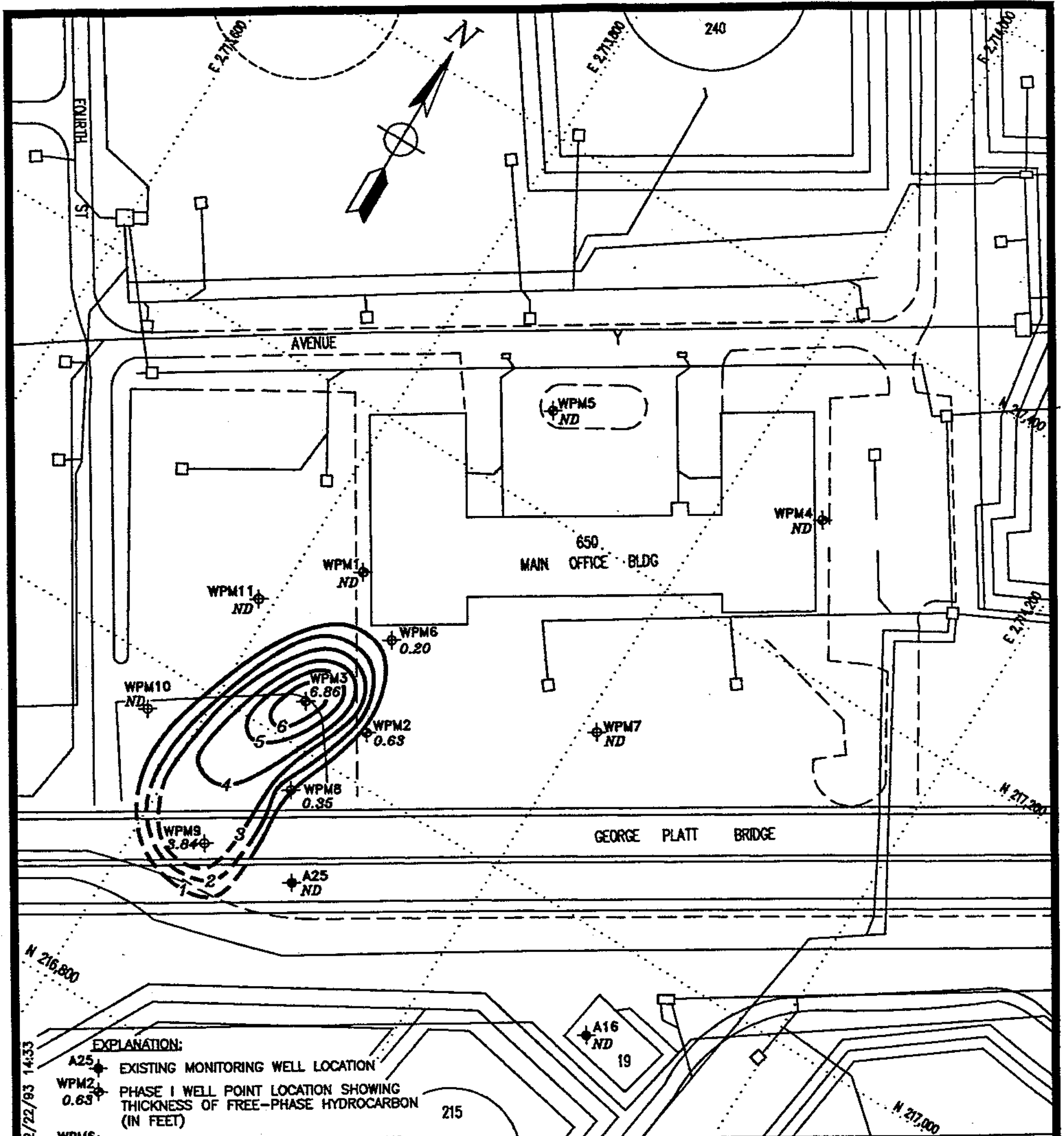


EXPLANATION:

A25	EXISTING MONITORING WELL LOCATION
WPM2 0.63	PHASE I WELL POINT LOCATION SHOWING THICKNESS OF FREE-PHASE HYDROCARBON (IN FEET)
WPM6 0.20	PHASE II WELL POINT LOCATION SHOWING THICKNESS OF FREE-PHASE HYDROCARBON (IN FEET)
ND	HYDROCARBON NOT DETECTED
1.0	LINE OF EQUAL HYDROCARBON THICKNESS (DASHED WHERE INFERRED)

NOTE:
WELL POINT LOCATIONS BASED ON FIELD MEASUREMENTS CONDUCTED BY DAMES & MOORE PERSONNEL.

0 50 100 FEET
GRAPHIC SCALE

(3) C:\ACAD\16000422\FPH-0293 02/22/93 14:33

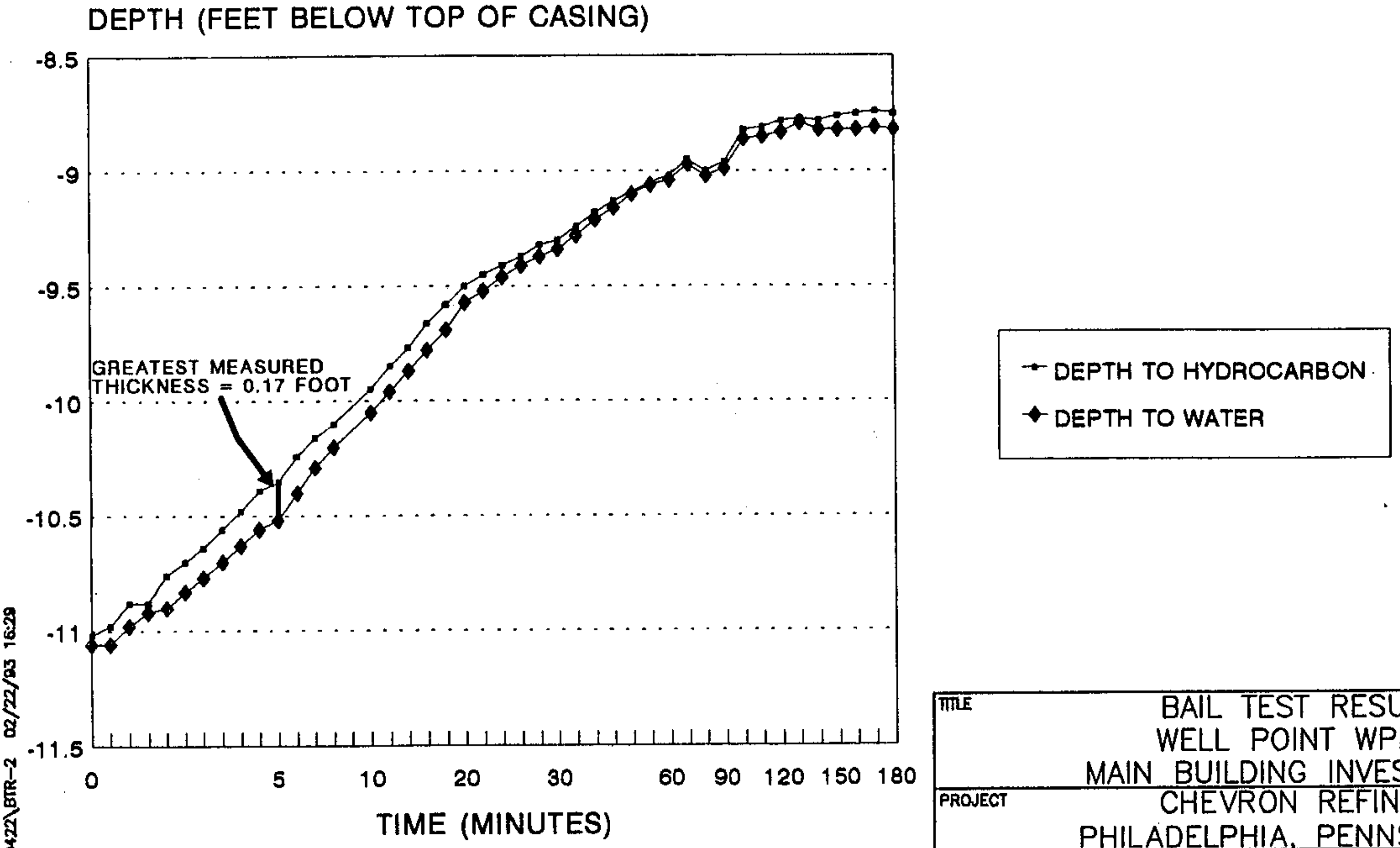
TITLE THICKNESS/EXTENT OF FREE-PHASE HYDROCARBON
FEBRUARY 11, 1993
MAIN BUILDING INVESTIGATION

PROJECT CHEVRON REFINERY
PHILADELPHIA, PENNSYLVANIA

DAMES & MOORE
WILLOW GROVE, PENNSYLVANIA

SCALE AS SHOWN	DWN. BY R.G.B.	JOB NO. 16000-422
DATE 2-25-93	APPR. BY T.J.G.	FIG. NO. 6

BAIL TEST RESULTS
WELL POINT WPM-2
MAIN BUILDING INVESTIGATION



NOTE:
THIS FIGURE BASED ON MEASUREMENTS COLLECTED DURING BAIL TEST OF WPM-2 CONDUCTED ON FEBRUARY 11, 1993.

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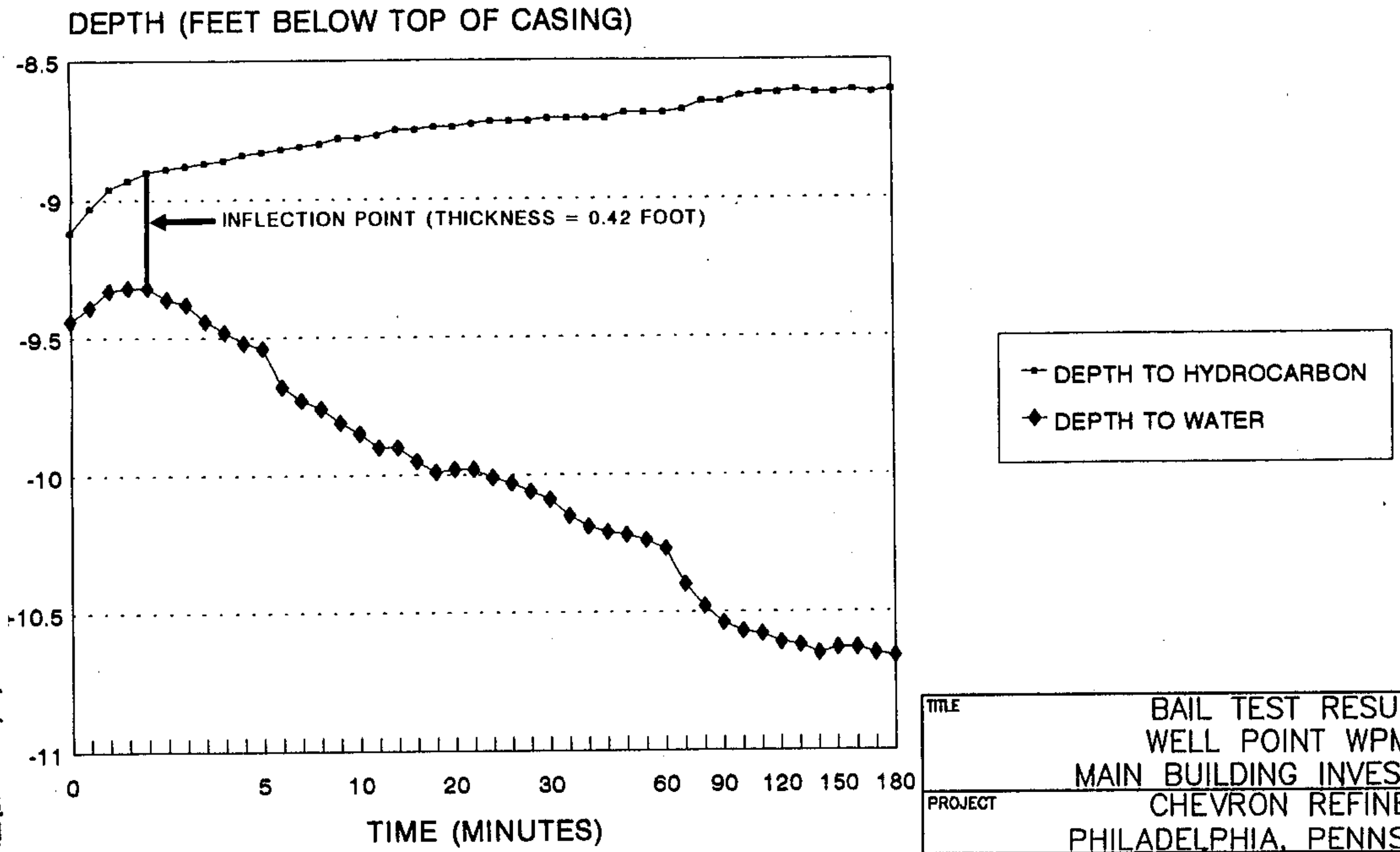
TITLE	BAIL TEST RESULTS WELL POINT WPM-2 MAIN BUILDING INVESTIGATION
PROJECT	CHEVRON REFINERY PHILADELPHIA, PENNSYLVANIA

DAMES & MOORE
WILLOW GROVE, PENNSYLVANIA

SCALE AS SHOWN	DWN. BY R.G.B.	JOB NO. 16000-422
DATE 2-22-93	APPR. BY T.J.G.	FIG. NO. 7

BAIL TEST RESULTS

WELL POINT WPM-3
MAIN BUILDING INVESTIGATION



NOTE:
THIS FIGURE BASED ON MEASUREMENTS COLLECTED DURING BAIL TEST OF WPM-3 CONDUCTED ON FEBRUARY 11, 1993.

