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GROUNDWATER AND SOILS REMEDIATION PROGRAM for TEXACO TUTU SERVICE STATION ST. THOMAS, U.S. VIRGIN ISLANDS

Erler & Kalinowski, Inc.

Consulting Engineers and Scientists

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Kalinowski, Inc.

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13 April 1995
(EKI 940058.00)

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13 April 1995

Mr. Paul Ryan
Texaco Inc.
Old Glenham Road
Glenham, NY 12527

Subject: Texaco Tutu Service Station
Groundwater and Soils Remediation Program Report
St. Thomas, U.S. V.I.
(EKI 940058.00)

Dear Mr. Ryan:

Pursuant to your request we are transmitting you two copies of the report describing the proposed groundwater and soils remediation program at the Texaco Tutu Service Station in St. Thomas, U.S. V.I. We are also sending the original report and additional copies to the Department of Planning and Natural Resources ("DPNR") in St. Thomas and copies to other interested parties as noted below.

Very truly yours,

ERLER & KALINOWSKI, INC.

Deborah A. Hart for

Carey E. Peabody, Ph. D, R.G.
Project Manager

cc: Leonard Reid, DPNR
Adrian Schottroff, DPNR
David Rosoff, DPNR
Timothy R. Knutson, Texaco Inc.
Chris Gibson, Archer & Greiner
Caroline Kwan, U.S. EPA Region II
Sally Odland, CDM Federal Programs Corporation

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Appendices

A - Hydrologic Model

B - Air Emissions Risk Screening Analysis

1.0 INTRODUCTION

1.1 Background

Based on the results of environmental investigations performed on behalf of Texaco Caribbean Inc. ("TCI") and the Tutu Environmental Investigation Committee ("TEIC", comprised of Esso Standard Oil and TCI), it has been determined that gasoline constituents have been released to the subsurface at the Texaco Tutu Service Station (the "site"), St. Thomas, U.S. Virgin Islands (GCL, 1994; Geraghty & Miller, 1995a).

The purpose of this report is to summarize the available geologic, hydrologic, and chemical data for the Texaco Tutu Service Station area and to propose a site remediation program to address chemicals of concern in unsaturated soil and groundwater.

1.2 Site Description and History

The Texaco Tutu Service Station is located in the upper Turpentine Run basin in Estate Anna's Retreat in east-central St. Thomas, U.S. Virgin Islands (Figure 1). It is located at the northeast corner of the intersection of Highways 38 and 384 (Figure 2). Since it was built in 1964, the Texaco Tutu Service Station has been in continuous operation as a retail outlet for gasoline and diesel fuel. In 1987, it was suspected that petroleum hydrocarbons had been released from the original steel underground storage tanks. These tanks and associated piping were removed in 1988 (Lebron Associates, 1988) and replaced with new facilities at a different location.

During 1993 and 1994, environmental investigations were performed which revealed the occurrence of a plume of petroleum hydrocarbons in groundwater which extends approximately 400 feet to the south of the site. The plume emanates from the vicinity of the original steel underground storage tanks (GCL, 1994; Geraghty & Miller, 1995a).

Analysis of soil samples from the unsaturated zone reveal concentrations of petroleum hydrocarbons (GCL, 1994; Geraghty & Miller, 1995a). According to Lebron and Associates (1990), strong petroleum hydrocarbon odors were noted after the tank excavation and before backfilling with clean imported material. Therefore, residual petroleum hydrocarbons likely exist in the subsurface.

1.3 Project Objectives

The primary objectives of the proposed site remediation program are to:

- remove free-phase petroleum hydrocarbons (or light non-aqueous phase liquid, "LNAPL"), if present,
- control and remediate groundwater with high concentrations of petroleum hydrocarbons on the site,
- remediate unsaturated soil and rock that may be affected by the petroleum hydrocarbon release at the site, and
- control further migration of the petroleum hydrocarbon plume down-gradient of the site.

2.0 CONCEPTUAL MODEL OF SUBSURFACE CONDITIONS

A conceptual model of subsurface conditions can be assembled by integrating the available geological, hydrological, and chemical data for the site and vicinity. Each of these components is discussed below briefly.

2.1 Geology

Geological data for the site and vicinity have been generated by others; the most recent reports include GCL (1994) and Geraghty & Miller (1995a).

Based on the available data, the bedrock in the vicinity of the site consists of Cretaceous volcanic and volcanoclastic units known as the Water Island Formation and the younger Louisenoj Formation. The Water Island Formation is composed primarily of extrusive basalt and basalt breccia. The base of the Louisenoj Formation consists of the Cabes Point Conglomerate, interpreted to be derived from erosion of the underlying Water Island rocks (Donnelly, 1966). Based on work reported in Geraghty & Miller (1995a), the Luisenoj Formation in the area of interest consists of augite andesite tuff, breccia, and debris flows that have undergone varying degrees of low-grade contact metamorphism. On the scale of the island, these units have been tilted into a northward-dipping homocline; dips range from 15 to 90 degrees and locally the formations are overturned (Donnelly, 1966).

These units are apparently offset by strike-slip and normal faults in the Tutu Valley, coincident with areas where lineaments have been mapped based upon topographic analysis (Geraghty & Miller, 1995a; see Figure 3).

Where weathered and altered near the ground surface, the bedrock units consist of clay-supported cobbles and boulders of the volcanic rock. This weathered bedrock (also known as saprolite) is locally overlain by clay-rich soil or, along the valley floor, Quaternary alluvial deposits. An isopach map which illustrates the thickness of the overlying sedimentary deposits and fill is shown on Figure 4.

2.2 Hydrology

Hydrological data for the vicinity of the Texaco Tutu Service Station have been compiled most recently in Geraghty & Miller (1995a). These data have been reviewed and evaluated in order to support the use of a groundwater flow model to help select groundwater extraction well locations and estimate flow rates necessary to achieve the project objectives. Basic hydrological data are discussed in this section. Implementation of the numerical model is discussed in Section 2.4.

The available data indicate that the water-bearing units in the vicinity of the Texaco Tutu Service Station consist of fine-grained sediments and fractured bedrock. These two units are hydraulically connected and the groundwater system is unconfined. Most groundwater production is from bedrock in zones of open fractures.

Groundwater elevation data for May 1994 are reproduced on Figure 5. This contour map indicates that groundwater flow is to the south in the vicinity of the site. The groundwater gradient is steeper north of the site and south of monitoring well MW-7 than at the site itself. This indicates that the shallow bedrock in the vicinity of the site is relatively more permeable than in the areas to the north and south.

As shown on cross section BB' (Figure 6), which trends east-west across the Texaco Tutu Service Station (see Figure 3 for cross-section location), the groundwater table apparently occurs within the zone of weathered bedrock. Unsaturated subsurface materials at the service station consist of silt, clayey silt, and weathered bedrock. Saturated subsurface materials consist of both weathered and unweathered bedrock.

According to Stevens and others (1981) wells drilled in the Tutu Valley range from 40 to 325 feet in depth. The depth of the wells typically indicates the depth of a zone of water-bearing fractures. Short-term yields from individual wells have been measured up to 100 gallons per minute, however sustained yields range from about 2 to 20 gpm.

Data from aquifer pumping tests performed at wells MW-6R (Geraghty & Miller, 1992), the Tillett well (Hamlin, 1985), and Four Winds III (Hydrologic Associates, Inc., 1993a) have been closely examined for hydraulic conductivity data for the vicinity of the site. Hydraulic conductivities derived for saturated bedrock in the vicinity of these three wells range from 716 feet/day (MW-6R) to 31 feet/day (Tillett) to 11 feet/day (Four Winds III). The variation in calculated hydraulic conductivities likely reflects the variability of fractures in bedrock both areally and vertically. Higher conductivities have been calculated for wells in areas that are thought to be cut by lineaments and where the hydraulic gradient is lower. In general, higher flow rates are expected in areas that are more highly fractured and where the fractures have not been subsequently sealed with secondary minerals.

2.3 Chemicals of Concern

The chemicals of concern beneath the Site consist of gasoline constituents and chlorinated volatile organic compounds. Specifically, they are:

Benzene	1,2-Dichloroethane	Vinyl Chloride
Toluene	1,2-Dichloroethene	Methylene Chloride
Ethylbenzene	Tetrachloroethene	
Xylene	Trichloroethene	

The gasoline constituents emanate, at least in part, from the location of the former underground storage tanks at the Texaco Tutu Service Station. Based upon Geraghty & Miller (1995a), the chlorinated VOCs emanate from sources upgradient of the service station and have mobilized in groundwater and soil gas beneath the Texaco Tutu Service Station.

2.3.1 Vadose Zone

Analyses of soil samples from the unsaturated zone reveal concentrations of petroleum hydrocarbons (GCL, 1994; Geraghty & Miller, 1995a). The available data are reproduced on Figure 7. U. S. EPA has directed TEIC to use the New York State Technical and Administrative Guidance Memorandum ("NYS TAGM") levels as remedial action screening levels for the Tutu area. Based on Geraghty & Miller (1995a), some of the data for soil from the Texaco Tutu Service Station exceed the NYS TAGM screening levels. In addition, according to Lebron and Associates (1990), strong petroleum hydrocarbon odors were noted after the tank excavation and before backfilling with clean imported material. Therefore, residual petroleum hydrocarbons apparently exist in the subsurface. The purpose of the planned soil vapor extraction system, discussed below, is to remediate these residuals.

2.3.2 Groundwater

The plume of gasoline constituents in groundwater that emanates from the area of the Texaco Tutu Service Station can be delineated by the extent of benzene in groundwater. In plan view, benzene concentrations are plotted and contoured on Figure 8. This is the areal extent of groundwater that is targetted for remediation.

Concentrations of total chlorinated VOCs in shallow (<50 foot depth) and deep (>50 foot depth) groundwater are illustrated on Figures 9 and 10. In the process of remediating the gasoline plume at the Texaco site, chlorinated VOCs that have been discharged by other parties will also be extracted and will require treatment.

Review and evaluation of available groundwater data for chlorinated VOCs discussed in Geraghty & Miller (1995a) indicates that there is a moderate to high probablility that dense non-aqueous phase liquids (DNAPLs) are present in the Tutu area. Historically (between September 1987 and January 1988), water samples from the Tillett well were reported to contain tetrachloroethylene ("PCE") at a concentration of 2,040 ug/L, greater than 1% of the maximum solubility of PCE in water. As discussed in Geraghty & Miller (1995a), such concentrations are suggestive of DNAPL in the subsurface.

More recent data from July 1994 reveal lower concentrations of PCE and other VOCs from the Tillett well. Highest chemical concentrations in the vicinity of the Texaco Tutu Service Station have been detected in groundwater from monitoring well, MW-16, which is located upgradient of the site and north of the Curriculum Center (Figure 9). If DNAPL persists in the subsurface, it likely occurs in this area where chemical concentrations in groundwater are highest.

Two cross-sections have been prepared which illustrate chemical distributions parallel (Section AA') and perpendicular (Section BB') to the southerly groundwater flow direction. (See Figure 3 for cross-section locations.) The principal VOCs of concern which occur along the axis of the plume are plotted on Figure 11; benzene concentrations are contoured on Figure 12 and total chlorinated VOC concentrations are plotted on Figure 13 .

Because gasoline is less dense than water, dissolved chemical plumes down-gradient of gasoline releases are typically shallow and do not commonly extend to great depths. At the Texaco Tutu Station, however, BTEX compounds have been detected at elevated concentrations in water from the deep monitoring well

TT-1D. In addition, such compounds have been detected in groundwater from the Tillett well. This vertical distribution suggests that chemicals of concern may have been drawn downward, possibly under the influence of pumping from the Tillett well. Assuming this is the case, the vertical extent of chemicals which emanate from the Texaco Tutu Station is assumed to be as much as 100 feet deep, the depth of the bottom of the Tillett well (Figure 12). As shown on Figure 13, total chlorinated VOC concentrations along this line of section are greater than 100 ug/L and average approximately 500 ug/L.

A lateral cross-section, BB', has been prepared which trends east-west across the southern edge of the Texaco Tutu Service Station (Figure 14). This section, oriented perpendicular to the chemical plume, illustrates the distribution of chemicals of concern migrating southward. Benzene concentrations are contoured on Figure 15 and total chlorinated VOC concentrations are plotted on Figure 16 . These figures indicate that the BTEX plume is relatively narrow given that these compounds have not been detected in monitoring wells MW-4, MW-4D, or TT-5.

The objectives of the planned groundwater remediation system, described below, are to:

- remove free-phase petroleum hydrocarbons (or light non-aqueous phase liquid, "LNAPL"), if present,
- control and remediate groundwater with high concentrations of petroleum hydrocarbons at the site with an onsite groundwater extraction system, and
- control further migration of the petroleum hydrocarbon plume down-gradient of the site with a separate off-site system.

Conceptual designs for these groundwater extraction systems are discussed in Section 3.

2.4 Numerical Flow Model

Because of the fractured nature of the bedrock in the Tutu area, it is difficult to predict with much reliability the hydraulic conductivity of a particular volume of rock. Nevertheless, the available hydraulic conductivity data coupled with the results of lineament analysis have been used as the basis for a numerical flow model for the site. This numerical flow model assumes that the system is sufficiently fractured that it can be modelled as an equivalent porous medium. This assumption, though not likely to hold across the model domain, has been made in order to allow a general estimate of the amount of water that will be extracted and require treatment at the Texaco Tutu Service Station and down-gradient of the site at the northern boundary of the Vitelco Property. This estimate is needed for the design of the groundwater remediation system.

In addition, some assessment is needed regarding the potential for dewatering in the area of potential DNAPL near monitoring well MW-16, north of the Curriculum Center. Extensive dewatering is undersirable in that potential DNAPL located in fractured bedrock could become destablized and mobilized under gravity to deeper levels of the aquifer.

As discussed more fully in Appendix A, the 2-dimensional hydraulic flow model, FLOWPATH (version 5) (Waterloo Hydrogeologic Software, 1994), was used to evaluate and predict flow conditions in an area 2000 feet x 2000 feet which includes the Texaco Tutu Service Station and the Vitelco property. Hydraulic data reported in Geraghty & Miller (1992; 1993; and 1995a), Hamlin (1985), and Hydrological Associates, Inc. (1993) were utilized in calibrating the numerical model to non-pumping steady-state conditions and to pumping conditions. Though calibrated, the model has inherent uncertainties given the limited available data. Nevertheless, results of simulations can be useful for selecting well locations and estimating flow rates.

Using the hydraulic model, the impacts of pumping from extraction wells constructed at the down-gradient edge of the Texaco Tutu Service Station and the up-gradient edge of the Vitelco property were evaluated. Results of simulations reported in Appendix A indicate that a single extraction well with a flow rate of 10 gpm located along the down-gradient edge of the Texaco Tutu Service Station should be adequate to capture chemicals emanating from the site. Pumping groundwater from two extraction wells with flow rates of 5 gpm each should also be adequate for achieving chemical capture. Under both scenarios, a drawdown of approximately 3 feet is predicted in the area of potential DNAPL located near monitoring well MW-16, north of the Curriculum Center.

Increasing extraction rates to 20 gpm for either one or two wells (combined flow) at the down-gradient edge of the Texaco Site results in predicted drawdowns of approximately 5 feet in the area of potential DNAPL located near monitoring well MW-16, north of the Curriculum Center.

Model simulations further indicate that groundwater extraction with a flowrate of 10 gpm at a single location at the northern edge of the Vitelco property will likely be adequate for achieving capture of chemicals at the front of the chemical plume.

The results of these model runs are incorporated into the remedial design as discussed, below, in Section 3.

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3.0 PROPOSED REMEDIAL ACTIONS

3.1 Remedial Action Objectives

The remedial action objectives for the Texaco Tutu Remediation Program are as follows:

- for the vadose zone, remove chemicals of concern in the source area to the extent feasible, and
- for groundwater, treat extracted groundwater to achieve Federal Drinking Water Standards (Maximum Contaminant Levels) for the compounds listed below:

Benzene	1,2-Dichloroethane	Vinyl Chloride
Toluene	1,2-Dichloroethene	Methylene Chloride
Ethylbenzene	Tetrachloroethene	
Xylene	Trichloroethene	

3.2 Conceptual Remedial Design

3.2.1 Design Summary

It is proposed that two separate remedial systems be constructed in order to meet the project objectives. The larger system will be constructed at the Texaco Tutu Service Station and the smaller remedial system will be located on the Vitelco property (Figure 17).

Groundwater extraction wells will be installed at the down-gradient property line of the Texaco Tutu Service Station to remediate and limit migration of petroleum compounds. Groundwater will be extracted from near the northern boundary of the Vitelco property to remediate and control further migration of the petroleum hydrocarbon plume down-gradient of the service station. At each groundwater extraction location, treatment units will be housed in a cargo container and treated water will be discharged to the storm sewer under a Territorial Pollutant Discharge Elimination System ("TPDES") permit.

At the Texaco Tutu Service Station, a soil vapor extraction ("SVE") system consisting of SVE wells installed in the vicinity of the former tank excavation will remediate soil that may contain high concentrations of petroleum hydrocarbons.

Catalytic oxidation will provide off-gas control. Extracted groundwater will be treated by air stripping followed by catalytic oxidation in order to achieve compliance with Federal Drinking Water Maximum Contaminant Levels ("MCLs"). At the Vitleco Property, due to the relatively low concentrations of chemicals, groundwater will be treated by air-stripping to meet MCLs.

The development and description of the treatment systems are discussed below.

3.2.2 Assumed Influent Organic Water Quality and Flow Rates

Table 1 shows the assumed groundwater influent chemical concentrations for both the Texaco Tutu Service Station and the Vitelco Property. At both sites, petroleum hydrocarbons and chlorinated VOCs are present. The design concentrations for the Texaco Tutu Service Station are based on: (1) a weighted average of the previously reported maximum concentrations of chemicals in groundwater from the deep and shallow monitoring wells located between monitoring wells MW -16 and TT-1 (GCL, 1994; Geraghty & Miller, 1995a) and (2) an assumed flow rate of 50 gallons per minute ("gpm"). (See Section 3.3.2.1 for discussion of assumed flow rate.)

For the Vitelco property, the design concentrations are based on: (1) previously reported analytical results for groundwater from MW-7 (GCL, 1994; Geraghty & Miller, 1995a) and (2) an assumed flow rate of 20 gpm. (See Section 3.4.1 for discussion of assumed flow rate.)

For both groundwater extraction locations, it is assumed that the concentrations of chlorinated VOCs in groundwater may increase with time unless the upgradient source area is contained. This assumption is reflected in the values given in Table 1. Table 3 shows the estimated treated water effluent concentrations and corresponding Federal MCLs.

