FINAL
REPORT ON RESULTS OF SOIL GAS SURVEY, TUTU, ST. THOMAS, U. S. VIRGIN ISLANDS

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1.0 EXECUTIVE SUMMARY

During November 1987, Geoscience Consultants, Ltd. (GCL) conducted a soil gas investigation in the vicinity of the Tutu service station of Texaco Caribbean, Inc., in St. Thomas, U. S. Virgin Islands. The survey results show a zone of significantly elevated total hydrocarbon concentrations (up to 690,000 micrograms per liter [ug/l] as benzene) in soil gas beneath the southwestern part of the service station site and beneath adjacent roadways west and south of the station. These values indicate the presence of hydrocarbons within the unsaturated soil zone. Another zone of moderately high soil gas total hydrocarbon values (up to 2,600 ug/l) was found 300 to 800 feet southwest of the station, within a topographic low beneath the southern part of the Four Winds Shopping Center parking lot. Moderately elevated total hydro-carbon values (up to 3,000 ug/l) were also found adjacent to an Esso service station near the southern end of the Four Winds Shopping Center parking lot. Soil gas hydrocarbons in these areas are probably a result of vaporization from hydrocarbons present in ground water.

A topographically high area around Tillett Gardens, an area of small shops, in which a relatively great depth to ground water (about 25 feet) and shallow depth to bedrock (about 5 feet) prevented adequate soil gas analysis, lies between the two mapped zones of elevated hydrocarbon values. Based on the soil gas analysis alone, it is therefore impossible to determine with certainty whether the two zones are parts of a single hydrocarbon plume or constitute two separate plumes. The presence of benzene, toluene and other hydrocarbons in the Tillett water well, which is located between the two zones, indicates that these compounds are present in ground water in at least part of the area where soil gas mapping was not feasible.

GCL also performed analyses for chlorinated compounds in soil gas at selected points in the vicinity of the Tutu service station and Tillett Gardens. Measurable concentrations of tetrachloroethylene (PCE) were found at all points sampled for chlorinated compounds, with the highest concentrations in soil gas near the LAGA building northeast of the Tutu

service station. The LAGA building, where PCE is known to have been used extensively in the past, is a possible source of the chlorinated hydrocarbons.

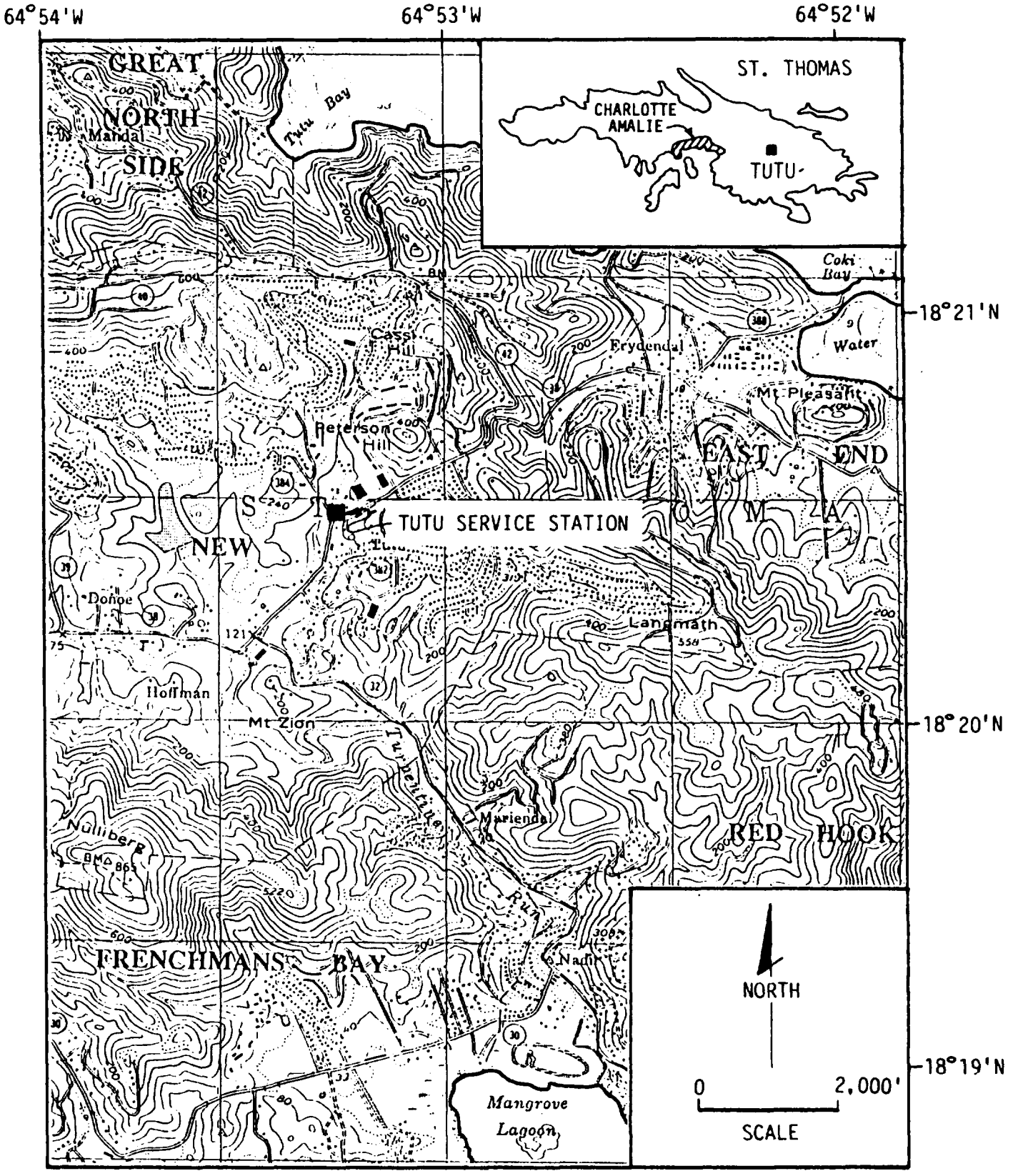
2.0 LOCATION AND HYDROGEOLOGIC BACKGROUND

2.1 LOCATION AND PURPOSE OF STUDY

During November 1987, Geoscience Consultants LTD. (GCL) conducted a soil gas survey in the vicinity of the Tutu service station of Texaco Caribbean, Inc. The purpose of the survey was to determine the range and spatial distribution of hydrocarbons present in the soil gas at the service station site, and to map the approximate extent of any hydrocarbon plume that might be encountered during the survey.

The Tutu service station is located at 18°20'31" North, 64°53'14" West, in Anna's Retreat Estate, St. Thomas, U. S. Virgin Islands (Figure 2-1). The station is on the northeast corner of the intersection of Highway 38 and Highway 384, on the eastern slope of the upper Turpentine Run basin. Nearby facilities include an auto parts store and garage north of the station, a fire station and the LAGA building (formerly a cloth manufacturing plant, now a public schools maintenance facility) uphill to the northeast of the station, and Tillett Gardens, a courtyard of small shops and a restaurant, south of the station (Figure 2-2). The Four Winds Shopping Center lies in a topographically low area along the axis of the upper Turpentine Run basin, west of the Tutu service station and Tillett Gardens.

Elevated concentrations of hydrocarbons, including benzene, toluene, and several chlorinated compounds, have been detected in water wells in the upper Turpentine Run basin (Geraghty and Miller, 1983, p. 73-74). The highest reported concentrations of benzene and toluene have been found in water from the Tillett well, located 250 feet south of the Texaco station and 300 feet northeast of an Esso service station (Figure 2-2). In August 1987, water samples from the Tillett well contained 1300 to 1400 parts per billion (ppb) of benzene and approximately 33 to 56 ppb of toluene (C. Dolan, EPA Region II, written communication). High concentrations of tetrachloroethylene (PCE) and other chlorinated compounds have also been found in the Tillett well.



Base from USGS Eastern St.Thomas 7.5 minute quadrangle.

GCL

FIGURE 2-1

TOPOGRAPHIC MAP SHOWING LOCATION OF TUTU SERVICE STATION, ST.THOMAS.

