FUGRO WEST, INC.

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RESULTS OF RISKED BASED CORRECTIVE ACTION EVALUATION

HOUSING AUTHORITY OF THE CITY OF ALAMEDA ALAMEDA, CALIFORNIA

Prepared for:
HOUSING AUTHORITY OF THE CITY OF ALAMEDA
701 Atlantic Avenue
Alameda, California 94501

Prepared by:
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44 Montgomery Street, Suite 1010
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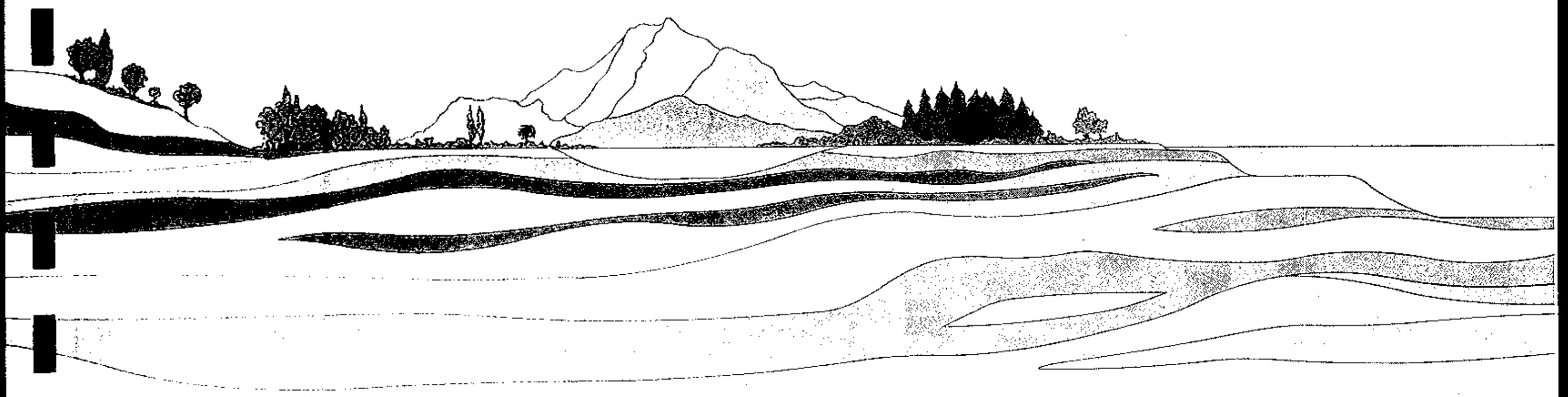
Project No. 9537-1311
November 1996



APPENDIX A

RBCA TOOL KIT SOFTWARE

- Output Table 1
- SSTL Calculation Formulas and Assumptions

FUGRO WEST, INC.

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December 2, 1996
Project No. 9537-1311

Housing Authority of the City of Alameda
701 Atlantic Avenue
Alameda, California 94501

Attention: Ms. Eileen Duffy

Results of Risked-Based Corrective Action Evaluation
Housing Authority of the City of Alameda
1916 Webster Street
Alameda, California

Dear Ms. Duffy:

The accompanying report provides the results of the Tier 2 Risk-Based Corrective Action (RBCA) for the Housing Authority of the City of Alameda (AHA) property located at 1916 Webster Street, in Alameda, California. Fugro West Inc. (Fugro) performed this evaluation under the terms of the AHA Notice to Proceed, dated October 14, 1996. A copy of this report will be forwarded to Ms. Eva Chu at the Alameda County Division of Environmental Health for her review and comment.

Fugro appreciates the opportunity to provide environmental consulting services to the AHA. If you have any additional questions or comments regarding this project, please contact me or Mr. Boudreau at (415) 296-1041.

Sincerely,

FUGRO WEST, INC.

Peter B. Hudson
Project Geologist

Stephen J. Boudreau
Regional Branch Manager
Senior Environmental Engineer

PBH:lah

c: Ms. Eva Chu, Alameda County Department of Environmental Health

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HOUSING AUTHORITY OF THE CITY OF ALAMEDA

PROJECT DESCRIPTION AND PURPOSE

This report presents the results of the Tier 2 Risked Based Corrective Action (RBCA) evaluation conducted by Fugro West Inc. (Fugro) for the Housing Authority of Alameda (AHA) property, located at 1916 Webster Street in Alameda California (subject property).

