DRAFT FINAL
FEASIBILITY STUDY
TUTU WELLS SITE
ST. THOMAS, U.S. VIRGIN ISLANDS

August 1995

Prepared for

Tutu Environmental Investigation Committee
San Juan, Puerto Rico

Prepared by

Geraghty & Miller, Inc.
201 West Passaic Street
Rochelle Park, New Jersey 07662
(201) 909-0700

DRAFT FINAL
FEASIBILITY STUDY
TUTU WELLS SITE
ST. THOMAS, U.S. VIRGIN ISLANDS

August 4, 1995

Prepared by Geraghty & Miller, Inc.

Brent C. O'Dell, P.E.
Project Engineer

Thomas V. Danahy
Senior Scientist/Project Manager

Daniel A. Nachman
Vice President/Project Director

TUT 007 1956

TABLE OF CONTENTS

CONTENTS

Page

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

CONTENTS (continued)

Page

TABLES

TABLES (continued)

TABLES (continued)

TABLES (continued)

FIGURES

<u>FIGURES</u> (continued)

APPENDICES

SECTION 1

DRAFT FINAL
FEASIBILITY STUDY
TUTU WELLS SITE
ST. THOMAS, U.S. VIRGIN ISLANDS

1. INTRODUCTION

In December 1989, Geraghty & Miller, Inc. was retained by the Tutu Environmental Investigation Committee (TEIC), which consists of Texaco Caribbean, Inc. (Texaco) and Esso Standard Oil, U.S.A., Inc. (Esso), to prepare a work plan for the investigation of two automotive service stations and the surrounding area in Tutu, Anna's Retreat, St. Thomas, U.S. Virgin Islands (USVI) (see Figure 1-1). Following discussions with the United States Environmental Protection Agency (USEPA), Geraghty & Miller submitted the revised Tutu Service Station Investigation Work Plan (Work Plan) in March 1992 (Geraghty & Miller, Inc. 1992a). This work plan was incorporated by reference into an Administrative Order by Consent (AOC) (No. II-RCRA-7003 and 9003-92-0401) dated February 19, 1992, with an effective date of March 4, 1992, that was issued to Texaco and Esso by the USEPA-Region II, pursuant to Subtitle I of the Resource Conservation and Recovery Act (RCRA). The AOC required the implementation of a Remedial Investigation (RI) and a Feasibility Study (FS) (USEPA 1992a).

In April 1992, Technical Memorandum I (Geraghty & Miller, Inc. 1992b) was submitted to the USEPA. This report provided the results of the preliminary reconnaissance activities described in the Work Plan (Geraghty & Miller, Inc. 1992a) that were implemented from December 1991 through April 1992. Technical Memorandum II (Geraghty & Miller, Inc. 1993a) was submitted to the USEPA in May 1993 after completion of the field activities described in the Work Plan for the Tutu Service Station Investigation. Technical Memorandum II provided a discussion of the field activities and the hydrogeological data collected, an interpretation of soil and groundwater flow conditions, the groundwater quality data, the data validation report, and an identification of remaining data gaps (Geraghty & Miller, Inc. 1993a). All work performed by Geraghty & Miller prior to May 1993, including Technical Memoranda I and II, is now referred to as the first phase (Phase I) of the Tutu Wells Site RI. During the summer and fall of 1993, communications between the USEPA and representatives for other Potentially Responsible Parties (PRPs) resulted in an increase in the number of the actively participating PRPs from two to seven, the formation of a Tutu PRP Committee, and an agreement to enlarge the study area to incorporate the area south of the Esso Tutu Service Station. Figure 1-2 shows the locations of the various properties at the Tutu Wells Site.

A Phase II RI Work Plan was submitted to the USEPA in December 1993 (Geraghty & Miller, Inc. 1993b). The Phase II RI Work Plan provided a summary of individual source investigations conducted by PRPs at numerous properties throughout the Tutu area, identified data gaps for the expanded RI study area (referred to as the Tutu Wells Site), and defined a scope of work to gather the data needed to define the nature and extent of impact to environmental quality at the Tutu Wells Site. The Phase II RI Work Plan was approved by the USEPA in a March 17, 1994 letter to Ms. Ana Gloria Ramos, former Designated Coordinator for the TEIC, from Ms. Carol Petersen, USEPA Chief for Region II Superfund New York/Caribbean Branch (USEPA 1994a). The Phase II RI was conducted from March to July 1994 in accordance with the Phase II RI Work Plan. A draft RI Report was submitted to the USEPA in October 1994; the draft RI Report provided the data collected during Phase II of the RI and included an evaluation of site conditions based on the large body of data collected by several investigators. USEPA comments on the draft RI Report were provided in a December 28, 1994 letter to Mr. John McBurney of *de maximis, inc.*, current Designated Coordinator for the TEIC (USEPA 1994b). A draft Final Phase II RI Report, dated January 31, 1995, was submitted to the USEPA on February 1, 1995. The Final Phase II RI Report (RI Report), dated April 6, 1995, was submitted to the USEPA on April 7, 1995 (Geraghty & Miller, Inc. 1995).

In conformance with the AOC and as presented in the Phase II RI Work Plan, Geraghty & Miller has prepared this FS Report as a companion to the RI Report.

1.1 PURPOSE OF THE FEASIBILITY STUDY

The purpose of this FS is to screen areas that may require remedial action, to identify remedial alternatives, and to assemble information to support the selection of soil and groundwater remedies that are best suited for the remediation of environmental impacts documented at the Tutu Wells Site.

Procedures and criteria used in this FS were designed to select the most environmentally sound, technically feasible, and cost-effective remedial action alternative for the site. This was accomplished through a phased approach wherein identification and screening of remedial technologies and process options were carried out concurrently with the RI site characterization (Geraghty & Miller, Inc. 1995). Subsequent phases consisted of development of alternative remedies, screening of the alternative technologies, detailed analysis of remedial alternatives, and comparative analysis of remedial alternatives. Development, screening, and analysis of remedial alternatives are the principal focus of this FS Report.

1.2 ORGANIZATION OF THE FEASIBILITY STUDY REPORT

The FS Report format is consistent with the format suggested by the USEPA (USEPA 1988a). Incorporated into this FS Report are pertinent data from previously submitted deliverables (Geraghty & Miller, Inc. 1995). The results of the Tutu Wells Site FS are provided in six sections and three appendices. One section provides references, and one appendix contains acronyms. Site characterization data were obtained from the RI Report (Geraghty & Miller, Inc. 1995). The Baseline Risk Assessment report for the Tutu Wells Site was prepared by a USEPA contractor (Camp, Dresser & McKee [CDM] Federal Programs Corporation 1995a). Soil screening levels (SSLs) based on site-specific soil leaching estimates (CDM Federal Programs Corporation 1995b) were provided by the USEPA for use in the Final FS Report.

This FS Report is organized as follows:

Section 1.0	Introduction
Section 2.0	Summary of Remedial Investigation Results
Section 3.0	Remedial Action Goals and General Response Actions
Section 4.0	Identification and Screening of Remedial Technologies
Section 5.0	Development and Screening of Remedial Alternatives
Section 6.0	Pre-Design Activities
Section 7.0	References

SECTION 2

2. SUMMARY OF REMEDIAL INVESTIGATION RESULTS

The RI Report identified the presence of chlorinated volatile organic compounds (VOCs) and petroleum hydrocarbons in the soil and groundwater at the Tutu Wells Site. The principal findings are summarized in this section. The comprehensive results are presented in detail in the RI Report (Geraghty & Miller, Inc. 1995).

2.1 SITE BACKGROUND

Summarized below is information about the site, including a description of the site location and physical setting with respect to topography, demographics, geology, and hydrogeology; a summary of the site history; a discussion of the nature and extent of contamination and contaminant fate and transport; and the results of the baseline risk assessment. This information is presented in greater detail in the RI Report (Geraghty & Miller, Inc. 1995) and in other site characterization documents.

2.1.1 Site Description, Geology, Hydrogeology, and Aquifer Characteristics

The physical setting of the Tutu Wells Site, including the topography, demographics, geology, and hydrogeology, was described in detail in the RI Report. This section presents a brief description of these physical characteristics as they pertain to the FS.

2.1.1.1 Description

The Tutu Wells Site is located within the Turpentine Run surface drainage basin, which occupies approximately 3.4 square miles in east-central St. Thomas (Figure 1-1). The Turpentine Run Basin is separated into an upper and lower basin. The Tutu Wells Site is located in the upper basin, which covers approximately 2.3 square miles. The lower basin covers 1.1 square miles (Jordan and Cosner 1973).

The Turpentine Run Basin trends north-south and is surrounded by relatively steep slopes. Other valleys in the area, such as the valley south of the Virgin Islands Housing Authority (VIHA) and the Curriculum Center (along which Route 384 runs), and the valley just west of the Benjamin Oliver School, trend northeast-southwest (see Figure 2-1). Land surface elevations along the Turpentine Run decrease from about 200 feet above mean sea level (msl) at the northern end of the site to approximately 100 feet above msl at the southern end of the site.

The Turpentine Run is an intermittent stream that traverses the length of the basin. In the upper Turpentine Run Basin, the stream generally flows from north to south following Route 38. In the lower basin, the stream turns around Mt. Zion and then trends southeast. Surface-water runoff is collected in a storm-water catchment system. Storm water and secondary sewage eventually discharge to the Turpentine Run. The Turpentine Run is partially channelized and ultimately discharges into Mangrove Lagoon and the Caribbean Sea.

According to the most recent census data (U.S. Census Bureau 1990), approximately 9,100 people live in the Tutu subdistrict of St. Thomas. The Tutu subdistrict, also known as Anna's Retreat, covers 1.5 square miles (4 square kilometers) in the central-eastern part of St. Thomas. Tutu is second to Charlotte Amalie in population density on St. Thomas and contains approximately 20 percent of the island's population.

Several two-lane paved roads, including Route 384, Route 38, and Highway 382, are located in the Tutu Wells Site. Various commercial establishments line these major roads, including shopping centers and stores, auto service stations, churches, and office buildings. Private homes (approximately 300) and multi-family housing, such as the VIHA buildings, generally occupy the less heavily traveled roads. At least three schools are also located within the Tutu Wells Site; these include an elementary school (the Seventh Day Adventist School) to the northeast, Gomez Junior High School to the northwest, and the Benjamin Oliver School to the east. Overall, approximately 50 percent of the land area is developed (with buildings and parking areas) and 50 percent is covered with soil and vegetation.

2.1.1.2 Geology

The surficial unconsolidated materials at the Tutu Wells Site consist of thin deposits of artificial fill and stream-transported sediments, which in some places overlie older Quaternary alluvial and colluvial deposits. The unconsolidated deposits overlie volcanic rock. On hills, steep slopes, and artificial cuts on the hillside, bedrock is exposed at land surface.

Geraghty & Miller's drilling programs have established that most of the shallow sediment under paved areas of the site consist of fill material and reworked native sediment. Along the axis of the valley, these sediments are underlain by Quaternary alluvial and colluvial deposits that appear to thicken southward. The alluvial and colluvial deposits present in the upper basin are relatively thin, with thicknesses usually varying from 0 to 2 feet, although thicknesses as great as 10 to 30 feet have been observed in isolated valley areas. The unconsolidated deposits consist of unstratified, poorly sorted mixtures of clay, silt, sand, gravel, cobbles, and boulders transported from the upper valley and the foothills by gravity and flash floods.

The alluvium/colluvium is underlain by moderately weathered, fractured volcaniclastic rock in which, in some areas, the original rock components have been partially replaced by clay, chlorite, and oxide minerals (Geraghty & Miller, Inc. 1995). The unconsolidated deposits grade downward into weathered bedrock, and the transition from unconsolidated deposits to weathered bedrock can be difficult to discern during drilling.

The bedrock usually consists of a gray to greenish-gray volcaniclastic tuff and breccia, with a fine-grained matrix and occasional clasts, ranging in diameter from 1 to 5 centimeters (cm). Visible mineral grains in the matrix include plagioclase, pyroxene, epidote, hornblende, and chlorite. At some locations, a coarse-grained volcanic breccia-debris flow underlies the finer grained tuffs and breccias. The debris flow consists of poorly sorted breccia, slump blocks, and cobbles up to 20 cm in diameter (Geraghty & Miller, Inc. 1995).

The thickness of the overburden at the Tutu Wells Site varies from 0 to a maximum of 30 feet in some localities (see Figure 2-2). Overburden is thickest along the axis of the Turpentine Run valley (in which Route 38 generally lies) and thinnest on valley slopes and hilltops. The thickness of weathered bedrock varies from 0 to approximately 6 feet. No consistent relationship was observed between weathered bedrock thickness and overburden thickness.

Based on a review of lithologic descriptions and blow counts recorded on available drilling logs, the overburden in the northern portion of the Tutu Wells Site (near the Curriculum Center) ranges in thickness from 2 to 5 feet. This area is a topographic high and the weathered bedrock is generally thin.

In the Turpentine Run valley, in the vicinity of the Texaco Tutu Service Station, the overburden thickness increases from approximately 2.5 feet along the valley edge (Monitoring Well TT-3D) to 16.5 feet within the valley (at Monitoring Well TT-1D). The thickness of weathered bedrock in this vicinity is approximately 6 feet.

At Four Winds Plaza, the overburden increases in thickness from approximately 3 feet (at Monitoring Well MW-2) to 30 feet (at Monitoring Well CHT-4). The weathered bedrock is less than 5 feet thick in this vicinity. Near the Esso Tutu Service Station, the overburden is between 5 and 29 feet thick, with generally thicker overburden in the southern and southwestern portions of the Esso property. Weathered bedrock was observed at a depth of 2 to 3 feet in the northeastern portion and of 12 to 14 feet at the southern portion of the Esso Tutu Service Station. Examination of available drilling logs indicates that the overburden at the Tom Cat Laundry and O'Henry Dry Cleaners is between 10 and 24 feet thick.

2.1.1.3 Hydrogeology

The regional direction of groundwater flow in the Turpentine Run Basin is toward and down the axis of principal valleys, with a primary southward direction. In the southern part of the study area, there is a southeast component of groundwater flow (Graves and Gonzales 1988; Geraghty & Miller, Inc. 1995). Groundwater in the Turpentine Run Basin occurs in two aquifers (Jordan and Cosner 1973). The primary aquifer is the fractured volcanic rock of the Water Island and Louisenhoj Formations and, locally, the Cabes Point Conglomerate. The secondary aquifer consists of the alluvial deposits in the lower Turpentine Run Basin. The Tutu Wells Site is located in the upper Turpentine Run Basin. Very thin alluvial deposits are also present in the upper basin, with thicknesses varying from less than 2 feet to 30 feet in isolated valley areas. However, these deposits do not constitute an aquifer capable of supplying useable amounts of water because of their limited areal extent and thickness, and because these deposits are often unsaturated. Most of the alluvial deposits, where saturated, may be hydraulically connected to the fractured volcanic rock. Saturated alluvial deposits most commonly occur where bedrock surfaces were incised by former streams and later filled with sediments or fill. An exception to this condition was observed at Western Auto, where alluvial deposits were only saturated in a perched zone within a gravel layer overlying a clay layer.

Groundwater in both units generally exists under unconfined (or water-table) conditions. Localized low permeability (fine-grained) layers in the alluvial deposits may result in perched water and possible confined bedrock conditions of limited extent. The bedrock aquifer may be partially confined in places by zones of relatively unfractured shallow rock.

Groundwater is stored and transmitted in fractures in the bedrock, which behaves as an unconfined aquifer. The water table occurs at depths of 5 to 106 feet below land surface (bls), with the greater depth to water generally occurring beneath ridges and hilltops (Geraghty & Miller, Inc. 1995). Since the groundwater is transmitted principally through fractures and the rock is more fractured along major lineaments, the aquifer demonstrates vertical, as well as horizontal, anisotropy.

In the study area, groundwater supply is derived from wells installed in the fractured volcanic rock. Supply well depths in the upper basin range from 73 to 325 feet bls (Stevens et al. 1981). The depths of these wells do not correlate with yield, but rather are an indication of where water-bearing fracture zones were penetrated. Short-term well yields in the upper basin range as high as 100 gallons per minute (gpm); sustained yields range between 2 and 21 gpm (Jordan and Cosner 1973).

Very little precipitation reaches the saturated zone as groundwater recharge. On St. Thomas, evapotranspiration may consume 95 percent or more of the incident rainfall (Jordan and Fisher 1977). The small fraction of precipitation that is not lost to evapotranspiration or storm-water runoff percolates downward through the thin overburden, or where overburden is not present, directly into the interconnecting network of fractures that transect the rock.

Recharge to the fractured volcanic rock in the upper basin results primarily from occasional major rainstorms and is dependent on the frequency and volume of rainfall. As a result of surface runoff and a high evapotranspiration rate, rainfall of at least 2 inches within a 24-hour period is necessary for recharge to occur. Annual recharge to the upper basin due to rainfall is estimated to be 130 million gallons (Jordan and Cosner 1973).

The bottom of the Tutu aquifer is not well defined. The physical bottom of the aquifer is the depth at which the fracture intensity diminishes and the fractures are no longer sufficiently interconnected to allow for significant groundwater flow. No information is available to indicate at what depth this phenomenon occurs. Chemically, the bottom of the aquifer could be defined by the transition from groundwater of natural chemistry acceptable for consumption to more mineralized water that can no longer be feasibly used or treated for public or commercial supply. There is limited evidence that groundwater below a depth of about 300 feet in the central and northern portion of the Tutu area is relatively mineralized connate water (Geraghty & Miller, Inc. 1983). In the southern portion of the Tutu area, the freshwater/saltwater interface may occur at shallower depths.

In the bedrock aquifer, three general zones (or depths) are monitored by the existing wells. The shallow monitoring wells monitor the zone extending approximately 8 to 10 feet below the water table. The deep monitoring wells monitor the zone from 30 to 50 feet below the water table, and the supply wells monitor the entire thickness of the aquifer. The supply wells were grouped with the deep monitoring wells for data interpretation.

Groundwater flow in the shallow zone is generally toward the south. Water-level measurements collected from shallow wells on May 10 and 23, 1994 during the Phase II RI were used to construct water-level contour maps (Geraghty & Miller, Inc. 1995). Figure 2-3 shows the shallow groundwater flow conditions measured on May 23, 1994. As shown on this figure, the shallow groundwater flow from the east and west converges beneath Route 38, toward what appears to be the axis of the Turpentine Run Basin. One of the principal fractures identified is oriented along Route 38 (CDM Federal Programs Corporation 1992); this fracture zone appears to act as a shallow groundwater discharge zone. The former stream channel of the Turpentine Run has been filled, and surface drainage is channelized through a storm sewer under the area.

Shallow groundwater flow is characterized by a steep hydraulic gradient. This steep gradient is indicative of the low overall permeability of the zone penetrated by the shallow wells. The gradient is less steep in the area that includes the Texaco Tutu Service Station and the north portion of the Four Winds Plaza parking lot, indicating that the shallow zone has a higher permeability in this area. This observation agrees with the information collected during well development. Monitoring Wells MW-3, MW-4, and MW-6R could sustain pumpage at rates of approximately 2 gpm, whereas most other shallow monitoring wells went dry when pumped for relatively short periods of time. The hydraulic gradient of the shallow portion of the aquifer steepens again in the vicinity of the Esso Tutu Service Station. Monitoring wells at and near the Esso Tutu Service Station have been pumped dry during well development and groundwater sampling.

Water levels measured in deeper monitoring wells on May 10 and 24, 1994 during the Phase II RI were used to construct water-level contour maps. Figure 2-4 shows deep groundwater flow conditions measured on May 23, 1994. This map indicates that the general gradient of groundwater flow in the deeper zone at the Tutu Wells Site is to the south, with a southeast component in the southern part of the study area. In the northern portion of the site near Monitoring Well MW-6D, a more gentle gradient indicates that the more permeable zone in the shallow bedrock also extends downward into the deeper monitored portion of the bedrock.

In general, there is a small downward vertical hydraulic gradient throughout most of the study area. A slight upward gradient was observed in 1994 in mid-May and mid-June in the northeastern portion of the Tutu Wells Site in Monitoring Wells MW-13/MW-13D. This upward gradient may be attributed to the slow recovery of Monitoring Well MW-13 after it was developed in May 1994. Pumpage of supply wells at the VIHA complex may increase the downward vertical hydraulic gradient in the northeastern portion of the Tutu Wells Site, which may explain the steep downward gradient observed at Monitoring Wells MW-13/MW-13D on July 20, 1992. As expected, a generally horizontal or slightly upward gradient is present near the former stream channel of the Turpentine Run (Monitoring Wells MW-6R/MW-6D). A predominantly downward gradient was observed in the Upper Turpentine Run Basin at Wells MW-1/MW-1D, TT-1/TT-1D, MW-4/MW-4D, MW-8/DW-1, MW-10/MW-10D, and SW-6/DW-2. Based on water-level measurements made in these wells on May 24, 1994, the steepest downward vertical gradient was observed at Monitoring Wells MW-20/MW-20D. However, this steep downward gradient may be a result of the incomplete recovery of Monitoring Well MW-20D, which had been developed 1 week earlier.

2.1.1.4 Summary of Aquifer Hydraulic Characteristics

Based on the evaluation of the data presented in the RI Report (Geraghty & Miller, Inc. 1995), the following conclusions have been developed:

- Zones of fracture have a controlling influence on the vertical and horizontal distribution of aquifer permeability and transmissivity. The highest transmissivity zones are located along the major fractures, particularly where major fracture zones intersect (e.g., in the northern part of the Four Winds Plaza parking lot). Transmissivity values calculated from wells located in this area ranged from approximately 20,400 to 90,500 gallons per day per foot (gal/day/ft), with hydraulic conductivities of approximately 70 to 300 gallons per day per square foot (gal/day/ft^2). In comparison, transmissivity values calculated from wells not located in the major fracture zones range from approximately 900 to 2,300 gal/day/ft (with hydraulic conductivities of approximately 3 to 7.7 gal/day/ft^2) (Geraghty & Miller, Inc. 1995).

- Based on the pumping tests of the Eglin III Supply Well, the aquifer's response to the pumpage of deep supply wells appears to be anisotropic in both the vertical and horizontal direction. Drawdown is greater in deep bedrock observation wells located along major fractures than in directions perpendicular to the orientation of those fractures.

- Based on the pumping tests of the Eglin III Supply Well, pumpage at a constant rate of approximately 31 gpm creates a zone of influence oriented northwest-southeast. The northeast-southwest extent of the zone of influence is approximately 500 feet and the northwest-southeast extent is approximately 1,045 feet (Geraghty & Miller, Inc. 1995).

2.1.2 History of Known Public Concerns

In 1982, Geraghty & Miller was retained by the USVI Department of Conservation and Cultural Affairs (DCCA) to inventory the groundwater resources of St. Croix, St. Thomas, and St. John and prepare a groundwater management plan for the USVI. As part of this program, sampling activities were carried out in the Turpentine Run Basin. These activities included an aquifer pumping test of the VIHA Well No. I (VIHA I). After 5 hours of pumping, Geraghty & Miller collected a groundwater sample on May 20, 1982 from the VIHA I supply well for analysis of USEPA priority pollutant organic compounds. The sample was sent to the USEPA in Edison, New Jersey, where it was forwarded to Mead CompuChem Laboratories in Research Triangle Park, North Carolina (Geraghty & Miller, Inc. 1983).

Chlorinated VOCs were detected in the VIHA I groundwater sample. Those constituents included 1,2-dichloroethene (1,2-DCE) at a concentration of 12 micrograms per liter (ug/L) (equivalent to parts per billion [ppb]), 55 ug/L of tetrachloroethene (PCE), and 10 ug/L of trichloroethene (TCE) (Geraghty & Miller, Inc. 1983). At that time, drinking water standards for these VOCs had not been established by the USEPA. In a report submitted to the DCCA, Geraghty & Miller recommended further investigation to identify the source of these chlorinated VOCs (Geraghty & Miller, Inc. 1983).

In July 1987, Mr. Eric Tillett, owner of Tillett Gardens, contacted the USVI Department of Planning and Natural Resources (DPNR) regarding an odor emanating from his well water. Representatives of the USEPA and its Technical Assistance Team (TAT) subsequently performed groundwater sampling at the Tillett well and six additional commercial wells located in Turpentine Run. The analytical results from this sampling event indicated that the Tillett well contained gasoline constituents and chlorinated VOCs, and that the other six commercial wells also contained elevated levels of chlorinated VOCs. Based on these results, the DPNR declared that an eminent health threat existed that could affect approximately 20,000 people living in St. Thomas and an indefinite number of tourists who vacation in St. Thomas.

Based on groundwater sampling results, the DPNR closed 13 commercial and five private wells in the Tutu area between July and September 1987 (USEPA 1991a). Many of these wells are currently in use for non-potable purposes. After the initial sampling of the six supply wells in July 1987, the USEPA's TAT sampling and screening analysis was expanded to include 24 supply wells, beginning in August 1987. Analyses for benzene, toluene, PCE, TCE, and 1,2-DCE were performed using a Photovac portable field gas chromatograph (GC) on samples collected monthly from August through December 1987. Photovac analyses were also performed on samples collected in January, February, May, August, and November 1988 and February, May, and August 1989 (Weston/Spill Prevention and Emergency Response [SPER] 1989).

Selected groundwater samples were submitted for laboratory analysis for VOCs during these various sampling events. The PCE concentration in the Harvey supply well was 7,600 ug/L in August 1987 (Western/SPER 1988).

In October 1987, groundwater samples were also analyzed for Hazardous Substance List (HSL) VOCs, base neutral and acid extractable compounds (BNAs), and metals by USEPA-contracted laboratories. Fourteen of the 24 supply wells sampled during this event had elevated values of VOCs, including trans-1,2-DCE, TCE, PCE, toluene, benzene, and methyl tertiary-butyl ether (MTBE). The October 1987 sampling event confirmed the August 1987 groundwater VOC sampling results and also detected arsenic (15 ug/L), selenium (15 ug/L), and zinc (460 ug/L) in some of the wells sampled (Weston/SPER 1988). The highest reported contaminant concentration for the October 1987 sampling event (excluding methylene chloride, which is a common laboratory contaminant) was 2,000 ug/L of PCE in the Harvey Supply Well sample (Weston/SPER 1988).

Laboratory analyses for HSL VOCs, BNAs, metals, and cyanide were performed on 18 supply well samples collected in November 1988 (Weston/SPER 1989). The USEPA also sampled and analyzed 123 cisterns that were filled with groundwater pumped from supply wells located in this area. Three of the cisterns contained total VOCs in excess of 1,000 ug/L (USEPA 1991a).

In January 1988, the USEPA initiated a limited Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) removal action that included the decontamination and cleaning of five residential cisterns contaminated by hazardous substances, modification of plumbing, delivery of water by tank trucks as a temporary alternative water supply, and implementation of a well-water monitoring program (USEPA 1991a).

On November 6, 1988, the USEPA sent Esso, O'Henry Dry Cleaners, and Texaco an information request letter under Section 104(e) of CERCLA and 3007 of RCRA regarding operations and waste containment and disposal at the Esso and Texaco Service Stations and the O'Henry facility. Based on the findings of this request, the USEPA issued a unilateral Administrative Order (AO) under CERCLA and RCRA on March 22, 1990 to Texaco, Esso, and O'Henry (USEPA 1990). This AO required these parties to assume the USEPA's well-water monitoring program, to provide potable water to residents with contaminated well water, and to coordinate and design plans to connect those residents to the public water supply.

In June 1989, the USEPA-Region II sent Texaco and Esso a draft AOC requiring the implementation of an RI in the Tutu area. Texaco and Esso formed the TEIC in March 1990 and retained Geraghty & Miller to prepare a work plan for, and to implement, the Tutu Service Station Investigation, which is now referred to as Phase I of the RI. A final AOC was entered into by the USEPA, Texaco, and Esso in February 1992 (USEPA 1992a).

In August 1991, the USEPA presented its Hazard Ranking System (HRS) document for the Tutu Wells Site (USEPA 1991a). In this document, at least nine PRPs were identified as known or potential sources of groundwater contamination. These PRPs include, from north to south, the VIHA, the Curriculum Center (former Laga facility), Ramsay Motors, Antilles Auto Parts, Texaco Tutu Service Station, Tillett Gardens, Esso Tutu Service Station, O'Henry Dry Cleaners, and Rodriguez Auto Parts (see Figure 1-2). Preliminary site assessments had been conducted at these properties by USEPA subcontractors. The Western Auto facility, which was investigated during Phase II activities by Geraghty & Miller and others, was not included in the HRS or preliminary site assessments.

2.2 NATURE AND EXTENT OF CONTAMINATION

The nature and extent of contamination was described in detail in the RI Report (Geraghty & Miller, Inc. 1995). This section provides a summary of environmental impacts to soil and groundwater quality.

2.2.1 Soil Quality

Soil sampling and soil-gas surveys were conducted during Phases I and II of the RI to identify the areas of impacted soil and to evaluate the nature and extent of impact to soil and groundwater quality. In addition, Geraghty & Miller compiled historical information and recent data from properties where independent investigations by other technical consultants were performed. These data are summarized in the RI Report (Geraghty & Miller, Inc. 1995).

Soil samples collected during the RI were analyzed for target compound list (TCL) VOCs, TCL BNAs, target analyte list (TAL) metals, cyanide, and/or total petroleum hydrocarbons (TPH). The USEPA directed the TEIC to use the USEPA's vadose zone modeling SSLs for BTEX and chlorinated VOCs as guidance values to identify areas that may require remediation of soils (CDM Federal Programs Corporation 1995b). These guidance values were developed specifically for the Curriculum Center (former Laga Building), Texaco Tutu Service Station, Esso Tutu Service Station, and O'Henry Dry Cleaners (CDM Federal Programs Corporation 1995b), and are provided in Table 2-1. Chemicals of concern (COCs) at the Tutu Wells Site were limited mainly to BTEX and chlorinated VOCs. TCL BNAs, such as polycyclic aromatic hydrocarbons (PAHs), were not considered COCs because (1) PAHs and other contaminants which were not detected in groundwater above MCLs, are not considered to be of concern for soils, (2) these contaminants are not generally very mobile, and (3) no direct exposure risks associated with these contaminants were identified in the Baseline Risk Assessment (CDM Federal Programs Corporation 1995a).

As directed by the USEPA, the potential need for soil remediation at the remaining properties within the Tutu Wells Site was determined using the guidance values provided for the Esso Tutu Service Station because the subsurface conditions at the Esso Tutu Service Station are representative of conditions throughout the Tutu Valley Building. Different guidance levels were developed by the USEPA for shallow and deep soil at each property, based on the vertical distance to the water table (see Table 2-1). The SSLs are considered as "to-be-considered" (TBC) criteria. These guidance levels will be referred to as SSLs, and these SSLs are further discussed in Section 3.1.2 (Preliminary Remedial Goals).

Exceedances of the USEPA's SSLs (CDM Federal Programs Corporation 1995b) for organic compounds were used as one of two criteria to determine if sites may require soil remediation. The second criterion used to identify areas that may require soil remediation included the USEPA-approved risk assessment of soil quality (CDM Federal Programs Corporation 1995a). Tables 2-2 and 2-3 provide summaries of the USEPA risk assessment soil quality threshold values for carcinogenic and non-carcinogenic risks, respectively. COCs were detected at several properties at concentrations below the USEPA's SSLs, indicating that releases of these constituents had potentially occurred, although the residual concentrations do not currently represent a threat to human health, groundwater, or the environment. At these locations, organic compounds were detected in soil gas and shallow soil above 10 ug/kg, indicating that releases had occurred. In addition, the presence of significant concentrations of these COCs in groundwater at these properties indicates that contaminants may be present at higher concentrations in soil and fractures in the unsaturated bedrock, which was not sampled.

For the Tutu Wells Site, the USEPA directed that soil be considered to be potentially impacted by metals and other inorganic compounds if the analytical result exceeded two times the average background value. It should be noted that the metal concentrations detected in soil at the

Tutu Wells Site are probably all present naturally and are not the result of operational history. In addition, metals do not partition to an appreciable degree into the aqueous phase. Therefore, any potential impact from metals would be from dermal contact or inhalation of dust. A complete evaluation of the potential impact of metals in soil through inhalation of dust or dermal contact is presented in the final baseline risk assessment prepared by CDM (CDM Federal Programs Corporation 1995a). The exposure assessment prepared by CDM indicated that metal concentrations at the individual properties do not pose a risk through contact or inhalation, with the possible exception of manganese at the Tillett property (CDM Federal Programs Corporation 1995a).

Based on the USEPA's SSLs (CDM Federal Programs Corporation 1995b), the properties with soil impacted by organic compounds include the Curriculum Center (former Laga building), Ramsay Motors, Texaco Tutu Service Station, Western Auto, Esso Tutu Service Station, and O'Henry Dry Cleaners (see Figure 1-2). Based on the USEPA subcontractor's risk assessment, the Tillett property is the only other property that may require soil remediation. Manganese and Aroclor 1242 (a polychlorinated biphenyl [PCB]) were found to be above the acceptable site-specific carcinogenic risks and the non-carcinogenic hazard quotient of 1 in surface soil at Tillett Gardens (CDM Federal Programs Corporation 1995a). Appropriate remedial measures may be required at this property (see Section 2.4 [Baseline Risk Assessment]).

The properties identified with soil concentrations above the USEPA's SSLs (CDM Federal Programs Corporation 1995b) were placed into the following two categories: properties with soil impacted by chlorinated VOCs, and properties with soil impacted by petroleum-related compounds including benzene, toluene, ethylbenzene, and xylene (BTEX).

2.2.1.1 Chlorinated VOCs in Soil

Chlorinated VOCs have been found in soil at various properties throughout the Tutu Wells Site. Based on the exceedance of USEPA's SSLs for chlorinated constituents, the Curriculum Center, Esso Tutu Service Station, and O'Henry Dry Cleaners were identified as having chlorinated VOC impacts to soil (see Table 2-4). The primary chlorinated VOCs include PCE, TCE, 1,2-DCE, 1,1,1-trichloroethane (1,1,1-TCA), and 1,1-dichloroethane (1,1-DCA).

At the Curriculum Center, PCE was detected in eight soil samples at the north-central side of the building in the vicinity of the former discharge pipe and alleged former waste pit, at concentrations ranging from approximately 3 to 180 micrograms per kilogram (ug/kg). TCE was detected in four soil samples at estimated concentrations ranging from 1J to 130J ug/kg. 1,1,1-TCA was detected in Soil Sample TWS-03 above the USEPA SSL. No other chlorinated VOCs were detected at the Curriculum Center. Although only one soil sample was reported above the USEPA's SSL for chlorinated VOCs, higher concentrations may be present in the soil beneath the building or in the unsaturated bedrock, which was not sampled. This interpretation is based on the very high soil gas results recorded during a soil gas survey conducted at the Curriculum Center in February and March 1994 (Geraghty & Miller, Inc. 1995) and on the high chlorinated VOC concentrations found in groundwater at the Curriculum Center. These concentrations, in conjunction with a very steep concentration gradient, suggest that chlorinated VOCs may be present as dense non-aqueous phase liquids (DNAPLs) in the fractures of the unsaturated and/or saturated bedrock.

At the Esso Tutu Service Station, PCE, TCE, 1,1,1-TCA, 1,2-DCE, and 1,1-DCA were detected above the USEPA's SSLs in four soil samples with individual chlorinated VOC concentrations ranging from 44 to 3,200 ug/kg (see Table 2-4). These chlorinated VOCs were detected in soil samples collected in the western portion of the site, near the north oil/water separator.

PCE was found in the vicinity of the O'Henry Dry Cleaners above the USEPA's SSLs in seven samples collected from the western portion of the property in concentrations ranging from 200D ("D" indicates value determined by secondary dilution) to 440,000 ug/kg (see Table 2-4). These detected PCE concentrations in soil indicate that PCE was released near the O'Henry Dry Cleaners. In addition, PCE concentrations greater than 10,000 ug/kg indicate a high possibility that DNAPL is present (USEPA 1992b). From 1987 to 1991, the PCE concentration in groundwater collected from the Harvey Supply Well, located downgradient of the O'Henry Dry Cleaners, ranged as high as 7,600 ug/L to 1,500 ug/L. Groundwater concentrations exceeding 1 percent of the solubility of PCE (1,500 ug/L) are indicative of a high potential for DNAPL in the subsurface (USEPA 1992b). Considering the historical and continued use of PCE as a dry cleaning solvent at the O'Henry facility and the soil and groundwater PCE concentrations above USEPA threshold values for identification of DNAPL presence (USEPA 1992b), DNAPL is considered to be present in the subsurface near the O'Henry Dry Cleaners.

2.2.1.2 BTEX in Soil

The USEPA SSLs were exceeded for BTEX at the Curriculum Center, Ramsay Motors, Texaco Tutu Service Station, Western Auto, and the Esso Tutu Service Station (see Table 2-4). In addition, Antilles Auto Parts may have contributed to some soil impact at the adjacent Ramsay Property, based on a previously reported waste oil spill. Similarly, although no constituents were found above USEPA SSLs at the Four Winds Plaza, potential impacts to soil cannot be ruled out due to the detection of elevated soil gas concentrations of diesel components.

BTEX compounds exceeded USEPA SSLs at Surface Soil Samples SS-12 and TWS-03 collected at the northeast corner of the Curriculum Center. Individual BTEX constituent concentrations exceeding the USEPA SSLs ranged from benzene at 2,700 ug/kg to toluene at 500,000 ug/kg.

At the Ramsay Motors property, BTEX compounds were found in two soil samples located in the vicinity of the underground storage tank (UST). Benzene and ethylbenzene concentrations were detected above their respective USEPA SSLs. Analytical results included an estimated concentration of 17 ug/kg of benzene in Soil Sample HB-2, and an estimated concentration of 190 ug/kg and 290 ug/kg of ethylbenzene in Soil Samples HB-5 and HB-2, respectively.

At the Texaco Tutu Service Station, BTEX compounds were found in the vicinity of the former USTs and at the oil/water separator. Two soil samples (Sample OW/SB-1 and TT-1D) and one field replicate (Sample TT-1D FR) collected at Texaco exceeded the USEPA SSLs for BTEX constituents. Results for individual BTEX constituents ranged from 69 ug/kg for benzene to 630 ug/kg for ethylbenzene. However, higher BTEX concentrations have been detected in excavated soil; floating product has been observed; and elevated BTEX concentrations have been detected in groundwater.

In the vicinity of Western Auto , BTEX constituents were reported in 21 soil samples at concentrations above the USEPA SSLs (see Table 2-4). USEPA SSLs were exceeded for all BTEX constituents. Individual BTEX compound concentrations above the USEPA SSLs ranged from estimated concentrations of toluene at 16 ug/kg and ethylbenzene at 16 ug/kg in Soil Sample T1-4 to 34,000 ug/kg of xylenes in Soil Sample SS-1. A shallow gravel layer underlying the pavement in the vicinity of the Western Auto facility contains noticeable oil. Post-excavation sampling for the UST closure was limited to TPH sample collection and analysis. The lack of more comprehensive sampling results for the UST closure and the shallow oily gravel layer indicate that soil volumes estimated for the purposes of this FS Report are preliminary. During pre-design activities, further data will be needed to determine the actual volume of soil that may require remediation.

At the Esso Tutu Service Station, BTEX constituents exceeded USEPA SSLs in 16 samples collected at the site in the vicinity of the pump island, the north oil/water separator, and the former UST excavation. Individual BTEX concentrations above the USEPA soil cleanup profile ranged from 26 ug/kg of ethylbenzene to 540,000 ug/kg of xylenes (see Table 2-4).

2.2.2 Groundwater Quality

During the Phase II RI, groundwater samples were collected from 51 monitoring wells and 15 supply wells at the Tutu Wells Site. The samples were analyzed for TCL VOCs, TCL BNAs, TAL metals, and various inorganic water quality parameters. The sampling confirmed and supplemented earlier efforts to delineate the horizontal and vertical extent of petroleum-related compounds (BTEX and MTBE) and chlorinated VOCs (including PCE, TCE, DCE, and vinyl chloride) in the groundwater at the Tutu Wells Site. The results of the 1994 Phase II RI comprehensive groundwater sampling event, the Phase I RI monitoring well sampling, and the results of eight supply well sampling events are discussed in detail in the RI Report (Geraghty & Miller, Inc. 1995).

2.2.2.1 Chlorinated VOCs

During the Phase I RI, Geraghty & Miller identified two separate chlorinated VOC plumes (Geraghty & Miller, Inc. 1993a). One plume originated in the vicinity of the Curriculum Center and was referred to as the northern chlorinated VOC plume. The other plume originated in the vicinity of O'Henry Dry Cleaners and was referred to as the southern chlorinated VOC plume.

Groundwater data from both the shallow and deep zones were plotted on one figure during Phase I (Geraghty & Miller, Inc. 1993a). As part of the Phase II evaluation, data from these zones were plotted on separate figures to identify trends more clearly. The Phase II RI Report also presented the data for PCE, TCE, 1,2-DCE, and vinyl chloride on individual maps for both the shallow and deep zones (Geraghty & Miller, Inc. 1995). The data presented in this manner support the identification of two separate total chlorinated VOC plumes in excess of 100 ppb, although the northern plume appeared to be separated into two discrete bodies in both the shallow and deep zones. In addition, in the shallow zone, the northern and southern chlorinated plumes appear to have merged, based on the outline of the 10-ppb contour.

The shallow northern chlorinated VOC plume, which originates near the Curriculum Center, extends approximately 1,600 feet south in the direction of groundwater flow to a point just southeast of Four Winds Plaza and is approximately 500 feet wide. The highest concentrations of total chlorinated VOCs occurred in shallow zone monitoring wells, where chlorinated VOC concentrations greater than 1,000 ppb were detected. The highest concentration was found in Monitoring Well MW-16 (3,543 ppb) at the Curriculum Center. The primary chlorinated VOCs detected in the northern plume are 1,2-DCE, PCE, and TCE. Vinyl chloride was also detected at high concentrations, but only in a few wells. The maximum concentrations of these compounds were 1,2-DCE at 2,100 ppb and vinyl chloride at 1,300 ppb (in Monitoring Well MW-16), PCE at 360 ppb (in Monitoring Well MW-1D), and TCE at 78 ppb (in Monitoring Well MW-1). Concentrations of total chlorinated VOCs greater than 1,000 ppb were not detected in any deep zone wells, but a total chlorinated VOC concentration of 931 ppb was detected in Monitoring Well MW-1D at the Curriculum Center. Historically, the concentration of PCE in the Tillett Supply Well, located downgradient of the Curriculum Center, has been reported up to 2,040 ug/L (Weston/SPER 1988), which exceeds 1 percent of the solubility of PCE. Based on USEPA guidance for DNAPL site characterization (USEPA 1992b), these data suggest the possible presence of DNAPL in the vicinity of the Curriculum Center.

The southern plume originates near the O'Henry Dry Cleaners and extends southeast approximately 4,000 feet; it is approximately 800 feet wide. In the shallow zone, the highest total concentration of VOCs detected in 1994 was 181 ppb in Monitoring Well OHMW-4, which is just downgradient of O'Henry Dry Cleaners. In the deep zone, total chlorinated VOCs were detected above 100 ppb in the Steele, LaPlace, Smith, and Harvey supply wells at concentrations between 137 and 173 ppb. The maximum concentrations of chlorinated VOCs were PCE at 140 ppb (in Monitoring Well OHMW-4) and 1,2-DCE at 100 ppb and TCE at 33 ppb (in the Steele Supply Well). Historically, chlorinated VOC concentrations (primarily PCE) in excess of 1,000 ppb have been detected adjacent to the O'Henry Dry Cleaners at Monitoring Well OHMW-4 (1,400 ppb in February 1990 and 1,000 ppb in January 1990) and the Harvey Supply Well (7,600 ppb in August 1987). The presence of PCE at concentrations in excess of 1,500 ppb suggests the possible presence of DNAPL in the saturated zone in the vicinity of the O'Henry Dry Cleaners.

2.2.2.2 Petroleum-Related Compounds

Two separate petroleum-related plumes have been delineated at the Tutu Wells Site. One plume is located near the Texaco Tutu Service Station and was measured to be approximately 400 feet long in its north-south dimension and 200 feet wide in its east-west dimension in 1994. The highest BTEX concentrations were detected in Monitoring Well TT-1 (58,700 ppb). Individual BTEX compounds were detected in Monitoring Well TT-1 at the following maximum concentrations: Benzene at 21,000 ppb, toluene at 16,000 ppb, ethylbenzene at 3,700 ppb, and xylenes at 18,000 ppb. The highest MTBE concentration detected was in Monitoring Well TT-4 (56,000 ppb). The highest n-propylbenzene concentration was detected in Monitoring Well TT-1 (450 ppb).

The second petroleum-related plume was located near the Esso Tutu Service Station and was measured to be approximately 200 feet long in its north-south dimension and 150 feet wide in its east-west dimension in 1994. The highest BTEX concentrations were detected in Monitoring Well SW-3 (39,300 ppb). BTEX compounds were detected in Monitoring Well SW-3 at the following maximum concentrations: Benzene at 10,000 ppb, toluene at 3,200 ppb, ethylbenzene at 4,100 ppb, and xylenes at 22,000 ppb. MTBE was detected at a maximum concentration of 89,000 ppb in this well.

2.2.2.3 Evaluation of the Potential Presence of Nonaqueous Phase Liquids

The presence of high concentrations of BTEX and chlorinated VOCs in groundwater indicates that nonaqueous phase liquids (NAPLs) may exist in the unsaturated or saturated zones at the Tutu Wells Site. NAPLs can either be less dense than water, such that they float on the water table and are termed light NAPLs (LNAPLs), or they are denser than water and sink through the aquifer as DNAPLs.

The detection in groundwater of individual chlorinated VOCs at concentrations in excess of 1 percent of their solubility is a strong indication of the possible presence of phase-separated chlorinated VOCs, or DNAPLs, below the water table. The possible presence of globules or droplets of DNAPL in bedrock fractures indicates that there is a potential source of chlorinated VOCs both in the unsaturated zone and below the water table that will continue to provide dissolved constituents. There are currently no technologies capable of completely removing DNAPLs from aquifers, especially in fractured bedrock, and their presence renders complete aquifer restoration impossible.

The absence of constituents above 1 percent solubility does not preclude the possibility of free product. For example, direct observations of floating product and sheens in some monitoring wells at the Esso Tutu and Texaco Tutu Service Stations confirmed the presence of LNAPLs, but BTEX concentrations in groundwater samples collected from these wells were not detected above 1 percent of the solubility of these individual compounds.

The solubility of benzene at 25 degrees Celsius (°C) is 1,750 milligrams per liter (mg/L). Therefore, 1 percent solubility would be 17.5 mg/L or 17,500 ug/L. Based on their solubilities, 1 percent solubility for the other BTEX constituents is 5,350 ug/L for toluene, 1,520 ug/L for ethylbenzene, and 1,750 ug/L for o-xylene.

The only locations where the concentrations of individual BTEX constituents exceeded 1 percent of the solubility were at Monitoring Wells TT-4 (located at the Texaco Tutu Service Station) and CHT-3 (located at the Esso Tutu Service Station). At Monitoring Well TT-4, benzene was detected at 21,000 ug/L, toluene was detected at 17,000 ug/L, ethylbenzene was detected at 3,300 ug/L, and total xylenes were detected at 17,000 ug/L. Floating product had been observed in Texaco Tutu Service Station Monitoring Wells MW-4D and MW-5, and product sheen and/or odors had been noted in Monitoring Wells TT-1, TT-1D, and TT-4.

At Monitoring Well CHT-3, ethylbenzene was found at 1,800 ug/L and total xylenes at 2,000 ug/L. Floating product has never been documented in Monitoring Well CHT-3, but product, sheen, and/or odors had been reported in Esso Tutu Service Station Monitoring Wells MW-9, MW-9S, and SW-7. Unlike DNAPLs, LNAPLs can be remediated through pumping and other technologies.

The current and historical soil and groundwater data for the various properties within the Tutu Wells Site were reviewed to assess the potential for DNAPL to be present in the subsurface. Based on this review, there is a moderate to high probability that DNAPL exists beneath the

O'Henry Dry Cleaners and Curriculum Center properties. The following information supports this conclusion:

- The historical use of PCE as a dry cleaning solvent at both locations suggests the high probability of a DNAPL release (USEPA 1992b).

- Concentrations of PCE in soil at the O'Henry Dry Cleaners exceed USEPA SSLs for potential groundwater contaminant source areas.

- Samples from the abandoned pipes in the floor of the Curriculum Center contained 30 percent PCE.

Groundwater samples from wells downgradient of the Curriculum Center and the O'Henry Dry Cleaners contained greater than 1 percent of the solubility of PCE (1,500 ug/L) (USEPA 1992b). For example, from 1987 to 1991, the maximum annual PCE concentration in the Harvey Supply Well, located downgradient of the O'Henry Dry Cleaners, ranged as high as 1,500 to 7,600 ug/L. In the Tillett Supply Well, which is downgradient of the Curriculum Center, the concentration of PCE was as high as 2,040 ug/L on July 22, 1987 (Weston/SPER 1988).

Therefore, DNAPL may be present in the vicinity of the Curriculum Center and the O'Henry Dry Cleaners. Due to the shallow depth to bedrock at the Curriculum Center, the release of DNAPL at this location could result in downward migration of DNAPL into the fractured bedrock above the water table. Similarly, at the O'Henry Dry Cleaners, a release of DNAPL near the land surface could migrate downward into the soil and weathered bedrock that is present above the water table.

2.3 CONTAMINANT FATE AND TRANSPORT

Contaminant fate and transport for soil and groundwater are evaluated in detail in the Phase II RI Report (Geraghty & Miller, Inc. 1995). Based on the results of soil and groundwater sampling at the Tutu Wells Site, numerous organic constituents were identified as COCs. To evaluate potential fate and transport processes for the COCs at the Tutu Wells Site, the physical and chemical properties of the constituents, the environmental transformation processes affecting the constituents, and the characteristics of the surrounding environment were examined. The primary COCs found in the soil and groundwater are chlorinated VOCs and petroleum-related compounds, primarily BTEX constituents.