3.2.3 Assumed Inorganic Water Quality

Table 2 shows the assumed influent inorganic water quality for both groundwater extraction locations. The design concentrations are based on a weighted average from previously reported chemical concentrations for monitoring wells TT-1 and TT-1D at the Texaco Tutu Service Station and from previously reported chemical concentrations for groundwater from MW-7 at the Vitelco Property (GCL, 1994; Geraghty & Miller, 1995a). It is assumed that all metals in groundwater are at naturally occurring background levels. No treatment for metals or inorganic compounds are planned at this time. As shown on Table 3, it is anticipated that Federal MCLs for inorganic compounds will be met.

3.2.4 Screening of Treatment Options

Treatment options for soil and groundwater remediation for the Tutu area were developed and screened by Geraghty & Miller (1995a). These options are shown in Table 4 and are further screened on the basis of their suitability to remediate both petroleum hydrocarbons and chlorinated VOCs, and on the basis of ease of maintenance at this remote location. Soil vapor extraction and catalytic oxidation for off-gas control have been retained as treatment for the vadose zone. For groundwater treatment, air stripping has been retained together with catalytic oxidation for off-gas control. Liquid phase carbon has also been retained.

3.2.5 Air Emissions Control

Based on discussions with the Department of Planning and Natural Resources, ("DPNR"). air discharge limits or permitting requirements have not been promulgated for remediation facilities for the U.S. Virgin Islands. Air emissions of benzene, 1,2-dichloroethane, trichloroethene, perchloroethene, vinyl chloride and methylene chloride are of potential concern because these chemicals have been identified as human carcinogens or probable human carcinogens (U.S. EPA 1994).

At the Texaco Tutu Service Station groundwater location, benzene emissions from the treatment system, without emissions control, are estimated to be on the order of 5 lb/day. At this level of emissions, it is likely that emissions control will be appropriate. Therefore, emissions control has been included in the remedial design for the Texaco Tutu Service Station groundwater location as discussed below.

For the Vitelco property groundwater location, a risk screening analysis was completed to assess the incremental potential lifetime carcinogenic risk due to air emissions from the treatment system without emissions control. EPA uses a general risk range of 1×10^{-4} to 1×10^{-6} (the probability that an individual will contract cancer over a 70 year lifetime due to exposure to chemicals of concern) as an acceptable "target range" for cleanup (U.S. EPA, 1990). Based on assumed emission rates, maximum ground concentrations estimated by an EPA approved air dispersion model (SCREEN2 1993), and EPA unit risk factors (U.S. EPA 1993, 1987, 1985), the incremental potential lifetime (70 year) carcinogenic risk at the Vitelco property location is estimated to be 1.0×10^{-6}. The carcinogenic risk over a 7-year period, about equal to the actual anticipated life of the project, is estimated to be 1.0×10^{-7}. The results of this assessment as well as the SCREEN2 air dispersion model results are included in Appendix B.

The 70 year and 7 year estimated incremental carcinogenic risks are both conservative. The risks are heavily weighted toward the assumed vinyl chloride emission; however, Table 1 shows that vinyl chloride has not been detected to date in groundwater monitoring well MW-7 at the Vitelco property location. The design vinyl chloride influent concentration, is conservatively estimated at 10 ppb.

Based on the 70 year and 7 year estimated risks, it is assumed that emissions control will not be required at the Vitelco property groundwater location.

3.3 Texaco Tutu Service Station Remediation Program

Figure 18 shows the conceptual plan layout for the Texaco Tutu Service Station. The system includes soil vapor extraction for remediation in the vadose zone and groundwater extraction and treatment for the saturated zone.

3.3.1 Vadose Zone

3.3.1.1 Soil Vapor Extraction

The available chemical data for soil samples from the vadose zone show concentrations of petroleum hydrocarbons in the proximity of the former underground storage tank (Figure 7). It is possible that residual petroleum hydrocarbons exist in the subsurface, perhaps as LNAPL. Therefore, a soil vapor extraction system is planned for the area of the former underground storage tank.

As shown on Figure 18, three new SVE wells will be constructed in this area. The boring log for monitoring well TT-4 indicates that gravelly clay was used as the imported backfill material for the underground storage tank excavation. It is anticipated that with clay soil, the radius of influence of the SVE wells will most likely not exceed 20 feet. Therefore, the locations of the wells are spaced so as to cover and overlap the former tank location area perimeter assuming a 20-foot radius of influence.

These wells will be screened to a depth approximately 1 to 2 feet below the lowest known water table elevation. The wells will be equipped with a means for recovering potential LNAPL.

Although a previous report (GCL, 1994) has suggested converting the existing groundwater monitoring wells, TT-1 and TT-4, to SVE wells, it appears they are both unsuitable. Both wells have been constructed with blank casing in the upper 5 feet of the vadose zone and with screened intervals that extend to depths of approximately 30 feet. Therefore, three new SVE wells will be constructed.

3.3.1.2 Treatment Units

Buried underground piping will convey soil vapor, groundwater and recovered LNAPL to the treatment units contained in the cargo container. The main components of the SVE system include a blower that will pull a vacuum of approximately 6-inches of mercury and a condensate knockout drum. The SVE off-gas will be treated by a catalytic oxidizer.

Initial soil vapor concentrations are assumed to be high based upon the elevated benzene concentrations detected in groundwater from monitoring wells TT-1 and TT-4. However, it is expected that these concentrations will decline with time.

3.3.2 Saturated Zone

3.3.2.1 Groundwater Extraction

As discussed in Section 2.4, a hydraulic flow model, FLOWPATH, was used to evaluate groundwater extraction rates and locations necessary to meet the objectives of this remediation program. Model results suggest that groundwater extraction from a single location would be adequate to achieve chemical capture at the Texaco Tutu Service Station. However, given the uncertainty of groundwater flow in fractured bedrock, two locations are proposed for groundwater extraction wells in order to have greater confidence that chemical capture will be achieved. For design purposes, it is assumed that extraction rates of 20 gpm to as much as 50 gpm could be required for the Texaco Tutu Service Station site.

Model results also suggest that drawdowns in the vicinity of monitoring well MW-16 will not be excessive compared to the historical groundwater fluctuations caused by pumping of supply wells and variable climatic conditions. To evaluate actual drawdowns in response to pumping extraction wells at the Texaco Tutu Service Station, it is proposed that water levels in MW-16 be monitored.

In order to avoid further spreading of groundwater with high concentrations of chemicals of concern, an upward gradient will be maintained at the service station. Therefore groundwater extraction at each location will be conducted using well pairs: one shallow (screened from an elevation of approximately 140 to 170 feet above mean sea level) and one deep (screened from approximately 90 to 130 feet above mean sea level). This configuration will allow flexibility in terms of controlling contaminant migration and maintaining upward gradients.

3.3.2.2 Groundwater Treatment Units

Groundwater treatment units will include an air stripper and a catalytic oxidizer (1000 scfm capacity). A low profile air stripper will treat the assumed influent chemical concentrations to current Federal MCLs. (See Table 3.) Propane will be provided as fuel for the catalytic oxidizer. In addition, a chemical feed system will be installed upstream of the air stripper to prevent carbonate scaling. Installation of a system for recovery of light non-aqueous phase liquid ("LNAPL") is also planned.

3.3.3 Texaco Tutu Service Station Treatment System

The components of the treatment system, including the SVE treatment units and the groundwater treatment units, are shown on the attached Process Schematic (Figure 19). Underground buried piping will convey the soil vapor, groundwater, and recovered LNAPL to the cargo container. A propane storage tank will provide fuel for the operation of the catalytic oxidizer.

Groundwater will be treated by air stripping. A catalytic oxidizer will treat off-gas from both the SVE system and the air stripper. As shown on Table 5, approximately 3 lbs of HCl per day will be formed from the catalytic oxidation process. It is therefore assumed that an air scrubber would not be required for an air permit. All treatment units as well as an LNAPL recovery storage tank will be housed within the cargo container. Provision will be made for potentially adding carbon vessels if found to be necessary for groundwater treatment in the future. Treated water will flow by gravity into storm sewer catch basin CB-10A.

3.4 Vitelco Site Remedial Plan

3.4.1 Groundwater Extraction

Based on results of the numerical model and evaluation of available data, a flow rate of 5 to 20 gpm is estimated to be required at the down-gradient front of the plume at the Vitelco property to limit further migration. The requirement for an upward gradient can be met by installing a well pair as follows: one shallow (screened from an elevation of 140 to 170 feet above mean sea level) and one deep (screened from 90 to 130 feet above mean sea level). This configuration will allow flexibility in terms of controlling contaminant migration and minimizing extraction volumes.

Submersible electrical pumps will be installed in each well.

3.4.2 Treatment Units

Groundwater treatment will consist of a low profile air stripper. In addition, a chemical feed system will be installed upstream of the air stripper to prevent carbonate scaling. As shown on Table 5, based on the BAAQMD screening method, air emissions control for this site will not be required.

3.4.3 Vitelco Treatment System

The components of the treatment system are shown on Figure 21. Underground piping will convey the groundwater to the cargo container. The groundwater will be treated with a low profile air stripper. All treatment will be housed within the cargo container. Treated water will be pumped into storm sewer catch basin CB-6-B. Provision will be made for potentially adding carbon vessels if found to be necessary for groundwater treatment in the future.

3.5 Permits

The following permits will be obtained as part of the remedial action:

PERMIT	ISSUING AGENCY
TPDES Permit	Department of Planning & Natural Resources and Environmental Protection Agency, Region II
Well Drilling Permit	St. Thomas Department of Public Works
Earth Change Permit	St. Thomas Department of Public Works
Air Permit	Department of Planning & Natural Resources and Environmental Protection Agency, Region II

4.0 PROJECT TASK ELEMENTS AND SCHEDULE

The proposed series of tasks to implement the remedial plan are listed below:

Task 1:	Perform Remedial Design
Task 2	Select Contractor
Task 3	Perform Active Construction
Task 4	Perform Initial Operation and Shakedown
Task 5	Start-up System
Task 6	Monitor and Evaluate System Performance

The schedule for performance of these tasks is dependent upon achieving access to areas affected by the remedial plan and gaining approval from the regulatory agencies.

To expedite implementation of this plan, TCI is actively working to gain access to affected properties.

This document is being submitted to the DPNR and the U. S. Environmental Protection Agency, Region II as a companion to Geraghty & Miller Inc.'s Feasibility Study (Geraghty & Miller, 1995b) in order to gain agency approval of the remedial plan for the Texaco Tutu Service Station in the context of the overall remedy for the Tutu Valley. It is hoped that concurrence on the Texaco Tutu plan can be reached rapidly so that implementation of the remedial system can begin at the earliest date possible. Once concurrence has been reached, a detailed implementation schedule will be prepared for agency review.

5.0 REFERENCES

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TABLES

TABLE 1

ASSUMED INFLUENT ORGANIC WATER QUALITY AND FLOWRATE

Texaco Tutu, U.S. Virgin Islands
(EKI 940058.00)

Parameter	Texaco Tutu Service Station					Vitelco Property	
	Shallow Max (1)	Deep Max (1)	Shallow Max (2)	Deep Max (2)	Design (3)	MW-7 (2)	Design
Design Flowrate	-	-	-	-	50	-	20
Benzene	23	1.6	21	1.7	17	0.021	0.03
Toluene	25	0.26	17	0.048	15	<0.01	0.01
Ethylbenzene	3	0.065	3.7	0.063	3	<0.01	0.01
Xylenes (Total)	17	0.62	18	0.062	13	<0.01	0.01
Naphthalene	-	-	0.76	0.016	0.5	0.01	0.01
Methyl tert butyl ether (MTBE)	52	1.5	56	1.9	46	0.42	0.5
1,2-Dichloroethane (DCA)	NR	0.033	0.29	<0.02	0.3	<0.01	0.01
1,2-Dichloroethene (DCE)	0.28	0.52	0.44	0.28	0.5	0.18	0.4
Tetrachloroethene (PCE)	0.031	0.058	0.056	0.023	0.05	0.13	0.2
Trichloroethene (TCE)	0.047	0.033	0.02	0.017	0.05	0.027	0.04
Vinyl chloride	0.056	0.15	<5	0.009	0.1	<0.01	0.01
Acetone	1.7	0.2	<5	<0.02	1	<0.01	0.01
Methylene Chloride	7	0.16	<5	<0.02	4	<0.01	0.01

NOTES:

1. Maximum concentrations shown are from the GCL Phase I RI dated 10 June 1994 for monitoring wells between MW-3 and TT-1.
2. Maximum concentrations shown are from the Geraghty & Miller Phase II report dated January 1995 for monitoring wells between MW-3 and TT-1.
3. Design concentrations for the Texaco Tutu Service Station are based on a weighted average of the deep and shallow wells. at a combined flowrate of 50 gpm plus a safety factor. In addition, chlorinated VOC concentrations have been increased to allow for possible concentration increase over time.
4. All concentrations are in parts per million.
5. < Indicates reported laboratory analytical result is below detection limit.

TABLE 2

ASSUMED INFLUENT INORGANIC WATER QUALITY AND FLOWRATE

Texaco Tutu, U.S. Virgin Islands
(EKI 940058.00)

Parameter	TEXACO TUTU SERVICE STATION								
	TT1				TT1-D				Design (3)
	Shallow (1) Indicator Parameter	Unfiltered Metals	Filtered Metals	Estimated Concentration	Deep (1) Indicator Parameter	Unfiltered Metals	Filtered Metals	Estimated Concentration	
Assumed Flowrate (gallons per minute)	-	-	-	30	-	-	-	20	50
Arsenic		2.9	4.6	4		2	2	2	3
Cadmium		3	3	3		3	3	3	3
Chromium		4.8	3	3		3	3	3	3
Copper		30.2	3	5		3	3	3	4
Cyanide	<10			10	<10			10	0.01
Lead		9.5	2	3		2.2	2	2	3
Mercury		0.1	0.1	0.10		0.1	0.1	0.10	0.10
Nickel		16.5	10	12		10	10	10	11
Nitrate (as N)	0.05 ppm			0.00005	2.1 ppm			0.002	0.0008
Nitrite (as N)	0.05 ppm			0.00005	0.1 ppm			0.0001	0.0001
Selenium		2	10	10		2	2	2	6

NOTES:

1. Concentrations shown are from the Geraghty & Miller Phase II report dated January 1995 for monitoring wells TTI (shallow) and TT-1D (deep).
2. All concentrations are in ppb unless noted otherwise.
3. Design concentrations are based on a weighted average of the estimated concentrations for TT1 and TT1-D.
4. < Indicates reported laboratory analytical result is below detection limit.

TABLE 2

ASSUMED INFLUENT INORGANIC WATER QUALITY AND FLOWRATE

Texaco Tutu, U.S. Virgin Islands
(EKI 940058.00)

Parameter	VITELCO PROPERTY			
	MW-7 (2) Indicator Parameter	MW-7 (2) Unfiltered Metals	MW-7 (2) Filtered Metals	Design
Assumed Flowrate (gallons per minute)	-	-	-	20
Arsenic		9.2	2	2
Cadmium		3	3	3
Chromium		1050	3	5
Copper		3	3	3
Cyanide	<10			10
Lead		4.8	2	3
Mercury		1	0.1	0.1
Nickel		445	15	15
Nitrate (as N)	3.2 ppm			3 ppm
Nitrite (as N)	0.25 ppm			0.25 ppm
Selenium		2	2	2

NOTES
1. All concentrations are in ppb unless noted otherwise.
2. Concentrations shown are from the Geraghty & Miller Phase II report dated January 1995 for monitoring well MW-7.
3. < Indicates reported laboratory analytical result is below detection limit.

TABLE 3

ESTIMATED EFFFLUENT TREATED WATER CONCENTRATIONS AND EFFLUENT FEDERAL DRINKING WATER STANDARDS

Texaco Tutu, U.S. Virgin Islands

(EKI 940058.00)

Parameter	Texaco Tutu Service Station		Vitelco Property		Current Federal MCLs (1)
	Range of Typical Expected Effluent Concentrations	Expected Maximum Effluent Concentrations	Range of Typical Expected Effluent Concentrations	Expected Maximum Effluent Concentrations	
Benzene	0.1 - 5	5	0.05 - 5	5	5
Toluene	0.1 - 20	60	0.01 - 20	60	1000
Ethylbenzene	0.01 - 20	60	0.01 - 20	60	700
Xylenes (Total)	0.05 - 20	60	0.01 - 20	60	10 ppm
1,2-Dichloroethane (DCA)	1 - 5	5	3 - 5	5	5
1,2-Dichloroethene (DCE)	0.5 - 15	45	0.5 - 15	45	70
Tetrachloroethene (PCE)	0.05 - 5	5	0.05 - 5	5	5
Trichloroethene (TCE)	0.05 - 5	5	0.01 - 5	5	5
Vinyl chloride	0.05 - 2	2	0.01 - 2	2	2
Methylene Chloride	0.5 - 5	5	0.3 - 5	5	5
Arsenic	3 - 20	50	2 - 20	50	50
Cadmium	3 - 5	5	3 - 5	5	5
Chromium	3 - 15	45	5 - 15	45	100
Copper	4 - 10	30	3 - 10	30	1300
Cyanide	10 - 20	60	10 -20	60	200
Lead	3 - 10	30	3 -10	30	1300
Mercury	0.1 - 0.5	1.5	0.1 - 0.5	1.5	2
Nickel	10 - 50	100	15 - 50	100	100
Nitrate (as N)	0.8 - 10 mg/l	10 mg/l	3 - 10 mg/l	10 mg/L	10 mg/L
Nitrite (as N)	0.1 - 1 mg/l	1 mg/l	0.25 - 1 mg/l	1 mg/l	1 mg/l
Selenium	6 - 50	50	2 -50	50	50

NOTES:

1. MCL values shown are from EPA Region IX, "Drinking Water Standards and Health Advisories Table", January 1995.
2. All concentrations are in ppb unless noted otherwise.