The RBCA was requested by the Alameda County Department of Environmental Health (ACDEH) following the completion of remediation activities at the subject property in August 1996. The intent of the RBCA analysis is to determine risks to human health and the environment associated with residual hydrocarbons in the soils beneath the building. Based on field observations and previous soil sampling, the extent of residual soils are limited. Removal of these soils was not warranted due to the inaccessible location beneath the existing concrete slab. In their letter dated October 7, 1996, the ACHED stated that in the current condition, the impact to health and the environment associated with these soils is low. This RBCA evaluation was completed assuming that a commercial/retail building will be constructed over the residual impacted soils.

This report discusses the project background, describes the RBCA process and Fugro's methodology and presents results of the analysis with conclusions. Appendix A contains supplemental output data tables, calculation procedures and assumptions. Figures of the subject property and previous sampling locations are also included.

SITE HISTORY AND PROJECT BACKGROUND

History and Uses of Subject Property

The subject property is located at the southeast corner of Webster Street and Atlantic Avenue in a commercial area of Alameda, California. (Figure 1) and consists of a warehouse building and adjacent parking lot (Figure 2). The warehouse building includes occupied tenant space and a warehouse area that is currently used by the AHA maintenance crews for equipment and vehicle storage. The building was built prior to 1950 and at one time contained a peanut butter production operation.

Removal of Underground Storage Tank & Soil Removal and Assessment by ASE (1986)

The AHA had a 280-gallon underground storage tank (UST) removed from the subject property in July 1986. Aqua-Science Engineers, Inc. conducted an environmental investigation after the UST was removed and determined that it had leaked and released gasoline to the subsurface soil and groundwater. Additional work included excavation of impacted soils in

September 1986 and installing groundwater monitoring wells MW-1, MW-2 and MW-3. In accordance with a Corrective Action Plan (CAP), Environmental Science and Engineering Inc. excavated additional soil in March 1994. The excavation area extended from the former UST location to within 6 feet of the northern fence line (Figure 2) Soil samples collected by ESE in March 1994, indicated that petroleum hydrocarbons remained in the soils south of the former UST, between the excavation and the building.

Additional Groundwater Well Installation and Monitoring by Fugro - October 1994

Fugro installed three additional groundwater monitoring wells (MW-4, MW-5, and MW-6) in October 1994. Monitoring wells MW-4 and MW-5 are sampled quarterly and the remaining monitoring wells are sampled annually. Ground water elevations in the monitoring wells are measured and recorded on a quarterly basis. Groundwater sample analyses indicate that monitoring wells MW-4 and MW-5 contain total petroleum hydrocarbons as gasoline (TPHg) and benzene, toluene, ethylbenzene and xylenes (BTEX).

Soil Sampling to Determine Extent of Hydrocarbons in Soil by Fugro - May 1996

Fugro conducted subsurface soil sampling in May 1996 to further define the extent of the TPHg and BTEX in the soils to the south, east and west of the former UST. Soil samples were obtained from locations inside and outside the building at depths ranging from 1.5 to 3.0 feet. below ground surface (bgs). Analysis of the samples indicated that hydrocarbon concentrations exceeding 1,000 parts per million (ppm) TPHg and 1 ppm BTEX remained in the subsurface soils adjacent to the former UST and north of the building. Petroleum hydrocarbon concentrations in soils decreased to the south, towards the interior of the building. Fugro prepared a report of findings for this investigation titled: *Results of Subsurface Soil Sampling, 1916 Webster Street, Alameda California,* dated June 3, 1996.

Removal of Additional Soil Containing Hydrocarbons subsurface

Based on subsurface soil sampling results, Fugro excavated and disposed approximately 75 cubic yards of soil containing TPHg and BTEX in August 1996. Fugro removed, as feasible, the majority of soil containing elevated concentrations of TPHg and BTEX from the area of the former LUST (Figure 2). Analysis of confirmatory soil samples indicated that residual soils, impacted with petroleum hydrocarbons remain to a limited extent, beneath the building. The details of the soil remediation effort are presented in the Fugro's report titled: *Soil Remediation and Closure Report,* dated October 2, 1996.

RBCA EVALUATION

Overview of RBCA Process

RBCA analysis provides a consolidated decision-making process for the assessment and response to petroleum-impacted soil and groundwater, based on the protection of human health and environment. The RBCA process utilizes a 3-tiered approach where corrective actions are tailored to the site-specific conditions and risks. The decision process integrates risk and exposure assessment practices recommended by the United States Environmental Protection Agency (EPA).

Components of Tier 2 Evaluation

Generally, the goal of the Tier 2 evaluation is to determine whether or not remedial measures will be required to meet target risk limits at relevant points of exposure (POE). The evaluation of risk is based on Site Specific Target Levels (SSTLs). SSTLs represent upperbound constituent concentrations that, if achieved throughout the source area, will prevent exceedance of applicable risk limits at the potential POE. Given a target risk limit, at the POE, the maximum allowable constituent concentration is based on applicable exposure factors and toxicity parameters.