The primary route of exposure to human receptors was transport of dissolved COCs in groundwater to supply wells used for domestic and commercial uses. Secondary exposure routes include potential ingestion, inhalation, and/or dermal contact with COCs in surficial soil.

2.4 BASELINE RISK ASSESSMENT

A baseline risk assessment for the Tutu Wells Site was prepared by CDM to evaluate the public health and environmental risks associated with constituents in the soil and groundwater. Both current and future risks associated with potential exposure to soil and groundwater from the Tutu Wells Site were addressed in this risk assessment (CDM Federal Programs Corporation 1995a).

Based on the risk assessment, only the surface soil at Tillett Gardens was found to exceed both the carcinogenic and non-carcinogenic acceptable risks. Groundwater risks were viewed for a site-wide rather than property-specific perspective, and specific compounds were found to exceed both the carcinogenic and non-carcinogenic risks for ingestion of groundwater. Subsurface soil did not exceed unacceptable risks for either carcinogenic or non-carcinogenic risks, where the soil is undisturbed.

As indicated in Table 2-2, the site-specific carcinogenic risk determined by the USEPA was exceeded for ingestion of surface soil at Tillett Gardens. The risk is attributed primarily to Aroclor 1242 (a PCB) and arsenic.

No properties other than Tillett Gardens had a carcinogenic risk from exposure to surface soil, and all properties at the Tutu Wells Site were below the carcinogenic risk for exposure to subsurface soil. The carcinogenic risk from ingestion of groundwater was exceeded for adults. The constituents contributing the majority of the risk were PCE and vinyl chloride.

For non-carcinogenic risks, the hazard index (HI) was exceeded for children via ingestion of surface soil at the Tillett property only; arsenic and manganese contributed to the majority of the risk (Table 2-3). In addition, due to manganese, the HI was greater than 1 via the inhalation pathway.

The HI was exceeded for all receptor populations including adult residents, children, site workers, and future construction workers (Table 2-3). In each instance, manganese accounted for the largest risk and was the only constituent of risk for site and construction workers. Total DCE, PCE, antimony, and vanadium were above the hazard quotient (HQ) for ingestion of groundwater by children.

Potential exposure pathways do exist for environmental receptors. Individual animals, such as lizards, may be exposed to low to moderate risks. However, the risk assessment has determined that the potential exposures to individual animals that may encounter COCs on-site will not result in an unacceptable risk to animal populations (CDM Federal Programs Corporation 1995a).

SECTION 3

3. REMEDIAL ACTION GOALS AND GENERAL RESPONSE ACTIONS

This section presents the remedial objectives, goals, and general response actions identified for the Tutu Wells Site. Remedial objectives and goals were established to address any unacceptable risks identified in the USEPA Baseline Risk Assessment (CDM Federal Programs Corporation 1995a). The USEPA's comments, made during the preparation of the RI Report (Geraghty & Miller, Inc. 1995) and the final Baseline Risk Assessment (CDM Federal Programs Corporation 1995a), were considered in the formulation of these goals and objectives.

3.1 REMEDIAL ACTION OBJECTIVES AND PRELIMINARY REMEDIAL GOALS

This section discusses the Remedial Action Objectives (RAOs) and preliminary remedial goals (PRGs) that will form the basis for the remediation of the Tutu Wells Site. RAOs are broad, media-specific objectives for protecting human health and the environment. These objectives were derived from the National Contingency Plan (NCP), USEPA guidance, and the results of the RI. PRGs are numerical standards and remedial endpoints for specific environmental media that, once they have been achieved, ensure that the RAOs have been satisfied.

3.1.1 <u>Remedial Action Objectives</u>

The RAOs for human health protection at the Tutu Wells Site are as follows:

- Remove and/or control the sources of groundwater contamination.

- Remove contamination in groundwater to the extent practical.

- Control the migration of impacted groundwater and limit the downgradient (i.e., southerly) migration.

- Prevent human ingestion of groundwater containing VOCs or BNAs in excess of federal maximum contaminant levels (MCLs) and non-zero Maximum Contaminant Level Goals (MCLGs) (see Table 3-1).

- Prevent human ingestion of groundwater containing site-related constituents in excess of the USVI DPNR Standards for Groundwater.

- Prevent human ingestion of groundwater exhibiting excess lifetime cancer risks greater than the range of 10^{-4} to 10^{-6} or hazard (non-cancer) indices greater than unity (1.0).

- Prevent human direct contact and exposure to contaminated soil that pose excess lifetime cancer risks greater than the range of 10^{-4} to 10^{-6} or hazard indices greater than unity (1.0).

- Minimize any potentially significant leaching of COCs from site soil into the groundwater.

- Protect human health and the environment by minimizing upconing of highly mineralized water and preventing saltwater intrusion. The bedrock aquifer in the Tutu Wells Site has a finite safe yield based on the rate of groundwater recharge from precipitation. Any groundwater remedial alternatives selected will have to be designed so as not to withdraw groundwater in excess of the aquifer's safe yield.

3.1.2 Preliminary Remedial Goals

PRGs consist of numerical limits or remedial target concentrations for specific constituents in specific media. These goals can be derived from the applicable or relevant and appropriate requirements (ARARs) identified for the site, naturally occurring or background concentrations, or health-based calculations derived using USEPA guidance on the development of risk-based PRGs (USEPA 1991b).

3.1.2.1 ARARs

Remedial actions must attain a general standard of cleanup that ensures protection of human health and the environment, is cost-effective, and uses permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practical. Cleanup standards and remedial design guidelines are usually based on ARARs. The potential ARARs for the Tutu Wells Site are divided into the following three major categories: chemical-specific requirements, location-specific requirements, and action-specific requirements. These ARARs are provided for federal and USVI statutes in Tables 3-2 to 3-7.

- Chemical-specific ARARs are health-based or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values that delineate the acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment.

- Location-specific ARARs are restrictions that may be placed on the concentration of hazardous substances or the conduct of activities solely because they occur in a particular location.

- Action-specific ARARs are generally performance, design, or other similar operational controls or restrictions on action related to management of hazardous substances or pollutants. These requirements address the particular activities that are selected to accomplish a remedy.

3.1.2.2 To-Be-Considered Material

TBC materials are non-promulgated advisories or guidance issued by federal or state agencies. They are not legally binding, and do not have the status of potential ARARs, but were considered in the selecting and implementing of remedial activities for the Site. For the purposes of this FS, one criterion is classified as a TBC, the USEPA's Vadose Zone Model for Soil Cleanup Concentrations (CDM Federal Programs Corporation 1995b). This TBC proposes guidance levels to evaluate potential impacts to groundwater quality from constituents in soil. These guidance levels are used in the FS as SSLs to determine if remedial action is necessary.

3.1.2.3 Remedial Action Levels and Cleanup Goals

Other PRGs will include the potential remedial action levels (RALs) and cleanup goals (CGs). RALs and CGs are developed to comply with ARARs and to be protective of human health and the environment. The RALs are chemical-specific criteria or concentrations that are used to determine if remediation is warranted. RALs can become CGs during the FS process if considered appropriate. CGs are chemical-specific criteria or concentrations that determine the degree of treatment or management required.

RALs do not exist for soil. The USEPA Baseline Risk Assessment determined that the COC concentrations detected in soil represent no risk via direct contact with human receptors, with the possible exception of PCBs and manganese at the Tillett property. The only possible impact from COCs in soil, therefore, is the potential for leaching to groundwater. For the Tutu Wells Site, the USEPA has developed SSLs to be used as screening levels, to identify COC concentrations in soil that could, by leaching, raise COC concentrations in groundwater above MCLs, and that may therefore warrant remediation (CDM Federal Programs Corporation 1995b). A comparison of compounds/analytes detected above the screening levels for soil is provided in Table 2-4.

For the purposes of this FS Report, RALs for groundwater are the MCLs established by the USEPA for drinking water (see Table 3-1). The CGs for groundwater used in this report are based on the anticipated discharge standards that apply to the location to which treated groundwater is discharged (i.e., potable water, surface water, groundwater, or publicly owned treatment works [POTW]) or on the groundwater quality standards if groundwater is treated or controlled in situ. In cases where DNAPL potentially exists in the bedrock (e.g., near the Curriculum Center and possibly near the O'Henry Dry Cleaners), groundwater technologies are discussed based on the ability of the technology to control further contamination by DNAPL, but not to reduce or eliminate DNAPL concentrations. Where DNAPL exists, CGs based on the groundwater source quality standards may not be achievable. A comparison of compounds/analytes detected above RALs for groundwater is provided in Table 3-8.

3.2 IDENTIFICATION OF GENERAL RESPONSE ACTIONS

General response actions consist of broadly conceived actions or categories of activities that will satisfy the RAOs for the Tutu Wells Site, either singly or in combination. General response actions potentially capable of, and appropriate for, meeting the RAOs discussed above were first identified during planning activities for the RI (Geraghty & Miller, Inc. 1995). The following medium-specific general response actions were retained for the Tutu Wells Site:

Soil

- No action
- Institutional controls
- Containment
- Treatment
- Removal and disposal

Groundwater

- No action
- Institutional controls
- Collection/containment
- Treatment
- Discharge

SECTION 4

4. IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

Potential remedial technologies capable of fulfilling the general response actions and meeting the RAOs set forth in Section 3.0 (Remedial Action Goals and General Response Actions) have been identified and are evaluated in this section. Remedial technologies applicable to soil and groundwater have been identified and screened for effectiveness and implementability.

The technologies evaluated in the following sections can, under appropriate conditions, be protective of human health and the environment, attain ARARs and PRGs, and may be implementable at the Tutu Wells Site. The technologies retained by the screening process are further evaluated in Section 4.6 (Further Evaluation of Screened Technologies).

4.1 TECHNOLOGY IDENTIFICATION

The identification of potential remedial technologies for this report utilized several sources of information, including the following:

- The remedial technologies contained in the USEPA "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (USEPA 1988a).
- The remedial technologies contained in the USEPA "Guidance on Remedial Actions for Contaminated Groundwater at Superfund Sites" (USEPA 1988b).
- Technology evaluation reports and compendia published by the USEPA under the Superfund Innovative Technology Evaluation (SITE) program.
- The remedial technologies contained in the USEPA "Presumptive Remedies: Site Characterization and Technology Selection for CERCLA Sites with Volatile Organic Compounds in Soils" (USEPA 1993).

4.2 TECHNOLOGY SCREENING CRITERIA

As required by USEPA guidance (USEPA 1988a), the technologies identified for the environmental media of concern were initially screened for effectiveness, implementability, and cost criteria. The evaluation of the technology focused on the following considerations:

- The estimated areas or volumes of media to be remediated and meeting the goals and objectives set forth in Section 3.0 (Remedial Action Goals and General Response Actions).

- The implementability and the potential impacts to human health and the environment during construction.

- The efficiency and reliability of the remedial technology or process option with respect to the contaminants and conditions at the Tutu Wells Site.

Implementability is based on the technical and administrative feasibility of implementing the technology. Technical implementability is used as an initial screen to eliminate those technologies that are clearly ineffective and unworkable at the Tutu Wells Site. Administrative implementability considers the ability to obtain necessary permits for on-site and off-site actions; the availability and capacity of treatment, storage, and disposal services; and the availability of necessary equipment and workers to implement the technology. Another factor that may affect administrative implementability is the ability of USEPA and the DPNR to execute enforceable agreements with responsible parties to better control withdrawal of groundwater. Unauthorized use of groundwater from the Tutu aquifer must be minimized to enable the chosen remedial action to be implemented, controlled, and effective.

Cost criteria play a limited role in initial screening of remedial technologies and process options. Relative capital and operation and maintenance (O&M) costs are used in this section, and more detailed cost analysis will be provided in Section 5.0 (Development and Screening of

Remedial Alternatives). In accordance with USEPA guidance (USEPA 1988a), the relative costs of technologies evaluated in this FS Report are characterized as low, moderate, or high (e.g., expensive) for comparison of similar technologies that would be utilized for the same objective.

Remedial technologies for soil are based on the guidance provided by the USEPA for presumptive remedies (USEPA 1993). Review of this guidance indicates that, in order of preference, soil vapor extraction (SVE), thermal desorption, and incineration are presumptive remedies that can successfully address the type of soil contamination present at the Tutu Wells Site. Due to the complex and heterogeneous soil characteristics at the site, application of these technologies will be considered both in-situ and ex-situ. Because the screening and comparative analysis of alternatives for soil are formulated in the USEPA (1993) guidance document, screening of remedial technologies for soil is not required. However, further evaluations of additional alternative technologies are provided for completeness.

4.3 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES FOR SOIL

In this section, potentially applicable technologies for remediating the COCs in impacted soil at the Tutu Wells Site are described and reviewed for technical implementability. A summary of the screening results for soil is presented in Table 4-1.

4.3.1 <u>No Action</u>

No action is defined as the absence of any protective steps to address the affected medium, with the possible exception of periodic site monitoring. Consideration of no action is required by the NCP because it evaluates the potential impacts associated with not implementing any remedial action for soil. The results of the Baseline Risk Assessment (CDM Federal Programs Corporation 1995b) indicate that the no action alternative may be applicable to impacted soil at several of the individual properties in the Tutu Wells Site area.

No action will be retained for further consideration and used as a baseline for comparing the effectiveness of active remedial measures for soil at the Tutu Wells Site.

4.3.2 Institutional Controls

Institutional controls encompass several strategies that limit or prevent the likelihood of human and environmental contact with impacted soil. Although institutional controls can be implemented to limit access to specific areas, they do not increase the volume or minimize constituent concentrations in the affected environmental media. At sites where a potential exists for exposure to impacted soil or groundwater, institutional controls can reduce the potential for exposure.

One type of institutional control that can be implemented at the Tutu Wells Site is access restrictions. Access restrictions are a type of institutional control that can be employed to address soil and groundwater contamination problems. Access restrictions consist of preventing human contact with contaminated soil. One such access restriction is a deed restriction.

Deed restrictions involve annotating the deed for the property to limit or prohibit use of the property for specific purposes or for specific uses of the property and/or soil. For example, deed restrictions could prohibit use of the property for residences, schools, or parks to prevent direct contact with impacted soil. Similarly, deed restrictions could prohibit a wide range of potential soil uses, such as use for fill at other properties.

Deed restrictions are a proven, reliable, and established method of institutional site control. Minimal maintenance is required, and health risks associated with implementation of this remedial technology are minimal. Costs associated with deed restrictions would include filing and legal fees and are anticipated to be moderate. Implementation and enforcement of deed restrictions would require continual monitoring at the restricted properties to ensure compliance with the restrictions.

Deed restrictions will be retained for further consideration as a remedial measure for soil at the Tutu Wells Site due to their potential effectiveness and implementability.

4.3.3 Containment

A containment technology considered for the contaminated soil at the Tutu Wells Site is capping. Containment serves three functions. First, it prevents direct contact by humans with impacted soil, thereby eliminating exposure pathways involving dermal contact, ingestion, or inhalation. Second, it eliminates the possibility of erosion and transport of impacted soil. Third, it reduces the infiltration of precipitation through the soil and the leaching of site constituents into the underlying groundwater.

Containment of impacted soil can be attained by capping the soil in place to reduce the potential for human exposure and control fugitive emissions from impacted soil. Caps can also be low-permeability barriers placed over an area of soil contamination to prevent surface-water infiltration (if potential leaching to groundwater is a concern). The types of materials that could be used for caps include soil, clay, asphalt, concrete, and polymer membranes. With the exception of concrete and asphalt, capping materials are generally covered by soil and vegetation compatible with the region.

Due to the fact that much of the Tutu Wells Site is currently covered with asphalt and concrete, at many properties, capping may consist only of checking the integrity of these surfaces and repairing or expanding them where necessary. Many of the source areas at the Tutu Wells Site are already capped by existing pavement, building foundations, or concrete pads. Improvement of existing surfaces and installation of new caps would eliminate direct contact and reduce or eliminate leaching of contaminants to the underlying groundwater.

No disposal or transportation requirements for waste are associated with this remedial technology. Only inspection and periodic maintenance costs are included to ensure the caps are intact.

The capital costs associated with capping are dependent on the construction materials selected for the cap and can range from low to moderate. The O&M costs will vary depending on the type of capping system installed.

Containing the soil at the Tutu Wells Site by capping is technically implementable and will be retained for further evaluation.

4.3.4 Treatment

As previously noted, the USEPA (1993) presumptive remedy guidance for treatment technologies for VOC-impacted soil has identified SVE as the primary presumptive remedy. For completeness, thermal desorption and incineration, which are secondary treatment options identified in the USEPA (1993) guidance, are also evaluated in the preliminary screening of technologies. Additional consideration is also given to bioventing, as it may be adaptable at specific properties within the Tutu Wells Site and the application of similar technologies in an ex-situ remedy. Ex-situ remedies are considered and evaluated in Section 4.3.5 (Removal Technologies).

4.3.4.1 In-Situ Soil Vapor Extraction

In-situ SVE is a treatment technology that consists of installing a network of vadose zone extraction wells or trenches through areas where soil contamination with VOCs exists. VOCs present in the unsaturated, interstitial spaces between the soil particles are extracted under the influence of a vacuum that is induced by a blower. This action upsets the equilibrium that exists between the constituents present in the interstitial vapor space and any constituents that might be present in an adsorbed phase on the soil particles or be present in a free phase. As the constituents in the vapor phase are removed by the vacuum, some of the adsorbed or free-phase constituents adjust to the shift in equilibrium by volatilizing into the soil pore spaces. These newly volatilized constituents are then removed under the constant influence of the vacuum that is induced by the extraction blower. For biodegradable compounds, such as BTEX, added benefit is gained from the enhanced biodegradation of these compounds by indigenous soil biota due to increased soil oxygen levels.

Often, soil vapors extracted using this approach must be treated to reduce or destroy the constituents present in the blower exhaust to acceptable discharge levels. Potential technologies evaluated for treating the exhaust from the extraction blower include vapor phase granular activated carbon (VPGAC), incineration, thermal oxidation (thermox), or catalytic oxidation (cat-ox).

Based on published information (Mobil 1992) regarding the treatment of VOCs in air, the following generalizations can be used as a guide to quickly determine an appropriate off-gas treatment technology for an SVE system:

- VPGAC is generally used where total VOC concentrations are below 50 parts per million by volume (ppm_v) and where poorly adsorbed compounds such as vinyl chloride do not require treatment. If air flow rates are low, VPGAC could prove to be a cost effective method of air treatment despite high VOC concentrations.

- Use of a thermox unit is suggested to treat hydrocarbon off-gas containing chlorinated VOCs present at concentrations greater than the 100 ppm_v or 10 percent of the total VOC concentration.

- Use of a cat-ox unit is suggested to treat hydrocarbon off-gases when initial concentrations are between 50 ppm_v and 10,000 ppm_v of total VOCs.

- At most sites, SVE and bioventing system VOC off-gas concentrations will decline rapidly (exponentially) with time. Based on industry experience, thermox or cat-ox units can be removed from a property after 6 to 12 months of operation. Thus, at certain properties, several off-gas treatment technologies could be used, depending on the off-gas concentrations. Therefore, the off-gas control technology selection will be a compromise between a unit that would provide adequate treatment at the higher initial concentrations and one that would be adequate and cost-effective at the longer-term, lower concentrations.

- In applications that require thermox or cat-ox systems due to high VOC concentrations, the off-gas treatment may be modified after the initial concentrations of VOCs fall below 50 ppm_v. A more cost-effective technology such as VPGAC is often applied in the lower concentration range. If vinyl chloride is present in the off-gas, the discharge concentration must be evaluated using air dispersion calculations to determine if vinyl chloride vapor concentrations would create potential human health concerns. Continued use of a thermox system may be required.

- Due to the higher costs of the thermox and cat-ox units (between \$60,000 and \$100,000 for a 600 standard cubic feet per minute [scfm] system), thermal destruction equipment can be moved from one site to another for re-use to reduce capital costs and maximize the use of the equipment.

For the cost estimates established in this FS, it has been assumed that a therm-ox unit will be used to treat vented VOC-laden air streams. Thermox was selected because chlorinated VOCs can deactivate or degrade conventional catalysts and VPGAC is generally not cost effective at recovering chlorinated VOCs at concentrations above 100 ppm_v. The Source Control Plan (SCP) for Texaco has included a cat-ox unit for off-gas treatment. A general summary of off-gas treatment technologies is provided in Table 4-2.

At the Tutu Wells Site, air dispersion modeling may be used to determine the need for off-gas treatments. However, due to the low soil concentrations detected, no off-gas treatment is anticipated for most of the individual sites. Furthermore, off-gas treatment, if any, should be of low duration due to the exponential decay of the concentrations over time from the SVE or bioventing systems.

SVE is a very reliable and cost-effective method for treating certain soil contaminated with a wide range of VOCs, provided that the soil properties are conducive to this technology. Implementability of the technology is moderate as permits for air discharge would be required. Based on the cleanup standards for soil, SVE can be evaluated on a site-specific basis.

The capital costs for in-situ vapor extraction would be moderate to high, and O&M costs would be moderate to high depending on the need and type of emission controls. The type of emission controls required at each property would have to be further evaluated during the pre-design phase. SVE will be retained for further consideration.

4.3.4.2 In-Situ Bioventing

In-situ bioventing is a treatment technology that is similar to SVE. The primary difference between the two treatment technologies is that bioventing employs much lower air flow rates, thereby enhancing biodegradation and minimizing contaminant volatilization and extraction. Drawing air through soil at low flow rates provides oxygen to indigenous bacteria and enhances their ability to aerobically biodegrade COCs. By reducing air flow rates, the removal of moisture from the vadose zone is minimized. Soil moisture is a factor that affects bacterial activity. A bioventing system may include the reinjection of contaminated gases (with or without some treatment), resulting in no off-gas discharge to the atmosphere, thus eliminating the need for vapor-phase treatment and an air discharge permit. Supplemental oxygen can be added to the reinjected gases to accelerate the rate of bioremediation.

Bioventing is particularly suitable at sites where non-halogenated volatile and semivolatile organic compounds (SVOCs) and certain fuel hydrocarbons are the primary COCs. Bioventing of halogenated VOCs may require additional precautions and in general is not very effective unless there is a co-metabolite present. Application of this technology would require evaluation on a property specific basis.

This treatment technology is relatively inexpensive to implement, as it does not require the use of expensive equipment or intensive O&M; however, it could have some limitations at properties where chlorinated VOCs are present. It is also very reliable and requires minimal downtime for maintenance and repairs. This treatment technology will be retained for further consideration.

4.3.5 Removal Technologies

Source removal can be achieved by excavating contaminated soil at the Tutu Wells Site. The excavated material would be containerized and tested for waste classification. If the soils is deemed non-hazardous, they could be disposed locally. If deemed hazardous, they would either be treated ex-situ and disposed of on-site as backfill or transported off-site to a hazardous waste treatment or disposal facility.

The impacted soil can be removed from the Tutu Wells Site by mechanical excavation. Standard excavating equipment, including backhoes, power shovels, and clamshells, can be used to excavate soil and can be decontaminated afterward. The excavated material can be staged for subsequent treatment or containment on-site or containerized and loaded directly into trucks for off-site treatment or disposal. Exposure to impacted soil during removal can be addressed by personal protective equipment. There is the potential for residential exposure to fugitive emissions or dust during excavation. However, engineering controls can minimize emissions.

Several ex-situ treatment and disposal options related to removal technologies are further discussed in this section. The technologies evaluated are Biopiles/ex-situ SVE, thermal desorption, and incineration (USEPA 1993). Implementation of this technology is favorable assuming an approved method of disposal is readily available, and/or replacement of treated soil can be accomplished. Excavation and disposal is potentially applicable and this process option will be retained for further analysis.

4.3.5.1 Biopiles/Ex-Situ SVE

Biopiles involve the ex-situ biological treatment of contaminated soil whereby the degradation of organic contaminants by micro-organisms occurs in an aboveground, controlled environment. Micro-organisms may be either indigenous or externally introduced. Oxygen is supplied to the piles via ambient air injection. The air can be blown directly into the pile or drawn through the piles using a vapor extraction blower. Where compounds are readily volatilized, such as is the case with many chlorinated VOCs, the bulk of the soil treatment takes place by volatilization with little or no biodegradation of the VOCs taking place. Biopiles applied to soil contaminated with BTEX, petroleum compounds, and other readily biodegradable hydrocarbons are designed to allow more biodegradation to take place with little or no volatilization.

An ex-situ SVE system is configured similar to a biopile but is designed to optimize volatilization. These systems are designed to draw a vacuum in a covered pile, thus inducing air flow through the soil piles and volatilizing the VOCs. Ex-situ SVE systems are applied in situations where in-situ SVE is impractical or of limited use. Chlorinated VOCs, BTEX, and other VOCs can be treated with this technology.

Depending on air emission limits, control of the VOC emissions from the biopile may be required. Vapor treatment will be dependent on contaminants; the same technologies evaluated for in-situ SVE treatment would apply.

The capital costs associated with biopiles and ex-situ SVE would be moderate to high due to the excavation of soil and the off-gas treatment technology used (if necessary). O&M would be moderate to high and would be based on the off-gas treatment technology used. These technologies will be retained for further evaluation.

4.3.5.2 On-Site Thermal Desorption

Thermal desorption is a thermal treatment technology that involves the application of elevated temperatures to soil to volatilize VOCs from excavated soils. Application of this technology may require the collection and treatment of the off-gases that are produced. The temperature used for thermal desorption (typically from around 400 to 1,100 degrees Fahrenheit [°F]) depends on the volatility and boiling point of the COCs.

Thermal desorption has been shown to be effective in treating soil with VOCs. Commercial units exist and are in operation, but use of these facilities would require off-island transport and disposal of excavated soil. On-site thermal desorption units are usually expensive and are cost-prohibitive where soil volumes are small.

The capital costs for thermal desorption would be high and O&M costs would be moderate to high depending on the need and type of emission controls. The costs to excavate and stockpile the contaminated soil would be moderate to high depending on the volume, area to be excavated, and COCs present. More cost-effective technologies are under consideration; this technology is not retained for further analysis.

4.3.5.3 Incineration

Incineration is another treatment technology similar to thermal desorption except that incineration treats VOCs in the excavated soil to temperatures greater than 1,000 °F in the presence of oxygen. This causes volatilization and combustion of the VOCs, converting them to carbon dioxide (CO_2), water, hydrogen chloride (HCl), nitrogen oxides (NO_x), and sulfur oxides (SO_x). Implementation of on-site incineration would be difficult due to permitting requirements and limited spacing which allows for air dispersion of emissions prior to reaching potential receptors. The disposal of incinerated ash, which would likely be considered a hazardous waste due to the potential metals content, would present implementation difficulties because off-island disposal would be required.

The most well-developed, proven, and commercially available form of thermal destruction is rotary kiln incinerators. These incinerators consist of slightly inclined, refractory-lined cylinders where soil and auxiliary fuel are injected into the high end of the kiln and passed through the combustion zone as the kiln slowly rotates for incineration. Temperatures within the combustion zone typically range from 1,200 to 1,800 °F, and the retention time can vary from several minutes to 1 hour or more. VOCs are oxidized to gases and inert ash within this zone, with ash being removed at the lower end of the kiln. Flue gases are passed through a secondary combustion chamber and then through air pollution control units for particulate and acid gas removal. Off-site disposal of soil would be required as the soil would not be reusable for fill or replacement.

The capital and O&M costs for this technology are high. The costs associated with excavating and stockpiling the contaminated soil are moderate to high depending on the volumes and depths of impacted soil. This technology is not retained for further consideration as there are more cost-effective and implementable technologies under consideration.

4.4 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES FOR GROUNDWATER

In this section, potentially applicable technologies for remediating the VOC contamination in groundwater at the Tutu Wells Site are described and evaluated. If treated water is considered for potable use, additional technologies to treat naturally occurring inorganic contaminants (e.g., precipitation, reverse osmosis, and ion exchange) are also evaluated. The primary COCs include chlorinated VOCs and petroleum-related hydrocarbon compounds.

During this screening process, technology types or technology process options are eliminated from further consideration based on effectiveness, implementability, and/or cost. The following sections present the results of this technology screening for the technologies evaluated. A summary of the screening results for groundwater is presented in Table 4-3.

4.4.1 No Action

No action is a general response action that is required by the USEPA and the NCP to be carried through to the detailed analysis phase of the FS. The no-action approach will be considered for evaluation of the potential impacts associated with not implementing any remedial action for groundwater. No action will be retained for further consideration and used as a baseline for comparing the effectiveness of active remedial measures for groundwater underlying the Tutu Wells Site.

4.4.2 Institutional Controls

Institutional controls encompass several strategies that limit or prevent the likelihood of human and environmental contact with impacted soil or groundwater. Although institutional controls can be implemented to limit access to specific areas, they do not increase the volume or minimize constituent concentrations in the affected environmental media. At sites where a potential exists for exposure to impacted soil or groundwater, institutional controls can effectively reduce the potential for exposure to site-related constituents.

4.4.2.1 Access Restrictions

One type of institutional control that can be implemented at the Tutu Wells Site is access restrictions. Access restrictions are a type of institutional control that can be employed to address soil. Access restrictions consist of preventing human contact with impacted groundwater. One such access restriction is deed restrictions.

Deed restrictions involve annotating the deed for the property to limit or prohibit use of groundwater on the property for specific purposes or for specific uses. For example, deed restrictions could prohibit a wide range of potential groundwater uses, such as pumping for water-supply use (development of the groundwater for human consumption), agricultural use (watering livestock or irrigating crops), or industrial use (cooling water or process make-up water).

Deed restrictions are a proven, reliable, and established method of institutional site control. No maintenance is required, and health risks associated with implementation of this remedial technology are minimal. Costs associated with deed restrictions would include filing and legal fees and are anticipated to be low. For those sites with contaminated groundwater, provisions for an alternate water supply would have to be made.

Deed restrictions will be retained for further consideration as a remedial measure for groundwater at the Tutu Wells Site due to their potential effectiveness and implementability.

4.4.2.2 Alternate Water Supply

Alternative residential water supply options are often considered in emergency situations, and/or when it is not practicable or feasible to actively restore groundwater to drinking water quality, and access to impacted groundwater is restricted. Three options are available for providing an alternate water supply source, including extension of public water supply lines, trucking water, and installation of a new community well for water supply.

4.4.2.2.1 Public Water Supply Extension

This remedial technology involves providing a supply of drinking water from a suitable, non-contaminated source to residents in the affected areas. This can be accomplished in the Tutu Wells Site area by extending the existing municipal water supply system in the area (managed by the Virgin Islands Water and Power Authority [WAPA]) to the affected users. Plans for future upgrades exist and they could be expanded to include connections to properties that have impacted residential wells.

The extension of the existing water supply system to affected users would be technically feasible, but construction of waterline extensions would be very expensive due to the shallow depth to bedrock and length of water line installation necessary to provide water to all affected residences. Connection costs for residences near the existing water main would be lower (approximately $2,000 per residence). Use of the public water supply system will not restore former commercial water supply entities in the Tutu Wells Site.

A public water supply extension for residential consumptive use will be retained for further consideration as a remedial alternative for groundwater at the Tutu Wells Site.

4.4.2.2.2 Trucking Water

In 1987, the DPNR closed 13 commercial wells and five private wells in the Tutu Wells Site area. Subsequently, the USEPA initiated a limited CERCLA Removal Action that included the delivery of water by tank trucks to the residents affected by the closure of the wells. This water delivery has been accepted by the USEPA as permanent solution for affected residents. It may be an option for consideration on a permanent basis for all residents in the Tutu Wells Site. Costs associated with trucking water would be high and would be contingent on the availability of water in other places in St. Thomas.

Trucking of water has been accepted in the past as a remedial alternative for groundwater supply at the Tutu Wells Site. For this reason, it will be retained for further consideration.

4.4.2.2.3 New Community Well

The installation of a new uncontaminated supply well for use in the affected Tutu Valley is another alternate water supply option. This new supply well could be used as a community watering point by the residents in the area who now rely on other sources of water (e.g., trucked water).

A new supply well may be technically implementable, but the cost of locating and developing and distributing water from an alternate supply well would be high. The well would have to be located outside of the area of impacted groundwater, and pipelines or trucking to distribute the water to residents would be required. There would also be no guarantees as to the quantity or quality of water in a new location.

This technology will not be retained for further consideration as a remedial alternative for the Tutu Wells Site, due to the high costs associated with locating an alternate water supply well and providing the required distribution operations and piping or trucking.

4.4.3 Collection/Containment

Collection of groundwater refers to the process of extracting or otherwise collecting impacted groundwater, and containment restricts migration of the impacted groundwater to other areas. Collection can be accomplished using subsurface drains, extraction wells, and well points. Containment can be accomplished by creating hydraulic barriers using extraction wells or through vertical physical barriers such as slurry or cutoff walls.

4.4.3.1 Extraction

Groundwater extraction is a common and proven method of collecting impacted groundwater and can be used effectively to hydraulically contain impacted groundwater from migrating beyond a site perimeter. In this section, several methods of extraction are described and evaluated for use at the Tutu Wells Site.

4.4.3.1.1 Extraction Wells

Groundwater extraction wells are a common method for intercepting impacted groundwater. Extraction wells have been utilized extensively at other Superfund sites and can be installed in most terrains.

The anisotropic conditions at the Tutu Wells Site would require additional testing to develop and document an extraction well system that hydraulically contains the contaminated groundwater. Based on field measurement adjustments and monitoring, a groundwater extraction well system could be installed that would contribute to the improvement of groundwater quality at the Tutu Wells Site by reducing constituent migration and removing COCs from the groundwater.

If existing supply wells or monitoring wells are utilized for collection of impacted groundwater, no capital costs for drilling would result. Otherwise, costs associated with drilling would be incurred. Drilling new wells for extraction of groundwater may require more wells than initially projected because some extraction wells may not provide the desired yield or capture zone. Capital costs would be incurred for purchase and installation of the extraction pumps. These costs would be relatively high due to the need for specialized construction materials (e.g., stainless steel, Teflon, or other non-corrosive metals/polymers for wetted parts) to resist the corrosive effects of chloride ions and other dissolved species present in the groundwater. O&M costs would be relatively high due to the energy requirements and general upkeep and maintenance of the pumps and well screens.

Extraction wells will be retained for further consideration. The decision to retain this technology was based on the potential effectiveness in enhancing groundwater remediation under the Tutu Wells Site.

4.4.3.1.2 Extraction/Injection Wells

This technology involves the reinjection of treated groundwater into the aquifer through injection wells by pumping or gravity flow. Reinjection has been used at several sites throughout the United States. The fundamental purpose of using injection wells is to ensure recharge of the aquifer and at the same time enhance the groundwater remediation by increasing the hydraulic gradient toward the extraction wells.

Controlling flow in fractured bedrock may not be achievable because of the low permeability and anisotropic nature of the aquifer. Plugging of bedrock fractures with precipitates and biological growth will decrease injection well performance and increase O&M costs. Also, there is a possibility of inducing lateral and/or downward migration of contaminants. Groundwater modeling and/or additional field measurements would be required to determine the recharge and recovery rates for the aquifer. A permit to discharge to groundwater would also be required and would require a treatment facility that would have to meet stringent discharge standards (e.g., MCLs).

The capital costs would be moderate to high depending on the number of injection wells required. The costs to operate and maintain the wells would be high.

This technology is not retained for further consideration because of the anticipated limitations in controlling hydraulic containment during combined extraction and injection in an anisotropic and complex aquifer.

4.4.3.2 Subsurface Drains

Subsurface drains consist of trenches excavated below the water table and filled with highly permeable material, such as gravel, and perforated piping as collection media. The permeable material and piping serve as conduits to induce flow from the subsurface to a collection point for extraction and treatment. The subsurface drain serves as a continuous barrier that maximizes groundwater extraction and minimizes contaminant migration. When gravity flow can be induced through proper design and construction, subsurface drains can operate very cost-effectively.

The effectiveness of subsurface drains may be reduced by the occurrence of pervious bedrock throughout the area. Should subsurface drains be constructed in areas of highly pervious bedrock, the drains may create enhanced migration pathways from the contaminant sources to bedrock fractures currently free of contamination.

Subsurface drains are unsuitable for remediation of the groundwater underlying the Tutu Wells Site due to the shallow depth to bedrock. The anisotropic conditions present in the area would make it difficult to avoid creating migration pathways that may spread, rather than contain, the contaminated groundwater. Furthermore, contaminated groundwater also occurs at a depth of 30 to more than 100 feet bls throughout the Tutu Wells Site. Subsurface drains could not be installed at the Site because conventional excavation cannot reach the depth required to create an effective hydraulic barrier. Even if specialized excavating equipment could be found to reach the required depths, the construction costs in bedrock would be excessively high.

Subsurface drains will not be retained for further consideration because of the difficulties associated with technical implementability and the excessive cost associated with construction.

4.4.3.3 Well Points

Well points are another common method of intercepting or collecting contaminated groundwater. Well points are similar to groundwater extraction wells in many respects. The primary differences are that well points are limited to smaller diameters and shallower depths and are most commonly installed in unconsolidated deposits. Due to the small diameters of well points (i.e., 2 inches or less), well points are interconnected (i.e., manifolded) to a central centrifugal or suction-lift pump above land surface rather than using individual pumps in each well point. Because of these limitations, well points are usually employed for temporary construction, such as dewatering at construction sites with a relatively shallow water table.

Well points are not a suitable method of collecting groundwater underlying the Tutu Wells Site. They would be ineffective because of the significant depth to groundwater (30 to 100 feet bls) and could not be constructed because of the prohibitive depths. Well points will not be retained for further consideration because of their ineffectiveness and construction difficulties.

4.4.3.4 Vertical Barriers

Vertical barriers are a remedial technology group that encompasses slurry walls and synthetic membrane cutoff walls. Both types of vertical barriers form physical barriers that restrict or prevent the migration of contaminated groundwater to other areas that are clean or less contaminated. These barriers can also be used in applications where clean groundwater from upgradient areas can be directed around the contaminated areas.

4.4.3.4.1 Slurry Wall

Slurry walls are the most common type of vertical barriers to control groundwater migration. A slurry wall is usually constructed of soil and bentonite as a means of reducing the horizontal permeability of the soil. Slurry walls are generally extended 2 to 3 feet into a confining geologic unit, and they are usually not installed through bedrock. Excavation of bedrock for slurry wall installation is expensive due to the specialized equipment required to remove the rock.

A slurry wall is constructed by using a backhoe to excavate a 2.5- to 4-foot wide trench in one pass. The trench is kept open by hydraulic shoring through the use of bentonite slurry. The bentonite slurry creates a filter cake on the sides of the trench because the slurry flows laterally into the soil. This filter cake consists of a layer of bentonite with low permeability. The trenches are generally dug by using a small backhoe and are less than 40 feet deep. Greater trench depths can be attained by using track-mounted backhoes and clamshell excavators attached to a kelly bar or crane. The practical maximum depth limit for slurry walls is about 100 feet in unconsolidated deposits.

Typically, soil excavated from the trench is used as backfill material to mix with the bentonite slurry. The permeability of the constructed slurry wall should be on the order of 10^{-6} to 10^{-7} centimeters per second (cm/sec). To improve the overall effectiveness, slurry walls are often constructed in conjunction with extraction wells and a cap.

Implementing the use of slurry walls at the Tutu Wells Site would be very difficult because contaminated groundwater underlying the site occurs mostly in fractured bedrock. For a slurry wall to function properly, it would need to be constructed through the bedrock and be keyed into an underlying unit. Based on geologic information, a suitable confining unit has not been identified at the Tutu Wells Site. Slurry walls are not generally excavated through bedrock due to the specialized construction techniques (e.g., use of explosives) required. Importing fill material may also be required as materials removed from the trench may not be satisfactory for slurry wall construction. Specialized construction equipment in the Virgin Islands, if available, would be expensive, and would be difficult to implement.

Slurry walls will not be retained for further consideration based on technical implementability limitations and the presence of bedrock, which creates very high construction costs.

4.4.3.4.2 Synthetic Membrane Cutoff Walls

Synthetic membrane cutoff walls are similar to slurry walls because they also involve the excavation of a trench. After the trench is excavated, a synthetic membrane (typically a sheet of polyethylene) is placed so that it covers the sides and bottom of the trench. Backfill material is then placed and compacted to fill the trench void.

Synthetic membrane cutoff walls share the same technical implementability limitations that make slurry walls unsuitable for the site. Synthetic membrane cutoff walls are generally limited to even shallower depths because no means of hydraulically shoring the sides of the trench exist to prevent collapse. The use of a synthetic membrane cutoff wall also requires a significant amount of material to fill the trench void, and fill material is expensive. Therefore, this technology is typically implemented only when groundwater occurs within a few feet of the land surface. As with slurry walls, synthetic membrane cutoff walls are generally not installed into bedrock.

This remedial technology will not be retained for further consideration. Similar to slurry walls, the decision not to retain this technology was based on the problems with technical implementability and the very high construction costs.

4.4.3.5 Enhanced Groundwater Recovery

Enhanced groundwater recovery is a remedial technology group that encompasses technologies that help reduce the time required for remediation. The enhancement recovery techniques evaluated are bedrock fracturing and vacuum enhanced recovery.

4.4.3.5.1 Bedrock Fracturing

Bedrock fracturing is a technology that is used to increase the flow of contaminated groundwater to extraction wells. Fracturing can be performed through the application of high pressure air or water to enhance existing fractures or create new fractures around the extraction wells. Another option would consist of creating an artificial fracture zone through controlled blasting to intercept contaminated groundwater flow. Fracturing would be positioned perpendicular to the groundwater flow, and extraction wells would be installed within this fracture zone.

The advantage of fracturing is the potential to increase the yield of extraction wells. By increasing the yield, the extraction wells could be pumped at a higher rate and the time for remediation would be reduced. However, maximum extraction rates would be limited by the established safe-yield of the aquifer within the Tutu Wells Site. Costs associated with using explosives would be high and O&M costs would be moderate.

Potential blasting restrictions due to underground utilities, residential areas, and buildings may limit the use of this technology at the Tutu Wells Site area. Another limitation is the possible presence of DNAPL contamination in the bedrock. Fracturing could mobilize DNAPL and enhance the downward and lateral migration of phase-separated contaminants.

Because this technology would be administratively difficult to implement and would have technical limitations, bedrock fracturing is not implementable and will not be retained for further consideration.

4.4.3.5.2 Vacuum Enhanced Recovery

This technology utilizes a vacuum to accelerate groundwater flow in low permeability formations. Vacuum extraction wells are installed in the areas of concern, and a vacuum is applied to the headspace above the static water level in these wells. Vapor and groundwater are extracted simultaneously. The combined effect (liquid and vapor removal) may significantly increase the contaminant removal rate.

The capital costs of vacuum enhanced recovery (VER) are moderate due to the specialized construction of dual extraction wells. O&M costs would be dependent on the number of dual extraction wells and blowers required. Implementation in bedrock would be difficult due to the high potential for short-circuiting in bedrock. Extensive pilot testing would be required to ensure its effectiveness.

Due to limitations (i.e., short circuiting) of controlling VER in bedrock, and because other more applicable technologies are under consideration, this technology is not retained for further consideration.

4.4.4 <u>Treatment</u>

This section presents two methods of treatment for groundwater (in-situ and ex-situ treatment).

4.4.4.1 In-Situ Treatment

In-situ treatment of affected groundwater consists of those technologies that can be applied without the extraction of groundwater. Potential in-situ remedial technologies include air sparging and bio-sparging.

4.4.4.1.1 Air Sparging

Air sparging is an in-situ treatment technology that can be applied without the extraction of groundwater to reduce organic concentrations in the subsurface environment. Air is injected below the contaminated saturated zone, causing turbulence and groundwater mixing, which increases the rate of soil and water contaminant desorption. Contaminants are transferred to the air phase and the air is pulled through the vadose zone to ground surface by extraction or vacuum wells.

Air sparging is most applicable in relatively permeable and homogeneous geologic formations. Its effectiveness is greatly diminished by the presence of clay layers or variations in permeability. Heterogeneous soil or complex bedrock fracture patterns may force the injected air to travel in a horizontal direction and drive the contaminants into uncontaminated areas. The anisotropy and relatively low permeability of the fractured rock and the depth to groundwater at the Tutu Wells Site limit the applicability of this technology. The capital cost of this option is moderate and O&M would be low to moderate. Air sparging could be considered on a property-specific basis at the Tutu Wells Site and will be retained for further consideration.

4.4.4.1.2 Bio-Sparging

Bio-sparging is an in-situ technology that can be used to remediate biodegradable organic compounds in subsurface saturated zones. The technology consists of introducing small amounts of air and nutrients into the subsurface to enhance the natural aerobic biodegradation of organic contaminants.

As with air sparging, depending on the geologic and hydrogeologic conditions, this technology can cause contaminants to migrate. The potential for contaminant migration limits the applicability of bio-sparging at the Tutu Wells Site; however, it may be appropriate at specific properties. Chlorinated VOCs in groundwater, which extend over a much larger area than the petroleum-related compounds, are not effectively biodegradable under aerobic conditions.

The cost of this option is low and O&M requirements are minimal. This technology is technically feasible; however, it would require additional evaluation to determine its effectiveness. Bio-sparging will be retained for further consideration.

4.4.4.2 Ex-Situ Treatment

Ex-situ treatment involves groundwater extraction followed by some form of treatment and discharge. The range of potential treatment technologies for VOCs in groundwater will be further limited by the ARARs identified for the site.

The ex-situ treatment technologies that will be considered for remediating the groundwater at the Tutu Wells Site are air stripping (packed tower aeration); granular activated carbon (GAC) adsorption; ultraviolet oxidation/reduction; and GAC fluidized bed systems for organic constituent treatment. To treat naturally occurring inorganic constituents; filtration, precipitation, flocculation, sedimentation, reverse osmosis, and ion exchange are being evaluated. These technologies are considered highly reliable for the treatment of groundwater and are screened in this section.

4.4.4.2.1 Air Stripping

Air stripping involves the transfer of VOCs from the liquid to the gaseous phase using a countercurrent air/water scrubber. This process usually involves aeration of the extracted groundwater in a packed tower. The tower packing consists of inert structured plates or randomly dumped geometric shapes. Both types of packing provide large surface areas for contact between the water and air phases.

Packed tower aeration is a proven technology that has been used to treat groundwater at numerous groundwater remediation sites. Proper operation of the process has demonstrated high levels of removal effectiveness for many VOCs. In some cases, complete treatment may require pretreatment or polishing to remove other constituents in addition to the VOCs. Therefore, air stripping may be a stand-alone technology for certain contaminants or may be one process in a more complex treatment system. Depending on contaminant loadings and regulatory requirements, treatment of the exhaust gases from the air stripper may be required to destroy or capture the VOCs that are transferred into the air phase.

The most common form of off-gas treatment is typically VPGAC. However, thermox or cat-ox units (as described in Section 4.3.4.1 [In-Situ Soil Vapor Extraction]) can be utilized where total VOC vapor concentrations exceed 50 ppm_v, or where chlorinated VOCs are present. Cat-ox is usually not considered where the concentrations of chlorinated VOCs are greater than 100 ppm_v, as they can deactivate conventional catalysts. A summary of off-gas treatment technologies is provided in Table 4-2.

Based on Geraghty & Miller's preliminary estimates for contaminant concentration in groundwater, no off-gas treatment should be required for the pumping scenario(s) considered. The need for off-gas treatment will be determined during the pre-design phase of the project.

Air stripping towers involve simple installation and start-up procedures. The system pumps and blowers are easily maintained, and the equipment draws minimal power. However, regular maintenance may be required to maintain optimal operating conditions. If properly maintained, a long service life can be expected for air stripping equipment.

Capital costs for air stripping would be low to moderate. O&M costs would be moderate to high depending on the need and type of emission controls, if required. Because it is very effective for removing VOCs present in the groundwater underlying the site, air stripping will be retained for further consideration. The decision to retain this technology for further consideration was based on the potential effectiveness and implementability of air stripping.

4.4.4.2.2 Granular Activated Carbon Adsorption

Adsorption utilizes porous media to cleanse waste streams of impurities. Typically, GAC is used because it has a higher affinity for many hydrocarbons and certain inorganic constituents. The adsorption mechanism is hindered, however, by the presence of some inorganic compounds, thus requiring removal of metals and/or solids prior to adsorption by GAC. Although adsorption does not destroy contaminants, it facilitates their disposal by transferring them from a fluid phase to a solid phase and concentrating them.

GAC adsorption would be an effective means of removing most VOCs present in the groundwater underlying the Tutu Wells Site. GAC adsorption does not effectively remove vinyl chloride. One way to reduce the rate of GAC depletion is to couple this technology with air stripping to remove the major portion of the VOCs. In such an application, GAC would serve as a polishing system to remove the remaining VOCs in the water effluent from the air stripper to attain the required system discharge limits.

GAC adsorption is also implementable given the site conditions. It is both constructable and operable and poses only minimal risks to human health and the environment. Close monitoring and periodic GAC replacement is necessary to prevent constituent breakthrough. Replacement is generally accomplished by either regeneration or acquisition of virgin GAC and disposition of spent GAC. Specialized equipment or labor is not required for GAC adsorption, and the necessary equipment is commercially available.

Capital costs related to GAC adsorption are moderate to high depending on the size of the contacting beds and on whether any ancillary equipment is needed. O&M costs would be dominated by the costs for transportation and disposal or regeneration of the spent GAC. Depending on the rate at which the GAC is exhausted, these costs would also be moderate to high.

Because it would be effective in the removal of VOCs present in the groundwater underlying the site, GAC adsorption will be retained for further consideration.

4.4.4.2.3 Filtration

Filtration is a technology that utilizes porous media to remove suspended solids from a waste stream by providing a preferential flow path for water while preventing the migration of suspended particles in the water, based on particle size. Commonly used filter media are sand, anthracite, or other specialty medias. Filtration is a proven and effective technology for the removal of suspended particles and is relatively easy to implement. However, periodic backwashing to discharge trapped particles, which would require monitoring and maintenance, would be required. Capital and O&M costs would be moderate. Filtration may be used as part of a more complex treatment system. Due to its potential effectiveness, filtration will be retained for further evaluation.