TUT 007 1579

TABLE 4

SCREENING OF TREATMENT OPTIONS

Texaco Tutu, U.S. Virgin Islands
Source Remediation Plan
(EKI 940058.00)

Treatment Option	Description	Discussion	Conclusion
SOIL TREATMENT			
No Action	No action	Does not address the remediation goal of limiting further migration of petroleum hydrocarbon plume down-gradient.	**Reject**
Soil Vapor Extraction	Vacuum extraction wells that pull air from the soil to facilitate the removal of volatile organics	Process will work adequately with BTEX and chlorinated VOCs. Will not remove some petroleum hydrocarbons, if any. Offgas controls will likely be needed. Process will add oxygen to the soil matrix and may enhance biodegradation of BTEX.	**Retain**
Catalytic Oxidation	Destruction of vapor-phase organics by catalysis under high temperature	Process will operate satisfactorily for offgas control by destroying chemicals of concern and creating hydrochloric acid. Requires operating costs for propane.	**Retain**
Bioventing	Extraction and/or injection of air in soils to enhance biological degradation of BTEX and non-halogenated VOCs.	Soil venting as a single process is not suitable for BTEX and chlorinated VOCs. However, as discussed above, soil vapor extraction will add oxygen to the soil and may enhance biodegradation of BTEX.	**Reject**
GROUNDWATER TREATMENT			
Bio-sparging	Injection of small amounts of air to enhance the natural aerobic biodegradation of VOCs	Process is most suitable for sites with only BTEX and non-halogenated VOCs.	**Reject**
Liquid-Phase Granular Activated Carbon (GAC) Adsorption	Adsorption of liquid-phase organics onto GAC beds in series	Some Site VOCs adsorb well onto GAC; however, adsorption of vinyl chloride, 1,2-DCA, and trans-1,2-DCE is less efficient. Process removes petroleum hydrocarbons, if any. Scaling unlikely. No air quality impacts. May be required to meet discharge limits.	**Retain**
Air Stripping by Shallow-tray Aeration ("low profile" unit)	Remove VOCs from groundwater by aeration in a series of shallow trays	Process will work adequately with BTEX and chlorinated VOCs. Will not remove some petroleum hydrocarbons if present. Iron or calcium carbonate scaling may occur. Offgas controls will likely be needed at the Texaco Tutu Station Site.	**Retain**

TABLE 4

SCREENING OF TREATMENT OPTIONS

Texaco Tutu, U.S. Virgin Islands
Source Remediation Plan
(EKI 940058.00)

Treatment Option	Description	Discussion	Conclusion
Vapor-Phase GAC Adsorption	Adsorption of vapor-phase organics in air stripper exhaust onto GAC beds in series	Vinyl chloride adsorbs very poorly in the vapor phase, leading to unsatisfactory GAC usage rate. Disposal not easily implementable at this remote location.	**Reject**
Catalytic Oxidation	Destruction of vapor-phase organics by catalysis under high temperature	Will operate satisfactorily for Site VOCs by destroying chemicals of concern and creating hydrochloric acid. Requires operating costs for propane.	**Retain**
Filtration	Remove soil particulates potentially containing heavy metals	Not considered at this time pending better definition of groundwater metal levels.	**Reject**
Precipitation, flocculation, sedimentation	Processes for the removal of metals and soils	Not considered at this time pending better definition of groundwater metal levels.	**Reject**
Chemical oxiadation/reduction	Redox reactions for metals removal	Not considered at this time pending better definition of groundwater metal levels.	**Reject**
Ion Exchange	Removal of heavy metals by ion exchange resin	Not considered at this time pending better definition of groundwater metal levels.	**Reject**
Fluidized bed/GAC	A bioremediation technology that combines the use of activated carbon with aerobic or anaerobic biological processes.	Process is effective in treatment of BTEX but not for chlorinated VOCs. Maintenance of this type of bioremediation technology may not be easily implementable at this remote location.	**Reject**
Natural attentuation	Reduction of constitutent concentrations through natural attentuation/degradation	Does not address the remediation goal of limiting further migration of petroleum hydrocarbon plume down-gradient.	**Reject**

NOTES:

1. Treatment options listed here were developed by Geraghty & Miller, Inc. in the report, "Development and Screening of Remedial Alternatives, Tutu Wells Site, St. Thomas, U.S. Virgin Islands", October 1994

TABLE 5

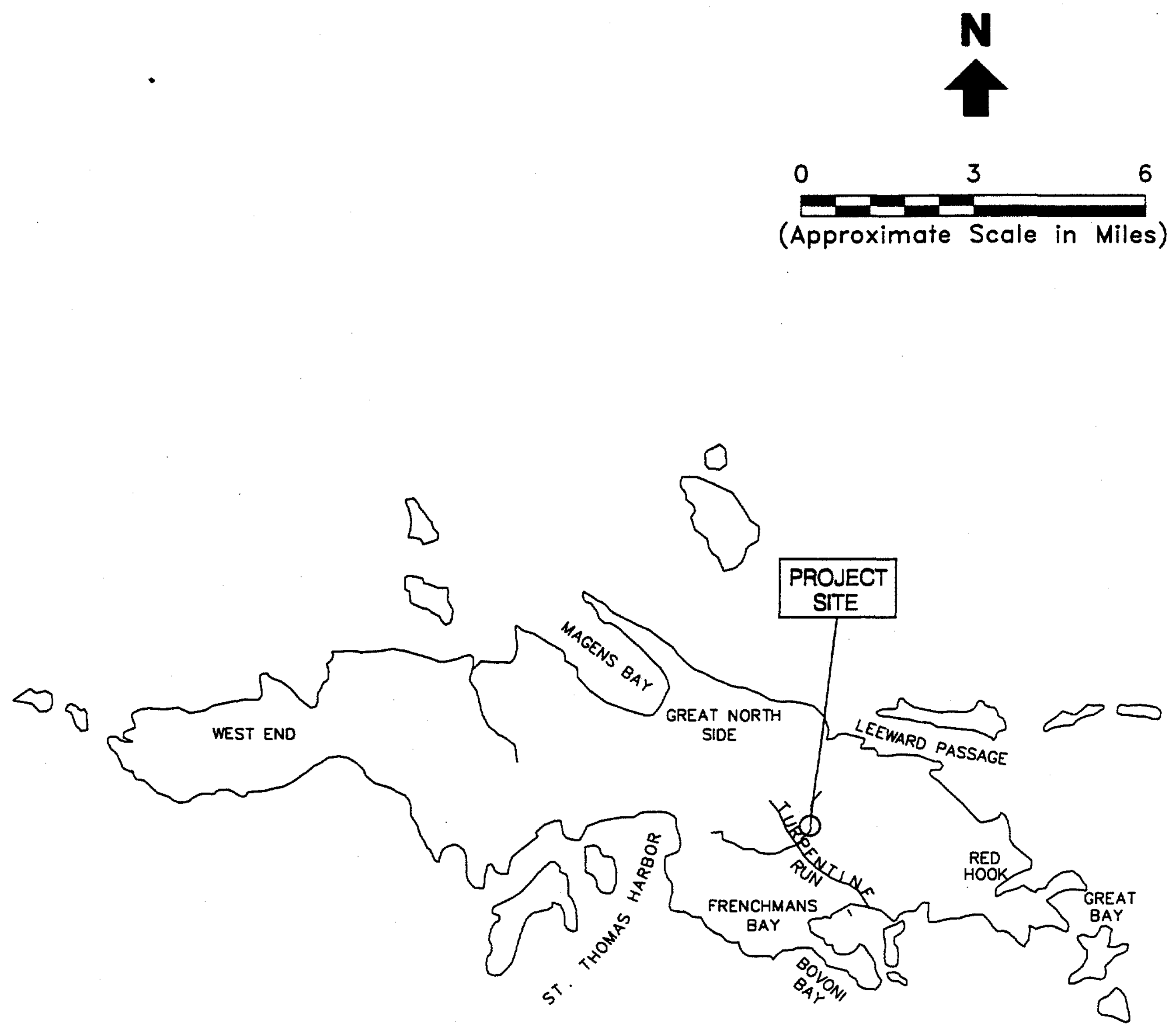
ESTIMATED AIR EMISSIONS
Texaco Tutu, U.S. Virgin Islands
(EKI 940058.00)

CHEMICALS OF CONCERN	TEXACO TUTU SERVICE STATION with Emissions Control (1)				VITELCO PROPERTY without Emissions Control (5)
	Mass in Air Air Stripper lb/day (2)	Mass in Air SVE lb/day (3)	Total Mass in Air lb/day	HCl Emissions (4)	Mass in Air Air Stripper lb/day (2)
Benzene	9	5	14	-	0.007
Toluene	9	6	15	-	0.002
Ethylbenzene	1	1	3	-	0.002
Xylene	7	4	11	-	0.002
Naphthalene	0.3	0.01	0.3	-	0.00
Methyl tert butyl ether (MTBE)	21	12	33	-	0.01
1,2-Dichloroethane (DCA)	0.2	0.01	0.2	0.1	0.001
1,2-Dichloroethene (DCE)	0.3	0.25	0.5	0.4	0.10
Tetrachloroethene (PCE)	0.04	0.01	0.05	0.05	0.03
Trichloroethene (TCE)	0.03	0.02	0.04	0.04	0.01
Vinyl chloride	0.06	0.1	0.16	0.2	0.002
Methylene Chloride	2	0.5	3	2.2	0.002
SUM HCl				2.9	

NOTES:

1. Emissions control is included in the remedial design due to benzene concentrations. Off-gas from the air stripper and SVE will be treated by catalytic oxidation.
2. Assumed air mass is based on estimated removal rates of chemicals by air stripping.
3. Assumed SVE air mass is conservatively estimated from groundwater data. Levels are expected to decrease with time.
4. Assumed hydrochloric acid (HCl) emitted to the atmosphere after air treatment by catalytic oxidation.
5. Emissions control is not included in the remedial design. Risk screening analysis (Appendix B) shows a 1×10^{-6} 70 year incremental cancer risk and a 7 year 1×10^{-7} incremental cancer risk.
6. Totals may be rounded.

FIGURES



Erler & Kalinowski, Inc.

Location of Tutu Area, St. Thomas

Texaco Tutu Service Station
St. Thomas, U.S.V.I.
April 1995
EKI 940058.00

Figure 1

TUT 007 1584

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TUTU WELLS SUPERFUND SITE
FIGURE 2
LOCATION OF THE TEXACO TUTU SERVICE STATION AND VICINITY (Page: TUT 007 1585)

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FIGURE 3
LINEAMENTS AND CROSS SECTION
LOCATIONS (Page: TUT 007 1586)

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FIGURE 4
THICKNESS (FEET) OF SEDIMENTARY AND FILL DEPOSITS (Page: TUT 007 1587)

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FIGURE 5
GROUNDWATER CONTOUR MAP, SHALLOW WELLS MAY 23-24 1994 (Page: TUT 007 1588)

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FIGURE 6
GEOLOGY AND WATER TABLE ALONG CROSS SECTION B-B' (Page: TUT 007 1589)

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FIGURE 7
SOIL SAMPLING RESULTS TEXACO TUTU SERVICE STATION (Page: TUT 007 1590)

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FIGURE 8
CONCENTRATIONS OF BENZENE (UG/L)
DETECTED IN GROUNDWATER MAY-JUNE
1994 (Page: TUT 007 1591)

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TUTU WELLS SUPERFUND SITE
FIGURE 9
CONCENTRATIONS OF TOTAL CHLORINATED VOCS (UG/L) DETECTED IN SHALLOW (<50 FEET) GROUNDWATER MAY – JUNE 1994
(Page: TUT 007 1592)

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TUTU WELLS SUPERFUND SITE
FIGURE 10
CONCENTRATIONS OF TOTAL CHLORINATED VOCS (UG/L) DETECTED IN DEEP (<50 FEET) GROUNDWATER MAY – JUNE 1994
(Page: TUT 007 1593)

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TUTU WELLS SUPERFUND SITE
FIGURE 11
CONCENTRATIONS OF VOLATILE CHEMICALS IN GROUNDWATER (UG/L) ALONG CROSS SECTION A-A'
(Page: TUT 007 1594)

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TUTU WELLS SUPERFUND SITE
FIGURE 12
BENZENE CONCENTRATIONS (UG/L) IN GROUNDWATER ALONG SECTION A-A' (UG/L)
(Page: TUT 007 1595)

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TUTU WELLS SUPERFUND SITE
FIGURE 13
TOTAL CHLORINATED VOCS (UG/L)
DETECTED IN GROUNDWATER ALONG
SECTION A-A' (Page: TUT 007 1596)

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TUTU WELLS SUPERFUND SITE
FIGURE 14
CONCENTRATIONS OF VOLATILE CHEMICALS (UG/L) DETECTED IN GROUNDWATER ALONG CROSS SECTION B-B' (Page: TUT 007 1597)

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TUTU WELLS SUPERFUND SITE
FIGURE 15
BENZENE CONCENTRATIONS (UG/L)
DETECTED IN GROUNDWATER ALONG
CROSS SECTION B-B' (Page: TUT 007 1598)

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TUTU WELLS SUPERFUND SITE
FIGURE 16
TOTAL CHLORINATED VOCS (UG/L)
DETECTED IN GROUNDWATER ALONG
CROSS SECTION B-B' (Page: TUT 007 1599)

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TUTU WELLS SUPERFUND SITE
FIGURE 17
CONCEPTUAL SITE LAYOUT FOR TEXACO AND VITELCO PROPERTIES
(Page: TUT 007 1600)

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TUTU WELLS SUPERFUND SITE
FIGURE 18
ENLARGEMENT OF CONCEPTUAL SITE LAYOUT TEXACO TUTU SERVICE STATION
(Page: TUT 007 1601)

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TUTU WELLS SUPERFUND SITE
FIGURE 19
TEXACO TUTU
(Page: TUT 007 1602)

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TUTU WELLS SUPERFUND SITE
FIGURE 20
ENLARGEMENT OF CONCEPTUAL SITE LAYOUT VITELCO PROPERTY
(Page: TUT 007 1603)

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TUTU WELLS SUPERFUND SITE
FIGURE 21
TEXACO TUTU
(Page: TUT 007 1604)

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APPENDICES

Appendix A - Hydrologic Model

APPENDIX A
HYDROLOGIC MODEL

1.0 INTRODUCTION

The Groundwater Remediation Program for the Texaco Tutu Service Station in St. Thomas, U.S.Virgin Islands includes plans for groundwater extraction at the down-gradient edge of the site and at the leading edge of the dissolved plume of gasoline constituents, approximately 400 feet to the south of the site. The overall objective for extracting groundwater is to limit further migration of chemicals of concern in groundwater. In order to design this system, estimates of groundwater extraction rates are needed. Therefore, based on the limited available hydraulic data, a numerical flow model for the site has been implemented in order to provide general estimates of groundwater extraction rates that will be required to achieve chemical capture.

2.0 HYDROGEOLOGICAL BACKGROUND

The primary aquifer in the Turpentine Run basin (Tutu Wells area) is unconfined and consists of fractured volcanic rock with relatively low permeabilities (Jordan and Cosner, 1973). The available hydrologic reports indicate that higher permeability conditions exist near the Texaco Tutu Service Station and northern portion of the Four Winds Shopping Center, due to the intersection of two fracture zones (Geraghty & Miller, Inc., May 1993; Hydrologic Associates U.S.A., Inc., October 1993).

3.0 COMPUTER CODE

The computer program FLOWPATH version 5 (Waterloo Hygrogeologic Software, 1994) has been used in this study. This model can simulate steady-state, two-dimensional horizontal aquifer flow. Model output includes groundwater elevation contour maps and capture zones.

4.0 MODEL ASSUMPTIONS

The following assumptions have been made in implementing FLOWPATH:

1. The system is sufficiently fractured that it can be modeled as an equivalent porous medium. Though this assumption is not likely to hold across the model domain, it has been made in order to allow a general data evaluation using numerical methods.
2. There is no groundwater pumping from existing water supply wells during the simulation period.
3. Infiltration and evaporation are neglected. Based on studies by the U.S. Geological Survey (Jordan and Cosner, 1973), 90 to 95 percent of rainfall is

returned to the atmosphere throughout the year. Therefore, the influence of rainfall and evaporation on groundwater levels can be assumed to be negligible.
4. The aquifer is isotropic, i.e., the conductivity at one point is the same in all directions. As discussed in Geraghty & Miller (1994), data developed during pumping of the Eglin III Supply Well demonstrated the existence of horizontal and vertical anisotropy in the shallow aquifer. However, inasmuch as no additional information about the degree of anisotropy is available, a simpler model of isotropy has been assumed.
5. For unconfined aquifers, the saturated thickness is a function of the groundwater elevation and the elevation of the bottom of the aquifer. The model incorporates measured hydraulic heads and assumes a bottom elevation of 90 feet, the assumed depth of contamination in the aquifer. FLOWPATH assumes all pumping wells fully penetrate the aquifer.
6. There is no vertical heterogeneity. In the absence of detailed hydrogeologic information, it is reasonable to neglect potential stratification of the aquifer and use a simpler 2-D model.

5.0 MODEL GRID

The size of the model domain is 2,000 feet by 2,000 feet. The finite-difference grid contains 33 rows and 33 columns. Smaller cells are used near the Texaco Service Station and potential locations of extraction wells. Figure A1 shows the domain and the grid of the model.

6.0 BOUNDARY CONDITIONS

The following boundary conditions have been applied to the FLOWPATH model:
1. Constant Head Boundaries: the northern (upper) boundary is set at a constant head value of 190 feet above mean sea level, and several constant heads (140 feet to 155 feet above mean sea level) are set along the southern (lower) boundary, in order to satisfy both non-pumping and pumping conditions inside the domain.
2. No-Flow Boundaries: the model assumes no water enters or exits from the lateral boundaries of the domain. This is consistent with low permeability conditions measured in the volcanic bedrock in areas that are not fractured.

7.0 MODEL INPUT

7.1 Porosity

The porosity of the aquifer is assumed to be 0.1. This value is consistent with the value incorporated in the computer simulation done by Gartner Lee International Inc. (1993).

7.2 Hydraulic Conductivity

The results of previous aquifer pumping tests were reviewed and evaluated for selecting conductivity values for the model. Table 1 shows results of some previous aquifer pumping tests and estimated hydraulic conductivities near the Texaco Service Station.

Table 1: Hydraulic Data from Previous Aquifer Pumping Tests

Pumping Test Well	Well Depth* (ft)	Estimated Transmissivity (gpd/ft)	Estimated Hydraulic Conductivity (ft/day)
MW-6R [1]	17	90,360	716
Tillett [2]	85	20,000	31
Four Winds III [3]	300	25,755	11.5
CHT-6D [3]	300	20,470 to 25,750	9.14 to 11.5

* below top of well casing

1. Geraghty & Miller (November, 1992)
2. Hamlin (July, 1985)
3. Hydrologic Associates, Inc. (1993)

Based upon these data and the results of a lineament study reported in Geraghty & Miller (1994), hydraulic conductivity values have been assigned to the model grids as illustrated on Figure A2. The area of highest hydraulic conductivity includes the Texaco Service Station, the northern portion of the Four Winds parking lot, and the vicinity of the Tillett supply well (Area 1 in Figure A2). On the basis of lineament analysis (Geraghty & Miller, 1994), this area is thought to be the most highly fractured in the Tutu Basin. Furthermore, relatively high hydraulic conductivities have been measured in this area at monitoring well MW-6R and the Tillett supply well.