(1)C:\ACAD\16000422\BTR-3 02/22/93 16:33

TITLE
BAIL TEST RESULTS
WELL POINT WPM-3
MAIN BUILDING INVESTIGATION

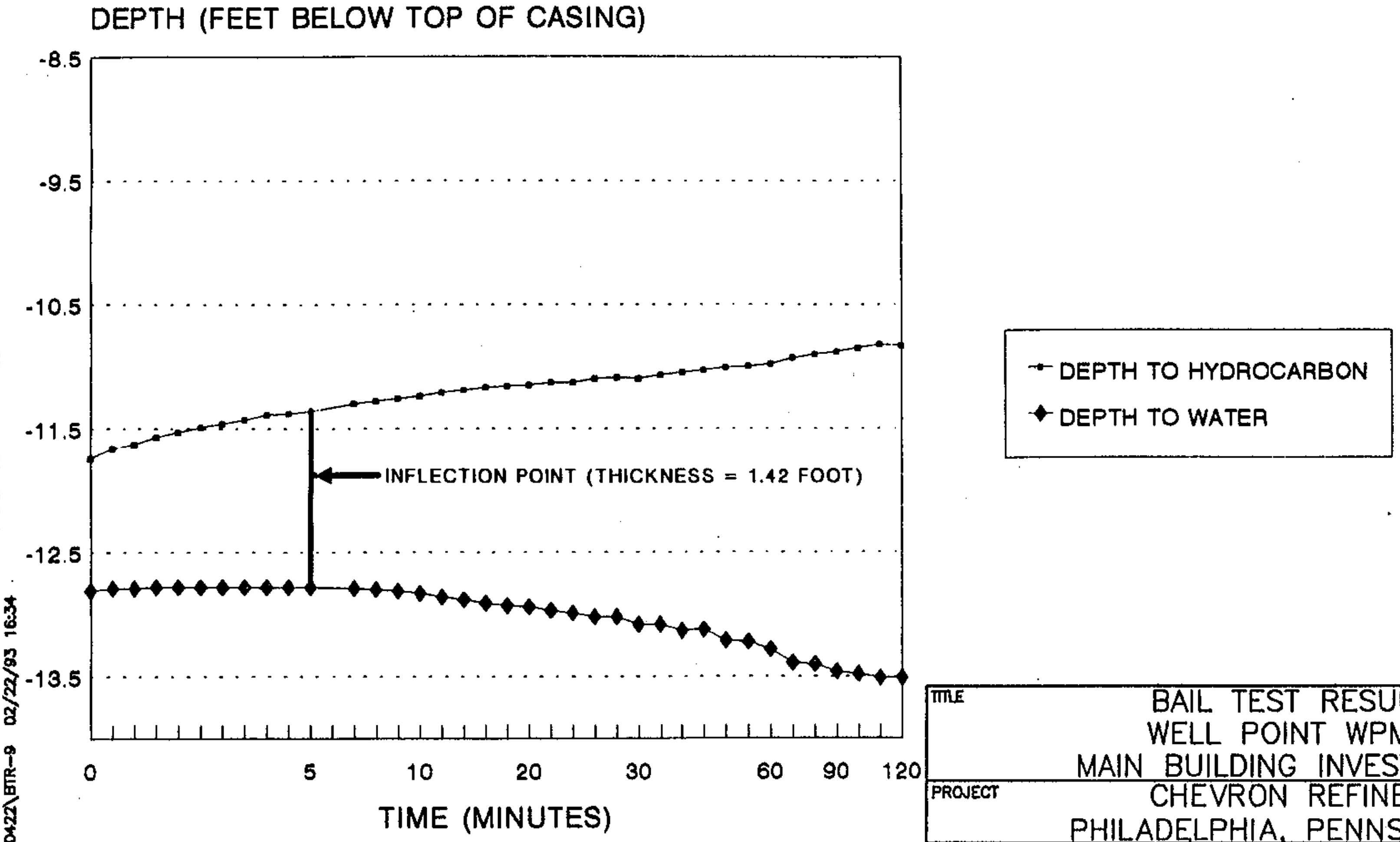
PROJECT
CHEVRON REFINERY
PHILADELPHIA, PENNSYLVANIA

DAMES & MOORE
WILLOW GROVE, PENNSYLVANIA

SCALE AS SHOWN	DWN. BY R.G.B.	JOB NO. 16000-422
DATE 2-22-93	APPR. BY T.J.G.	FIG. NO. 8

BAIL TEST RESULTS

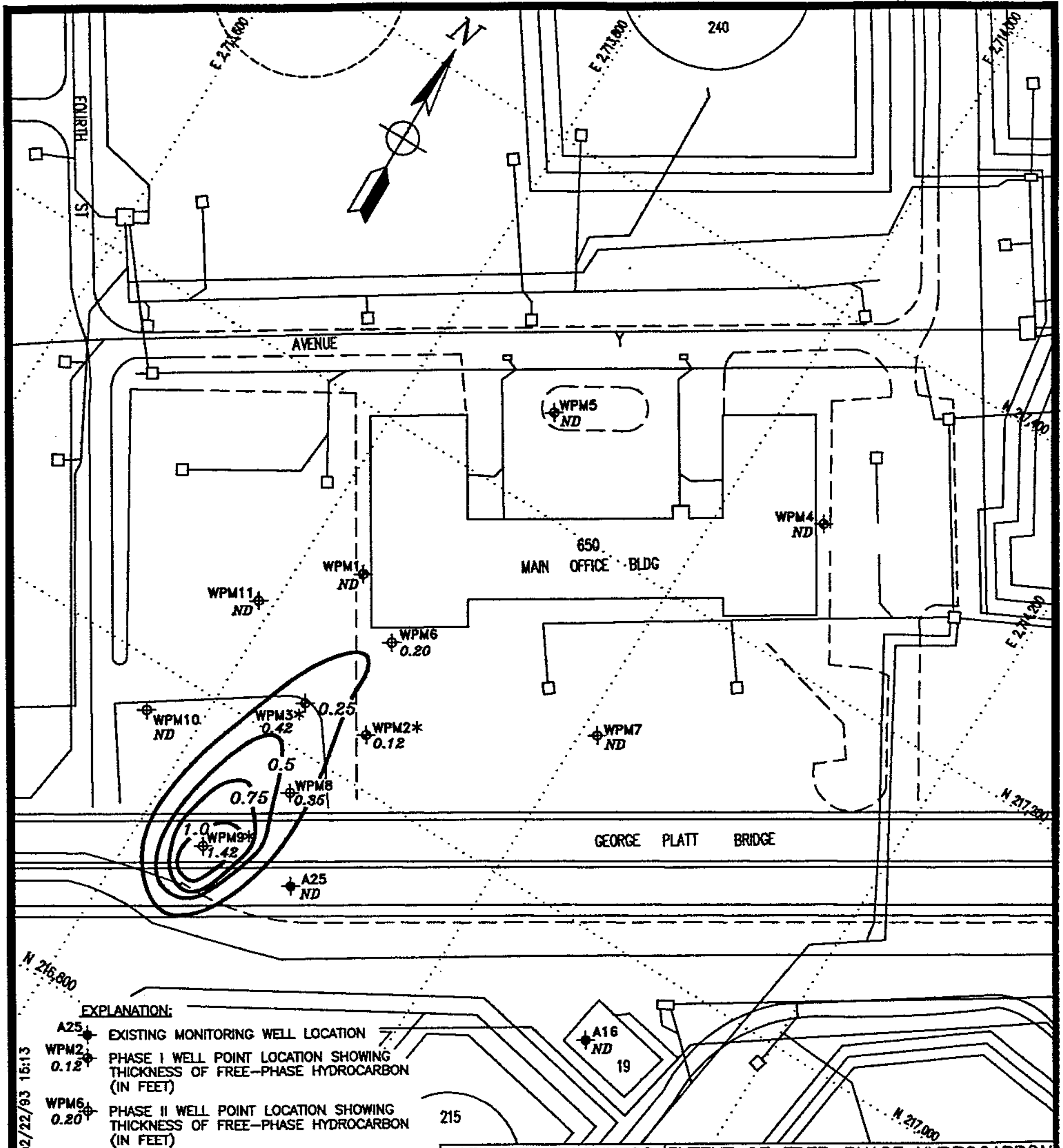
WELL WPM-9
MAIN BUILDING INVESTIGATION



NOTE:
THIS FIGURE BASED ON MEASUREMENTS COLLECTED DURING BAIL TEST OF WPM-9 CONDUCTED ON FEBRUARY 11, 1993.

(1) C:\ACAD\16000422\BTR-9 02/22/93 16:34

TITLE	BAIL TEST RESULTS WELL POINT WPM-9 MAIN BUILDING INVESTIGATION				
PROJECT	CHEVRON REFINERY PHILADELPHIA, PENNSYLVANIA				
DAMES & MOORE WILLOW GROVE, PENNSYLVANIA					
SCALE	AS SHOWN	DWN. BY	R.G.B.	JOB NO.	16000-422
DATE	2-22-93	APPR. BY	T.J.G.	FIG. NO.	9



EXPLANATION:

A25 — EXISTING MONITORING WELL LOCATION

WPM2 0.12 — PHASE I WELL POINT LOCATION SHOWING THICKNESS OF FREE-PHASE HYDROCARBON (IN FEET)

WPM6 0.20 — PHASE II WELL POINT LOCATION SHOWING THICKNESS OF FREE-PHASE HYDROCARBON (IN FEET)

ND HYDROCARBON NOT DETECTED

1.0 — LINE OF EQUAL HYDROCARBON THICKNESS

* INDICATES THE HYDROCARBON THICKNESS CALCULATED FROM BAIL TEST RESULTS. ALL OTHERS MEASURED WITH AN INTERFACE PROBE.

NOTE:
WELL POINT LOCATIONS BASED ON FIELD MEASUREMENTS CONDUCTED BY DAMES & MOORE PERSONNEL.

0 50 100 FEET

GRAPHIC SCALE

(4) C:\ACAD\16000422\AFPH0293 02/22/93 15:13

TITLE
ESTIMATED THICKNESS/EXTENT OF FREE-PHASE HYDROCARBON
FEBRUARY 11, 1993
MAIN BUILDING INVESTIGATION

PROJECT
CHEVRON REFINERY
PHILADELPHIA, PENNSYLVANIA

DAMES & MOORE
WILLOW GROVE, PENNSYLVANIA

SCALE AS SHOWN	DWN. BY R.G.B.	JOB NO. 16000-422
DATE 3-12-93	APPR. BY T.J.G.	FIG. NO. 10

APPENDIX A

LABORATORY REPORT - SIMULATED DISTILLATION ANALYSIS

Caleb Brett

Inchcape
Testing
Services

February 22, 1993

Houston, Texas

Our Reference: HO/93-00581
Your Reference:

Dames & Moore
2360 Maryland Road
Willow Grove, PA 19090

ATTN: Thomas Glancey

Reference: To analyze two submitted samples of Unknown Hydrocarbons received on February 18, 1993.

Dear Thomas:

Please find enclosed the original and three (3) copies of our report(s) on the above referenced "**submitted sample(s)** and our invoice for services rendered.

Should you have any questions regarding this report, please do not hesitate to contact us at your convenience.

We trust you find all in order and thank you for requesting our services.

Very Truly Yours,

Richard S. Lee

Richard S. Lee
CALEB BRETT U.S.A., Inc.

Enclosures:
RSL:11

9809 Rowlett Road, Houston, TX 77075
Tel: (713) 946-2420 FAX: (713) 946-0206

Caleb Brett

Caleb Brett U.S.A., Inc.

Your Ref:

Date: 22-FEB-1993

Laboratory Report No. 93-000581-0-HOUS; 1

Dames & Moore
2360 Maryland Road
Willow Grove, PA 19090

For the Attention of Thomas Glancey

SAMPLE DETAILS: 2 Sample(s) received on 18-FEB-1993

SOURCE : Dames & Moore

DESCRIPTION :

	LAB REF
WPM-2 Hydrocarbon Job #16000-422	001-00
WPM-3 Hydrocarbon Job #16000-422	002-00

CONTAINERS : 40 mL Glass Vial **SEALS** : NONE

RESULTS : SEE ATTACHED SHEETS

(TOTAL NUMBER OF PAGES 2)

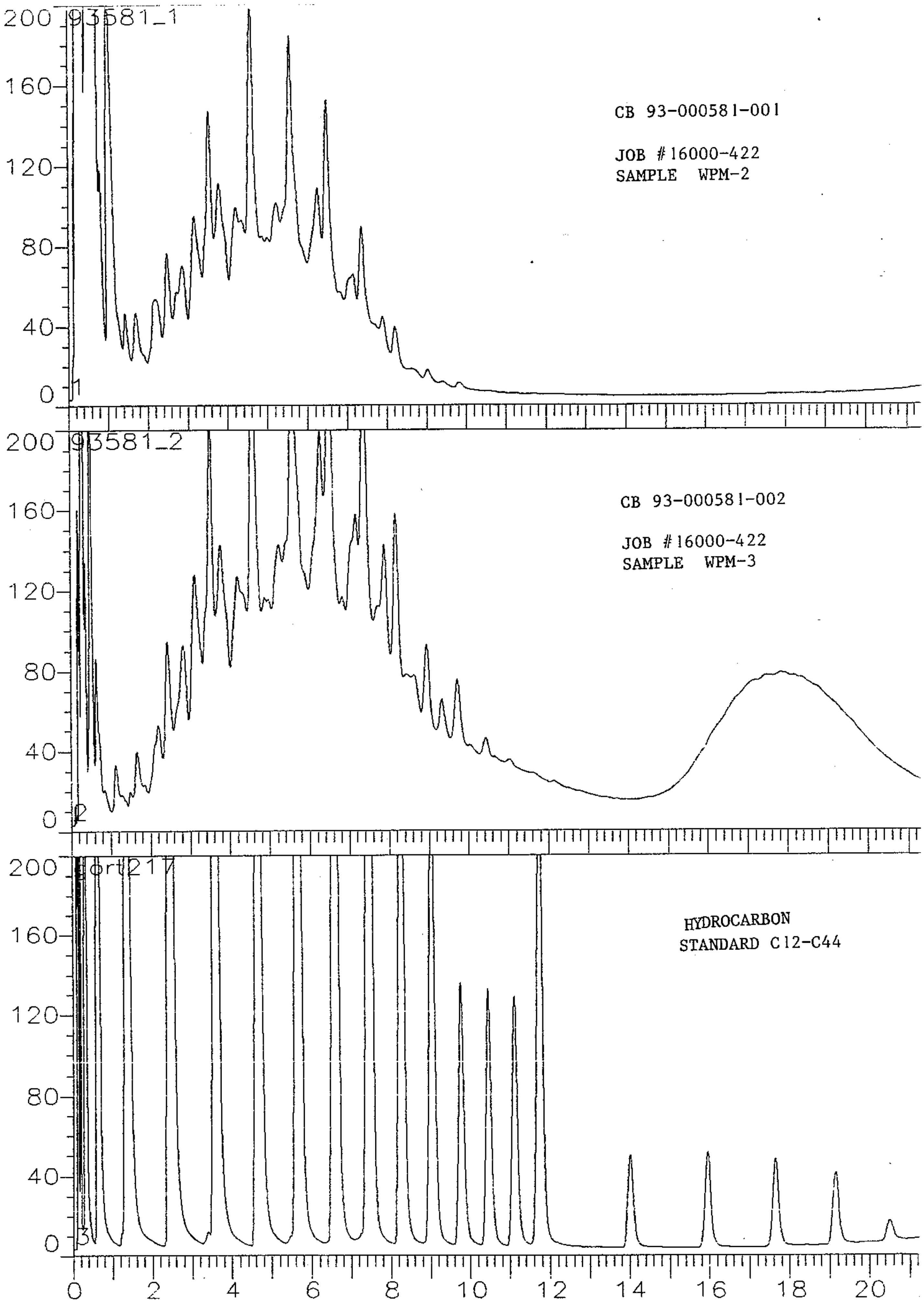
Approved by: Richard S. Lee
Richard S. Lee