4.4.4.2.4 Precipitation, Flocculation, and Sedimentation

Precipitation, flocculation, and sedimentation have been applied widely to a variety of wastewaters for the removal of suspended solids and metals. The groundwater enters a rapid mix tank where chemicals are added to oxidize the suspended metals, soften the water, and adjust the pH to preferentially precipitate the target metals. The water then flows to a chamber in which a flocculent (e.g., anionic polymer, cationic polymer, and/or alum) is added and gently agitated so as not to shear the floc. The water then flows to a settling basin in which the flocculated particles agglomerate and settle quiescently. Sedimentation relies on gravity to remove flocculated particles (as opposed to filtration, which screens particles of a given diameter).

Precipitation, flocculation, and sedimentation constitute a proven technology for the removal of metals, insoluble inorganic salts, and suspended solids. This technology is dependent on chemical additives and requires regular sludge removal and disposal; therefore, O&M costs would be moderate. These processes will be retained for further consideration.

4.4.4.2.5 Reverse Osmosis

Reverse osmosis can be used for the separation of both organic and inorganic constituents from an aqueous stream. Separation is achieved by preferential passage of one or more constituents in an aqueous medium through a semi-permeable membrane. An applied pressure is used to overcome osmotic pressure, which is a result of a solution trying to reach an equilibrium condition. Typically the operating conditions of these systems consume large amounts of energy to establish the required pressure differential. Effluents from the process include a permeate stream, composed primarily of water, and a concentrate stream containing water and the constituents removed from the water. The concentrate stream may require treatment or disposal as a regulated material.

Reverse osmosis has been demonstrated to be an effective remedial technology for the treatment of dissolved nitrates and metals in groundwater. Organic compounds with a molecular weight of greater than 200 are generally removed by this process. Pretreatment of the groundwater is required if oil and grease and/or suspended solids are present in the water. The technology is highly temperature-sensitive, not easily adaptable to variation in flow and loading, complicated to operate and maintain, and very high in cost. This technology has been used in other portions of the Tutu Valley for removal of dissolved solids and is potentially applicable at the Tutu Wells Site. However, capital and O&M costs are high. This technology will be retained for further consideration.

4.4.4.2.6 Ion Exchange

Ion exchange is a highly dependable technology for inorganic and some organic compounds. It involves the transfer of constituent ions and cations from water to an exhaustible ion exchange resin. This resin is relatively insoluble granular material that has acid or basic radicals exposed on its surface. As ion exchange generally softens the water, a polishing step may also be required to adjust effluent hardness. Ion exchange systems have low O&M costs but a high capital cost. This option is a proven technology for the removal of inorganic compounds and is retained for further analysis.

4.4.4.2.7 Ultraviolet Oxidation/Reduction

Ultraviolet (UV) oxidation/reduction is a technology that destroys dissolved organic constituents (e.g., VOCs) in groundwater by means of chemical oxidation. Specifically, the oxidation process that takes place involves an oxidation-reduction (redox) reaction because one of the species involved gains electrons and another loses electrons, thereby destroying organic compounds. Ozone and hydrogen peroxide are widely used as oxidants in conjunction with UV light to remove organic compounds. Due to the expense, safety issues, and instability of ozone, hydrogen peroxide, rather than ozone, will be considered for the Tutu Wells Site.

UV light catalyzes the chemical oxidation of organic compounds in groundwater by its combined effect on the organic constituents and its reaction with hydrogen peroxide. Many organic constituents absorb UV light and undergo a change in their chemical structure, and many become more reactive with chemical oxidants. UV light at less than a 400-nanometer (nm) wavelength reacts with hydrogen peroxide molecules to form hydroxyl radicals. UV oxidation/reduction has been demonstrated to completely destroy chlorinated VOCs such as those found in the Tutu Wells Site (e.g., PCE, and TCE) with minimal air emissions.

A UV oxidation/reduction system can handle variable flow rates and loadings; however, where groundwater is excessively hard, pretreatment for the removal of dissolved solids is required. Without pretreatment, the calcium deposits would coat the quartz tubes and prevent the extracted groundwater from being exposed to UV light.

The capital and operating costs are high, and the O&M costs are high due to the complexity of the system and energy consumption. Although this technology has high associated capital and O&M costs, it is an effective treatment technology for the COCs found in groundwater in the Tutu Wells Site. This technology will be retained for further consideration.

4.4.4.2.8 GAC Fluidized Bed System

The GAC fluidized bed system is a bioremediation technology that combines the use of activated carbon with an aerobic or anaerobic biological process to treat biologically degradable VOCs in groundwater. Activated carbon is utilized as the inert medium for attached microbial growth in the fluid bed reactor. As water passes upward through the bed of medium, the bed lifts and expands until it "fluidizes." This increases the surface area available for microbial growth, which enables an increased rate of organic compound degradation. The increased surface area offers the advantage of reduced system size, making the GAC fluid bed system easily portable. As the microorganisms begin to grow, a bio-film develops, grows, and rises to the top of the bed where the film is removed. Little, if any, off-gas is produced, and a minimal amount of carbon replacement is necessary since the carbon is biologically regenerated within the fluid bed.

GAC fluidized bed reactors would be particularly effective in treatment of biodegradable petroleum-related COCs identified in the Tutu Wells Site groundwater. Capital and O&M costs would be moderate. This technology is considered to be potentially applicable to the Tutu Wells Site and therefore will be subject to further analysis.

4.4.4.3 Natural Remediation

Natural remediation is the reduction of constituent concentrations through attenuation and degradation. Natural attenuation relies on the natural ability of groundwater to lower contaminant concentrations through physical, chemical, and biological processes until cleanup levels are met. Portions of the Tutu Wells Site aquifer that have been impacted by site constituents will naturally attenuate with time. Active remediation of these areas through extraction and treatment will not enhance or shorten the time frame in which aquifer remediation can occur. Monitoring and institutional controls would also be implemented to ensure that no off-site receptors will be impacted. Capital costs and O&M costs would be low to moderate. As this technology has potential use at the Tutu Wells Site, this technology will be retained for further consideration.

4.4.5 Discharge

The discharge point of treated groundwater will be an important factor that will affect the cost and implementability of the remedial alternative that will be ultimately selected.

There are several technologies that can be considered for the discharge of treated groundwater. These methods include discharge to a POTW; transport to a RCRA-permitted treatment, storage, and/or disposal facility (TSDF); discharge to a surface-water body; conveyance to a beneficial user for non-potable purposes; re-injection; or re-use for drinking water (potable use). In some cases, these methods may or may not be coupled with treatment. The discharge options at the Tutu Wells Site are considered only in combination with collection and treatment.

In this section, the effectiveness of each discharge option is evaluated, implementability issues are reviewed, and the costs associated with implementing each discharge option are evaluated. A summary of the technology screening of discharge options is provided in Table 4-3.

4.4.5.1 Discharge to Publicly Owned Treatment Works

Discharge of treated groundwater from a site to a local POTW is an established reliable technology. This approach involves trucking extracted groundwater to a nearby treatment plant or discharging treated groundwater to a sanitary collection system that conveys the discharge to the local POTW. In either case, final discharge of the treated groundwater would be through the outfall of the local POTW. Discharge of the water into the sewer system may require pretreatment prior to its acceptance at the POTW. This technology is a common and effective way to dispose treated groundwater.

Based on Geraghty & Miller's review, the local POTW that services the Tutu Wells Site is currently operating at capacity and cannot accept new discharges. There are plans for POTW expansion in the near future that would make this approach easier to implement. However, these plans are in the preliminary stages of development and cannot currently be considered in the evaluations. Implementation of this technology would require local POTW expansion.

If available POTW treatment capacity existed, approvals would be needed from the USVI Department of Public Works (DPW) for discharge into the sanitary sewer system. If the discharge were to comprise a significant portion of the total flow into the local POTW, it is possible that the treatment efficiency at the local POTW could be reduced. This could cause the DPW to object to the discharge and require an alternative to be considered. Also, discharging treated groundwater to the local POTW would not be an effective re-use of the treated groundwater, as the subsequent discharge point would not replenish the Tutu aquifer.

The capital and O&M costs associated with this technology would be low to moderate, depending on the level of treatment that would be required to meet permit limits. Geraghty & Miller anticipates that treatment to background groundwater quality would be sufficient. There are significant implementability issues that must be resolved prior to implementing this technology. Since the current POTW does not have the capacity for the expected effluent flow rates (approximately 100 gpm), discharge to the local POTW will not be considered for discharge of treated water.

4.4.5.2 Discharge to a RCRA-Permitted Treatment, Storage, and/or Disposal Facility

Disposal at a RCRA TSDF is not an effective technology for the discharge of groundwater. No facilities of this type operate on a commercial basis within the USVI. Implementing this technology for groundwater treatment would involve off-island transport and disposal at a RCRA-permitted TSDF in the mainland United States. This option would be administratively difficult to implement due to the transport of impacted groundwater off-island, and the costs associated with executing the transport and disposal would be prohibitively high. For these reasons, this technology will not be retained for further consideration.

4.4.5.3 Discharge to Surface Water

Discharge to a surface-water body is a potential technology for discharge of treated groundwater at the Tutu Wells Site. The treated groundwater could potentially be discharged into Turpentine Run, the stream that transects the Tutu Valley. Effectiveness of this disposal technology would be favorable because there is a surface-water body that could effectively receive the discharge of treated water

A surface-water discharge would require application for a Territorial Pollution Discharge Elimination System (TPDES) permit. Discharge limits associated with the issuance of the permit may be less stringent than MCL requirements, reducing the level of treatment that would be required for potable discharge options. Review of background data collected by the U.S. Geological Survey (USGS) (1973) indicates that surface-water quality in the vicinity of the Tutu Wells Site is similar in background inorganic concentrations to that found in groundwater. Therefore, treatment for inorganic water quality parameters should not be necessary unless it affects the operation of the treatment system. Additionally, the effluent from the treatment system may actually provide some benefit to existing conditions downstream, providing a continued source of flow for the stream. Stationary wastewater treatment plants discharge downstream of the proposed remedial alternative discharge and would provide some dilution of effluents downstream.

An assessment of potential impact to a wetland identified by the USEPA will be needed. Table 4-4 provides background water quality data from the USGS gauging station at Turpentine Run at Mt. Zion. Effluent quality parameters similar to these could be established. Continual monitoring of the effluent quality would also be required to ensure compliance with the permit limits.

The extraction of groundwater and subsequent discharge to the Turpentine Run would not provide a beneficial re-use of treated groundwater in the Tutu Valley. However, surface water could potentially recharge groundwater downstream of the point of discharge through infiltration within the natural stream channels and would potentially become available for re-use downgradient.

Implementability issues exist with this technology, as a TPDES permit requires, at a minimum, 12 to 18 months to secure, and negotiations with local regulatory agencies will be regional. The costs to implement this option would be low to moderate, depending on the permit limits that would have to be met. This option is technically implementable and will be retained for further consideration.

4.4.5.4 Conveyance to Beneficial Non-Potable User

Another method for discharging extracted groundwater is re-use of the treated water for beneficial non-potable use. This technology would be effective and provides a re-use of the extracted groundwater in the study area.

This method would involve piping the treated groundwater to a point where it could be distributed for commercial or industrial purposes or residential non-potable use. There are several commercial users (e.g., laundromat, car wash, and concrete plant) in the area that could make use of non-potable water, deriving a beneficial use for the groundwater resource.

This technology may be administratively difficult to implement. Treated groundwater use would be required and would involve negotiations with several commercial users to ensure continual use. A commitment for continual use of groundwater may be difficult for a commercial user to anticipate, as commercial groundwater uses could vary throughout the year. Conversely, the collection and containment objectives for the groundwater pumpage would require nearly continuous operation.

The treatment requirements associated with this discharge option would not be as stringent as compliance to MCLs, but the water would require treatment to background water quality at a minimum. The costs associated with implementation would be moderate.

This option will not be retained for further consideration in this FS Report due to the implementability issues associated with finding a beneficial user that could accept the anticipated flow rate.

4.4.5.5 Re-Injection

Re-injection of treated groundwater would involve discharging treated groundwater into injection wells or infiltration galleries where it could be introduced back into the aquifer. This may not be as effective as other options depending on how and where it is implemented.

This technology would allow re-use of extracted groundwater, through infiltration and recharge, and may also enhance groundwater remediation, by enhancing the flushing action caused by continual pumping. Re-injection could be accomplished in several ways; the two most common methods are shallow re-injection through the use of infiltration trenches or galleries, and deeper re-injection through the use of re-injection wells.

The use of re-injection wells would be difficult to implement due to the anisotropic conditions of the underlying fractured bedrock. O&M costs would be high due to the potential for plugging of reinjection wells with precipitation and biological growths. If infiltration galleries are used, a sufficient area would be required for construction of the disposal beds. The effect of recharge or groundwater flow in the bedrock aquifer would be difficult to monitor and control.

This type of disposal would require a TPDES permit to discharge to groundwater and could require treatment of the extracted groundwater to MCLs. The anticipated time frame required to secure a permit to discharge to groundwater would be approximately 12 to 18 months.

Due to limitations of maintaining hydraulic control during injection into an anisotropic and complex aquifer, and high associated O&M costs, this technology will not be considered for further evaluation.

4.4.5.6 Distribution for Potable Use

The most direct beneficial re-use option is providing groundwater for potable use to residents. This would be an effective discharge option, would involve re-use of groundwater in the Tutu Wells Site, and would provide an additional drinking water source in St. Thomas. Beneficial re-use for potable use is an important consideration on St. Thomas due to the limited water supply resources available on the island.

After treatment, groundwater would be stored, tested, and distributed to residential users, either through distribution mains or trucking, for potable water use. The local water purveyor, the WAPA, has a distribution system in place and is planning to improve the distribution system in the vicinity of the Tutu Wells Site. A direct connection to this system is feasible, possibly supplemented by a storage tank, to provide additional storage that could be used during high demand periods. During periods of low use, the treated water could be discharged to waste, either directly or through storage tank overflow.

Potable use would require treatment of extracted groundwater to remove inorganic constituents that are naturally occurring in the valley, such as total dissolved solids (TDS), in excess of secondary MCLs. Treatment of inorganic constituents would increase the complexity of the treatment facility required and could double the capital costs for treatment when compared to the costs associated with non-potable use. Annual O&M costs would also increase, due to the added requirement of sludge handling and disposal.

Discharge of treated groundwater into the public water supply system would also create administrative issues. Approvals would be needed from the WAPA, and stringent effluent discharge requirements would have to be met. Treatment to meet MCL requirements would have to be provided. Requirements for testing of the treated water prior to distribution could also be required. For cost-estimate purposes, Geraghty & Miller has assumed that a 2-day turnaround of treated water analyses would be conducted and a 3-day storage capacity would be provided to allow for confirmation of acceptable potable water quality prior to distribution. In order to better evaluate the cost for this potentially important discharge option, Geraghty & Miller prepared a detailed cost estimate for a typical groundwater remedial alternative using a potable use discharge option for the Tutu Wells Site. Appendix A provides a cost estimate for the potable use discharge option.

Capital and O&M costs would be significantly higher than other discharge technologies due to the increased level of treatment required. Due to the implementability issues associated with this technology and the high cost, it will not be retained for further consideration.

4.5 TECHNOLOGIES RETAINED FOR FURTHER CONSIDERATION

A number of potentially suitable and feasible remedial technologies have been identified and subjected to a screening process in accordance with the USEPA guidance (USEPA 1988a). The outcome of this process was the selection of several remedial technologies and process options for soil and groundwater that will be retained for further consideration. The following technologies were retained for remediation of soil and groundwater underlying the Tutu Wells Site:

Soil

- No Action
- Institutional Controls
  - Access Restrictions
    - Deed Restrictions
- Containment
  - Capping
- In-Situ Treatment
  - In-Situ Soil Vapor Extraction (SVE)
  - Bioventing
- Ex-Situ Treatment
  - SVE Treatment
  - Biopiles
- Removal and Disposal
  - Excavation and Off-Site Disposal
  - Excavation On-Site Treatment and On-Site Disposal

Groundwater

- No Action
- Institutional Controls
  - Access Restrictions
    - Deed Restrictions
- Alternate Water Supply
  - Trucking Water
  - Public Water Supply Extension
- Collection/Containment

- Extraction
  - Extraction Wells
- In-Situ Treatment
  - Air-Sparging
  - Bio-Sparging
- Ex-Situ Treatment
  - Air Stripping
  - GAC Adsorption
  - Filtration
  - Precipitation/Flocculation/Sedimentation
  - Reverse Osmosis
  - Ion Exchange
  - UV Oxidation/Reduction
  - GAC Fluidized Bed
- Natural Remediation
- Discharge
  - Discharge to Surface Water

The soil and groundwater technologies listed above have survived screening and may be applicable for remedial applications at the Tutu Wells Site. These screened technologies could be applied separately or in conjunction as a system. For the purposes of this FS Report, representative assemblies of the most effective technologies are compiled for comparison purposes. As indicated by FS guidance (USEPA 1988a), the cost difference between different process options will not significantly affect the overall comparison of remedial alternatives. For soil, the following representative technologies are used:

- Capping.
- In-situ SVE/bioventing.
- Ex-situ SVE/biopiles and onsite disposal.

- Excavation and offsite disposal.

For groundwater, the following representative technologies are used:

- Collection/containment.
- Ex-situ treatment using air stripping and GAC adsorption.

4.6 FURTHER EVALUATION OF SCREENED TECHNOLOGIES

The technologies identified in Section 4.5 (Technologies Retained for Further Consideration) are further evaluated in this section. Site-specific characteristics are considered to recommend a specific remedial technology for soil and groundwater. Soil remedial alternatives are evaluated for individual properties. Groundwater remedial alternatives are discussed on a site-wide basis. In addition, Source Control Plans (SCPs) for soil and groundwater contamination near the Texaco and Esso service stations are discussed for consistency, scheduling, and coordination of proposed remedial actions. The technologies considered for further evaluation in this FS are those best suited to address the overall environmental concerns at the Tutu Wells Site and to meet the RAOs.

4.6.1 Source Control Plans

Implementation of SCPs has been proposed at the Texaco Tutu Service Station and the Esso Tutu Service Station. In this section, a summary description is provided to describe each SCPs. More detailed descriptions of these remedial alternatives have been prepared by independent consultants and have been, or will be, submitted to the USEPA under separate cover. Discussions of the SCPs in this FS are limited to a conceptual evaluation of the technologies proposed. The effect of these SCPs on the planned site-wide remediation at the Tutu Wells Site is also evaluated in this FS.

4.6.1.1 Texaco Tutu Service Station Source Control Plan

Groundwater extraction wells will be installed at the downgradient property line of the Texaco Tutu Service Station to remediate and contain the migration of petroleum compounds dissolved in groundwater. It is estimated that total groundwater pumpage necessary for optimum capture of BTEX at the Texaco facility will be approximately 20 gpm. Groundwater will also be extracted from a well near the northern boundary of the Vitelco property to remediate and control the further migration of the portion of the petroleum hydrocarbon plume that is downgradient of the service station. This proposed extraction well at the Vitelco property will be pumped at a rate of approximately 10 gpm. The combined pumpage for the Texaco SCP will be approximately 30 gpm. At each groundwater extraction location, the groundwater will be routed to treatment units housed in a cargo container. Extracted groundwater will be treated by air stripping to achieve compliance with Federal Drinking Water MCLs. The treated water will be discharged to the storm sewer under a TPDES permit.

At the Texaco Tutu Service Station, an 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. Cat-ox will be used to provide off-gas control.

The SCPs proposed at the Texaco Tutu Service Station can be effective at remediating soil at the site and can provide effective capture of the source area for groundwater impacted by petroleum hydrocarbons. The technologies presented are in conformance with those screened in the FS and can be optimized and refined during operation to maximize remediation of the source area.

4.6.1.2 Esso Tutu Service Station Source Control Plan

SCPs will be implemented at the Esso Tutu Service Station. Groundwater will be extracted from four shallow recovery wells (presently assumed to be existing Monitoring Wells MW-9 or

CHT-2, SW-7, SW-1, and CHT-3) on or near the Esso property. Available site hydraulic data indicate that the combined groundwater withdrawal rate from these wells will range from 5 to 15 gpm. Extracted groundwater will be treated on-site through an existing air stripping and GAC system. Treated groundwater will ultimately be discharged, under a TPDES permit, to the storm sewer beneath the Four Winds Plaza (Turpentine Run). Given prior mass loading calculations and permit requirements, it has been assumed that a de minimis waiver can be obtained for untreated air stripper off-gas.

Pending site pilot studies, bioventing and biosparging may be incorporated into the Esso SCPs to elevate oxygen levels and increase the biodegradation of dissolved COCs. Residual soil impact will be addressed through an integrated bioventing and SVE program. The conceptual design for this system presently incorporates two horizontal vapor extraction trenches and a minimum of four biosparging wells. One vapor extraction trench will be positioned adjacent to the north oil/water separator. The second trench will be installed near the pump island. Off-gas treatment will be evaluated further in the pre-design phases of implementation.

The SCPs proposed at the Esso Tutu Service Station can be effective at remediating soil at the site and can provide effective capture of the source area for groundwater impacted by petroleum hydrocarbons. The technologies presented are in compliance with those screened in the FS and can be optimized during the operation to maximize remediation of the source area.

4.6.2 Soil Remedial Technologies

Geraghty & Miller has compared the soil data collected during the RI to the SSLs established for soil at the Tutu Wells Site (see Table 2-4). Seven sites have been identified as potentially requiring remedial action for soil; these sites are the Curriculum Center, Ramsay Motors, Texaco Tutu Service Station, Tillett Gardens, Western Auto, Esso Tutu Service Station, and O'Henry Dry Cleaners. The potential need for remediation at Tillett Gardens was identified in the Baseline Risk Assessment (CDM Federal Programs Corporation 1995a). Table 4-5 identifies the properties potentially requiring soil remediation, the contaminants at each property that exceed SSLs, and the areas and estimated soil volumes potentially requiring remediation.

The remedial technologies for soil that were retained based on initial screening were listed in Section 4.5 (Technologies Retained for Further Consideration). These remedial technologies were considered on a property-specific basis to evaluate the application of these technologies to the specific site conditions. A few of the technologies or process options were combined during the evaluation. For example, No Action and Institutional Controls were combined because if the No Action alternative was selected, Institutional Controls would be required to be implemented in conjunction with the No Action alternative (see Table 4-6).

Capping of soil containing contaminants above acceptable levels is generally applicable to all areas of the Tutu Wells Site. Capping may consist of (1) continued maintenance of existing concrete or asphalt paving or (2) installation of a new cap (see Table 4-7).

The in-situ treatment technologies (In-Situ SVE and Bioventing) and the ex-situ treatment technologies (Ex-Situ SVE and Biopiles) were combined for this property-specific evaluation (see Tables 4-8 and 4-9). The selection of in-situ or ex-situ treatment for soil is a fundamental decision based on the COCs present and site conditions such as volume (which determines cost-effectiveness), building foundations and physical access (which affects implementability), and subsurface conditions, such as soil type (which affects the potential effectiveness).

Regardless of whether in-situ or ex-situ treatment is selected, the treatment methods will be selected based on the contaminants present. SVE (in-situ or ex-situ) will be effective in reducing both chlorinated VOCs and BTEX constituents. However, bioventing (in-situ) and biopiles (ex-situ) would provide an additional treatment option for BTEX constituents.

Excavation and disposal of impacted soil at affected properties would result in complete removal of the impacted areas from the Tutu Wells Site (see Table 4-10). The excavated soil would be classified as either hazardous or non-hazardous waste through laboratory testing of representative samples by Toxicity Characteristic Leaching Procedure (TCLP) methods. If deemed hazardous, comparison of laboratory results with contaminant levels identified in the federal Land Disposal Restrictions (LDRs) would determine if land disposal is allowable. If the material excavated is considered non-hazardous, the material would be disposed at the Bovoni landfill located approximately 2 miles southwest of the Tutu Wells Site. This is the only disposal option on St. Thomas, and this option would require extensive testing to demonstrate the material is non-hazardous. If the excavated material is considered hazardous, the material would be shipped for treatment and for disposal at an approved hazardous waste facility off-island. For the purposes of cost estimates, this FS Report includes disposal costs based on disposal as a hazardous material.

In addition to the property-specific evaluation of technologies presented in Tables 4-6 through 4-10, each property is discussed further below. Based on the specific site conditions, the remedial technologies for soil will be compiled into Soil Remedial Alternatives (SRAs), which represent an assembly of applicable soil technologies to derive site-wide remedial alternatives.

4.6.2.1 Curriculum Center

Soil sampling conducted during the RI at the Curriculum Center indicated the presence of BTEX constituents above SSLs in the vicinity of the northeast corner of the Curriculum Center building (see Figure 4-1). Chlorinated VOCs (including PCE) have been detected in soil and soil gas at the north and northwest portions of the building, but were not found in soil above the SSLs during the RI. However, chlorinated VOCs may be present at higher concentrations in the unsaturated bedrock (which was not sampled) underlying the property, as suggested by the high chlorinated VOC concentrations in the groundwater near and downgradient of the Curriculum Center.

Due to the shallow depth to bedrock and the limited extent of BTEX-impacted soils, excavation and disposal is proposed at the northeast corner of the Curriculum Center. Excavation and ex-situ treatment on-site will also be considered; however it may be more expensive to implement due to the relatively low soil volume (see Table 4-5).

To remediate the potential presence of DNAPLs in the unsaturated bedrock, an SVE program is being considered for implementation at the Curriculum Center. SVE is a presumptive remedy for VOC contamination. Capping can also be implemented at the soil surface to reduce a groundwater infiltration into the unsaturated bedrock, thus reducing the leaching of contaminants to groundwater. The bedrock surface is relatively shallow at the Curriculum Center, making capping potentially applicable to controlling the impact of DNAPLs in unsaturated bedrock. Additional property characterization of a remedy would be required to determine the potential locations of DNAPLs prior to implementation. The potential locations of soil remediation and bedrock remediation at the Curriculum Center are shown on Figure 4-1. Preliminary SVE well locations are based on a soil gas survey performed by Geraghty & Miller (Geraghty & Miller, Inc. 1995). These locations would have to be better defined by further drilling and sampling in suspected source areas prior to implementation of this remedial technology.

4.6.2.2 Ramsay Motors

Soil impacted by BTEX has been detected above the SSLs near the waste oil UST beneath the Ramsay Motors maintenance garage (see Figure 4-2). Groundwater samples collected from downgradient monitoring wells did not show the presence of BTEX compounds during the RI. The small volume of potential soil for remediation makes capping the most cost-effective technology. Because existing cracks in the concrete may allow for infiltration of rainfall and surface spills, the floor slab would need to be removed and replaced to provide an appropriate cap. Due to the location of the waste oil UST beneath the concrete floor slab of the maintenance garage, excavation for soil remediation is not considered cost-effective because it would require complete demolition of the building. If downgradient monitoring wells continue to show no presence of BTEX constituents, capping (i.e., replacement of the concrete floor) would be the most effective soil remedy.

4.6.2.3 Texaco Tutu Service Station

Soil impacted by BTEX constituents was found at the Texaco Tutu Service Station. The unconsolidated deposits and the upper portion of the fractured bedrock underlying the Texaco Tutu Service Station are relatively permeable and could be treated in-situ with either SVE or bioventing. Due to the high vapor pressure of BTEX constituents, SVE is considered the preferred in-situ treatment alternative of the two. Also, SVE tends to enhance biodegradation of BTEX constituents, in addition to volatilization of BTEX. The small volume of impacted soil may make excavation and disposal a more economical alternative than in-situ treatment. Ex-situ treatment of excavated soil prior to disposal on-site could also be considered; however, the small volume of impacted soil may make the cost of on-site ex-situ treatment prohibitive. The potential locations of soil remediation at the Texaco Tutu Service Station are shown on Figure 4-3. A SCP currently being prepared for implementation at the Texaco Tutu Service Station was discussed in Section 4.6.1.1 (Texaco Tutu Service Station Source Control Plans).

4.6.2.4 Tillett Gardens

In the USEPA's Baseline Risk Assessment (CDM Federal Programs Corporation 1995a), arsenic and PCBs were determined to be present in soil at Tillett Gardens at concentrations above safe exposure levels. Due to the small volume of impacted soil identified, capping or excavation and disposal are the only alternatives considered viable. Figure 4-4 illustrates the potential location of remediation for Tillett Gardens.

4.6.2.5 Western Auto

The soil near Western Auto location was impacted by BTEX constituents. Previous UST removals were completed by Western Auto (ENSR Consulting and Engineering [ENSR] 1994); the available data suggest that impacted soil may still be present in that area. The soil in the vicinity of the former USTs consists primarily of clay with a relatively low permeability and would not be a suitable medium for in-situ remediation. SVE and bioventing are not considered viable and will not be considered at the Western Auto property. It is likely that clumps of excavated clay would require extensive pulverization and reworking prior to attempting on-site treatment. Because of the low permeability clay, excavation and on-site ex-situ treatment are also considered ineffective.

Excavation and disposal and capping of the impacted soil at the Western Auto facility are the only two options considered. Excavation and disposal may be difficult to implement due to the need to excavate close to existing buildings. In addition, work should also include removal or elimination of potential source areas as defined in previous studies (ENSR 1994; Geraghty & Miller, Inc. 1995). Buried 4-inch diameter PVC piping may be a potential source and should be investigated further. For the purposes of this FS, a 2-foot thick layer of soil extending 2.5 feet east and west of the PVC pipe was assumed to require remediation. This PVC pipe is not related to Western Auto operations. However, the further investigation and possible remediation of the PVC pipe should be coordinated with Western Auto due to the proximity of the PVC pipe and the former Western Auto USTs. The areas where remediation is potentially required near the Western Auto facility are illustrated on Figure 4-5. The shaded area on this figure encompasses an area where soil was previously removed as part of the UST removal. A credit for removal of 35 cubic yards of soil related to the prior UST closure was included in the cost evaluation. Geraghty & Miller has assumed that the 35 cubic yards of clean backfill may need to be excavated, but this volume will not require treatment or disposal. Further pre-design work is needed to determine if additional soil remedial measures are appropriate.

4.6.2.6 Esso Tutu Service Station

Constituents detected in soil in the area of the Esso Tutu Service Station consist of VOCs, primarily BTEX constituents. Chlorinated VOCs were detected in soil in the western portion of the Esso property.

Shallow unconsolidated deposits at the Esso Tutu Service Station consist primarily of relatively coarse gravel fill material and may be appropriate for SVE. Bioventing in the vicinity of the north oil/water separator would not be appropriate due to the presence of chlorinated VOCs, which are not readily biodegradable under aerobic conditions. BTEX constituents are easily removed through the application of SVE or bioventing. Also, SVE tends to enhance biodegradation of BTEX constituents, in addition to volatilization of BTEX. SVE would be preferred and would be faster than bioventing. Due to the presence of the building foundation, excavation options would be difficult to implement, but are potentially implementable. SVE is therefore considered as the preferred alternative with localized areas that may be suitable for bioventing. Figure 4-6 illustrates the areas to be considered for remediation at the Esso Tutu Service Station. Soil concentrations above SSLs reported in Borings B-101 and B-102 may be due to the presence of perched water that may contain dissolved contaminants in the aqueous phase. Additional soil sampling and investigation will be implemented as part of the pending SCP for the Esso property. A SCPs currently being prepared for implementation was discussed previously in Section 4.6.1.2 (Esso Tutu Service Station Source Control Plan).

4.6.2.7 O'Henry Dry Cleaners

PCE concentrations above the SSLs were detected in soil at the southeast corner of the building; these concentrations were the highest concentrations of chlorinated VOCs observed throughout the Tutu Wells Site. The shallow unconsolidated deposits underlying the O'Henry Dry Cleaners are relatively permeable and could be remediated using SVE. PCE is readily removed using SVE. Bioventing is not effective in the treatment of halogenated VOCs; therefore, bioventing will not be considered further. Even though in-situ SVE would be applicable, the small volume of impacted soil may make excavation and disposal a more economical alternative than in-situ treatment. Ex-situ application of SVE may also be appropriate. Four soil remedies are evaluated for the O'Henry Dry Cleaners, including (1) capping, (2) in-situ SVE treatment, (3) excavation, ex-situ SVE treatment, and on-site disposal, and (4) excavation and off-site disposal. Figure 4-7 illustrates the locations potentially requiring remediation at the O'Henry Dry Cleaners.

To remediate the potential presence of DNAPLs in the unsaturated bedrock, an SVE program is being considered for implementation at the O'Henry Dry Cleaners. SVE is a presumptive remedy for VOC contamination. Capping can also be implemented at the soil surface to reduce infiltration of precipitation into the unsaturated bedrock, thus reducing the leaching of contaminants to groundwater. Additional property characterization of a remedy would be required to determine the potential locations of DNAPLs prior to implementation. The potential locations of soil remediation and bedrock remediation at the O'Henry Dry Cleaners are shown on Figure 4-7. These locations will have to be better defined by further drilling and sampling in suspected source areas prior to implementation of this remedial technology.

4.6.3 Groundwater Remedial Alternatives

Both in-situ and ex-situ treatment technologies for groundwater remediation have been retained for consideration. However, due to the complex and anisotropic fractured bedrock aquifer that underlies the site, in-situ treatment is not considered viable for site-wide groundwater treatment. The only in-situ technology retained for consideration is biosparging, which will be evaluated on a site-by-site basis for remediation of BTEX constituents in shallow groundwater. More conventional groundwater extraction and ex-situ treatment technologies will be considered, including air stripping, GAC adsorption, filtration, precipitation/flocculation, sedimentation, ion exchange, chemical oxidation/reduction, fluidized bed/GAC, natural remediation, and well head treatment. These treatment technologies will be considered in conjunction with three general groundwater collection and containment extraction well approaches, as follows:

- Source Containment and Point-of-Entry Treatment Systems (POETs).
- Plume Containment.
- Source and Plume Containment.

The technology screening for discharge options from ex-situ groundwater treatment systems in Section 4.4.5 (Discharge) resulted in the selection of discharge to surface water as the preferred option.

SCPs are proposed for implementation at the Texaco Tutu Service Station and the Esso Tutu Service Station to treat and contain the plumes related to the groundwater contamination with BTEX constituents at each of these properties (see Figure 4-8). These SCPs will be initiated prior to the complete FS remedy. Data collected during operation of these Source Control Systems will be analyzed as part of the design phase for the FS remedy. However, implementation of SCPs at the service stations has been considered to ensure that they are compatible with the groundwater remedial alternatives (GRAs) proposed in this FS Report. Those SCPs include discharge to Turpentine Run via a TPDES permit.

4.6.3.1 Collection and Containment

The RAOs identified two criteria that each groundwater containment scenario must meet, as follows: (1) minimize the upconing of mineralized groundwater from deeper portions of the aquifer, and (2) not exceed the maximum safe yield of the aquifer. Based on an estimated catchment area of 1.08 square miles (upgradient of potential recovery wells) and an aquifer recharge rate of 3.3 inches per year (Jordan and Fisher 1977), Geraghty & Miller has estimated the maximum safe yield for the Tutu Wells Site area to be approximately 118 gpm, assuming continual pumpage (24 hours/day, 365 days/year).

After consideration of GRA 1 (No Action/Industrial Controls), three groundwater recovery scenarios have been assembled for evaluation. The preferred scenario for groundwater collection and containment is to use several groundwater recovery wells strategically placed throughout the Tutu Wells Site. For purposes of this FS, three potential plume containment recovery wells, Recovery Wells RW-1, RW-2, and RW-3, are proposed. Recovery Well RW-1 is envisioned at the southern end of the northern chlorinated VOC plume, and Recovery Wells RW-2 and RW-3 are envisioned at the southern end of the southern chlorinated VOC plume. Similarly, two potential source containment wells, Recovery Wells RW-4 and RW-5, are proposed. Recovery Well RW-4 is envisioned at the downgradient edge of the Curriculum Center property, and Recovery Well RW-5 is envisioned at the downgradient edge of the O'Henry property (see Figure 4-9).

Containment of impacted groundwater will be achieved by implementing one of the following recovery well system scenarios. Each scenario is associated with a specific GRA, and each scenario has been named after the type of wells that are emphasized (i.e., pumped at maximum rates) in that scenario. In addition to GRA 1 (No Action/Institutional Controls), the proposed GRAs are briefly described below and evaluated further in Section 5.3 (Development and Evaluation of Remedial Alternatives for Groundwater).

- GRA 2 - Source Containment and POETs

  In this scenario, Recovery Wells RW-4 and RW-5 would be pumped at 20 gpm and 35 gpm, respectively, to achieve containment of groundwater with high concentrations of chlorinated VOCs near the contaminant sources. For cost comparison with other GRAs, these wells were assumed to pump to a common influent feed line and then to a central treatment facility. The maximum total groundwater pumpage to the treatment system would be 55 gpm. Existing private supply wells (situated at locations that could provide effective plume containment) would be equipped with POET systems and pumped to provide containment of the VOC plumes beyond the source containment wells. Geraghty & Miller has assumed that the maximum total extraction from private wells would be 15 gpm. This pumping rate for supply wells assumes an average pumpage of 1.25 gpm from each of four residential wells (i.e., Steele, La Place, Smith, and Matthias) and 10 gpm from one commercial supply well, Four Winds I. Estimated maximum pumpage associated with the Texaco Tutu Service Station and Esso Tutu Service Station SCPs would be 30 gpm and 10 gpm, respectively. The maximum total groundwater pumpage for this scenario (GRA 2) would be 110 gpm (see Table 4-11).

- GRA 3 - Plume Containment

This scenario involves pumping of three plume containment wells (Recovery Wells RW-1, RW-2, and RW-3). Groundwater would be pumped to a common influent feed line and then to a central treatment facility. Proposed Recovery Wells RW-1, RW-2, and RW-3 would be pumped at maximum rates of 15 gpm each, for a total of 45 gpm for these three plume containment wells. Existing supply wells would not be pumped in this scenario. The Texaco Tutu Service Station and Esso Tutu Service Station source control wells are assumed to pump at estimated maximum total rates of 30 gpm and 10 gpm, respectively. The maximum groundwater pumpage under this scenario would be 85 gpm (see Table 4-11).

- GRA 4 - Source and Plume Containment

In this scenario, the plume containment wells and source control wells (all five potential recovery wells) would be pumped to a common influent feed and then to a central treatment facility. Recovery Wells RW-1 through RW-3 would each be pumped at a rate of 15 gpm; Recovery Wells RW-4 and RW-5 would be pumped at approximately 20 gpm and 35 gpm, respectively. The maximum total groundwater pumpage from recovery wells would be 100 gpm. The 40 gpm total for the source control pumpage at the Texaco Tutu Service Station (30 gpm) and Esso Tutu Service Station (10 gpm) would bring the overall maximum pumpage rate to 140 gpm, which exceeds the estimated safe yield of the catchment area of 118 gpm (see Table 4-11). It should be noted, however, that there is a significant difference in the anticipated time frames for pumpage of the site-wide plume containment and source containment wells compared to the extraction wells associated with the SCPs at the two service stations. Due to the small size of the BTEX plumes and the biodegradable nature of BTEX constituents, Geraghty & Miller anticipates that the SCPs will achieve their remedial goals in 3 to 7 years of operation. In contrast, it is envisioned that the site-wide recovery wells will likely have to operate for much longer time periods (on the order of 10 to 30 years), due to the large areas of the chlorinated VOC plumes and the potential for the existence of DNAPLs at two source areas.

Geraghty & Miller anticipates that the SCPs will be implemented in 1995 or early 1996, while the site-wide groundwater remedy will not be implemented until late 1996 or 1997, allowing time for public comment on the selected remedy and pre-design work. Therefore, it is possible that the SCPs will be near completion when the site-wide groundwater remedy is implemented. Pumping rates can be adjusted during any period of overlap to maintain overall capture of contaminants and to maintain total pumpage below the estimated safe yield of the aquifer in the affected area. If the SCP groundwater pumpage is reduced, the site-wide groundwater recovery wells will provide collection and containment for the BTEX constituents in groundwater. However, the SCP pumpage should be maintained as much as possible to provide more effective withdrawal of the BTEX constituents.

Geraghty & Miller has assumed that all the proposed recovery wells will be installed to a depth of approximately 150 feet bls and will be screened across the shallow and deep portions of the bedrock aquifer (i.e., fully penetrating). The depth of 150 feet bls was selected to maximize the complete penetration of the aquifer without intercepting the deeper portions of the aquifer that contain mineralized water. Deep mineralized water contains elevated TDS and chloride. If drawn upward by pumpage, the mineralized water could degrade the quality of shallow groundwater. This mineralized water could also accelerate corrosion and fouling of the recovery and treatment systems. Therefore, a depth of 150 feet bls was selected as the optimum depth for recovery wells for the chlorinated VOC-impacted groundwater. For areas where impacted groundwater may occur below 150 feet bls, Geraghty & Miller has assumed that upward groundwater flow induced by recovery well pumpage and natural attenuation will remediate the deeper portions of the aquifer over time.

The locations of the proposed recovery wells were based on a preliminary capture zone analysis, which is summarized in Appendix B. Estimated capture zones for proposed SCPs at the Texaco Tutu and Esso Tutu Service Stations are illustrated on Figure 4-8, with the shallow groundwater contour map and the BTEX concentrations in groundwater contours. Estimated capture zones at maximum pumping rates in GRA 2 and GRA 3 and proposed groundwater recovery well locations are illustrated on Figure 4-10. The proposed groundwater recovery well locations for GRA 4 are illustrated on Figure 4-9. The pumping rates of the proposed recovery wells under the different GRAs evaluated are summarized in Table 4-11.

4.6.3.2 Treatment

In this section further evaluations of treatment technologies are provided. The potential effectiveness of in-situ treatment technologies (i.e., air-sparging and bio-sparging) that survived screening is difficult to evaluate without site-specific pilot testing, especially in a heterogeneous matrix of fractured bedrock. This FS Report allows the possibility for these technologies to be evaluated further because they may be beneficial. Because the effectiveness and associated costs are not well known, air-sparging and bio-sparging have not been included in the groundwater remedial alternatives assembled for comparison in this FS Report. In this section, further evaluations of the ex-situ treatment schemes for a central treatment facility and for the proposed POET systems are provided. In Section 4.6.3.3 (Natural Remediation), the basis for applying natural remediation in the downgradient (i.e., southeastern) portion of the chlorinated VOC plume are discussed.

Each collection and containment option discussed in Section 4.6.3.1 (Collection and Containment) will be associated with a central treatment facility. The central treatment facility will consist of one or more of the ex-situ groundwater treatment technologies that were retained from the initial screening. The technologies chosen for a central treatment facility are contingent on several factors, including existing performance data and the type of contaminants, and the concentration of contaminants present in the extracted groundwater.

Similar to soil, SCPs for groundwater treatment are proposed for implementation at the Texaco Tutu Service Station and the Esso Tutu Service Station. These SCPs consider similar treatment technologies and discharge options to those considered in this FS. No further groundwater treatment options are considered for the Texaco Tutu Service Station and the Esso Tutu Service Station. These SCPs were previously described in Section 4.6.1.1 (Texaco Tutu Service Station Source Control Plan), and Section 4.6.1.2 (Esso Tutu Service Station Source Control Plan).

Existing performance data related to a treatment system located on the Esso Tutu Service Station property indicate that an air stripper combined with GAC polishing (of the aqueous effluent) is an effective treatment method for groundwater at the Tutu Wells Site. These technologies, used separately or in combination, are effective methods for VOC removal and can be applied to all the pumping options considered.

Groundwater quality data have been collected throughout the Tutu Wells Site. Although these data may not be an accurate indicator of the influent groundwater quality from a recovery well, this information can be used to estimate influent groundwater quality to a central treatment facility.

Influent groundwater quality to each treatment facility was determined by using a mass flow balance, averaging the flow rate and contaminant concentration for each collection and containment well scenario. This predicted groundwater quality was evaluated against the MCL primary and secondary standards to determine the level of treatment that may be required. In some instances, secondary standard variances may be appropriate for some parameters, such as TDS, since elevated levels of some naturally occurring inorganic parameters are common in the USVI. The influent levels of contamination will vary with each collection and containment well scenario, as different recovery wells may be used and flows from the recovery wells would be combined prior to treatment; however, groundwater quality between scenarios would not vary enough to warrant consideration of different treatment facility schemes. Table 4-4 provides a summary of the predicted groundwater quality compared to MCLs for the Source Containment and POETs scenario (GRA 2), the Plume Containment scenario (GRA 3), and the Source and Plume Containment scenario (GRA 4). The estimated influent concentrations in Table 4-4 represent weighted averages for the blended wells based on (1) groundwater quality near the proposed recovery wells and (2) the estimated flow rate from each well.

One treatment scheme has been developed for a central treatment facility (i.e., discharge to surface water). This scheme is based on the level of treatment required for this discharge option. The primary reason for installing the central treatment facility is to remove the COCs identified in the RI (Geraghty & Miller, Inc. 1995). Therefore, VOC treatment and removal, consisting of air stripping and potentially GAC polishing, is included in this treatment scheme. Air stripping and GAC adsorption are selected as representative technologies for cost comparison purposes in this FS Report. Other treatment technologies that survived screening (e.g., filtration, reverse osmosis, ion exchange) are viable technologies that are typically used for treatment of inorganic constituents.

The groundwater treatment scheme shown on Figure 4-11 treats the groundwater to background groundwater quality and does not address naturally occurring inorganic constituents that are present above secondary MCLs (e.g., TDS and chloride). The treatment scheme proposed for the central treatment facility assumes that chemical sequestering of the dissolved constituents can be achieved successfully. This assumption is based on the assumed hardness, iron, and manganese concentrations in the influent to the central treatment facility, and on the assumption that the concentrations of these constituents are slightly below the maximum point where sequestering can still be achieved. If actual hardness, iron, and manganese concentrations are higher than assumed, sequestering may not be implementable. Modifications to the pre-treatment scheme may be required depending on the accuracy of these assumptions. This groundwater treatment option is also considered applicable for a surface-water discharge option; however, chemical feed rates or level of treatment may need to be modified to meet TPDES requirements. These modifications should not significantly change the treatment scheme or cost. Treatability testing, including a pilot test with actual groundwater recovery well samples, may be a required step in the pre-design phase.

Even if the assumptions made for groundwater quality and level of treatment are not confirmed during pilot testing or during the final design phases of implementation of the selected GRA, the new data will not likely change the findings of this FS. In other words, evaluation of new results would most likely be consistent for each GRA, since the costs for each option will be increased by approximately the same amount.

POET systems are a form of treatment that will be considered as a groundwater treatment method in this FS. POET systems refer to low capacity package groundwater treatment systems, that are designed to be a low-maintenance and reliable form of treatment for individual wells. The term POET indicates that treatment will be provided at the point of entry to a residence rather than at the point of use (i.e., at the wellhead rather than at the drinking fountain). The POET systems utilize either air stripping or GAC technologies and will be selected based on the anticipated maximum pumping rate of each well, expected TDS concentrations, and the COC concentrations expected. A summary of the potential POET supply well installations is provided in Table 4-12. Due to the maximum safe yield for the catchment area of 118 gpm and the pumpage of recovery wells, the maximum total average flow of all the POET supply wells that could be allowed is estimated to be approximately 15 gpm. This average flow allows for typical residential usage of the five supply wells that were selected for POET installation based on their location in the central portion of the groundwater plumes.

4.6.3.3 Natural Remediation

Proposed groundwater remedial alternatives are designed to capture the majority of the chlorinated VOCs. The SCPs are designed to control BTEX. Due to aquifer safe yield limitations on total pumpage and to optimize groundwater recovery efforts, lower concentrations of total chlorinated VOCs (i.e., less than 100 ug/L) will not be recovered, rather these concentrations will be allowed to attenuate and degrade naturally. A portion of the plume with chlorinated VOC concentrations less than 100 ug/L may not be completely contained and will migrate downgradient to the southeast. The following calculations (using half-lives and groundwater flow velocities) are presented to estimate the time required for natural remediation to be effective at reducing chlorinated VOC concentrations to MCLs.

Table 4-13 presents a summary of published half-lives for COCs in groundwater (Howard et al. 1991). A half-life represents the amount of time required for natural degradation to reduce a concentration to one-half of the initial concentration. The degradation rates and concentrations on Table 4-14 are based on a first order decay of unimolecular constituents. These half-lives are based on estimated rates of aerobic degradation of COCs in groundwater based on field and laboratory data (Howard et al. 1991).

Using the average half-life values in Table 4-13 and assuming an initial concentration of 100 ug/L of total chlorinated VOCs, the time required for natural degradation to reduce individual chlorinated VOC concentrations below MCLs is approximately 5.33 years, which is equivalent to 1,945 days (see Table 4-14). The ratios of the individual chlorinated VOCs in the assumed initial 100-ug/L concentration (see Table 4-14) were based on the ratio of compounds present at the Matthias Supply Well. If groundwater recovery systems are operated to capture and remove chlorinated VOCs at or above 100 ug/L, the groundwater concentrations at 100 ug/L that are not recovered will require approximately 5.33 years to naturally degrade below MCLs. This is a conservative estimate because other factors (such as adsorption, dispersion, and dilution) will also reduce groundwater concentrations. These calculations do not consider the potential variations of concentrations due to the formation of breakdown products. Because PCE is not formed as a breakdown product, the calculations for PCE represent a conservative estimate.

Chlorinated VOCs in the deeper portions or lateral portions of the aquifer not captured by recovery wells should degrade below MCL concentrations within a maximum time frame of approximately 5.33 years. Due to the existing groundwater flow regime, the deeper and lateral portions of the main body of the chlorinated VOC plumes will not significantly expand over the time required for natural degradation to achieve MCLs. However, the downgradient portion of the existing chlorinated VOC plume in the southeastern part of the study area will continue to migrate with the prevailing groundwater flow. To assess the additional area that may be potentially impacted by chlorinated VOCs above MCLs, the downgradient extent of potential impact can be estimated by calculating the groundwater flow velocity and multiplying this velocity by the time required to reach MCLs.