The hydraulic conductivity of 716 ft/day, measured during the aquifer pumping test at MW-6R (Table 1), has been neglected for two reasons. First, monitoring well MW-6R is 17 feet deep and much shallower than the planned extraction wells. Therefore, results from this test are not likely to be representative of the modeled aquifer. Secondly, this value is about one order of magnitude greater than the values measured during other aquifer pumping tests. This suggests that results from monitoring well MW-6R may be anomalously high. For example, the Tillett well, which is screened to the depth of the planned extraction wells (approximately 100 feet), has a hydraulic conductivity of 31 ft/day. This value is thought to be more representative of the aquifer where it is highly fractured. Therefore the model has been calibrated assuming a hydraulic conductivity value for Area 1 of K1 = 30 feet/day.

Contiguous zones of potentially fractured rock (Area 3 in Figure A2), have been assigned a hydraulic conductivity of 11 feet/day as was measured during the aquifer pumping test at the Four Winds III well. A transition zone, Area 2 in Figure A2, is included in order to eliminate discontinuities in the numerical model. This area has been assigned a hydraulic conductivity value of 18 feet/day, an intermediate value.

The rest of the domain, Area 4, has been assigned a hydraulic conductivity value of 0.1 feet day, consistent with values measured for relatively unfractured volcanic rocks. The final selection of hydraulic conductivity input was performed during Model Calibration, discussed below.

8.0 MODEL CALIBRATION

The model has been calibrated against both: (1) steady-state, non-pumping conditions and (2) transient, pumping conditions.

8.1 Steady State Calibration

Groundwater elevations measured on September 28, 1992 (Geraghty & Miller, 1993; Figure 3-2) were selected as representative of steady state conditions. Using the assumptions and input values, discussed above, model simulations successfully reproduced these measured groundwater elevations. A simulated groundwater contour map at steady state is illustrated on Figure A3.

8.2 Transient State Calibration

Limited data are available for performing a transient state calibration. Geraghty & Miller (1993; Appendix H), reported that a pumping rate of 9.25 gpm at MW-6R does not affect groundwater elevations at monitoring wells MW- 4, MW-5, and MW-7. This aquifer pumping test was simulated using the numerical model and similar results were observed.

Hamlin (1985) reports that the Tillett well sustained a pumping rate of 46.4 gpm. This pumping rate was evaluated using the numerical model and was found to be sustainable in the model.

After testing various values of hydraulic conductivity for K1, K2, K3, and K4 during the model calibration phase, a final set of values were selected that best fit the measured data. These values are given in Table 2, below.

Table 2 - Final Hydraulic Conductivity Input Values

conductivity region	Conductivity value (ft/day)
Area 1 (K1)	30
Area 2 (K2)	18
Area 3 (K3)	11
Area 4 (K4)	0.1

9.0 EVALUATION OF EXTRACTION WELL LOCATIONS AND PUMPING RATES

Four different groundwater extraction scenarios were evaluated during this study. Scenarios 1 and 2 consider two extraction well locations at the Texaco site and one location down-gradient on the Vitelco property. Scenarios 3 and 4 consider single extraction wells on each of the two properties

9.1 Scenario 1 - Two Texaco Wells Extract at 5 gpm, Each One Vitelco Well Extracts at 10 gpm

Scenario 1 considers three extraction wells with the locations shown on Figure A4.

Two extraction wells (T-1 and T-2) are located on the down-gradient edge of Texaco Tutu Service Station, close to Monitoring Well TT-1. Their function is to remediate and limit migration of highly contaminated groundwater at the Texaco Station. Two wells are considered in this scenario so that dewatering is minimized in the vicinity of the Curriculum Center, which is located northeast of Texaco. Pumping rates for T-1 and T-2 are 5 gpm for each well.

Another extraction well (P-1) is located adjacent to monitoring well MW-7 south of the Texaco Station on the Vitelco property. In this scenario it is pumped at a rate of 10 gpm. Extraction well P-1 is located at the leading edge of the Texaco plume and is intended to capture chemicals and limit their future migration.

The results of the Scenario 1 simulation are shown in Figure A5, A6, and A7. Figure A5 illustrates the resultant groundwater elevations and shows that approximately 3 feet of drawdown could be induced in the vicinity of the Curriculum Center. The capture zone at the Texaco Station (Figure A6) appears more than adequate to capture chemicals in groundwater. The capture zone at the Vitelco property (Figure A7) appears adequate to capture chemicals at the leading edge of the plume.

9.2 Scenario 2 - Two Texaco Wells Extract at 10 gpm, Each

One Vitelco Well Extracts at 10 gpm

In scenario 2, three wells with the same locations as in Scenario 1 are simulated. The pumping rate for P-1 is the same with 10 gpm. However, the pumping rates for T-1 and T-2 are increased to 10 gpm for both wells in order to observe the drawdown near the Curriculum Center. The capture zones become greater by increasing the pumping rates of Well T-1 and T-2, while the drawdown near the Curriculum Center also increases to 5 feet in this scenario. The simulated groundwater contours and the capture zones are shown on Figures A8, A9, and A10.

9.3 Scenario 3 - One Texaco Well Extracts at 10 gpm One Vitelco Well Extracts at 10 gpm

Two extraction wells are considered in this scenario and their locations are shown on Figure A11. In this scenario, only one extraction well (T-3) is installed along the down-gradient property line of the Texaco Station, close to monitoring well TT-1. The pumping rate for T-3 is 10 gpm. The Vitelco extraction well, P-1, is pumped at 10 gpm in this scenario. The total extraction rate, therefore, is the same as in Scenario 1. The resultant groundwater contour map and the capture zones for these two wells are shown on Figures A12, A13, and A14. In this simulation, the drawdown at the Curriculum Center is about 3 feet, which is the same as in Scenario 1. The results of this simulation suggest that only one extraction well (T-3) at the Texaco Service Station may be adequate for achieving chemical capture.

9.4 Scenario 4 - One Texaco Well Extracts at 20 gpm One Vitelco Well Extracts at 10 gpm

Two wells with the same locations as in Scenario 3 are considered in this scenario. The pumping rate for P-1 is the same, 10 gpm, while the pumping rate for T-3 increases to 20. The resultant groundwater contour map and the capture zones are shown on Figures A15, A16, and A17. Figure A15 shows that the drawdown near the Curriculum Center increases to 5 feet in this scenario.

10.0 CONCLUSIONS

The effects of pumping from extraction wells constructed at the down-gradient edge of the Texaco Tutu Service Station and the up-gradient edge of the Vitelco property were evaluated using the numerical flow model, FLOWPATH. Results of simulations indicate that a single extraction well with a flow rate of 10 gpm located along the down-gradient edge of the Texaco Tutu Service Station should be adequate to capture chemicals at the site. Pumping groundwater from two extraction wells with flow rates of 5 gpm each should also be adequate for achieving chemical capture. Under both scenarios, a drawdown of approximately 3 feet is predicted for the area of potential DNAPL located near monitoring well MW-16, north of the Curriculum Center.

Increasing extraction rates for the Texaco site to 20 gpm for either one or two wells (combined flow) results in predicted drawdowns of approximately 5 feet in the area of potential DNAPL located near monitoring well MW-16, north of the Curriculum Center.

Model simulations further indicate that groundwater extraction at a single location at the northern edge of the Vitelco property should likely be adequate for achieving capture of chemicals at the front of the chemical plume.

Because of the numerous assumptions embedded in the model, these results should be considered a guide for design purposes. Actual conditions are likely to be variable given the fractured nature of the bedrock in the Tutu area.

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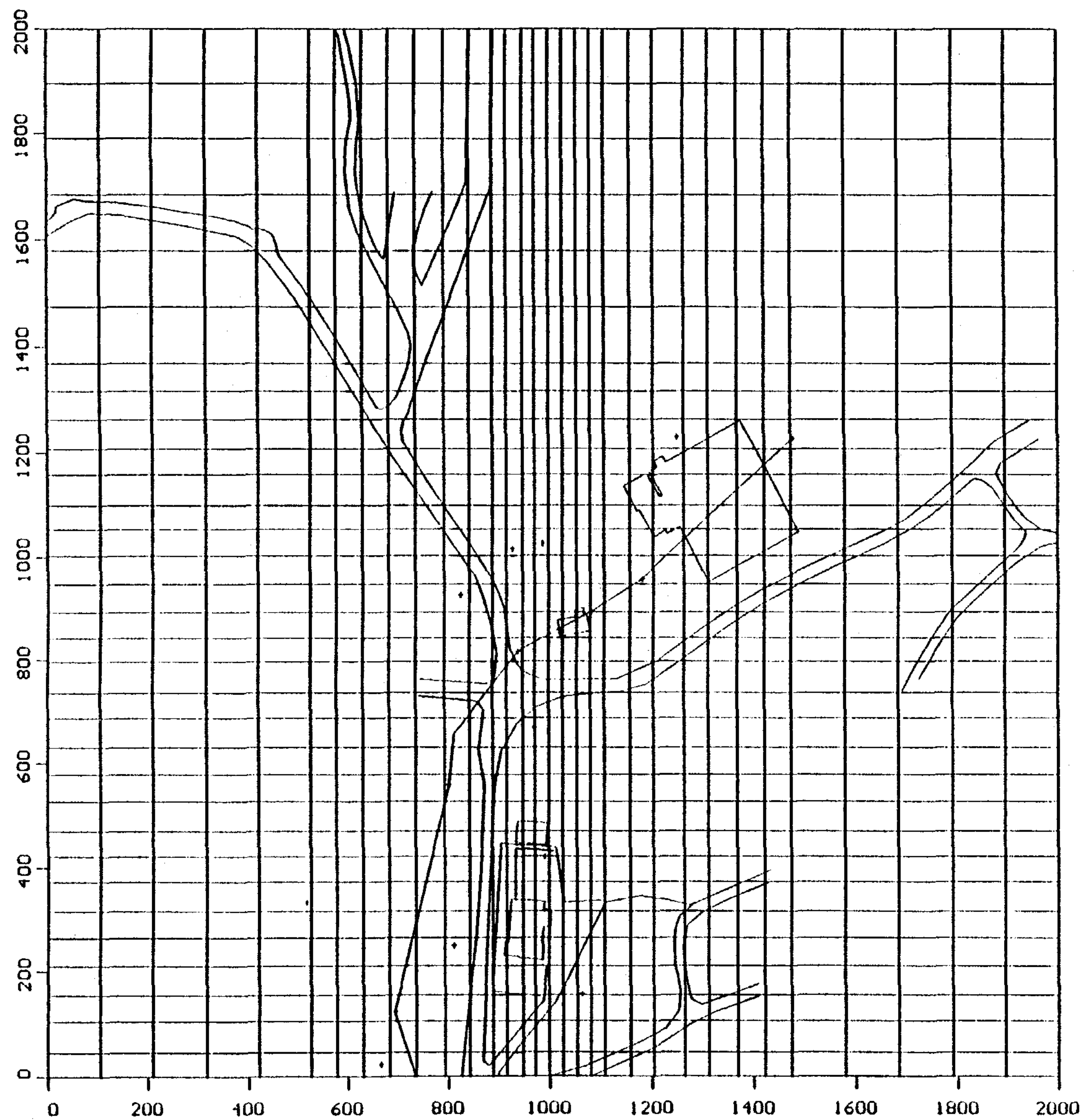

FLOWPATH 5.04

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Model Dimensions

No. rows	:	33
No. columns	:	33
No. pumps	:	0
No. injct	:	0
No. const. heads	:	68
No. const. flux	:	0
No. river nodes	:	0
No. drain nodes	:	0

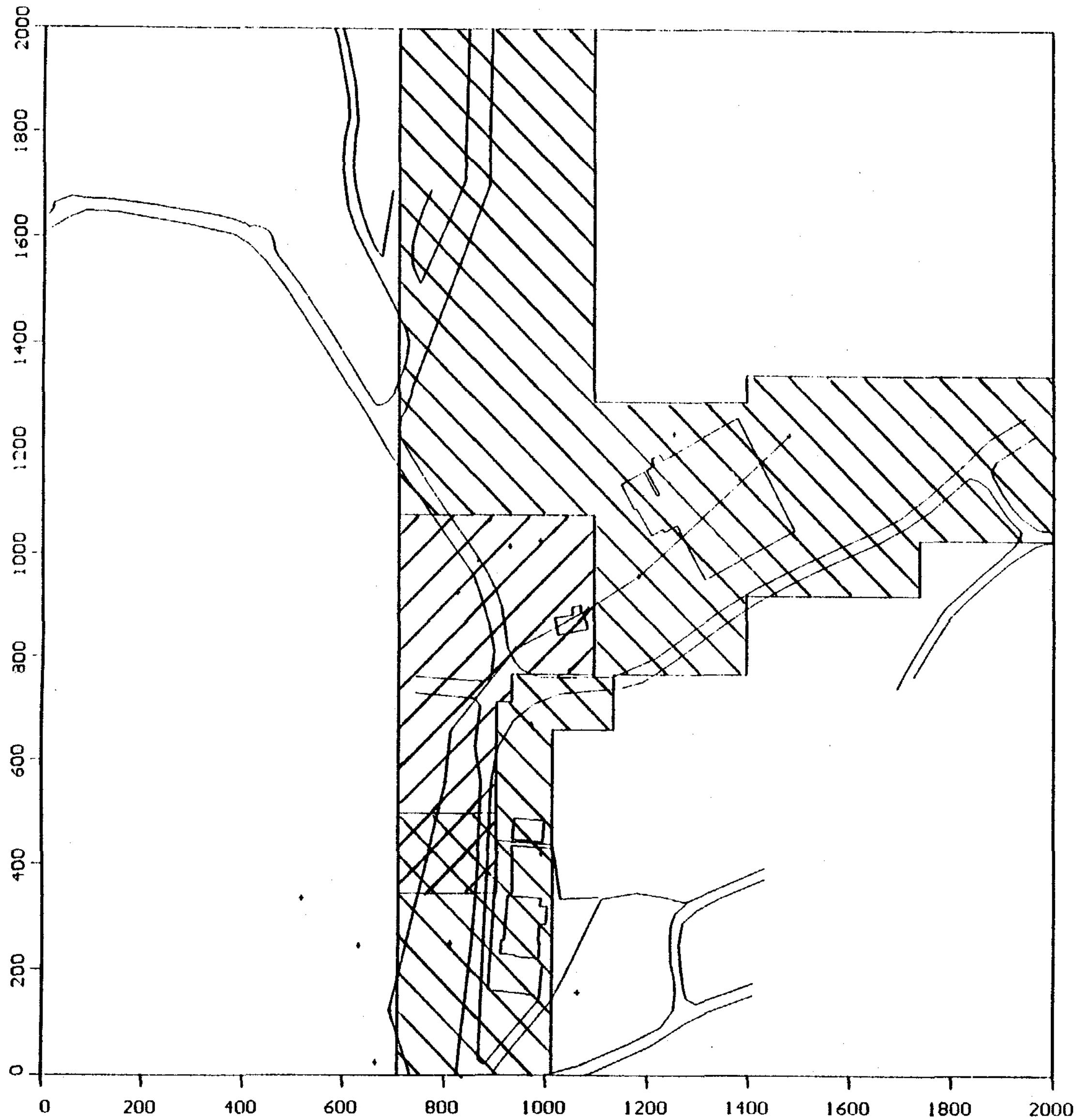
Units : [ft][day]

Data Set : FLOWBASE

Erler & Kalinowski, Inc.

Modeling Domain and Grid

FLOWPATH Output
Texaco Tutu Service Station
St. Thomas, U.S.V.I.
April 1995
EKI 940058.00
Figure A1



FLOWPATH 5.04

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software

Model Dimensions

No. rows : 33
No. columns : 33
No. pumps : 0
No. injct : 0
No. const. heads : 68
No. const. flux : 0
No. river nodes : 0
No. drain nodes : 0

Hydraulic Heads (ft)
Min : 140.000
Max : 190.000

Units : [ft][day]

Data Set : FBASE

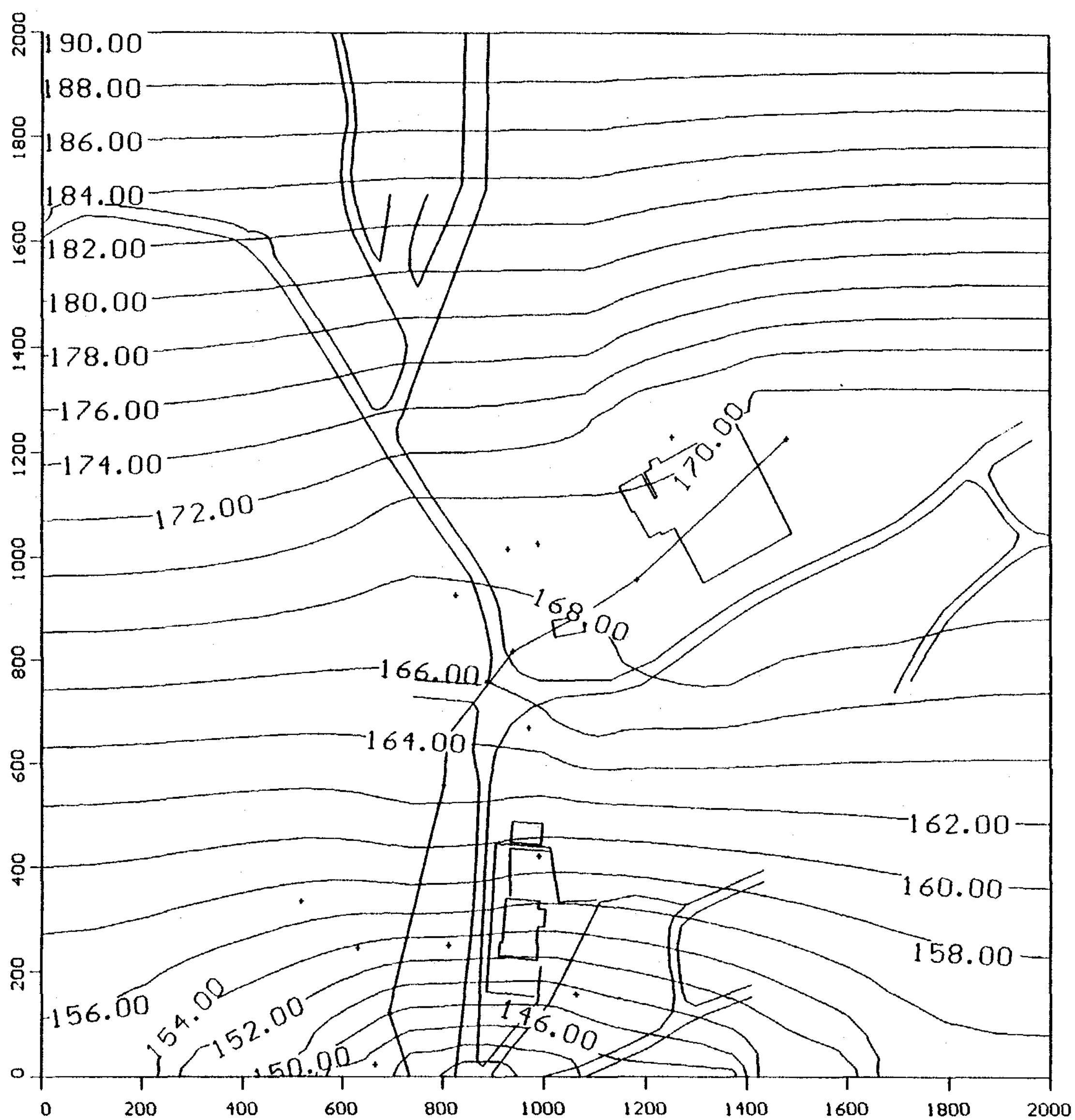
Area 1	K1 = 30 feet/day
Area 2	K2 = 18 feet/day
Area 3	K3 = 11 feet/day
Area 4	K4 = 0.1 feet/day

Erler & Kalinowski, Inc.