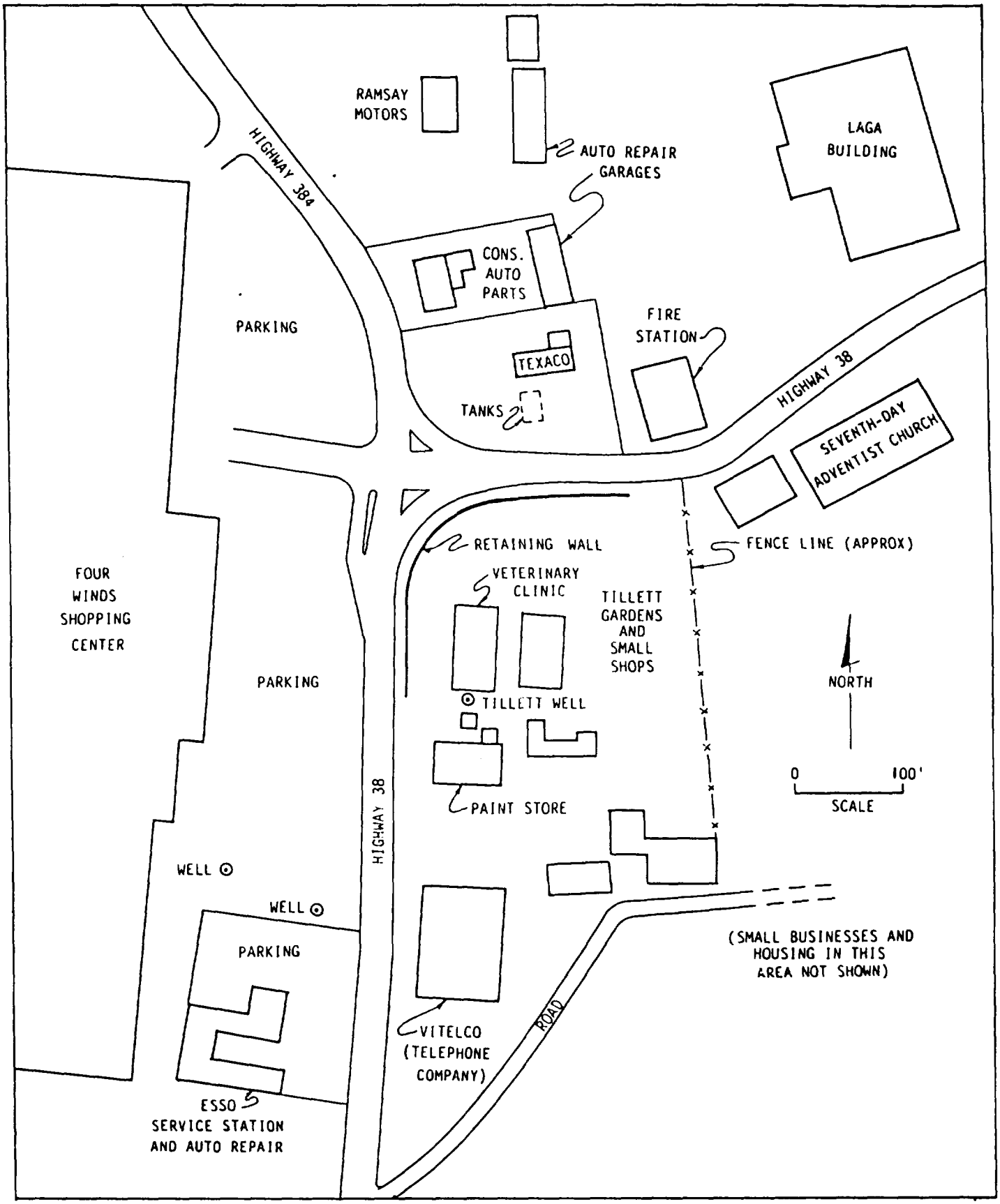


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FIGURE 2-2

MAP OF CENTRAL TUTU AREA, ST. THOMAS,

SHOWING TEXACO TUTU SERVICE STATION AND NEARBY FACILITIES.

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2.2 REGIONAL GEOLOGY

The lithology of the Virgin Islands consists dominantly of volcanic rocks, including spilites (albitized basalts), keratophyres (extrusive igneous rocks containing albite and mafic minerals), andesites, and volcanic breccias and conglomerates derived from the igneous rocks. The Louisenhoj Formation, which comprises the bedrock material throughout the upper Turpentine Run basin, consists dominantly of augite andesite tuff and associated volcanic breccias (Donnelly, 1966). The Louisenhoj Formation is tentatively dated as Albian (late Early Cretaceous) in age (Donnelly, 1966). The Louisenhoj Formation rocks in the vicinity of Tutu have been extensively deformed and fractured by tectonic activity during Late Cretaceous and Tertiary time.

2.3 REGIONAL HYDROLOGY

The upper Turpentine Run basin contains one of the most productive and heavily used aquifers on the island of St. Thomas. Stevens and others (1981) list 26 water wells in the Tutu area, and new wells have been completed since their report was prepared. In 1983, Geraghty and Miller estimated that "current pumpage in the upper basin may approach or exceed the estimated safe yield of 300,000 gpd [gallons per day] calculated by the USGS [U. S. Geological Survey]" (p. 68).

Ground water pumped from the upper Turpentine Run basin is derived primarily from fracture zones in the underlying Louisenhoj bedrock. To assure adequate supply, wells in the basin are commonly drilled to depths of 100 feet or more, although the water table is generally no more than 20 to 30 feet deep in the central part of the basin. Significant drawdowns occur in many wells due to pumping and seasonal water table fluctuations.

Ground water in the upper Turpentine Run basin contains total dissolved solids (TDS) of 700 to 1,800 milligrams per liter (mg/l), consisting dominantly of bicarbonate, sodium and chloride (Geraghty and Miller, 1983, p. 73, 76). Limited data from deep wells suggests that TDS concentration tends to increase with depth in the aquifer (Geraghty and

Miller, 1983). Geraghty and Miller also report nitrate concentrations in excess of 10 mg/l (as nitrogen) from Virgin Islands Housing Authority (VIHA) wells 1 and 2, which are located approximately 800 feet northeast of the Tutu station, and elevated levels of chlorinated hydrocarbons in well VIHA-1.

3.0 METHODS OF STUDY

Work performed by GCL at the Tutu service station site to date has included a preliminary site investigation, a soil gas survey, and limited hydrogeologic studies as judged appropriate for interpretation of the soil gas data. The results of the preliminary site investigation were reported in Section 3.3 of the Work Plan for Soil Gas Survey, Texaco Service Station, Tutu, St. Thomas, U. S. Virgin Islands, and were used in preparation of that work plan. The methods and results of the soil gas survey and associated hydrogeologic studies are described in this report.

3.1 SOIL GAS SURVEY

The soil gas survey at the Tutu site was conducted during November 2-18, 1987. This task consisted of soil gas sampling at points on the service station site and in nearby areas, and on-site analysis of the soil gas for selected hydrocarbons using a gas chromatograph (GC) owned and operated by Tracer Research Corporation (Tracer) of Tucson, Arizona. The gas chromatograph was equipped with detectors capable of identifying total and aromatic hydrocarbons and halogenated compounds, using flame ionization detector (FID) and electron capture detector (ECD) techniques. Soil gas sampling and analysis were performed as described in the Work Plan for Soil Gas Survey and Quality Assurance Project Plan for Soil Gas Survey dated October 1987, as approved by and with amendments requested by the U.S. Environmental Protection Agency Region II (USEPA) and the Virgin Islands Department of Planning and Natural Resources (DPNR) during discussions in the field.

The sampling and analysis were conducted in accordance with standardized procedures which have been used by GCL and Tracer at numerous sites. Soil gas samples were collected by driving a 2-cm diameter hollow galvanized steel probe to the sampling depth and evacuating 5 to 10 liters of soil gas from immediately above the drive point with a vacuum pump. A syringe was inserted through the silicone evacuation line to collect a 10-milliliter gas sample for immediate on-site analysis. Withdrawal of the sample from the evacuation line and its injection and analysis in the GC were performed by an experienced Tracer chemist.

The initial soil gas sampling grid consisted of 20 points located on the service station property, and 3 points located north and east of the station which were selected in order to define background hydrocarbon values. Samples at each point were taken from a depth of 5 feet below the ground surface and from the greatest depth achievable by hand driving of the probe, if greater than 5 feet. Samples were analyzed for total hydrocarbons, excluding methane. Since the methane peak on the chromatogram normally includes the peaks of ethane and propane as well, the resulting "total hydrocarbon" values thus include only concentrations of molecules containing 4 or more carbon atoms, which typically comprise the major constituents of commercial gasoline and similar petroleum products. Additionally, an effort was made to quantify the amounts of benzene, toluene, ethyl benzene and xylene (BTEX) in the soil gas; however, it was found that the OV-101 column employed for the FID work failed in most cases to distinguish the individual BTEX constituents. The OV-101 column has been used by GCL and Tracer in numerous soil gas investigations, and in previous cases has adequately defined all BTEX constituents.

Because a zone of high hydrocarbon values was identified in the southwestern portion of the station site, the sampling grid was extended to the west and south in order to determine the extent of the hydrocarbon plume. Due to the need to avoid water lines, sewer lines, underground electrical lines, and other cultural features, the points of the extended grid were not spaced as regularly as had been anticipated in the work plan. Probes were driven to the greatest depth attainable, which was generally about 5 feet, and a single sample was taken from the maximum depth achieved at each point. The sampling grid was extended southward and westward to the southern part of the Four Winds Shopping Center parking lot (see Section 4.1.2 of this report). Samples were analyzed for total hydrocarbons and BTEX using the OV-101 column.

During the last few days of the hydrocarbon survey, the USEPA representative at the site requested that another column be employed in an attempt to better quantify individual BTEX constituents in the soil gas. Texaco

Caribbean concurred with the request, and discussions were held with chemists from Tracer and from Camp Dresser and McKee Federal Programs Corporation (CDM-FPC) to identify an appropriate column. The Carbopak AT-1000 column, a much slower column than the OV-101, was selected.

During calibration of the system, it became apparent that the full-length AT-1000 column was unsuitable for field use because of its excessive retention time. The AT-1000 column required as much as an hour to analyze one sample, as compared with about 5 minutes for the OV-101. After a few attempts, the column was cut to a length of 1.5 feet (from its original 6-foot length), which shortened the run time to about 15 minutes, and was used to analyze a single sample taken from the vicinity of the underground storage tanks (USTs) at the Tutu service station. The column proved capable of quantifying benzene at this location, but toluene, ethyl benzene and xylene, if present, were still undeterminable due to interference by other peaks on the chromatogram. Due to the excessive run times required to obtain results that were little better than those obtained with the OV-101, no further attempts were made to use the AT-1000 column. The soil gas survey is intended as a preliminary screening tool to define the approximate extent of any hydrocarbons identified in the soil zone. The use of total hydrocarbon values is adequate to perform that task.

Although chlorinated compounds in significant quantities were considered unlikely to have resulted from activities at the Tutu service station, their presence in ground water is a matter of concern. GCL therefore conducted a limited soil gas sampling program which was intended to determine whether these compounds could have come from the Texaco station. Sampling for 6 chlorinated hydrocarbons was performed at 9 points near the Tutu station and upgradient from the Tillett water well, in which some of the compounds have been detected. Analyses were performed using the electron capture detector. The soil gas sample collection procedure was identical to that used in sampling for petroleum components.

3.2 AUXILIARY HYDROGEOLOGIC STUDIES

During the soil gas survey, GCL also conducted limited investigations into the local hydrogeologic setting in order to better define potential flow paths of hydrocarbons in the subsurface. GCL hydrogeologists measured static water level in wells close to the Tutu site, determined major fracture orientations in nearby exposures of bedrock, and recorded other topographic and geologic data relevant to potential migration pathways.

4.0 RESULTS OF SOIL GAS SURVEY

4.1 PETROLEUM HYDROCARBONS

The results of FID analyses for petroleum hydrocarbons for each soil gas point analyzed are presented in Table 4-1. Copies of all results, as recorded and supplied by the on-site chemist, are included in Appendix A of this report. Copies of chromatograms annotated by the on-site chemist will be made available, as required, in a supplement to this report.