The source area is considered the impacted media and can be either surface soils, subsurface soils and/or groundwater. SSTLs are determined on the basis of site-specific source area data (total area, depth, contaminant concentrations), potential points of exposure and exposure pathways. Typically, if petroleum constituents in the soil or groundwater exceed the SSTLs, further remediation, evaluation or interim response for principle risk sources, is necessary. The following section dicusses Fugro's methodology in completing the RBCA evaluation.

Fugro's Approach to Assessing Potential Risks of Residual Hydrocarbons

As stated above, the purpose of this RBCA evaluation is to determine if the soils and groundwater containing petroleum hydrocarbons constituents, specifically benzene, represent a risk to human health and the environment. Fugro's approach was to establish SSTL values based on representative concentrations of the BTEX constituents and determine whether they are exceeded given the proposed uses of the subject property. The SSTL values represent the maximum allowable BTEX concentrations in the source area based on an individual carcinogenic target risk of 10E-5 (0.00001). Exceedence of the SSTL is directly indicative of exceedence of this risk limit. According to the ACHED, a target risk of 10E-5 is appropriate because the subject property is zoned as commercial within city of Alameda. Fugro's methodology was discussed with representatives at the ACHED during this evaluation.

In addition to representative constituent concentrations, various other site-specific data is required for the SSTL calculations. These data includes: source area characteristics, exposure pathway information and receptor information. These data are obtained by direct measurement or are based on conservative assumptions (default values).

Fugro utilized the *Tier 2 RBCA Tool Kit - Spreadsheet and Modeling Software,* prepared by Groundwater Services, Inc. (GSI) of Houston , Texas to assist with the calculations necessary for the calculation of the SSTL with the applicable risks. The spreadsheet modeling system is consistent with Appendix X.2 of the American Society for Testing and Materials (ASTM) *Standard Guide for Risked-Based Corrective Action Applied at Petroleum Release Sites, (Designation E 1739-95)"* However, selected algorithms and default parameters have been updated to reflect advances in evaluation methods.

The following sections discuss the characteristics of the source area, representative BTEX concentrations, potential exposure pathways, and potential receptors.

Characteristics of Source Area - Impacted Soil

The soil source area is considered the silty sand containing residual concentrations of petroleum hydrocarbons that remain after the soil remediation in August 1996. The purposes of this evaluation, Fugro has conservatively set the dimensions of the source area at 22 feet by 15 feet, or 330 square feet. The depths of the impacted soils extends from 2 feet below ground surface (bgs) to 5 feet bgs. Currently, approximately 2 feet of silty clay fill material overlies the silty sand. The vadose zone is estimated at 4 feet thick. The approximate limits of the soil source area are based on BTEX concentrations in soils, detected within the building (May 1996) and on the southern extent of the soil excavation (August 1996). Figures 3 and 4 shows the location of the building relative to the soil boring locations area of excavated soil. Figure 5 is a detailed schematic of the soil excavation showing locations of verification soil sampling locations.

Characteristics of Source Area - Groundwater

The groundwater source area is considered groundwater beneath the source area soils. Groundwater samples collected from monitoring wells MW-4 and MW-5 (Figure 2) have contained concentrations of TPHg and BTEX since October 1994. For this evaluation, Fugro estimates the depth to groundwater at 4 feet bgs. This depth is the average groundwater depth over a two year period in monitoring wells MW-4 and MW-5. The capillary zone thickness for the silty sands underlying the subject property is estimated at 1 foot. The extent of impacted groundwater appears limited to the backfilled excavation and is not migrating downgradient or off the subject property.

Determining Representative BTEX Concentrations in Soil and Groundwater

The SSTLs were established using representative BTEX concentrations determined through previous soil and groundwater sampling data. The previous data was collected during the subsurface soil sampling in May 1996; the soil remediation activities in August 1996 and the quarterly groundwater monitoring event in September 1996 (Fugro, June, 1996 and September 1996).

Representative Concentration of BTEX in Soil

The representative BTEX concentrations for soil, used to calculate the SSTL, were derived by calculating the 95% upper confidence limit (UCL) for each BTEX constituent at the limits of the source area. The maximum BTEX concentrations were detected along the south wall of the soil excavation (Figure 5). The south sidewall represents the limit that impacted soils could be feasibly removed without excavating beneath the building. Soil samples collected from the south sidewall were averaged by depth (2, 3 and 4 feet bgs) as indicated in Table 1. The averaged result at each depth was used as a discrete data point to calculate the representative concentration.