Hydraulic Conductivity Values

FLOWPATH Output
Texaco Tutu Service Station
St. Thomas, U.S.V.I.
April 1995
EKI 940058.00
Figure A2

TUT 007 1615



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Model Dimensions

No. rows	: 33
No. columns	: 33
No. pumps	: 0
No. injct	: 0
No. const. heads	: 68
No. const. flux	: 0
No. river nodes	: 0
No. drain nodes	: 0

Hydraulic Heads (ft)
Min : 140.000
Max : 190.000

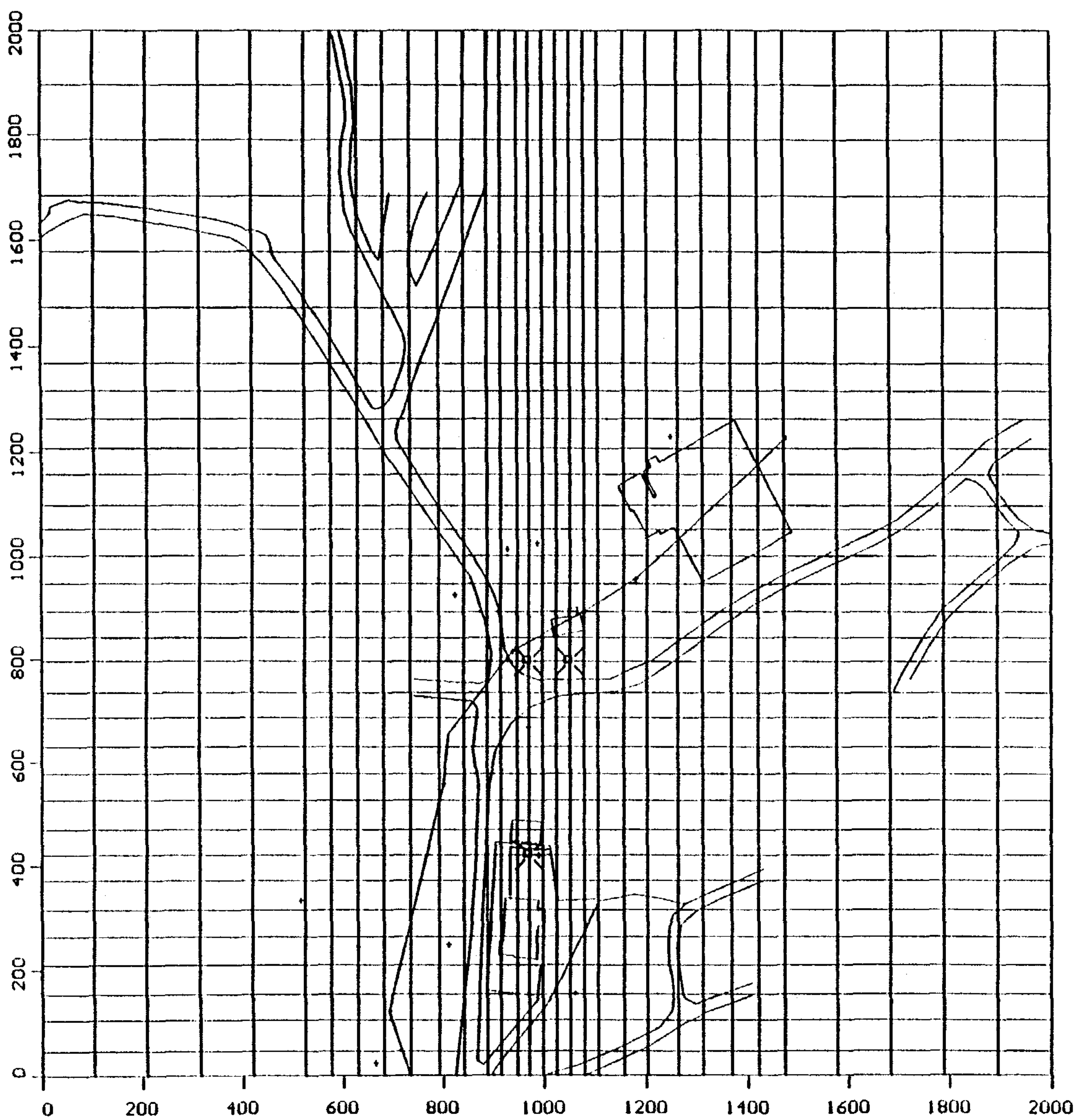
Units : [ft][day]
Data Set : FBASE

Erler & Kalinowski, Inc.

Simulated Groundwater Elevations Without Pumping

FLOWPATH Output

Texaco Tutu Service Station
St. Thomas, U.S.V.I.
April 1995
EKI 940058.00
Figure A3



FLOWPATH 5.04

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software

Model Dimensions

No. rows	: 33
No. columns	: 33
No. pumps	: 3
No. injct	: 0
No. const. heads	: 68
No. const. flux	: 0
No. river nodes	: 0
No. drain nodes	: 0

Units : [ft][day]

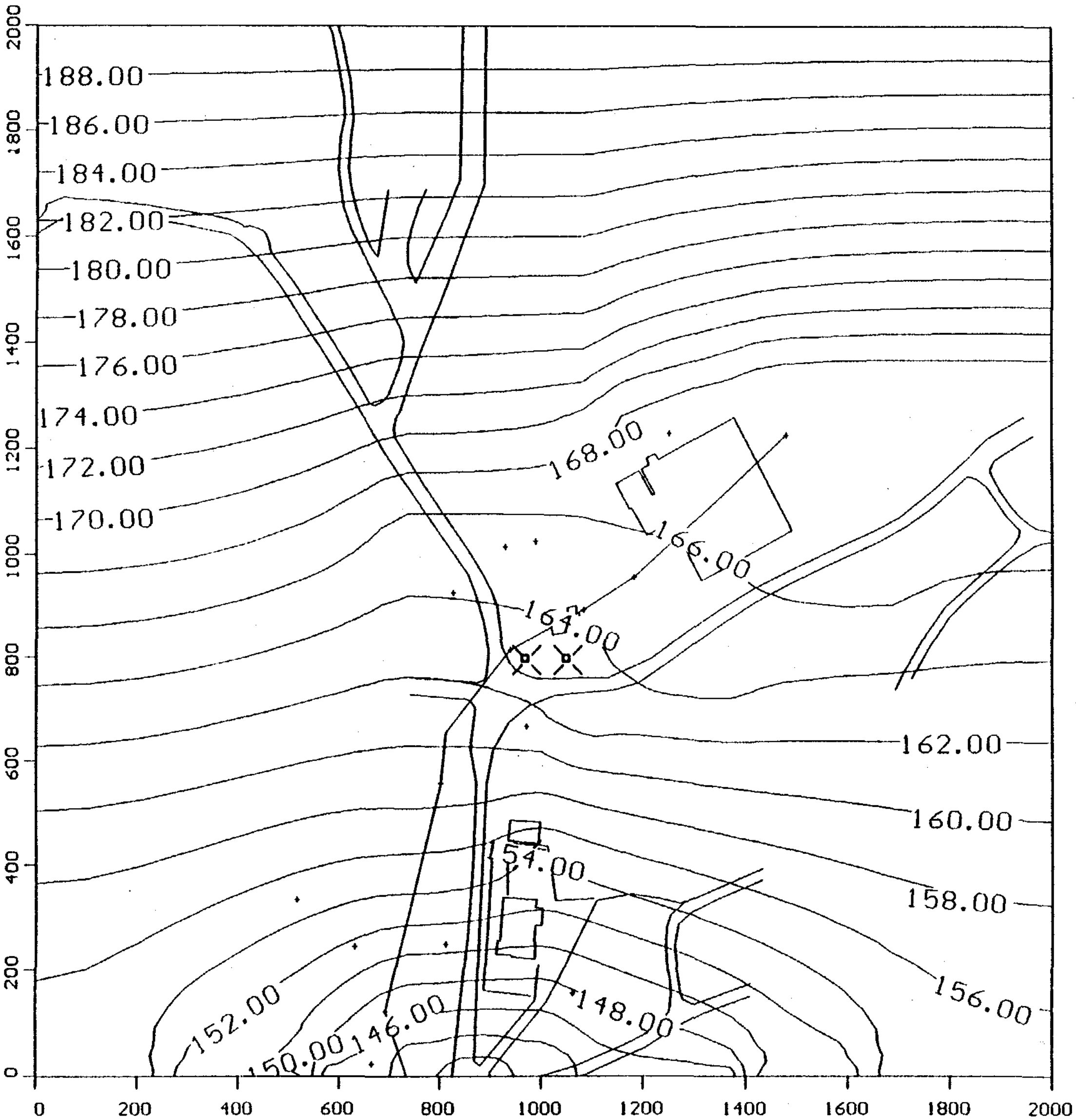
Data Set : FLOW2

Erler & Kalinowski, Inc.

Scenarios 1 and 2 - Extraction Well Locations

FLOWPATH Output
Texaco Tutu Service Station
St. Thomas, U.S.V.I.
April 1995
EKI 940058.00
Figure A4

TUT 007 1617



FLOWPATH 5.04

Model Dimensions

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No. columns	: 33
No. pumps	: 3
No. injct	: 0
No. const. heads	: 68
No. const. flux	: 0
No. river nodes	: 0
No. drain nodes	: 0

Hydraulic Heads (ft)

Min :	140.000
Max :	190.000

Units : [ft][day]

Data Set : F1

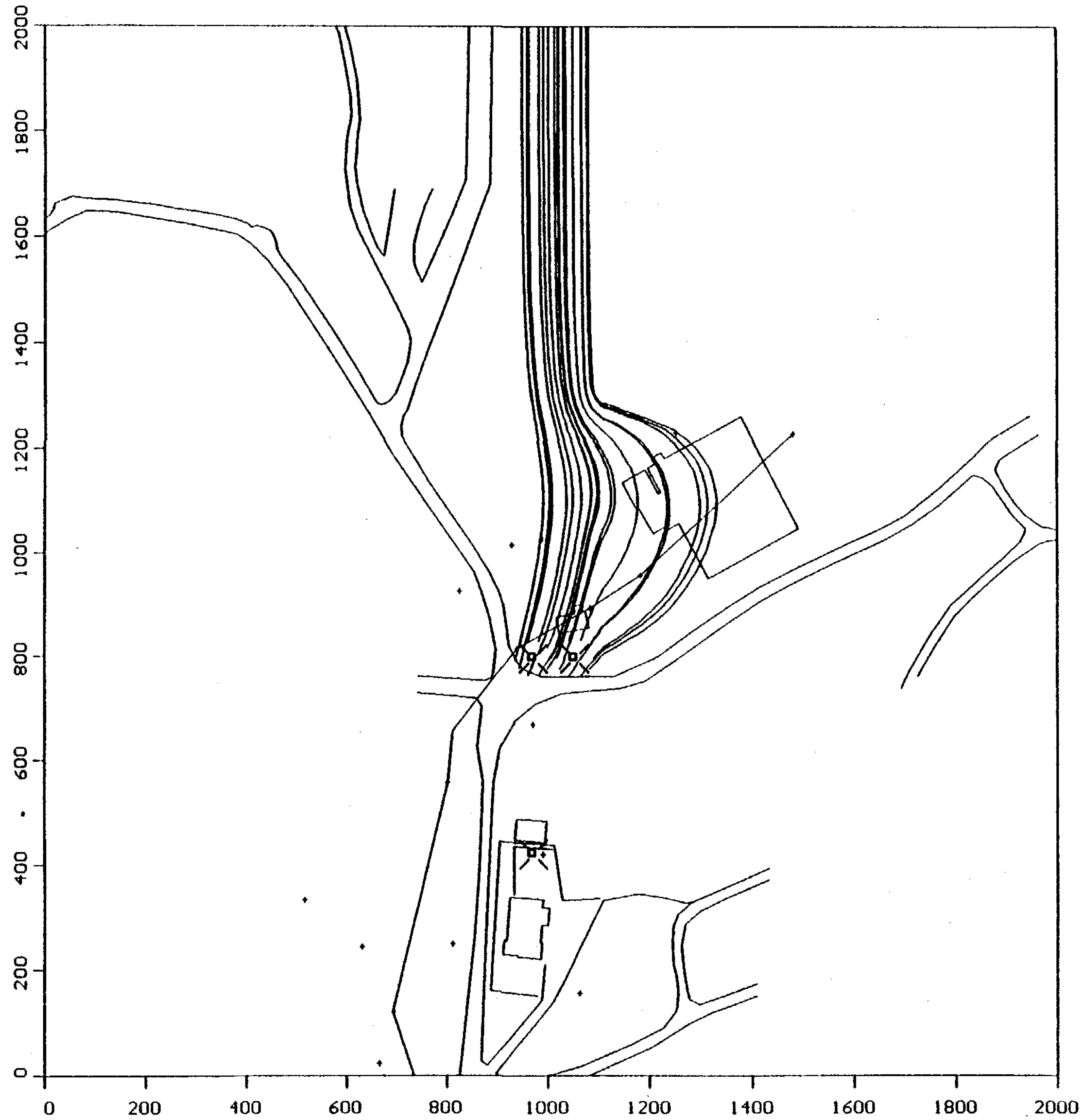
Erler & Kalinowski, Inc.

Scenario 1 - Simulated Groundwater Elevations With Pumping

FLOWPATH Output

Texaco Tutu Service Station
St. Thomas, U.S.V.I.
April 1995
EKI 940058.00
Figure A5

TUT 007 1618



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Model Dimensions

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No. columns	:	33
No. pumps	:	3
No. injct	:	0
No. const. heads	:	68
No. const. flux	:	0
No. river nodes	:	0
No. drain nodes	:	0

Units : [ft][day]

Data Set : F1

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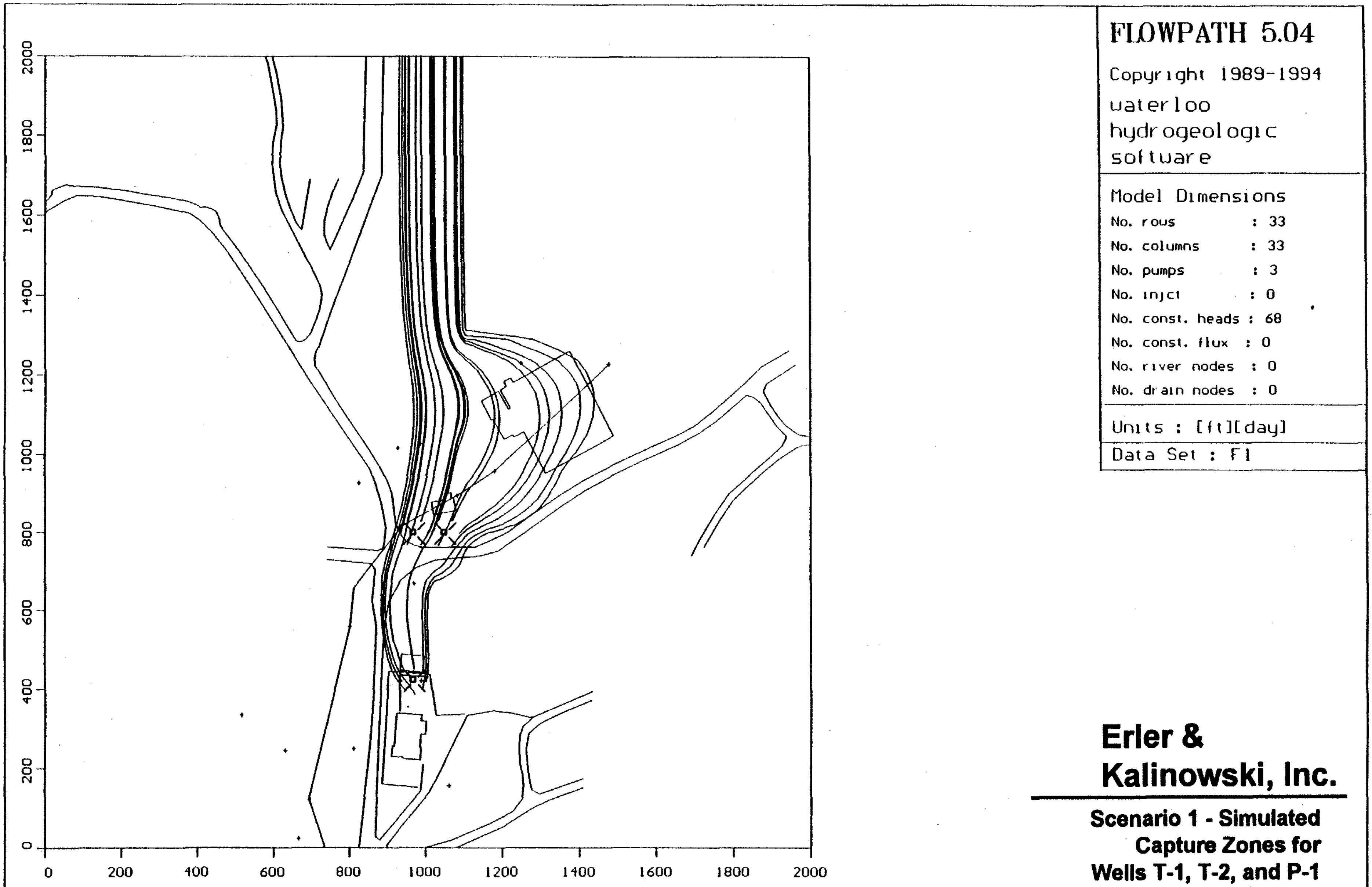
Scenario 1- Simulated Capture Zones for Wells T-1 and T-2