Background concentrations were established based on analyses at three points (Background 1, Background 2, and the Drift Point) located north and northeast of the station. These points were in areas considered unlikely to be affected by any hydrocarbons which might have resulted from activities at the station. Total hydrocarbon concentrations in these locations ranged from <0.01 ug/l to 0.9 ug/l. At the Drift Point, repeat samples were taken daily by inserting separate soil gas probes within an area of less than 100 square feet, to determine whether soil gas values varied significantly over time. Daily samples taken at the Drift Point varied between 0.1 and 0.9 ug/l, with the highest value recorded at a depth of 4 feet, which was achieved on only one day. For drift samples taken at depths of 2 to 2.5 feet, total hydrocarbon concentrations varied from 0.1 to 0.4 ug/l, indicating temporal variation by up to a factor of 4 in soil gas hydrocarbon values.

The soil gas survey identified three zones in which concentrations of total hydrocarbons (excluding methane) were significantly in excess of background concentrations. These were:

- the southwestern portion of the Tutu station site and the adjacent roadways
- the southern part of the Four Winds Shopping Center parking lot
- adjacent to the Esso service station at the southern end of the Four Winds parking lot

It was not possible to verify with certainty whether these three zones in fact represent portions of the same hydrocarbon plume, or whether they

TABLE 4-1

CONCENTRATIONS OF PETROLEUM HYDROCARBONS IN SOIL GAS, TUTU AREA

(All concentration values in micrograms per liter)

LOCATION	DEPTH	DATE	BENZENE	TOLUENE	ETHYL BENZENE	XYLENES	TOTAL HYDROCARBONS (WITHOUT CH4)
Background 1	5	11/06/87	<0.01	<0.01	<0.02	<0.01	0.2
Background 2	4	11/06/87	<0.01	<0.01	<0.02	<0.01	<0.01
A-1	5	11/04/87	<230	<260	<280	<260	38,000
A-2	4.5	11/04/87	I	I	<280	<260	110,000
A-2	8.5	11/04/87	I	I	<280	<260	690,000
A-2A	4.5	11/05/87	<0.01	<0.01	<0.01	<0.01	<0.01
A-2A	7	11/05/87	I	<13	<14	<13	7,600
A-3	5	11/05/87	I	<13	<14	<13	4,600
A-3.5	5	11/05/87	I	<13	<14	<13	3,600
A-4	4.5	11/05/87	<0.01	<0.01	<0.01	<0.01	<0.01
A-4	5.5	11/05/87	I	<0.3	<0.3	<0.3	68
B-1	5	11/04/87	I	<510	<570	<530	610,000
B-2	5	11/04/87	I	I	<280	<260	280,000
B-2	8.5	11/04/87	I	I	<280	<260	220,000
B-3	5	11/04/87	I	I	<280	<260	35,000
B-3	8	11/04/87	I	I	4,000	<110	120,000
B-3.5	5	11/04/87	I	<26	<28	<27	6,400
B-4	5	11/04/87	<0.02	<0.02	<0.03	<0.03	<0.02
B-4-C	5	11/05/87	<0.01	<0.01	<0.01	<0.01	0.1
B-4-C	5	11/06/87	<0.01	<0.01	<0.02	<0.01	<0.01
B-4-C	7	11/06/87	<0.01	<0.01	<0.02	<0.01	0.5
C-1	5	11/05/87	I	<130	<130	<130	130,000
C-2	5	11/05/87	I	<130	<140	<130	72,000
C-3	5	11/05/87	I	<0.5	<0.6	<0.5	1,000
C-4	4	11/04/87	<0.09	<0.1	<0.1	<0.1	<0.09
C-4	7	11/04/87	<0.9	<1	<1	<1	1,700
D-1	4.5	11/05/87	<0.01	<0.01	<0.01	<0.01	8
D-2	2.5	11/05/87	I	<0.5	<0.6	<0.5	1,000
D-3	5	11/05/87	<0.01	<0.01	<0.01	<0.01	<0.01
D-4	4	11/04/87	<0.09	0.5	<0.1	<0.1	4
F-1	4.5	11/10/87	<0.02	<0.02	<0.03	<0.02	0.06
F-1	6	11/10/87	<0.02	<0.02	<0.03	<0.02	<0.02
F-2	4.5	11/10/87	<0.02	<0.02	<0.03	<0.02	0.07
F-3	6.5	11/10/87	<0.02	<0.02	<0.03	<0.02	0.4
F-4	6.5	11/10/87	<0.02	<0.02	<0.03	<0.02	0.2

I = interference with adjacent peaks

TEXC\TABLE4-1.PRN

TABLE 4-1 (Continued)

LOCATION	DEPTH	DATE	BENZENE	TOLUENE	ETHYL BENZENE	XYLENES	TOTAL HYDROCARBONS (WITHOUT CH4)
F-4	9.5	11/10/87	<0.02	<0.02	<0.03	<0.02	0.3
F-5	5.5	11/10/87	<0.02	<0.02	<0.03	<0.02	0.2
F-6	6	11/10/87	<0.02	<0.02	<0.03	<0.02	0.4
F-7	3.5	11/11/87	<0.02	<0.03	<0.03	<0.03	10
F-8	6	11/11/87	<0.02	<0.03	<0.03	<0.03	2
F-9	2	11/12/87	<0.02	<0.02	<0.03	<0.02	6
F-10	5.5	11/12/87	I	<6	<7	<6	2,600
F-11	4	11/12/87	I	<0.5	<0.5	<0.5	120
F-12	3.5	11/12/87	0.4	<0.1	<0.1	<0.1	40
F-13	5.5	11/12/87	0.02	<0.02	<0.03	<0.02	7
F-14	2	11/12/87	I	<12	<14	<13	3,000
F-15	2.5	11/13/87	<0.02	<0.02	<0.03	<0.03	43
F-16	6	11/13/87	<0.02	<0.02	<0.03	<0.03	11
F-17	5	11/14/87	<0.02	<0.03	<0.03	<0.03	33
F-18	3.5	11/14/87	<0.02	0.07	<0.03	<0.03	0.2
F-19	5	11/14/87	I	<5	<6	<6	1,800
F-20	6	11/14/87	<0.02	<0.03	<0.03	<0.03	26
F-21	6	11/14/87	<0.02	<0.03	<0.03	<0.03	1
F-22	6	11/14/87	<0.02	<0.03	<0.03	<0.03	0.2
T-1	5	11/09/87	<0.01	<0.01	<0.01	<0.01	<0.01
T-1	7	11/09/87	<0.02	<0.02	<0.02	<0.02	<0.02
T-2	5	11/09/87	<0.02	<0.02	<0.02	<0.02	<0.02
T-2	7	11/09/87	<0.02	<0.02	<0.02	<0.02	<0.02
T-3	4	11/09/87	<0.2	<0.2	<0.3	<0.3	230
T-5	4	11/06/87	<0.01	<0.01	<0.02	<0.01	0.6
T-6	2.5	11/09/87	<0.02	<0.02	<0.02	<0.02	<0.02
T-7	5	11/09/87	<0.02	<0.02	<0.02	<0.02	<0.02
T-7	5.5	11/09/87	<0.02	<0.02	<0.02	<0.02	10
T-8	2	11/09/87	<0.02	<0.02	<0.02	<0.02	0.9
T-10	3	11/09/87	<0.02	<0.02	<0.02	<0.02	10
T-11	5	11/09/87	<0.02	<0.02	<0.02	<0.02	3
T-12	3.5	11/09/87	<0.02	<0.02	<0.02	<0.02	0.4
T-13	4.5	11/09/87	<0.02	<0.02	<0.02	<0.02	5
T-14	5.5	11/12/87	<0.02	<0.02	<0.03	<0.02	2
T-15	3.5	11/12/87	<0.02	<0.02	<0.03	<0.02	0.02

I = interference with adjacent peaks

TEXC\TABLE4-1.WK1

TABLE 4-1 (Concluded)

LOCATION	DEPTH	DATE	BENZENE	TOLUENE	ETHYL BENZENE	XYLENES	TOTAL HYDROCARBONS (WITHOUT CH4)
T-16	5.5	11/13/87	<0.02	<0.02	<0.03	<0.03	0.4
T-17	6	11/13/87	<0.02	<0.02	<0.03	<0.03	0.2
T-17	6	11/14/87	<0.02	<0.03	<0.03	<0.03	<0.02
T-18	5.5	11/13/87	<0.02	<0.02	<0.03	<0.03	0.4
T-19	6	11/13/87	<0.02	<0.02	<0.03	<0.03	0.2
T-19	10	11/13/87	<0.02	<0.02	<0.03	<0.03	2
T-20	4.5	11/14/87	<0.02	<0.03	<0.03	<0.03	0.2
Z-1	5	11/11/87	I	<7	<7	<7	4,000
Z-2	3.5	11/11/87	I	<52	<58	<54	28,000
Z-4	6	11/11/87	I	<26	<29	<26	12,000
Z-5	5	11/11/87	I	<5	<6	<5	860
Drift 1	4	11/04/87	<0.02	<0.02	<0.03	<0.03	0.9
Drift 2	2.5	11/05/87	<0.01	<0.01	<0.01	<0.01	0.1
Drift 3	2	11/06/87	<0.01	<0.01	<0.02	<0.01	0.2
Drift 4	2	11/09/87	<0.01	<0.01	<0.01	<0.01	0.2
Drift 5	2.5	11/11/87	<0.02	<0.03	<0.03	<0.03	0.4
Drift 6	2	11/12/87	<0.02	<0.02	<0.03	<0.02	0.4
Drift 6	2	11/13/87	<0.02	<0.02	<0.03	<0.03	0.2
Drift 7	2	11/14/87	<0.02	<0.03	<0.03	<0.03	0.4

I = interference with adjacent peaks

TEXC\TABLE4-1.WK1

are entirely separate, because lithologic and hydrologic conditions in the intervening area prevented adequate soil gas analysis (see Section 4.1.2).