The average linear velocity of groundwater flow is the velocity of groundwater moving in a general downgradient direction. This velocity can be calculated using an equation derived from Darcy's law as follows:

$$V = \frac{K}{n} \frac{dh}{dl}$$

where V = Average linear velocity, in feet per day

K = Hydraulic conductivity, in feet per day

n = Effective porosity (unitless)

$\frac{dh}{dl}$ = Hydraulic gradient (unitless)

For the southeastern portion of the study area, the nearest values for K were calculated from the pumping test at the Eglin III Supply Well. Calculated K values for the Eglin III pumping test ranged from 6.37 to 7.61 gal/day ft^2; (Geraghty & Miller, Inc. 1995). Based on the distribution of fractures interpreted from fracture trace analysis (Geraghty & Miller, Inc. 1995), the Harthman Crusher Supply Well may be characterized by a density and length of fractures to similar to the southeast portion of the study area. As such, the hydraulic conductivity (K) value calculated for the Harthman Crusher Supply Well (21.1 gal/day ft^2) may provide another applicable estimate for the K values in the southeastern portion of the study area (Geraghty & Miller, Inc. 1995). Conversion of the K values to units of feet per day yields a maximum K value of 1.02 feet per day for the vicinity of the Eglin III Supply Well and 2.82 feet per day for the Harthman Crusher Supply Well, with an average K value of 1.92 feet per day. Values of effective porosity for pyroclastic rocks such as the andesitic tuff found at the Tutu Wells Site may range from 14 to 40 percent (Keller 1960). Using the average K value of 1.92 feet per day, a hydraulic gradient of 0.0689, and an effective porosity of 0.20 (i.e., 20 percent), an average linear velocity of 0.661 foot per day (ft/day) was calculated for the southeastern portion of the study area.

Multiplying 5.33 years (equivalent to 1,945 days, the estimated time required to achieve MCLs using the average half-lives) by an average linear velocity of 0.661 ft/day (the larger groundwater velocity calculated for the vicinity of the Matthias and Delegarde Supply Wells) yields a value of 1,286 feet, which represents the maximum downgradient extent of migration of chlorinated VOCs above MCLs from the 100-ug/L contour line in the vicinity of the Matthias Supply Well. Chlorinated VOCs above the MCLs have been identified at the Delegarde Supply Well, approximately 950 feet downgradient of the 100-ug/L chlorinated VOC contour line. The minimum, average, and maximum input values for the half-life and travel time calculations are presented in Table 4-15. The average half-life and travel time calculations presented above indicate that the southeastern edge of contaminants above MCLs may potentially migrate approximately another 336 feet downgradient of the Delegarde Supply Well before natural degradation would reduce the groundwater concentrations below MCLs. This is a very conservative estimate because other retardation factors (e.g., adsorption and dilution with non-impacted groundwater) will also limit the downgradient extent of chlorinated VOCs above MCLs. In addition, it is likely that the hydraulic gradient will decrease, similar to the decrease in the topographic gradient, downgradient of the Delegarde Supply Well. The Dench Supply Well, the nearest downgradient supply well, is located approximately 2,200 feet downgradient of the Delegarde Supply Well. Sampling of the Dench Supply Well over three sampling events (September 25, 1990; February 5,1991; and March 31,1993) indicated that COCs were not present and that all results were below MCLs (Geraghty & Miller, Inc. 1993c).

In summary, once the site-wide groundwater recovery is started, the main body of the chlorinated VOC plume will be captured; this main body will no longer be a continuing source of COCs to lateral and downgradient portions of the plume. Groundwater (with a maximum concentration of 100 ug/L total VOCs) not captured by the recovery wells should naturally degrade to below MCLs within approximately 5 years. During this time, the southeast portion of the plume may continue to migrate downgradient, but it will most likely degrade and dissipate below MCLs before reaching the nearest downgradient groundwater supply well.

SECTION 5

5.4.8 Summary of Comparative Analysis of Alternatives

Table 5-13 provides a summary of the preferred remedial alternatives for each of the seven NCP evaluation criteria. SRA 3 and SRA 4 are the soil remedies that have been designated most often as the preferred alternative. SRA 3 (Institutional Controls/Capping/In-Situ SVE/Excavation and Off-site Disposal) is the preferred soil remedial option for four of the seven criteria. SRA 4 (Institutional Controls/Capping/Ex-Situ SVE/Excavation and Off-site Disposal) is slightly better, having been designated the preferred soil remedial option for five of the seven criteria. GRA 4 (Institutional Controls/Source and Plume Containment/Treatment/Discharge) is the most commonly selected preferred groundwater remedy (four of the seven criteria).

5. DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES

In this section, screened technologies from Section 4.0 (Identification and Screening of Remedial Technologies) are assembled into remedial alternatives to address the impacts to human health and the environment that could result from COCs in soil and groundwater at the Tutu Wells Site. Each remedial alternative is assessed based on the evaluation criteria provided in Section 5.1 (Evaluation Criteria) and on its effectiveness in achieving the goals and objectives established in Section 3.0 (Remedial Action Goals and General Response Actions).

The RALs and CGs identified in Section 3.0 were utilized in formulating a basis for compliance to the RAOs established for the site. As discussed in Section 3.1.2.3 (Remedial Action Levels and Cleanup Goals), RALs do not exist at this time for soils. For the Tutu Wells Site, the USEPA has developed SSLs to be used as screening levels to determine if soil remediation may be warranted at individual properties.

5.1 EVALUATION CRITERIA

The evaluation criteria used to examine the remedial alternatives are derived from CERCLA statutory requirements and other program initiatives, such as the NCP promulgated by the USEPA. Each remedial alternative is evaluated against the NCP criteria as described in "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA-Interim Final" (USEPA 1988a). The NCP criteria consist of the following nine factors, which each remedial alternative must adequately address:

- Overall protection of human health and the environment.
- Compliance with ARARs.
- Long-term effectiveness and permanence.
- Reduction of toxicity, mobility, or volume.
- Short-term effectiveness.
- Implementability.

- Cost.
- State acceptance.
- Community acceptance.

The first two criteria relate directly to statutory findings that must be made as part of a Record of Decision (ROD). For this reason, they are categorized as threshold criteria with which each remedial alternative must comply. The next five criteria are commonly referred to as the primary balancing criteria. These five criteria make up the major portion of the comparative analysis of remedial alternatives. The remaining two criteria, state and community acceptance, are commonly referred to as modifying criteria. These criteria will be evaluated following completion of the RI/FS and subsequent comment review. Table 5-1 presents a summary of the evaluation of the NCP criteria for soil remedial alternatives. Table 5-2 presents a summary of the evaluation of the NCP criteria for groundwater remedial alternatives.

5.2 DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES FOR SOIL

In this section, soil remedial alternatives (SRAs) have been assembled and are evaluated against seven of the nine factors set forth by the NCP. Each SRA must address these seven criteria satisfactorily to be considered further as a potential remedy. Two criteria (state and community acceptance) will be evaluated by the USEPA during and after the FS comment period. A summary of the evaluation of the NCP criteria for SRAs is presented in Table 5-1.

In some cases, individual property owners have carried out site-specific investigations and some of them are developing proposals for remedial action independent of this evaluation. These proposals are considered separately in this FS Report, to assess the relationship of these proposals with the site-wide remediation.

Based on the available data, Geraghty & Miller has focused the evaluation of technologies for soil treatment on the three presumptive remedies presented in USEPA guidance (USEPA 1993), which are SVE, thermal desorption, and incineration. Excavation of impacted soils is also considered, combined with on-site treatment or off-site disposal. This alternative is provided for those sites where volumes of impacted soil are small, such that treatment is not cost-effective. Based on detailed evaluation of the three presumptive remedies, the published USEPA guidance selects SVE as the primary presumptive remedy, followed by, in order of preference, thermal desorption and incineration. SVE has been selected as the primary remedy to evaluate because the remaining remedies were screened out in Section 4.0 (Identification and Screening of Remedial Technologies) due to implementability aspects and cost difficulties.

The time frames needed for soil remediation at the various properties will be contingent on the effectiveness of the SRA selected and the site-specific conditions. Based on experience with similar site conditions (i.e., geology and COCs), in-situ SVE treatment systems usually attain CGs approximately 2 to 5 years after start-up. Ex-situ SVE treatment systems can attain CGs within 1 or 2 years of start-up because the soil is more effectively treated in a more controlled environment. Due to the potential presence of DNAPL in bedrock near the Curriculum Center and the O'Henry Dry Cleaners, this FS Report assumes in-situ SVE will be applied for the entire remedial action, which is assumed to be 30 years as specified in FS guidance (USEPA 1988a) for comparison of alternatives.

Compliance with CGs will be determined through compliance monitoring sampling. For in-situ and ex-situ soil treatment remedies, soil samples will be collected to determine if CGs have been attained or if no further significant reduction of contaminant levels can be achieved. No further remedial action would be required thereafter. Excavation and disposal would require sampling during excavation to ensure the full extent of impacted soil has been removed. Compliance monitoring of in-situ SVE systems in bedrock would have to be based on evaluations of the potential DNAPL present in the unsaturated bedrock areas. With further characterization of the DNAPL areas, the in-situ SVE system influent concentrations should be reviewed periodically to evaluate the point of diminishing returns. It is likely the influent concentrations will eventually display an asymptote trend, at which point the further implementation of SVE will no longer significantly reduce the contaminant levels, making it impractical to continue SVE treatment. If the compliance monitoring for a remedial action indicates that significant reduction of the contaminant levels has not been achieved, other remedial actions may need to be considered.

Based on the screening of technologies, Geraghty & Miller has focused the evaluation of remedial technologies for soil and has assembled the following SRAs:

- SRA 1: No Action/Institutional Controls.

- SRA 2: Institutional Controls/Capping.

- SRA 3: Institutional Controls/Capping/In-Situ SVE (soil and bedrock)/Excavation and Off-Site Disposal.

- SRA 4: Institutional Controls/Capping/Ex-Situ SVE/Excavation and On-Site Disposal.

- SRA 5: Institutional Controls/Capping/In-Situ SVE (bedrock)/Excavation and Off-Site Disposal.

These SRAs are assembled using USEPA presumptive remedies and representative technologies that survived screening in this FS Report. These SRAs are assembled in order from generally the lowest level of action or disturbance of the site (SRA 1) to the highest level of action or disturbance of the site (SRA 5). Each SRA has a particular technology that is the main theme or emphasis of the SRA (e.g., In-Situ SVE for SRA 3 and Ex-Situ SVE for SRA 4). However, the technology emphasized by a particular SRA may not be effective or applicable due to site-specific conditions at each property (e.g., shallow depth to bedrock or water table, proximity to building foundations, type of potential exposure pathways). If a given technology was not considered effective or applicable at a particular property, a more effective technology was used with the SRA. As such, SRAs are composed of a mixture of technologies that are typically dominated by the emphasized technology.

5.2.1 SRA 1: No Action/Institutional Controls

In this section, SRA 1 (No Action/Institutional Controls) is described and evaluated.

5.2.1.1 Description of SRA 1

This alternative, as proposed, would involve implementing deed restrictions. No treatment or disposal actions would be taken for soil remediation. Existing remedial actions that are currently in place for soil, if any, would remain in place (e.g., paving, concrete pads, or capping). In some cases, individual property owners have carried out property-specific investigations and some of them are developing proposals for remedial action independent of this evaluation. The remediation proposals and plans resulting from these property-specific investigations are not considered part of this alternative because proposed remedial actions currently considered by individual property owners may not ultimately be implemented.

Institutional controls considered for the Tutu Wells Site would consist of deed restrictions that restrict, regulate, or limit soil contact and excavation. Deed restrictions are assumed to be necessary at properties that have been identified with contaminant concentrations in soil above the

SSLs or USEPA acceptable risk values (CDM Federal Programs 1995a, 1995b). The properties where deed restrictions might be applied are the Curriculum Center, Ramsay Motors, Texaco Tutu Service Station, Tillett Gardens, Western Auto, Esso Tutu Service Station, and O'Henry Dry Cleaners. Such restrictions could consist of the following:

- Placing limitations on property usage (e.g., restricted to commercial or industrial use).
- Prohibiting excavation or soil disturbance at any of the impacted areas without permit approval, proper worker-protection precautions, and air monitoring for potential fugitive emissions during excavation.
- Prohibiting the use or transport of excavated soil or rock from impacted areas.
- Prohibiting removal or disturbance of bedrock at properties where DNAPL may be present (e.g., the Curriculum Center and O'Henry Dry Cleaners).

5.2.1.2 Evaluation of SRA 1

Based on the results of the RI (Geraghty & Miller, Inc. 1995) and the Baseline Risk Assessment (CDM Federal Programs Corporation 1995a), soil at some properties within the Tutu Wells Site pose an unacceptable risk to human health and exceed the SSLs established for the Tutu Wells Site. There are several properties, however, that have exceedances just above the SSLs. Further risk analysis or continued natural biodegradation may indicate that soil remediation is not necessary at these properties, making SRA 1 implementable. Confirmatory sampling and testing should be done prior to implementation to ensure that other remediation is not warranted. Soil exceedances of SSLs would be expected to continue to exist after implementation of this SRA, at least at some properties. Institutional controls may not be easily implementable and would involve some administrative time to put into effect.

For the purposes of serving as a baseline for comparing remedial alternatives, and in conformance with CERCLA guidance, the No Action/Institutional Controls alternative will be retained for further consideration.

The estimated capital cost to implement SRA 1 is $15,000. The cost breakdown for the activities that comprise SRA 1 is presented in Table 5-3.

5.2.2 SRA 2: Institutional Controls/Capping

This section presents a description and evaluation of SRA 2 (Institutional Controls/Capping).

5.2.2.1 Description of SRA 2

This alternative would involve implementing the following actions:

- Implementation of deed restrictions at individual properties.
- Design and implement capping at all the properties where impacted soil and where DNAPLs in bedrock are present.

This alternative limits access to contaminated areas through deed restrictions and eliminates direct exposure to COCs through capping. Capping is proposed for each of the individual properties evaluated. This alternative would also significantly reduce the leaching of COCs to groundwater. This is an important factor as the greatest potential impact to human health and the environment from soil and potential DNAPLs in unsaturated bedrock at the Tutu Wells Site is through leaching of COCs to groundwater.

Each individual property has been evaluated against the SSLs for the Tutu Wells Site. The seven properties listed in Section 5.2.1.1 (Description of SRA 1) have been evaluated on an individual property basis for SRA 2. Based on the property-specific circumstances, capping could be installed, modified, and/or maintained at each property. Some individual properties are paved and for all practical purposes are already capped. Other individual properties would require the installation of a cap or pavement, where necessary. In addition to the restoration and maintenance of the existing pavement at the Texaco Tutu Service Station and the Esso Tutu Service Station, SCPs (that include in-situ SVE and/or bioventing) will be implemented at these properties. Where DNAPLs are suspected in unsaturated bedrock, capping of the soils will be performed. At O'Henry Dry Cleaners, DNAPL impact in bedrock is suspected underneath the impacted soils. At areas where DNAPL is suspected, capping is already provided by the building foundation.

5.2.2.2 Evaluation of SRA 2

This alternative is protective of human health and the environment when combined with groundwater containment and treatment. Institutional controls may not be easily implementable and would involve some administrative time to put into effect. Capping will prevent human and animal contact with impacted soils, will reduce infiltration of water through the impacted soils, and will reduce erosion. Capping will also reduce the leaching of contaminants from unsaturated bedrock to groundwater.

Capping and implementation of a soil erosion and sediment control plan at selected properties will reduce erosion and the potential for exposure to hazardous materials. Capping will also increase the quality of surface-water run-off.

Capping of the individual sites can be an effective method of reducing the transport of VOCs. However, the technology will not reduce the level of VOCs in the soils or in unsaturated bedrock. Exceedances of chemical-specific goals would be expected to continue. Action-specific and location-specific ARARs are expected to be met through proper remedial design and engineering, and through careful implementation.

Caps should be designed and constructed to reduce water and air infiltration through contaminated soils and water infiltration through unsaturated bedrock. The reduction of water infiltration will provide a long-term benefit by reducing the potential for migration of contaminants from impacted soil into groundwater.

The toxicity and volume of contamination in impacted soil and unsaturated bedrock will not be substantially reduced. The mobility of the COCs will be reduced by reducing the potential for leaching of contaminants into the groundwater due to the reduction in infiltration. The amount of residual contamination will not be reduced.

Moderate short-term impacts, such as fugitive emissions and erosion, may be associated with installing the caps. Air monitoring can be performed to identify harmful emissions and emissions that can be mitigated during cap installations. Dust control and emissions monitoring and control measures implemented during construction will provide short-term protection of human health and the environment.

The implementation of SRA 2 is feasible and favorable. Geomembrane, pavement, concrete, and soil caps are routinely installed using standard construction procedures and equipment. Standard construction practices would be followed with the appropriate health and safety protective measures.

SRA 2 is estimated to take approximately 12 to 18 months to implement. Costs for this SRA would include administrative expenses related to implementing institutional controls and engineering, material, and construction costs. The estimated capital cost to implement SRA 2 with the SCPs is $338,000. The present-worth value of the estimated O&M costs for maintaining the caps and the SCPs is $441,000. The total estimated cost for SRA 2 with the SCPs is $779,000. The cost breakdown for the activities that comprise SRA 2 is presented in Table 5-4.

5.2.3 SRA 3: Institutional Controls/Capping/In-Situ SVE (Soil and Bedrock)/Excavation and Off-Site Disposal

This section presents a description and evaluation of SRA 3.

5.2.3.1 Description of SRA 3

This alternative would involve implementing the following actions:

- Implementation of deed restrictions limiting access to specified areas on individual properties and future usage.

- Capping in areas where direct exposure to surface soil is considered a health threat.

- In-situ SVE, bioventing, or excavation and off-site disposal, depending on property-specific conditions.

This alternative limits access to contaminated areas through deed restrictions, eliminates direct exposure to COCs through capping, and provides SVE treatment at impacted areas. Each individual property has been evaluated against the SSLs for the Tutu Wells Site. Some individual properties are paved and for all practical purposes are capped, and will only require maintenance and upkeep. Other individual properties would require the installation of a complete cap or pavement system, where necessary.

The soil remediation for SRA 3 would consist of the actions listed at each of the following sites, respectively:

<u>Curriculum Center</u>

- Excavation and disposal (in southeast U.S.) of impacted soil due to shallow depth to bedrock and small soil volumes.

- In-situ SVE in unsaturated bedrock areas where DNAPL may be present above the water table.

- Thermal oxidation for off-gas treatment.

Ramsay Motors

- Capping of impacted soil. Existing maintenance garage floor slab is cracked and is suspected to have released surface spills to the subsurface (Cooper Environmental, Inc. 1993). Geraghty & Miller's cost estimate assumes the concrete slab will be removed and replaced.

Texaco Tutu Service Station

- SVE for in-situ treatment of impacted soil.

- Catalytic oxidation for off-gas treatment (based on the SCP design; Erler & Kalinowski, Inc. 1995a, 1995b).

Tillett Gardens

- Capping of impacted surface soil (to eliminate the exposure pathways).

Western Auto

- Excavation and off-site disposal (in southeast U.S.) of impacted soils after waste classification (for cost estimating purposes, Geraghty & Miller has assumed the soil will be classified as a hazardous waste). SVE would not be effective at Western Auto due to clayey soil.

Esso Tutu Service Station

- In-situ SVE and bioventing in areas of impacted soil.

O'Henry Dry Cleaners

- In-situ SVE for treatment of impacted soil.
- In-situ SVE in the unsaturated bedrock areas where DNAPLs may be present above the water table.
- Thermal oxidation for off-gas treatment.

Based on the specific circumstances present at each individual property, SRA 3 could be designed and installed. Reevaluating the necessity for remediation at each property should be conducted during the pre-design phase to confirm that remediation is indeed warranted and to document COC concentrations in soil prior to remedial action. Capping the areas where treatment is to be installed may also be made part of the design to limit direct exposure to the impacted soil; impermeable liners may also prevent "short circuiting" of SVE treatment that may occur in shallow soil areas. In most cases, SRA 3 would consist of the installation of SVE wells, a blower, and an off-gas treatment system, and excavation and off-site disposal of soil as a hazardous waste.

5.2.3.2 Evaluation of SRA 3

Based on the results of the RI (Geraghty & Miller, Inc. 1995), soil quality at several properties in the Tutu Wells Site area may represent the potential to leach COCs to groundwater, posing an unacceptable risk to human health and the environment. Implementation of institutional controls combined with SVE treatment and, potentially capping, can effectively mitigate the potential exposure pathways for COCs in soil and meet the NCP requirements for protection of human health and the environment.

Institutional controls may not be easily implementable and would involve some administrative time to implement. However, institutional controls can be effective in regulating unauthorized soil excavation or property use.

Impermeable covers, where implemented, will reduce the infiltration of water through impacted soil, which will reduce the potential for leaching of COCs into the groundwater. Impermeable covers will also prevent human and animal contact with contaminated soil and reduce erosion. Implementation of soil erosion and sediment control at selected properties will reduce erosion and the potential for exposure to hazardous materials. Impermeable covers will also increase the quality of surface-water run-off.

SVE will reduce the level of contaminants in soil at the specified properties, thus reducing the potential for leaching of contaminants to groundwater and subsequent off-site migration. Air emission controls on the SVE system will be protective of human health and the environment by meeting emission permit standards.

This SRA would be designed to meet the CGs for the site. Exceedances of chemical-specific goals may persist depending on the level of contamination that can be extracted at each individual property. Sites where capping is implemented will continue to exceed the chemical-specific goals. Action-specific and location-specific ARARs are expected to be met through proper remedial design and engineering, and through careful implementation.

SVE and/or bioventing is expected to be an effective method of reducing the concentrations of COCs. Further effectiveness may be achieved by installing a cap that would be designed and constructed to reduce water and air infiltration during operation of the SVE system. The reduction of water infiltration will provide a long-term benefit by reducing the potential for migration of contaminants from impacted soil into groundwater.

This SRA reduces the toxicity, mobility, and volume of soil contamination at individual properties through treatment. The potential for leaching of contaminants into the groundwater will be reduced since the potential source areas will be treated and/or capped. The amount of residual contamination at each site will depend on the effectiveness of the remediation.

Moderate short-term impacts would be realized due to fugitive emissions and the potential erosion associated with installing caps, SVE wells, and/or excavation. Dust control and emissions monitoring and control measures implemented during construction will provide short-term protection of human health and the environment. Air monitoring will be performed to identify harmful emissions during installation.

SRA 3 is implementable. In-situ SVE and bioventing are technically and administratively implementable, and have been demonstrated to be effective in treating the COCs identified at the Tutu Wells Site. SVE is effective at treating chlorinated VOCs and BTEX. Bioventing can be applied where BTEX treatment is the primary objective. However, the time required to remediate the impacted area will be longer than if more dynamic treatment using in-situ SVE is applied. Additional pilot testing will be required to refine engineering design parameters and operating conditions. Where SVE is to be used to treat potential DNAPLs in unsaturated bedrock, extensive site characterization to confirm the presence and extent of DNAPLs in the unsaturated zone should be performed with care, to minimize the further mobilization of the potential DNAPL in the subsurface.

Construction of the cap and SVE system is not expected to involve any significant implementability problems. Geomembrane, pavement, concrete, and soil caps are routinely installed using standard construction procedures and equipment. Standard construction practices will be followed with the appropriate health and safety protective measures.

Capital costs associated with SRA 3 would include administrative and engineering costs related to permitting and engineering design; potential air modeling; pilot testing; and material and construction costs. O&M costs would involve costs related to the O&M of vapor-phase treatment unit(s) and the costs of inspecting and maintaining the soil caps. Additional soil investigation may be required at some individual properties to verify that remediation is indeed warranted and to document soil concentrations prior to remedial actions.

The estimated capital cost to implement SRA 3 with the SCPs is $1,561,000. The present-worth value of the estimated O&M costs for maintaining the caps and the SVE/SCP systems is $2,553,000. The total estimated cost for SRA 3 with SCPs is $4,114,000. The cost breakdown for the activities that comprise SRA 2 is presented in Table 5-5.

5.2.4 SRA 4: Institutional Controls/Capping/Ex-Situ SVE/Excavation and On-Site Disposal

This alternative proposes the implementation of institutional controls and excavation of impacted soil at identified properties, and ex-situ SVE treatment for soil remediation. Soil would be treated to CGs and replaced in the excavated area. In-situ SVE systems would be installed in fractured bedrock where DNAPLs potentially exist in the unsaturated zone (i.e., the Curriculum Center and O'Henry Dry Cleaners). Impacted soil beneath existing buildings may not be suitable for excavation due to potential impacts to nearby structures and foundations. Capping or in-situ SVE would be more suitable at these locations.

5.2.4.1 Description of SRA 4

This alternative would involve implementing the following actions:

- Implementation of deed restrictions limiting access to specified areas at individual properties and future site usage.

- Installation of a treatment system, consisting of ex-situ SVE or biopiles, and a off-gas treatment system.

- Capping in areas where any of the following conditions exist:
  - Direct exposure to surface soil is considered a health threat.
  - Existing buildings may limit feasibility and cost-effectiveness of excavation for ex-situ treatment.

Deed restrictions, where applicable, would be implemented to restrict site access and future usage. In most cases, SRA 4 would consist of the installation of SVE wells, a blower, and an off-gas treatment system. For the proposes of this FS Report, the use of thermal or catalytic oxidation will be assumed for off-gas treatment. Capping the areas where treatment is to be installed may also be made part of the design to limit direct exposure to the impacted soil and to prevent short circuiting of in-situ SVE systems.

In summary, the soil remediation for SRA 4 would consist of the actions listed below for each of the following sites, respectively:

Curriculum Center

- Excavation, ex-situ SVE, and replacement of remediated soil.

- In-situ SVE in bedrock or in soil areas not suitable for excavation (i.e., near building foundations) to remediate adsorbed chlorinated VOCs or DNAPLs that may be present in the unsaturated zone.

Ramsay Motors

- Capping by replacement of cracked concrete.

Texaco Tutu Service Station

- In-situ SVE and/or bioventing treatment of impacted soils.

- Catalytic oxidation for off-gas treatment (based on the SCP design; Erler & Kalinowski, Inc. 1995a, 1995b).

Tillett Gardens

- Capping of impacted soil areas (to eliminate the exposure pathways).

Western Auto

- Excavation and off-site disposal (in southeast U.S.) of impacted soil after waste classification (for cost estimating purposes, Geraghty & Miller has assumed the soil will be classified as hazardous waste). SVE would not be effective at Western Auto due to clayey soil.

Esso Tutu Service Station

- In-situ SVE and/or bioventing treatment of impacted soil.

O'Henry Dry Cleaners

- Excavation, ex-situ treatment of impacted soils, and replacement of remediated soil.

- In-situ SVE in bedrock or in soil areas not suitable for excavation (i.e., near building foundations) to remediate DNAPL that may be present in the unsaturated zone.

5.2.4.2 Evaluation of SRA 4

Soil quality at several properties in the Tutu Wells Site area may pose an unacceptable risk to human health and the environment. Implementation of institutional controls combined with treatment and/or capping, where required, can effectively mitigate the potential exposure pathways present for soil.

Capping will reduce the infiltration of water through contaminated soil, which will reduce the potential for leaching of COCs into groundwater. These measures will also prevent human and animal contact with contaminated soil and reduce erosion.

SVE will reduce the level of contaminants in soil at the specified properties, thus reducing the potential for leaching of contaminants to groundwater and subsequent off-site migration. Air emission controls on the SVE systems and covering of the soil piles (if using ex-situ SVE treatment) will be protective of human health and the environment by meeting emission permit standards.

Capping and implementation of soil erosion and sediment control at selected properties will reduce erosion and the potential for exposure to hazardous materials. Capping will also increase the quality of surface-water run-off. Dust control and emissions monitoring and control measures implemented during construction will provide short-term protection of human health and the environment.

This SRA would be designed to meet the CGs for the site. Exceedances of chemical-specific goals may occur depending upon the level of contamination that can be extracted through ex-situ SVE treatment. Action-specific and location-specific ARARs can be met through proper remedial design and engineering, and through careful implementation. At properties where capping is implemented, chemical-specific ARARs are expected to continue to be exceeded.

This SRA would reduce the toxicity, mobility, and volume of soil contamination at individual properties through treatment. The potential for leaching of contaminants into groundwater will be reduced since the source will be treated, reducing the source volume. If required, the impacted soil will be capped, reducing mobility. The amount of residual contamination at each site will depend on the effectiveness of each excavation and treatment system. The effectiveness may also be limited by the amount of soil that can be excavated due to potential structural concerns near building foundations.

Moderate short-term impacts would be realized due to fugitive emissions and the potential erosion associated with installing caps, excavation of soil, and installation of SVE equipment. Air monitoring may be required to identify harmful emissions during installation. Dust control and emissions monitoring and control measures implemented during construction will provide short-term protection of human health and the environment. Standard health and safety precautions would be maintained to mitigate any risks from drilling extraction wells in waste areas.

This SRA is implementable. SVE is technically and administratively implementable, and has been demonstrated to be effective in treating the COCs identified at the Tutu Wells Site. Additional pilot work may be required to refine engineering design parameters and operating conditions. Construction of caps and SVE systems should not involve any significant implementability problems. Geomembrane, pavement, concrete, and soil caps are routinely installed using standard construction procedures and equipment. Standard construction practices will be followed with the appropriate health and safety protective measures.

Capital costs associated with SRA 4 would include administrative and engineering costs related to permitting and engineering design, and possible air modeling and pilot testing, and material and construction costs. O&M costs would involve costs related to the O&M of vapor phase treatment unit(s). Additional soil evaluations at some individual properties may also be required to verify that remediation is warranted.

The estimated capital cost to implement SRA 4 with the SCPs is $1,530,000. The present-worth value of the estimated O&M for SRA 4 with the SCPs is $2,524,000. The total estimated cost for SRA 4 with the SCPs is $4,054,000. The cost breakdown for the activities that comprise SRA 4 is presented in Table 5-6.

5.2.5 SRA 5: Institutional Controls/Capping/In-Situ SVE (Bedrock)/Excavation and Off-Site Disposal

In this section, SRA 5 is described and evaluated against the NCP criteria.

5.2.5.1 Description of SRA 5

This alternative would involve implementing the following actions:

- Implementation of institutional controls.
- Excavation and off-site disposal of impacted soil at individual properties identified.
- Implementation of the SCPs using in-situ SVE at the Texaco and Esso properties.
- Capping selected areas where impacted soil is present.
- In-situ SVE treatment in bedrock at the Curriculum Center and the O'Henry Dry Cleaners.
- Restoration of excavated areas.

Soil at individual properties where contamination is above the SSLs identified for the Tutu Wells Site would be excavated and containerized as required. The exceptions to this would be Tillett and Ramsay Motors where capping would be implemented, and the Texaco and Esso properties where the SCPs would be implemented. The excavated soil would be containerized and sampled to determine if it should be classified as hazardous waste. Based on that sampling, the soil would be disposed as appropriate and as approved by the USEPA and the appropriate U.S. Virgin Island agencies. Geraghty & Miller has assumed, for the purposes of this FS Report, that all excavated soil will be disposed as hazardous waste. Fill material would be brought in to restore each of the areas to grade. Topsoil and seed or paving would be installed to finish the restoration.

After restoration is complete, deed restrictions (if necessary) would be placed on the property restricting current and future use. During all phases of the remediation, it will be necessary to implement dust and volatile emission control measures, soil erosion, and sediment control measures.

5.2.5.2 Evaluation of SRA 5

This alternative would protect human health and the environment by effectively removing the source of contamination from individual properties or by effectively eliminating the risk of exposure by leaching of COCs to groundwater through capping.

This alternative would require air monitoring, use of personal protective equipment, and engineering controls for the control of fugitive emissions during the excavation and handling of waste materials to provide short-term protection of human health.

This alternative is expected to meet potential CGs for the Tutu Wells Site by placing the material in a permitted off-site landfill. Soil that is classified as hazardous would have to be shipped to a hazardous waste landfill outside the USVI (a site in the southeast U.S. is assumed for cost purposes). By removing the contaminated soil, the potential for leaching of COCs into groundwater would be eliminated.

Location-specific and action-specific ARARs are expected to be met through proper remedial design and implementation. Chemical-specific ARARs could be met through in-situ SVE treatment and ex-situ off-site disposal. The only exceptions would be for the Ramsay and Tillett properties where capping will eliminate the exposure pathway, but capping will not reduce the contaminant concentration.

Contaminated soil removal and off-site disposal represents a permanent remedial solution for soil contamination at the Tutu Wells Site. The remediated area would be backfilled with clean fill and graded to restore existing grade. Erosion control measures would be implemented.

Off-site disposal and replacement with clean fill will reduce the toxicity, mobility, and volume of the impacted soil in the Tutu Wells Site area. Source removal will decrease the potential for leaching of COCs into groundwater. The volume of contamination in the soil medium will be significantly reduced on-site, and the effectiveness of the removal of the soil would be contingent upon the ability to completely remove the impacted soil.

Due to the proximity of private residences and a business district in the vicinity of the Tutu Wells Site, there are more potential short-term impacts associated with this alternative than with the other SRAs. The volatile nature of some of the COCs present at the Tutu Wells Site could result in the release of harmful emissions during excavation, handling, and transport. Measures such as temporary enclosures and daily cover may be needed to contain these emissions. Air treatment would be needed for these enclosures and air monitoring would be required to monitor for off-site migration of fugitive emissions. Specific health and safety practices for the selected properties can be developed to control exposure to on-site workers and personnel, as well as to potential off-site receptors.

Excavation of contaminated soil and transfer to an off-site landfill is expected to be difficult to implement. The depth and location of some excavations may require the installation of lateral support members (e.g., sheet piles), and/or underpinning of building foundations. Excavation may not be implementable for impacted soil areas beneath footings. Bedrock that may be impacted could not be excavated. Transportation of hazardous materials on local roads will be difficult, as will the transportation of impacted soil by barge. The logistics of transporting the material from the site to the off-island landfill must be tightly controlled and will be administratively difficult to implement. Capped areas will be significantly easier to implement as a remedy.

Capital costs for SRA 5 would consist of administrative and engineering costs, and costs related to excavation, transport, disposal, and monitoring. O&M costs would be minimal and would be limited to the areas that are capped.

The estimated capital cost to implement SRA 5 with the SCPs is $2,065,000. No O&M costs will be incurred after excavation and disposal is completed. However, the O&M required to maintain the caps at the Ramsay and Tillett properties, the in-situ SVE in bedrock at the Curriculum Center and the O'Henry Dry Cleaners and the SCPs has an estimated present-worth value of approximately $2,460,000. The estimated grand total for SRA 5 and the SCPs is $4,525,000. The cost breakdown for the activities that comprise SRA 5 is presented in Table 5-7.

5.3 DEVELOPMENT AND EVALUATION OF REMEDIAL ALTERNATIVES FOR GROUNDWATER

In general, the proposed groundwater remedies are pump and treat scenarios. Past experience with sites where DNAPLs have been identified indicates that portions of the fractured bedrock may never be fully restored. Therefore, it is assumed that each GRA will continue to operate for the entire remedial action. For the purposes of cost comparison, FS guidance (USEPA 1988a) recommends the use of 30 years for the duration of remedial actions. At some point in time during the life cycle of the remedial action, groundwater recovery and treatment may no longer assist in the reduction of contaminants levels to CGs (i.e., MCLs). Once this asymptotic level is reached, the groundwater remedial action will no longer be able to significantly reduce the COCs in groundwater.

Every five years during the life cycle of a remedial action (or more frequently, as needed), a performance review of the remedial system should be performed to determine if portions of the aquifer have obtained MCLs. The results of the semi-annual compliance monitoring samples will provide data for these remedial system performance reviews. If VOC concentrations in portions of the aquifer are reduced below MCL concentrations, the possible use of groundwater for beneficial uses may be allowed in specified areas.

Four remedial alternatives have been developed to address impacted groundwater on a site-wide basis. The four groundwater remedial alternatives (GRAs) assembled for comparison are the following:

- GRA 1: No Action/Institutional Controls.
- GRA 2: Institutional Controls/Source Containment/
  POET Systems/Treatment/Discharge.
- GRA 3: Institutional Controls/Plume Containment/Treatment/Discharge.
- GRA 4: Institutional Controls/Source and Plume Containment/Treatment/Discharge.

5.3.1 GRA 1: No Action/Institutional Controls

In this section, GRA 1: No Action/Institutional Controls is described and evaluated.

5.3.1.1 Description of GRA 1

This remedial alternative would involve implementing deed restrictions and monitoring. Deed restrictions on groundwater use may include the following:

- Requiring the decommissioning of domestic and commercial wells. Existing unpermitted supply wells can be decommissioned by removing the pump and placing a removable plug in the well. The wells can be reestablished at some point in the future, when and if groundwater quality improves to allow extraction and use of untreated groundwater.

- Prohibiting unauthorized usage of groundwater or the installation of new wells.

- Placing restrictions on the water supply sources for future residential growth.

- Limiting water system installations to connection to the Water and Power Authority (WAPA) distribution system or an alternate authorized source.

GRA 1 includes semi-annual groundwater sampling to monitor groundwater quality and contaminant migration. For purposes of comparison, the monitoring program includes the sampling of approximately 15 wells at or near the plume boundary for TCL VOCs and BNAs, and the monitoring program will be assumed to last throughout the remedial action (30 years).

Restrictions on groundwater use would be established to prevent the installation of new supply wells in the affected area. To prevent future use of the existing wells, all existing supply wells at the Tutu Wells Site would be decommissioned. The DPNR would be responsible for enforcing restrictions on groundwater use and for ensuring that no unpermitted groundwater pumpage occurs. Water would continue to be supplied as it is currently being supplied (i.e., through collection of rain water and trucking water from an alternate source).

5.3.1.2 Evaluation of GRA 1

Based on the results of the RI (Geraghty & Miller, Inc. 1995) and the Baseline Risk Assessment (CDM Federal Programs Corporation 1995a), the groundwater under the site currently poses and will continue to pose an unacceptable risk to human health by ingestion. Implementation of institutional actions will not control the migration of impacted groundwater. This alternative would guard against potential impacts to human health within the Tutu Wells Site area, but may not protect human health off-site since plume migration would not be controlled. Institutional controls may not completely prevent unauthorized use of groundwater; unauthorized use of groundwater could still occur. Currently, there have not been any documented impacts to ecological receptors resulting from exposure to impacted groundwater, and the RI indicated such impacts are not likely (Geraghty & Miller, Inc. 1995). Potential impacts to ecological receptors are not discussed in the Baseline Risk Assessment.

This alternative would not be in compliance with chemical-specific ARARs. Exceedances of these ARARs would be expected to continue. The long-term effectiveness of this alternative is questionable. Groundwater transport of contaminants would continue, and risks from direct contact and other pathways, although reduced, would not be eliminated. No appreciable reduction in toxicity, mobility, or volume of the contaminants at the Tutu Wells Site would result from implementation of this alternative.

Short-term effectiveness is favorable as there would be little or no short-term impacts associated with implementation of GRA 1. Minimal short-term impacts, relating to decommissioning of the existing wells in the area, can be assumed. Personal protective equipment for workers would control exposure during implementation, if warranted. The time to implement this alternative would be approximately 12 months from the date all required approvals were obtained.

Institutional controls may not be easily implementable and would involve considerable administrative time. The DPNR would be responsible for preventing unauthorized groundwater pumpage.

The total cost for this alternative would be a combination of administrative costs associated with securing deed restrictions, the construction costs related to abandonment of the existing wells, and the commercial costs related to monitoring and laboratory testing.

The estimated capital cost to implement GRA 1 is $15,000. The estimated present-worth value of the estimated cost to conduct groundwater monitoring over 30 years is $1,757,000. The total estimated cost is $1,772,000. The cost estimates presented do not include a cost for devaluation of property due to deed restrictions. The cost breakdown for the activities that comprise GRA 1 is presented in Table 5-8.

5.3.2 GRA 2: Institutional Controls/Source Containment/POET Systems/Treatment/Discharge

This section describes GRA 2 and summarizes the evaluation based on the criteria established by the NCP.

5.3.2.1 Description of GRA 2

This remedial alternative involves implementing the following:

- Implementation of deed restrictions related to future site usage and water supply well installation.
- Installation of groundwater recovery wells for hydraulic control of contaminant sources.
- Long-term monitoring of groundwater.
- Installation of POET systems at selected existing supply wells.
- Installation of a central treatment facility.
- Discharge of treated groundwater to surface water via the storm sewer near the O'Henry Dry Cleaners (see Figure 5-1).
- Natural attenuation of the dissolved chlorinated VOC plume downgradient of the Smith and Matthias Supply Wells.

This remedial alternative proposes a methodology for hydraulic containment of the potential groundwater contamination source areas that exhibit the highest groundwater VOC concentrations, and incorporates ex-situ treatment of groundwater and discharge of the treated groundwater to surface water.

The groundwater remediation proposed for GRA 2 consists of containing high-concentration portions of the existing chlorinated VOC plumes by providing source containment at the potential sources of groundwater contamination (i.e., the Curriculum Center area and the area proximate to O'Henry Dry Cleaners) and allow selected private wells to pump utilizing POETs for treatment. The currently proposed SCPs at the Texaco Tutu Service Station and the Esso Tutu Service Station will provide source containment where BTEX constituents are the primary COCs. The source containment would provide hydraulic barriers around source areas, thus reducing COCs in other parts of the aquifer and potentially reducing the time to reach CGs in large portions of the Tutu Wells Site. The recovery well scheme that would be implemented in GRA 2 involves the use of the Source Recovery Wells pumping scenario described in Section 4.6.3.1 (Collection and Containment) (see capture zones for Recovery Wells RW-4 and RW-5 in Figure 4-10, with pumpage of selected private domestic and commercial wells). Pilot studies may be required to evaluate the most effective technologies for treatment.

Pumpage for commercial potable supply would not be permitted. Selected wells equipped with POET systems would be allowed to pump for private use or for sale for non-potable uses. For the purposes of this FS Report, the supply wells assumed to have POET systems include the Four Winds I, Steele, LaPlace, Matthias, and Smith Supply Wells (see Table 4-12). These wells were selected because they are located in the center of the chlorinated VOC plumes and could therefore provide containment and removal of contaminants. This selection of supply wells for pumpage is preliminary; the final selection will be made by the USEPA and the DPNR if GRA 2 is selected.

The remaining wells would be decommissioned and/or sealed. The Four Winds I Supply Well could pump at an average rate of 10 gpm; the remaining four wells would be allowed to pump at an average rate of 1.25 gpm each, equivalent to normal residential usage rates for each well. The total average pumping rate allowed in GRA 2 for supply wells is approximately 15 gpm.

Effluent quality will be specified by the requirements of the permit to discharge to surface water. The treatment scheme that would be employed is illustrated on Figure 4-11. Figure 5-1 illustrates the conceptual layout for this GRA. The total flow capacity of the treatment facility would be 55 gpm.

A number of residential and commercial wells within the Tutu Wells Site would have to be decommissioned. Residential groundwater use in some areas could interfere with the hydraulic containment program and reduce the program's effectiveness in containing the impacted groundwater.

In areas of the aquifer where groundwater is not anticipated to create adverse impacts to human health (i.e., in the area beyond the Delegarde Well and the deeper portions of the aquifer), natural attenuation is proposed. Active remediation of these portions of the aquifer will not decrease the time required to remediate the site and would increase remediation costs substantially.

5.3.2.2 Evaluation of GRA 2

This remedial alternative includes POET systems (which the USEPA does not consider to be an adequate long-term solution for the potential impact on human health) that are unfavorable for protection of human health. The USEPA considers POET systems to pose potential risks to consumers due to potential equipment malfunctions. The effectiveness of controlling off-site migration is contingent upon developing an effective containment program.

This alternative has the potential for compliance with anticipated ARARs related to groundwater. Potential chemical-specific ARARs for discharge can be met through ex-situ treatment, and site constituent migration will be reduced by the proposed pumping of residential wells. Natural attenuation can, in time, allow portions of the aquifer to meet the potential chemical-specific ARARs for groundwater. The effectiveness of natural attenuation will be contingent on the effective capture of the residential well pumping. Geraghty & Miller anticipates that complete capture will not be accomplished through implementation of a residential well pumping program; therefore, GRA 2 may not protect human health off-site.

The remedial alternative is essentially a pump and treat system, which is a proven long-term and permanent groundwater containment remedy at many CERCLA sites. The containment program has the potential to prevent some, but not all, off-site contaminant migration. Geraghty & Miller anticipates that source containment would result in an eventual decrease in constituent concentrations site-wide and would also guard against drawing groundwater contaminants with higher VOC concentrations toward groundwater with lower VOC concentrations, thereby minimizing contaminant migration.

The use of POET systems with institutional controls may not be effective as a long-term or permanent remedy. The potential for off-site groundwater transport of contaminants may still exist, depending on the ability to utilize private wells and to coordinate their pumpage to hydraulically contain impacted groundwater. These factors suggest that long-term effectiveness and permanence may be limited. The reduction of toxicity, mobility, and volume would be moderate because effective source control would maximize constituent removal from groundwater, and intermittent pumping of residential wells equipped with POETs would also result in some reduction in the volume of COCs in groundwater.

Short-term effectiveness is moderately favorable; there would be minimal impacts related to implementation of recovery wells, POET systems, and a central treatment facility. The time to implement institutional controls and execute well abandonment would be moderate; however, additional time may be required for start-up of the recovery program and treatment system. Installation of POETs may be difficult to implement due to potential problems with installation on individual properties. Property would have to be secured for construction of the treatment systems, and access agreements for recovery wells would be required. A permit for discharge to surface water would be required, and time to construct a treatment system would be required. Personal protective equipment for workers would be used to control exposure during implementation, if needed.

Administrative implementability may be difficult. Wells are owned by individual property owners, which may create a need for a significant amount of coordination to implement. It may be difficult to ensure that the unpermitted wells are not pumped and that the safe yield of the aquifer is not exceeded. Operation issues could be significant due to maintenance related to a treatment facility and the operation of individual property owner POET systems. The reliability of POET system technologies has proven satisfactory when used as an interim measure. Monitoring of the POET systems would involve periodic O&M requirements throughout the life of the remedial action, and the risk of exposure would be high if monitoring requirements were insufficient to detect system failures. Implementation time is estimated to be approximately 12 to 18 months from the date approvals for installation are obtained.

The costs to implement this remedial alternative would consist of the administrative cost and the engineering, material, and installation costs of the collection, treatment, and discharge systems. There would also be O&M costs associated with operating the collection/treatment system, monitoring of the plume, and providing O&M for the POET systems. The estimated capital cost to implement GRA 2 with the SCPs is $2,366,000 with an estimated total O&M present-worth cost of $7,793,000 and an estimated grand total of $10,159,000 (see Table 5-9).

5.3.3 GRA 3: Institutional Controls/Plume Containment/Treatment/Discharge

This section describes and evaluates GRA 3, using the criteria established by the NCP.

5.3.3.1 Description of GRA 3

The following actions would be implemented:

- Implementation of deed restrictions related to further site groundwater use.
- Decommissioning of residential and commercial wells.
- Installation of groundwater recovery wells for hydraulic control of plume migration.
- Construction of a central groundwater treatment facility.
- Discharge of treated groundwater to surface water.
- Natural attenuation of dissolved plume downgradient of Recovery Wells RW-2 and RW-3, and below an approximate depth of 150 feet bls.

This remedial alternative proposes a methodology for hydraulic containment of the delineated plumes and incorporates ex-situ treatment of groundwater and discharge of the treated groundwater to surface water.

The proposed containment program would include the installation of Recovery Wells RW-1, RW-2, and RW-3 strategically placed to hydraulically contain plume migration (see Figure 4-10). Existing supply wells would be decommissioned to avoid influencing the containment program and to control unauthorized exposure to groundwater impacted by site constituents. Potable water would continue to be supplied as it is now. The containment program would be as described in Section 4.6.3.1 (Collection and Containment).

Recovered groundwater would be collected and conveyed to a central treatment facility. Treatment of the groundwater for surface-water discharge would be accomplished using a treatment facility similar to the facility illustrated on Figure 4-11. The total flow capacity of the treatment facility would be 45 gpm.

A number of residential and commercial wells within the Tutu Wells Site would have to be decommissioned. Residential and commercial groundwater use in some areas would counteract the hydraulic containment program and reduce the program's effectiveness in containing the impacted groundwater.

Property acquisition would be required for the central treatment facility. Sufficient room would be needed to construct the facility and meet local ordinance set-back requirements. A site located in the vicinity of the southern plume containment wells is assumed. Such a location would be at a lower elevation when compared to the rest of the Tutu Wells Site, thus reducing pumping requirements.

Natural attenuation is proposed for the portions of the plume where groundwater impacts exist southeast of Recovery Wells RW-2 and RW-3, and for groundwater below a depth of approximately 150 feet bls.

The implementation of institutional controls could initially be as extensive as those proposed in GRA 1, but could be reduced later in the remedial action depending on the effectiveness of the GRA in meeting CGs. Unauthorized groundwater pumpage will have to be effectively controlled throughout the remedial action. A monitoring program of the same scope as proposed in GRA 1 would also be required with GRA 3.

5.3.3.2 Evaluation of GRA 3

This remedial alternative can adequately address the impact that the Tutu Wells Site will have on human health. Although the potential for unauthorized use of groundwater would still exist, implementation of institutional controls with a containment program would effectively eliminate the potential exposure pathways by which groundwater would present a health risk. With monitoring and adjustment, an effective containment program can be developed that would control off-site migration, thereby reducing the potential for off-site human health impacts. The portions of the plume where natural attenuation is proposed will be naturally remediated over time. Natural attenuation will effectively reduce COCs below concentrations that could cause impacts to human health or the environment.

This alternative has the potential for compliance with anticipated ARARs related to groundwater. Potential chemical-specific ARARs for discharge can be met through ex-situ groundwater treatment. Site constituent migration will be reduced by plume containment. The effectiveness of natural attenuation in meeting chemical-specific ARARs downgradient of Recovery Wells RW-2 and RW-3 will be contingent on the effectiveness of plume capture.

Location-specific and action-specific ARARs will be met with through engineering controls and proper implementation. Since there may be sources that would continue to be active under this scenario, it is likely that portions of the aquifer will never meet the MCLs for groundwater without treatment.