FLOWPATH Output

Texaco Tutu Service Station
St. Thomas, U.S.V.I.
April 1995
EKI 940058.00

Figure A6



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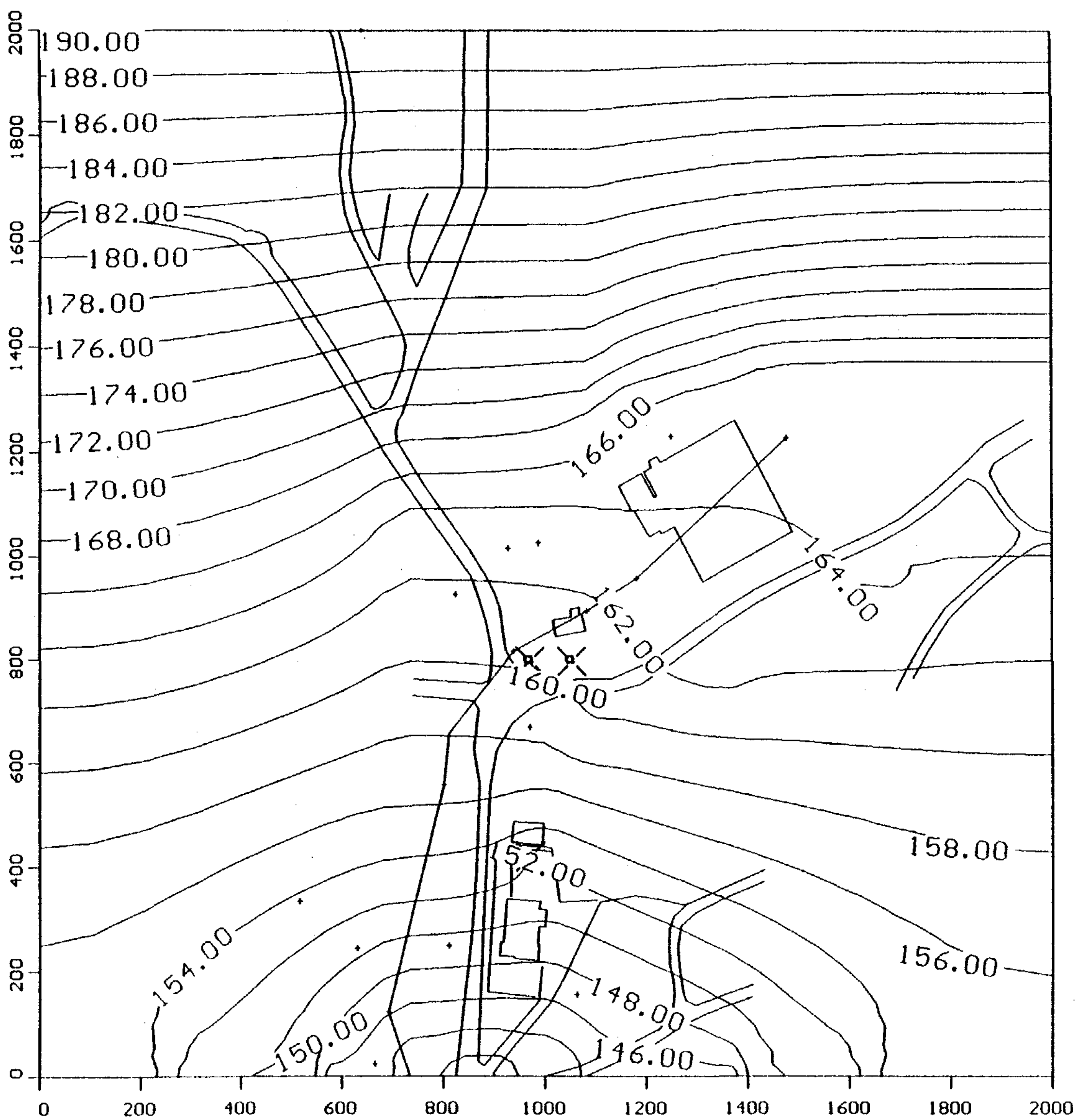
Scenario 1 - Simulated Capture Zones for Wells T-1, T-2, and P-1

FLOWPATH Output
Texaco Tutu Service Station
St. Thomas, U.S.V.I.
April 1995
EKI 940058.00
Figure A7



FLOWPATH 5.04

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Model Dimensions

No. rows	: 33
No. columns	: 33
No. pumps	: 3
No. injct	: 0
No. const. heads	: 68
No. const. flux	: 0
No. river nodes	: 0
No. drain nodes	: 0

Hydraulic Heads (ft)

Min : 140.000

Max : 190.000

Units : [ft][day]

Data Set : F2

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Scenario 2 - Simulated Groundwater Elevations With Pumping

FLOWPATH Output

Texaco Tutu Service Station
St. Thomas, U.S.V.I.
April 1995
EKI 940058.00
Figure A8

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Model Dimensions

No. rows	:	33
No. columns	:	33
No. pumps	:	3
No. injct	:	0
No. const. heads	:	68
No. const. flux	:	0
No. river nodes	:	0
No. drain nodes	:	0

Units : [ft][day]

Data Set : F2

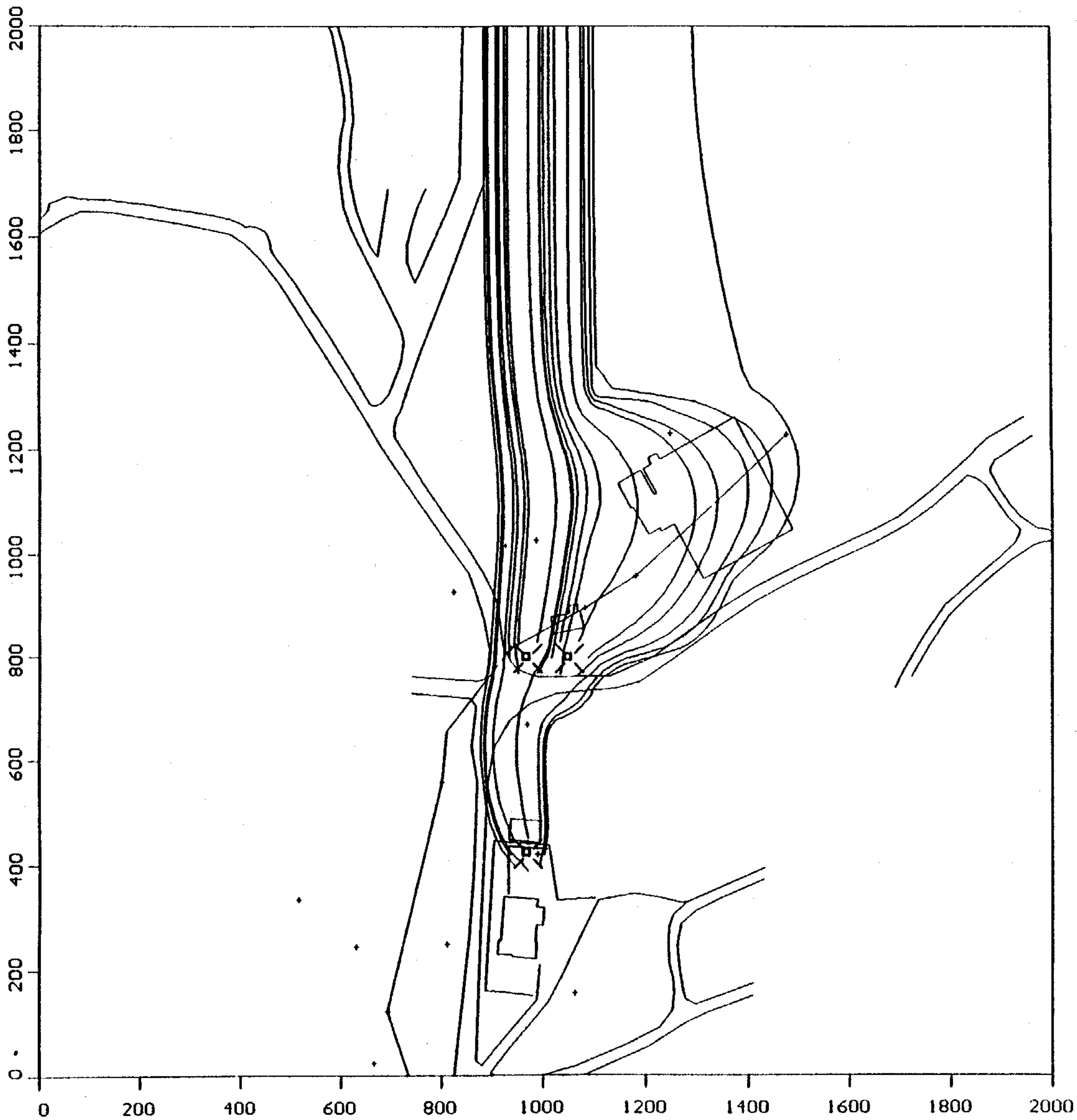
Erler & Kalinowski, Inc.

Scenarios 2 - Simulated Capture Zones for Wells T-1 and T-2

FLOWPATH Output

Texaco Tutu Service Station
St. Thomas, U.S.V.I.
April 1995
EKI 940058.00

Figure A9



FLOWPATH 5.04

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Model Dimensions

No. rows	: 33
No. columns	: 33
No. pumps	: 3
No. injct	: 0
No. const. heads	: 68
No. const. flux	: 0
No. river nodes	: 0
No. drain nodes	: 0

Units : [ft][day]

Data Set : F2

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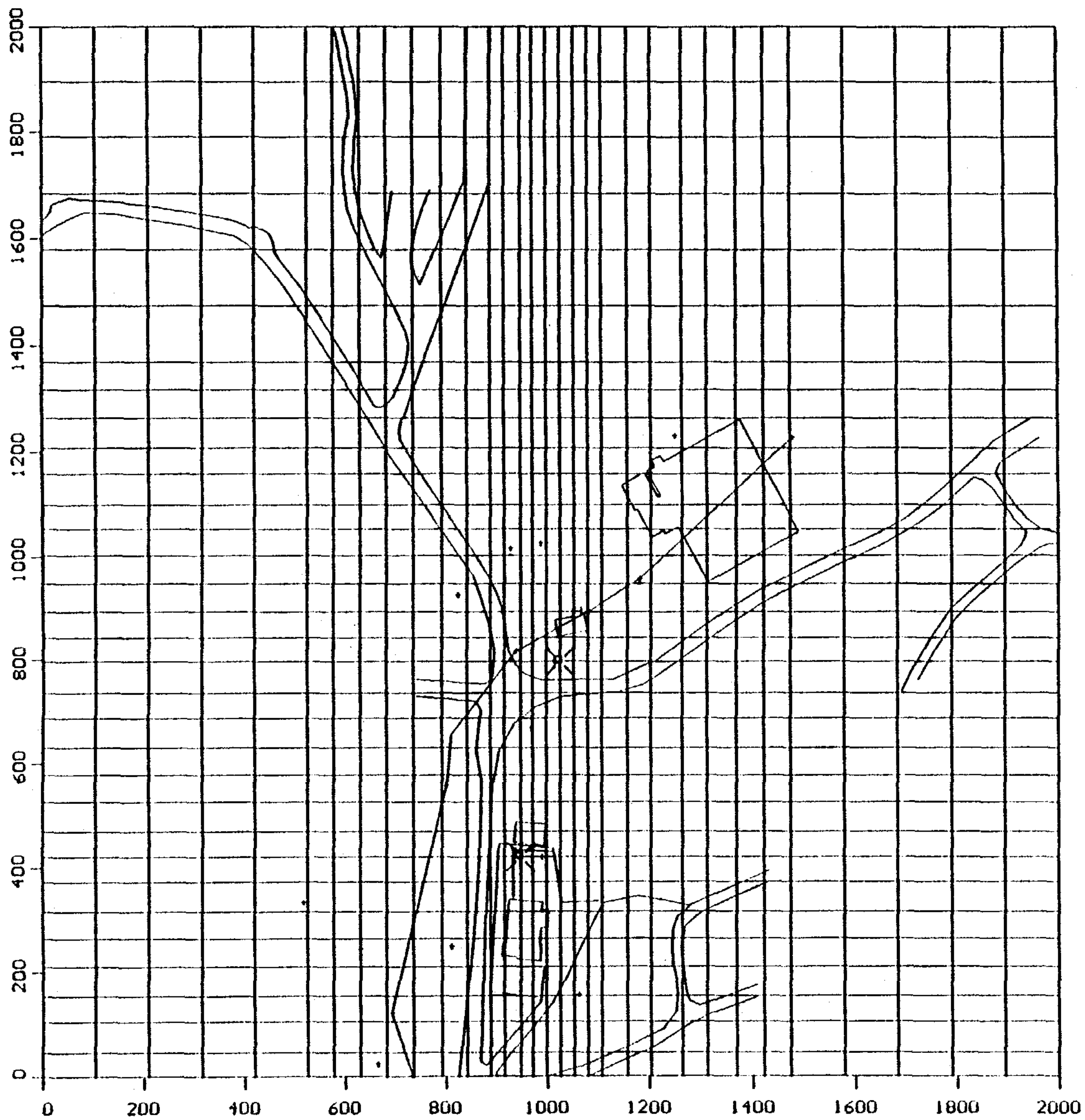
Scenario 2 - Simulated Capture Zones for Wells T-1, T-2, and P-1

FLOWPATH Output

Texaco Tutu Service Station
St. Thomas, U.S.V.I.
April 1995
EKI 940058.00
Figure A10



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Model Dimensions

No. rows	: 33
No. columns	: 33
No. pumps	: 2
No. injct	: 0
No. const. heads	: 68
No. const. flux	: 0
No. river nodes	: 0
No. drain nodes	: 0

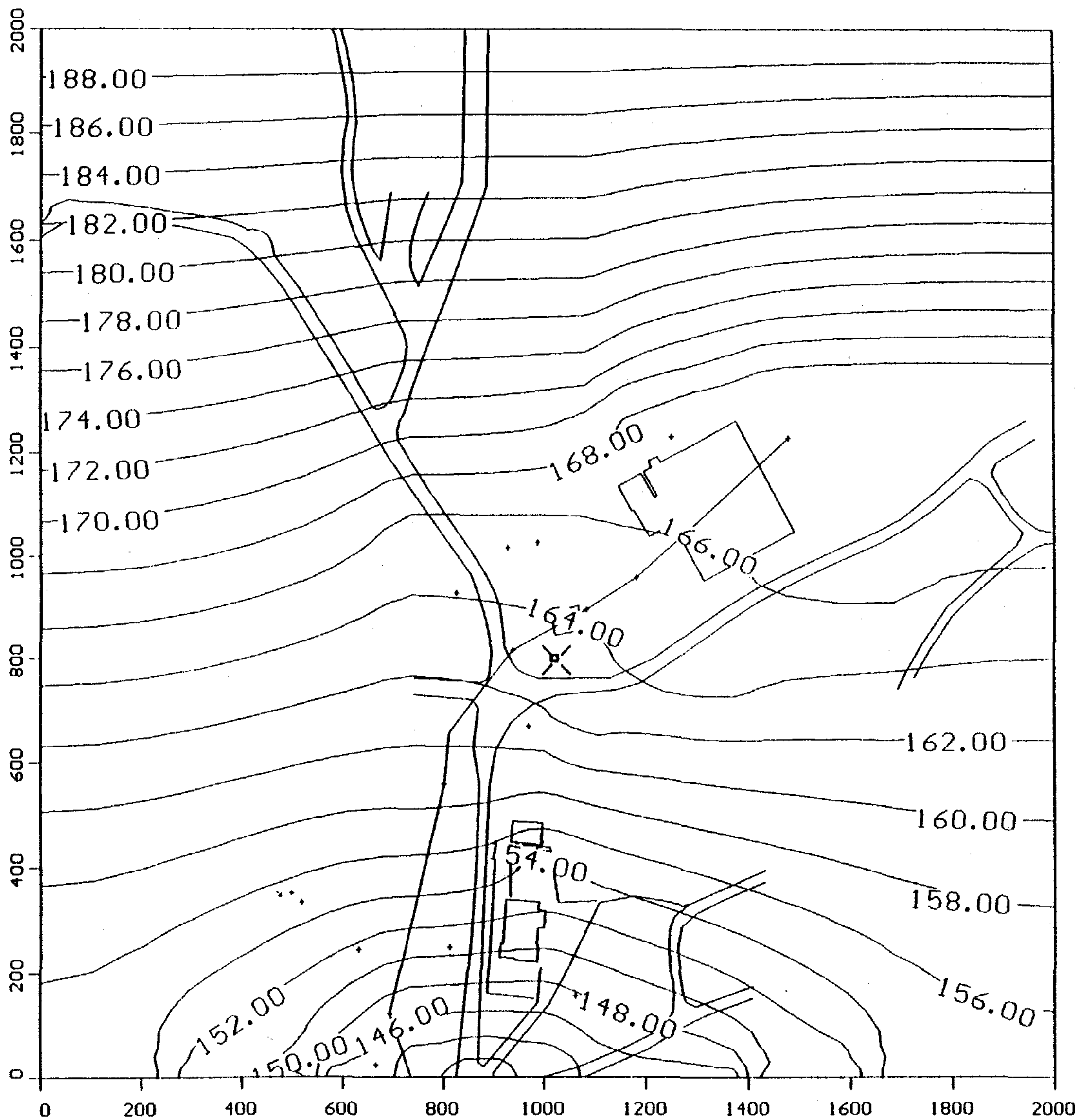
Units : [ft][day]

Data Set : FLOW3

Erler & Kalinowski, Inc.