4.1.1 Service Station Site

Soil gas hydrocarbon values measured on and immediately adjacent to the Tutu service station site are shown in Figure 4-1. In cases where a hole was sampled at two different depths, both concentration values are shown, but the value from the greater depth was used in mapping the concentration contours. In all holes except B-2, the deeper point yielded the higher value; in B-2 the values determined at 5 feet and 8.5 feet were similar.

A zone of hydrocarbon concentrations significantly higher than background levels is centered southwest of the underground storage tanks and extends southward and westward beneath the highways adjacent to the station property (Figure 4-2; Zone I, Figure 4-3). Elevated hydrocarbon concentrations were found consistently at depths of about 5 feet and at depths of about 8 feet (maximum depth of probe penetration) in the central part of this area; however, at some points along the station boundaries (A-4, A-2A, C-4) hydrocarbon concentrations appear to increase significantly with depth between 4 feet and 8 feet.

There was no evidence of significant hydrocarbon presence along the northern and eastern boundaries of the station site. The value of 1,700 ug/l recorded in hole C-4 near the north boundary of the station is probably a result of hydrocarbon vapors migrating from the adjacent oil separator pit. Movement of hydrocarbons east of the station area would be inhibited by the steep southwestward topographic and water table gradients.

4.1.2 Other Areas With Hydrocarbon Concentration Above Background Levels

An attempt was made to trace the zone of elevated hydrocarbon concentrations to the south across Highway 38 from the Tutu station. However, no

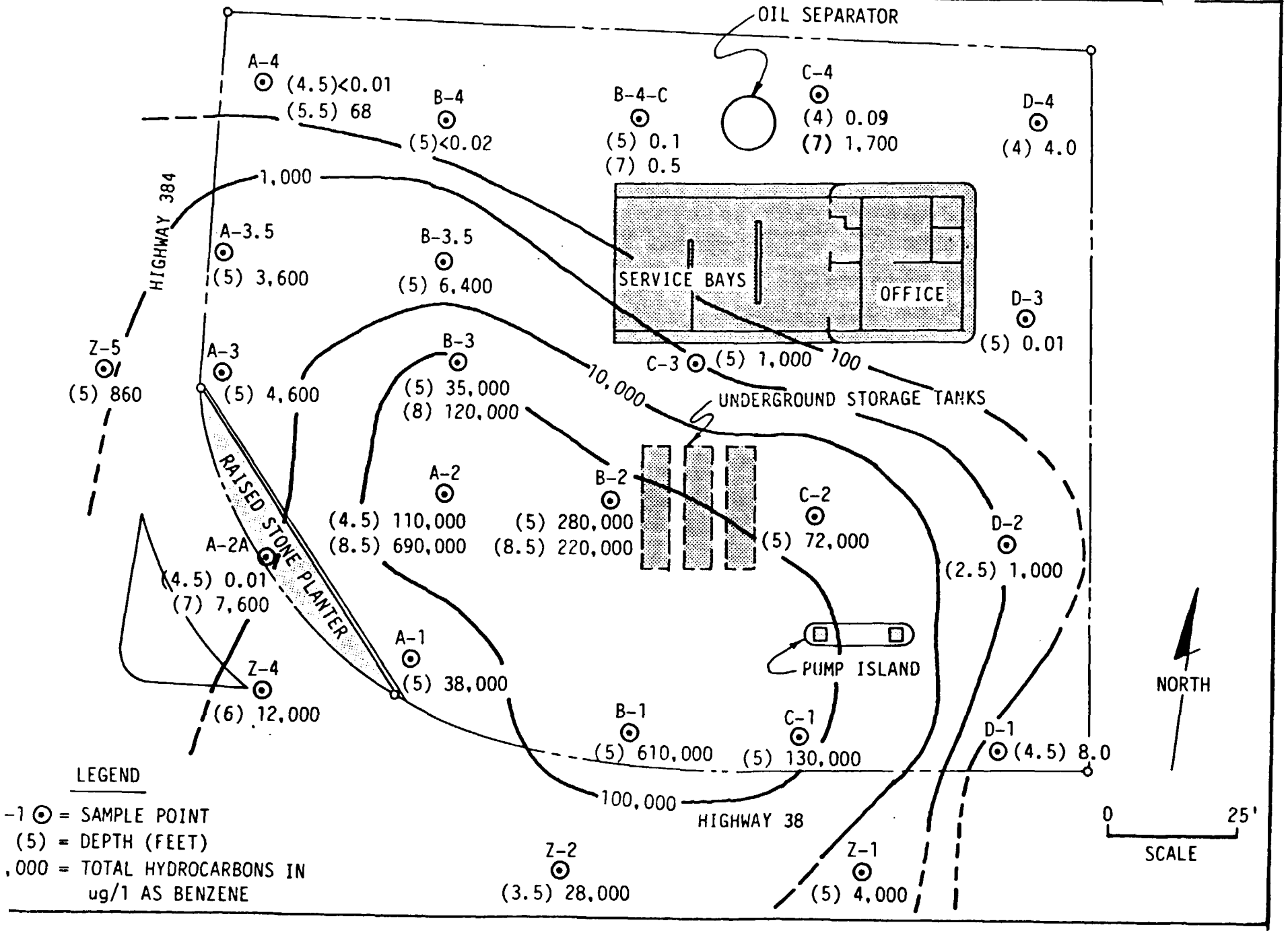


FIGURE 4-1
CONCENTRATIONS OF TOTAL PETROLEUM HYDROCARBONS IN SOIL GAS ON TUTU SERVICE STATION SITE

GCL

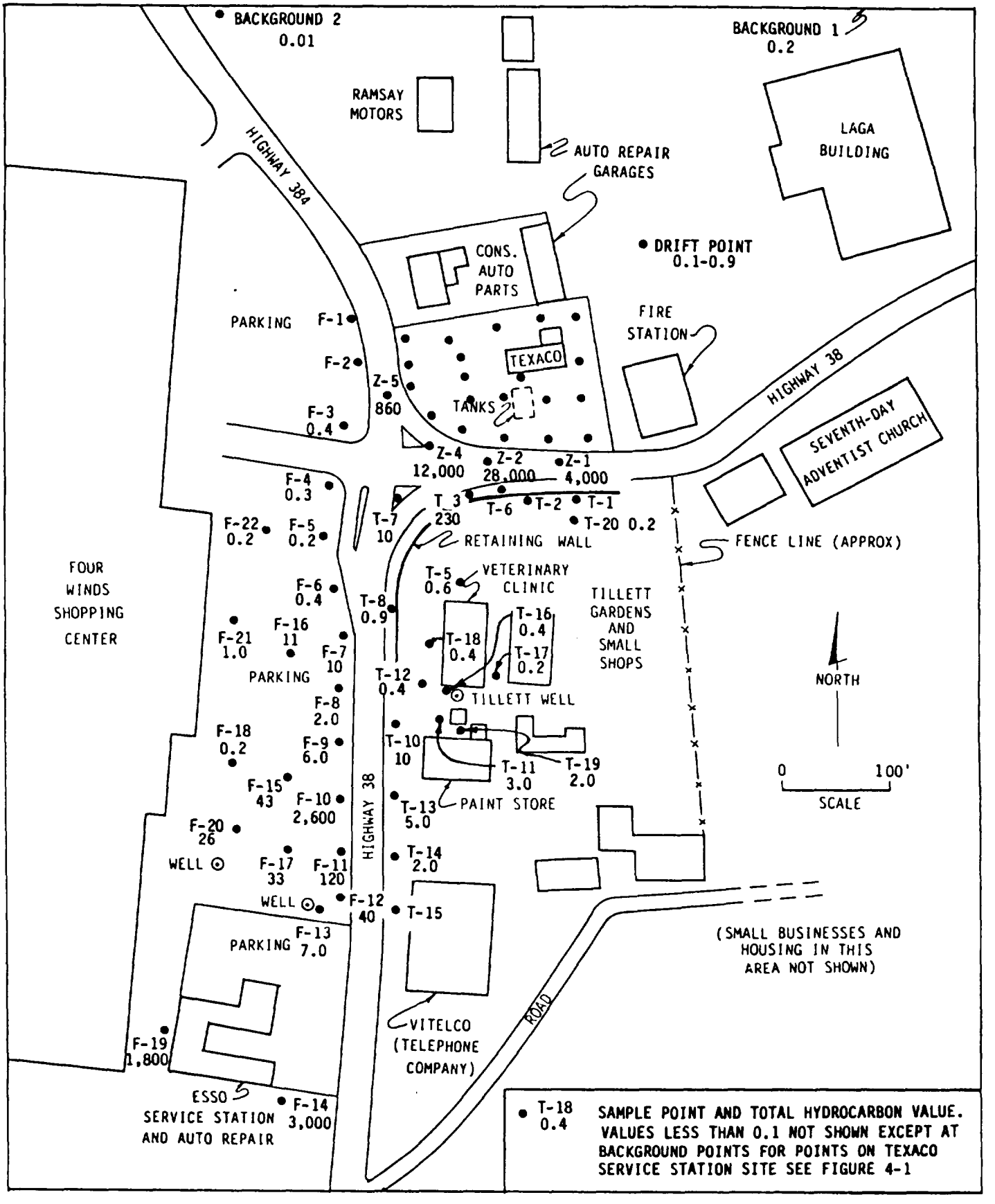
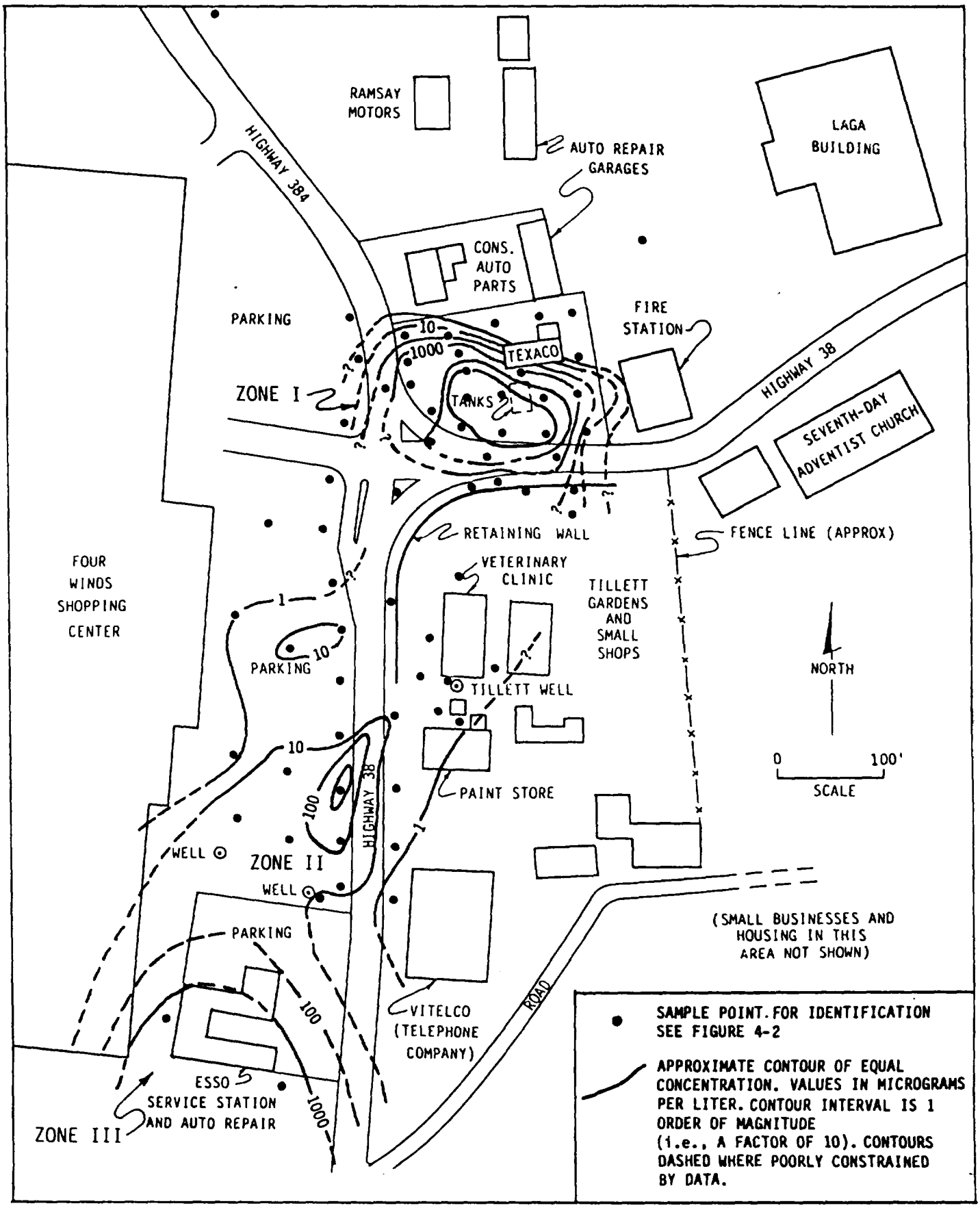