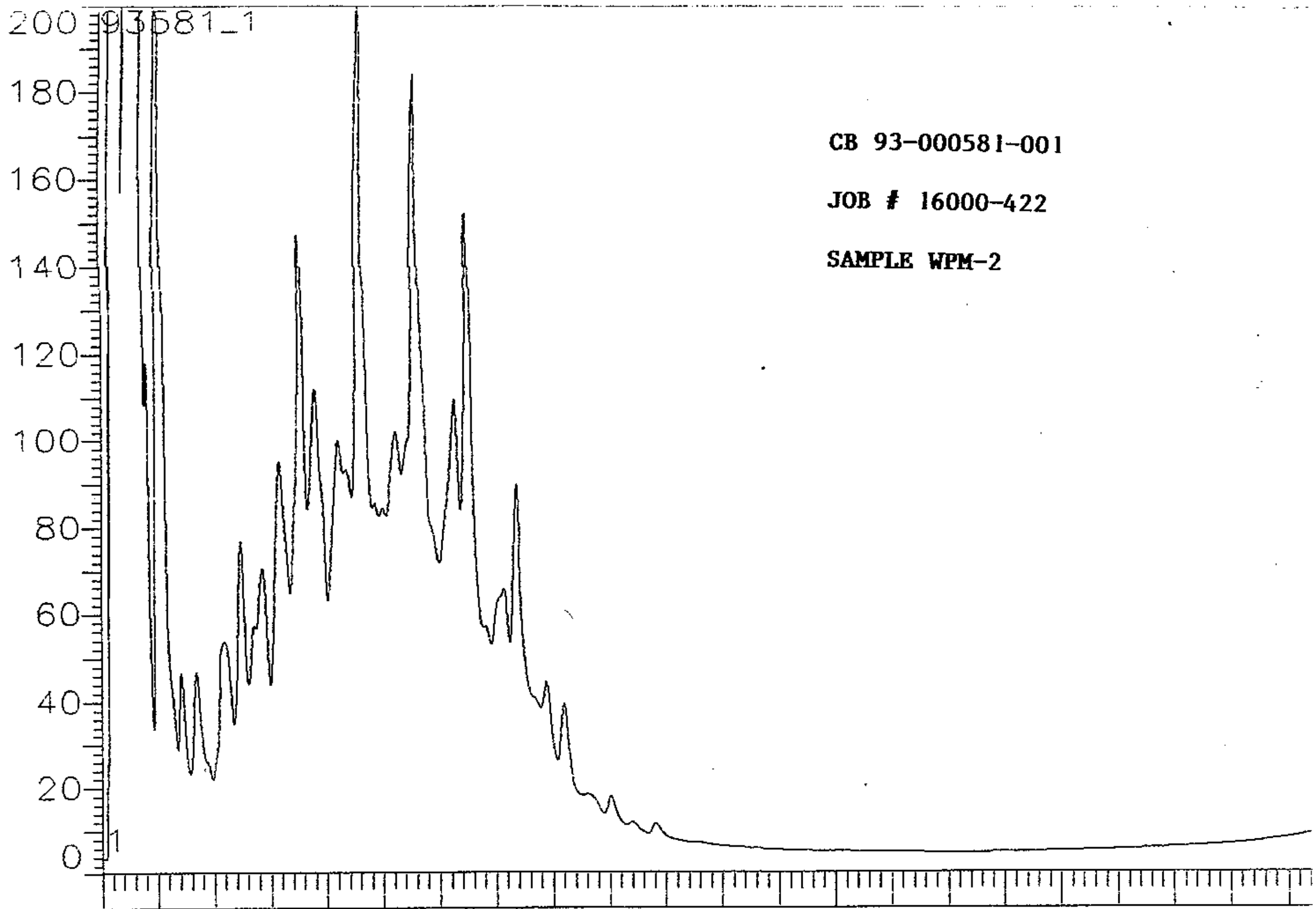
Sample ID	Description
93-000581-0-HOUS-001-00	WPM-2 Hydrocarbon Job #16000-422
93-000581-0-HOUS-002-00	WPM-3 Hydrocarbon Job #16000-422

Sample	Boiling Range Distribution
001-00	See Attached Report
002-00	See Attached Report

Methods

Boiling Range Distribution : - D2887

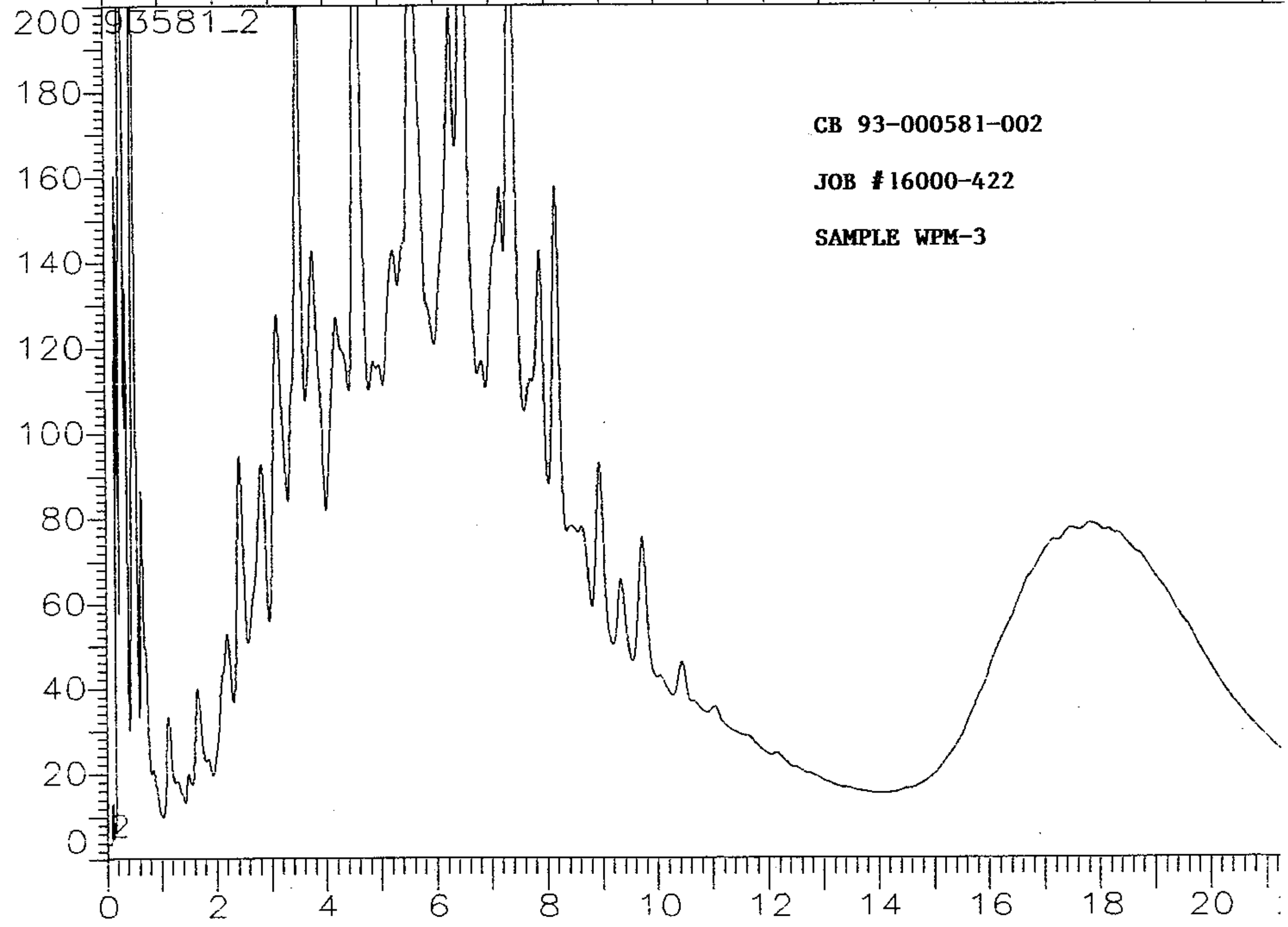

93581_1
200
160
120
80
40
0
1
CB 93-000581-001
JOB #16000-422
SAMPLE WPM-2
93581_2
200
160
120
80
40
0
2
CB 93-000581-002
JOB #16000-422
SAMPLE WPM-3
gort217
200
160
120
80
40
0
3
HYDROCARBON
STANDARD C12-C44
0
2
4
6
8
10
12
14
16
18
20



CB 93-000581-001

JOB # 16000-422

SAMPLE WPM-2



CB 93-000581-002

JOB #16000-422

SAMPLE WPM-3

Chromatogram

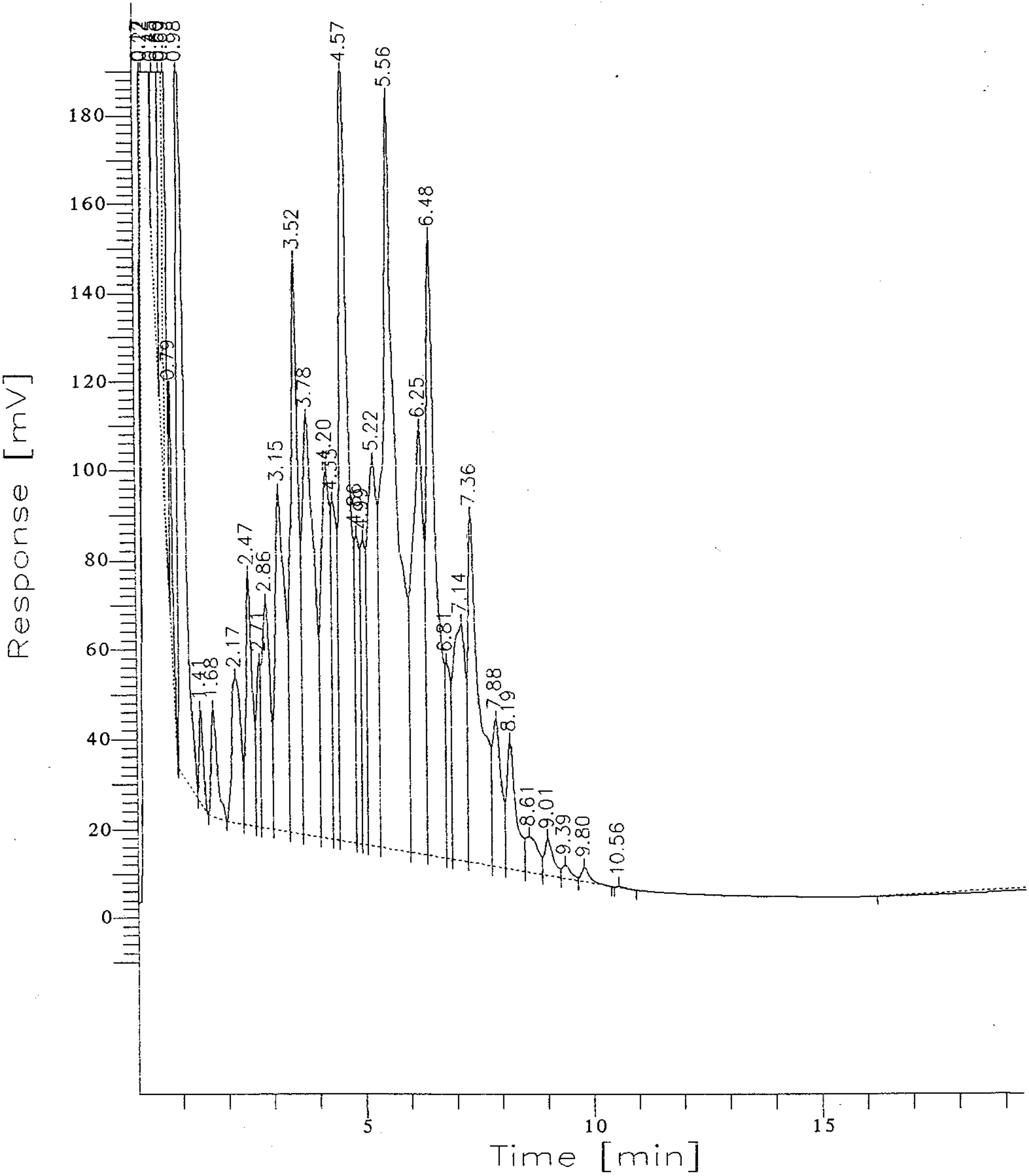
Sample Name : 93581-001,#WPM-2
FileName : C:\2700\GC6\93581_1.RAW
Method : D2887A.ins
Start Time : 0.01 min
Scale Factor: 0

End Time : 20.00 min
Plot Offset: -10 mV

Sample #: 4
Date : 2/22/93 09:14 AM
Time of Injection: 2/19/93 05:28 PM
Low Point : -10.00 mV
Plot Scale: 200 mV