**Scenarios 3 and 4 -
Extraction Well Locations**

FLOWPATH Output
Texaco Tutu Service Station
St. Thomas, U.S.V.I.
April 1995
EKI 940058.00
Figure A11



FLOWPATH 5.04

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Model Dimensions

No. rows	: 33
No. columns	: 33
No. pumps	: 2
No. injct	: 0
No. const. heads	: 68
No. const. flux	: 0
No. river nodes	: 0
No. drain nodes	: 0

Hydraulic Heads (ft)

Min :	140.000
Max :	190.000

Units : [ft][day]

Data Set : F3

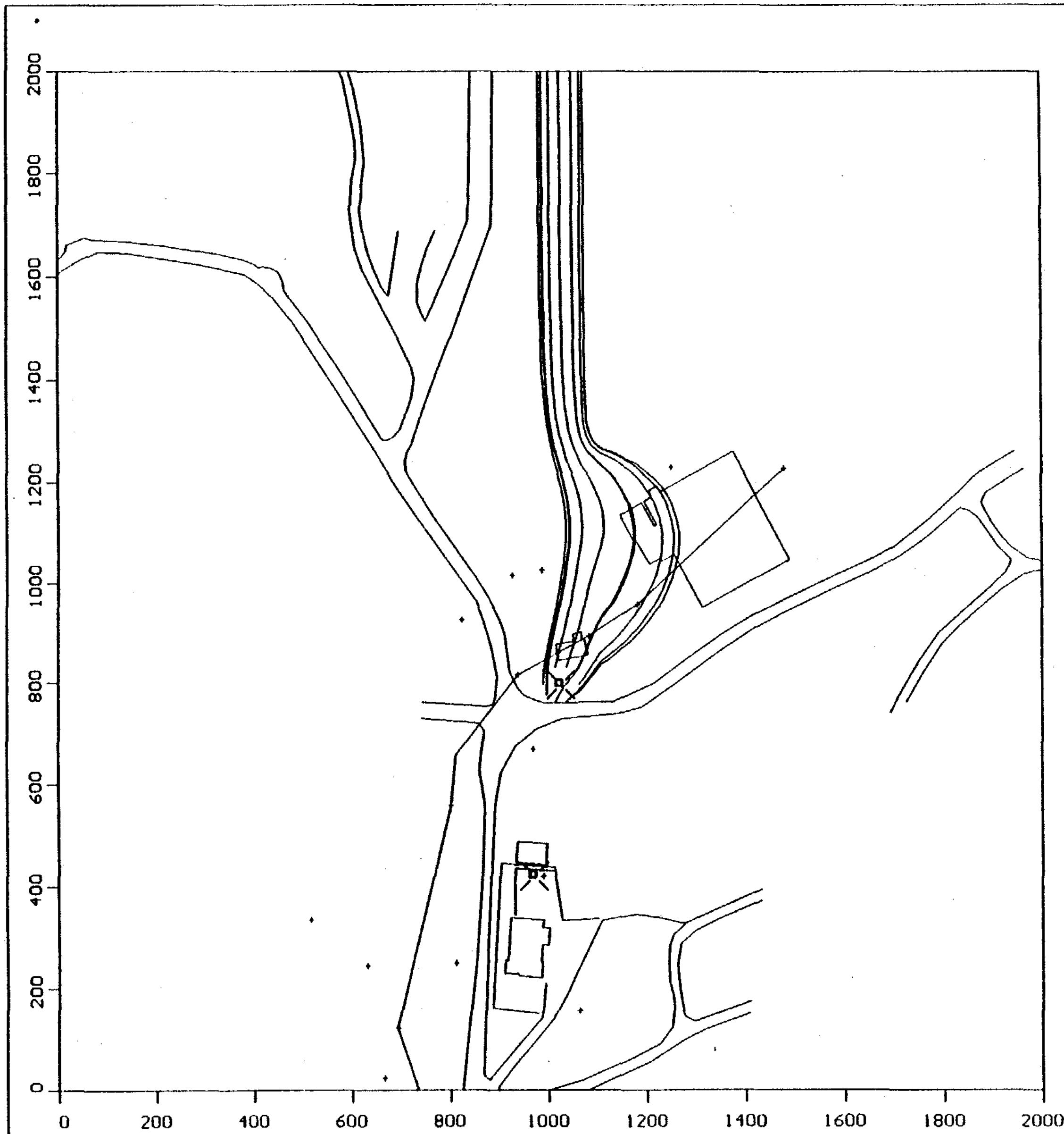
Erler & Kalinowski, Inc.

Scenario 3 - Simulated Groundwater Elevations With Pumping

FLOWPATH Output

Texaco Tutu Service Station
St. Thomas, U.S.V.I.
April 1995
EKI 940058.00
Figure A12

TUT 007 1625



FLOWPATH 5.04

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Model Dimensions

No. rows : 33
No. columns : 33
No. pumps : 2
No. injct : 0
No. const. heads : 68
No. const. flux : 0
No. river nodes : 0
No. drain nodes : 0

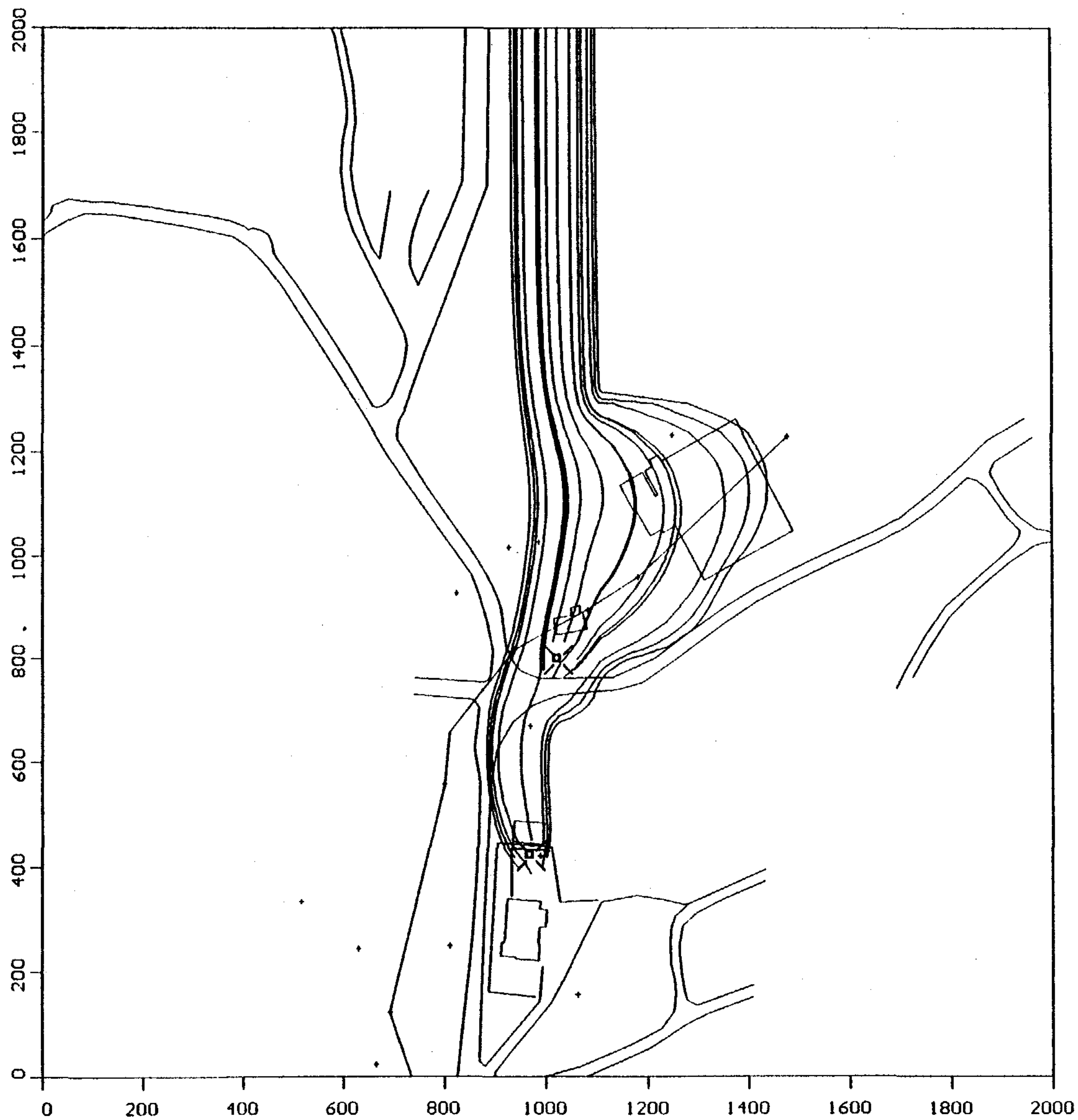
Units : [ft][day]

Data Set : F3

Erler & Kalinowski, Inc.

Scenario 3 - Simulated Capture Zone for Well T-3

FLOWPATH Output
Texaco Tutu Service Station
St. Thomas, U.S.V.I.
April 1995
EKI 940058.00
Figure A13



FLOWPATH 5.04

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Model Dimensions

No. rows	: 33
No. columns	: 33
No. pumps	: 2
No. injct	: 0
No. const. heads	: 68
No. const. flux	: 0
No. river nodes	: 0
No. drain nodes	: 0

Units : [ft][day]

Data Set : F3

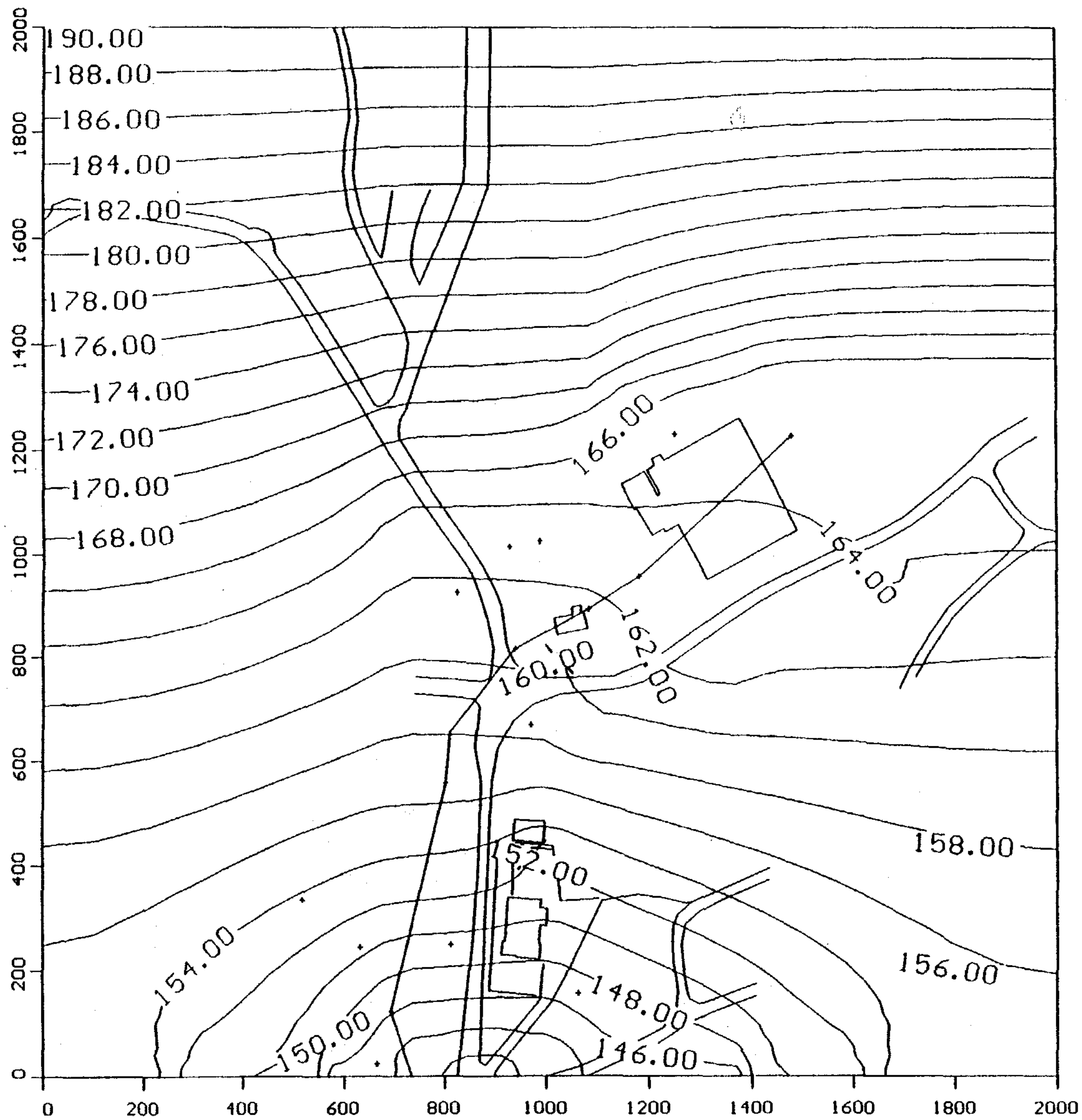
Erler & Kalinowski, Inc.

Scenarios 3 - Simulated Capture Zones for Wells T-3 and P-1

FLOWPATH Output

Texaco Tutu Service Station
St. Thomas, U.S.V.I.
April 1995
EKI 940058.00
Figure A14

TUT 007 1627



FLOWPATH 5.04

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Model Dimensions

No. rows	: 33
No. columns	: 33
No. pumps	: 2
No. injct	: 0
No. const. heads	: 68
No. const. flux	: 0
No. river nodes	: 0
No. drain nodes	: 0

Hydraulic Heads (ft)

Min : 140.000

Max : 190.000

Units : [ft][day]

Data Set : F4

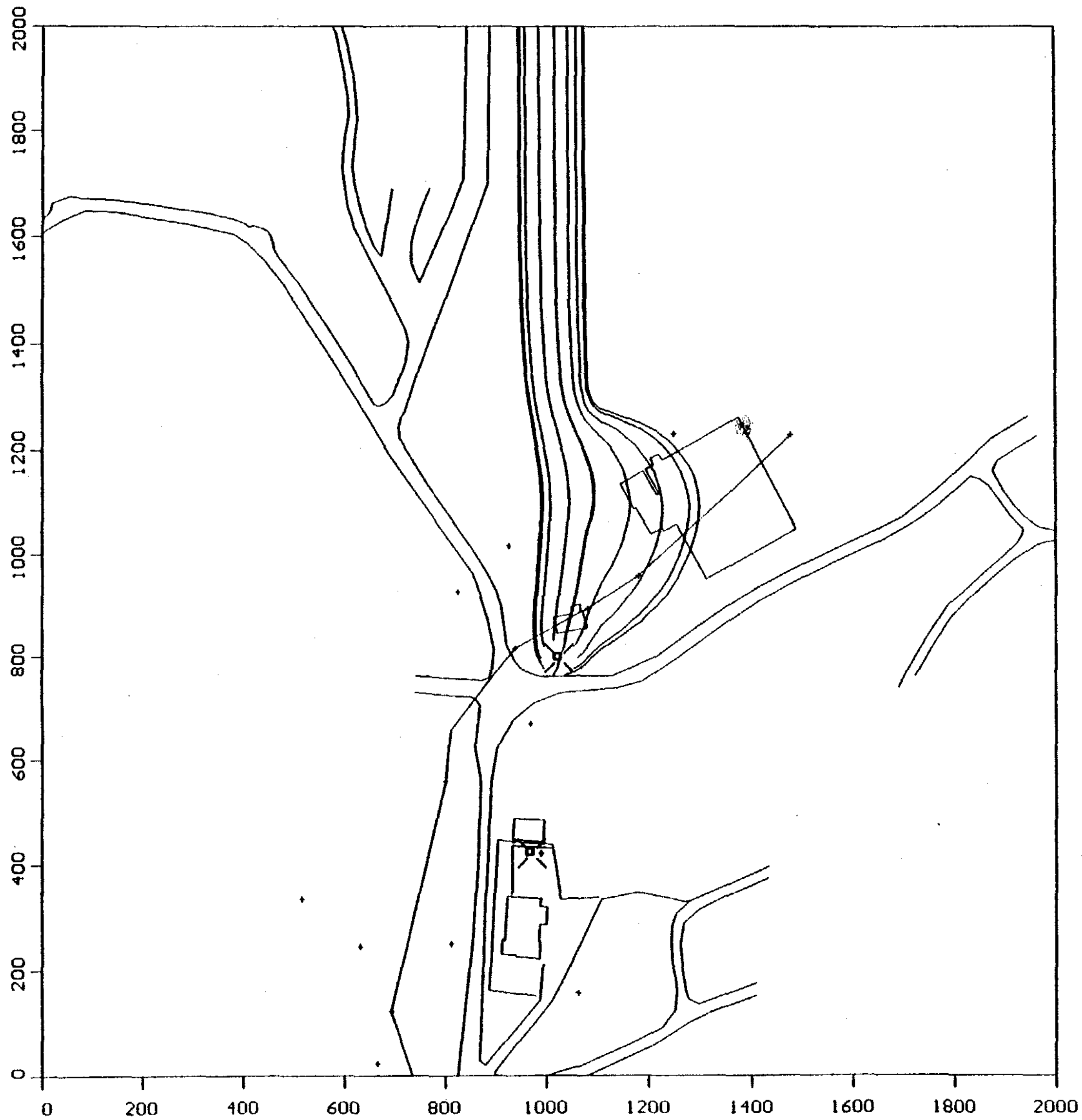
Erler & Kalinowski, Inc.

Scenario 4 - Simulated Goundwater Elevations With Pumping

FLOWPATH Output

Texaco Tutu Service Station
St. Thomas, U.S.V.I.
April 1995
EKI 940058.00

Figure A15



FLOWPATH 5.04

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Model Dimensions

No. rows	: 33
No. columns	: 33
No. pumps	: 2
No. injct	: 0
No. const. heads	: 68
No. const. flux	: 0
No. river nodes	: 0
No. drain nodes	: 0

Hydraulic Heads (ft)

Min :	140.000
Max :	190.000

Units : [ft][day]

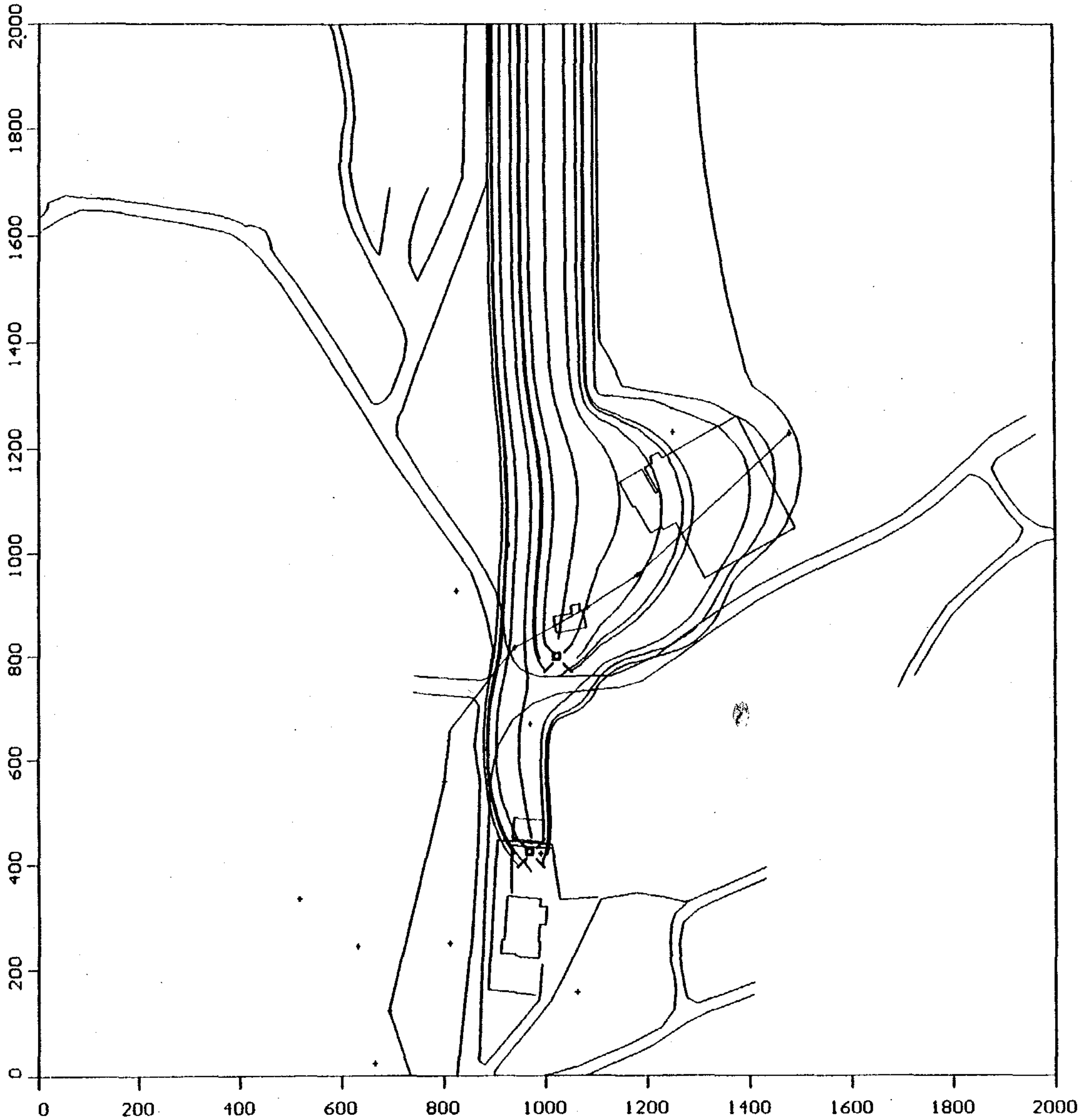
Data Set : F4

Erler & Kalinowski, Inc.