FIGURE 4-2

CONCENTRATIONS OF TOTAL PETROLEUM HYDROCARBONS IN SOIL GAS IN THE TUTU AREA, UPPER TURPENTINE RUN BASIN. ALL CONCENTRATIONS IN MICROGRAMS PER LITER, REPORTED AS BENZENE.



GCL

FIGURE 4-3
CONTOURS OF TOTAL PETROLEUM HYDROCARBON CONCENTRATIONS
IN SOIL GAS, TUTU AREA, UPPER TURPENTINE RUN BAS TUT 003 1034

values of hydrocarbons in excess of background levels were detected in the area between the Tillett well and the north boundary of the Tillett property at Highway 38, except at points under the sidewalk and under a traffic island (points T-3 and T-7, Figure 4-2). Topographically, the northern part of the Tillett property, southeast of the retaining wall shown in Figure 2-2, is 10 to 15 feet higher than the land surface at the service station, and it was not possible to achieve depths greater than about 5 feet in placing the soil gas probes because of the presence of bedrock at that depth. Ground water is at a depth of about 25 to 30 feet beneath the Tillett property, and thus is 20 feet or more below the greatest depth of probe penetration. Therefore, the possible presence of petroleum hydrocarbons at depths too great to be sampled beneath the Tillett property could not be determined.

South of the Tillett well, detectable concentrations of hydrocarbons were found in the southern part of the Four Winds Shopping Center parking lot, near the Esso station and locally along the east side of Highway 38 (Zones II and III, Figure 4-3). Although most of the constituents identified appear to be petroleum components, there was some admixture of other compounds (up to about 5 ug/l as benzene in some holes) which appear to have a different origin. Since significant concentrations of halogenated compounds were found in holes near this area, it is possible that the unidentified constituents identified by the FID represent some of the halogenated compounds.

It was possible to identify and map Zones II and III southwestward to and beyond the Esso service station at the south end of the Four Winds parking lot, even though bedrock in much of the area prevented probe penetration to depths greater than about 5 feet (Figure 4-3). South and west of the Esso station, increased soil gas hydrocarbon concentrations were found, relative to those which were found immediately north of the station. The soil gas survey was terminated at this location, because of

the presence of increased hydrocarbon concentrations probably attributable to a different source. Tracing of any soil gas plume not potentially attributable to the Texaco station was outside the scope of the work plan.

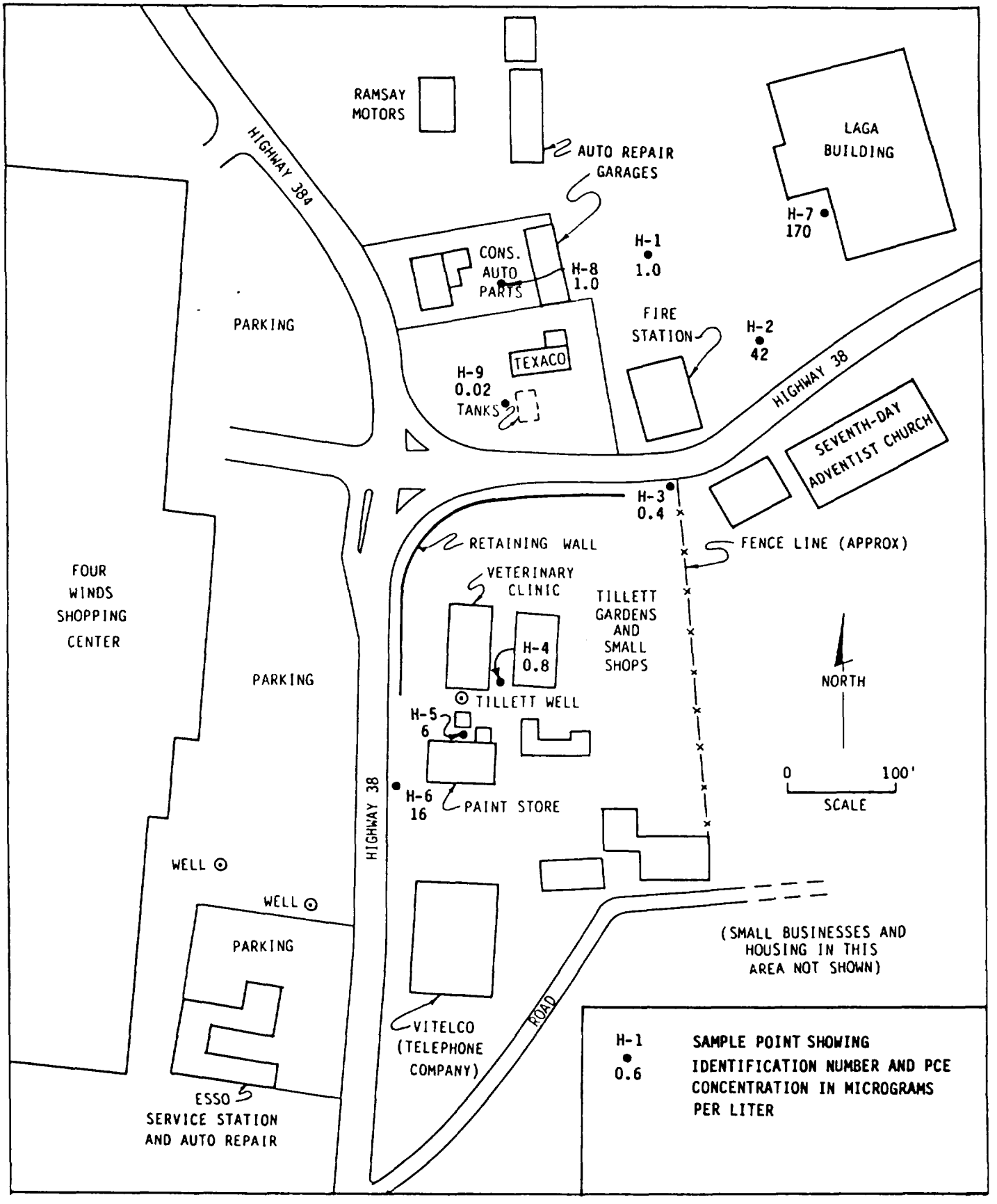
4.2 CHLORINATED HYDROCARBONS

Because chlorinated hydrocarbons have been identified in water samples from the Tillett well and other wells in the Tutu area, a limited number of soil gas points were sampled and analyzed for chlorinated compounds. These points were located in the vicinity of the Tillett well, on and adjacent to the Texaco service station, and near the LAGA building (Figure 4-4). Samples were analyzed for:

- methylene chloride (dichloromethane)
- chloroform (trichloromethane)
- trichloroethane (TCA)
- carbon tetrachloride (tetrachloromethane)
- trichloroethylene (TCE)
- tetrachloroethylene (PCE)

Results of the chlorinated hydrocarbon analyses are listed in Table 4-2. No significant concentration of any chlorinated compound was identified in hole H-9, located on the Texaco station, in the center of the known petroleum hydrocarbon plume. Methylene chloride (6 ug/l) was identified in soil gas beneath the property north of the Texaco service station, and TCA was identified at several locations, with the largest value (10 ug/l) being recorded in hole H-6, south of the Tillett well.