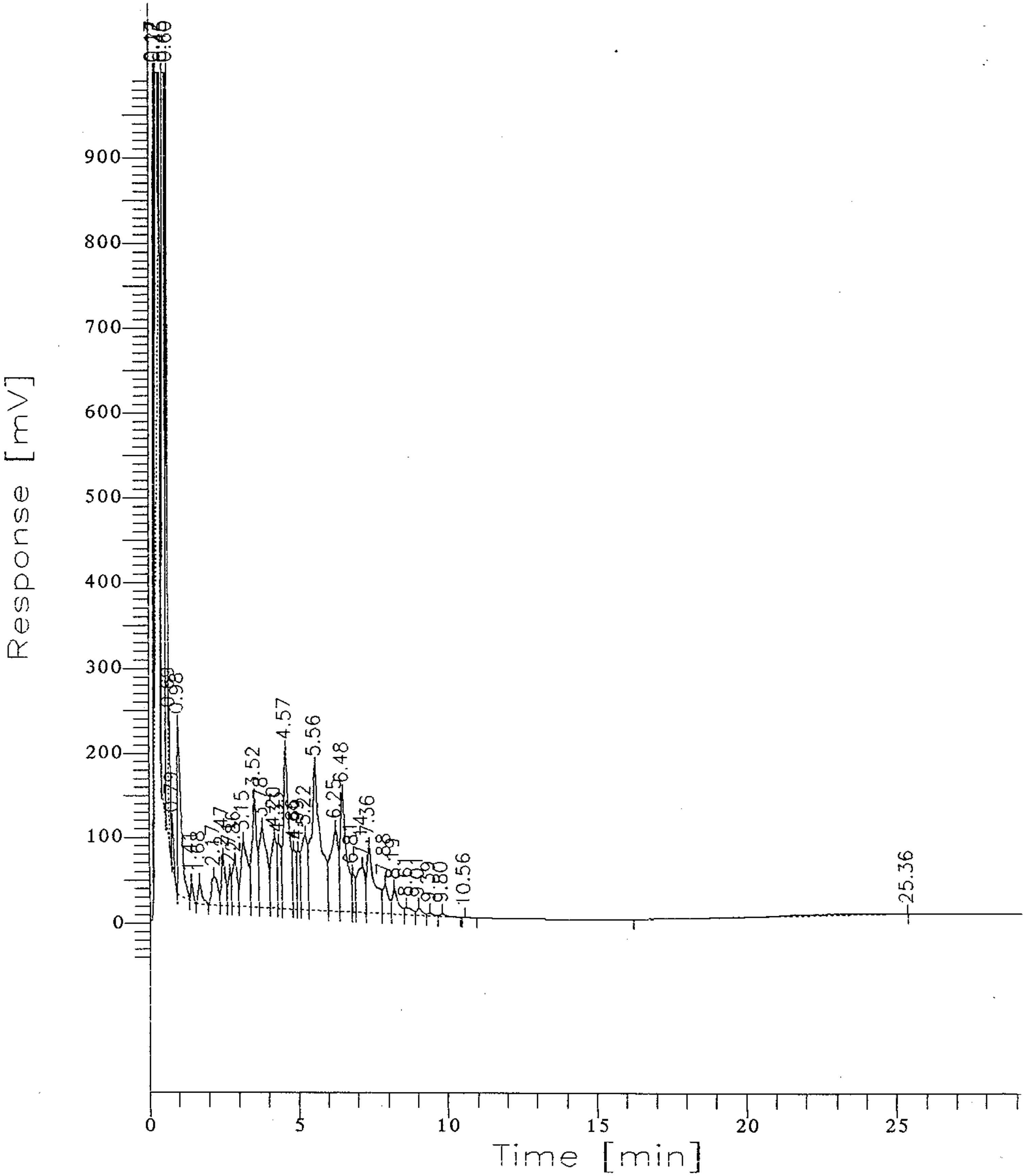
Page 1 of 1

High Point : 190.00 mV



Chromatogram

Sample Name : 93581-001,#WPM-2
Sample #: 4
Page 1 of 1
FileName : c:\2700\gc6\93581_1.raw
Date : 2/19/93 05:58 PM
Method : d2887a.ins
Time of Injection: 2/19/93 05:28 PM
Start Time : 0.00 min
End Time : 30.00 min
Low Point : -46.29 mV
High Point : 1000.00 mV
Scale Factor: 1
Plot Offset: -46 mV
Plot Scale: 1046 mV



```
=============================================================================
Software Version: 3.2 <16C20>
Sample Name  : 93581-001,#WPM-2          Time         : 2/19/93  05:58 PM
Sample Number: 4                         Study        : SIMDIST
Operator     :

Instrument   : GC_6_PE                   Channel : A     A/D mV Range : 1000
AutoSampler  : NONE
Rack/Vial    : 0/0

Interface Serial # : 2135574871   Data Acquisition Time: 2/19/93  05:28 PM
Delay Time      : 0.00   min.
End Time        : 30.00  min.
Sampling Rate   : 2.0000   pts/sec

Raw Data File   : c:\2700\gc6\93581_1.raw
Result File     : c:\2700\gc6\93581_1.rst
Instrument File: c:\2700\gc6\d2887a.ins
Process File    : c:\2700\gc6\d2887a.prc
Sample File     : c:\2700\gc6\d2887a.smp
Sequence File   : C:\2700\GC6\D2887.seq

Inj. Volume     : 1 ul                  Area Reject        : 0.00
Sample Amount   : 1.0000                Dilution Factor    : 1.00

=============================================================================


                                DEFAULT REPORT

Peak   Time     Area        Height      Area   Norm. Area BL Area/Height
 #    [min]   [uV*sec]       [uV]       [%]       [%]             [sec]
-----------------------------------------------------------------------------
  1    0.171  2301854.50 875407.69    5.42          5.42 BV       2.6295
  2    0.215  3464914.50 680195.81    8.16          8.16 VB       5.0940
  3    0.454  6420767.50 865752.94   15.13         15.13 BV       7.4164
  4    0.604  3204386.00 907686.94    7.55          7.55 VE       3.5303
  5    0.691   540973.50 165920.44    1.28          1.28 EV       3.2604
  6    0.792   213723.03  53554.29    0.50          0.50 VB       3.9908
  7    0.980  1749421.75 202093.95    4.12          4.12 BV       8.6565
  8    1.411   124514.41  20855.01    0.29          0.29 VB       5.9705
  9    1.682   220503.50  23790.10    0.52          0.52 BB       9.2687
 10    2.174   458677.84  32142.22    1.08          1.08 BV      14.2703
 11    2.469   542379.00  55745.85    1.28          1.28 VV       9.7295
 12    2.705   238897.48  36545.58    0.56          0.56 VV       6.5370
 13    2.859   619119.63  50159.28    1.46          1.46 VV      12.3431
 14    3.153  1195252.00  75296.17    2.82          2.82 VV      15.8740
 15    3.525  1504020.13 128246.19    3.54          3.54 VV      11.7276
 16    3.780  1627842.25  92890.03    3.84          3.84 VV      17.5244
 17    4.199  1119951.88  81804.77    2.64          2.64 VV      13.6905
 18    4.334   660206.38  75368.82    1.56          1.56 VV       8.7597
 19    4.574  2491209.00 186995.05    5.87          5.87 VV      13.3223
 20    4.855   506083.28  68612.74    1.19          1.19 VV       7.3759
 21    4.993   501737.88  67849.01    1.18          1.18 VV       7.3949
 22    5.222  1253354.00  85580.37    2.95          2.95 VV      14.6453
 23    5.564  3720547.75 168826.77    8.77          8.77 VV      22.0377
 24    6.251  1711812.50  94816.07    4.03          4.03 VV      18.0540
 25    6.481  2008549.25 138646.73    4.73          4.73 VV      14.4868
 26    6.806   336673.72  43595.61    0.79          0.79 VV       7.7227
 27    7.140   974963.19  52791.45    2.30          2.30 VV      18.4682
 28    7.357  1369704.25  77190.97    3.23          3.23 VV      17.7444
 29    7.884   437373.06  32672.84    1.03          1.03 VV      13.3864
 30    8.194   412312.13  28286.69    0.97          0.97 VV      14.5762
```

```
 31    8.606    150962.67   8080.15   0.36        0.36 VV      18.6832
 32    9.011    114715.42   8308.48   0.27        0.27 VV      13.8070
 33    9.386     43459.23   3016.89   0.10        0.10 VV      14.4053
 34    9.804     42639.59   3292.52   0.10        0.10 VB      12.9504
 35   10.558      2752.52    236.45   0.01        0.01 BB      11.6411
 36   25.364    159397.50     17.86   0.38        0.38 BB    8924.5752
------------------------------------------------------------------------------------
               42445652.00    5.49e6 100.00     100.00
```

Separation Systems, Inc.
Sample: 93581-001,#WPM-2

BOILING POINT DISTRIBUTION TABLE
ASTM D-2887

%OFF	BP (F)	BP (C)	%OFF	BP (F)	BP (C)
IBP	166	74	FBP	816	436
2	167	75			
4	170	77			
6	172	78			
8	174	79			
10	177	81			
12	179	82			
14	183	84			
16	189	87			
18	192	89			
20	194	90			
22	196	91			
24	199	93			
26	201	94			
28	204	96			
30	208	98			
32	210	99			
34	211	99			
36	216	102			
38	225	107			
40	236	113			
42	245	118			
44	272	133			
46	295	146			
48	310	154			
50	322	161			
52	332	167			
54	341	172			
56	347	175			
58	354	179			
60	363	184			
62	370	188			
64	378	192			
66	382	194			
68	387	197			
70	395	202			
72	403	206			
74	411	211			
76	417	214			
78	421	216			
80	428	220			
82	437	225			
84	444	229			
86	451	233			
88	458	237			
90	470	243			
92	482	250			
94	494	257			
96	516	269			
98	565	296			

CALIBRATION FILE: gort217
CALIBRATION DATE: 02/19/93
SLICE WIDTH: 0.50 sec
INTEGRATION START TIME: 0.25 min
INTEGRATION END TIME: 21.75 min

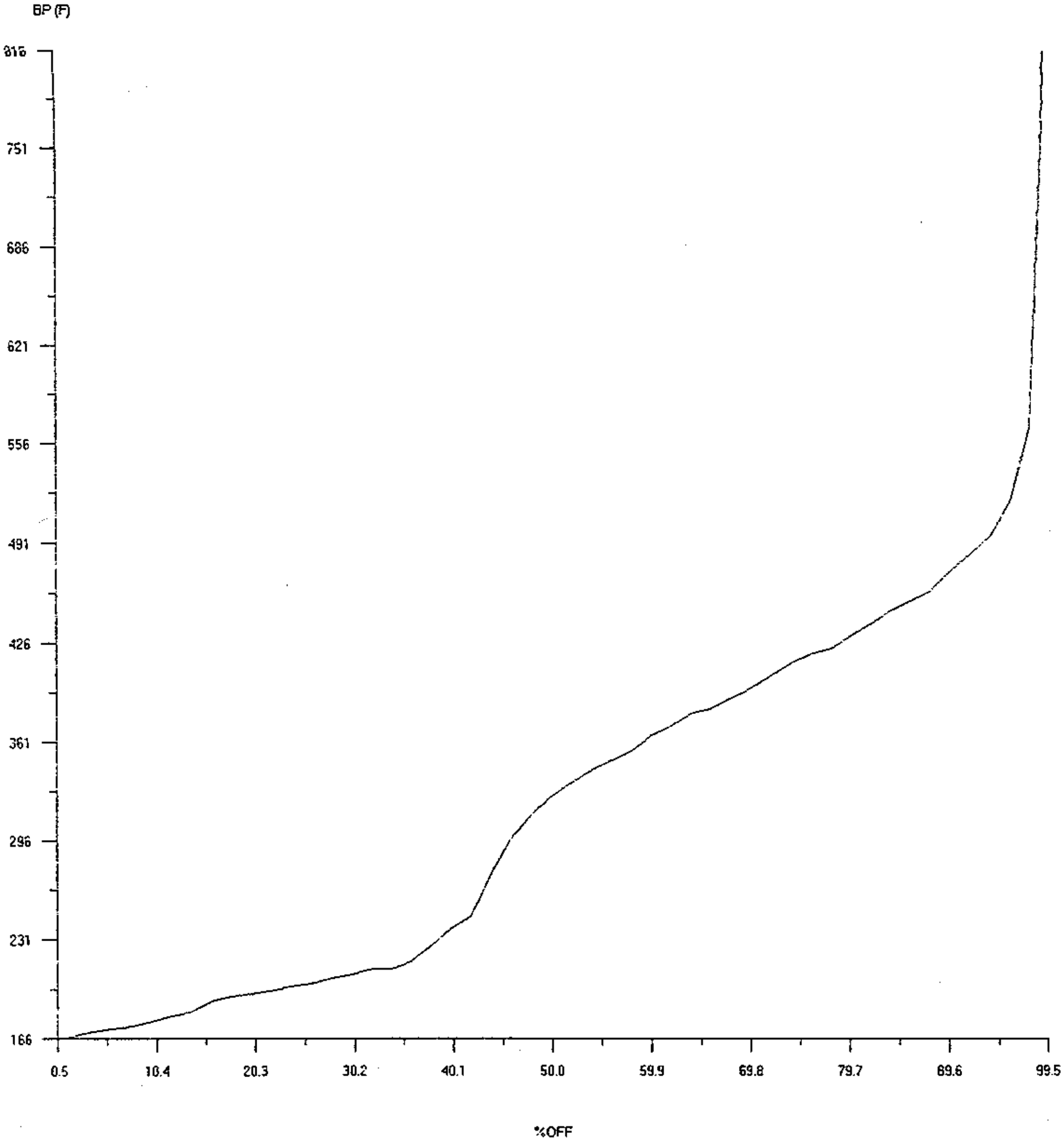
BASELINE SUBTRACTED: bkrg217
SAMPLE OFFSET: 3535
BASELINE OFFSET: 3510

TOTAL AREA: 1.100965E+08

Separation Systems, Inc.

Sample: 93581-001,#WPM-2

SIMDIS PLOT
ASTM D-2887



Chromatogram

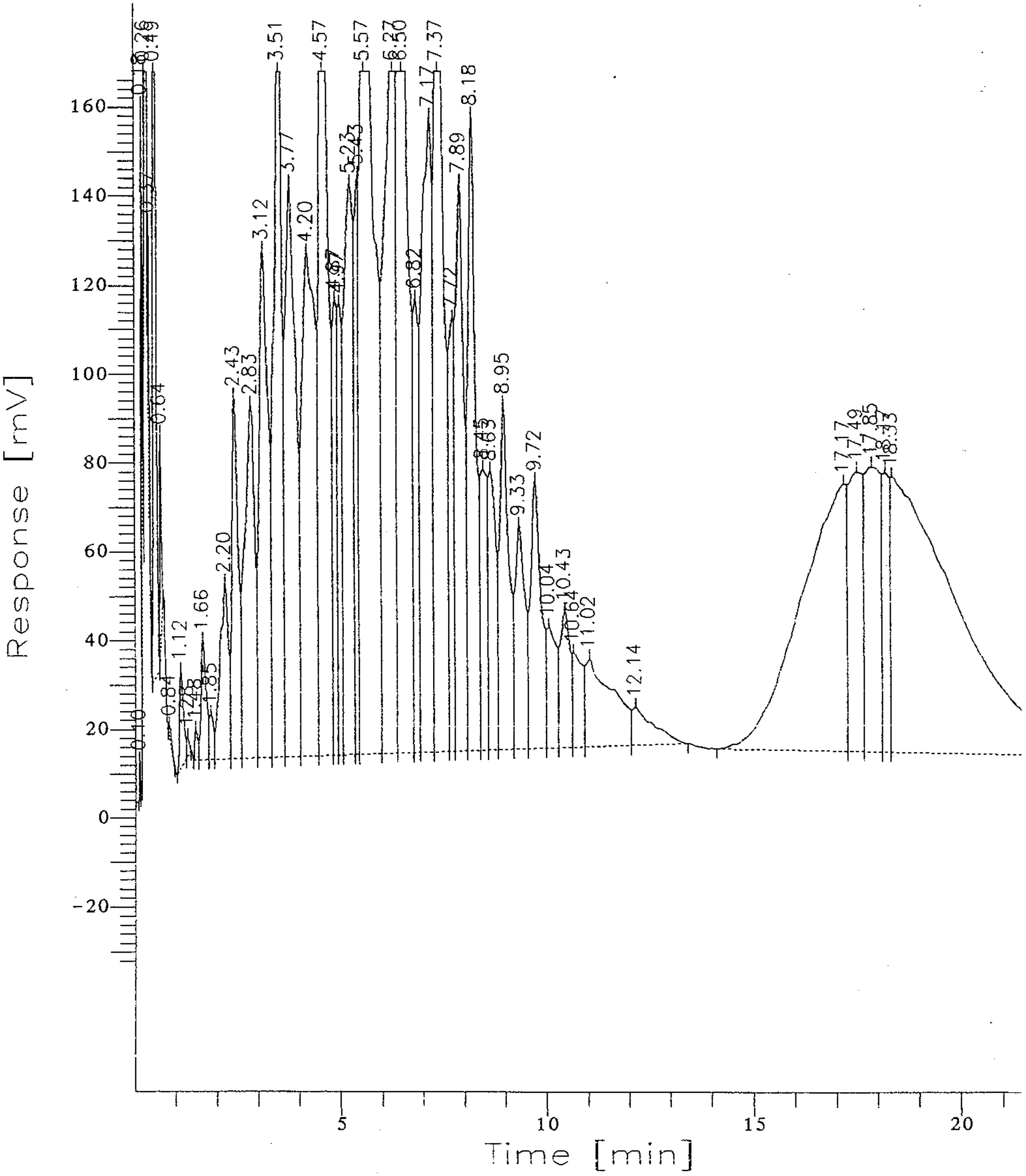
Sample Name : 93581-002#WPM-3
FileName : C:\2700\GC6\93581_2.RAW
Method : D2887A.ins
Start Time : 0.01 min
Scale Factor: 0

End Time : 22.00 min
Plot Offset: -32 mV

Sample #: 4
Date : 2/22/93 09:17 AM
Time of Injection: 2/19/93 06:15 PM
Low Point : -32.10 mV
Plot Scale: 200 mV