The toxicity, mobility, and volume of impacted groundwater would be reduced through containment and pumping; however, the potential presence of DNAPL in the bedrock aquifer at the Tutu Wells Site could act as a continual source of groundwater contamination throughout the life of the remedial action.

Short-term effectiveness is moderately favorable; there would be impacts related to implementation of the recovery wells and a central treatment facility. In addition, GRA 3 is not an optimal collection system because COCs will migrate from the source areas through the aquifer to the plume containment recovery wells. The time to implement institutional controls and execute well decommissioning would be moderate; however, the time required for start-up of the recovery program and treatment system is estimated to be approximately 12 to 18 months. Property would have to be secured for construction of the central treatment facility and access agreements for recovery wells would be required. Personal protective equipment for workers would be used to control exposure during implementation.

The implementability of this alternative would be more similar to other options. A permit would be required for surface-water discharge of treated water. Unauthorized groundwater pumpage that would interfere with the effectiveness of this remedial system would need to be enforced. Approvals for discharge could take as long as 12 to 18 months to secure.

The costs to implement this remedial alternative would consist of administrative cost and the engineering, material, and installation costs of the collection, treatment, and discharge systems.

There would also be O&M costs associated with operating the collection/treatment system and monitoring of groundwater quality and the rate of attenuation.

The capital cost to implement GRA 3 with the SCPs is approximately $2,357,000. The estimated total O&M present-worth cost estimated for GRA 3 and the SCPs is $6,143,000. The estimated grand total cost is $8,680,000 (see Table 5-10).

5.3.4 GRA 4: Institutional Controls/Source and Plume Containment/Treatment/ Discharge

This section presents a description and evaluation of GRA 4, using the criteria established by the NCP.

5.3.4.1 Description of GRA 4

The following actions would be implemented:

- Implementation of deed restrictions related to further site groundwater usage.
- Decommissioning of residential and commercial wells.
- Installation of groundwater recovery wells for hydraulic control of plume migration.
- Installation of groundwater recovery wells for hydraulic control of areas identified as potential source areas.

- Construction of a central groundwater treatment facility.

- Discharge of treated groundwater to surface water.

- Natural attenuation of dissolved plume downgradient of Recovery Wells RW-2 and RW-3, and below an approximate depth of 150 feet bls.

This action proposes the containment of plume migration and hydraulic source containment in areas that are suspected of being sources of impacts to groundwater. The areas where source containment would be proposed are the Curriculum Center, Texaco Tutu Service Station, Esso Tutu Service Station, and O'Henry Dry Cleaners. The Texaco Tutu Service Station and the Esso Tutu Service Station are being addressed through the implementation of the SCPs (see Figure 4-8). The other potential source areas would be addressed through the installation of source containment Recovery Wells RW-4 and RW-5. Migration of the plume will be addressed through the installation of plume containment Recovery Wells RW-1, RW-2, and RW-3 (see Figure 4-9).

The source containment would provide hydraulic barriers around source areas, thus reducing COCs in other parts of the aquifer and would likely reduce the time to reach CGs in other large portions of the Tutu Wells Site. The plume containment wells will guard against the continued migration of COCs away from suspected source locations. The recovery well scheme that would be implemented is the Source and Plume Containment pumping scenario described in Section 4.6.3.1 (Collection and Containment).

Recovered groundwater would be collected and conveyed to a central treatment facility; the treated water would be discharged to surface water. The total flow capacity of the treatment facility would be 100 gpm. Figure 4-11 presents a schematic of the treatment system. All private wells will be decommissioned within the Tutu Wells Site.

Property acquisition would be required for the central treatment facility. Sufficient room would be needed to construct the facility and meet local ordinance set-back requirements. A site located in the vicinity of the southern plume containment wells is assumed. Such a location would be at a lower elevation when compared to the rest of the Tutu Wells Site, thus reducing pumping requirements.

Natural attenuation is proposed for the portions of the plume where groundwater impacts exist southeast of the Recovery Wells RW-2 and RW-3, and for groundwater below a depth of approximately 150 feet bls.

The implementation of institutional controls could initially be as extensive as those proposed in GRA 1, but could be reduced later in the remedial action depending on the effectiveness of the source area containment. Unauthorized groundwater pumpage will have to be effectively controlled throughout the remedial action. A monitoring program of the same scope as proposed in GRA 1 would also be required.

5.3.4.2 Evaluation of GRA 4

This alternative can adequately address the impact that contaminated groundwater under the Tutu Wells Site will have to human health. The potential for unauthorized use of groundwater would still exist. Implementation of institutional controls with plume and source control would effectively eliminate the potential exposure pathways by which groundwater would present a health risk.

Geraghty & Miller anticipates that plume and source containment would result in the most effective approach for reducing constituent concentrations site-wide and would also guard against drawing groundwater with a higher constituent concentration toward groundwater with lower constituent concentrations, thus minimizing contaminant migration within the Tutu Wells Site. The portions of the plume where natural attenuation is proposed will be naturally remediated over time. Natural attenuation will effectively reduce COCs below concentrations that could cause impacts to human health or the environment.

This alternative has the potential for compliance with anticipated ARARs related to groundwater. However, if DNAPLs are present in the fractured bedrock, as is currently suspected, remediation of the aquifer as a whole to drinking water quality ARARs will not be feasible. The effectiveness of natural attenuation meeting chemical-specific ARARs downgradient of Recovery Wells RW-2 and RW-3 will be contingent on the effectiveness of plume capture. Location-specific and action-specific ARARs will be met through engineering controls and proper implementation. Since there may be sources that would continue to be active under this scenario, it is likely that portions of the aquifer will never meet the MCLs for groundwater without treatment.

The toxicity, mobility, and volume of the impacted groundwater would be reduced. This GRA would be the most effective alternative in addressing this criterion. The effects of DNAPL that may be present in the bedrock aquifer would be reduced, and source containment should decrease the time required to reduce contaminant concentrations within most of the aquifer.

Long-term effectiveness and permanency can be considered favorable. The dual containment program can guard against off-site contaminant migration and can reduce further impacts caused by source areas. Implementing this program may enable the eventual use of portions of the aquifer for water supply, although under specific institutional controls. A method of replacing this source may have to be implemented (e.g., continuing current alternate supply practices).

Short-term effectiveness is moderately favorable. There would be minimal impacts related to implementation of recovery wells and the central treatment facility. The time required to implement institutional controls and execute well decommissioning would be moderate; however, the time required for start-up of the treatment system could take an estimated 12 to 18 months. The installation of recovery wells would be required. Due to the greater number of recovery wells, GRA 4 would be more expensive than GRA 2 or GRA 3. Well development and monitoring would be required to ensure the effective capture of groundwater. A permit for discharge to a surface water would be required and construction time could be longer than for GRA 2 or GRA 3 due to the additional number of recovery wells and the additional piping that must be installed.

Properties would have to be secured for construction of the treatment system, and access agreements for recovery wells would be required. Personal protective equipment for workers, if needed, would control exposure during implementation. Assuming this procedure is used, the estimated time to implement this alternative would be approximately 12 to 18 months.

Implementability would not be favorable as this GRA has the potential for the most significant administrative requirements. Discharge permits could take 12 to 18 months to secure. This alternative also places the greatest withdrawal demand on the Tutu aquifer and may create upconing of mineralized water in areas of the aquifer. Therefore, pre-design studies must carefully optimize required pumping rates.

The costs to implement this remedial alternative would consist of administrative costs, and engineering, material, and installation costs related to the collection/containment/treatment and discharge systems. The costs for GRA 4 would tend to be higher than for other groundwater remedial alternatives due to the increased amount of materials and installation required.

The capital cost to implement GRA 4 with the SCPs is approximately $3,175,000. The estimated total O&M present-worth cost estimated for GRA 4 and the SCPs is $7,328,000. The estimated grand total cost is $10,503,000 (see Table 5-11).

5.4 COMPARATIVE ANALYSIS OF ALTERNATIVES

In Section 5.1 (Evaluation Criteria), Section 5.2 (Development and Evaluation of Remedial Alternatives for Soil) and Section 5.3 (Development and Evaluation of Remedial Alternatives for Groundwater), Geraghty & Miller assembled and evaluated the SRAs and GRAs with respect to their conformance with the seven evaluation criteria established by NCP guidance. The results of the evaluations of SRAs are summarized in Table 5-1, and the results of the evaluations of GRAs are summarized in Table 5-2. This section describes the results of the evaluations conducted and provides a recommendation for a preferred remedy for each of the seven criteria evaluated and listed in Section 5.1 (Evaluation Criteria).

5.4.1 <u>Protection of Human Health and the Environment</u>

The protection of human health and the environment is one of two threshold criteria that must be complied with for the effective implementation of a remedial alternative. The remedy that is implemented must minimize impacts to human health and the environment.

All of the SRAs, except for SRA 1 (No Action/Institutional Controls) which cannot meet the requirements of this criterion, are effective in complying with this criterion. Treatment of the impacted soil (as with SRA 3 or SRA 4) would be preferred because removal of the soil (as in SRA 5) removes the contaminants, but it does not necessarily reduce the contaminant volume. SRA 2 (Institutional Controls/Capping) does not involve implementing a treatment technology; it mitigates migration and exposure. SRA 2 does not reduce the contaminant volume. Therefore, either SRA 3 or SRA 4 should be considered the preferred remedy for compliance with protection of human health and the environment.

Of the GRAs considered, GRA 2, GRA 3, and GRA 4 will meet this criterion as long as recovery well capture zones are effective and institutional controls are effectively enforced. If effective capture is not obtained, these remedies will not be fully protective of human health, especially if natural attenuation does not alleviate the remaining groundwater contaminants. Therefore, the alternative that provides the most effective capture of impacted groundwater would be considered the preferred remedy under this criterion. GRA 4 will provide the maximum protection of human health and the environment because it provides the maximum capture of impacted groundwater by implementing both plume and source containment. Implementing source containment will hopefully expedite the remediation of other portions of the aquifer and make these portions of the aquifer useable some time in the future.

5.4.2 Compliance with ARARs

Compliance with ARARs is the second threshold criterion (along with protection of human health and the environment), that must be achieved by a remedial alternative. Compliance with ARARs relates to a remedy's ability to comply with chemical-, action-, and location-specific criterion for implementation of a particular remedy. It also refers to the ability of a remedy to meet other potentially applicable criteria, advisories, or guidance. The most important ARARs for evaluation of SRAs include the SSLs which are the preliminary CGs and the RCRA LDRs. The SSLs are actually TBCs rather than ARARs because these are guidance values for soil developed by the USEPA (CDM Federal Programs 1995b). The RCRA LDRs are also important, especially when considering excavation and off-site disposal as a remedial alternative. Other ARARs, mainly associated with permitting (i.e., permit applications and administration, air and water discharge limits), can be achieved though proper administration and engineering controls (i.e., treatment system design).

SRA 1 and SRA 2 do not comply with the SSLs because soil contaminant levels are not reduced below SSLs. The RCRA LDRs are not applicable to SRA 1 and SRA 2 because no soil removal is involved in these SRAs. SRA 3, SRA 4, and SRA 5 can comply with the SSLs. Excavation and disposal proposed in SRA 3, SRA 4, and SRA 5 can comply with the RCRA LDRs.

Compliance with potential ARARs can be accomplished with all the SRAs except for SRA 1 and SRA 2. SRA 1 takes no action and SRA 2 reduces exposure and contaminant migration pathways via capping, but SRA 1 and SRA 2 do not reduce the contaminant levels in soil. SRA 3 and SRA 4 can comply with this criterion by reducing the toxicity or volume of impacted soil; SRA 5 can comply with this criterion by removing impacted soil from the site and disposing the impacted soil in a permitted hazardous waste disposal facility. A preferred remedy would maximize contaminant reduction and volume and not relocate soil from one area to another without treatment. Therefore, SRA 3 and SRA 4, which provide for contaminant reduction, would be the preferred soil remedies for this criterion.

The ARAR requirements for groundwater involve the ability of a remedy to comply with applicable discharge treatment criteria and regulations. The most important ARARs for the evaluation of the GRAs are MCLs, TPDES permit requirements, and protection of wetlands. The MCLs are the preliminary CGs for groundwater; the MCLs are also used as preliminary discharge limit requirements for the proposed treatment systems. If MCLs are met in the treated water discharge, TPDES discharge limits for surface-water discharge should also be achieved. Depending on the final TPDES permit requirements, the discharge limits may be less stringent than MCLs. A possible wetland area has been identified in the southeast corner of the study area by the USEPA.

Surface-water discharge rates will need to be evaluated to determine if an unacceptable water-level rise could impact the wetlands. Preliminary evaluation indicates that the large size of the drainage basin relative to the potential increased surface-water flow should result in little or no hydraulic impact. However, a more detailed analysis will be required as part of the pre-design activities. All the GRAs can comply with the potential ARARs except for GRA 1 (No Action/Institutional Controls). The containment treatment schemes proposed have the ability to meet the anticipated ARARs. Because GRA 4 is the most aggressive groundwater recovery scenario, GRA 4 is the preferred alternative to attempt to achieve MCLs in the aquifer.

5.4.3 Short-Term Effectiveness

Short-term effectiveness evaluates the effectiveness of a remedy in protecting human health and the environment during implementation of the remedy. The least obtrusive remedies causing the least disturbance would be the most responsive to this criterion.

The SRA that is responsive to the RAOs and would comply with this criterion the best is SRA 2 (Institution Controls/Capping). In-situ treatment of impacted soil will minimize the fugitive emissions caused by installation of the remedy and will reduce the off-site impacts related to the remedial action. This will result in a greater ability to control exposure to potentially hazardous conditions. Minimizing excavation and transport of impacted soil will also minimize the off-site impacts due to fugitive emissions or potential accidental releases. Therefore, SRA 2 would seem to be the most responsive to this criterion.

All of the GRAs can comply with this criterion with the implementation of engineering controls or safety equipment. However, GRA 1 is not responsive to the RAOs for the site and would not be implementable due to non-compliance with other NCP criteria. The most effective remedy to address this criterion would be the remedial action that is responsive to RAOs and minimizes the amount of construction or disturbance that is required for installation. Therefore, GRA 2 would seem to be the most effective GRA at addressing this criterion. The construction related to GRA 3 and GRA 4 is greater than GRA 2, thus creating more potential for impacts to workers and residents in the area.

5.4.4 Long-Term Effectiveness

Long-term effectiveness relates to the ability of a remedy to reduce the risks associated with the potential for exposure, the impacted media at the site, and the adequacy of the remedy in managing or minimizing the residual risk after the remedial action is complete. In areas where DNAPL may be present in bedrock, the long-term effectiveness of a remedy may not be accomplished due to the inefficiencies of locating and removing DNAPLs in bedrock.

The SRA that is responsive to the RAOs and would comply with this criterion would also be the most reliable in terms of compliance with RAOs in the future. SRA 1 does not meet the RAOs established for the site. The SRA that addresses this criterion is a remedy that either removes or reduces impacted soil volume from the site. SRA 3, SRA 4, and SRA 5 all provide this reliability. SRA 2 is effective at minimizing the transport of impacted soil or leaching of contaminants; however it requires maintenance and does not totally eliminate potential future exposure. The actual preferred remedy for this criterion would be based on the effectiveness of treatment methods that cannot be anticipated until pilot testing is completed at each respective property. SRA 5 involves the removal of the soil off-site, eliminating the soil source areas from the property. The removal of impacted soil in SRA 5 will be limited by building foundations and it is likely that not all of the impacted soil can be removed. Therefore, it would seem be the most favorable remedies for complying with this criterion are SRA 3 and SRA 4. This is contingent on the effectiveness of each alternative in meeting the CGs.

The most effective remedy to address this criterion for groundwater would be the remedial action that is responsive to RAOs and provides the best potential for remediation of the aquifer. Therefore, GRA 4 (Source and Plume Containment) would seem to be the most effective GRA at addressing this criterion because GRA 4 will provide the maximum protection of human health and the environment and will provide both plume and source containment. GRA 4 will also remove the most impacted groundwater, thus increasing the amount of mass that can be removed.

5.4.5 Reduction in Toxicity, Mobility, and Volume

To comply with this criterion, treatment or reduction in contaminant volume must be provided. The soil remedies that provide treatment of impacted soil are SRA 3 and SRA 4. The other SRAs considered either do not address the RAOs for the site or do not provide treatment. Of the two remedies that provide treatment, SRA 4 has the most potential for reducing COCs in soil because soil would be treated in an engineered environment for contaminant reduction rather than in situ. Therefore, SRA 4 would be the most responsive SRA to this criterion.

The most responsive GRA to this criterion would be the one that extracts and treats the most impacted groundwater. This maximizes the reduction in toxicity, mobility, and volume. GRA 4 is the most active GRA remedy related to groundwater removal and treatment, and therefore would be the most responsive GRA to this criterion.

5.4.6 Implementability

Implementability deals with the technical and administrative feasibility of implementing an alternative and the ease with which a remedy can be implemented. Those remedies that can be controversial or heavily regulated would be difficult to implement. Implementability also involves the associated ease of construction and operations or simplicity of the installation and operations.

The SRA that addresses this criterion the most effectively is the remedy that is anticipated to be the least administratively burdensome, the least controversial, and the most technically feasible option. Therefore, the remedy that 1) minimizes the permitting requirements, 2) is most reliable, and 3) minimizes the impacts to residents in the area will be the most administratively implementable. Of the SRAs evaluated, SRA 2, SRA 3, SRA 4, and SRA 5 are all implementable. From an administrative perspective, the actual preferred remedy relating to this criterion would be SRA 3 because it minimizes excavation of impacted soil and also minimizes the required transportation of impacted soil through residential areas for off-site disposal. From a technical perspective, the most effective SRA would be SRA 4.

The GRA that would seem to be the most implementable would be GRA 3. This GRA is the least obtrusive as it minimizes the amount of impact to the area. The treatment system design for GRA 3 would be more simple to operate, as it would entail the lowest flow rate, and would require the least amount of equipment and materials to implement.

5.4.7 Cost

The remedial alternative that addresses the RAOs for the site and is the most cost-effective will be the most responsive to this criterion. Table 5-12 presents a comparative summary of costs. Of the SRAs considered, the most cost-effective based on the assumptions provided in Appendix C is SRA 2 (excluding SRA 1 which does not meet the threshold criteria). Of the GRAs considered, the most cost-effective alternative based on the assumptions provided in Appendix C is GRA 3 (excluding GRA 1 which does not meet the threshold criteria).

SECTION 6

6. PRE-DESIGN ACTIVITIES

Several pre-design activities must be completed before the selected remedy can be implemented. Some of the additional data that will be needed prior to implementing the selected remedy are described below. Work plans for pre-design sampling and testing and treatability studies should be submitted to the USEPA and DPNR for review.

6.1 PRE-DESIGN ACTIVITIES FOR SOIL REMEDIATION

Although a significant amount of data has been gathered to characterize the Tutu Wells Site, little engineering design data exist that can be used to determine the design parameters for the proposed SVE systems or for the proposed treatment facility. Prior to implementing SVE at any of the properties where it is proposed, additional soil sampling (rock sampling at the Curriculum Center), soil-gas sampling, and pilot testing should be conducted to ensure that the SVE systems will work effectively.

Air permeability testing of the subsurface to determine soil permeability for SVE is suggested. This testing should consist of establishing a vacuum on a monitoring well while the air pressure fluctuations in nearby wells or other subsurface vacuum measuring points are measured.

Additional delineation of soil contamination is needed at two locations. First, the extent and source of the shallow oily gravel layer and its relationship with the buried PVC pipe west of the Four Winds Plaza and Western Auto should be determined. Second, soil borings should be advanced at the center of the high chlorinated VOC soil gas readings north of the building and through the floor slab in the northwest and west-central portions of the Curriculum Center (former Laga building) to determine the extent of chlorinated VOCs in the subsurface in these areas. Sampling of abandoned floor piping inside the building indicated high concentrations of PCE (approximately 30 percent PCE). This fact, in conjunction with known previous dry cleaning operations in the northwest corner of the building and the distribution of chlorinated VOCs in groundwater, indicate that a source of contamination may exist under the building. This source should be delineated to determine the extent of contamination, to determine the potential for continuing releases, and to evaluate appropriate remedial actions (if necessary).

Prior to the implementation of any remedial actions for soil, confirmatory sampling should be performed. Bioremediation (especially of BTEX constituents) will continue under natural conditions. Sampling prior to remedial action will address the following objectives:

- Confirm the need for remedial action.
- Determine soil concentrations prior to remedial action.
- Provide additional delineation of the extent of impacted soil.
- Provide data for comparison with post-remedial sampling to evaluate the effectiveness of the remedial action.

6.2 PRE-DESIGN ACTIVITIES FOR GROUNDWATER REMEDIATION

If air sparging or biosparging is selected for groundwater remediation, treatability studies will be needed to determine the following:

- The potential effectiveness of this technology.
- Air injection rates that can be achieved.
- The radius of influence that can be achieved (to determine sparging well spacing).

Prior to final design of a groundwater recovery (or extraction) system, it may be necessary to install and monitor additional wells to further define the following:

- The horizontal component of groundwater flow and contaminant trensport.
- The horizontal and vertical extent of contamination.
- The hydraulic characteristics of the aquifer in the areas of recovery or extraction.

The number of recovery wells and their locations presented in this FS Report are preliminary and may be modified and optimized based on updated pre-design data. During pre-design, it may be necessary to use a predictive model to simulate the movement of groundwater and contaminants under various extraction well scenarios (e.g., number of wells, rates of extraction).

Once a groundwater recovery system is designed, it may be necessary to install additional wells to monitor the effectiveness of groundwater recovery (i.e., capture zones). Once the recovery or extraction wells are installed, pumping tests will be needed to determine their yield and the concentrations of contaminants in the recovered groundwater.

6.3 PRE-DESIGN ACTIVITIES FOR TREATMENT SYSTEMS

The treatment systems used for groundwater and SVE will require more specific data regarding influent concentrations and to evaluate the need for a treatment component for the air discharge is necessary. A discharge monitoring plan should be prepared for air discharges and treated water discharges. An assessment of the potential impacts on a USEPA-identified wetland may be a necessary component of the discharge to surface-water permit application. An evaluation of the potential magnitude of water-level rise and associated hydraulic impact of the discharge on the wetland may be needed. If a potentially significant water-level rise is predicted, a delineation of the wetland may be necessary. A preliminary review of the drainage basin characteristics seems to indicate that no detrimental impact would be created; this may need to be further evaluated during the permit application.

Groundwater containment and treatment facility design will require installation of test recovery wells and aquifer pumping tests to determine the actual zones of hydraulic capture and the number and spacing of the recovery wells needed. In addition, pilot testing may needed to evaluate the effectiveness of the proposed technologies for treating groundwater contamination.

Property acquisition, as discussed in Appendix C, will be required for a site for the construction of a central treatment facility. Figure 5-1 shows a conceptual layout for piping and the treatment system. A site evaluation would be required to find the most appropriate location.

Additional evaluation of natural inorganic groundwater concentrations may be needed. The existing groundwater at the Tutu Wells Site has high naturally occurring concentrations of inorganic parameters not related to the COCs at the site (e.g., TDS, manganese, iron, and chloride). These inorganic parameters could also impact the overall operations of the central treatment facility due to the potential need for pretreatment (e.g., precipitation of metal oxides or salts). The need for sequestering agents to address this concern will have to be confirmed during the pre-design activities. Actual influent data from pumping tests and a pilot study will be needed to provide final design requirements for the central treatment facility.

SECTION 7

7. REFERENCES

Camp, Dresser & McKee (CDM) Federal Programs Corporation. 1992. Letter to C. Kwan, U.S. Environmental Protection Agency. Re: Technical Memorandum I. April 24, 1992.

Camp, Dresser & McKee (CDM) Federal Programs Corporation. 1995a. Final Endangerment Assessment, Tutu Wells Site, St. Thomas, U.S. Virgin Islands. 3 Volumes, EPA Work Assignment No. 073-2P1D, Contract No. 68-W9-0024. January 12, 1995.

Camp, Dresser & McKee (CDM) Federal Programs Corporation. 1995b. Final Report - Estimation of Soil Cleanup Concentrations Required to Protect Groundwater as a Source of Drinking Water, Tutu Wells Site, St. Thomas, U.S. Virgin Islands. Work Assignment No. 073-2P1D. Document Control No. 7720-073-FR-CGTV. July 11, 1995.

Cooper Environmental, Inc. 1993. Site Investigation Report, Ramsay Motors, Tutu, St. Thomas, U.S. Virgin Islands. CEI Project No. 92115. December 8, 1993.

Department of Conservation and Cultural Affairs, St. Thomas, Virgin Islands. 1979. Environmental Laws and Regulations of the Virgin Islands. Reprinted from Titles 12 and 19 of the Virgin Islands Code and the Virgin Islands Rules and Regulations.

ENSR Consulting and Engineering (ENSR). 1994. Four Winds Plaza, Western Auto, St. Thomas, U. S. Virgin Islands, Closure Report for Underground Storage Tanks. Document Number 7218-001-200. June 1994.

Erler & Kalinowski, Inc. (EKI). 1995a. Groundwater and Soil Remediation Program for Texaco Tutu Service Station, St. Thomas, U.S. Virgin Islands. April 13, 1995.

Erler & Kalinowski, Inc. (EKI). 1995b. Technical Memorandum I, Basis for Design of the Groundwater and Soil Remediation, Source Control Program, Texaco Tutu Service Station, St. Thomas, U.S. Virgin Islands. June 1995.

Forensic Environmental Services, Inc. (FES). 1995. (See Appendix B, page 2)

Geraghty & Miller, Inc. 1983. Report on Current Groundwater Conditions in the U.S. Virgin Islands. Prepared for the U.S. Virgin Islands Department of and Cultural Affairs, April 1983, 80 pp.

Geraghty & Miller, Inc. 1992a. Tutu Service Station Investigation Work Plan, St. Thomas, U.S. Virgin Islands. March 1992.

Geraghty & Miller, Inc. 1992b. Technical Memorandum I, Tutu Service Station Investigation, St. Thomas, U.S. Virgin Islands. April 1992.

Geraghty & Miller, Inc. 1993a. Technical Memorandum II, Tutu Service Station Investigation, St. Thomas, U.S. Virgin Islands. May 1993.

Geraghty & Miller, Inc. 1993b. Phase II Remedial Investigation Work Plan, Tutu Wells Site, St. Thomas, U.S. Virgin Islands. December 1993.

Geraghty & Miller, Inc. 1993c. Eighth Sampling Report, March/April 1993, Tutu Wells Site, St. Thomas, U.S. Virgin Islands. July 1993.

Geraghty & Miller, Inc. 1995. Final Phase II Remedial Investigation Report, Tutu Wells Site, St. Thomas, U.S. Virgin Islands. April 6, 1995.

Graves, R.P., and R. Gonzales. 1988. Potentiometric Surface of the Turpentine Run Aquifer in the Tutu Area, Eastern St. Thomas, U.S. Virgin Islands. September 1987. U.S. Geological Survey, Water Resources Investigation Report 88-4131.

Howard, Philip H., and others. 1991. Handbook of Environmental Degradation Rates. Lewis Publishers, Inc. Second Printing 1991.

Jordan, D.G., and O.J. Cosner, 1973. A Survey of the Water Resources of St. Thomas, Virgin Islands, U.S. Geological Survey Open-File Report, 55 pp.

Jordan, D.G., and D.W. Fisher. 1977. Relation of Bulk Precipitation and Evaporation to Water Quality and Water Resources, St. Thomas, U.S. Virgin Islands. U.S. Geological Survey Water-Supply Paper 1663-I.

Keller, G.V. 1960. Physical Properties of Tuffs in the Oak Spring Formation, Nevada. U.S. Geological Survey Professional Paper 400-B.

Mobil. 1992. Off-Gas Treatment Systems for Soil/Groundwater Remediation Systems. Mobil U.S. Marketing Division, Environmental Bulletin No. 04-050/3-92/04. March 9, 1992.

Stevens, K.E., F. Gomez-Gomez, and J. Alicia. 1981. Water Wells in the U.S. Virgin Islands, Part. 1, St. Thomas, U.S. Geological Survey Open-File Report 82-82.

U.S. Census Bureau. 1990. Population Data for the Tutu Subdistrict of St. Thomas, U.S. Virgin Islands.

U.S. Environmental Protection Agency (USEPA). 1987. Guidelines for Delineation of Wellhead Protection Areas, U.S. EPA, Office of Groundwater Protection. EPA 440/6-87-010. June 1987.

U.S. Environmental Protection Agency (USEPA). 1988a. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA-Interim Final. EPA/540/G-89/W04. OSWER Directive No. 9355.3-01.

U.S. Environmental Protection Agency (USEPA). 1988b. Guidance on Remedial Actions for Contaminated Groundwater at Superfund Sites. EPA/540/G-88/003. OSWER Directive No. 9283.1-2.

U.S. Environmental Protection Agency (USEPA). 1990. Administrative Order No. II-9003-0401, March 22, 1990.

U.S. Environmental Protection Agency (USEPA). 1991a. Hazardous Ranking System (HRS) Documentation Record, Tutu Wellfield. August 1991.

U.S. Environmental Protection Agency (USEPA). 1991b. Risk Assessment Guidance for Superfund: Vol. 1 Human Health Evaluation Manual (Part B, Development of Risk Based Preliminary Remediation Goals-Interim). OSWER Directive 9285.7-01B.

U.S. Environmental Protection Agency (USEPA). 1991c. Delineation of Wellhead Protection Areas in Fractured Rocks. EPA 570/9-91-009. June 1991.

U.S. Environmental Protection Agency (USEPA). 1992a. Administrative Order on Consent No. II-RCRA-7003 and 9003-92-0401. February 19, 1992.

U.S. Environmental Protection Agency (USEPA). 1992b. Estimating Potential Occurrences of DNAPL at Superfund Sites. Publication: 9355.4-07FS. January 1992.

U.S. Environmental Protection Agency (USEPA). 1993. Presumptive Remedies: Site Characterization and Technology Selection for CERCLA Sites with Volatile Organic Compounds in Soils. EPA/540/F-93/048. OSWER Directive No. 9355.0-48FS.

U.S. Environmental Protection Agency (USEPA). 1994a. Letter to A.G. Ramos, Designated Coordinator for the TEIC from C. Petersen, USEPA Chief for Region II Superfund New York/Caribbean Branch. Re: Approval of the Phase II RI Work Plan, Tutu Wells, Site, St. Thomas, U.S. Virgin Islands. March 17, 1994.

U.S. Environmental Protection Agency (USEPA). 1994b. Letter to J. McBurney and G. Seibel, TEIC Designated Coordinator. Re: Comments on the Draft Phase II Remedial Investigation and Development and Screening of Remedial Alternatives Report. December 28, 1994.

U.S. Environmental Protection Agency (USEPA). 1994c. Technical Background Document for Draft Soil Screening Level Guidance. PA-540/R-94/0-18 OSWER Directive No. 9355.4-14.

U.S. Geological Survey (USGS). 1973. Water Records of U.S. Virgin Islands, 1962-69. Robison, T. M. and other (Authors). United States Department of the Interior Geological Survey prepared in cooperation with the National Park Service and the Government of the Virgin Islands of the United States.

Weston/Spill Prevention and Emergency Response (SPER), Division II TAT. 1988. Memorandum from Arnaldo Martinez, TAT II PM and Douglas Henne, TAT II-QC to Carlos O'Neill, USEPA Caribbean Field Office. Re: St. Thomas, Tutu HSL Sampling RTAT-02-F-04398. January 27, 1988.

Weston/Spill Prevention and Emergency Response (SPER), Division II TAT. 1989. Memorandum to L.E. Santos, OSC, EPA Caribbean Field Office. Re: Final Results of the November 1988 TCL Sampling and Comparison to TCL Sampling Conducted October 1987. May 1, 1989.

TABLES

Table 2-1. Summary of Soil Screening Levels Provided by the U.S. Environmental Protection Agency, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Property	Depth (ft bls)	Chlorinated VOCs (ppb)	BTEX Compounds (ppb)
Curriculum Center (former LAGA Facility)	0.0 - 2.8	731	150
	2.8 - 35.0	73	37
Texaco Tutu Service Station	0.0 - 8.7	290	67
	8.7 - 15.0	29	13
Esso Tutu Service Station	0.0 - 4.0	320	74
	4.0 - 15.0	32	15
O'Henry Dry Cleaners	0.0 - 1.6	375	--
	1.7 - 22.0	31	--
Other properties (1)	0.0 - 4.0	320	74
	4.0 - 15.0	32	15

Soil screening levels are based on site-specific estimates for leaching of contaminants that may result in exceedance of groundwater drinking standards (CDM Federal Programs Corporation 1995b).

ft bls Feet below land surface.
VOCs Volatile organic compounds.
BTEX Benzene, toluene, ethylbenzene, and xylenes.
ppb Parts per billion, equivalent to micrograms per kilogram (ug/kg).
-- No values provided.
(1) The U.S. Environmental Protection Agency (USEPA) directed the use of soil screening levels for the Esso Tutu Service Station at all other properties.

Table 2-2. Summary of Carcinogenic Risks Exceeding the U.S. Environmental Protection Agency Guidance Value, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Media	Receptor Population	Exposure Routes	Total Pathway RME Value	Individual RME Values Contributing the Greatest Risks	
Groundwater (Sitewide)	Adult residents	Ingestion	6.6×10^{-4}	PCE Vinyl chloride	1.2×10^{-4} 4.5×10^{-4}
	Children (0 to 6 years)	Ingestion	3.1×10^{-4}	Vinyl chloride	2.1×10^{-4}
	Site worker	Ingestion	2.0×10^{-4}	Vinyl chloride	1.3×10^{-4}
Surface soil (Tillett property)	Adult residents	Ingestion	4.4×10^{-4}	Aroclor 1242 Arsenic	4.3×10^{-4} 8.2×10^{-6}
	Children (0 to 6 years)	Ingestion	3.0×10^{-3}	Aroclor 1242 Arsenic	1.0×10^{-3} 1.9×10^{-5}

RME Resonable maximum exposure.
PCE Tetrachloroethene.

Source: CDM Federal Programs Corporation (1995a).

TUT 007 2140

Table 2-3. Summary of Noncarcinogenic Risks Exceeding the U.S. Environmental Protection Agency Hazard Quotient of 1, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Media	Receptor Population	Exposure Routes	Total Pathway HI	Individual HQs Contributing the Greatest Risks	
Groundwater	Adult residents	Ingestion	1.9×10^{01}	Total DCE	1.2×10^{0}
				Manganese	2.6×10^{0}
	Children (0 to 6 years)	Ingestion	6.7×10^{01}	Total DCE	2.8×10^{0}
				PCE	1.3×10^{0}
				Manganese	6.0×10^{0}
				Antimony	1.6×10^{0}
				Vanadium	1.0×10^{0}
	Site worker	Ingestion	1.0×10^{01}	Manganese	9.2×10^{0}
	Future construction worker	Ingestion	9.1×10^{01}	Manganese	8.2×10^{0}
Surface soil (Tillett property)	Children (0 to 6 years)	Ingestion	3.0×10^{01}	Manganese	2.2×10^{0}
				Arsenic	4.3×10^{0}
		Inhalation	3.1×10^{01}	Manganese	3.1×10^{0}

HI Hazard index.
HQ Hazard quotient.
DCE 1,2-Dichloroethene.
PCE Tetrachloroethene.

Source: CDM Federal Programs Corporation (1995a).

Table 2-4. Summary of Analytes Detected in Soil above Soil Screening Levels at the Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Property	Parameter	Depth (ft bls)	SSLs (ug/kg)	Sample Name	Sample Interval (ft bls)	Concentration (ug/kg)
Chlorinated VOC Constituents						
Curriculum Center	1,1,1-Trichloroethane	0.0 - 2.8	731	TWS-03	0.0 - 0.3	1,800
Esso Tutu Service Station	Tetrachloroethene	0.0 - 4.0	320	B-103	0.0 - 1.0	394
				SS-3	3.0	1,100
		4.0 - 15.0	32	SS-7	5.0	520
				SS-8	7.0	1,500
	1,1,1-Trichloroethane	4.0 - 15.0	32	SS-7	5.0	44
				SS-8	7.0	58
	Trichloroethene	4.0 - 15.0	32	SS-8	7.0	45
	1,1-Dichloroethane	0.0 - 4.0	320	SS-3	3.0	560
		4.0 - 15.0	32	SS-8	7.0	70
	1,2-Dichloroethene(trans)[1]	0.0 - 4.0	320	SS-3	3.0	3,200
		4.0 - 15.0	32	SS-7	5.0	75
				SS-8	7.0	110
O'Henry Dry Cleaners	Tetrachloroethene	0.0 - 1.6	375	e-01	(Surface Soil)	440,000 *
				e02-02	1.5 - 2.5	180,000
				OHSS-1	2.0	5,400 D
		1.7 - 22.0	31	OHSS-1	5.0	59,000 D
					8.0	400 J
				OHSS-1FR	5.0	22,000
				B-13	4.0 - 6.0	200 D
	Trichloroethene	1.7 - 22.0	31	e02-02	1.5 - 2.5	75
BTEX Constituents						
Curriculum Center	Benzene	0.0 - 2.8	150	SS-12	0.0 - 0.5	6,300 J
				TWS-03	0.0 - 0.3	2,700
	Toluene	0.0 - 2.8	150	SS-12	0.0 - 0.5	270,000
				TWS-03	0.0 - 0.3	500,000
	Ethylbenzene	0.0 - 2.8	150	SS-12	0.0 - 0.5	12,000 J
				TWS-03	0.0 - 0.3	47,000
	Xylenes	0.0 - 2.8	150	SS-12	0.0 - 0.5	77,000
				TWS-03	0.0 - 0.3	420,000
Ramsay Motors	Benzene	4.0 - 15.0	15	HB-2	4.5	17 J
	Ethylbenzene	0.0 - 4.0	74	HB-5	2.3	190 J
		4.0 - 15.0	15	HB-2	4.5	290

See last page for footnotes.

Table 2-4. Summary of Analytes Detected in Soil above Soil Screening Levels at the Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Property	Parameter	Depth (ft bls)	SSLs (ug/kg)	Sample Name	Sample Interval (ft bls)	Concentration (ug/kg)
Texaco Tutu Service Station	Benzene	0.0 - 8.7	67	TT-1D	4.5 - 5.0	(170)
				TT-1D FR	4.5 - 5.0	69
	Ethylbenzene	0.0 - 8.7	67	OW/SB-1	6.5	(630)
				TT-1D	4.5 - 5.0	110 / (210)
				TT-1D FR	4.5 - 5.0	140
		8.7 - 15.0	13	OW/SB-1	9.5	67 / (50)
Esso Tutu Service Station	Benzene	0.0 - 4.0	74	SS-3	3.0	880
				TP-3	(Northeast Floor)	230 J
				TP-5	(Center Floor)	1,100
				TP-8	(South)	93
		4.0 - 15.0	15	B-102	10.0 - 12.0	625
				SS-7	5.0	160
				SS-8	7.0	270
	Toluene	0.0 - 4.0	74	SS-3	3.0	53,000
				SS-4	3.0	4,600
				SS-5	3.0	6,500
				SW-3	0.0 - 2.0	520
				TP-3	(Northeast Floor)	5,200
				TP-6	(East Floor)	180,000
		4.0 - 15.0	15	B-101	8.0 - 10.0	28
					10.0 - 12.0	548
				SS-1	9.0	46,000
				SS-7	5.0	33,000
				SS-8	7.0	51,000
	Ethylbenzene	0.0 - 4.0	74	SS-3	3.0	11,000
				SS-4	3.0	990
				SS-5	3.0	520
				SW-3	0.0 - 2.0	170
				TP-8	(South Wall)	520
				TP-5	(Center Floor)	7,000
				TP-6	(East Floor)	55,000
		4.0 - 15.0	15	B-101	10.0 - 12.0	304
				B-102	4.0 - 6.0	58
					8.0 - 10.0	1,117
					10.0 - 12.0	1,037
				B-103	7.0 - 7.5	26
				SS-1	9.0	12,000
				SS-7	5.0	1,700
				SS-8	7.0	11,000

See last page for footnotes.

Table 2-4. Summary of Analytes Detected in Soil above Soil Screening Levels at the Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Property	Parameter	Depth (ft bls)	SSLs (ug/kg)	Sample Name	Sample Interval (ft bls)	Concentration (ug/kg)
Esso Tutu Service Station (continued)	Xylenes	0.0 - 4.0	74	SS-3	3.0	77,400
				SS-4	3.0	24,200
				SS-5	3.0	29,000
				SW-3	0.0 - 2.0	1,170
				TP-2	(North Floor)	1,600 E
				TP-3	(Northeast Floor)	31,000 E
				TP-6	(East Floor)	540,000
				TP-7	Southwest Floor	300 E
				TP-8	(South Wall)	220
		4.0 - 15.0	15	B-101	8.0 - 10.0	168
					10.0 - 12.0	2,295
				B-102	8.0 - 10.0	1,141
					10.0 - 12.0	575 **
				SS-1	9.0	80,400
				SS-7	5.0	58,000
				SS-8	7.0	78,000
Western Auto						
	Benzene	0.0 - 4.0	74	SS-1	2.0	140
		4.0 - 15.0	15	SS-6	5.0 - 6.0	34
				T1-2	4.0	29 J
	Toluene	0.0 - 4.0	74	SS-1	2.0	3,900
				T2-AS	0.0 - 0.5	760 J
				T2-ASRE	0.0 - 0.5	800 J
		4.0 - 15.0	15	MW-24-2	4.0 - 6.0	(34)
				T1-3	4.0	25 J
				T1-4	4.0	16 J
				T2-1S	6.7	28 J
				T2-3S	6.7	740 J
	Ethylbenzene	0.0 - 4.0	74	SS-1	2.0	1,600
				SS-2	3.0	850
				T2-AS	0.0 - 0.5	890 J
				T2-ASRE	0.0 - 0.5	1,000 J
				T2-SN	1.0 - 1.5	230
				T2-4S	1.0 - 1.5	150
		4.0 - 15.0	15	SS-4	5.0 - 6.0	37
				SS-5	5.0 - 6.0	100
				SS-6	5.0 - 6.0	420
				SS-7	5.0 - 6.0	270
				SS-8	5.0	340
				SS-9	5.0	290
				T1-1	4.0	100
				T1-2	4.0	240
				T1-3	4.0	20 J
				T1-4	4.0	16 J
				T2-1S	6.7	230
				T2-2S	6.7	29 J
				T2-3S	6.7	980 J

See last page for footnotes.

Table 2-4. Summary of Analytes Detected in Soil above Soil Screening Levels at the Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Property	Parameter	Depth (ft bls)	SSLs (ug/kg)	Sample Name	Sample Interval (ft bls)	Concentration (ug/kg)
Western Auto (continued)	Xylenes	0.0 - 4.0	74	SS-1	2.0	34,000
				SS-2	3.0	501
				T2-AS	0.0 - 0.5	5,800
				T2-ASRE	0.0 - 0.5	6,100
				T2-SN	1.0 - 1.5	120
		4.0 - 15.0	15	SS-4	5.0 - 6.0	128
				SS-5	5.0 - 6.0	125
				SS-6	5.0 - 6.0	2,700
				SS-8	5.0	53
				T1-1	4.0	85
				T1-2	4.0	210
				T2-1S	6.7	430
				T2-2S	6.7	51 J
				T2-3S	6.7	7,000

SSLs based on USEPA-subcontractor (CDM Federal Programs Corp. 1995b) report on vadose zone modeling. Criteria are site-specific, except for data from soil samples collected from Western Auto and Ramsay Motors, which are screened against criteria applicable to the Esso Tutu Service Station.

Data reported in parentheses at Western Auto are from soil samples collected by ENSR Consulting & Engineering , Inc.

Data reported in parentheses at the Texaco Tutu Service Station are from soil samples collected by Blasland, Bouck & Lee, Inc.

*	Reported by the U.S. Environmental Protection Agency as tetrachloroethane; this is believed to be a typographical error.
**	Result includes only methylxylene; o- and p-xylene data not available.
(1)	1,2-Dichloroethene (1,2-DCE) results reported as total 1,2-DCE and SSL applies to the trans-1,2-DCE isomer.
SSLs	Soil Screening Levels. SSLs provided by the USEPA (CDM Federal Programs Corporation 1995b); see note above.
BTEX	Benzene, toluene, ethylbenzene, and xylenes.
FR	Field replicate.
VOC	Volatile organic compound.
J	Result detected below reporting limit and/or an estimated concentration.
D	Analyte identified at a secondary dilution.
E	Exceeds instrument calibration range.
ug/kg	Micrograms per kilogram, equivalent to parts per billion (ppb).
ft bls	Feet below land surface.
USEPA	U.S. Environmental Protection Agency.

Table 3-1. Groundwater Chemical-Specific Remedial Action Levels Identified for the Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Parameters	Groundwater RALs: USEPA MCLs (mg/L)	MCLGs (mg/L)
Inorganics		
Aluminum	0.05 to 0.20 [(1)]	--
Antimony	0.006	0.006
Arsenic	0.05	--
Barium	2.0	2.0
Beryllium	0.004	0
Cadmium	0.005	0.005
Calcium	--	--
Chromium	0.1	0.1
Cobalt	--	--
Copper	TT	1.3
Iron	0.3 [(1)]	--
Lead	TT	0
Magnesium	--	--
Manganese	0.05	--
Mercury	0.002	0.002
Nickel	0.1	0.1
Potassium	--	--
Selenium	0.05	0.05
Silver	0.1	--
Sodium	--	--
Thallium	0.002	0.0005
Vanadium	--	--
Zinc	5.0	--
Cyanide	0.2	0.2
Nitrate (as N)	10.0	10.0
Chloride	250 [(1)]	--
pH (units)	6.5-8.5	--
Total dissolved solids	500 [(1)]	--
Volatile Organic Compounds		
Chloromethane	--	--
Bromomethane	--	--
Vinyl chloride	0.002	0
Chloroethane	--	--
Methylene chloride	0.005	--
Acetone	--	--

See last page for footnotes.

Table 3-1. Groundwater Chemical-Specific Remedial Action Levels Identified for the Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Parameters	Groundwater RALs: USEPA MCLs (mg/L)	Groundwater RALs: MCLGs (mg/L)
Volatile Organic Compounds (continued)		
Carbon disulfide	--	--
1,1-Dichloroethene	0.007	0.007
1,1-Dichloroethane	--	--
1,2-Dichloroethene(cis)	0.07	0.07
1,2-Dichloroethene(trans)	0.1	0.1
Chloroform	--	--
1,2-Dichloroethane	0.005	0
2-Butanone	--	--
1,1,1-Trichloroethane	0.2	0.2
Carbon tetrachloride	0.005	0
Vinyl acetate	--	--
Bromodichloromethane	--	--
1,1,2,2-Tetrachloroethane	--	--
1,2-Dichloropropane	--	--
trans-1,2-Dichloropropene	--	--
Trichloroethene	0.005	0
Dibromochloromethane	--	--
1,1,2-Trichloroethane	0.005	0.003
Benzene	0.005	0
cis-1,3-Dichloropropene	--	--
Bromoform	--	--
2-Hexanone	--	--
4-Methyl-2-pentanone	--	--
Tetrachloroethene	0.005	0
Toluene	--	1
Chlorobenzene	--	--
Ethylbenzene	0.7	0.7
Styrene	0.1	0.1
Total xylenes	10	10
Pesticides/PCBs		
alpha-BHC	--	--
beta-BHC	--	--
delta-BHC	--	--
gamma-BHC(Lindane)	--	--
Heptachlor	--	0
Aldrin	--	0

See last page for footnotes.

G:\APROJECT\TUTU\PR0013.037\DATA\CHEM.XLS

Table 3-1. Groundwater Chemical-Specific Remedial Action Levels Identified for the Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Parameters	Groundwater RALs USEPA MCLs (mg/L)	MCLGs (mg/L)
Pesticides/PCBs, continued		
Heptachlor epoxide	--	--
Endosulfan I	--	--
Dieldrin	--	--
4,4'-DDE	--	--
Endrin	0.002	0.002
Endosulfan II	--	--
4,4'-DDD	--	--
Endosulfan sulfate	--	--
4,4'-DDT	--	--
Methoxychlor	0.04	0.04
Chlordane(alpha and/or gamma)	--	0
Toxaphene	0.003	0
Aroclor 1016	--	--
Aroclor 1221	--	--
Aroclor 1232	--	--
Aroclor 1242	--	--
Aroclor 1248	--	--
Aroclor 1254	--	--
Aroclor 1260	--	--
Endrin ketone	--	--
Semivolatile Organic Compounds		
Phenol(s)	--	--
bis(-2-Chloroethyl)ether	--	--
2-Chlorophenol	--	--
1,3-Dichlorobenzene	0.6	0.6
1,4-Dichlorobenzene	0.075	--
Benzyl alcohol	--	--
1,2-Dichlorobenzene	0.6	0.6
2-Methylphenol	--	--
bis(2-Chloroisopropyl)ether	--	--
4-Methylphenol	--	--
N-Nitroso-di-propylamine	--	--
Hexachloroethane	--	--
Nitrobenzene	--	--
Isophorone	--	--
2-Nitrophenol	--	--

See last page for footnotes.

Table 3-1. Groundwater Chemical-Specific Remedial Action Levels Identified for the Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Parameters	Groundwater RALs: USEPA MCLs (mg/L)	MCLGs (mg/L)
Semivolatile Organic Compounds (continued)		
2,4-Dimethylphenol	--	--
Benzoic acid	--	--
bis(2-Chloroethoxy)methane	--	--
2,4-Dichlorophenol	--	--
1,2,4-Trichlorobenzene	0.07	0.07
Naphthalene	--	--
4-Chloroaniline	--	--
Hexachlorobutadiene	--	--
4-Chloro-3-methylphenol	--	--
2-Methylnaphthalene	--	--
Hexachlorocyclopentadiene	0.05	0.05
2,4,6-Trichlorophenol	--	--
2,4,5-Trichlorophenol	--	--
2-Chloronaphthalene	--	--
2-Nitroaniline	--	--
Dimethylphthalate	--	--
Acenaphthylene	--	--
3-Nitroaniline	--	--
Acenaphthene	--	--
2,4-Dinitrophenol	--	--
4-Nitrophenol	--	--
Dibenzofuran	--	--
2,4-Dinitrotoluene	--	--
2,6-Dinitrotoluene	--	--
Diethylphthalate	--	--
4-Chlorophenyl-phenylether	--	--
Fluorene	--	--
4-Nitroaniline	--	--
4,6-Dinitro-2-methylphenol	--	--
N-Nitrosodiphenylamine	--	--
4-Bromophenyl-phenylether	--	--
Hexachlorobenzene	0.001	0
Penta-chlorophenol	0.001	0
Phenanthrene	--	--
Anthracene	--	--
Di-n-butylphthalate	--	--
Fluoranthene	--	--

See last page for footnotes.