PCE was detected in all nine of the holes sampled for chlorinated compounds. The lowest PCE concentration (0.02 ug/l) was found at the Texaco station; the highest (170 ug/l) was found adjacent to the loading dock at the LAGA building. PCE was also identified at points near the Tillett well, although benzene and toluene, known to exist in the well water, had



GCL

FIGURE 4-4

CONCENTRATIONS OF PCE IN SOIL GAS IN THE TUTU AREA, UPPER TURPENTINE RUN BASIN

TABLE 4-2

CONCENTRATIONS OF CHLORINATED HYDROCARBONS IN SOIL GAS, TUTU AREA

(All concentration values in micrograms per liter)

SAMPLE	DEPTH	DATE	METHYLENE CHLORIDE	CHLOROFORM	TCA	CARBON TETRACHLORIDE	TCE	PCE
H-1	3	11/17/87	<0.9	<0.006	0.02	<0.0005	<0.004	1
H-2	3.5	11/17/87	<0.9	<0.006	0.05	<0.0005	0.5	42
H-3	4	11/17/87	<0.09	<0.0006	<0.0002	<0.00005	<0.0004	0.4
H-4	3.5	11/17/87	<0.09	<0.0006	0.005	<0.00005	<0.0004	0.8
H-5	4	11/17/87	<0.2	<0.001	<0.0004	<0.0001	0.05	6
H-6	4.5	11/17/87	<30	<0.2	10	<0.02	<0.1	16
H-7	5	11/17/87	<0.9	<0.006	0.04	<0.0005	0.6	170
H-8	5	11/17/87	6	<0.006	<0.002	<0.0005	0.3	1
H-9	5.5	11/17/87	<0.09	<0.0006	<0.0002	<0.00005	<0.0004	0.02

TEXC\TABLE4-2.PRN

not been detectable at the same points. The greater volatility of the chlorinated compounds relative to the petroleum components explains the comparative ease with which they can be traced in soil gas, assuming both are present in ground water.

No attempt was made to delineate the boundaries of any chlorinated hydrocarbon plume, which is likely to be areally extensive. PCE has been found in water from a Virgin Islands Housing Authority well approximately 600 feet northeast of the LAGA building, as well as in the Tillett well and one of the Four Winds water wells (Geraghty and Miller, 1983, p. 74; C. Dolan, EPA Region II, written communication). A possible source of the PCE is the LAGA building, presently used as a public schools office and service facility. The LAGA building formerly housed a cloth factory, closed about 1981, in which tetrachloroethylene (also known as perchloroethylene, or "perk") is reported to have been used extensively. Unsubstantiated verbal reports of local residents indicate that the "perk" may have been disposed of to the ground surface near the building.

5.0 PROBABLE MIGRATION PATHWAYS

5.1 GROUND-WATER DATA

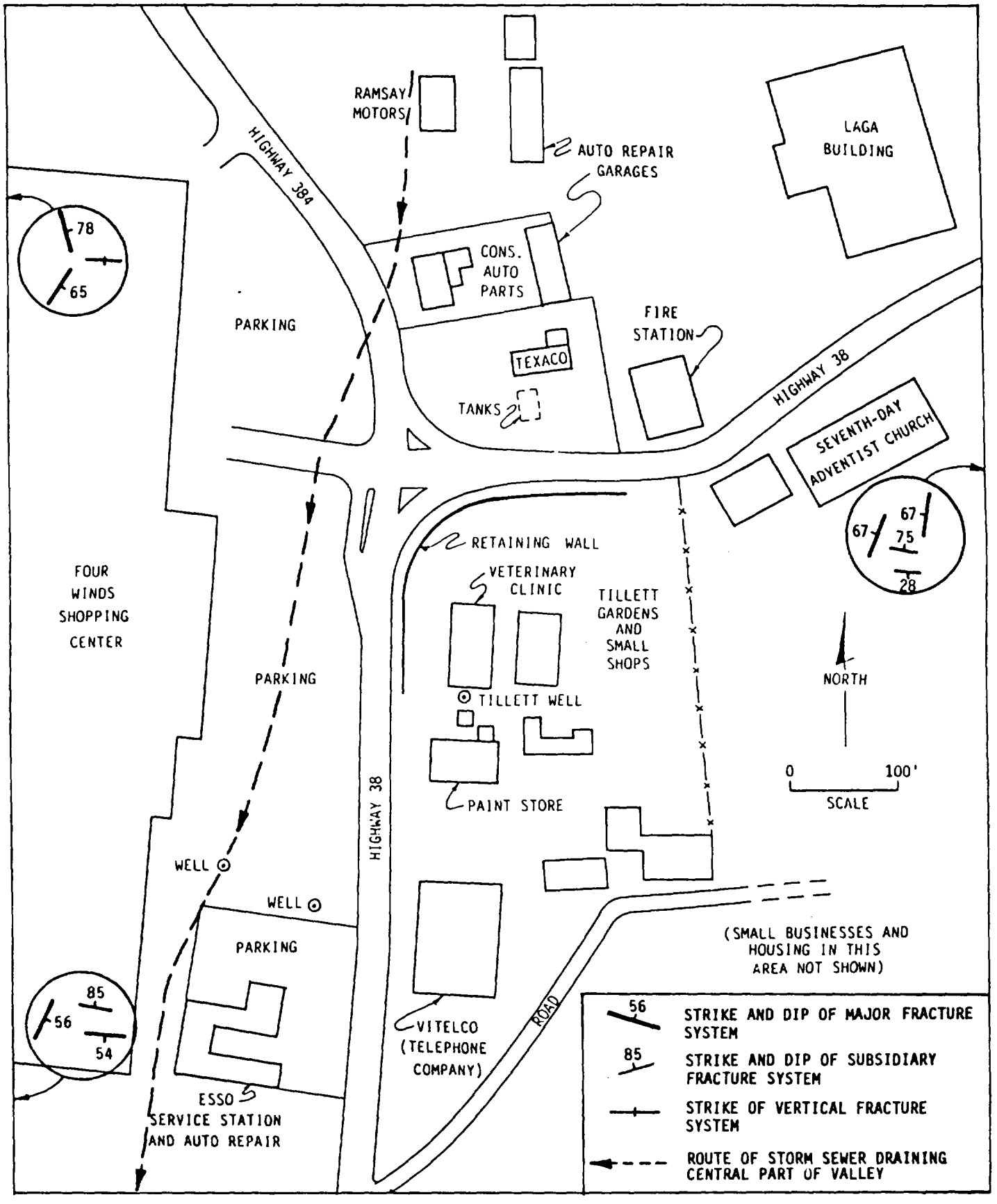
The water table in the upper Turpentine Run basin is generally within 30 feet or less of the ground surface, and is influenced by the local topography.

During November 1987 the static water levels were measured by GCL in the Tillett well and the eastern Four Winds well. The western Four Winds well was not measurable because it lacked an adequate port for insertion of the water level probe. Water levels were 23.2 feet below top of casing in the Tillett well, and 14.0 feet in the eastern Four Winds well. Taking into account the difference in well head elevations (approximately 28 feet), this indicates a difference of about 19 feet in water-table elevations at the two wells, and a water-table gradient of about 0.076, if the Four Winds well is assumed to be directly downgradient from the Tillett well. The gradient along the valley axis may be less than this figure, whereas that on the eastern slope may be greater. It is not known whether the Tillett and Four Winds wells intersect the same fracture zone, or zones which are hydraulically connected.

5.2 BEDROCK FRACTURE SYSTEMS

Most ground water in the upper Turpentine Run basin is contained within fracture systems of the Louisenhoj bedrock. Only minimal flow is expected in the matrix of this fine-grained volcanic unit. Observations of the soil profile, where it is exposed in road cuts and construction excavations, indicated that the zone of significant weathering extends to only about 6 feet below the surface in most areas, with fractured bedrock below that level. These observations were confirmed by the difficulty encountered in driving soil gas probes deeper than about 5 or 6 feet in most of the study area. Consequently, the direction of local ground-water flow will be strongly influenced by the orientation of the bedrock fracture systems through which the water is moving.

Bedrock fracture orientations are not consistent throughout the upper Turpentine Run basin. Orientations measured on outcrops exposed west of the Four Winds Shopping center (west side of valley) and east of the Seventh-Day Adventist Church and School (east side of valley) are shown schematically in Figure 5-1. There are major fracture systems striking north-northeast on both sides of the valley; however, those on the west side of the valley dip to the southeast, while these on the east side dip to the northwest. Consequently, these two systems differ by about 60° in actual fracture orientation. It is not known whether there is an abrupt transition along a defined boundary between these two systems at some point within the valley, or whether the orientation of the fractures rotates gradually from one position to the other as one moves across the valley.



GCL

FIGURE 5-1
ORIENTATIONS OF MAJOR FRACTURE SYSTEMS
IN THE TUTU AREA, UPPER TURPENTINE RUN BASIN

6.0 CONCLUSIONS

The soil gas survey conducted by Texaco Caribbean, Inc., and GCL in the Tutu area of St. Thomas identified a zone of elevated petroleum hydrocarbon values in the subsurface on the southwestern part of the Texaco Tutu service station site (Zone I). The very high soil gas hydrocarbon values in this area (up to 690,000 ug/l) indicate the probability that hydrocarbons have migrated through the unsaturated soil zone, leaving large residual concentrations. The source of the hydrocarbons appears to be the USTs at the Texaco station.

Elevated hydrocarbon values were traced southward to the south side of Highway 38 and westward to the center of Highway 384. Points located on the west side of Highway 384 indicate no significant hydrocarbon presence in that area. Due to elevated bedrock and greater depth to water (25 to 30 feet), it was not possible to determine the extent of petroleum hydrocarbon presence in the vicinity of the Tillett well, in which the presence of benzene and toluene has been reported in ground water. The same constraints limited complete mapping of the hydrocarbon plume on the south side of Highway 38 across from the Texaco service station.