Page 1 of 1

High Point : 167.90 mV

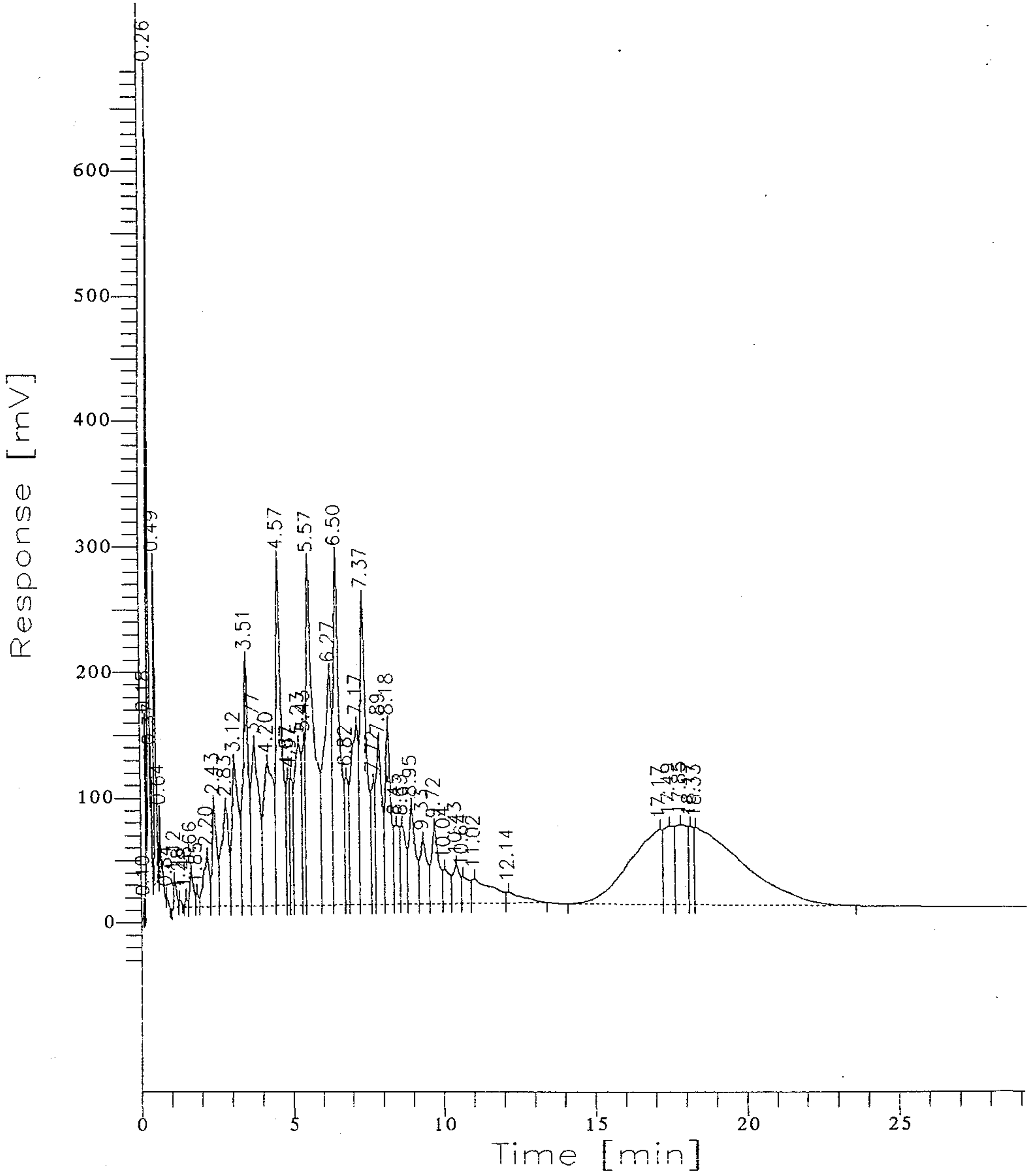


Chromatogram

Sample Name : 93581-002#WPM-3
FileName : c:\2700\gc6\93581_2.raw
Method : d2887a.ins
Start Time : 0.00 min
End Time : 30.00 min
Scale Factor: 1
Plot Offset: -30 mV

Sample #: 4
Date : 2/19/93 06:45 PM
Time of Injection: 2/19/93 06:15 PM
Low Point : -30.31 mV
High Point : 680.08 mV
Plot Scale: 710 mV

Page 1 of 1



```
==============================================================================
Software Version: 3.2 <16C20>
Sample Name  : 93581-002#WPM-3              Time          : 2/19/93  06:45 PM
Sample Number: 4                            Study         : SIMDIST
Operator     :

Instrument   : GC_6_PE                      Channel : A    A/D mV Range : 1000
AutoSampler  : NONE
Rack/Vial    : 0/0

Interface Serial # : 2135574871   Data Acquisition Time: 2/19/93  06:15 PM
Delay Time       : 0.00   min.
End Time         : 30.00  min.
Sampling Rate    : 2.0000   pts/sec

Raw Data File    : c:\2700\gc6\93581_2.raw
Result File      : c:\2700\gc6\93581_2.rst
Instrument File: c:\2700\gc6\d2887a.ins
Process File     : c:\2700\gc6\d2887a.prc
Sample File      : c:\2700\gc6\d2887a.smp
Sequence File    : C:\2700\GC6\D2887.seq

Inj. Volume      : 1 ul                     Area Reject       : 0.00
Sample Amount    : 1.0000                   Dilution Factor   : 1.00

==============================================================================


                                    DEFAULT REPORT
Peak  Time      Area        Height      Area   Norm. Area BL Area/Height
 #    [min]  [uV*sec]        [uV]       [%]       [%]            [sec]
------------------------------------------------------------------------------
  1    0.105      9992.75    9676.21    0.01       0.01 BB       1.0327
  2    0.175    210174.00  128039.70    0.30       0.30 BB       1.6415
  3    0.260    955628.00  549432.00    1.38       1.38 BB       1.7393
  4    0.369     80997.00   52325.60    0.12       0.12 BB       1.5479
  5    0.492   1045590.25  256256.48    1.51       1.51 BB       4.0803
  6    0.635    121288.73   47103.14    0.18       0.18 BB       2.5750
  7    0.839     10951.75    2446.59    0.02       0.02 BB       4.4763
  8    1.118    139927.17   21584.67    0.20       0.20 BV       6.4827
  9    1.278     19975.09    4205.31    0.03       0.03 VB       4.7500
 10    1.480     35363.03    6738.98    0.05       0.05 BV       5.2475
 11    1.656    240934.78   26697.96    0.35       0.35 VV       9.0245
 12    1.847     69233.52   10039.90    0.10       0.10 VV       6.8958
 13    2.197    562356.25   39455.08    0.81       0.81 VV      14.2531
 14    2.427    847543.25   81272.68    1.22       1.22 VV      10.4284
 15    2.829   1332670.75   79297.70    1.92       1.92 VV      16.8059
 16    3.119   1807080.50  114128.19    2.61       2.61 VV      15.8338
 17    3.505   2395998.50  195784.14    3.46       3.46 VV      12.2380
 18    3.769   2302699.75  128849.51    3.33       3.33 VV      17.8712
 19    4.195   2586642.00  113229.66    3.74       3.74 VV      22.8442
 20    4.573   3497028.50  275556.03    5.05       5.05 VV      12.6908
 21    4.874    802411.75  102395.45    1.16       1.16 VV       7.8364
 22    4.972    749529.56  101544.98    1.08       1.08 VV       7.3813
 23    5.232   1939139.00  128393.46    2.80       2.80 VV      15.1031
 24    5.426    818961.38  130202.77    1.18       1.18 VV       6.2899
 25    5.574   5218082.00  272473.13    7.54       7.54 VV      19.1508
 26    6.269   3327813.50  184897.72    4.81       4.81 VV      17.9981
 27    6.499   4124926.00  277517.91    5.96       5.96 VV      14.8636
 28    6.824    895774.50  102029.80    1.29       1.29 VV       8.7795
 29    7.171   2505091.00  142795.47    3.62       3.62 VV      17.5432
 30    7.370   3440775.25  243216.28    4.97       4.97 VV      14.1470
```

```
 31    7.720    854603.69  97317.95    1.23         1.23 VV       8.7816
 32    7.889   1752476.00 127681.59    2.53         2.53 VV      13.7254
 33    8.177   1858960.75 142769.56    2.68         2.68 VV      13.0207
 34    8.445    748947.50  63132.75    1.08         1.08 VV      11.8631
 35    8.631    841090.63  62732.56    1.22         1.22 VV      13.4076
 36    8.951   1202191.25  77636.54    1.74         1.74 VV      15.4849
 37    9.333    855949.00  50231.45    1.24         1.24 VV      17.0401
 38    9.723   1054637.00  60119.07    1.52         1.52 VV      17.5425
 39   10.038    439194.97  27120.33    0.63         0.63 VV      16.1943
 40   10.434    513196.91  30478.69    0.74         0.74 VV      16.8379
 41   10.636    343743.16  21129.33    0.50         0.50 VV      16.2685
 42   11.023    929736.75  19573.97    1.34         1.34 VV      47.4986
 43   12.139    306299.38   8449.30    0.44         0.44 VB      36.2515
 44   17.170   4542566.00  60172.54    6.56         6.56 BV      75.4923
 45   17.491   1488937.75  63001.88    2.15         2.15 VV      23.6332
 46   17.848   1714217.50  64200.55    2.48         2.48 VV      26.7010
 47   18.167    780922.38  62876.47    1.13         1.13 VV      12.4200
 48   18.334   6927280.00  61986.84   10.00        10.00 VB     111.7541
-----------------------------------------------------------------------------------------
                 69249536.00     4.92e6  100.00       100.00
```

BOILING POINT DISTRIBUTION TABLE
ASTM D-2887

%OFF	BP (F)	BP (C)	%OFF	BP (F)	BP (C)
IBP	166	74	FBP	1036	558
2	173	78			
4	200	93			
6	272	133			
8	304	151			
10	319	159			
12	331	166			
14	341	172			
16	348	176			
18	357	181			
20	367	186			
22	376	191			
24	382	194			
26	387	197			
28	397	203			
30	405	207			
32	413	212			
34	418	214			
36	423	217			
38	430	221			
40	438	226			
42	445	229			
44	450	232			
46	454	234			
48	462	239			
50	471	244			
52	479	248			
54	485	252			
56	491	255			
58	501	261			
60	510	266			
62	520	271			
64	534	279			
66	549	287			
68	569	298			
70	591	311			
72	621	327			
74	665	352			
76	736	391			
78	799	426			
80	824	440			
82	842	450			
84	857	458			
86	872	467			
88	886	474			
90	900	482			
92	915	491			
94	931	499			
96	952	511			
98	982	528			

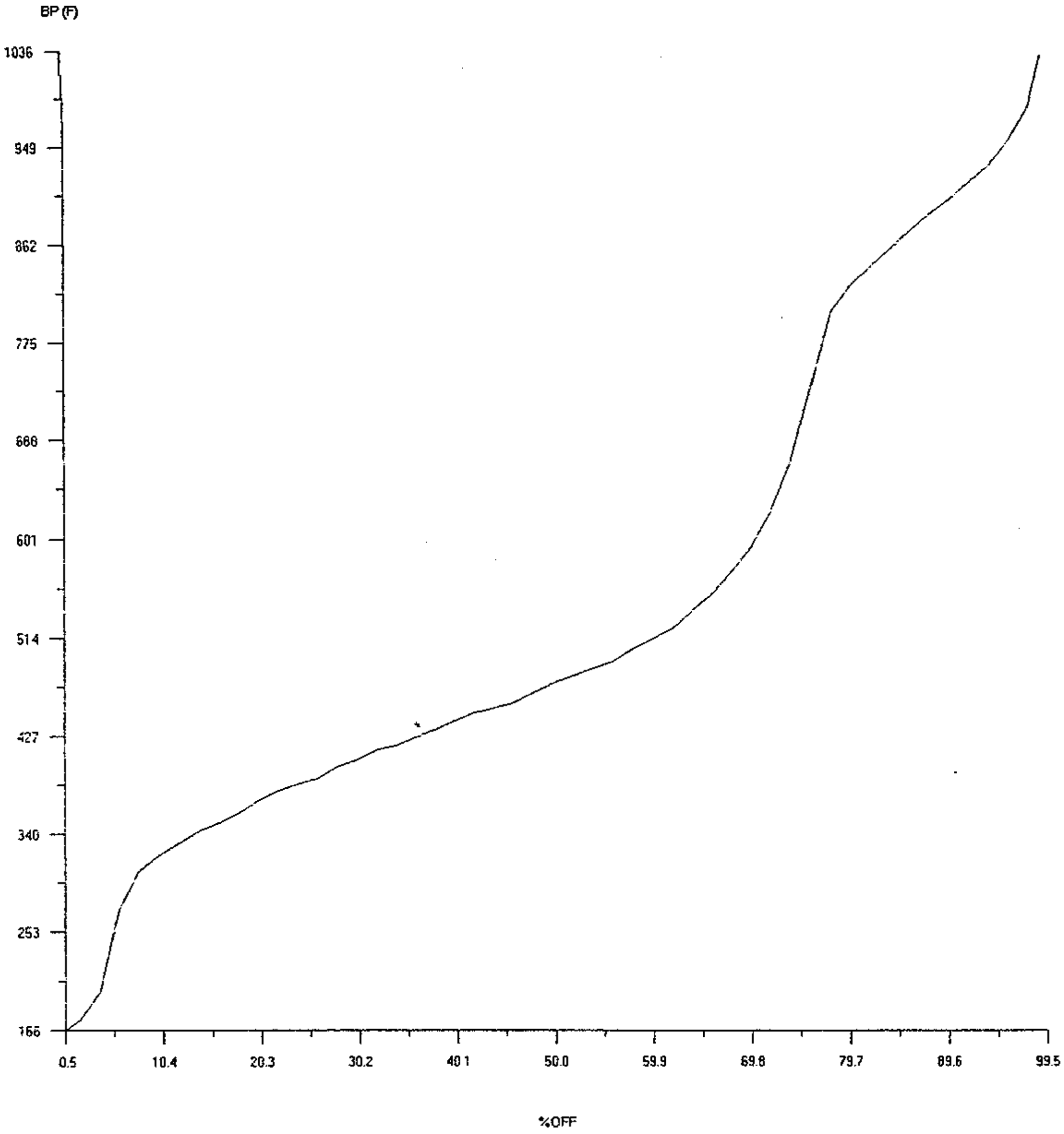
CALIBRATION FILE: gort217
CALIBRATION DATE: 02/19/93
SLICE WIDTH: 0.50 sec
INTEGRATION START TIME: 0.25 min
INTEGRATION END TIME: 24.50 min