G:\APROJECT\TUTU\PR0013.037\DATA\CHEM.XLS

Table 3-1. Groundwater Chemical-Specific Remedial Action Levels Identified for the Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

	Groundwater RALs	
Parameters	USEPA MCLs (mg/L)	MCLGs (mg/L)
Semivolatile Organic Compounds (continued)		
Pyrene	--	--
Butylbenzylphthalate	0.1 (P)	0 (P)
3,3'-Dichlorobenzidine	--	--
Benzo(a)anthracene	0.0001 (P)	0 (P)
bis(2-Ethylhexyl)phthalate	0.006	0
Chrysene	--	--
Di-n-octyl phthalate	--	--
Benzo(b)fluoranthene	0.0002 (P)	0 (P)
Benzo(k)fluoranthene	--	--
Benzo(a)pyrene	0.0001	0
Indeno(1,2,3-c d)pyrene	0.0004 (P)	0 (P)
Dibenz(g,h)anthracene	0.0003 (P)	0 (P)
Benzo(g,h,i)perylene	--	--

All RALs expressed in milligrams per liter (mg/L) unless indicated.
Currently, there are no federal standards for soil or sediment.

mg/L	Milligrams per liter.
TT	Treatment Technique (Action Levels: Copper 1.3 mg/L, lead 0.015 mg/L). Values determined by USEPA.
(1)	Value classified as a Secondary Maximum Contaminant Level (SMCL).
USEPA	U.S. Environmental Protection Agency.
RALs	Remedial Action Levels.
MCLs	Maximum contaminant levels.
MCLGs	Maximum contaminant level goals.
PCBs	Polychlorinated biphenyls.
--	No standard available.
(P)	Proposed.

G:\APROJECT\TUTU\PR0013.037\DATA\CHEM.XLS

Table 3-2. Summary of Potential Federal Location-Specific Applicable or Relevant and Appropriate Requirements, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Requirement	Applicable or Relevant and Appropriate Requirements	Comments
Protection of Floodplains E.O. 11988, 40 CFR 6 App A		
Requires the USEPA to minimize potential harm to or within floodplains.	Yes	Portions of the Tutu Wells Site lie within the boundaries of a 100-year floodplain.
Protection of Wetlands E.O. 11990, 40 CFR 6 App A; 40 CFR 230		
Requires the USEPA to minimize potential harm to or within wetlands.	Yes	Wetland area has been identified the USEPA adjacent to the Tutu Wells Site. Remedial activities are not anticipated to disturb this area.
Fish and Wildlife Coordination Act 16 USC §661 et seq.§; 30 CFR 340/330; 40 CFR 6		
Protects fish and wildlife resulting from control or structural modification of a natural stream or body of water.	No	Remedial activities are not expected to impact the wildlife present at the Tutu Wells Site.
Endangered Species Act 16 USC §1531 et seq.; 50 CFR 200, 402		
Protects endangered and threatened species and preserves their habitat.	Yes	Endangered species (Epicrates monensis granti) and critical habitat (Zanthoxylem thomasianium) were identified in the Endangerment Assessment for the Tutu Wells Site. Remedial activities are not expected to impact endangered species or critical habitats.

See last page for footnotes.
g:\aproject\tutu\pr0013.037\data\FLSARAR.XLS

Table 3-2. Summary of Potential Federal Location-Specific Applicable or Relevant and Appropriate Requirements, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Requirement	Applicable or Relevant and Appropriate Requirements	Comments
Wilderness Act 16 USC §1131 et seq.; 50 CFR 35		
Limits activities within an area designated as a wilderness area.	No	The proposed remedial actions are not within a federally owned area designated as a wilderness area.
National Wildlife Refuge System 16 USC §668; 50 CFR 27		
Limits activities within a national wildlife refuge.	No	The proposed remedial actions are not within an area designated as part of the National Wildlife Refuge System.
Wild and Scenic Rivers Act 16 USC §1271 et seq.; 40 CFR 6.302(e)		
Protects rivers that are designated as wild, scenic, or recreational.	No	The Tutu Wells Site is not near a wild, scenic, or recreational river.
National Historic Preservation Act 16 USC §470; 36 CFR 60, 63, 65		
Requires preservation of properties listed on or eligible for listing on the National Register of Historic Places or the National Historical Landmark Program.	No	No historic, architectural, or cultural resources included on either of the national lists are located in areas where remedial actions are planned.

See last page for footnotes.

Table 3-2. Summary of Potential Federal Location-Specific Applicable or Relevant and Appropriate Requirements, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Requirement	Applicable or Relevant and Appropriate Requirements	Comments
<u>Clean Water Act Section 404</u> 33 USC §1344, 40 CFR 230, 33 CFR 320-330		
Requires permit for discharge of dredged or fill material into waters of the United States, including wetlands.	No	Remedial activities will not involve discharge of dredged or fill material.
<u>Coastal Zone Management Act</u> 16 USC §1451, 15 CFR 928, 40 CFR 6.302(d)		
Requires approval by the state coastal zone management program (CZM) for actions affecting the coastal zone, including lands thereunder and adjacent shorelands.	No	The site is not within an area designated as a coastal zone.
<u>Rivers and Harbors Act</u> 33 USC §403, 33 CFR 32-330		
Regulates activities in navigable waters in the United States	No	The Tutu Wells Site is not near navigable waters.

See last page for footnotes.

Table 3-2. Summary of Potential Federal Location-Specific Applicable or Relevant and Appropriate Requirements, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Requirement	Applicable or Relevant and Appropriate Requirements	Comments
Marine Protection, Research and Sanctuaries Act 15 CFR 922; 33 CFR 324		
Requires a permit to dump any material into the ocean waters of the United States.	No	Remedial activities will not involve dumping of material into ocean waters.
Manages designated marine environments of special national significance.	No	The Tutu Wells Site does not meet the criteria as a national marine sanctuary.
Outer Continental Shelf Act 33 CFR 322	No	The site is not within an area designated by this act.
Requires a permit for structures or work in or affecting navigable United States water.		
Archaeological and Historic Preservation Act 16 USC §469; 40 CFR 6.301(a)	Yes	Archaeological resources were identified at the Tutu Park Shopping Center. Remedial activities are not anticipated to further impact archaeological resources in this area.
Limits activities in the areas identified as historic or archaeological resources.		

CFR Code of Federal Regulations.
USC United States Code.
USEPA United States Environmental Protection Agency.
E.O. Executive Order.

Table 3-3. Summary of Potential Federal Action-Specific Applicable or Relevant and Appropriate Requirements, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Requirement	Applicable or Relevant and Appropriate Requirements	Comments
<u>Clean Air Act</u> 40 CFR Part 61		
Establishes primary and secondary standards for air emissions.	Yes	Remedial activities under consideration will discharge off-gas to the air (i.e., air stripping).
<u>General Pretreatment Regulations</u> 40 CFR 403.5 and Local POTW Regulations		
Establishes pretreatment standards for discharge of pollutants into a POTW.	Yes	Remedial activities under consideration may involve discharge to a POTW.
<u>RCRA Land Disposal Restrictions</u> 40 CFR 268 (Subparts C and D)		
Land disposal restrictions for movement of excavated material.	Yes	Remedial activities under consideration may require excavation and disposal of contaminated soil.

CFR Code of Federal Regulations.
POTW Publicly Owned Treatment Works.
RCRA Resource Conservation and Recovery Act

TUT 007 2155

Table 3-4. Summary of Potential Federal Chemical-Specific Applicable or Relevant and Appropriate Requirements and To-Be-Considered Material, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Requirement	Applicable or Relevant and Appropriate Requirements and To-Be-Considered Material	Comments
Federal Safe Drinking Water Act 40 CFR 141; 40 CFR 143		
Establishes MCLs for drinking water.	Yes	Remedial activities under consideration may provide potable water to residents and commercial users.
Federal Surface Water Quality Standards 40 CFR 131		
Establishes MCLs for discharge to surface water.	Yes	Remedial activities under consideration may involve discharge to surface water (Turpentine Run).
Federal Ambient Air Quality Standards 40 CFR Part 61; 40 CFR Section 52.21		
Establishes primary and secondary air quality standards.	Yes	Remedial activities may involve emissions to ambient air.
USEPA's Vadose Zone Model - To-Be-Considered Material Soil Cleanup Concentration		
Proposes guidance levels to evaluate potential impacts to groundwater quality from constituents in soil.	Yes	Constituents detected in soil at investigated properties will be compared to soil screening levels as remedial action levels to determine if remediation is potentially warranted and will be used to develop remediation goals (CDM Federal Programs Corporation 1995b).

CFR Code of Federal Regulations.
MCLs Maximum Contaminant Level.
USEPA United States Environmental Protection Agency.

Table 3-5. Summary of Potential U.S. Virgin Islands Location-Specific Applicable or Relevant and Appropriate Requirements, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Requirement	Applicable or Relevant and Appropriate Requirements	Comments
Water Resources Conservation VIC, Title 12, Chapter 5, Sections 151 and 153		
Water conservation required to protect natural resources. Requires a permit for well installation or changes.	Yes	Remedial activities under consideration may require the installation of extraction wells.
Environmental Protection VIC, Title 12, Chapter 13, Section 533		
Requires an "earth change plan" before land is cleared, graded, filled, or otherwise disturbed.	Yes	Portions of the Tutu Wells Site may require capping, regrading, or excavation to implement remedial activities.
Coastal Zone Management VIC, Title 12, Chapter 21, Section 903		
Limits activities with the U.S. Virgin Islands Coastal Zone to protect marine resources.	No	The Tutu Wells Site is not within an area designated a coastal zone.

VIC Virgin Islands Environmental Code (USVI/DCCA 1979).

TUT 007 2157

Table 3-6. Summary of Potential U.S. Virgin Islands Action-Specific Applicable or Relevant and Appropriate Requirements, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Requirement	Applicable or Relevant and Appropriate Requirements	Comments
<u>Water Pollution Control</u> VIC, Title 12, Chapter 7, Sub-Section 184, Division 3		
Requires any person proposing to commence a discharge of pollutants to complete a TPDES application.	Yes	Discharge of treated groundwater to the Turpentine Run may be considered.
<u>Air Pollution Control</u> VIC, Title 12, Chapter 9, Section 206-20		
Requires permitting of controlled air discharges to atmosphere.	Yes	Equipment related to remedial action will emit air pollutants. Remedial activities under consideration will discharge off-gas to the air (i.e., air stripping).
<u>Sewage Disposal</u> VIC, Title 19, Chapter 55, Section 1522-4		
Regulates waste that may be disposed to a sanitary sewer.	Yes	A potential discharge option is to the local POTW.
<u>Water Resources Conservation</u> VIC, Title 12, Chapter 5, Sections 151, 155, 156, 159		
Requires a permit for withdrawal of water in excess of 500 gpd (regulates groundwater pumpage).	Yes	Remedial activities under consideration may involve withdrawal of groundwater in excess of 500 gpd.

VIC Virgin Islands Environmental Code.
TPDES Territorial Pollution Discharge Elimination System.
POTW Publicly owned treatment works.
gpd Gallons per day.

Table 3-7. Summary of Potential U.S. Virgin Islands Chemical-Specific Applicable or Relevant and Appropriate Requirements, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Requirement	Applicable or Relevant and Appropriate Requirements	Comments
Drinking Water Standards VIC, Title 19, Chapter 51, Section 1303-16		
Establishes maximum contaminant levels for drinking water supplies.	Yes	Remedial activities under consideration may provide potable water to residents and commercial users.

VIC Virgin Islands Environmental Code.

TUT 007 2159

Table 3-8. Summary of Analytes Detected in Groundwater Above Remedial Action Levels at the Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Parameter	RAL (ug/L)	Well Designation	Concentration (ug/L) 5/94	6/94	7/94
Volatile Organic Compounds					
Vinyl chloride	2	MW-3	--	48	--
		MW-15	--	260 D	--
		MW-16	--	1300	--
		TT-3D	--	9 J	--
		TT-5	--	42	--
1,2-Dichloroethene(total)*	100	CHT-7D	--	91	--
		DW-1	--	92 J	--
		La Place**	95	--	--
		MW-1	--	950 D	--
		MW-1D	--	500	--
		MW-3	--	440 D	--
		MW-4	--	76 J	--
		MW-6D	--	100	--
		MW-7	--	180	--
		MW-8	--	88 J	--
		MW-10	76 J	--	--
		MW-10D	110 J	--	--
		MW-15	--	1500 D	--
		MW-16	--	2100	--
		Steele**	100	--	--
		Tillett	360 D	--	--
		TT-2	--	330	--
		TT-2FR	--	330	--
		TT-3D	--	280	--
		TT-5	--	180	--
1,2-Dichloroethane	5	TT-1	--	290	--
Trichloroethene	5	MW-1	--	78	--
		MW-1D	--	71	--
		MW-3	--	17 J	--
		MW-4	--	6 J	--
		MW-6D	--	11	--
		MW-7	--	27	--
		MW-8	--	10 J	--
		MW-10	18 J	--	--
		MW-10D	14 J	--	--
		MW-12D	9 J	--	--
		MW-15	--	23	--
		MW-16	--	72 J	--
		MW-17	--	9 J	--
		MW-21D	--	14 J	--
		OHMW-4	16	--	--
		Smith	19 J	--	--
		Tillett	45	--	--
		TT-2	--	20 J	--
		TT-2 FR	--	20J	--
		TT-3D	--	15 J	--

See last page for footnotes.

Table 3-8. Summary of Analytes Detected in Groundwater Above Remedial Action Levels at the Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Parameter	RAL (ug/L)	Well Designation	Concentration (ug/L) 5/94	6/94	7/94
Volatile Organic Compounds (continued)					
Benzene	5	CHT-3	--	1700	--
		KFC-1	--	110 J	--
		MW-5	--	460 DJ	--
		MW-7	--	21	--
		SW-2	--	550 J	--
		SW-3	--	10000 J	--
		SW-7	--	99 J	--
		SW-7 FR	--	110J	--
		TT-1	--	21000 D	--
		TT-1D	--	1700 D	--
		TT-4	--	21000	--
Tetrachloroethene	5	CHT-6D	--	12	--
		CHT-7D	--	36	--
		Delegarde	15 J	--	--
		DW-1	--	42 J	--
		DW-2	18	--	--
		MW-1	--	330 D	--
		MW-1D	--	360	--
		MW-3	--	56	--
		MW-4	--	20 J	--
		MW-4D	--	17 J	--
		MW-6D	--	31	--
		MW-6R	--	10	--
		MW-7	--	130	--
		MW-8	--	38 J	--
		MW-10	34 J	--	--
		MW-10D	48 J	--	--
		MW-12D	33 J	--	--
		MW-13D	--	28 J	--
		MW-15	--	120	--
		MW-16	--	71 J	--
		MW-17	--	37	--
		MW-20D	--	22 J	--
		MW-21D	--	45 J	--
		MW-25	--	11	--
		OHMW-1	10	--	--
		OHMW-2	26	--	--
		OHMW-3	6 J	--	--
		OHMW-4	140	--	--
		Ramsay	11	--	--
		Smith	110 J	--	--
		SW-4	--	15 J	--

See last page for footnotes.

Table 3-8. Summary of Analytes Detected in Groundwater Above Remedial Action Levels at the Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Parameter	RAL (ug/L)	Well Designation	Concentration (ug/L) 5/94	6/94	7/94
Volatile Organic Compounds (continued)					
Tetrachloroethene (continued)	5	Tillett	180	--	--
		TT-2	--	90	--
		TT-3	--	91	--
		TT-3D	--	23	--
Toluene	1000	SW-3	--	3200 J	--
		TT-1	--	16000 D	--
		TT-4	--	17000	--
Ethylbenzene	700	CHT-3	--	1800 D	--
		MW-5	--	760 DJ	--
		SW-3	--	4100 J	--
		TT-1	--	3700 D	--
		TT-4	--	3300 J	--
Xylenes (total)	10000	SW-3	--	22000 J	--
		TT-1	--	18000 D	--
Inorganic Compounds/Analytes					
Aluminum	50 to 200	Four Winds II FR**	--	--	63.1 B
		Harvey**	--	--	111 B
		CHT-7D	--	118 B	--
		Delegarde	1890 B	--	--
		Gassett**	154 B	--	--
		MW-1	--	18600 J	--
		MW-6R	--	46400	--
		MW-7	--	10300	--
		MW-8	--	28700	--
		MW-9S	2050	--	--
		MW-10	956	--	--
		MW-10D	160 B	--	--
		MW-11D	147 B	--	--
		MW-12D	93.9	--	--
		MW-15	--	3730 J	--
		MW-17	--	33000 J	--
		MW-24	--	4160	--
		MW-25	--	15800	--
		OHMW-1	245000	--	--
		OHMW-2	8970	--	--
		OHMW-3	60000	--	--
		OHMW-4	356000	--	--
		Smith	60.9 B	--	--
		SW-5	12100	--	--
		SW-6	14500	--	--

See last page for footnotes.

Table 3-8. Summary of Analytes Detected in Groundwater Above Remedial Action Levels at the Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Parameter	RAL (ug/L)	Well Designation	Concentration (ug/L) 5/94	6/94	7/94
Inorganic Compounds/Analytes (continued)					
Aluminum (continued)	50 to 200	TT-1	--	6130 J	--
		TT-1D	--	153 B	--
		TT-2	--	1090 J	--
		TT-5	--	787 J	--
		DW-1	--	300	--
		DW-2	1490	--	--
Antimony	6	Four Winds II **	--	--	22 B
		KFC-1	--	18.6 BJ	--
		MW-1	--	17.6 B	--
		MW-2	--	15 B	--
		MW-3	--	17 B	
		MW-4	--	20.1 B	--
		MW-5	--	20.1 B	--
		MW-6D	--	25.3 B	--
		MW-7	--	21.3 B	--
		MW-13D	--	424 B	--
		MW-18	--	20.6 B	--
		MW-21D	--	19.6 B	--
		MW-22D	--	22.3 BJ	--
		OHMW-1	16.1 B	--	--
		OHMW-3	50.7 B	--	--
		SW-2	--	15.4 BJ	--
		SW-3	--	16.4 BJ	--
		SW-7	--	19.2 BJ	--
		SW-7FR	--	17.6 BJ	--
		TT-1	--	19.7 B	--
		TT-3D	--	19 B	--
		VIHA I **	--	--	20.6 B
Arsenic	50	OHMW-2	80.8	--	--
Barium	2000	MW-13D	--	4400 B	--
		OHMW-4	4320	--	--
Beryllium	4	MW-13D	--	40.8 B	--
Chromium	100	DW-2	628	--	--
		MW-1	--	453	--
		MW-2	--	619	--
		MW-6R	--	203	--
		MW-7	--	1050	--
		MW-8	--	210	--
		MW-13D	--	4300	--
		MW-17	--	238	--
		OHMW-1	2200	--	--
		OHMW-3	4610	--	--
		OHMW-4	397	--	--

See last page for footnotes.

Table 3-8. Summary of Analytes Detected in Groundwater Above Remedial Action Levels at the Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Parameter	RAL (ug/L)	Well Designation	Concentration (ug/L) 5/94	6/94	7/94
Inorganic Compounds/Analytes (continued)					
Copper	TT	MW-13D	--	1730 J	--
		OHMW-4	1370	--	--
Iron	300	Delegarde	4120 J	--	--
		DW-1	--	1150	--
		Gassett**	300	--	--
		Harvey**	--	--	2500
		DW-2	--	3100	--
		KFC-1	--	80000 J	--
		MW-1	--	25600	--
		MW-1D	--	10500	--
		MW-2	--	19900	--
		MW-3	--	3830	--
		MW-4	--	7590	--
		MW-4D	--	1440	--
		MW-5	--	5730	--
		MW-6R	--	56900	--
		MW-7	--	44800	--
		MW-8	--	49700	--
		MW-9S	3760	--	--
		MW-10	1410	--	--
		MW-10D	607	--	--
		MW-11D	323	--	--
		MW-12D	334	--	--
		MW-13	--	3670	--
		MW-13D	--	378000	--
		MW-15	--	5360	--
		MW-17	--	43500	--
		MW-18	--	68500 J	--
		MW-19	--	3420 J	--
		MW-20	--	23900	--
		MW-20D	--	37800	--
		MW-21D	--	19400	--
		MW-24	--	6890	--
		MW-25	--	30500	--
		OHMW-1	338000	--	--
		OHMW-2	15700	--	--
		OHMW-3	154000	--	--
		OHMW-4	572000	--	--
		SW-2	--	14100 J	--
		SW-3	--	108000 J	--
		SW-4	--	5140	--
		SW-5	18600	--	--
		SW-6	20300 J	--	--
		SW-7	--	14800 J	--
		Tillett	530	--	--
		TT-1	--	7810	--
		TT-1D	--	515	--
		TT-2	--	2320	--
		TT-5	--	1130	--

See last page for footnotes.

Table 3-8. Summary of Analytes Detected in Groundwater Above Remedial Action Levels at the Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Parameter	RAL (ug/L)	Well Designation	Concentration (ug/L)		
			5/94	6/94	7/94
Inorganic Compounds/Analytes (continued)					
Lead	TT	Gassett	167	--	--
		MW-1	--	27.1 J	--
		MW-9S	53.7	--	--
		MW-18	--	27.4	--
		MW-20	--	16	--
		MW-20D	--	20	--
		OHMW-1	48.3	--	--
		OHMW-2	201	--	--
		OHMW-3	17.3	--	--
		OHMW-4	71.8	--	--
		SW-3	--	143	--
		SW-7	--	70.8	--
		SW-7FR	--	93.8 J	--
Manganese	50	CHT-7D	--	282	--
		Delegarde	163 B	--	--
		Four Winds II **	--	--	125
		Four Winds II FR**	--	--	119
		Harvey**	267	--	--
		DW-2	620	--	--
		KFC-1	--	1030 J	--
		MW-1	--	570	--
		MW-1D	--	338	--
		MW-2	--	366	--
		MW-3	--	2540	--
		MW-4	--	1290	--
		MW-4D	--	55.1	--
		MW-5	--	1080	--
		MW-6R	--	736	--
		MW-7	--	453	--
		MW-8	--	2350	--
		MW-9S	2560	--	--
		MW-10	597	--	--
		MW-10D	216	--	--
		MW-12D	114	--	--
		MW-13	--	110	--
		MW-13D	--	20400	--
		MW-15	--	149	--
		MW-16	--	532	--
		MW-17	--	1550	--
		MW-18	--	3740 J	--
		MW-19	--	72.6 J	--
		MW-20	--	997	--
		MW-20D	--	1140	--
		MW-21D	--	402	--
		MW-24	--	215	--
		MW-25	--	982	--

See last page for footnotes.

Table 3-8. Summary of Analytes Detected in Groundwater Above Remedial Action Levels at the Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Parameter	RAL (ug/L)	Well Designation	Concentration (ug/L) 5/94	6/94	7/94
Inorganic Compounds/Analytes (continued)					
Manganese (continued)	50	OHMW-1	5870	--	--
		OHMW-3	3180	--	--
		OHMW-4	13500	--	--
		SW-2	--	943 J	--
		SW-3	--	6340 J	--
		TT-1	--	1710	--
		TT-1D	--	1880	--
		TT-2	--	1220	--
		TT-4	--	957	--
		TT-5	--	1110	--
Mercury	2	OHMW-1	3.1	--	--
Nickel	100	MW-4D	--	460	--
		DW-2	374	--	--
		MW-1	--	124	--
		MW-2	--	266	--
		MW-6R	--	127	--
		MW-7	--	445	--
		MW-8			--
		MW-10D	189	--	--
		MW-13D	--	2050	--
		MW-17	--	140	--
		OHMW-1	1120 J	--	--
		OHMW-3	1840 J	--	--
		OHMW-4	603 J	--	--
Thallium	2	DW-1	--	2.4 B	--
		MW-24	--	2.1 B	--
Chloride	250,000	Eglin I**	269	--	--
		Eglin III**	368	--	--
		Harvey**	--	--	1700
		Matthias**	294	--	--
		MW-21D	--	402	--
		OHMW-1	354	--	--
		OHMW-2	332	--	--
		OHMW-3	351	--	--
		Smith	335	--	--
		SW-5	378	--	--
Total Dissolved Solids	500,000	CHT-3	--	1320	--
		CHT-6D	--	850	--
		CHT-7D	--	870	--
		Delegarde	1440	--	--
		DW-1	--	910	--
		DW-2	--	870	--
		Eglin I**	1180	--	--
		Eglin III**	1330	--	--

See last page for footnotes.

Table 3-8. Summary of Analytes Detected in Groundwater Above Remedial Action Levels at the Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Parameter	RAL (ug/L)	Well Designation	Concentration (ug/L) 5/94	6/94	7/94
Inorganic Compounds/Analytes (continued)					
Total Dissolved Solids (continued)	500,000	Four Winds I**	--	--	1240
		Gassett**	700	--	--
		Harthman Race Track	1100	--	--
		Harvey**	--	--	1190
		KFC-1	--	1070	--
		La Place**			
		Matthias**	1360	--	--
		MW-1	--	920	--
		MW-1D	--	880	--
		MW-2	--	910	--
		MW-3	--	900	--
		MW-4	--	920	--
		MW-4D	--	1180	--
		MW-5	--	810	--
		MW-6D	--	840	--
		MW-6R	--	910	--
		MW-7	--	760	--
		MW-8	--	920	--
		MW-9S	830	--	--
		MW-10	790	--	--
		MW-12D	640	--	--
		MW-13	--	900	--
		MW-13D	--	1520	--
		MW-15	--	990	--
		MW-17	--	870	--
		MW-18	--	800	--
		MW-19	--	1040	--
		MW-20	--	500	--
		MW-20D	--	780	--
		MW-21D	--	2260	--
		MW-22D	--	1890	--
		MW-24	--	940	--
		MW-25	--	950	--
		OHMW-1	354	--	--
		OHMW-2	1110	--	--
		OHMW-3	1290	--	--
		OHMW-4	1040	--	--
		Ramsay	870	--	--
		Smith	335	--	--
		SW-5	378	--	--
Nitrate (as N) (mg/L)	10,000	Gassett**	11.3	--	--
		Harthman Race Track	13.6	--	--
		MW-1	--	12.4	--
		MW-2	--	15.9	--
		MW-13	--	10.6	--
		MW-17	--	22.7	--
		MW-24	--	13.3	--
		Ramsay	10	--	--

See last page for footnotes.

G:\APROJECT\TUTU\PR0013.037\DATA\MCL.XLS

Table 3-8. Summary of Analytes Detected in Groundwater Above Remedial Action Levels at the Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

*	Analytical results reported for total isomers (cis- and trans-) for 1,2-dichloroethene (1,2-DCE); RAL is for trans- isomer.
**	Sample results were not validated.
--	Not available.
mg/L	Milligrams per liter.
ug/L	Micrograms per liter.
B	The reported value was obtained from a reading that was less than the Contract Required Detection Limit (CRDL), but greater than or equal to the Instrument Detection Limit (IDL).
J	Estimated value.
D	Compound concentration was determined at a secondary dilution factor.
RAL	Remedial Action Level.
TT	Treatment technique. (Action Levels: Copper 1,300 ug/L, lead 15 ug/L). Values in parentheses are determined by the USEPA.
USEPA	U.S. Environmental Protection Agency.

Note: RALs derived from Federal Drinking Water Standards.

Table 4-1. Development and Screening of Technologies for Soil, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

General Response Action	Remedial Technology	Process Options	Description	Screening Comments
No Action	None	Not applicable	No action.	Required for consideration by NCP (comparison with other alternatives).
Institutional Controls	Access restrictions	Deed restrictions	Restrictions on property by limiting access and use of areas of contamination.	Potentially applicable.
Containment	Capping	Capping	Installation of low-permeable barrier over areas of contamination.	Potentially applicable.
Treatment	In-situ	Soil vapor extraction (SVE)	Vacuum (extraction) wells that pull air from the soil to facilitate the removal of VOCs.	Potentially applicable.
		Bioventing	Extraction and/or injection of air in soils to enhance biological degradation of BTEX and non-halogenated VOCs, and semi-VOCs.	Potentially applicable with only non-halogenated VOCs.

See last page for footnotes.

Table 4-1. Development and Screening of Technologies for Soil, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

General Response Action	Remedial Technology	Process Options	Description	Screening Comments
Removal	Excavation	Excavation and disposal	Removal and disposal of contaminated soil.	Potentially applicable.
	Ex-situ Treatment	Biopile/SVE	Excavated soils are stockpiled and mixed with nutrients and/or oxygen to enhance biodegradation.	Potentially applicable.
		Thermal desorption	Excavated soils are exposed to high temperatures to volatilize VOCs; the off-gas from these operations are then treated and discharged. The treated soils can be disposed back to the site as backfill.	Not applicable; cost prohibitive.
		Incineration	Soils are excavated and exposed to extremely high temperatures to volatilize VOCs. Incineration may take place on-site or off-site.	Not applicable; cost prohibitive.

NCP National Contingency Plan.
VOCs Volatile organic compounds.
BTEX Benzene, toluene, ethylbenzene, and xylene.
SVE Soil vapor extraction.
Option not retained for further analysis.

TUT 007 2170

Table 4-2. Off-Gas Treatment Technology Evaluation, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Technology	Advantages	Disadvantages
Thermal Oxidation (Thermox)	High removal efficiencies (>99%)	High operating T (>1,400°F)
	Low capital cost	High insulation maintenance
	Low sensitivity to process condition changes	High metal fatigue due to high T
	Can process up to 70% LEL	May be limited to processing <25% LEL in future
	Effective in chlorinated solvent destruction	High fuel consumption
	Enables faster remediation	Fire codes may make permitting difficult
Catalytic Oxidation	Low operating T (<1,250°F)	High capital cost
	Relatively safe-operates below 25% LEL	Risk of catalyst poisoning/deactivation
	No NOx formation	Reduced catalyst activity after 5 years
	Very low fuel costs	Extends remediation time for highly-contaminated sites
	Stainless steel interior	Need larger unit at high concentration due to dilution air
	Very little metal fatigue	
	Effective heat recovery	
	High destruction effectiveness with additional catalyst	
Vapor Phase Granular Activated Carbon (VPGAC)	Effective at low mass flows	Very high cost at moderate/high mass flows
	No external fuel requirements	Must maintain inlet stream <50% relative humidity
	Easy to permit	Potential future liability from carbon disposal sites
	High removal efficiencies	Transfers contaminate from vapor to solid - not destroyed
		Minimal effect on MTBE
		Sensitive to process condition changes
		Limited to <25% LEL
		Desorbed by high blower outlet T/high heat of adsorption

>	Less than.
LEL	Lower explosive limit.
%	Percent.
F	Farenheit.
NOx	Nitrogen oxide(s).
T	Temperature.
MTBE	Methyl tertiary butyl ether.

Table 4-3. Development and Screening of Technologies for Groundwater, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

General Response Action	Remedial Technology	Process Options	Description	Screening Comments
No Action	None	Not available	No action.	Required for consideration by NCP (comparison with other alternatives).
Institutional Controls	Access restrictions	Deed restrictions	Deeds for property in the area would include restrictions on wells.	Potentially applicable.
	Alternative water supply	Public water supply	Extension of existing water system to serve residences in contaminated plumes.	Potentially applicable.
		Trucking water	Delivery of potable water to serve residences.	Potentially applicable.
		New community well	Provide community watering point for use by residents.	Not applicable due to high expense and administrative difficulties associated with installation of a well, and construction of distribution piping.
Collection/Containment	Extraction	Extraction wells	Series of recovery wells to extract contaminated groundwater.	Potentially applicable.
		Extraction/injection wells	Injecting uncontaminated water to increase flow to extraction wells.	Not applicable;anisotropic conditions inhibit hydraulic control during combined extraction and injection.
	Subsurface drains	Interceptor trenches	Perforated pipe in trenches backfilled with porous media to collect contaminated water.	Not applicable due to shallow depth to bedrock.

TUT 007 2172

See last page for footnotes.

Table 4-3. Development and Screening of Technologies for Groundwater, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

General Response Action	Remedial Technology	Process Options	Description	Screening Comments
Collection/Containment (continued)	Well points	Well points	Extraction wells of smaller diameter and shallower depths.	Not applicable due to depths of contamination.
	Vertical barriers	Slurry wall	Barrier that involves applying a low permeability material (bentonite) in soil.	Not implementable in bedrock; practically infeasible.
		Synthetic membrane cutoff walls	Barrier that involves applying a low permeability liner in soil	Not implementable in bedrock; practically infeasible.
	Enhanced groundwater recovery	Bedrock fracturing	Enhanced recovery of contaminated water through the detonation of explosives in the saturated zone.	Potentially applicable in non-residential and/or open areas.
		Vacuum enhanced recovery	Enhanced recovery of contaminated water through application of vacuum at extraction wells.	Not applicable; limitations due to anisotropic bedrock conditions.
Treatment	In-situ	Air sparging	Injection of air into saturated zone to strip VOCs from groundwater.	Potentially applicable.
		Biosparging	Injection of small amounts of air into the saturated zone to enhance the natural aerobic biodegradation of VOCs. The stripped VOCs are captured by an SVE system for further processing.	Potentially applicable (properties with non-halogenated VOCs).

See last page for footnotes.

Table 4-3. Development and Screening of Technologies for Groundwater, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

General Response Action	Remedial Technology	Process Options	Description	Screening Comments
Treatment (continued)	Ex-situ	Air stripping	Mixing large volumes of air with water in a packed column to promote transfer of VOCs to air.	Potentially applicable.
		Granular activated carbon (GAC)	Adsorption of contaminants onto activated carbon by passing water through carbon. Not cost effective at removing vinyl chloride.	Potentially applicable.
		Filtration	Filtering to remove solids.	Potentially applicable.
		Precipitation, flocculation, sedimentation	Processes for the removal of metals and solids.	Potentially applicable.
		Reverse osmosis	Membrane diffusion to remove metals and solids.	Potentially applicable.
		Ion exchange	Ionic species removal for metal.	Potentially applicable.
		UV oxidation/ reduction	Redox reactions for organic removal.	Potentially applicable.
		GAC fluidized bed system	Combines fluidized bed technology with GAC.	Potentially applicable.
	Natural remediation	Attenuation and degradation	Reduction of constituent concentrations through natural attenuation/degradation.	Potentially applicable.

See last page for footnotes.

Table 4-3. Development and Screening of Technologies for Groundwater, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

General Response Action	Remedial Technology	Process Options	Description	Screening Comments
Discharge	Off-site discharge	Discharge to POTW	Treated groundwater discharged to local sanitary sewer (USVI-DPW).	Not applicable;capacity for flow rate does not currently exist.
		Discharge to surface water	Treated groundwater discharged to Turpentine Run.	Potentially applicable; permitting-dependent.
		Conveyance to beneficial non-potable user	Treated groundwater used to supplement commercial water supply (Non-potable use).	Not applicable; difficulties due to implementability issues.
		Distribution for potable-use	Treated groundwater used for drinking water.	Not applicable; difficulties due to implementability issues and high costs.
		Discharge to RCRA-permitted TSDF	Recovered groundwater would be shipped to a RCRA TSDF facility for treatment.	Not applicable; no permitted sites in U.S. Virgin Islands. Shipment would not be cost effective.
		Re-injection	Treated groundwater re-injected into the aquifer.	Not applicable; anisotropic conditions inhibit hydraulic control.

POTW Publicly owned treatment works.
USVI-DPW U.S. Virgin Islands - Department of Public Works.
(shaded) Eliminated from further consideration in preliminary screening.
NCP National Contingency Plan.
VOC Volatile organic compound.
O&M Operation and maintenance.
SVE Soil vapor extraction.
GAC Granular activated carbon.
UV Ultraviolet.
RCRA Resource Conservation and Recovery Act.
TSDF Treatment, storage and/or disposal facility.

Table 4-4. Summary of Influent Concentrations and Maximum Contaminant Levels, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Parameters	GRA 2 Source Containment Wells Total Concentration	GRA 2 Source Containment Wells Dissolved Concentration	GRA 3 Plume Containment Wells Total Concentration	GRA 3 Plume Containment Wells Dissolved Concentration	GRA 4 Source and Plume Containment Wells Total Concentration	GRA 4 Source and Plume Containment Wells Dissolved Concentration	Background Water Quality Inorganics Turpentine Run [6]	Maximum Contaminant Level
Organic Constituents (ug/L) (1)								
Tetrachloroethene (PCE)	4970.00	NA	85.00	NA	2770.00	NA	---	5.00
Trichloroethene (TCE)	40.00	NA	16.00	NA	30.00	NA	---	5.00
1,2-Dichloroethene (1,2-DCE)	360.00	NA	49.00	NA	220.00	NA	---	0.1 [4]
Inorganic Constituents (mg/L)								
Iron	105.00	NO	0.15	NO	205.00	0.18	0.0	0.30
Magnesium	55.00	50.00	33.00	36.00	115.00	38.00	77	---
Manganese	1.50	0.140	0.05	0.050	5.00	0.034	--- [5]	0.05
Potassium	4.00	4.00	5.00	6.00	45.00	5.00	--- [5]	---
Sodium	280.00	290.00	336.00	370.00	289.00	314.00	519.00	---
Calcium	76.00	72.00	37.00	39.00	90.00	47.00	30.0	---
Hardness as CaCO3	NA	395 [2]	NA	230.00	NA	310 [2]	392.0	---
Chloride	180.00	NA	245.00	NA	207.00	NA	440.0	250 [3]
Total Dissolved Solids (TDS)	NA	1100.00	NA	1260.00	NA	1115.00	1,700	500 [3]

Recovery wells within catchment area include Recovery Well RW-1 (which is near existing Monitoring Well MW-12D), Recovery Wells RW-2 and RW-3 (which are near the Smith and Matthias Supply Wells), Recovery Well RW-4 (which is near Monitoring Well OHMW-4), and Recovery Well RW-5 (which is near monitoring well cluster MW-1/MW-1D). Data related to proposed Recovery Well RW-4 included historic water quality data from the Harvey Supply well. These data indicate a past PCE concentration at 7,600 parts per billion (ppb) or ug/L. Total/dissolved concentrations are based upon sample data collected from associated monitoring wells.

(1) Data refer to concentrations of individual volatile organic compound (VOC) constituents identified in groundwater samples.
(2) Hardness is a quantification of water quality as indicative of the presence of calcium carbonate (CaCO3).
(3) Value refers to Secondary Maximum Contaminant Levels.
(4) Value represents trans- isomer of 1,2-dichloroethene.
(5) Sodium and potassium were combined in reference document[6].
(6) Water quality data taken from reference entitled "Water Records of U.S. Virgin Islands 1962-1969." Sample was recorded at the Mt. Zion Gauging Station on July 22, 1964 (U.S. Geological Survey 1973).
GRA Groundwater remedial alternative.
NA Not applicable.
NO Not detected above sample qualification limit.
--- Not available.
ug/L Micrograms per liter.
mg/L Milligrams per liter.

Table 4-5. Summary of Estimated Impacted Soil Volumes, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Property	Constituents of Concern	Estimated Area of Impacted Soils (area, ft^2) [A]	Depth to Bottom of Impacted Soils (feet) [B]	Thickness (feet) [C]	Volume of soils Previously Remediated (cubic yards) (1) [D]	Volume of Soils Requiring Excavation (cubic yards) [(AxB)/27]	Soil Volume Currently Requiring Remediation (cubic yards) (2) [(AxC)/27-D]
Curriculum Center	BTEX, and 1,1,1-TCA	240	0.5	0.5	0	5	5
Ramsay Motors	Benzene and ethylbenzene	40[4]	5	4	0	8[3]	6
Texaco Tutu Service Station	Benzene and ethylbenzene	200	5	5	0	37	37
		25[5]	4	2	0	4	2
Tillett Gardens	Manganese and PCBs	25[5]	2	2	0	2	2
Esso Tutu Service Station	PCE, 1,1-DCA, 1,2-DCE, BTEX	290[6]	9	9	20	97	77
		25[5]	8	1	0	7	1
		50[7]	12	4	0	22	8
		190[8]	9	0	63	0	0
		200[8]	9	0	67	0	0
Western Auto	Benzene, toluene, and xylene	150	6	6	10	33	23
		440	7	7	25	114	89
		460[9]	2	2	0	34	34
O'Henry Dry Cleaners	PCE	400	8	8	0	119	119
					Total	482	403

ft^2 Square feet.
(1) Soil removed during previous tank removals as part of early removal actions prior to FS.
(2) In some instances soil volumes that need to be excavated may include soils that do not require remediation or that were previously remediated. Therefore, soil volumes requiring excavation may be different from those requiring remediation.
(3) Includes volume of existing underground storage tank.
(4) Estimated area based on area of impacted soils defined on Figure 4-2.
(5) Area around individual impacted soil samples is assumed to be 5' x 5'.
(6) Near north oil/water separator at Esso.
(7) Includes soil samples B-101 and B-102 (see previous note 5).
(8) Assumes impacted soil removed with installation of new underground storage tanks prior to FS.
(9) Includes the 4-inch PVC pipe area at Four Winds Plaza near Western Auto.
BTEX Benzene, toluene, ethylbenzene, and xylene.
PCE Tetrachloroethene.
1,1-DCA 1,1-Dichloroethane.
1,2-DCE 1,2-Dichloroethene(cis/trans).
1,1,1-TCA 1,1,1-Trichloroethane.
PCBs Polychlorinated biphenyls.

Table 4-6. Evaluation of No Action/Institutional Controls Technologies Option on Property-Specific Basis, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Properties	Description	Effectiveness	Implementability	Cost	Screening Comments
Curriculum Center	Deed restrictions for soil and bedrock excavation and groundwater use.	Some natural degradation would occur, but most of the contaminants volume would not be reduced. Limited effectiveness.	Easily implemented.	Low	Retained. - Provides comparison for other options. - Required by NCP.
Ramsay Motors	Deed restrictions for soil excavation and groundwater use.	Some natural degradation would occur; may be effective due to the comparatively low COC concentrations.	Easily implemented.	Low	Retained. - Provides comparison for other options. - Required by NCP.
Texaco Tutu Service Station	Deed restrictions for soil excavation and groundwater use.	Some natural degradation would occur, but most of the contaminants volume would not be reduced. Limited effectiveness.	Easily implemented.	Low	Retained. - Provides comparison for other options. - Required by NCP.
Tillett Gardens	Deed restrictions for soil excavation and groundwater use.	Contaminant volume would not be significantly reduced. Limited effectiveness.	Easily implemented.	Low	Retained. - Provides comparison for other options. - Required by NCP.
Western Auto	Deed restrictions for soil excavation and groundwater use.	Some natural degradation would occur, but most of the contaminant volume would not be reduced. Limited effectiveness.	Easily implemented.	Low	Retained. - Provides comparison for other options. - Required by NCP.
Esso Tutu Service Station	Deed restrictions for soil excavation and groundwater use.	Some natural degradation would occur, but most of the contaminant volume would not be reduced. Limited effectiveness.	Easily implemented.	Low	Retained. - Provides comparison for other options. - Required by NCP.
O'Henry Dry Cleaners	Deed restrictions for soil and bedrock excavation and groundwater use.	Some natural degradation would occur, but most of the contaminant volume would not be reduced. Limited effectiveness.	Easily implemented.	Low	Retained. - Provides comparison for other options. - Required by NCP.

NCP National contingency plan.
COC Constituents of concern.

TUT 007 2178

Table 4-7. Evaluation of Capping Technology Option on Property-Specific Basis, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Properties	Description	Effectiveness	Implementability	Cost	Screening Comments
Curriculum Center	Install asphalt paving over impacted soil to reduce infiltration.	Effective	Easily implemented.	Low	Retained. - Capping can be effective in reducing infiltration; easily implemented.
Ramsay Motors	Remove and replace cracked concrete floor slab in maintenance garage.	Effective	Easily implemented.	Low	Retained. - Capping can be effective in reducing infiltration; easily implemented.
Texaco Tutu Service Station	Inspect and maintain existing concrete paving and replace if necessary.	Effective	Easily implemented.	Low	Retained. - Capping can be effective in reducing infiltration; easily implemented.
Tillett Gardens	Install asphalt paving over impacted soil to reduce infiltration and limit direct contact.	Effective	Easily implemented.	Low	Retained. - Capping can be effective in reducing infiltration; easily implemented.
Western Auto	Inspect and maintain existing concrete paving and replace if necessary.	Effective	Easily implemented.	Low	Retained. - Capping can be effective in reducing infiltration; easily implemented.
Esso Tutu Service Station	Inspect and maintain existing asphalt paving and replace if necessary.	Effective	Easily implemented.	Low	Retained. - Capping can be effective in reducing infiltration; easily implemented.
O'Henry Dry Cleaners	Install asphalt paving over impacted soil to reduce infiltration.	Effective	Easily implemented.	Low	Retained. - Capping can be effective in reducing infiltration; easily implemented.

TUT 007 2179

Table 4-8. Evaluation of In-Situ SVE and Bioventing Technologies Option on Property-Specific Basis, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Properties	*Description*	*Effectiveness*	*Implementability*	*Cost*	*Screening Comments*
Curriculum Center	In-situ SVE or bioventing in soil and in-situ SVE in bedrock.	Potentially effective. Bioventing would not be effective for chlorinated VOCs.	Implementable.	High costs for bedrock. Costs would be prohibitively high for soil due to small volume.	Retained for bedrock. Not retained for soil; not cost effective.
Ramsay Motors	In-situ SVE or bioventing in soil.	Potentially effective. SVE and bioventing would be potentially effective for BTEX concentrations.	Implementable.	Moderate to high.	Not retained. - Not cost effective due to building proximity.
Texaco Tutu Service Station	In-situ SVE or bioventing in soil.	Potentially effective. SVE and bioventing would be potentially effective for BTEX concentrations.	Implementable.	Moderate to high.	Retained.
Tillett Gardens	In-situ SVE or bioventing in soil.	Not effective for manganese and PCBs.	Not implementable.	Not applicable.	Not retained. - Not applicable for treatment of manganese and PCBs.
Western Auto	In-situ SVE or bioventing in soil.	Not effective in tight clay formations.	Implementable.	Moderate to high.	Not retained. - Not effective in clay.
Esso Tutu Service Station	In-situ SVE or bioventing in soil.	Potentially effective. SVE and bioventing would be potentially effective for BTEX. Bioventing would not be effective due to the presence of chlorinated VOCs.	Implementable.	Moderate.	Retained.
O'Henry Dry Cleaners	In-situ SVE or bioventing in soil and in-situ SVE in bedrock.	Potentially effective. Bioventing would not be effective due to the presence of chlorinated VOCs.	Implementable.	Moderate.	Retained.

SVE Soil vapor extraction.
PCBs Polychlorinated biphenyls.
BTEX Benzene, toluent, ethylbenzene, and xylene.
VOCs Volatile organic compounds.

TUT 007 2180

Table 4-9. Evaluation of Ex-Situ SVE and Biopiles Technologies Option on Property-Specific Basis, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Properties	Description	Effectiveness	Implementability	Cost	Screening Comments
Curriculum Center	Excavate soil and treat using ex-situ SVE or biopiles.	This technology will not be effective for unsaturated bedrock which may contain chlorinated VOCs or DNAPL.	Not implementable for bedrock. Implementable for soil.	Due to small volume of soil, costs may be high.	Retained for soil. - Not retained for bedrock. - Not effective or implementable for bedrock.
Ramsay Motors	Excavate soil and treat using ex-situ SVE or biopiles.	Potentially effective.	Difficult to implement because UST is under building.	Due to small volume and location of soil, costs would be prohibitively high.	Not retained. - Not cost effective. - Difficult to implement.
Texaco Tutu Service Station	Excavate soil and treat using ex-situ SVE or biopiles.	Potentially effective.	Implementable.	Moderate to high.	Retained.
Tillett Gardens	Excavate soil and treat using ex-situ SVE or biopiles.	Not effective treatment for manganese or PCBs detected at Tillett property.	Not applicable.	Not applicable.	Not retained. - Not applicable treatment for manganese and PCBs.
Western Auto	Excavate soil and treat using ex-situ SVE or biopiles.	May not be potentially effective due to the type of soil being treated (clay).	Implementable.	Costs would be prohibitively high due to presence of clay.	Not retained. - Not cost effective.
Esso Tutu Service Station	Excavate soil and treat using ex-situ SVE or biopiles.	Potentially effective.	Implementable.	Moderate to high.	Retained.
O'Henry Dry Cleaners	Excavate soil and treat using ex-situ SVE or biopiles.	Potentially effective.	Implementable.	Moderate to high.	Retained.

SVE Soil vapor extraction.
VOCs Volatile organic compounds.
DNAPL Dense non-aqueous phase liquids.
PCBs Polychlorinated biphenyls.
UST Underground storage tank.