Moderately elevated concentrations of hydrocarbons were found in soil gas beneath the southern part of the Four Winds Shopping Center parking lot (Zone II) and adjacent to the Esso station (Zone III), 300 to 800 feet downgradient from the Texaco station. The hydrocarbons encountered in soil gas in this zone are probably derived by volatilization from a plume of hydrocarbons moving with the ground water in the upper Turpentine Run aquifer. However, based on the soil gas data, it was not possible to determine with certainty whether Zones I, II and III are discontinuous or whether they in fact represent parts of a single plume. It is not possible to delineate such a plume by soil gas methods beneath the bedrock high which underlies the Tillett property. Other direct methods of sampling ground water and vadoze zone will be required to define the relationship between the two areas of elevated soil gas concentrations.

Elevated levels of PCE were found in much of the study area, and other chlorinated hydrocarbons were found in some locations. The source of these compounds appears to be northeast of the Texaco service station, and is possibly the LAGA building, where PCE is known to have been used extensively in the past.

7.0 REFERENCES CITED

Donnelly, T. W., 1966, Geology of St. Thomas and St. John, U. S. Virgin Islands, in Hess, H. H., ed., Caribbean Geological Investigations: Geological Society of American Memoir 98, p. 85 - 176.

Geraghty and Miller, Inc., 1983, Report on Current Groundwater Conditions in the U. S. Virgin Islands, unpublished report prepared for the Government of the U. S. Virgin Islands, 80 p.

Stevens, K. E., Gómez, F., and Alicea, J., 1981, Water Wells in the U. S. Virgin Islands: Part One, St. Thomas: U. S. Geological Survey Open-File Report 82-82.

APPENDIX A

TRACER RESEARCH CORPORATION REPORT OF ANALYTICAL RESULTS

GEOSCIENCE CONSULTANTS/TEXACO/TUTU, VIRGIN ISLANDS

Tracer Research Corporation

Sample	Depth	Date	Benzene (ug/l)	Toluene (ug/l)	Ethyl Benzene (ug/l)	Xylenes (ug/l)	Total Hydroc.w/o CH4 (ug/l)
S6-A1	5'	11/04	<230	<260	<280	<260	38,000
S6-A2	4.5'	11/04	I	I	<280	<260	110,000
S6-A2	8.5'	11/04	I	I	<280	<260	690,000
S6-A2A	4.5'	11/05	<0.01	<0.01	<0.01	<0.01	<0.01
S6-A2A	7'	11/05	I	<13	<14	<13	7,600
S6-A3	5'	11/05	I	<13	<14	<13	4,600
S6-A3.5	5'	11/05	I	<13	<14	<13	3,600
S6-A4	4.5'	11/05	<0.01	<0.01	<0.01	<0.01	<0.01
S6-A4	5.5'	11/05	I	<0.3	<0.3	<0.3	68
S6-B1	5'	11/04	I	<510	<570	<530	610,000
S6-B2	5'	11/04	I	I	<280	<260	280,000
S6-B2	8.5'	11/04	I	I	<280	<260	220,000
S6-B3	5'	11/04	I	I	<280	<260	35,000
S6-B3	8'	11/04	I	I	4,000	<110	120,000
S6-B3.5	5'	11/05	I	<26	<28	<27	6,400
S6-B4	5'	11/04	<0.02	<0.02	<0.03	<0.03	<0.02
S6-B4C	5'	11/05	<0.01	<0.01	<0.01	<0.01	0.1
S6-B4C	5'	11/06	<0.01	<0.01	<0.02	<0.01	<0.01
S6-B4C	7'	11/06	<0.01	<0.01	<0.02	<0.01	0.5
S6-BG1	5'	11/06	<0.01	<0.01	<0.02	<0.01	0.2
S6-BG2	4'	11/06	<0.01	<0.01	<0.02	<0.01	<0.01
S6-C1	5'	11/05	I	<130	<130	<130	130,000
S6-C2	5'	11/05	I	<130	<140	<130	72,000
S6-C3	5'	11/05	I	<0.5	<0.6	<0.5	1,000
S6-C4	4'	11/04	<0.09	<0.1	<0.1	<0.1	<0.09
S6-C4	7'	11/04	<0.9	<1	<1	<1	1,700
S6-D1	4.5'	11/05	<0.01	<0.01	<0.01	<0.01	8
S6-D2	2.5'	11/05	I	<0.5	<0.6	<0.5	1,000
-D3	5'	11/05	<0.01	<0.01	<0.01	<0.01	<0.01
-D4	4'	11/04	<0.09	0.5	<0.1	<0.1	4
[illegible]-01	4.5'	11/10	<0.02	<0.02	<0.03	<0.02	0.06
[illegible]-01	6'	11/10	<0.02	<0.02	<0.03	<0.02	<0.02
[illegible]-02	4.5'	11/10	<0.02	<0.02	<0.03	<0.02	0.07
[illegible]-03	6.5'	11/10	<0.02	<0.02	<0.03	<0.02	0.4
[illegible]-04	6.5'	11/10	<0.02	<0.02	<0.03	<0.02	0.2

A-1

TUT 003 1047

ations:
interference with adjacent peaks
not analyzed

Analyzed by M. Krotenberg

Checked by M. Krotenberg

Proofed by [illegible]

GEOSCIENCE CONSULTANTS/TEXACO/TUTU, VIRGIN ISLANDS

Tracer Research Corporation

Sample	Depth	Date	Benzene (ug/l)	Toluene (ug/l)	Ethyl Benzene (ug/l)	Xylenes (ug/l)	Total Hydroc.w/o CH4 (ug/l)
SGF-04	9.5'	11/10	<0.02	<0.02	<0.03	<0.02	0.3
SGF-05	5.5'	11/10	<0.02	<0.02	<0.03	<0.02	0.2
SGF-06	6'	11/10	<0.02	<0.02	<0.03	<0.02	0.4
SGF-07	3.5'	11/11	<0.02	<0.03	<0.03	<0.03	10
SGF-08	6'	11/11	<0.02	<0.03	<0.03	<0.03	2
SGF-09	2'	11/12	<0.02	<0.02	<0.03	<0.02	6
SGF-10	5.5'	11/12	I	<6	<7	<6	2,600
SGF-11	4'	11/12	I	<0.5	<0.5	<0.5	120
SGF-12	3.5'	11/12	0.4	<0.1	<0.1	<0.1	40
SGF-13	5.5'	11/12	0.02	<0.02	<0.03	<0.02	7
SGF-14	2'	11/12	I	<12	<14	<13	3,000
SGF-15	2.5'	11/13	<0.02	<0.02	<0.03	<0.03	43
SGF-16	6'	11/13	<0.02	<0.02	<0.03	<0.03	11
SGF-17	5'	11/14	<0.02	<0.03	<0.03	<0.03	33
SGF-18	3.5'	11/14	<0.02	0.07	<0.03	<0.03	0.2
SGF-19	5'	11/14	I	<5	<6	<6	1,800
SGF-20	6'	11/14	<0.02	<0.03	<0.03	<0.03	26
SGF-21	6'	11/14	<0.02	<0.03	<0.03	<0.03	1
SGF-22	6'	11/14	<0.02	<0.03	<0.03	<0.03	0.2
SGT-01	5'	11/09	<0.01	<0.01	<0.01	<0.01	<0.01
SGT-01	7'	11/09	<0.02	<0.02	<0.02	<0.02	<0.02
SGT-02	5'	11/09	<0.02	<0.02	<0.02	<0.02	<0.02
SGT-02	7'	11/09	<0.02	<0.02	<0.02	<0.02	<0.02
SGT-03	4'	11/09	<0.2	<0.2	<0.3	<0.3	230
SGT-05	4'	11/06	<0.01	<0.01	<0.02	<0.01	0.6
SGT-06	2.5'	11/09	<0.02	<0.02	<0.02	<0.02	<0.02
SGT-07	5'	11/09	<0.02	<0.02	<0.02	<0.02	<0.02
SGT-07	5.5'	11/09	<0.02	<0.02	<0.02	<0.02	10
SGT-08	2'	11/09	<0.02	<0.02	<0.02	<0.02	0.9
SGT-10	3'	11/09	<0.02	<0.02	<0.02	<0.02	10
SGT-11	5'	11/09	<0.02	<0.02	<0.02	<0.02	3
SGT-12	3.5'	11/09	<0.02	<0.02	<0.02	<0.02	0.4
SGT-13	4.5'	11/09	<0.02	<0.02	<0.02	<0.02	5
SGT-14	5.5'	11/12	<0.02	<0.02	<0.03	<0.02	2
SGT-15	3.5'	11/12	<0.02	<0.02	<0.03	<0.02	0.02

Notations:
I interference with adjacent peaks
NA not analyzed

Analyzed by M. Krotenberg

Checked by M. Krotenberg

Proofed by L. Laplander

GEOSCIENCE CONSULTANTS/TEXACO/TUTU, VIRGIN ISLANDS

Tracer Research Corporation

Sample	Depth	Date	Benzene (ug/l)	Toluene (ug/l)	Ethyl Benzene (ug/l)	Xylenes (ug/l)	Total Hydroc.w/o CH4 (ug/l)
SGT-16	5.5'	11/13	<0.02	<0.02	<0.03	<0.03	0.4
SGT-17	6'	11/13	<0.02	<0.02	<0.03	<0.03	0.2
SGT-17	6'	11/14	<0.02	<0.03	<0.03	<0.03	<0.02
SGT-18	5.5'	11/13	<0.02	<0.02	<0.03	<0.03	0.4
SGT-19	6'	11/13	<0.02	<0.02	<0.03	<0.03	0.2
SGT-19	10'	11/13	<0.02	<0.02	<0.03	<0.03	2
SGT-20	4.5'	11/14	<0.02	<0.03	<0.03	<0.03	0.2
SGZ-01	5'	11/11	I	<7	<7	<7	4,000
SGZ-02	3.5'	11/11	I	<52	<58	<54	28,000
SGZ-04	6'	11/11	I	<26	<29	<26	12,000
SGZ-05	5'	11/11	I	<5	<6	<5	860
Drift 1	4'	11/04	<0.02	<0.02	<0.03	<0.03	0.9
Drift 2	2.5'	11/05	<0.01	<0.01	<0.01	<0.01	0.1
Drift 3	2'	11/06	<0.01	<0.01	<0.02	<0.01	0.2
Drift 4	2'	11/09	<0.01	<0.01	<0.01	<0.01	0.2
Drift 5	2.5'	11/11	<0.02	<0.03	<0.03	<0.03	0.4
Drift 6	2'	11/12	<0.02	<0.02	<0.03	<0.02	0.4
Drift 6	2'	11/13	<0.02	<0.02	<0.03	<0.03	0.2
Drift 7	2'	11/14	<0.02	<0.03	<0.03	<0.03	0.4