BASELINE SUBTRACTED: bkrg217
SAMPLE OFFSET: 3523
BASELINE OFFSET: 3510

TOTAL AREA: 1.696380E+08

Sample: 93581-002#WPM-3

SIMDIS PLOT
ASTM D-2887

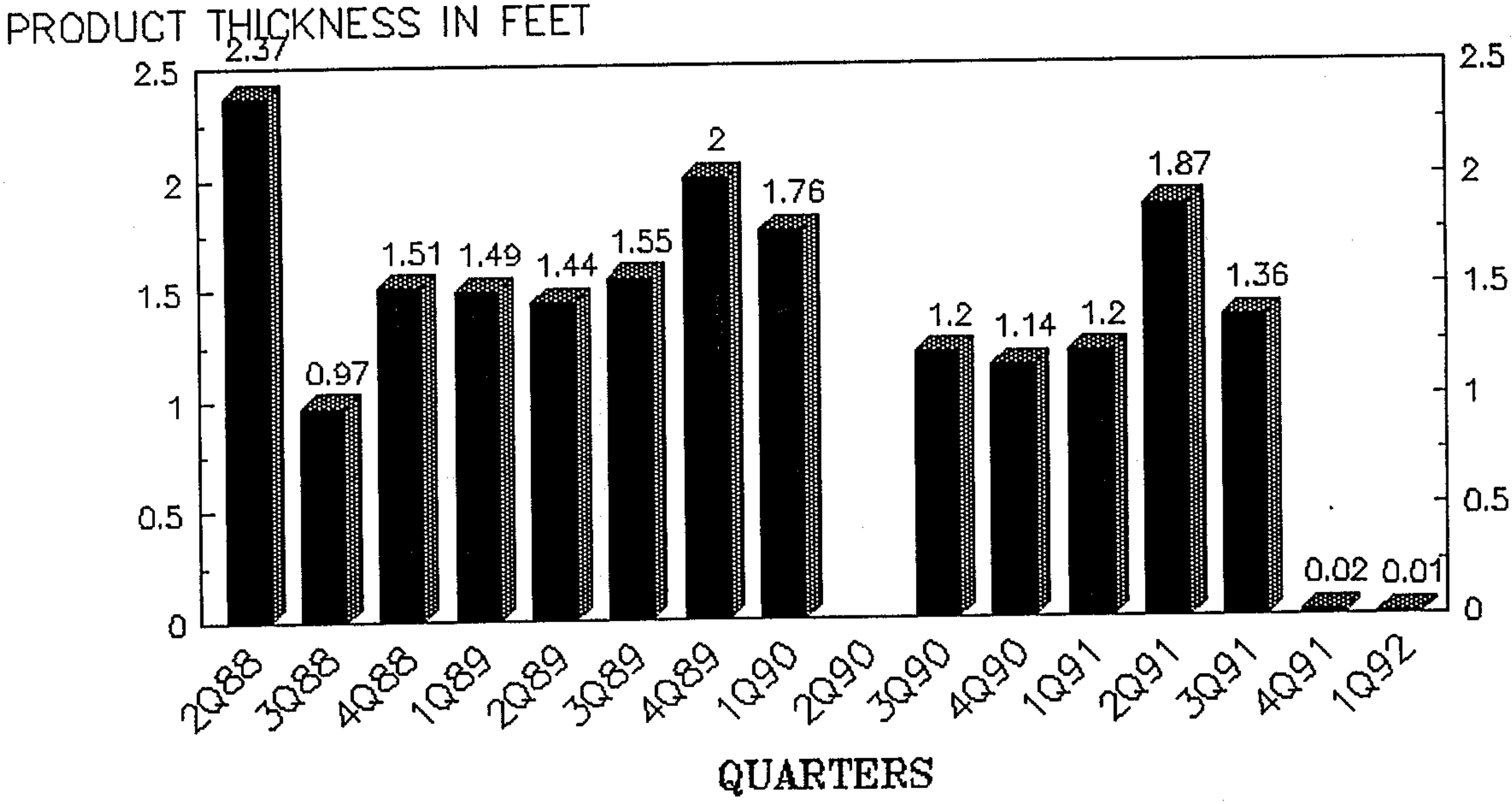


APPENDIX B

HISTOGRAMS OF FREE-PHASE HYDROCARBON THICKNESS

WELL MONITORING REPORT

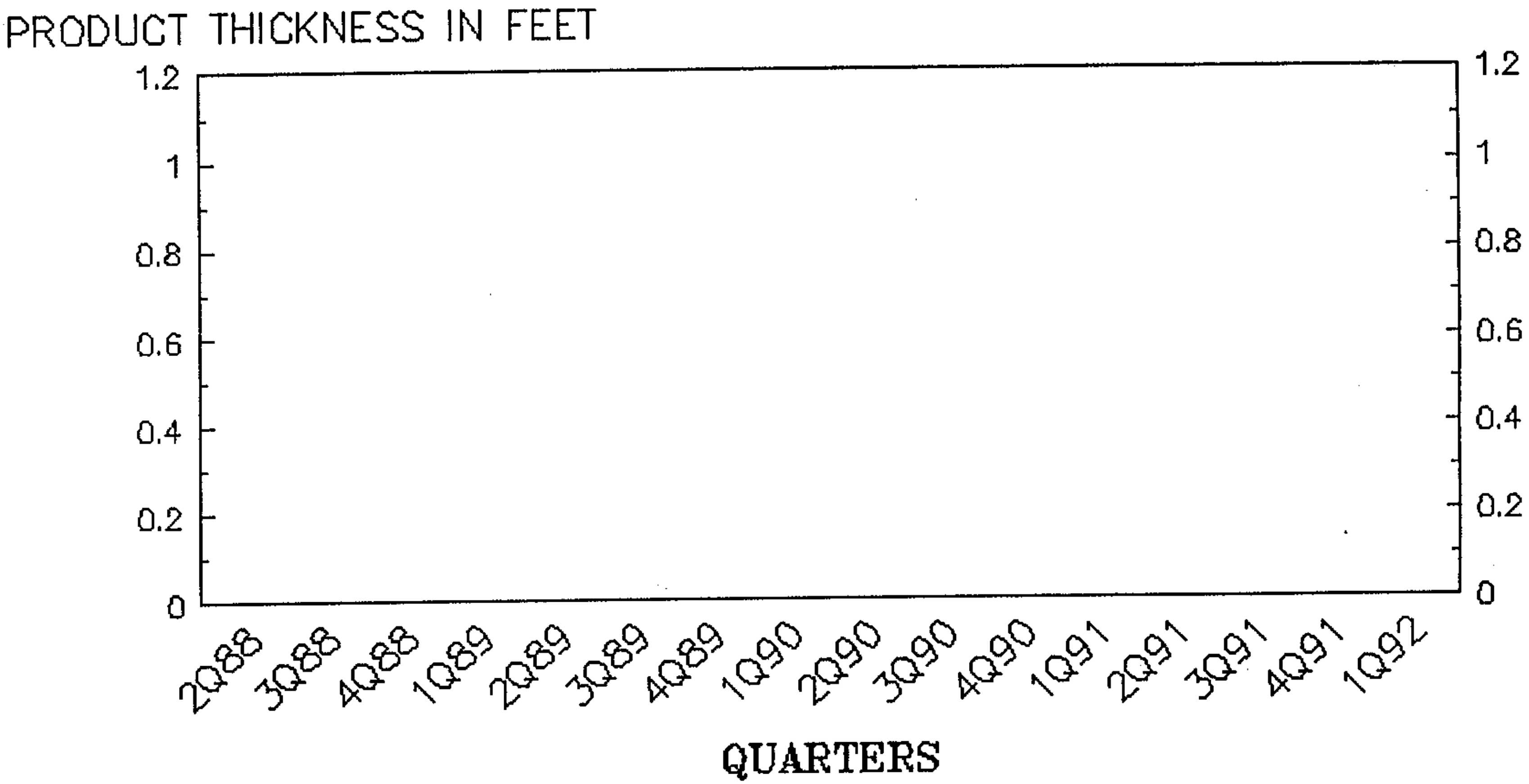
4A WELL (LOCATED EAST OF #2 WAREHOUSE)



A THICKNESS MEASUREMENT COULD NOT BE
OBTAINED BECAUSE OF PRODUCT VISCOSITY
FOR THE 2ND QTR 1990

WELL MONITORING REPORT

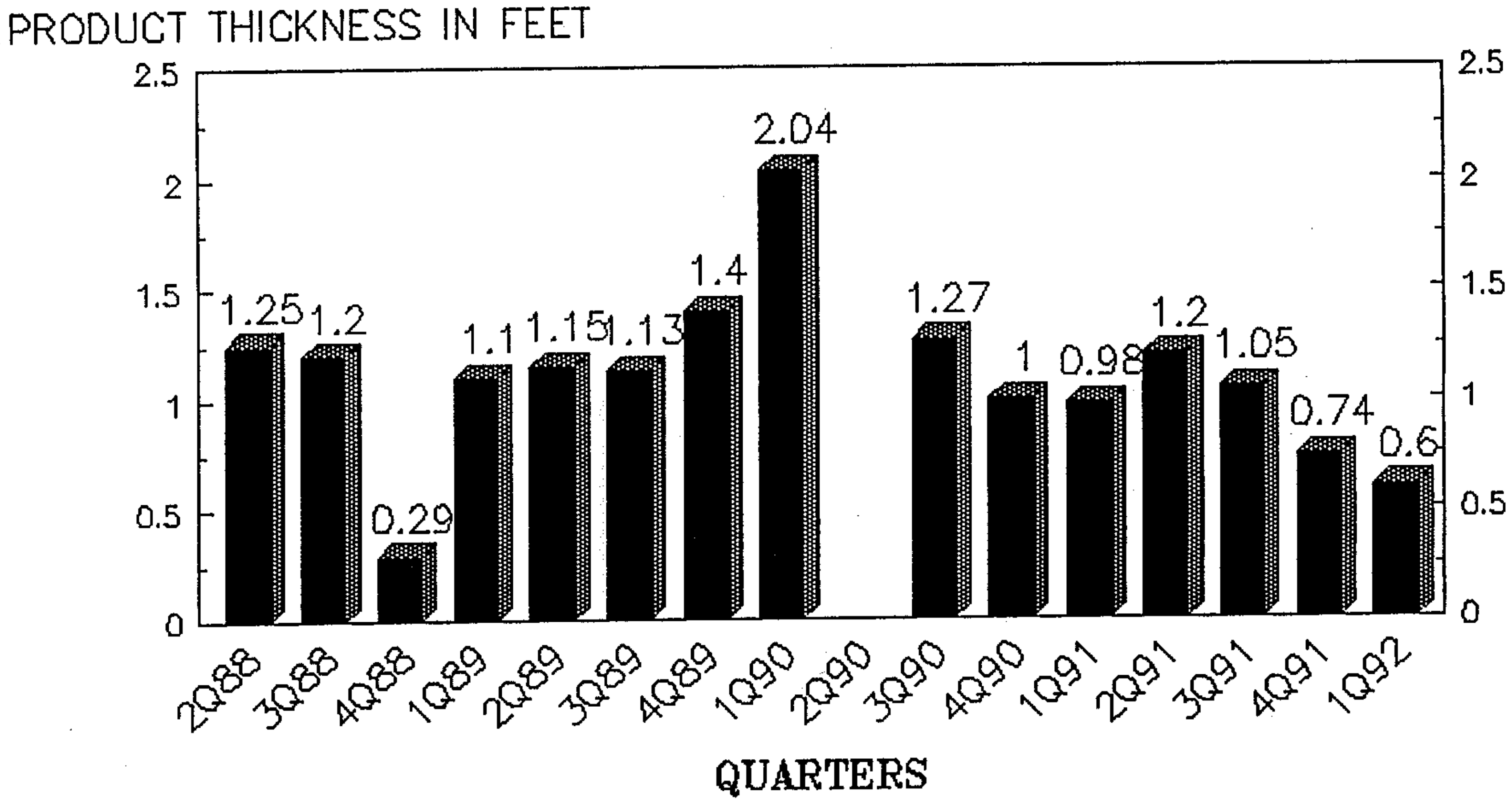
5A WELL (NEAR 579 & 706 TANKS)



PRODUCT HAS HIGH VISCOSITY AND DIFFICULT TO GET
AN ACCURATE MEASUREMENT

WELL MONITORING REPORT

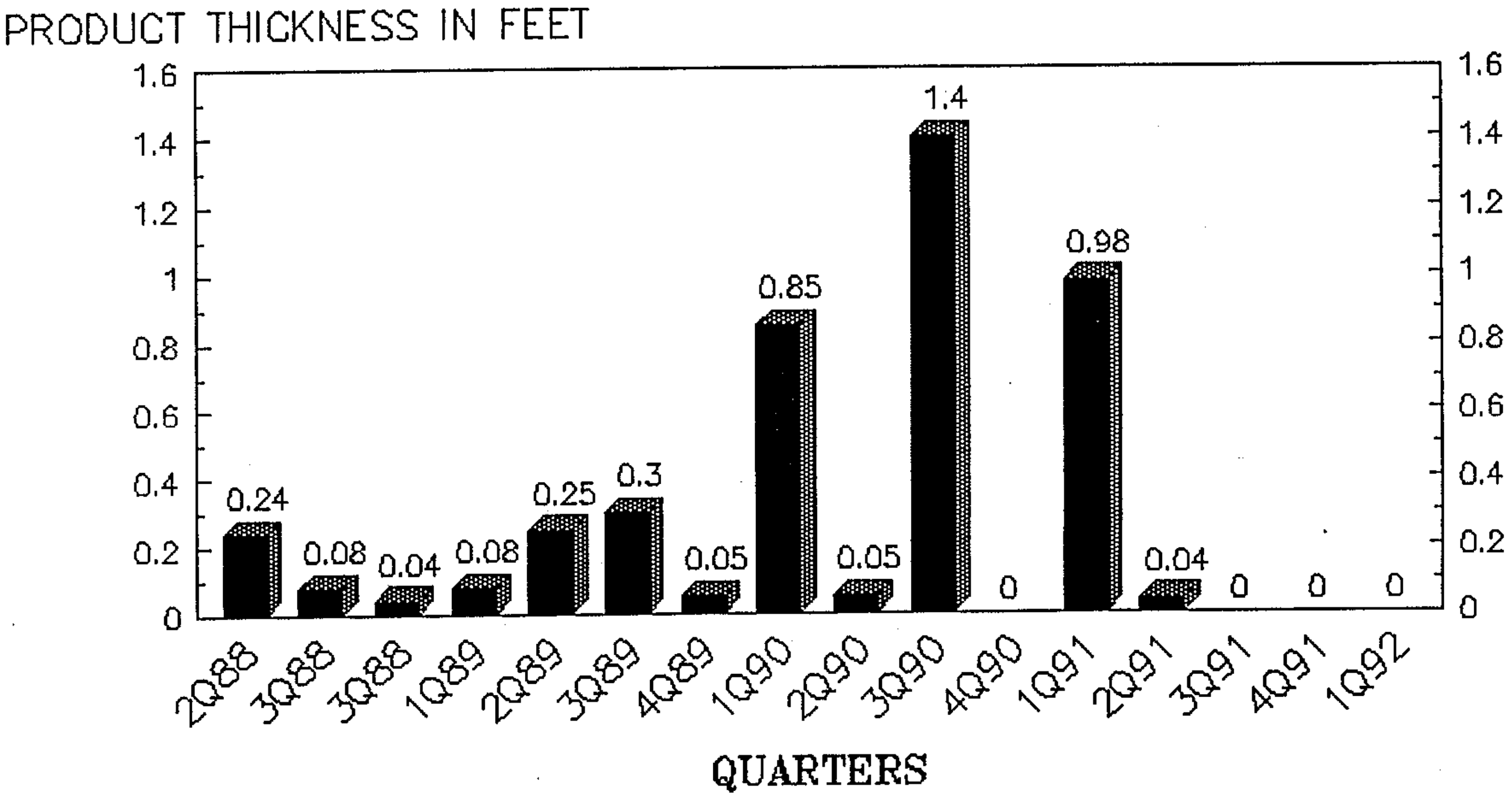
7A WELL (LOCATED @ TANK CAR LOADING RACK)