TUT 007 2181

Table 4-10. Evaluation of Excavation and Off-Site Disposal Technology Option on Property-Specific Basis, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Properties	*Description*	*Effectiveness*	*Implementability*	*Cost*	*Screening Comments*
Curriculum Center	Excavate soil, containerize, and ship off-site for disposal. Hazardous waste disposal may be necessary.	Very effective at removing impacted soil. Bedrock would not be addressed.	Implementable for soil. Not implementable for bedrock.	High	Retained for soil. Not retained for bedrock. - Not implementable.
Ramsay Motors	Excavate soil, containerize, and ship off-site for disposal. Hazardous waste disposal may be necessary.	Very effective at removing impacted soil.	Implementable for soil. Difficult to implement because impacted soils are under building.	High	Not retained. - Difficult implementation and high cost due to building overlying UST.
Texaco Tutu Service Station	Excavate soil, containerize, and ship off-site for disposal. Hazardous waste disposal may be necessary.	Very effective at removing impacted soil.	Implementable for soil.	High	Retained.
Tillett Gardens	Excavate soil, containerize, and ship off-site for disposal. Hazardous waste disposal may be necessary.	Very effective at removing impacted soil.	Implementable for soil.	High	Not retained. - Not cost effective due to small volume of soil.
Western Auto	Excavate soil, containerize, and ship off-site for disposal. Hazardous waste disposal may be necessary.	Very effective at removing impacted soil.	Implementable for soil.	High	Retained.
Esso Tutu Service Station	Excavate soil, containerize, and ship off-site for disposal. Hazardous waste disposal may be necessary.	Very effective at removing impacted soil.	Implementable for soil.	High	Retained.
O'Henry Dry Cleaners	Excavate soil, containerize, and ship off-site for disposal. Hazardous waste disposal may be necessary.	Very effective at removing impacted soil. Bedrock would not be addressed.	Implementable for soil. Not implementable for bedrock.	High	Retained.

UST Underground storage tank.

Table 4-11. Summary of Proposed Pumping Rates for New Recovery Wells, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

	Groundwater Remedial Alternative Pumping Scenarios		
	GRA 2 Source Containment and POETs (gpm)	GRA 3 Plume Containment (gpm)	GRA 4 Source and Plume Containment (gpm)
Proposed Containment Wells			
RW-1	--	15	15
RW-2	--	15	15
RW-3	--	15	15
RW-4	20	--	20
RW-5	35	--	35
Total Containment Wells	55	45	100
Supply Wells with POETs	15	--	--
Esso Source Control	10	10	10
Texaco Source Control	30	30	30
	110	85	140 **

Pumping scenarios should not exceed safe yield of catchment area of 118 gpm.

Estimated pumping rates are based on available site data. Final pumping rates will be based on pilot studies and initial operations data.

** Source control at the two service stations is assumed to be of short duration, ranging from 3 to 7 years.

gpm Gallons per minute.
GRA Groundwater remedial alternative.
POET Point of entry treatment.
-- No pumpages.

G:\APROJECT\TUTU\PR0013.037\DATA\SUMPMP1.XLS

Table 4-12. Summary of Potential POET Supply Well Installations for GRA 2, Tutu Wells Site, U.S. Virgin Islands.

POET Supply Well	GRA 2 Average Flow Rate (gpm)	GRA 2 Design Flow Rate (gpm)	Contaminants of Concern	Design Concentration (ppb)	Maximum Contaminant Limit (ppb)	Proposed Treatment
Four Winds I	10	10	1,2-Dichloroethene	64	5	GAC Unit
Steele	1.25	10	1,2-Dichloroethene	100	5	GAC Unit
La Place	1.25	10	1,2-Dichloroethene	95	5	GAC Unit
Matthias	1.25	10	1,2-Dichloroethene	15	5	GAC Unit
			Trichloroethene	6	5	
Smith	1.25	10	1,2-Dichloroethene	39	5	GAC Unit
			Tetrachloroethene	19	5	
			Trichloroethene	110	5	
Total Average Flow (gpm)	15					
Total Average Flow (gpd)	21,600					

POET Point of entry treatment.
GRA Groundwater remedial alternative.
gpm Gallons per minute.
ppb Parts per billion.
GAC Granular activated carbon.
gpd Gallons per day.

TUT 007 2184

Table 4-13. Half-Lives of Chlorinated Compounds in Groundwater, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Chlorinated Compounds	Range of Half-Lives in Groundwater	Average Half-Lives in Groundwater
PCE	1 to 2 years	1.5 years
TCE	10.7 months to 4.5 years	2.7 years
Vinyl chloride	2 months to 7.9 years	4.0 years
1,2-DCE	2 months to 7.9 years	4.0 years

Half-lives taken from Howard and others (1991). These half-lives are estimated scientific judgments based on published data for field or laboratory test results for aerobic degradation.

PCE Tetrachloroethene
TCE Trichloroethene
1,2-DCE 1,2-Dichloroethene (includes both cis- and trans-isomers).

G:\APROJECT\TUTU\PR0013.037\DATA\HLFLIVES.XLS

Table 4-14. Estimated Natural Degradation Rates for Groundwater Contaminants, Tutu Well Site, St. Thomas, U.S. Virgin Islands.

Chlorinated Compound	Assumed Initial Concentration (ug/L)	Concentration After One Half-Life (ug/L)	Concentration After Two Half-Lives (ug/L)	Concentration After Three Half-Lives (ug/L)	USEPA MCL and Estimated Time to Achieve MCL Using Maximum Half-Lives
PCE	**58.8**	(2.0 years max.) **29.4 (1.5 years ave.)** (1.0 year min.)	(4.0 years max.) **14.7 (3.0 years ave.)** (2.0 years min.)	(6.0 years max.) **7.35 (4.5 years ave.)** (3.0 years min.)	(7.10 years max.) **5.0 (5.33 years ave.)** (3.56 years min.)
1,2-DCE	**29.4**	(7.9 years max.) **14.7 (4.0 years ave.)** (0.167 year min.)	(15.8 years max.) **7.35 (8.0 years ave.)** (0.334 year min.)	(23.7 years max.) **3.65 (12.0 years ave.)** (0.501 year min.)	(0 years max.) **70/100* (0 years ave.)** (0 years min.)
TCE	**11.8**	(4.5 years max.) **5.9 (2.7 years ave.)** (0.89 year min.)	(9.0 years max.) **2.95 (5.4 years ave.)** (1.78 years min.)	(13.5 years max.) **1.475 (8.1 years ave.)** (2.67 years min.)	(5.58 years max.) **5.0 (3.34 years ave.)** (1.10 years min.)
Initial Total	**100.0**				

Half-lives for groundwater contaminants are from Howard and others (1991).

Initial concentration was assumed to be 100 ug/L, which represents maximum concentration that may not be captured by proposed recovery wells. The ratio of chlorinated compounds detected at the Matthias Supply Well were used to calculate a total concentration of 100 ug/L. Concentration variations due to formation of breakdown products are not included.

MCL	Maximum contaminant level.
PCE	Tetrachloroethene.
1,2-DCE	1,2-Dichloroethene.
TCE	Trichloroethene.
*	MCLs for cis-1,2-DCE (70 ug/L) and trans-1,2-DCE (100 ug/L).
max.	Maximum.
ave.	Average.
min.	Minimum.
ug/L	Micrograms per liter.

Table 4-15. Range of Values for Travel-Time and Natural Degradation of Tetrachloroethene, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Range of Travel-Time Calculation	Groundwater Hydraulic Conductivity (feet per day)	Effective Porosity	Groundwater Flow Velocity (feet per day)	Estimated Time to Achieve MCL for PCE	Length of Downgradient Migration (feet)
Maximum	2.82	0.14	1.39	7.10 years (2,592 days)	3,603
Average	1.92	0.2	0.661	5.33 years (1,945 days)	1,286
Minimum	1.02	0.4	0.176	3.56 years (1,299 days)	229

Time to achieve MCL is based on half-lives for groundwater contaminants are from Howard and other (1991). Initial concentration was assumed to be 100 micrograms per liter (ug/L) total VOCs, which represents maximum concentration that may not be captured by proposed recovery wells. The ratio of chlorinated compounds detected at the Matthias Supply Well were used to calculate a total concentration of 100 ug/L. Assumed initial concentration of PCE is 58.8 ug/L.

PCE Tetrachloroethene.
MCL Maximum contaminant level.
VOCs Volatile organic compounds.

Table 5-1. Evaluation of NCP Criteria for Soil Remedial Alternatives, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Description	Overall Protection of Human Health and Environment	Compliance with Anticipated ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, and Volume	Short-Term Effectiveness	Implementability	Cost	U.S. Virgin Islands Acceptance *	Community Acceptance *
SRA 1: No Action/ Institutional Controls	Unfavorable	Unfavorable	Unfavorable	Unfavorable	Favorable	Favorable	Favorable	---	---
SRA 2: Institutional Controls/ Capping	Favorable	Unfavorable	Moderately Favorable	Unfavorable	Moderately Favorable	Moderately Favorable	Moderately Favorable	---	---
SRA 3: Institutional Controls/ Capping/In-Situ SVE/ Excavation and Off-Site Disposal	Favorable	Favorable	Favorable	Favorable	Favorable	Moderately Favorable	Moderately Favorable	---	---
SRA 4: Institutional Controls/ Capping/Ex-Situ SVE/ Excavation and Off-Site Disposal	Favorable	Favorable	Favorable	Favorable	Moderately Favorable	Moderately Favorable	Moderately Favorable	---	---
SRA 5: Institutional Controls/Capping/ Excavation and Off-Site Disposal	Favorable	Favorable	Favorable	Favorable	Favorable	Moderately Favorable	Moderately Favorable	---	---

NCP	National Contingency Plan.
ARARs	Applicable or relevant and appropiate requirements.
*	Acceptance criteria will be assessed following comment on the Remedial Investigation and Feasibility Study (RI/FS) Reports and proposed plan.
SRA	Soil remedial alternative.
Unfavorable	Medium specific-term indicating the alternative does not address the goal adequately.
Moderately Favorable	Medium specific-term indicating an acceptable level of comfort based on U.S. Environmental Protection Agency (USEPA) guidance. Other alternatives may address the goal more effectively.
Favorable	Medium specific-term indicating an acceptable level of satisfaction of goals, based on USEPA guidance.
SVE	Soil vapor extraction.

TUT 007 2188

Table 5-2. Evaluation of NCP Criteria for Groundwater Remedial Alternatives, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Description	Overall Protection of Human Health and Environment	Compliance with Anticipated ARARs	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, and Volume	Short-Term Effectiveness	Implementability	Cost	U.S. Virgin Islands Acceptance *	Community Acceptance *
GRA 1: No Action/ Institutional Controls	Unfavorable	Unfavorable	Unfavorable	Unfavorable	Favorable	Favorable	Favorable	---	---
GRA 2: Institutional Controls/ Source Containment/ POET Systems/Treatment Discharge	Unfavorable	Favorable	Unfavorable	Moderately Favorable	Moderately Favorable	Moderately Favorable	Moderately Favorable	---	---
GRA 3: Institutional Controls/ Plume Containment/ Treatment/Discharge	Favorable	Favorable	Favorable	Moderately Favorable	Moderately Favorable	Moderately Favorable	Moderately Favorable	---	---
GRA 4: Institutional Controls/ Source and Plume Containment/ Treatment/Discharge	Favorable	Favorable	Favorable	Favorable	Moderately Favorable	Moderately Favorable	Moderately Favorable	---	---

NCP	National Contingency Plan.
ARARs	Applicable or relevant and appropiate requirements.
*	Acceptance criteria will be assessed following comment on the remedial investigation and feasibility study (RI/FS) report and proposed plan.
GRA	Groundwater remedial alternative.
Unfavorable	Medium specific-term indicating the alternative does not address the goal adequately.
Moderately Favorable	Medium specific-term indicating an acceptable level of comfort based on U.S. Environmental Protection Agency (USEPA) guidance. Other alternatives may address the goal more effectively.
Favorable	Medium specific-term indicating an acceptable level of comfort based on USEPA guidance.
POET	Point-of-entry treatment.

Table 5-3. Cost Estimate - SRA 1 (No Action/Institutional Controls), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
CAPITAL COSTS				
Deed Restrictions	1	L.S.	$10,000	$10,000
		Subtotal		$10,000
		Administration & Legal Costs (20%)		$2,000
		Contingency (25%)		$2,500
		TOTAL CAPITAL COST - TREATMENT		$14,500
TOTAL CAPITAL COST - SRA 1			SAY	$15,000
GRAND TOTAL - SRA 1				$15,000

SRA Soil remedial alternative.
L.S. Lump sum.

Source (design assumptions) of capital costs is presented in Appendix C.

g:\aproject\tutu\pr0013.037\data\SRA1CST.XLS

Table 5-4. Cost Estimate - SRA 2 (Institutional Controls/Capping), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
CAPITAL COSTS				
Deed Restrictions	1	L.S.	$10,000	$10,000
Pavement Restoration & Capping				
Curriculum Center	27	S.Y.	$20	$540
Ramsay Motors	40	C.Y.	$400	$16,000
Texaco Tutu Service Station	25	S.Y.	$20	$500
Tillett Gardens	3	S.Y.	$20	$60
Esso Tutu Service Station	41	S.Y.	$20	$820
Western Auto	117	S.Y.	$20	$2,340
O'Henry Dry Cleaners	44	S.Y.	$20	$880
		Subtotal		$31,140
		Administration & Legal Costs (20%)		$6,228
		Engineering Design (10%)		$3,114
		Construction Supervision (15%)		$4,671
		Contingency (25%)		$7,785
		TOTAL CAPITAL COST -		$52,938
			SAY	$53,000
TOTAL CAPITAL COST - SRA 2				$53,000
TOTAL CAPITAL COST - SCP AT ESSO (In-Situ SVE)				$150,000
TOTAL CAPITAL COST - SCP AT TEXACO (In-Situ SVE)				$135,000
TOTAL CAPITAL COST - SRA 2 AND SCPs				$338,000
O&M (ANNUAL) COSTS - SRA 2				
Pavement & Cap Maintenance (Sealing, patching)				
Curriculum Center	27	S.Y.	$3	$81
Ramsay Motors	370	S.Y.	$1	$370
Texaco Tutu Service Station	25	S.Y.	$3	$75
Tillett Gardens	3	S.Y.	$3	$9
Esso Tutu Service Station	41	S.Y.	$3	$123
Western Auto	117	S.Y.	$3	$351
O'Henry Dry Cleaners	44	S.Y.	$3	$132
		Subtotal		$1,141
		Administration & Legal Costs (15%)		$171
		Contingency (25%)		$285
		TOTAL ANNUAL O&M COST		$1,597
O&M (ANNUAL) PRESENT WORTH - SRA 2, YEAR 30 (3% discount rate)				$31,310
Pavement & Cap Replacement	1	L.S.	$16,060	$16,060
O&M PRESENT WORTH - SRA 2, YEAR 15 (3% discount rate)				$10,309
TOTAL O&M PRESENT WORTH - SRA 2				$41,619
			SAY	$42,000

Table 5-4. Cost Estimate - SRA 2 (Institutional Controls/Capping), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST		TOTAL COST
O&M (ANNUAL) COSTS (TO YEAR 5) - SCPs					
SCP at Esso	1	L.S.	$20,000		$20,000
SCP at Texaco	1	L.S.	$67,000		$67,000
O&M (ANNUAL) PRESENT WORTH - SCPs, YEAR 5 (3% discount rate)					$398,434
TOTAL O&M PRESENT WORTH - SCPs (In-Situ SVE)				SAY	$399,000
TOTAL O&M PRESENT WORTH - SRA 2 AND SCPs					$441,000
GRAND TOTAL - SRA 2					$95,000
GRAND TOTAL - SRA 2 AND SCPs					$779,000

L.S. Lump Sum.
C.Y. Cubic yard.
S.Y. Square yard.
SRA Soil remedial alternative.
SCP Source control plan.
O&M Operation and maintenance.

Source (design and O&M assumptions) used for cost estimates is presented in Appendix C.

Table 5-5. Cost Estimate - SRA 3 (Institutional Controls/Capping/In-Situ SVE [Soil and Bedrock]/Excavation and Off-Site Disposal), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
CAPITAL COSTS				
Deed Restrictions	1	L.S.	$10,000	$10,000
Pavement Restoration & Capping				
Ramsay Motors	40	C.Y.	$400	$16,000
Tillett Gardens	3	S.Y.	$20	$60
Curriculum Center				
Excavation	5	C.Y.	$70	$350
Off-Site Disposal	5	C.Y.	$2,230	$11,150
Site Restoration	5	C.Y.	$50	$250
Excavated soil sample analysis	1	EA.	$1,500	$1,500
Western Auto				
Excavation	181	C.Y.	$70	$12,670
Off-Site Disposal	146	C.Y.	$2,230	$325,580
Site Restoration	181	C.Y.	$50	$9,050
Excavated soil sample analysis	9	EA.	$1,500	$13,500
In-Situ SVE Systems				
Curriculum Center (in bedrock)	1	L.S.	$170,000	$170,000
O'Henry Dry Cleaners(in soils)	1	L.S.	$50,000	$50,000
O'Henry Dry Cleaners(in bedrock)	1	L.S.	$130,000	$130,000
		Subtotal		$750,110
		Administration & Legal Costs (20%)		$150,022
		Engineering Design (10%)		$75,011
		Construction Supervision (15%)		$112,517
		Contingency (25%)		$187,528
		TOTAL CAPITAL COST -		$1,275,187
			SAY	$1,276,000
TOTAL CAPITAL COST - SRA 3				$1,276,000
TOTAL CAPITAL COST - SCP AT ESSO (In-Situ SVE)				$150,000
TOTAL CAPITAL COST - SCP AT TEXACO (In-Situ SVE)				$135,000
TOTAL CAPITAL COST - SRA 3 AND SCPs				$1,561,000
O&M (ANNUAL) COSTS (TO YEAR 5) - SRA 3				
Pavement & Cap Maintenance (Sealing, patching)				
Ramsay Motors	370	S.Y.	$1	$370
Tillett Gardens	3	S.Y.	$3	$9
In-Situ SVE Systems				
Curriculum Center (in bedrock)	1	L.S.	$35,000	$35,000
O'Henry Dry Cleaners(in soils)	1	L.S.	$14,500	$14,500
O'Henry Dry Cleaners(in bedrock)	1	L.S.	$35,000	$35,000
		Subtotal		$84,879
		Administration & Legal Costs (15%)		$12,732
		Contingency (25%)		$21,220
		TOTAL ANNUAL O&M COST		$118,831

(continued on next page)

Table 5-5. Cost Estimate - SRA 3 (Institutional Controls/Capping/In-Situ SVE [Soil and Bedrock]/Excavation and Off-Site Disposal), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
O&M (ANNUAL) COSTS (TO YEAR 5) - SRA 3 (continued)				
O&M (ANNUAL) PRESENT WORTH - SRA 3, YEAR 1 to 5 (3% discount rate)				$544,208
O&M (ANNUAL) COSTS (YEAR 6 TO 30) - SRA 3				
Pavement & Cap Maintenance (Sealing, patching)				
Ramsay Motors	370	S.Y.	$1	$370
Tillett Gardens	3	S.Y.	$3	$9
In-Situ SVE Systems				
Curriculum Center (in bedrock)	1	L.S.	$35,000	$35,000
O'Henry Dry Cleaners(in bedrock)	1	L.S.	$35,000	$35,000
		Subtotal		$70,379
		Administration & Legal Costs (15%)		$10,557
		Contingency (25%)		$17,595
		TOTAL ANNUAL O&M COST		$98,531
O&M (ANNUAL) PRESENT WORTH - SRA 3, YEAR 6 to 30 (3% discount rate)				$1,479,983
EQUIPMENT INSTALLATION, AND MATERIAL REPLACEMENT - SRA 3				
Major Equipment	1	L.S.	$160,000	$160,000
	O&M PRESENT WORTH (Year 15) (3% discount rate)			$102,704
Minor Equipment	1	L.S.	$5,000	$5,000
	O&M PRESENT WORTH (Years 5, 10, 15, 20, 25) (3% discount rate)			$16,400
Pavement & Cap Replacement (Ramsay Motors & Tillett only)	1	L.S.	$16,060	$16,060
	O&M PRESENT WORTH (Year 15) (3% discount rate)			$10,309
TOTAL O&M PRESENT WORTH - SRA 3				$2,154,000
O&M (ANNUAL) COSTS (TO YEAR 5) - SCPs				
SCP at Esso	1	L.S.	$20,000	$20,000
SCP at Texaco	1	L.S.	$67,000	$67,000
O&M (ANNUAL) PRESENT WORTH - SCPs, YEAR 5 (3% discount rate)				$398,434
TOTAL O&M PRESENT WORTH - SCPs (In-Situ SVE)			SAY	$399,000
TOTAL O&M PRESENT WORTH - SRA 3 AND SCPs				$2,553,000
GRAND TOTAL - SRA 3				$3,430,000
GRAND TOTAL - SRA 3 AND SCPs				$4,114,000

Table 5-5. Cost Estimate - SRA 3 (Institutional Controls/Capping/In-Situ SVE [Soil and Bedrock]/Excavation and Off-Site Disposal), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

L.S.	Lump sum.
A.	Each.
.Y.	Square yard.
C.Y.	Cubic yard.
SVE	Soil vapor extraction.
O&M	Operation and maintenance.
SRA	Soil remediation alternative.
SCP	Source control plan.

Source (design and O&M assumptions) used for cost estimates is provided in Appendix C.

Table 5-6. Cost Estimate - SRA 4 (Institutional Controls/Capping/Ex-Situ SVE/In-Situ SVE/Excavation and On-Site Disposal), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
CAPITAL COSTS				
Deed Restrictions	1	L.S.	$10,000	$10,000
Pavement Restoration & Capping				
Ramsay Motors	40	C.Y.	$400	$16,000
Tillett Gardens	3	S.Y.	$20	$60
Western Auto				
Excavation	181	C.Y.	$70	$12,670
Off-Site Disposal	146	C.Y.	$2,230	$325,580
Site Restoration	181	C.Y.	$50	$9,050
Excavated soil sample analysis	9	EA.	$1,500	$13,500
Ex-Situ SVE Systems				
Curriculum Center	1	L.S.	$10,000	$10,000
O'Henry Dry Cleaners	1	L.S.	$35,000	$35,000
In-Situ SVE Systems				
Curriculum Center (in bedrock)	1	L.S.	$170,000	$170,000
O'Henry Dry Cleaners(in bedrock)	1	L.S.	$130,000	$130,000
		Subtotal		$731,860
		Administration & Legal Costs (20%)		$146,372
		Engineering Design (10%)		$73,186
		Construction Supervision (15%)		$109,779
		Contingency (25%)		$182,965
		TOTAL CAPITAL COST -		$1,244,162
TOTAL CAPITAL COST - SRA 4				$1,245,000
TOTAL CAPITAL COST - SCP AT ESSO (In-Situ SVE)				$150,000
TOTAL CAPITAL COST - SCP AT TEXACO (In-Situ SVE)				$135,000
TOTAL CAPITAL COST - SRA 4 AND SCPs				$1,530,000
O&M (ANNUAL) COSTS (YEARS 1 AND 2) - SRA 4				
Pavement & Cap Maintenance (Sealing, patching)				
Ramsay Motors	370	S.Y.	$1	$370
Tillett Gardens	3	S.Y.	$3	$9
Ex-Situ SVE Systems				
Curriculum Center	1	L.S.	$12,000	$12,000
O'Henry Dry Cleaners	1	L.S.	$12,000	$12,000
In-Situ SVE Systems				
Curriculum Center (in bedrock)	1	L.S.	$35,000	$35,000
O'Henry Dry Cleaners(in bedrock)	1	L.S.	$35,000	$35,000
		Subtotal		$94,379
		Administration & Legal Costs (15%)		$14,157
		Contingency (25%)		$23,595
TOTAL (ANNUAL) O&M COSTS (YEARS 1 AND 2) - SRA 4				$132,131

(continued on next page)

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
O&M (ANNUAL) COSTS (YEARS 1 AND 2) - SRA 4 (continued)				
	O&M PRESENT WORTH (Years 1 and 2) (3% discount rate)			$252,832
O&M (ANNUAL) COSTS (YEARS 3 TO 30) - SRA 4				
Pavement & Cap Maintenance (Sealing, patching)				
Ramsay Motors	370	S.Y.	$1	$370
Tillett Gardens	3	S.Y.	$3	$9
In-Situ SVE Systems				
Curriculum Center (in bedrock)	1	L.S.	$35,000	$35,000
O'Henry Dry Cleaners(in bedrock)	1	L.S.	$35,000	$35,000
		Subtotal		$70,379
		Administration & Legal Costs (15%)		$10,557
		Contingency (25%)		$17,595
TOTAL (ANNUAL) O&M COSTS (YEARS 3 TO 30) - SRA 4				$98,531
	O&M PRESENT WORTH (Years 3 to 30) (3% discount rate)			$1,742,715
EQUIPMENT INSTALLATION, AND MATERIAL REPLACEMENT - SRA 4				
Major Equipment	1	L.S.	$160,000	$160,000
	O&M PRESENT WORTH (Year 15) (3% discount rate)			$102,704
Minor Equipment	1	L.S.	$5,000	$5,000
	O&M PRESENT WORTH (Years 5, 10, 15, 20, 25) (3% discount rate)			$16,400
Pavement & Cap Replacement	1	L.S.	$16,060	$16,060
	O&M PRESENT WORTH (Years 15) (3% discount rate)			$10,309
TOTAL O&M PRESENT WORTH - SRA 4				$2,125,000
O&M (ANNUAL) COSTS (TO YEAR 5) - SCPs				
SCP at Esso	1	L.S.	$20,000	$20,000
SCP at Texaco	1	L.S.	$67,000	$67,000
O&M (ANNUAL) PRESENT WORTH - SCPs, YEAR 5 (3% discount rate)				$398,434
TOTAL O&M PRESENT WORTH - SCPs (In-Situ SVE)			SAY	$399,000
TOTAL O&M PRESENT WORTH - SRA 4 AND SCPs				$2,524,000

TUT 007 2197

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
GRAND TOTAL - SRA 4				$3,370,000
GRAND TOTAL - SRA 4 AND SCPs				$4,054,000

L.S. Lump sum.
EA. Each.
C.Y. Cubic yard.
S.Y. Square yard.
O&M Operations and maintenance.
SVE Soil vapor extraction.
SRA Soil Remedial alternative.
SCP Source control plan.
Source (design and O&M assumptions) used for cost estimates is presented in Appendix C.

Table 5-7. Cost Estimate - SRA 5 (Institutional Controls/Capping/In-Situ SVE [Bedrock]/Excavation and Off-Site Disposal), Tutu Wells Site, St. Thomas, U.S.Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
CAPITAL COSTS				
Deed Restrictions	1	L.S.	$10,000	$10,000
Excavation	305	C.Y.	$70	$21,350
Off-Site Disposal	270	C.Y.	$2,230	$602,100
Site Restoration	305	C.Y.	$50	$15,250
Excavated soil sample analysis	16	EA.	$1,500	$24,000
In-Situ SVE Systems				
Curriculum Center (in bedrock)	1	L.S.	$170,000	$170,000
O'Henry Dry Cleaners(in bedrock)	1	L.S.	$130,000	$130,000
PAVEMENT RESTORATION & CAPPING				
Ramsay Motors	40	C.Y.	$400	$16,000
Tillett Gardens	3	S.Y.	$20	$60
		Subtotal		$988,760
		Administration & Legal Costs (30%)		$296,628
		Engineering Design (10%)		$98,876
		Construction Supervision (15%)		$148,314
		Contingency (25%)		$247,190
		TOTAL CAPITAL COST -		$1,779,768
TOTAL CAPITAL COST - SRA 5			SAY	$1,780,000
TOTAL CAPITAL COST - SCP AT ESSO (In-Situ SVE)				$150,000
TOTAL CAPITAL COST - SCP AT TEXACO (In-Situ SVE)				$135,000
TOTAL CAPITAL COST - SRA 5 AND SCPs				$2,065,000
O&M (ANNUAL) COSTS - SRA 5				
In-Situ SVE Systems				
Curriculum Center (in bedrock)	1	L.S.	$35,000	$35,000
O'Henry Dry Cleaners(in bedrock)	1	L.S.	$35,000	$35,000

(continued on next page)

Table 5-7. Cost Estimate - SRA 5 (Institutional Controls/Capping/In-Situ SVE [Bedrock]/Excavation and Off-Site Disposal), Tutu Wells Site, St. Thomas, U.S.Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
O&M (ANNUAL) COSTS - SRA 5 (continued)				
Pavement & Cap Maintenance (Sealing, patching)				
Ramsay Motors	370	S.Y.	$1	$370
Tillett Gardens	3	S.Y.	$3	$9
		Subtotal		$70,379
		Administration & Legal Costs (15%)		$10,557
		Contingency (25%)		$17,595
		TOTAL ANNUAL O&M COST		$98,531
O & M PRESENT WORTH - SRA 5, YEAR 30 (3% discount rate)				$1,931,239
EQUIPMENT INSTALLATION, AND MATERIAL REPLACEMENT				
Major Equipment	1	L.S.	$160,000	$160,000
	O&M PRESENT WORTH (Year 15) (3% discount rate)			$102,704
Minor Equipment	1	L.S.	$5,000	$5,000
	O&M PRESENT WORTH (Years 5, 10, 15, 20, 25) (3% discount rate)			$16,400
Pavement & Cap Replacement	1	L.S.	$16,060	$16,060
	O&M PRESENT WORTH (Year 15) (3% discount rate)			$10,309
TOTAL O&M PRESENT WORTH - SRA 5				$2,061,000
O&M (ANNUAL) COSTS (TO YEAR 5) - SCPs				
SCP at Esso	1	L.S.	$20,000	$20,000
SCP at Texaco	1	L.S.	$67,000	$67,000
O&M (ANNUAL) PRESENT WORTH - SCPs, YEAR 5 (3% discount rate)				$398,434
TOTAL O&M PRESENT WORTH - SCPs (In-Situ SVE)			SAY	$399,000
TOTAL O&M PRESENT WORTH - SRA 5 AND SCPs				$2,460,000

Table 5-7. Cost Estimate - SRA 5 (Institutional Controls/Capping/In-Situ SVE [Bedrock]/Excavation and Off-Site Disposal), Tutu Wells Site, St. Thomas, U.S.Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
GRAND TOTAL - SRA 5				$3,841,000
GRAND TOTAL - SRA 5 AND SCPs				$4,525,000

L.S. Lump sum.
EA. Each.
S.Y. Square yard.
C.Y. Cubic yard.
SVE Soil vapor extraction.
O&M Operation and maintenance.
SCP Source control plan.
SRA Soil remediation alternative.

Source (design and O&M assumptions) used for cost estimates is provides in Appendix C.

Table 5-8. Cost Estimate - GRA 1 (No Action/Institutional Controls), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
CAPITAL COSTS				
Deed Restrictions	1	L.S.	$10,000	$10,000
		Subtotal		$10,000
		Administration & Legal Costs (20%)		$2,000
		Contingency (25%)		$2,500
		TOTAL CAPITAL COST - TREATMENT		$14,500
TOTAL CAPITAL COST - GRA 1			SAY	$15,000
O&M (ANNUAL) COSTS				
Groundwater Monitoring	2	Sample rounds/year	$32,000	$64,000
		Subtotal		$64,000
		Administration & Legal Costs (15%)		$9,600
		Contingency (25%)		$16,000
		TOTAL ANNUAL O&M COST		$89,600
O&M PRESENT WORTH, YEAR 30 (3% discount rate)				$1,756,196
TOTAL O&M PRESENT WORTH - GRA 1				$1,757,000
GRAND TOTAL - GRA 1				$1,772,000

GRA Groundwater remedial alternative.
L.S. Lump sum.
O&M Operation and maintenance.

Source (design and O&M assumptions) for cost estimates is provided in Appendix C.

G:\APROJECT\TUTU\PR0013.037\DATA\GRA1CST.XLS

Table 5-9. Cost Estimate - GRA 2 (Institutional Controls/Source Containment/POET Systems/Treatment/Discharge), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
CAPITAL COSTS				
Deed Restrictions	1	L.S.	$10,000	$10,000
Site Preparation/Mobilization	1	L.S.	$40,000	$40,000
Well Decommissioning	12	EA.	$1,000	$12,000
Site Acquisition	1	L.S.	$25,000	$25,000
Groundwater Extraction System				
Recovery Well Installation	2	EA.	$38,000	$76,000
Submersible Pumps (installed)	2	EA.	$6,000	$12,000
4"-6" Double-Walled PVC Pipe (installed, with leak detection)	2,300	L.F.	$65	$149,500
Pre-Treatment (PO4)	1	L.S.	$15,000	$15,000
Low Profile Air Stripper (installed)	1	L.S.	$25,000	$25,000
Thermal Oxidizer (installed, if required)	1	L.S.	$185,000	$185,000
Liquid Phase Carbon Treatment System (installed, if required)	1	L.S.	$35,000	$35,000
Process Pumps	4	EA.	$5,000	$20,000
Piping (installed)	200	L.F.	$10	$2,000
Discharge Pumps	2	EA.	$10,000	$20,000
Piping (installed)	50	L.F.	$30	$1,500
Treatment Building (installed)	600	S.F.	$60	$36,000
Electric				
Electric Panel and Plant Wiring	1	L.S.	$50,000	$50,000
Conduit to Wells	2,300	L.F.	$2	$4,600
POET Systems (includes new well pump)				
GAC Unit (1-10 gpm)	5	EA.	$5,000	$25,000
General Contractor	1	L.S.	$80,000	$80,000
		Subtotal		$823,600
		Administration & Legal Costs (20%)		$164,720
		Engineering Design (10%)		$82,360
		Construction Supervision (15%)		$123,540
		Contingency (25%)		$205,900
		TOTAL CAPITAL COST - TREATMENT		$1,400,120
TOTAL CAPITAL COST - GRA 2				$1,401,000
TOTAL CAPITAL COST - SCP AT ESSO				$100,000
TOTAL CAPITAL COST - SCP AT TEXACO				$865,000
TOTAL CAPITAL COST - GRA 2 AND SCPs				$2,366,000

Table 5-9. Cost Estimate - GRA 2 (Institutional Controls/Source Containment/POET Systems/Treatment/ Discharge), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
O&M (ANNUAL) COSTS - GRA 2				
Groundwater Monitoring	2	Sample rounds/year	$32,000	$64,000
Electricity (Avg)	240,000	Kilowatt-hour	$0.10	$24,000
Chemical Usage (PO4)	1	L.S.	$10,000	$10,000
Supplemental Fuel (Propane)	1	L.S.	$25,000	$25,000
Carbon Replacement	2,000	Pounds of carbon	$6	$12,000
Carbon Replacement (POET)	1,000	Pounds of carbon	$6	$6,000
System Operation (one person - full time)	1	L.S.	$35,000	$35,000
POET System Monitoring (Avg)	60	EA.	$1,000	$60,000
Treatment System Monitoring (Avg)	12	EA.	$1,000	$12,000
		Subtotal		$248,000
		Administration and Legal Costs (15%)		$37,200
		Contingency (25%)		$62,000
		TOTAL ANNUAL O&M COST		$347,200
O&M PRESENT WORTH - GRA 2, YEAR 30 (3% discount rate)				$6,806,000
EQUIPMENT REPLACEMENT - GRA 2				
Major Equipment Replacement	1	L.S.	$260,000	$260,000
	O&M PRESENT WORTH (Year 15) (3% discount rate)			$166,894
Minor Equipment Replacement	1	L.S.	$25,000	$25,000
	O&M PRESENT WORTH (Years 5, 10, 15, 20, 25) (3% discount rate)			$81,998
TOTAL O&M PRESENT WORTH - GRA 2				$7,055,000
O&M (ANNUAL) COSTS (TO YEAR 5) - SCPs				
SCP at Esso	1	L.S.	$60,000	$60,000
SCP at Texaco	1	L.S.	$101,000	$101,000
		TOTAL ANNUAL O&M COST		$161,000
O&M PRESENT WORTH - SCPs, YEAR 5 (3% discount rate)				$738,000
TOTAL O&M PRESENT WORTH - GRA 2 AND SCPs				$7,793,000
GRAND TOTAL - GRA 2				$8,456,000
GRAND TOTAL - GRA 2 AND SCPs				$10,159,000

Table 5-9. Cost Estimate - GRA 2 (Institutional Controls/Source Containment/POET Systems/Treatment/Discharge), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST

L.F.	Linear feet.
S.F.	Square feet.
L.S.	Lump Sum.
EA.	Each.
gpm	Gallons per minute.
POET	Point-of-Entry Treatment.
GAC	Granular Activated Carbon.
PO4	Orthophosphates.
O&M	Operation and maintenance.
PVC	Polyvinyl chloride.
SCP	Source control plan.
GRA	Groundwater remedial alternative.

Source (design and O&M assumptions) for cost estimates is provided in Appendix C.

Table 5-10. Cost Estimate - GRA 3 (Institutional Controls/Plume Containment/Treatment/ Discharge), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
CAPITAL COSTS				
Deed Restrictions	1	L.S.	$10,000	$10,000
Site Preparation/Mobilization	1	L.S.	$40,000	$40,000
Well Decommissioning	17	EA.	$1,000	$17,000
Site Acquisition	1	L.S.	$25,000	$25,000
Groundwater Extraction System				
Recovery Well Installation	3	EA.	$38,000	$114,000
Submersible Pumps (installed)	3	EA.	$6,000	$18,000
4"-6" Double-Walled PVC Pipe (installed, with leak detection)	3,300	L.F.	$65	$214,500
Pre-Treatment (PO4)	1	L.S.	$15,000	$15,000
Low Profile Air Stripper (installed)	1	L.S.	$25,000	$25,000
Thermal Oxidizer (if required, installed)	1	L.S.	$185,000	$185,000
Liquid Phase Carbon Treatment System (if required, installed)	1	L.S.	$35,000	$35,000
Process Pumps	4	EA.	$5,000	$20,000
Piping (installed)	200	L.F.	$10	$2,000
Discharge Pump	2	EA.	$10,000	$20,000
Piping (installed)	50	L.F.	$30	$1,500
Treatment Building (installed)	600	S.F.	$60	$36,000
Electric				
Electric Panel and Plant Wiring	1	L.S.	$50,000	$50,000
Conduit to Wells	3,300	L.F.	$2	$6,600
General Contractor	1	L.S.	$90,000	$90,000
		Subtotal		$924,600
		Administration & Legal Costs (20%)		$184,920
		Engineering Design (10%)		$92,460
		Construction Supervision (15%)		$138,690
		Contingency (25%)		$231,150
		TOTAL CAPITAL COST - TREATMENT		$1,571,820
TOTAL CAPITAL COST - GRA 3				$1,572,000
TOTAL CAPITAL COST - SCP AT ESSO				$100,000
TOTAL CAPITAL COST - SCP AT TEXACO				$865,000
TOTAL CAPITAL COST - GRA 3 AND SCPs				$2,537,000

G:\APROJECT\TUTU\PR0013.037\DATA\GRA3CST.XLS

Table 5-10. Cost Estimate - GRA 3 (Institutional Controls/Plume Containment/Treatment/Discharge), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
O&M (ANNUAL) COSTS - GRA 3				
Groundwater Monitoring	2	Sample rounds/year	$32,000	$64,000
Electricity (Avg)	270,000	Kilowatt-hour	$0.10	$27,000
Chemical Usage (PO4)	1	L.S.	$10,000	$10,000
Supplemental Fuel (Propane)	1	L.S.	$25,000	$25,000
Carbon Replacement	2,000	Pounds of carbon	$6	$12,000
System Operation (one person - full time)	1	L.S.	$35,000	$35,000
Treatment System Monitoring (Avg)	12	EA.	$1,000	$12,000
		Subtotal		$185,000
		Administration and Legal Costs (15%)		$27,750
		Contingency (25%)		$46,250
		TOTAL ANNUAL O&M COST		$259,000
	O&M PRESENT WORTH, YEAR 30 (3% discount rate)			$5,077,000
EQUIPMENT REPLACEMENT - GRA 3				
Major Equipment Replacement	1	L.S.	$260,000	$260,000
	O&M PRESENT WORTH (Year 15) (3% discount rate)			$166,894
Minor Equipment Replacement	1	L.S.	$49,035	$49,035
	O&M PRESENT WORTH (Years 5, 10, 15, 20, 25) (3% discount rate)			$160,830
TOTAL O&M PRESENT WORTH - GRA 3				$5,405,000
O&M (ANNUAL) COSTS (TO YEAR 5) - SCPs				
SCP at Esso	1	L.S.	$60,000	$60,000
SCP at Texaco	1	L.S.	$101,000	$101,000
		TOTAL ANNUAL O&M COST		$161,000
	O&M PRESENT WORTH, YEAR 5 (3% discount rate)			$738,000
TOTAL O&M PRESENT WORTH - GRA 3 AND SCPs				$6,143,000
GRAND TOTAL - GRA 3				$6,977,000

G:\APROJECT\TUTU\PR0013.037\DATA\GRA3CST.XLS

Table 5-10. Cost Estimate - GRA 3 (Institutional Controls/Plume Containment/Treatment/Discharge), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
GRAND TOTAL - GRA 3 AND SCPs				$8,680,000

L.F. Linear feet.
S.F. Square feet.
L.S. Lump Sum.
EA. Each.
PVC Polyvinyl chloride.
PO4 Orthophosphates.
O&M Operation and maintenance.
SCP Source control plan.
GRA Groundwater remedial alternative.
Source (design and O&M assumptions) for cost estimates is provided in Appendix C.

Table 5-11. Cost Estimate - GRA 4 (Institutional Controls/Source and Plume Containment/Treatment/Discharge), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
CAPITAL COSTS				
Deed Restrictions	1	L.S.	$10,000	$10,000
Site Preparation/Mobilization	1	L.S.	$40,000	$40,000
Well Decommissioning	17	EA.	$1,000	$17,000
Site Aquisition	1	L.S.	$25,000	$25,000
Groundwater Extraction System				
Recovery Well Installation	5	EA.	$38,000	$190,000
Submersible Pumps (installed)	5	EA.	$6,000	$30,000
4"-6" Double-Walled PVC Pipe (installed, with leak detection)	5,200	L.F.	$65	$338,000
Pre-Treatment (PO4)	1	L.S.	$25,000	$25,000
Low Profile Air Stripper (installed)	1	L.S.	$40,000	$40,000
Thermal Oxidizer (if required, installed)	1	L.S.	$250,000	$250,000
Liquid Phase Carbon Treatment System (if required, installed)	1	L.S.	$50,000	$50,000
Process Pumps	4	EA.	$5,000	$20,000
Piping (installed)	200	L.F.	$10	$2,000
Discharge Pump	2	EA.	$10,000	$20,000
Piping (installed)	50	L.F.	$30	$1,500
Treatment Building (installed)	600	S.F.	$60	$36,000
Electric				
Electric Panel and Plant Wiring	1	L.S.	$70,000	$70,000
Conduit to Wells	5,200	L.F.	$2	$10,400
General Contractor	1	L.S.	$125,000	$125,000
		Subtotal		$1,299,900
		Administration & Legal Costs (20%)		$259,980
		Engineering Design (10%)		$129,990
		Construction Supervision (15%)		$194,985
		Contingency (25%)		$324,975
		TOTAL CAPITAL COST - TREATMENT		$2,209,830
TOTAL CAPITAL COST - GRA 4				$2,210,000
TOTAL CAPITAL COST - SCP AT ESSO				$100,000
TOTAL CAPITAL COST - SCP AT TEXACO				$865,000
TOTAL CAPITAL COST - GRA 4 AND SCPs				$3,175,000

G:\APROJECT\TUTU\PR0013.037\DATA\GRA4CST.XLS

Table 5-11. Cost Estimate - GRA 4 (Institutional Controls/Source and Plume Containment/Treatment/ Discharge), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
O&M (ANNUAL) COSTS				
Groundwater Monitoring	2	Sample rounds/year	$32,000	$64,000
Electricity (Avg)	470,000	Kilowatt-hour	$0.10	$47,000
Supplemental Fuel (Propane)	1	L.S.	$38,000	$38,000
Chemical Usage (PO4)	1	L.S.	$10,000	$10,000
Carbon Replacement	3,000	Pounds of carbon	$6	$18,000
System Operation (one person - full time)	1	L.S.	$35,000	$35,000
Treatment System Monitoring (Avg)	12	EA.	$1,000	$12,000
		Subtotal		$224,000
		Administration & Legal Costs (15%)		$33,600
		Contingency (25%)		$56,000
		TOTAL ANNUAL O&M COST		$313,600
O&M PRESENT WORTH, YEAR 30 (3% discount rate)				$6,147,000
EQUIPMENT REPLACEMENT - GRA 4				
Major Equipment Replacement	1	L.S.	$365,000	$365,000
	O&M PRESENT WORTH (Year 15) (3% discount rate)			$234,294
Minor Equipment Replacement	1	L.S.	$63,490	$63,490
	O&M PRESENT WORTH (Years 5, 10, 15, 20, 25) (3% discount rate)			$208,241
TOTAL O&M PRESENT WORTH - GRA 4				$6,590,000
O&M (ANNUAL) COSTS (TO YEAR 5) - SCPs				
SCP at Esso	1	L.S.	$60,000	$60,000
SCP at Texaco	1	L.S.	$101,000	$101,000
		TOTAL ANNUAL O&M COST		$161,000
O&M PRESENT WORTH - SCPs, YEAR 5 (3% discount rate)				$738,000
TOTAL O&M PRESENT WORTH - GRA 4 AND SCPs				$7,328,000
GRAND TOTAL - GRA 4				$8,800,000

G:\APROJECT\TUTU\PR0013.037\DATA\GRA4CST.XLS

Table 5-11. Cost Estimate - GRA 4 (Institutional Controls/Source and Plume Containment/Treatment/Discharge), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
GRAND TOTAL - GRA 4 AND SCPs				$10,503,000

L.F. Linear feet.
S.F. Square feet.
L.S. Lump Sum.
EA. Each.
PVC Polyvinyl chloride.
GRA Groundwater remedial alternative.
PO4 Orthophosphates.
O&M Operation and maintenance.
SCP Source control plan.

Source (design and O&M assumptions) for cost estimates is provided in Appendix C.

Table 5-12. Cost Comparison of Remedial Alternatives, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Remedial Alternative	Capital Cost	Present Worth O & M	Total Cost
SRA 1	$15,000	--	$15,000
SRA 2 and SCPs	$338,000	$441,000	$779,000
SRA 3 and SCPs	$1,561,000	$2,553,000	$4,114,000
SRA 4 and SCPs	$1,530,000	$2,524,000	$4,054,000
SRA 5 and SCPs	$2,065,000	$2,460,000	$4,525,000
GRA 1	$15,000	$1,757,000	$1,772,000
GRA 2 and SCPs	$2,366,000	$7,793,000	$10,159,000
GRA 3 and SCPs	$2,537,000	$6,143,000	$8,680,000
GRA 4 and SCPs	$3,175,000	$7,328,000	$10,503,000

SRA Soil remedial alternative.
SCPs Source control plans for the Texaco and Esso properties.
GRA Groundwater remedial alternative.
O&M Operations and maintenance.

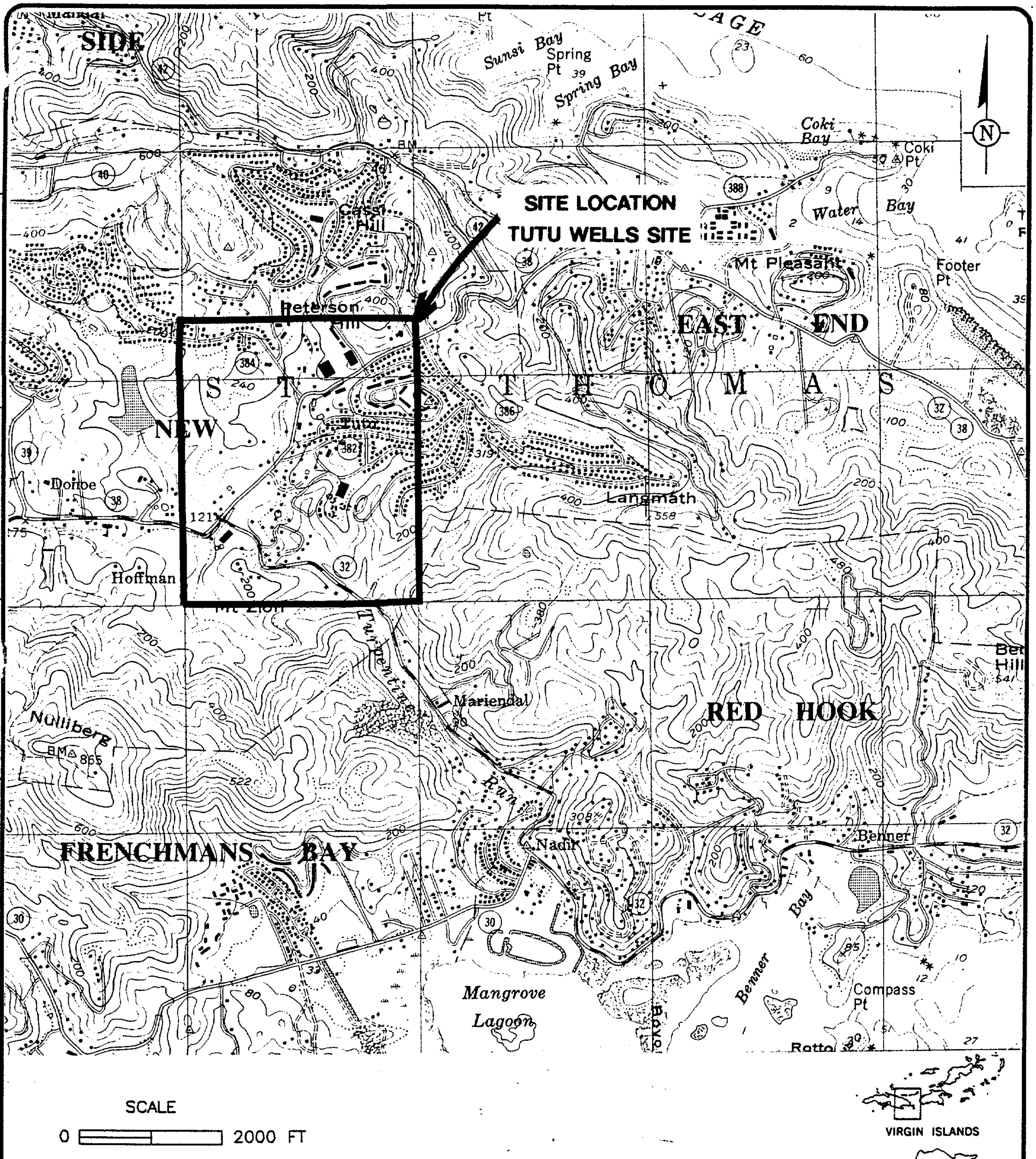
G:\APROJECT\TUTU\PR0013.037\DATA\TB512CST.XLS

Table 5-13. Summary of Comparative Analysis of Preferred Remedial Alternatives for Soil and Groundwater, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

NCP Criteria	Preferred Remedial Alternatives Soil	 Groundwater
Protection of human health and the environment.	SRA 3 and SRA 4	GRA 4
Compliance with ARARs.	SRA 3 and SRA 4	GRA 4
Short-term effectiveness.	SRA 2	GRA 2
Long-term effectiveness.	SRA 3 and SRA 4	GRA 4
Reduction of toxicity, mobility, or volume.	SRA 4	GRA 4
Implementability	SRA 3 and SRA 4	GRA 3
Cost	SRA 2	GRA 3

NCP National contingency plan.
SRA Soil remedial alternative.
GRA Groundwater remedial alternative.
ARARs Applicable or relevant and appropriate requirements.