Scenario 4 - Simulated Capture Zone for Well T-3

FLOWPATH Output
Texaco Tutu Service Station
St. Thomas, U.S.V.I.
April 1995
EKI 940058.00
Figure A16

TUT 007 1629



FLOWPATH 5.04

waterloo hydrogeologic software

Model Dimensions

No. rows	: 33
No. columns	: 33
No. pumps	: 2
No. injct	: 0
No. const. heads	: 68
No. const. flux	: 0
No. river nodes	: 0
No. drain nodes	: 0

Hydraulic Heads (ft)

Min :	140.000
Max :	190.000

Units : [ft][day]

Data Set : F4

Erler & Kalinowski, Inc.

Scenario 4 - Simulated Capture Zones for Wells T-3 and P-1

FLOWPATH Output

Texaco Tutu Service Station
St. Thomas, U.S.V.I.
April 1995
EKI 940058.00
Figure A17

Appendix B - Air Emissions Risk Screening Analysis

TABLE B-1

AIR EMISSIONS - RISK SCREENING ANALYSIS
Vitelco Property Groundwater Treatment System
Tutu Texaco Service Station
(EKI 940058.00)

Chemical of Concern	Assumed Emission Rate (g/s)	Maximum Ground Concentration for 1 g/s Emission Rate (ug/m^3)	Maximum Ground Concentration for Estimated Emission Rate (ug/m^3)	Unit Risk Factor ($1/(ug/m^3)$)	70 Year Incremental Carcinogenic Risk	7 Year Incremental Carcinogenic Risk
Benzene (3)	3.77E-05	606.5	22.9E-3	8.3E-6	1.9E-7	1.9E-8
1,2-Dichloroethane (DCA) (3)	8.08E-06	606.5	4.9E-3	2.6E-5	1.3E-7	1.3E-8
Tetrachloroethene (PCE) (4)	1.81E-04	606.5	109.8E-3	5.8E-7	6.4E-8	6.4E-9
Trichloroethene (TCE) (4)	5.03E-05	606.5	30.5E-3	1.7E-6	5.2E-8	5.2E-9
Vinyl chloride (5&7)	1.3E-5	606.5	7.6E-3	8.4E-5	6.4E-7	6.4E-8
Methylene Chloride (3)	1.2E-5	606.5	7.3E-3	4.7E-7	3.4E-9	3.4E-10
			Total Maximum Incremental Cancer Risk		1.0E-6	1.1E-7

NOTES:
1. Assumed emission rates are based on estimated off-gas from groundwater air stripper.
2. Maximum long term impact at a height of 4 meters above the stack and located 29 meters away from the stack based on a 1 g/s total chemical emission rate from the stack (10% of one hour value obtained using SCREEN2 program, 175 SCFM, simple and complex terrain terrain, downwash from Mike's paints, Stack ht = 16 ft)
3. Unit risk factors are those included in IRIS (1995).
4. Unit risk factors are those included in U.S. EPA Health Assesment documents.
5. Unit risk factors are those included in the U.S. EPA Health Effects Assessment Summary Tables, FY 1994 Annual.
6. Estimated maximum risk = (Emission Rate)x(Maximum Ground Concentration for 1 g/s Emission Rate)x(Unit Risk Factor)
7. Totals may be rounded.

Two model runs using the Screen2 air dispersion model for air emissions emanating from the proposed groundwater treatment system at the Vitelco Property location, St. Thomas, U.S.Virgin Islands are described below. The two model runs were generated to determine the worst-case air emissions scenario and resulting maximum chemical concentration for a 1 g/s emission rate. This concentration is used in the calculation for the incremental carcinogenic risk shown on Table B-1. The assumptions of the two models runs are described below and the SCREEN2 printout results follow.

Model No. 1, "tutu5":

Assumptions:

- The treatment system is located on flat terrain (approximate elevation 180 feet)
- Stack height = 16 feet
- Air dispersion is toward the east and northeast of the treatment system, and up a hill. (The complex terrain and simple terrain inputs model this geography.)

Results:

- The maximum concentration (6,065 ug/m^3) occurred at a distance of 29 meters from the stack.

Model No. 2, "tutuflt2":

Assumptions:

- The treatment system is located on flat terrain (approximate elevation 180 feet)
- Stack height = 16 feet
- Air dispersion is toward the north, west, and south of the treatment system, down a hill or across flat terrain (The simple terrain inputs model this geography.)

Results:

- The maximum concentration (4660 ug/ m^3) occurred at a distance of 29 meters from the stack.

****** SCREEN2 MODEL ******
**** VERSION DATED 92245 ****

IBM-PC VERSION (1.01)

SERIAL NUMBER 6759 SOLD TO ERLER & KALINOWSKI

04/12/95
12:01:46

tutu5 MODEL NO. 1

COMPLEX TERRAIN INPUTS:

SOURCE TYPE	=	POINT
EMISSION RATE (G/S)	=	1.00000
STACK HT (M)	=	4.8766
STACK DIAMETER (M)	=	.0914
STACK VELOCITY (M/S)	=	12.6994
STACK GAS TEMP (K)	=	296.1500
AMBIENT AIR TEMP (K)	=	294.2600
RECEPTOR HEIGHT (M)	=	.0000
URBAN/RURAL OPTION	=	URBAN

BUOY. FLUX = .002 M**4/S**3; MOM. FLUX = .335 M**4/S**2.

FINAL STABLE PLUME HEIGHT (M) = 7.5
DISTANCE TO FINAL RISE (M) = 200.6

			VALLEY 24-HR CALCS		**SIMPLE TERRAIN 24-HR CALCS**				
TERR HT (M)	DIST (M)	MAX 24-HR CONC (UG/M**3)	CONC (UG/M**3)	PLUME HT ABOVE STK BASE (M)	CONC (UG/M**3)	PLUME HT ABOVE STK HGT (M)	SC	U10M (M/S)	UST
5.	53.	3909.	46.86	6.3	3909.	3.2	6	1.0	1.
6.	57.	3511.	60.93	6.3	3511.	3.2	6	1.0	1.
6.	61.	3164.	73.78	6.3	3164.	3.2	6	1.0	1.
7.	82.	108.7	108.7	6.3	.0000	.0	0	.0	.
7.	102.	110.4	110.4	6.5	.0000	.0	0	.0	.
8.	116.	103.6	103.6	6.7	.0000	.0	0	.0	.
9.	126.	97.49	97.49	6.8	.0000	.0	0	.0	.
6.	134.	852.6	91.87	6.9	852.6	3.2	6	1.0	1.
9.	139.	88.86	88.86	6.9	.0000	.0	0	.0	.
10.	148.	82.81	82.81	7.0	.0000	.0	0	.0	.

OFF-SITE SCHOOL

04/12/95
12:01:46

tutu5

SIMPLE TERRAIN INPUTS:

SOURCE TYPE	=	POINT
EMISSION RATE (G/S)	=	1.00000
STACK HEIGHT (M)	=	4.8766
STK INSIDE DIAM (M)	=	.0914
STK EXIT VELOCITY (M/S)	=	12.6994
STK GAS EXIT TEMP (K)	=	296.1500
AMBIENT AIR TEMP (K)	=	294.2600
RECEPTOR HEIGHT (M)	=	1.5000
URBAN/RURAL OPTION	=	URBAN

MODEL NO. 1 CONTINUED

BUILDING HEIGHT (M) = 9.1435
MIN HORIZ BLDG DIM (M) = 12.1914
MAX HORIZ BLDG DIM (M) = 18.2870

BUOY. FLUX = .002 M**4/S**3; MOM. FLUX = .335 M**4/S**2.

*** FULL METEOROLOGY ***

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 1. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
4.	.0000	0	.0	.0	.0	.00	.00	.00	NA

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 1. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
11.	.0000	0	.0	.0	.0	.00	.00	.00	NA

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 2. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
15.	.0000	0	.0	.0	.0	.00	.00	.00	NA

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 2. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
16.	.0000	0	.0	.0	.0	.00	.00	.00	NA

****
*** SCREEN DISCRETE DISTANCES ***
****

MODEL NO. 1 CONT.

* TERRAIN HEIGHT OF 3. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
19.	.0000	0	.0	.0	.0	.00	.00	.00	NA

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 4. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
OFF SITE HOUSE 24.	.0000	0	.0	.0	.0	.00	.00	.00	NA

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 4. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
25.	.0000	0	.0	.0	.0	.00	.00	.00	NA

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 4. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
27.	.0000	0	.0	.0	.0	.00	.00	.00	NA

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 4. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES **

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
29.	6065. MAXIMUM (RESIDENCE)	3	1.0	1.0	320.0	.86	7.79	6.50	SS

****
*** SCREEN DISCRETE DISTANCES ***
****

MODEL NO. 1 CONT.

*** TERRAIN HEIGHT OF 4. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
32.	5792.	3	1.0	1.0	320.0	.66	7.98	6.69	SS

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 4. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
34.	5561.	3	1.0	1.0	320.0	.46	8.14	6.85	SS

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 5. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
37.	5310.	4	1.0	1.0	320.0	.25	8.33	7.03	SS

****
*** SCREEN DISCRETE DISTANCES ***
****

*** TERRAIN HEIGHT OF 5. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
42.	4871.	4	1.0	1.0	320.0	.05	8.67	7.38	SS

DWASH= MEANS NO CALC MADE (CONC = 0.0)
DWASH=NO MEANS NO BUILDING DOWNWASH USED
DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB

****
* SUMMARY OF TERRAIN HEIGHTS ENTERED FOR *
* SIMPLE ELEVATED TERRAIN PROCEDURE *
****

TERRAIN HT (M)	DISTANCE RANGE (M) MINIMUM	MAXIMUM
1.	4.	--
1.	11.	--

MODEL NO. 1 CONT.

2.	15.	--
2.	16.	--
3.	19.	--
4.	24.	--
4.	25.	--
4.	27.	--
4.	29.	--
4.	32.	--
4.	34.	--
5.	37.	--
5.	42.	--

```
*** CAVITY CALCULATION - 1 ***          *** CAVITY CALCULATION - 2 ***
 CONC (UG/M**3)        =   3987.         CONC (UG/M**3)        =   5981.
 CRIT WS @10M (M/S) =      1.00          CRIT WS @10M (M/S) =      1.00
 CRIT WS @ HS (M/S) =      1.00          CRIT WS @ HS (M/S) =      1.00
 DILUTION WS (M/S)  =      1.00          DILUTION WS (M/S)  =      1.00
 CAVITY HT (M)      =     11.73          CAVITY HT (M)      =     10.23
 CAVITY LENGTH (M)  =     19.85          CAVITY LENGTH (M)  =     10.17
 ALONGWIND DIM (M)  =     12.19          ALONGWIND DIM (M)  =     18.29
```

```
****************************************
*** SUMMARY OF SCREEN MODEL RESULTS ***
****************************************
```

CALCULATION PROCEDURE	MAX CONC (UG/M**3)	DIST TO MAX (M)	TERRAIN HT (M)	
SIMPLE TERRAIN	6065.	29.	4.	
COMPLEX TERRAIN	3909.	53.	5.	(24-HR CONC)
BUILDING CAVITY-1	3987.	20.	--	(DIST = CAVITY LENGTH)
BUILDING CAVITY-2	5981.	10.	--	(DIST = CAVITY LENGTH)

```
***************************************************
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
***************************************************
```

RUN ENDED ON 04/12/95 AT 12:01:48

****** SCREEN2 MODEL ******
**** VERSION DATED 92245 ****

IBM-PC VERSION (1.01)

SERIAL NUMBER 6759 SOLD TO ERLER & KALINOWSKI

04/13/95
13:08:33

tutuflt2 MODEL NO. 2

SIMPLE TERRAIN INPUTS:

SOURCE TYPE	=	POINT
EMISSION RATE (G/S)	=	1.00000
STACK HEIGHT (M)	=	4.8766
STK INSIDE DIAM (M)	=	.0914
STK EXIT VELOCITY (M/S)	=	12.6994
STK GAS EXIT TEMP (K)	=	296.1500
AMBIENT AIR TEMP (K)	=	294.2610
RECEPTOR HEIGHT (M)	=	1.5000
URBAN/RURAL OPTION	=	URBAN
BUILDING HEIGHT (M)	=	9.1435
MIN HORIZ BLDG DIM (M)	=	12.1914
MAX HORIZ BLDG DIM (M)	=	18.2870

BUOY. FLUX = .002 M**4/S**3; MOM. FLUX = .335 M**4/S**2.

*** FULL METEOROLOGY ***

****
*** SCREEN DISCRETE DISTANCES ***
****

"FLAT TERRAIN"

*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST (M)	CONC (UG/M**3)	STAB	U10M (M/S)	USTK (M/S)	MIX HT (M)	PLUME HT (M)	SIGMA Y (M)	SIGMA Z (M)	DWASH
2.	.0000	0	.0	.0	.0	.00	.00	.00	NA
3.	.0000	0	.0	.0	.0	.00	.00	.00	NA
5.	.0000	0	.0	.0	.0	.00	.00	.00	NA
6.	.0000	0	.0	.0	.0	.00	.00	.00	NA
8.	.0000	0	.0	.0	.0	.00	.00	.00	NA
9.	.0000	0	.0	.0	.0	.00	.00	.00	NA
11.	.0000	0	.0	.0	.0	.00	.00	.00	NA
12.	.0000	0	.0	.0	.0	.00	.00	.00	NA
14.	.0000	0	.0	.0	.0	.00	.00	.00	NA
15.	.0000	0	.0	.0	.0	.00	.00	.00	NA
18.	.0000	0	.0	.0	.0	.00	.00	.00	NA
21.	.0000	0	.0	.0	.0	.00	.00	.00	NA
24.	.0000	0	.0	.0	.0	.00	.00	.00	NA
27.	.0000	0	.0	.0	.0	.00	.00	.00	NA
29.	4660.	3	1.0	1.0	320.0	4.93	7.79	6.50	SS
30.	4568.	3	1.0	1.0	320.0	4.93	7.90	6.60	SS
33.	4420.	3	1.0	1.0	320.0	4.93	8.07	6.77	SS
36.	4277.	4	1.0	1.0	320.0	4.93	8.24	6.95	SS
38.	4139.	4	1.0	1.0	320.0	4.93	8.41	7.12	SS

MAXIMUM

TUT 007 1639

MODEL NO. 2 CONTINUED

46.	3757.	4	1.0	1.0	320.0	4.93	8.92	7.63	SS
53.	3417.	4	1.0	1.0	320.0	4.93	9.43	8.14	SS
61.	3117.	4	1.0	1.0	320.0	4.93	9.94	8.65	SS
69.	2851.	5	1.0	1.0	10000.0	4.93	10.45	9.16	SS
76.	2615.	5	1.0	1.0	10000.0	4.93	10.96	9.67	SS
84.	2405.	5	1.0	1.0	10000.0	4.93	11.47	10.18	SS
91.	2123.	5	1.0	1.0	10000.0	4.93	12.26	10.97	SS
99.	1924.	5	1.0	1.0	10000.0	4.93	13.06	11.47	SS
107.	1752.	5	1.0	1.0	10000.0	4.93	13.86	11.96	SS
114.	1603.	5	1.0	1.0	10000.0	4.93	14.66	12.45	SS
122.	1473.	5	1.0	1.0	10000.0	4.93	15.45	12.93	SS

DWASH= MEANS NO CALC MADE (CONC = 0.0)
DWASH=NO MEANS NO BUILDING DOWNWASH USED
DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB

*** CAVITY CALCULATION - 1 ***
CONC (UG/M**3) = 3987.
CRIT WS @10M (M/S) = 1.00
CRIT WS @ HS (M/S) = 1.00
DILUTION WS (M/S) = 1.00
CAVITY HT (M) = 11.73
CAVITY LENGTH (M) = 19.85
ALONGWIND DIM (M) = 12.19

*** CAVITY CALCULATION - 2 ***
CONC (UG/M**3) = 5981.
CRIT WS @10M (M/S) = 1.00
CRIT WS @ HS (M/S) = 1.00
DILUTION WS (M/S) = 1.00
CAVITY HT (M) = 10.23
CAVITY LENGTH (M) = 10.17
ALONGWIND DIM (M) = 18.29

****
*** SUMMARY OF SCREEN MODEL RESULTS ***
****

CALCULATION PROCEDURE	MAX CONC (UG/M**3)	DIST TO MAX (M)	TERRAIN HT (M)	
SIMPLE TERRAIN	4660.	29.	0.	
BUILDING CAVITY-1	3987.	20.	--	(DIST = CAVITY LENGTH)
BUILDING CAVITY-2	5981.	10.	--	(DIST = CAVITY LENGTH)

****
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
****

RUN ENDED ON 04/13/95 AT 13:08:36