A THICKNESS MEASUREMENT COULD NOT BE
OBTAINED BECAUSE OF PRODUCT VISCOSITY
FOR THE 2ND QTR 1990

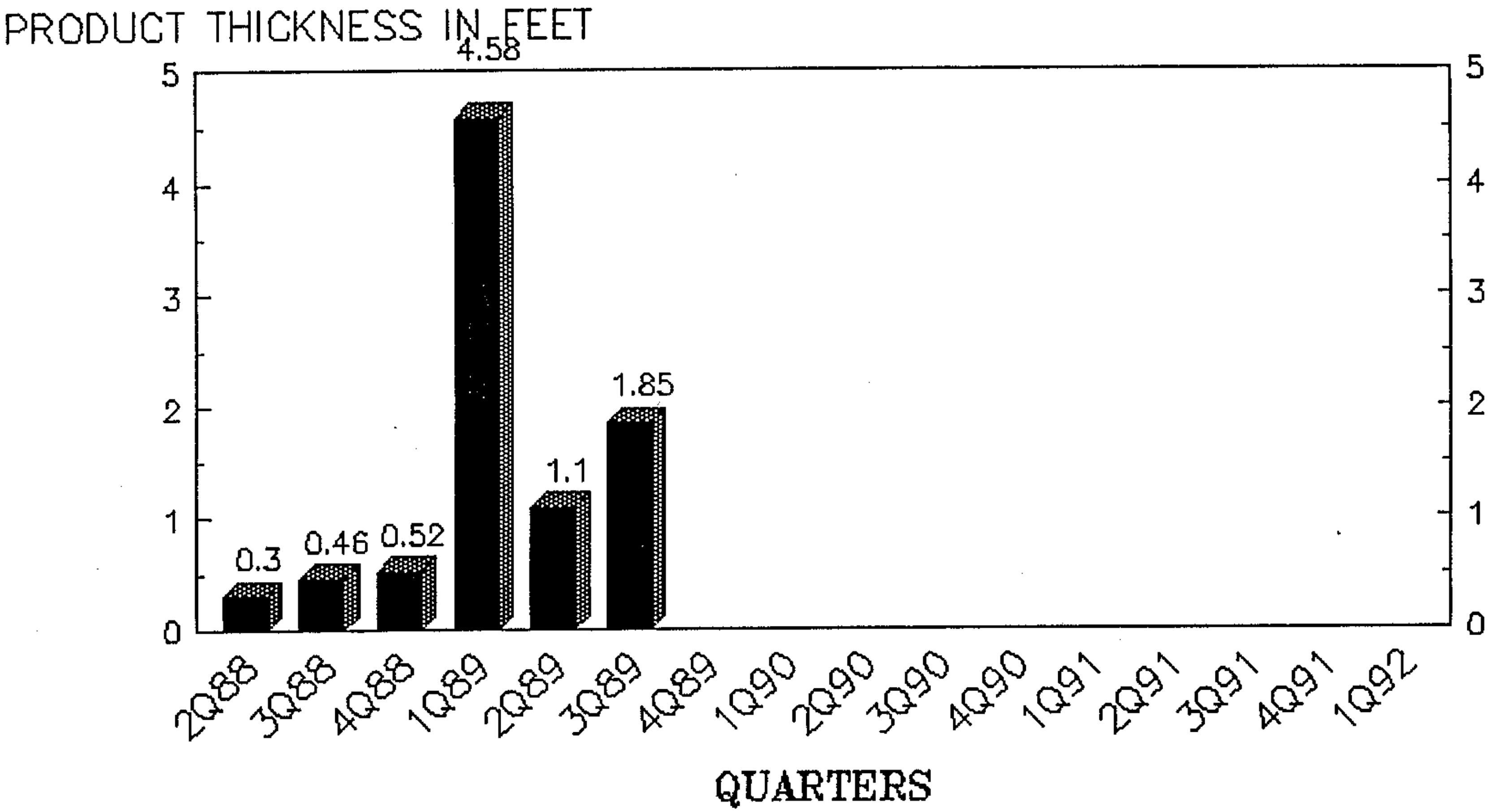
WELL MONITORING REPORT

8A WELL (BEHIND PACKAGE DEPT BLDG 621)



WELL MONITORING REPORT

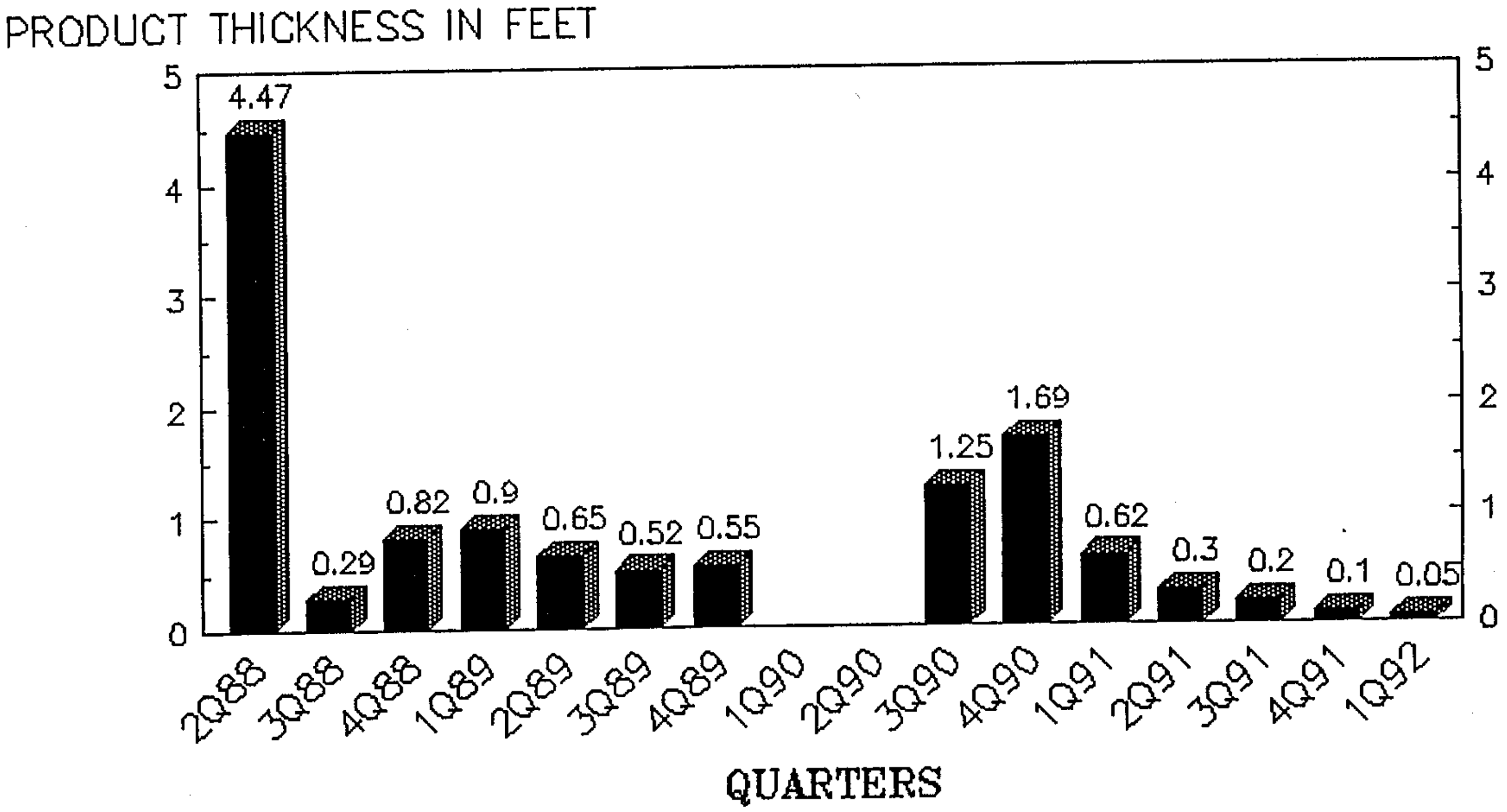
21A WELL (LOCATED @ SLURRY WALL BY B.H.)



A THICKNESS MEASUREMENT COULD NOT BE OBTAINED BECAUSE OF PRODUCT VISCOSITY FROM 4Q89 TO 1Q92

WELL MONITORING REPORT

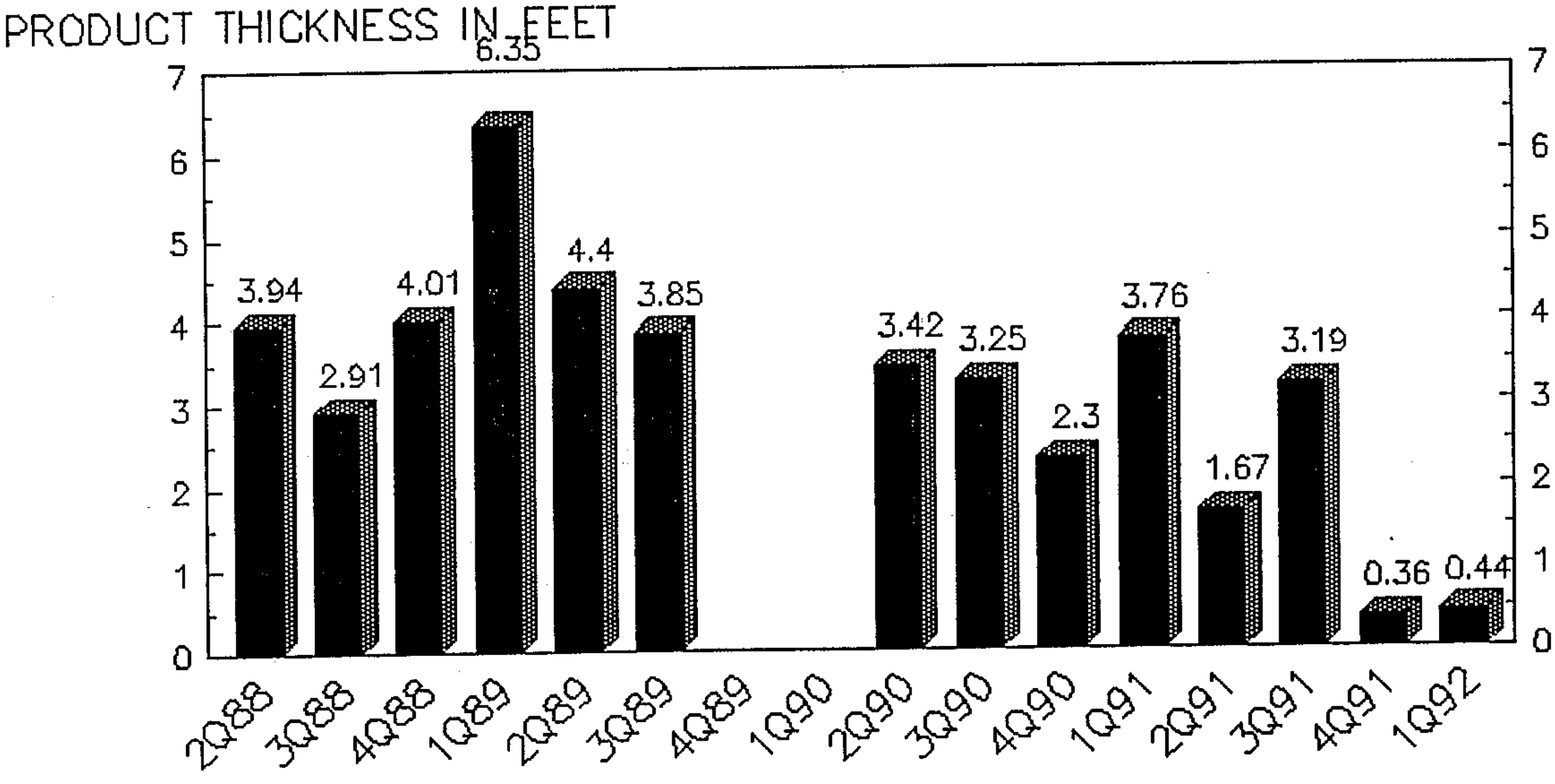
22A WELL (LOCATED @ 320 TANK)



A THICKNESS MEASUREMENT COULD NOT BE OBTAINED BECAUSE OF PRODUCT VISCOSITY FOR 1ST QTR 90 & 2ND QTR 90

WELL MONITORING REPORT

24A WELL (LOCATED @ AVE E)