FIGURES



SOURCE: USGS–EASTERN ST. THOMAS, VIRGIN ISLANDS, 1954 (PHOTOREVISED – 1982)

DWG | PRJCT NO.: PR0013.036 | HARD FILE: TU-421 | DRAWING: | CHECKED: D. STERN | APPROVED: T. DANAHY | DRAFTER: A. | 2-24-95

GERAGHTY & MILLER, INC.
Environmental Services
A Heidemij Company

SITE LOCATION

TUTU WELLS SITE
ST. THOMAS, U.S. VIRGIN ISLANDS

FIGURE
1-1

EPA REGION II
SCANNING TRACKING SHEET

DOC ID # 65014

DOC TITLE/SUBJECT:

TUTU WELLS SUPERFUND SITE
FIGURE 1-2
PROPERTY LOCATIONS
(Page: TUT 007 2216)

THIS DOCUMENT IS OVERSIZED AND CAN BE LOCATED IN THE ADMINISTRATIVE RECORD FILE AT THE

SUPERFUND RECORDS CENTER
290 BROADWAY, 18TH FLOOR
NEW YORK, NY 10007

EPA REGION II
SCANNING TRACKING SHEET

DOC ID # 65014

DOC TITLE/SUBJECT:

TUTU WELLS SUPERFUND SITE
FIGURE 2-1
BASE MAP WITH TOPOGRAPHIC CONTOURS
(Page: TUT 007 2217)

THIS DOCUMENT IS OVERSIZED AND CAN BE LOCATED IN THE ADMINISTRATIVE RECORD FILE AT THE

SUPERFUND RECORDS CENTER
290 BROADWAY, 18TH FLOOR
NEW YORK, NY 10007

EPA REGION II
SCANNING TRACKING SHEET

DOC ID # 65014

DOC TITLE/SUBJECT:

TUTU WELLS SUPERFUND SITE
FIGURE 2-2
OVERBURDEN THICKNESS
(Page: TUT 007 2218)

THIS DOCUMENT IS OVERSIZED AND CAN BE LOCATED IN THE ADMINISTRATIVE RECORD FILE AT THE

SUPERFUND RECORDS CENTER
290 BROADWAY, 18TH FLOOR
NEW YORK, NY 10007

EPA REGION II
SCANNING TRACKING SHEET

DOC ID # 65014

DOC TITLE/SUBJECT:

TUTU WELLS SUPERFUND SITE
FIGURE 2-3
GROUNDWATER CONTOUR MAP SHALLOW WELLS, MAY 23 TO 24, 1994
(Page: TUT 007 2219)

THIS DOCUMENT IS OVERSIZED AND CAN BE LOCATED IN THE ADMINISTRATIVE RECORD FILE AT THE

SUPERFUND RECORDS CENTER
290 BROADWAY, 18TH FLOOR
NEW YORK, NY 10007

EPA REGION II
SCANNING TRACKING SHEET

DOC ID # 65014

DOC TITLE/SUBJECT:

TUTU WELLS SUPERFUND SITE
FIGURE 2-4
GROUNDWATER CONTOUR MAP DEEP BEDROCK WELLS, MAY 23 TO 24, 1994
(Page: TUT 007 2220)

THIS DOCUMENT IS OVERSIZED AND CAN BE LOCATED IN THE ADMINISTRATIVE RECORD FILE AT THE

SUPERFUND RECORDS CENTER
290 BROADWAY, 18TH FLOOR
NEW YORK, NY 10007

EPA REGION II
SCANNING TRACKING SHEET

DOC ID # 65014

DOC TITLE/SUBJECT:

TUTU WELLS SUPERFUND SITE
FIGURE 4-1
SOIL IMPACTED WITH BTEX AND VOCS ABOVE SOIL SCREENING LEVELS CURRICULUM CENTER (FORMER LAGA FACILITY) (Page: TUT 007 2221)

THIS DOCUMENT IS OVERSIZED AND CAN BE LOCATED IN THE ADMINISTRATIVE RECORD FILE AT THE

SUPERFUND RECORDS CENTER
290 BROADWAY, 18TH FLOOR
NEW YORK, NY 10007

EPA REGION II
SCANNING TRACKING SHEET

DOC ID # 65014

DOC TITLE/SUBJECT:

TUTU WELLS SUPERFUND SITE
FIGURE 4-2
SOIL IMPACTED WITH BTEX ABOVE SOIL SCREENING LEVELS RAMSAY MOTORS
(Page: TUT 007 2222)

THIS DOCUMENT IS OVERSIZED AND CAN BE LOCATED IN THE ADMINISTRATIVE RECORD FILE AT THE

SUPERFUND RECORDS CENTER
290 BROADWAY, 18TH FLOOR
NEW YORK, NY 10007

EPA REGION II
SCANNING TRACKING SHEET

DOC ID # 65014

DOC TITLE/SUBJECT:

TUTU WELLS SUPERFUND SITE
FIGURE 4-3
SOIL IMPACTED WITH BTEX ABOVE SOIL SCREENING LEVELS TEXACO TUTU SERVICE STATION (Page: TUT 007 2223)

THIS DOCUMENT IS OVERSIZED AND CAN BE LOCATED IN THE ADMINISTRATIVE RECORD FILE AT THE

SUPERFUND RECORDS CENTER
290 BROADWAY, 18TH FLOOR
NEW YORK, NY 10007

EPA REGION II
SCANNING TRACKING SHEET

DOC ID # 65014

DOC TITLE/SUBJECT:

TUTU WELLS SUPERFUND SITE
FIGURE 4-4
SOIL IMPACTED WITH PCBS AND MANGANESE ABOVE USEPA RISK ASSESSMENT VALUES TILLETT GARDENS
(Page: TUT 007 2224)

THIS DOCUMENT IS OVERSIZED AND CAN BE LOCATED IN THE ADMINISTRATIVE RECORD FILE AT THE

SUPERFUND RECORDS CENTER
290 BROADWAY, 18TH FLOOR
NEW YORK, NY 10007

EPA REGION II
SCANNING TRACKING SHEET

DOC ID # 65014

DOC TITLE/SUBJECT:

TUTU WELLS SUPERFUND SITE
FIGURE 4-5
SOIL IMPACTED WITH BTEX ABOVE SOIL SCREENING LEVELS ADJACENT TO THE WESTERN AUTO FACILITY
(Page: TUT 007 2225)

THIS DOCUMENT IS OVERSIZED AND CAN BE LOCATED IN THE ADMINISTRATIVE RECORD FILE AT THE

SUPERFUND RECORDS CENTER
290 BROADWAY, 18TH FLOOR
NEW YORK, NY 10007

EPA REGION II
SCANNING TRACKING SHEET

DOC ID # 65014

DOC TITLE/SUBJECT:

TUTU WELLS SUPERFUND SITE
FIGURE 4-6
SOIL IMPACTED WITH BTEX AND VOCS
ABOVE SOIL SCREENING LEVELS ESSO
TUTU SERVICE STATION (Page: TUT 007 2226)

THIS DOCUMENT IS OVERSIZED AND CAN BE LOCATED IN THE ADMINISTRATIVE RECORD FILE AT THE

SUPERFUND RECORDS CENTER
290 BROADWAY, 18TH FLOOR
NEW YORK, NY 10007

EPA REGION II
SCANNING TRACKING SHEET

DOC ID # 65014

DOC TITLE/SUBJECT:

TUTU WELLS SUPERFUND SITE
FIGURE 4-7
SOIL IMPACTED WITH VOCS ABOVE SOIL SCREENING LEVELS O'HENRY DRY CLEANERS (Page: TUT 007 2227)

THIS DOCUMENT IS OVERSIZED AND CAN BE LOCATED IN THE ADMINISTRATIVE RECORD FILE AT THE

SUPERFUND RECORDS CENTER
290 BROADWAY, 18TH FLOOR
NEW YORK, NY 10007

EPA REGION II
SCANNING TRACKING SHEET

DOC ID # 65014

DOC TITLE/SUBJECT:

TUTU WELLS SUPERFUND SITE
FIGURE 4-8
CAPTURE ZONES OF PROPOSED SOURCE CONTROL PLANS FOR BTEX CONSTITUENTS
(Page: TUT 007 2228)

THIS DOCUMENT IS OVERSIZED AND CAN BE LOCATED IN THE ADMINISTRATIVE RECORD FILE AT THE

SUPERFUND RECORDS CENTER
290 BROADWAY, 18TH FLOOR
NEW YORK, NY 10007

EPA REGION II
SCANNING TRACKING SHEET

DOC ID # 65014

DOC TITLE/SUBJECT:

TUTU WELLS SUPERFUND SITE
FIGURE 4-9
PROJECTED CAPTURE ZONES FOR
GROUNDWATER REMEDIAL ALTERNATIVE
GRA 4 (Page: TUT 007 2229)

THIS DOCUMENT IS OVERSIZED AND CAN BE LOCATED IN THE ADMINISTRATIVE RECORD FILE AT THE

SUPERFUND RECORDS CENTER
290 BROADWAY, 18TH FLOOR
NEW YORK, NY 10007

EPA REGION II
SCANNING TRACKING SHEET

DOC ID # 65014

DOC TITLE/SUBJECT:

TUTU WELLS SUPERFUND SITE
FIGURE 4-10
GENERALIZED COMBINED CAPTURE ZONES
(Page: TUT 007 2230)

THIS DOCUMENT IS OVERSIZED AND CAN BE LOCATED IN THE ADMINISTRATIVE RECORD FILE AT THE

SUPERFUND RECORDS CENTER
290 BROADWAY, 18TH FLOOR
NEW YORK, NY 10007

EPA REGION II
SCANNING TRACKING SHEET

DOC ID # 65014

DOC TITLE/SUBJECT:

TUTU WELLS SUPERFUND SITE
FIGURE 4-11
SCHEMATIC OF GROUNDWATER TREATMENT OPTION FOR DISCHARGE TO SURFACE WATER (Page: TUT 007 2231)

THIS DOCUMENT IS OVERSIZED AND CAN BE LOCATED IN THE ADMINISTRATIVE RECORD FILE AT THE

SUPERFUND RECORDS CENTER
290 BROADWAY, 18TH FLOOR
NEW YORK, NY 10007

EPA REGION II
SCANNING TRACKING SHEET

DOC ID # 65014

DOC TITLE/SUBJECT:

TUTU WELLS SUPERFUND SITE
FIGURE 5-1
CONCEPTUAL LAYOUT OF PROPOSED GROUNDWATER REMEDIES
(Page: TUT 007 2232)

THIS DOCUMENT IS OVERSIZED AND CAN BE LOCATED IN THE ADMINISTRATIVE RECORD FILE AT THE

SUPERFUND RECORDS CENTER
290 BROADWAY, 18TH FLOOR
NEW YORK, NY 10007

APPENDIX A

APPENDIX A

SUMMARY OF DESIGN ASSUMPTIONS FOR POTABLE WATER DISCHARGE COST ESTIMATE

APPENDIX A

SUMMARY OF DESIGN ASSUMPTIONS FOR POTABLE WATER DISCHARGE COST ESTIMATE

To evaluate the cost for selecting discharge option for potable use, the various design assumptions for potable treatment and discharge for Groundwater Remedial Alternative 4 (GRA 4) are presented below. A detailed cost estimate for potable discharge for GRA 4 is presented in Table A-1. Estimated costs are based on means cost estimating data, vendor information, and engineering experience. The accuracy of such cost estimates is in conformance with current USEPA guidance (+50 percent to -30 percent). Comparison of the cost for potable discharge with the discharge to surface water option for GRA 4 demonstrates that the potable use discharge option is much more costly. Because the potable use discharge option is not cost-effective and it may be difficult to implement, this discharge option was not used in the assembly of GRAs in this FS Report.

DESIGN ASSUMPTIONS FOR GROUNDWATER EXTRACTION SYSTEMS

1. Design assumptions for deed restrictions, mobilization, well decommissioning, and groundwater extraction systems are the same as for the discharge to surface water.

DESIGN ASSUMPTIONS FOR SITE ACQUISITION

1. Cost of property purchase for treatment area and for obtaining right-of-ways for recovery wells. Property required is assumed to be two times greater for a potable (approximately 1.5 acres) vs. non-potable (approximately 0.75 acre) application.

DESIGN ASSUMPTIONS FOR GROUNDWATER TREATMENT SYSTEM

1. Chemical treatment for potable use assumed to be ion exchange (for inorganic solids removal). Cost assumes all components necessary to run ion exchange unit.

Component sizing is based on estimated flow rates. Backwash from the ion exchange is assumed to be discharged to the publicly-owned treatment works (POTW) (+ 1,200 gallons/day).

2. Sand filters are assumed to be dual media type with 4 gallon per minute/square foot (gpm/sf) application rate, based on estimated flow. A portion or all of the backwash (if required) will be recovered to the head of the plant.

3. For GRA 2 and GRA 3, a 5,000-gallon sludge holding tank (thickener) for process waste from ion exchange and potentially a portion of backwash effluent (if required) is assumed. For GRA 4, an 8,000-gallon tank and appurtenances are assumed.

4. For GRA 2 and GRA 3, the nitric acid feed for pH adjustment is estimated at a maximum of 2 gallons per day (gpd), if needed, and includes all associated appurtenances. For GRA 4, the nitric acid feed for pH adjustment is estimated at a maximum of 3 gpd, if needed, and includes all associated appurtenances.

5. The low-profile air stripper is a tray aeration unit with blower, controls, and appurtenances. The unit costs are based on vendor quotes, based on the estimated groundwater quality for each GRA and the estimated flow rate. Based on the preliminary VOC concentrations, one stripper is assumed to be sufficient to treat the groundwater.

6. The thermal oxidizer, if required, is assumed to be a 1,000-standard cubic feet per minute (scfm) unit for GRA 2 and GRA 3, with fan, controls, and appurtenances. For GRA 4, a 2,000-scfm unit is assumed with all associated appurtenances. Preliminary calculations indicate that air treatment associated with the groundwater treatment system is not required for any of the GRAs considered. Final design

evaluations may vary; therefore, thermal oxidation for treatment of air discharge is included.

7. Liquid phase granular activated carbon (GAC) treatment is provided as a back-up "polishing unit," in case the air stripper malfunctions. For GRA 2 and GRA 3, GAC units were assumed to be two 2,000-pound units in parallel, with a permanent installation. For GRA 4, GAC units are assumed to be configured in the same manner except 3,000-pound units in parallel would be used. By-pass piping can be provided to minimize carbon use.

8. Process pumps are assumed to be centrifugal pumps rated as follows:

   - GRA 2 (four) 2-horsepower (hp) pumps, piping and appurtenances.
   - GRA 3 (four) 2-hp pumps, piping and appurtenances.
   - GRA 4 (four) 5-hp pumps, piping and appurtenances.

   Potable use includes a backup pump.

9. Discharge pumps are assumed to be vertical turbine pumps rated as follows:

   - GRA 2 (two) 2-hp pumps, piping and appurtenances.
   - GRA 3 (two) 2-hp pumps, piping and appurtenances.
   - GRA 4 (two) 5-hp pumps, piping and appurtenances.

   Potable use includes a backup pump.

10. A holding tank is assumed to be aboveground, welded steel construction with concrete foundation, level measuring devices, and appurtenances. The tank is sized to provide approximately 1 day storage based on the estimated flow rate capacity of the facility.

11. A distribution tank, assumed to be an elevated welded steel tank with concrete foundation, level measuring devices, and appurtenances, sized to provide approximately 2 days' storage based on the estimated flow rate capacity of the facility.

12. The treatment building is sized to accommodate major equipment components of the treatment facility. The cost includes labor and equipment, and butler type building set on a poured concrete foundation.

13. Lump sum cost for electrical includes Motor Control Center (MCC), starters, electric service and connections, controls and control panel, leak detection, and remote dial out. Electrical conduit will go to each well for the submersible pumps and use the same trench as the extraction piping (it is assumed that no emergency back up power will be provided).

14. It is assumed that for GRA 3 and GRA 4, water will continue to be supplied as it is now, by rainwater cisterns or by trucking water.

Operation & Maintenance (O&M) Assumptions for GRAs

1. Electrical costs are for the well pumps, blowers, and process and discharge pumps associated with the treatment units. An allowance for building heating and lighting is also included. The power usage is estimated to be equivalent to 62 hp, operating 24 hours a day plus 25 percent. Cost estimates been made utilizing an average price of electricity per kilowatt hour of $ 0.10.

2. Chemical usage based influent groundwater quality and estimated influent flow rate, and vendor quotation. Storage is not provided because the product is delivered in storage containers.

3. Carbon replacement is assumed to be minimal due to the redundancy provided by the air stripper. For GRA 4, it is assumed that one unit change-out every year (3,000 lbs) will be performed.

4. Supplemental fuel for Therm-Ox is assumed to be propane. For the 1,000-scfm unit, 10,000 therms/year (equivalent to 100,000 BTUs per year) at $1.00/therm is assumed, and 15,000 therms/year is assumed for the 2,000-scfm unit.

5. System operation assumes one full-time person for the treatment facility and effluent monitoring.

6. System monitoring is expressed as a sampling average annually. It is assumed that 30 samples will be collected to monitor quality for potable use (1 sample every 2 weeks plus 4 will be required for compliance monitoring). Additional samples will be collected and tested by the operator using a portable gas chromatograph (GC) on average of two samples per week.

ASSUMPTIONS FOR EQUIPMENT INSTALLATION AND MATERIAL REPLACEMENT

1. Major equipment replacement entails complete replacement of process equipment such as air strippers, portable GC, GAC, and ion exchange units, and 10 percent of the storage tanks' capital cost (for painting and maintenance)

2. Minor equipment replacement entails replacing pumps and blowers, etc., every 5 years (10 percent of chemical treatment and electrical costs, 5 percent of groundwater recovery systems [includes well pumps and treatment building], 50 percent for discharge and process pumps and piping).

Table A-1. Estimated Cost of Potable Discharge Option for GRA 4 (Institutional Controls, Source and Plume Containment, Treatment, and Discharge), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
CAPITAL COSTS				
Deed Restrictions	1	L.S.	$10,000	$10,000
Site Preparation/Mobilization	1	L.S.	$25,000	$25,000
Well Decommissioning	17	EA.	$1,000	$17,000
Site Acquisition	1	L.S.	$25,000	$25,000
Groundwater Extraction System				
Recovery Well Installation	5	EA.	$38,000	$190,000
Submersible Pumps (Installed)	5	EA.	$6,000	$30,000
4"-6" Double-Walled PVC Pipe (Installed, with Leak Detection)	5,200	L.F.	$65	$338,000
Chemical Treatment (Ion Exchange)	1	L.S.	$85,000	$85,000
Low Profile Air Stripper (Installed)	1	L.S.	$40,000	$40,000
Thermal Oxidizer (If required, installed)	1	L.S.	$250,000	$250,000
Sand Filters with Backwash Pump	1	L.S.	$70,000	$70,000
Liquid Phase Carbon Treatment System (If required, Installed)	1	L.S.	$50,000	$50,000
Sludge Handling Equipment	1	L.S.	$20,000	$20,000
Process Pumps	4	EA.	$5,000	$20,000
Piping (Installed)	400	L.F.	$10	$4,000
Discharge Pump	2	EA.	$10,000	$20,000
Piping (Installed)	100	L.F.	$30	$3,000
pH Adjustment System	1	L.S.	$10,000	$10,000
Holding Tank (144,000 gallons, installed)	1	L.S.	$180,000	$180,000
Elevated Distribution Tank (290,000 gallons, installed)	1	L.S.	$725,000	$725,000
Treatment Building (Installed)	1,600	S.F.	$60	$96,000
Portable GC Analyzer	1	L.S.	$20,000	$20,000
Electric				
Electric Panel and Plant Wiring	1	L.S.	$100,000	$100,000
Conduit to Wells	5,200	L.F.	$2	$10,400
General Contracting	1	L.S.	$240,000	$240,000
		Subtotal		$2,578,400
		Administration & Legal Costs (20%)		$515,680
		Engineering Design (10%)		$257,840
		Construction Supervision (15%)		$386,760
		Contingency (25%)		$644,600
		TOTAL CAPITAL COST - TREATMENT		$4,383,280
TOTAL CAPITAL COST - GRA 4				$4,384,000

Table A-1. Estimated Cost of Potable Discharge Option for GRA 4 (Institutional Controls, Source and Plume Containment, Treatment, and Discharge), Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

ITEMS	QUANTITY	UNIT	UNIT COST	TOTAL COST
O&M (ANNUAL) COSTS				
Groundwater Monitoring	2	Sample rounds/year	$32,000	$64,000
Electricity (Avg)	511,000	Kilowatt-hour	$0.10	$51,100
Supplemental Fuel (Propane)	1	L.S.	$15,000	$15,000
Carbon Replacement	3,000	Pounds of Carbon	$6	$18,000
Chemical Usage	1	L.S.	$10,000	$10,000
Sludge Disposal (non-hazardous)	350	C.Y.	$350	$122,500
System Operation (One person - full time)	1	L.S.	$35,000	$35,000
Treatment System Monitoring (Avg)	30	EA.	$1,000	$30,000
GC Chemical Buffer Solutions and Equipment	1	L.S.	$5,000	$5,000
		Subtotal		$350,600
		Administration & Legal Costs (10%)		$35,060
		Contingency (25%)		$87,650
		TOTAL ANNUAL O&M COST		$473,310
	O&M PRESENT WORTH, YEAR 30 (3% discount rate)			$9,277,065
EQUIPMENT REPLACEMENT				
Major Equipment Replacement	1	L.S.	$365,500	$365,500
	O&M PRESENT WORTH (Year 15) (3% discount rate)			$234,600
Minor Equipment Replacement	1	L.S.	$87,740	$87,740
	O&M PRESENT WORTH (Years 5, 10, 15, 20, 25) (3% discount rate)			$287,774
TOTAL O&M PRESENT WORTH - GRA 4				$9,800,000
GRAND TOTAL - GRA 4				$14,184,000

L.F.	Linear feet.
S.F.	Square feet.
L.S.	Lump Sum.
EA.	Each.
gpm	Gallons per minute.
GAC	Granular Activated Carbon.
PO4	Orthophosphates.
O&M	Operation and maintenance.
GC	Gas-Chromatography.
Note:	Refer to Appendix C for source (design and O & M assumptions) for cost estimates.

EPA REGION II
SCANNING TRACKING SHEET

DOC ID # 65014

DOC TITLE/SUBJECT:

TUTU WELLS SUPERFUND SITE
FIGURE A-1
SCHEMATIC OF GROUNDWATER TREATMENT OPTION FOR POTABLE USE
(Page: TUT 007 2242)

THIS DOCUMENT IS OVERSIZED AND CAN BE LOCATED IN THE ADMINISTRATIVE RECORD FILE AT THE

SUPERFUND RECORDS CENTER
290 BROADWAY, 18TH FLOOR
NEW YORK, NY 10007

APPENDIX B

APPENDIX B

SUMMARY OF CAPTURE ZONE ANALYSES

APPENDIX B

SUMMARY OF CAPTURE ZONE ANALYSES

CAPTURE ZONE ANALYSIS FOR THE TEXACO TUTU SERVICE STATION SOURCE CONTROL PLAN

For the purposes of this FS Report the following assumptions for the proposed Source Control Plan for the Texaco Tutu Service Station were used to calculate the potential capture zone for the proposed extraction wells. These assumptions are based on the aquifer characteristics presented in the RI report (Geraghty & Miller, Inc. 1995) and the proposed Source Plan prepared by Erler and Kalinowsky, Inc. (EKI) (1995a).

The proposed extraction wells for source control near the Texaco Tutu Service Station include the following:

- Proposed Texaco Extraction Well TEW-1 will replace Monitoring Well TT-1 (at the Texaco Tutu Service Station);

- Proposed Texaco Extraction Well TEW-2 will be located approximately 25 feet west of Monitoring Well MW-7 (at the Vitelco Property).

In addition, a third shallow Texaco Extraction Well TEW-3 is proposed at the Texaco Tutu Service Station as a contingency if proposed Texaco Extraction Well TEW-1 cannot obtain the desired capture. Deep extraction wells TEW-1D, TEW-2D, and TEW-3D are also proposed for groundwater monitoring and possibly pumping, if necessary, to achieve capture throughout the vertical extent of groundwater contamination.

The well screens for the proposed extraction wells TEW-1 and TEW-2 would be placed at 170 feet to 140 feet msl (EKI 1995a). For groundwater modeling, EKI selected the elevation of 90 feet msl as the base of the aquifer (i.e., approximate saturated thickness of 72 feet) based on the projected maximum depth of benzene, toluene, ethylbenzene, and xylene (BTEX) contamination. This depth would be the designed maximum depth for capture of contaminants. EKI (1995b) prepared a capture zone analysis based on numerical modeling of groundwater flow. The predicted capture zone for the combined effect of pumpage from the two proposed primary shallow Texaco Extraction Wells TEW-1 (at 20 gpm) and TEW-2 (at 10 gpm) was prepared by EKI (1995b) and is shown on Figure 4-8.

CAPTURE ZONE ANALYSIS FOR THE ESSO TUTU SERVICE STATION SOURCE CONTROL PLAN

For the purposes of this FS Report, the following assumptions for the proposed Source Control Plan for the Esso Service Station were used to calculate the potential capture zone for the proposed extraction wells. These assumptions are based on the aquifer characteristics presented in the RI report (Geraghty & Miller, Inc. 1995), the well selection and estimated pumping rates from Forensic Environmental Services, Inc. (FES) (1995), and the proposed Source Control Plan prepared by FES.

The proposed extraction wells for source control at the Esso Tutu Service Station include the following: Monitoring Well SW-1, Monitoring Well SW-7, Monitoring Well CHT-3, and Monitoring Well MW-9. Existing monitoring wells are proposed to be used as extraction wells for the Esso Tutu Service Station.

FES prepared and plotted the results of capture zone analyses for the four proposed extraction wells based on an aquifer thickness of 50 feet. This depth would be the designed maximum depth for the capture of BTEX contaminants. For the purpose of this FS Report, the predicted capture zones of the four proposed primary shallow extraction wells are shown on Figure 4-8.

SITE-WIDE CAPTURE ZONE ANALYSIS

The dimensions of the capture zones for potential Recovery Wells RW-1, RW-2, RW-3, RW-4, and RW-5 under the pumping scenario for GRA 4 were calculated using Equation 1 described below. The capture zones and locations of the recovery wells are shown on Figure 4-9.

Equation 1:

$y = (Q/(2\pi TI) \arctan(y/x)$ (USEPA 1991c)

where

- y = Distance from the center axis of the capture zone to the edge, in feet.
- x = Distance from the recovery well along the axis of the capture zone to the downgradient edge, in feet.
- Q = Pumping rate of recovery well, in gallons per day (gpd).
- T = Transmissivity of the formation, in gpd/foot.
- I = Local hydraulic gradient. (I = change in hydraulic head/change in distance.)

To adequately plot the capture zones, three dimensions are needed:

- W_o The width of the capture zone in the immediate vicinity of the recovery well.
- X_o The distance from the well to the downgradient extent of the capture zone.
- W The maximum width of the capture zone, upgradient of the recovery well.

Solving Equation 1 for the above parameters, the following equations were obtained:

Equation 2: $W_o = Q/(2\,TI)$, and (USEPA 1987, 1991c)

Equation 3: $X_o = Q/(2\pi TI)$ (USEPA 1987, 1991c)

Using Equation 2, the pumping rate of the recovery well was calculated with the following equation:

$$Q = W_o (2TI)$$

where

W_o is measured on Figure 4-9.

T is obtained from the results of nearby pumping tests;

I is calculated from the groundwater contours shown on Figure 4-9.

The variables used to solve for the dimensions of capture zones are listed in Table B-1.

Equation 3 was used to calculate the distance X_o.

where

Q is the pumping rate obtained from Equation 2, and T and I were the variables described above.

Due to the high calculated pumping rate necessary for capture, two adjacent recovery wells, Recovery Wells RW-2 and RW-3, were proposed for the capture of the southern plume of chlorinated volatile organic compounds (VOCs).

The optimum spacing of the pumping wells was calculated with the following equation:

Equation 4:

$$D = Q/(2 \pi TI)$$

using the variables in Table B-1,

$Q = 6.68\ ft^3/\ min$

$T = 0.14\ ft^2/\ min$

$I = 0.079$

$D = 96.6$ feet.

g:\aproject\tutu\PR0013.037\reports\captzone.doc

Table B-1. Values Used to Determine Capture Zones and Pumping Rates of Proposed Pumping Wells, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Recovery Well	Location	Capture Zone Width (W_o) (feet)	Estimated Transmissivity (T) (ft_2/min)	Hydraulic Gradient (I)	Pumping Rate (Q) (ft_3/min)	Pumping Rate (Q) (gpm)	Downgradient Dimension (X_o) (feet)
Esso Tutu Service <u>Station - Source Control Plan</u>							
MW-9		26.9	0.024	0.0426	0.33	2.5	8.6
SW-7		26.9	0.024	0.0426	0.33	2.5	8.6
SW-1		26.9	0.024	0.0426	0.33	2.5	8.6
CHT-3		26.9	0.024	0.0426	0.33	2.5	8.6
<u>Site-Wide Recovery Wells</u>							
RW-1	Toe of northern plume	170	0.14	0.04	1.9	14.3	54.1
RW-2 and RW-3	Toe of southern plume	260	0.14 (assumed)	0.079 (assumed)	5.75	43	82.8
RW-4	LAGA/Curriculum Center	250	0.14	0.033	2.31	17.5	79.6
RW-5	O'Henry Dry Cleaners	211	0.14	0.079	5.2	35	75.4

Capture zone analyses for Texaco Extraction Wells TEW-1 and TEW-2 prepared by Erler & Kalinowski, Inc. (EKI, 1995b).

ft_2/min Square feet per minute.
ft_3/min Cubic feet per minute.
gpm Gallons per minute.

APPENDIX C

APPENDIX C

SUMMARY OF DESIGN ASSUMPTIONS FOR SOIL AND GROUNDWATER REMEDIATION COST ESTIMATES

APPENDIX C

SUMMARY OF DESIGN ASSUMPTIONS FOR SOIL AND GROUNDWATER REMEDIATION COST ESTIMATES

Note: Estimated costs are based on Means Cost Estimating Data, vendor information, and engineering experience. The accuracy of such cost estimates is in conformance with current U.S. Environmental Protection Agency (USEPA) Guidance (+50 percent to -30 percent).

SOIL

COST ASSUMPTIONS FOR DEED RESTRICTIONS

1. Deed Restrictions for soils are as described in SRA 1, and include estimated costs for filing and application fees. Administrative and legal fees are included in a separate line item.

DESIGN ASSUMPTIONS FOR CAPPING (ALL SITES)

1. 6-inch thick, compacted gravel base.

2. For areas where there is pavement currently in place, installation will match existing conditions.

3. 3-inch thick layer of bituminous paving with seal coat.

4. At Ramsay Motors, it is assumed that complete replacement of concrete floor will be required (4-inch thick slab on grade, 6-inch by 6-inch welded wire mesh reinforcement, formed and in place). The cap will be formed concrete which is

typically estimated by the cubic yard (CY). This is different that the estimated costs for pavement capping which is estimated based on the area to be capped in square yards (SY).

5. Estimated costs for pavement installation assumes that paving is completed at the same time; under one paving contract.

6. Operation and maintenance (O&M) consists of inspection for cap integrity and, if necessary, application of surface treatments to improve the effectiveness of asphalt caps.

7. Complete replacement of each cap is assumed at year 15.

DESIGN ASSUMPTIONS FOR EXCAVATION AND OFF-SITE DISPOSAL (SRA 5)

1. Administrative, legal and engineering cost percentages are higher for this SRA (when compared to other SRAs) due to the increased regulatory requirements and administrative duties associated with the transport of hazardous material. Engineering design includes work plan preparation, implementation plan and permitting. Administrative and legal fees include tracking of manifests, filing, contracting with haulers and disposal facilities, and an allowance for legal fees related to the remedial action.

2. Excavation areas and volumes based on Table 4-5.

3. Cost to excavate includes labor and equipment, and excavation support (e.g., sheet piling) where needed.

4. Cost of disposal assumes off-island disposal to southeast, United States. Includes transport, freight, and disposal.

5. Site restoration includes importing clean backfill from a local source, compaction, and restoration to or near current conditions.

6. It is assumed that one land disposal restriction (LDR) testing sample will be required for every 20 cubic yards (CY) of soil excavated.

7. It is assumed that no O&M will be required after completion of the excavation and disposal SRA.

DESIGN ASSUMPTIONS FOR IN-SITU SOIL VAPOR EXTRACTION (SVE)

<u>General Assumptions (for all properties)</u>

1. Administrative and legal fees include filing, contracting with consultants and vendors, and an allowance for legal fees related to the remedial action. Engineering design fees include pilot testing, work plan preparation, design of SVE system and preparation of an implementation plan and permitting. Construction fees include environmental monitoring and construction observation.

2. Separate line items are provided for soil source control plans (SCPs) at Texaco Tutu Service Station and Esso Tutu Service Station. These estimates are lump sum amounts which represent the total estimated costs of the SCPs (including engineering design, administrative and legal costs). These estimates are based on independent consultant estimates taken from SCP designs currently being formulated and are included for informational purposes.

3. SCPs are assumed to be in operation for 5 years.

Curriculum Center (in Bedrock) (Assumes 30-Year Operation Life)

1. Site characterization of potential DNAPL locations.

2. Three-SVE wells to ± 60 feet below land surface (bls) (into bedrock). (20 standard cubic feet per minute [scfm] shall be evacuated from each well [total 60 scfm]).

3. One-5 horsepower (hp) blower with filter and moisture knockout and temporary enclosure (skid mounted).

4. 500 linear feet of trenching (2-feet wide x 4-feet deep).

5. 500 linear feet of 4-inch diameter PVC pipe.

6. Trenching includes excavation, backfill, and compaction, and bedrock removal (assumes 50 percent rock removal and restoration).

7. Thermal oxidizer (Therm-Ox) for vapor phase treatment (100 scfm unit). Where ex-situ SVE is applied, Therm-Ox proposed will have sufficient capacity to treat both air flow rates (100 scfm-60scfm = 40scfm). No vapor treatment of hydrochloric acid is assumed.

8. Cost for air permit and modeling, if necessary.

9. O&M costs:

   - Electrical for blower and Therm-Ox $4,500/year (45,000 kW-hr/yr @ $0.10/kW-hr).

   - System operator $12,000/year.

- Air sampling (assumes 26 samples/year @ $500/sample).

- Supplemental fuel (propane) (5,000 therms/year @ $1.0/therm).

<u>O'Henry Dry Cleaners</u> (in Bedrock) (Assumes 30-Year Operation Life)

1. Site characterization of potential DNAPL locations.

2. Three-SVE wells to ± 40 feet below land surface (bls) (into bedrock).

3. One-5 horsepower (hp) blower with filter and moisture knockout and temporary enclosure (skid mounted).

4. 200 linear feet of trenching (2-feet wide x 4-feet deep).

5. 200 linear feet of 4-inch diameter PVC pipe.

6. Trenching includes excavation, backfill, and compaction.

7. Therm-Ox for vapor phase treatment (100 scfm unit) where in-situ and ex-situ SVE is applied it is assumed that the unit proposed will have adequate capacity (100 scfm - 20 scfm = 80 scfm). A new unit is proposed when combined with excavation and disposal

8. Cost for air permit and modeling, if necessary.

9. O&M costs:

   - Electrical for blower and Therm-Ox $4,500/year (45,000 kW-hr/yr @ $0.10/kW-hr).
   - System operator $12,000/year.
   - Air sampling (assumes 26 samples/year @ $500/sample).
   - Supplemental fuel (propane) (5,000 therms/year @ $1.0/therm).

<u>O'Henry Dry Cleaners</u> (in Soils) (Assumes 5-Year Operation Life)

1. One-SVE well ± 20 feet bls.

2. One-2-hp blower with filter and moisture knockout on skid, and temporary enclosure (skid mounted).

3. Blower skid placed adjacent to SVE well (minimal piping and trenching).

4. Vapor phase treatment is assumed to utilize the Therm-Ox unit proposed for in-situ treatment of bedrock.

5. Cost for air permit, if needed.

6. O&M costs:
   - Added electrical cost for the additional blower $ 2,500/year (25,000 kw-hr/yr @ $ 0.10/kw-hr). Other costs for O & M are included for the in-situ SVE system that is installed for bedrock.

- Soil compliance sampling (assumes 4 samples/year TCL VOCs and sampling equipment ($3,000/sample).

<u>Texaco Tutu Service Station</u> (In Soils) (Assumes 5-Year Operation Life)

1. Based on SCP and estimated costs prepared by Erler and Kalinowski, Inc.

<u>Esso Tutu Service Station</u> (In Soils) (Assumes 5-Year Operation Life)

1. Based on SCP and estimated costs prepared by Forensic Environmental, Inc.

DESIGN ASSUMPTIONS FOR EX-SITU SVE
(By Property)

<u>General Assumptions (for all properties)</u>

1. Administrative and legal fees include filing, contracting with consultants and vendors, and an allowance for legal fees related to the remedial action. Engineering design fees include pilot testing, work plan preparation, design of SVE system and preparation of an implementation plan and permitting. Construction fees include environmental monitoring and construction observation.

2. A 2-year operating period is assumed.

3. Excavation areas and volumes based on Table 4-5.

4. Cost to excavate includes labor and equipment, excavation support [e.g., sheet piling] where needed.

5. Excavated soil will be stockpiled in prepared areas (e.g., plywood enclosure with SVE piping and liner installation). It is assumed that sufficient area is available at each property.

6. Vapor emissions will be treated with Therm-Ox units, if required.

7. SVE piping and blower sized for each stockpiled area (2-hp blower with and moisture knockout [skid], temporary enclosure and 100 linear feet of perforated piping).

8. Site restoration includes using treated excavated soil as compacted backfill and pavement restoration, if required.

9. O&M consists of electrical costs for the blowers and Therm-Ox unit. Soil sampling of stockpiled soil (four composite, every 6 months).

10. O&M costs:

    - Soil sampling of stockpiled soil (assumes eight samples/year @ $1,500/sample).

11. The estimated cost to install ex-situ SVE at the Curriculum Center and existing ex-situ at O'Henry assumes the treatment system associated with the in-situ SVE treatment system for bedrock will be used. An additional blower and piping will be added for the ex-situ treatment. O&M costs associated with air treatment are included under costs for O&M for in-situ SVE system in bedrock.

ASSUMPTIONS FOR EQUIPMENT INSTALLATION AND MATERIAL REPLACEMENT

1. Major equipment replacement entails complete replacement of Therm-Ox units at the Curriculum Center and O'Henry dry cleaners.

2. Minor equipment entails complete replacement of blower and appurtenances at the Curriculum Center and O'Henry dry cleaners.

GROUNDWATER

General Assumptions (for all properties)

1. Administrative and legal fees include filing, contract negotiations, and an allowance for legal fees related to the remedial action. Engineering design fees include pilot testing, work plan preparation, design of groundwater collection and treatment system, and preparation of an implementation plan and permitting. Construction fees include environmental monitoring and construction observation.

2. Separate line items are provided for groundwater source control plans (SCPs) at Texaco Tutu Service Station and Esso Tutu Service Station. These estimates are lump sum amounts which represent the total estimated costs of the SCPs (including engineering design, administrative and legal costs). These estimates are based on independent consultant estimates taken from SCP designs currently being formulated; and are included for informational purposes.

3. SCPs are assumed to be in operation for 5 years.

DESIGN ASSUMPTIONS FOR DEED RESTRICTIONS

1. Deed Restrictions for groundwater are as described in GRA 1, and include estimated costs for filing and application fees.

2. The monitoring program assumes sampling and analysis of 15 wells and analyzing for TCL VOCs, semi-annually.

DESIGN ASSUMPTIONS FOR SITE PREPARATION/MOBILIZATION

1. Site preparation, mobilization includes grading for access roads, treatment building, and access to recovery wells.

DESIGN ASSUMPTIONS FOR WELL DECOMMISSIONING

1. Wells will be decommissioned by using locked well seals to prevent use and to allow access only for sampling.

DESIGN ASSUMPTIONS FOR SITE ACQUISITION

1. Cost of property purchase for treatment area, and obtaining right-of-ways for recovery wells. Property required is assumed to be approximately 0.75 acre.

DESIGN ASSUMPTIONS FOR GROUNDWATER EXTRACTION SYSTEMS

1. Recovery well installation includes drilling, material (black steel casing, stainless steel screen, etc.), well development, and well head enclosure. Depth of wells is assumed to be 150 feet into bedrock.

2. Cost for piping includes labor and equipment for trenching and backfilling. Assumes open trench installation. Preliminary piping layouts are mainly beneath existing roads for easier access approval and implementation. Minimal rock excavation is assumed.

3. Well pumps are assumed to be as follows:

   - GRA 2 (two) 4-hp submersible pumps and appurtenances.
   - GRA 3 (three) 4-hp submersible pumps and appurtenances.
   - GRA 4 (five) 4-hp submersible pumps and appurtenances.

DESIGN ASSUMPTIONS FOR GROUNDWATER TREATMENT SYSTEM

1. Pre-treatment consists of a chemical sequestering unit for the addition of orthophosphates with pumps to prevent the deposition of solids in the low-profile air stripper. Sequestering systems are based on estimated flow rates and include chemical pumps and piping. Chemical storage is not provided (included in delivery price) because product is delivered in storage containers.

2. The low profile air stripper is assumed to be a tray aeration unit with blower, controls, and appurtenances. The unit costs are based on vendor quotes, based on the estimated groundwater quality for each GRA and the estimated flow rate. Based on the preliminary VOC concentrations, it is assumed one stripper is sufficient to treat the groundwater.

3. The Therm-Ox, if required, is assumed to be a 1,000-scfm unit for GRA 2 and GRA 3, with fan, controls, and appurtenances. For GRA 4, a 2,000-scfm unit is assumed with all associated appurtenances. Preliminary calculations indicate that air treatment associated with the groundwater treatment system is not required for

any of the GRAs considered. Final design evaluations may vary; therefore, thermal oxidation for treatment of air discharge is included.

4. Liquid phase granular activated carbon (GAC) treatment is provided as a back-up "polishing unit", in case the air stripper malfunctions. For GRA 2 and GRA 3, GAC units were assumed to be two 2,000-pound units in parallel, with a permanent installation. For GRA 4, GAC units are assumed to be configured in the same manner except 3,000-pound units in parallel would be used. By-pass piping can be provided to minimize carbon use.

5. Process pumps (including standbys) are assumed to be centrifugal pumps rated as follows

   - GRA 2 (four) 2-hp pumps, piping and appurtenances.
   - GRA 3 (four) 2-hp pumps, piping and appurtenances.
   - GRA 4 (four) 5-hp pumps, piping and appurtenances.

6. Discharge pumps (including standbys) are assumed to be vertical turbine pumps rated as follows:

   - GRA 2 (two) 2-hp pumps, piping and appurtenances.
   - GRA 3 (two) 2-hp pumps, piping and appurtenances.
   - GRA 4 (two) 5-hp pumps, piping and appurtenances.

7. The treatment building is sized to accommodate major equipment components of the treatment facility. The cost includes labor and equipment, and butler type building set on a poured concrete foundation.

8. Lump sum cost for electrical includes an allowance for a Motor Control Center (MCC), starters, electric service and connections, controls and control panel, leak

detection and remote dial out. Electrical conduit will go to each well for the submersible pumps and use the same trench as the extraction piping (no emergency back up).

9. For GRA 2, the POETs are residential size (10 gallons per minute [gpm] max flow rate), installed with pump and ejector piping. It is assumed that minimal upgrades to electrical wiring are required.

10. It is assumed that water continues to be supplied as it is now, by cisterns or by trucked water.

O&M Assumptions GRAs

1. Electrical costs are for the well pumps, blowers, process and discharge pumps associated with the treatment units. It also includes an allowance for building heating and lighting. The following power usage assumptions have been made utilizing an average price of electricity per kilowatt hour of $ 0.10.

    - GRA 2 - 29-hp equivalents full time (+/- 25 %).
    - GRA 3 - 33-hp equivalents full time (+/- 25 %).
    - GRA 4 - 57-hp equivalents full time (+/- 25 %).

2. Chemical usage based influent groundwater quality and estimated influent flow rate, and vendor quotation. Storage is not provided because product is delivered in storage containers.

3. Carbon replacement is assumed to be minimal due to the redundancy provided by the air stripper. For GRA 2 and GRA 3, one unit changeout every year (2,000 lbs) and for GRA 4, one unit changeout every year (3,000 lbs).

4. Supplemental fuel for Therm-Ox assumed to be propane. 25,000 therms/year at $1.00/therm is assumed for the 1,000 scfm unit and 38,000 for the 2,000 scfm unit is assumed.

5. For GRA 2, it is assumed the POET systems will use an average of 200 lbs. GAC/year.

6. System operation assumes one full-time person for the treatment facility effluent monitoring and POET system monitoring.

7. System monitoring is expressed as sampling average annually. It is assumed that 12 samples per year are analyzed for permit compliance monitoring. For POET systems, one sample per month per installation is assumed, or 60 samples per year.

8. O&M costs for the SCPs were provided as lump sum and assumed to operate for five years.

ASSUMPTIONS FOR EQUIPMENT INSTALLATION AND MATERIAL REPLACEMENT

1. Major equipment replacement entails complete replacement of process equipment such as air strippers, POETs, GAC units, and Therm-Ox.

2. Minor equipment replacement entails replacing pumps and blowers, etc., every 5 years (10 percent of chemical treatment, air stripper, and electrical costs, 5 percent of groundwater recovery systems [includes well pumps and treatment building]), 50 percent discharge and process pumps and piping).

APPENDIX D

APPENDIX D

LIST OF ACRONYMS AND ABBREVIATIONS

Table D-1. Acronyms and Abbreviations Used, Feasibility Study, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Acronym or Abbreviation	Meaning
AOC	Administrative Order by Consent.
ARAR	Applicable or Relevant and Appropriate Requirements.
AST	Aboveground storage tank.
BNAs	Base/neutral and Acid extractable compounds.
BTEX	Benzene, toluene, ethylbenzene, and xylenes.
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act.
CG	Cleanup Goal.
COCs	Constituents of Concern.
DCA	1,1-dichloroethane.
DCCA	U.S. Virgin Islands Department of Conservation and Cultural Affairs (Precursor to DPNR).
1,2-DCE	1,2-dichloroethene.
DNAPL	Dense non-aqueous phase liquid.
DPNR	U.S. Virgin Islands Department of Planning and Natural Resources.
FS	Feasibility Study.
ft/day	Feet per day.
GAC	Granular activated carbon.
gal/day/ft	Gallons per day per foot.
gal/day/ft2	Gallons per day per square foot.
GC	Gas chromatograph (or Chromatography).
gpm	Gallons per minute.
GRA	Groundwater Remedial Alternative.
HI	Hazard Index.
HQ	Hazard Quotient.
HRS	Hazardous Ranking System.
HSL	Hazardous Substance List.
IRM	Interim Remedial Measure.
LDR	Land Disposal Restrictions.
LNAPL	Light, non-aqueous phase liquid
MCL	Maximum Contaminant Level.
MCLG	Maximum Contaminant Level Goal.
mg/kg	Milligrams per kilogram.
mg/L	Milligrams per liter.
MTBE	Methyl tertiary-butyl ether.
NCP	National Contingency Plan.
PCB	Polychlorinated biphenyl.
PCE	Tetrachloroethene (or perchloroethylene).
POET	Point-of-Entry Treatment.
POTW	Publicly-Owned Treatment Works.
ppb	Parts per billion.
PRG	Preliminary Remedial Goal.
PRPs	Potentially Responsible Parties.
PVC	Polyvinyl chloride.

Table D-1. Acronyms and Abbreviations Used, Feasibility Study, Tutu Wells Site, St. Thomas, U.S. Virgin Islands.

Acronym or Abbreviation	Meaning
RAL	Remedial Action Level.
RAO	Remedial Action Objective.
RCRA	Resource Conservation and Recovery Act.
RI	Remedial Investigation.
RO	Reverse osmosis.
RW	Recovery Well.
SCP	Source Control Plan.
SRA	Soil Remedial Alternative.
SSL	Soil Screening Level.
SVE	Soil vapor extraction.
TAL	Target Analyte List.
TAT	Technical Assistance Team.
TBC	To-Be-Considered material.
TCA	1,1,1-trichloroethane
TCE	Trichloroethene.
TCL	Target Compound List.
TDS	Total dissolved solids.
TEIC	Tutu Environmental Investigation Committee.
TPH	Total petroleum hydrocarbons.
TSDF	Treatment, Storage, and/or Disposal Facility.
ug/kg	Micrograms per kilogram.
ug/L	Micrograms per liter.
USEPA	U.S. Environmental Protection Agency.
UST	Underground storage tank.
USVI	U.S. Virgin Islands.
VC	Vinyl chloride.
VIHA	Virgin Islands Housing Authority.
VOCs	Volatile organic compounds.
WAPA	Water and Power Authority.