Notations:
I interference with adjacent peaks
NA not analyzed

Analyzed by M. Krotenberg

Checked by M. Krotenberg

Proofed by L. Laplander

GEOSCIENCE CONSULTANTS/TEXACO/TUTU, VIRGIN ISLANDS

Tracer Research Corporation

Sample	Depth	Date	Ch2Cl2 (ug/l)	CHCl3 (ug/l)	TCA (ug/l)	CCl4 (ug/l)	TCE (ug/l)	PCE (ug/l)
SGH-01	3'	11/17	<0.9	<0.006	0.02	<0.0005	<0.004	1
SGH-02	3.5'	11/17	<0.9	<0.006	0.05	<0.0005	0.5	42
SGH-03	4'	11/17	<0.09	<0.0006	<0.0002	<0.00005	<0.0004	0.4
SGH-04	3.5'	11/17	<0.09	<0.0006	0.005	<0.00005	<0.0004	0.8
SGH-05	4'	11/17	<0.2	<0.001	<0.0004	<0.0001	0.05	6
SGH-06	4.5'	11/17	<30	<0.2	10	<0.02	<0.1	16
SGH-07	5'	11/17	<0.9	<0.006	0.04	<0.0005	0.6	170
SGH-08	5'	11/17	6	<0.006	<0.002	<0.0005	0.3	1
SGH-09	5.5'	11/17	<0.09	<0.0006	<0.0002	<0.00005	<0.0004	0.02

Notations:
I interference with adjacent peaks
NA not analyzed

Analyzed by M. Krotenberg

Checked by M. Krotenberg

Proofed by L. Lanlander

APPENDIX B

FIELD SYSTEM QUALITY ASSURANCE AUDIT OF OPERATIONAL PROCEDURES

GCL

FIELD SYSTEM AUDIT OF OPERATIONAL PROCEDURES, SOIL GAS INVESTIGATION AT TEXACO TUTU SERVICE STATION, TUTU, ST. THOMAS, U.S. VIRGIN ISLANDS

Introduction

On November 6, 1987, a Field System Audit of the work being conducted by Geoscience Consultants, Ltd. (GCL) and Tracer Research Corporation (TRC) at the Tutu service station of Texaco Caribbean, Inc., on the island of St. Thomas, was performed by the GCL Quality Assurance (QA) Officer, Randall T. Hicks. The Field System Audit was conducted on the third day of soil gas sampling and analysis conducted by GCL and TRC at the Tutu site. Observations, recommendations, and corrective actions performed during the Field System Audit are described in this report.

Project History and Procedures

Texaco Caribbean, Inc. has contracted with GCL to conduct a soil gas investigation at the Tutu site in St. Thomas, U.S. Virgin Islands. The Tutu survey is designed to determine the levels of hydrocarbons which are found in soil gas from the areas surrounding underground storage tanks at the facility, to determine if a release has occurred from the tanks, and to assist in the definition of any soil or ground water contamination plumes.

Soil gas hydrocarbon values are determined by inserting a steel probe into the soil, withdrawing soil gas by use of a vacuum pump, and analyzing the gas for hydrocarbons using an on-site gas chromatograph (GC). Detailed descriptions for sampling and analytical procedures are in GCL's Work Plan and Quality Assurance Project Plan for the Tutu site (October 1987).

Field sampling and analytical procedures commenced at the Tutu site on November 3, 1987.

Purpose of Field System Audit

The Field System Audit was conducted to verify that procedures described in the Work Plan (WP) and Quality Assurance Project Plan (QAPP) were being adhered to in the field at the Tutu site, to determine whether any procedures required modification based on experience in the field, and to recommend any other procedural changes in field activities that might be necessary or desirable to improve the final work product.

Field Observations

No major technical problems were found with the work performed at the Tutu site. It was determined that significant difficulty exists using the current column and detector (OV-101 Column, Flame Ionization Detector) in the GC, as called for in the approved Work Plan and QAPP, to quantify benzene and toluene in soil gas. This could be the result of one of two situations:

- Benzene and toluene have selectively been flushed or biodegraded in the vadose zone, even in areas with significant total hydrocarbons as detected by the FID.
- Benzene and toluene are obscured by interference peak(s) and therefore not quantifiable with the presently used column in the GC.

In order to resolve this problem and to quantify the presence or absence of benzene and toluene in soil gas it was recommended, based on discussions between GCL, TRC, EPA and CDM-FPC (J. Appel - GCL; A.A. Gutierrez - GCL; Dan Evans - TRC; John Mihalich - CDM-FPC; Jim Ockalini-CDM - Boston), that a Carbopak 1000 column that will have a much longer retention time and allow a clean determination of the presence or

absence of benzene and toluene be used at the Tutu site. It was agreed by all concerned that if this procedure failed to identify and quantify benzene and toluene, these constituents would be considered absent in soil gas. It must be noted, however, that this can be the case even though these constituents may be present in ground water, due to the biodegradation and flushing of the vadose zone and restriction of ground water to fractured bedrock. Furthermore it must be noted that, although the individual constituents have not been detected, the plume mapping using total hydrocarbons and detectable halocarbons on the electron capture detector (ECD) has been extremely successful over the majority of the site.

The principal technical problems were not encountered with the site work, but instead, with the site Work Plan and QAPP. Portions of the plans are not appropriate for actual site conditions. Other portions of the plans do not significantly add to accomplishing the goals of the project or were not being done routinely by TRC, and we recommended deletion of these practices from the QAPP and Work Plan. These recommended changes are summarized in Table 1.

Conclusions and Recommendations

The Field System Audit indicated that not all the procedures described in the WP and QAPP are followed exactly as planned previously due to site-specific conditions. The reasons for these discrepancies are valid and summarized in Table 1. Since the proposed changes to the Work Plan and QAPP tend to improve the quality and/or speed at which data can be collected during the project, it is recommended that the revised procedures, presently in use, be continued during further sampling and analysis and be incorporated into the Work Plan and QAPP for the Tutu site.

GCL is confident that the procedural revisions to the QAPP described in this report will result in improved data quality and a better final work product.

TABLE 1

RECOMMENDATIONS FOR CHANGES TO WORK PLAN AND QAPP

RECOMMENDED CHANGE	JUSTIFICATION FOR THE CHANGE	PAGE
Remove Russ Erbes from TRC.	Schleyer and Hicks will serve adequately for TRC.	1 (Q) Figure 2-1 (Q)
Do not employ PID Detectors in the Gas Chromatograph to conform with actual practice.	High humidity coupled with high levels of hydrocarbons will result in operational problems (clouding the window).	2 (Q) p.8 (WP)
Utilize a Carbopack 1000 column on selected samples.	BTEX concentrations were not determined with existing columns.	Appendix B, p.5 (Q)
Reference to NBS Standards should be deleted.	Standards are prepared by Chem Services, Inc pursuant to procedures outlined in Appendix B, p. 5.	5 (Q) 7 (Q)
The purpose of the control point should be stated in more detail.	It was unclear to field personnel. The control point is utilized to test for variability in analysis due to factors not related to any contamination (e.g., weather conditions, smog, etc.)	6 (Q)
Indicate that "preliminary" evaluation of data is conducted in the field.	Any statistical tests, detailed mapping and correlation of soil gas data with other hydro-geologic features will be conducted after all data are assembled into a logical format.	6 (Q)
Utilize a "one-point" Calibration for the GC, not a three point calibration as described. Justify the adequacy of this calibration which is presently being used in the field.	The one-point calibration is appropriate for soil gas surveys.	7 (Q)
The text addressing sample splits should be re-written for clarity.	Only one sample is taken from each point. After 10 samples, a selected point is repeated, sampled and analyzed.	p.9 (Q)
Appendix A should be retitled to read Tracer Research Corporation Methods of Operation for Soil Gas Analyses Using TRC's Mobile Laboratory and Probe Driver.	The title may suggest that the methods discussed will be used at Tutu. Most of the specific methods were modified to suit this remote location.	Appendix A (Q)
Appendix B should be modified throughout to reflect Actual Site Procedures.	Although this could not be fully anticipated, site conditions dictated special methods not described in the appendix (e.g., driving probes by hand, refrigeration of the standards).	Appendix B (Q)
Delete references to a second sample for each point to conform to actual practice.	It is not done and is not necessary.	Appendix B, p.1 (Q)
"Observations" should be made by GCL staff not TRC.	GCL staff is in a better position and it is GCL's responsibility to describe the site conditions for each sample point.	Appendix B, p.3 (Q)

TABLE 1 (CONTINUED)

RECOMMENDED CHANGE	JUSTIFICATION FOR THE CHANGE	PAGE
Obtain QA data on Chem Services Inc standards.	No data are provided.	Appendix B, p.6 (Q)
Dilute field standards should be refrigerated.	During field work variation of the standard was significant when not refrigerated.	Appendix B, p.6 (Q)
The water used to prepare the standard should be analyzed daily.	Distilled water from grocery stores has been found to contain hydrocarbons or halocarbons at other locations.	Appendix B, p.6 (Q)
Primary standards may be kept at the site to conform with actual practice.	No technical reason for keeping such standards off site was presented by site personnel.	Appendix B, p.7 (Q)
The syringe blank procedure should reflect field practice.	Field method is equivalent. A 10 ml syringe is filled with Nitrogen 2. Then a "micro" syringe is used to obtain a sample from the 1st syringe, the smaller sample is analyzed.	Appendix B, p.8, p.12 (Q)
System blanks may be run daily to conform with actual practice.	System blanks after every 10 samples is excessive and not necessary to assume quality of analytical results.	Appendix B, p.8, p.14 (Q)
Syringes and other equipment may be baked for 1/2 hour at 80°C rather than overnight at 70° to conform with actual practice.	The level of "Cleaning" is sufficient.	Appendix B, p.9, p.12 (Q)

note: (Q) = QAPP
(WP) = Work Plan