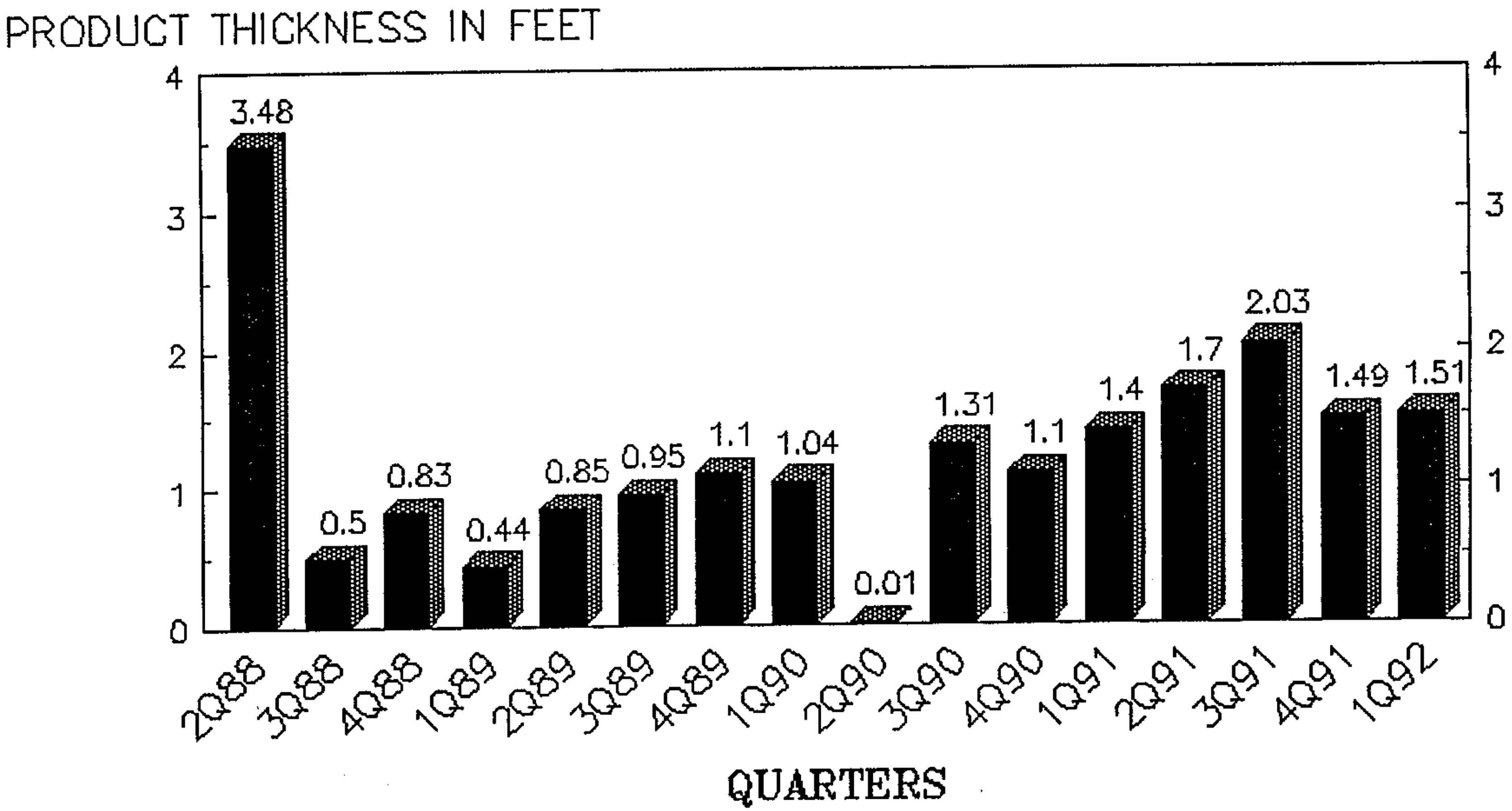


QUARTERS

A THICKNESS MEASUREMENT COULD NOT BE
OBTAINED BECAUSE OF PRODUCT VISCOSITY
FOR 4TH QTR 89 & 1ST QTR 90

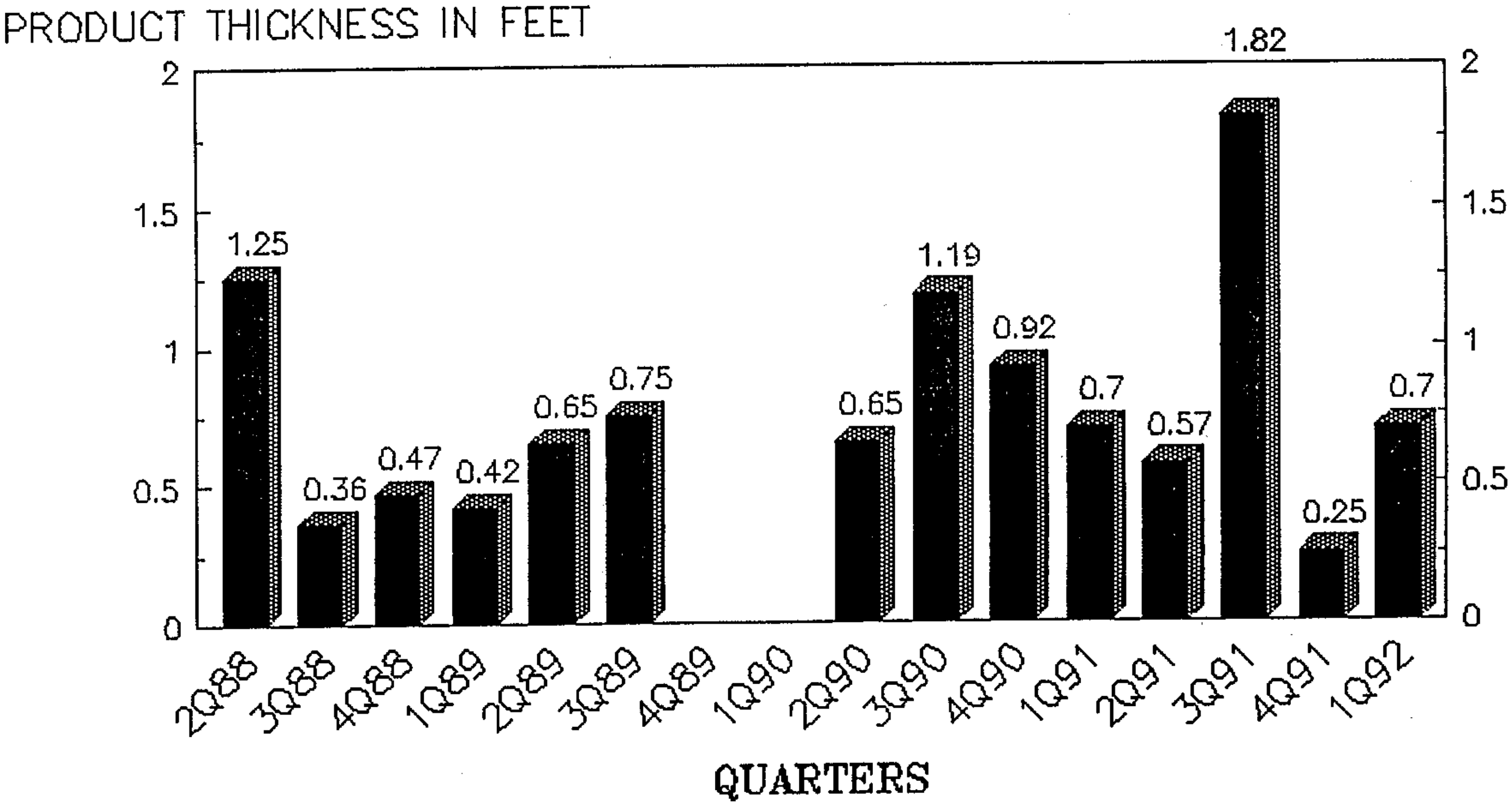
WELL MONITORING REPORT

39B WELL (LOCATED @ SAND BLAST AREA)



WELL MONITORING REPORT

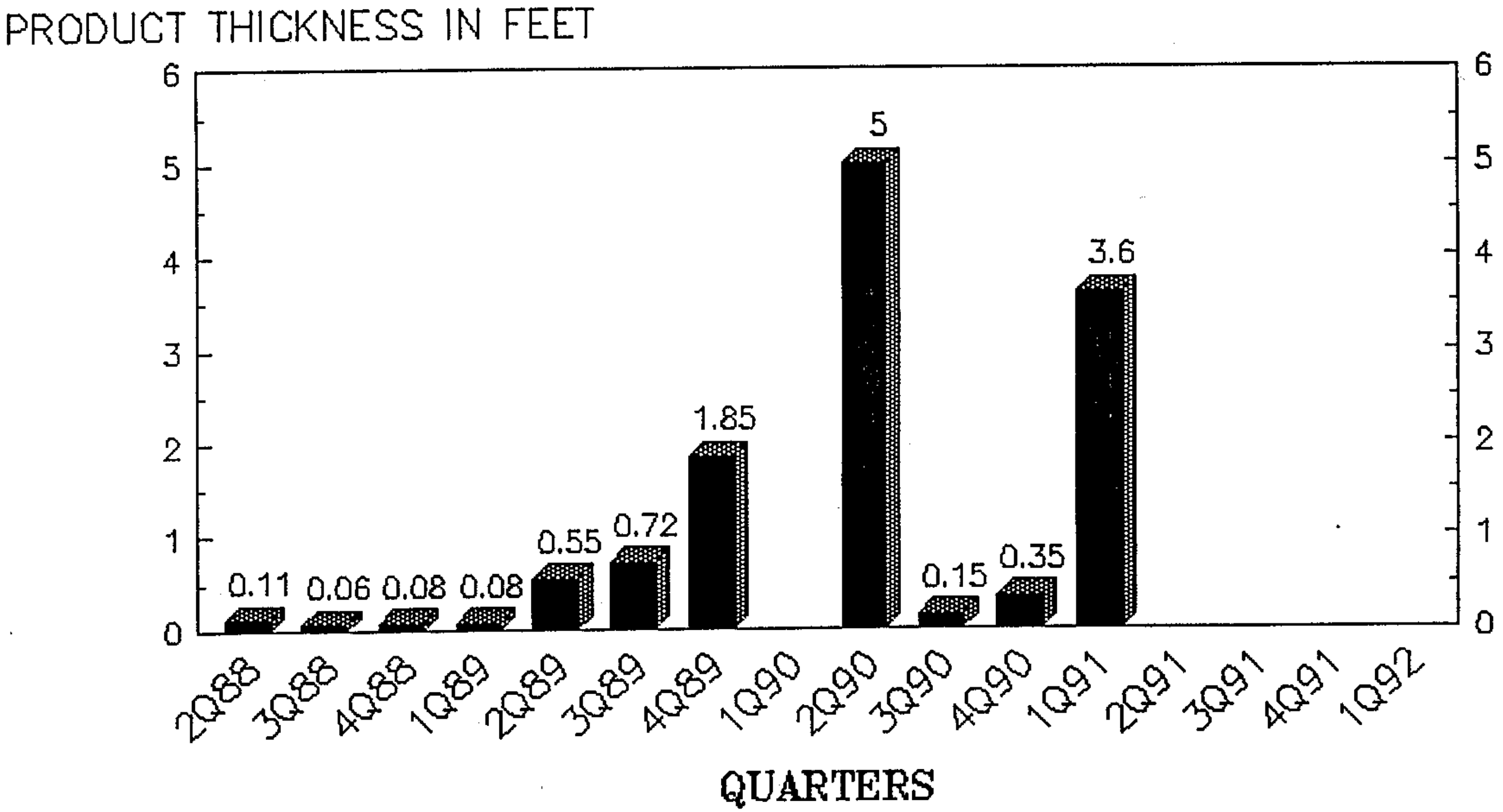
43B WELL (LOCATED @ 680 TK BY #3 BH.)



A THICKNESS MEASUREMENT COULD NOT BE
OBTAINED BECAUSE OF PRODUCT VISCOSITY
FOR 4TH QTR 1989 & 1ST QTR 1990

WELL MONITORING REPORT

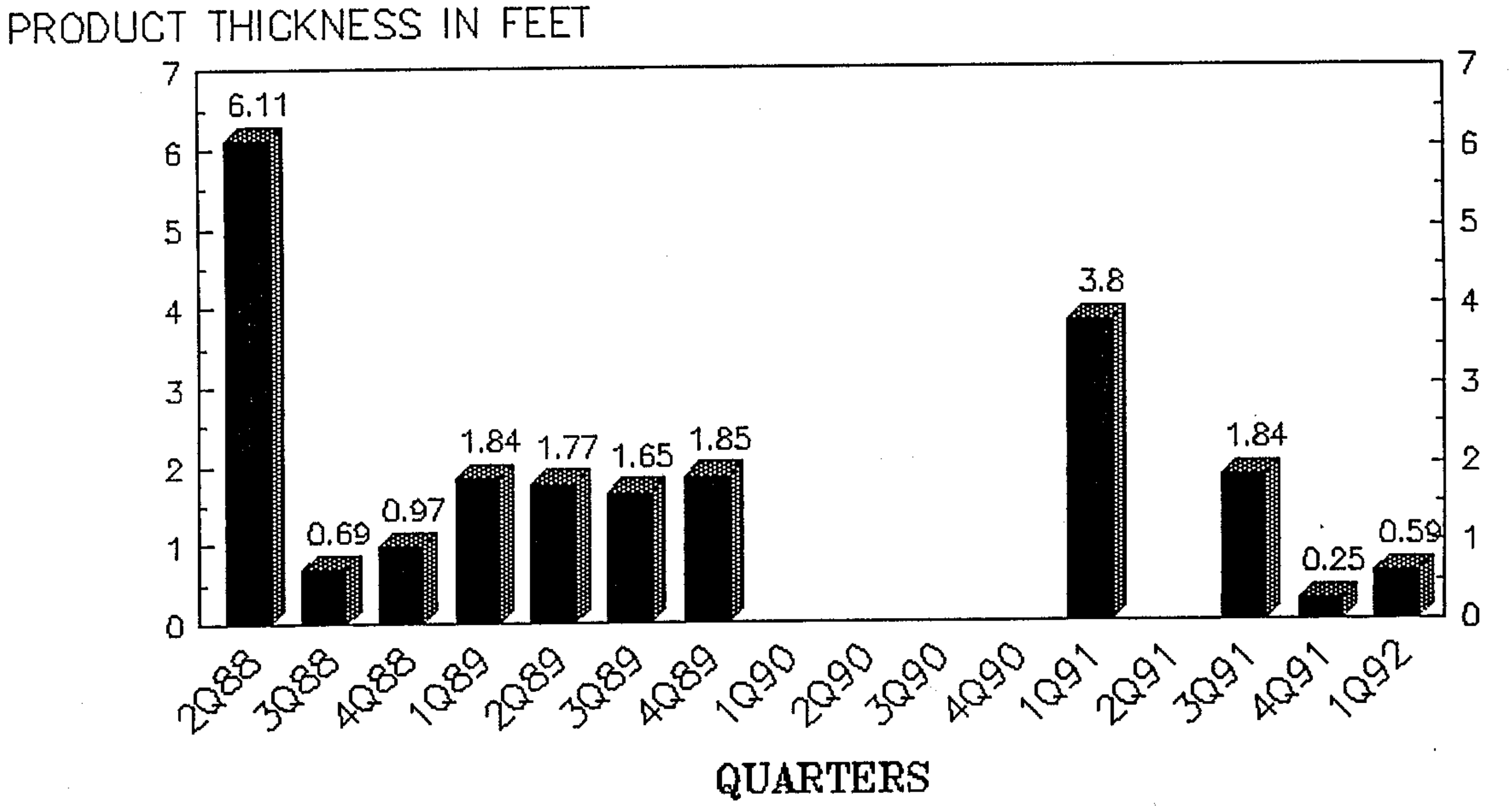
47B WELL (LOCATED @ 1333 UNIT)



A THICKNESS MEASUREMENT COULD NOT BE
OBTAINED BECAUSE OF PRODUCT VISCOSITY
IN THE 1Q90,2,3 4Q91 1Q92

WELL MONITORING REPORT

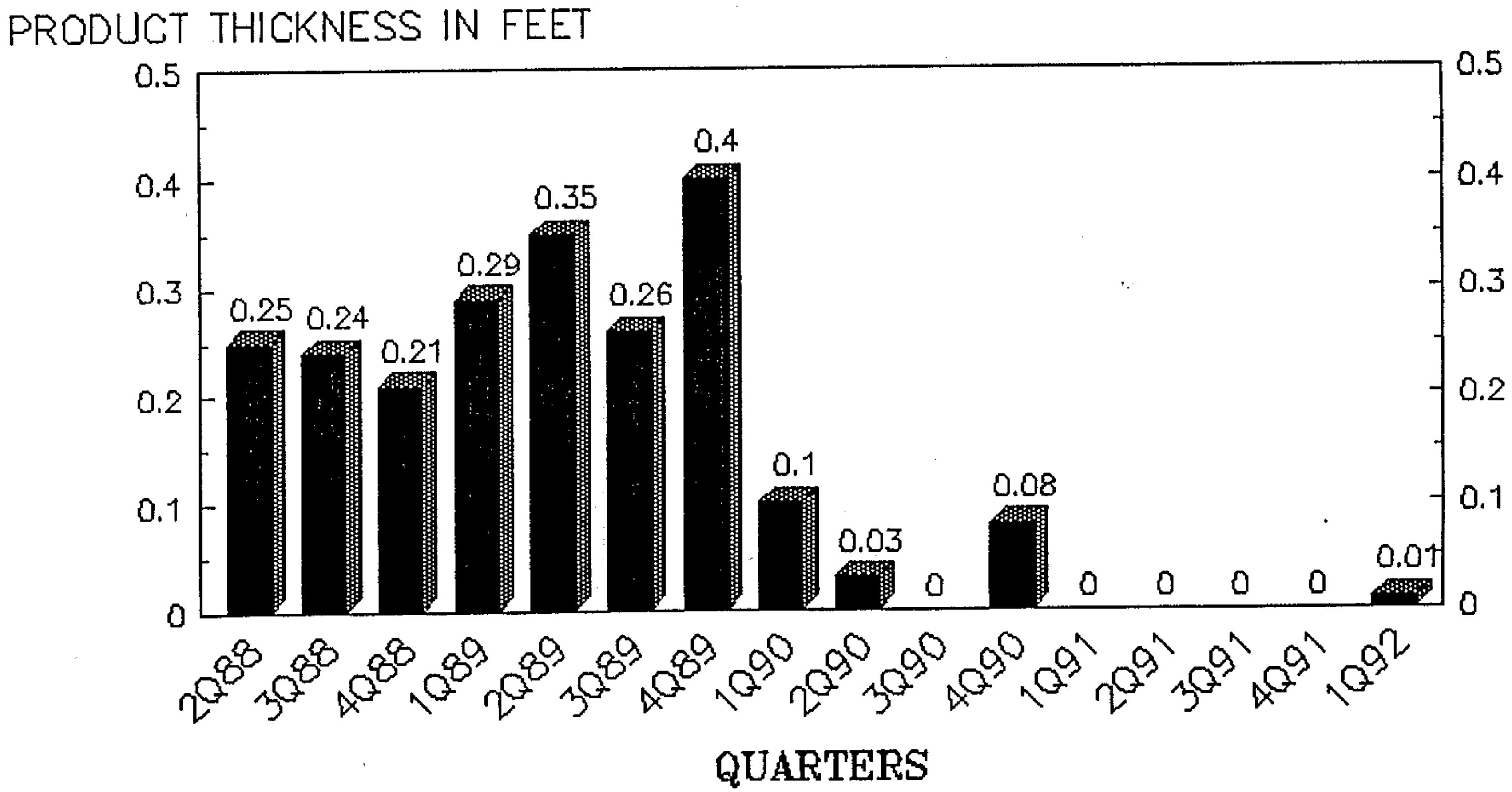
65C WELL (LOCATED @ 137 UNIT PREHEAT BUNDLES)



A THICKNESS MEASUREMENT COULD NOT BE
OBTAINED BECAUSE OF PRODUCT VISCOSITY
DURING 1990 & 2ND QTR 1991

WELL MONITORING REPORT

97C WELL (LOCATED @ #3 SEPERATOR)



DID NOT MONITOR 3RD QTR 90