BTEX concentrations less than 0.5 ppm were detected in soil borings (FB-1-3, 12, 13) at 5 and 15 feet within the building (Figure 3) and at the east and west ends of the south sidewall of the excavation (Figure 5). The BTEX concentrations in these samples represent the conservative limits of the source zone beneath the building. These soil sample results were used as discrete data points for the determination of the representative concentration of source area soils. Table 1 lists the individual BTEX concentrations for soils used to determine the representative concentrations (95% UCL).

Concentrations of BTEX, representative of the source area are: benzene at 1.1 mg/kg, toluene at 0.62 mg/kg ethylbenzene at 0.53 mg/kg, and xylenes at 1.4 mg/kg. Table 1 lists the representative concentrations (95 % UCL) for BTEX.

Representative Concentration of BTEX in Groundwater

The latest groundwater data (September, 1996) from monitoring wells MW-4 and MW-5 were used to determine representative concentrations of BTEX in the ground water. The maximum BTEX concentrations were used as representative concentrations for the calculation of the SSTLs (Table 1). The representative concentrations determined for groundwater at the subject property are: benzene at 0.62 mg/kg and 0.5 mg/kg for toluene, ethylbenzene and xylenes.

TABLE 1 Soil and Groundwater Data used for Determination of Representative Concentrations.

Soil/Groundwater Sample Identification	Sampling Date	TPH - Gasoline	Benzene	Toluene	Ethyl-benzene	Xylenes (Total)	Averaged or Single Data Point
SOIL (mg/kg)							
SSE-2'	8/21/96	70	2.1	5.0	1.1	4.6	AVERAGED
S-2.5'	8/21/96	460	6.2	16	5.9	22	5.2
SSW-3'	8/21/96	190	6.2	1.7	3.9	13	AVERAGED
SSE-3.5'	8/21/96	180	3.7	6.9	3.9	15	8.05
S-4.5'	8/21/96	330	5.3 ✓	13	5.0	14	AVERAGED
SSW-4.5'	8/21/96	58	3.7	0.28	0.68	2.1	7.15
SSE(EXT)-3'	8/27/96	5	0.2	0.006	0.025	0.068	SINGLE
WSW-3'	8/21/96	2.7	0.24	ND	0.044	0.11	SINGLE
FB-1	5/3/96	0.3	0.031	ND	ND	ND	SINGLE
FB-3	5/3/96	0.4	0.008	ND	ND	ND	SINGLE
FB-12	5/3/96	23	0.3	0.180	0.060	0.210	SINGLE
GROUNDWATER (ug/L)							
MW-4	9/10/96	130	16	0.7	ND	ND	SINGLE
MW-5	9/10/96	1,200	620	ND	ND	ND	SINGLE
REPRESENTATIVE CONCENTRATION SOIL 95% URL			1.1 mg/kg	0.62 mg/kg	0.53 mg/kg	1.4 mg/kg	
REPRESENTATIVE CONCENTRATION GROUNDWATER MAXIMUM VALUE			0.62 mg/L	0.5 mg/L	0.5 mg/L	0.5 mg/L	

NOTES:
Averaged = Two discrete soil concentrations from different areas were averaged based on depth for a representative data point.
Single = Soil concentrations form one location represent a single data point.
Parts per Million (ppm) = milligrams per Liter (mg/L)=1,000 x.ug/kg or parts per billion (ppb)
ND - Not Detected above indicated method reporting limit.

7.6
8.05
7.15

Exposure Pathways

This RBCA evaluation involves comparing calculated SSTL values for BTEX to representative concentrations in the subsurface soil and groundwater. These calculations were based on the assumption that a commercial structure, such as a retail mall, is built over the source area.

Risk determination requires identification of complete exposure pathways to define potential receptors and apply relevant risk goals. An exposure pathway is complete if: 1) contaminant transport occurs without existing and future control measures and 2) the receptor could potentially contact impacted media at the POE under current or future land use. Based on the conditions and proposed development at the subject property, the potential routes of exposure applicable to this risk evaluation are air pathways. The exposure parameters used for this evaluation are default values set forth by the ASTM and are listed in on Output Table 1, Appendix A. The relevant air exposure pathways considered in this evaluation are:

- Volatilization to ambient (outdoor) air from subsurface soils.
- Volatilization to enclosed space from subsurface soils
- Volatilization to ambient (outdoor) air from impacted groundwater
- Volatilization to enclosed space from groundwater.
- Direct ingestion or dermal contact for construction workers.

Groundwater ingestion pathways are not considered in this evaluation because dissolved petroleum hydrocarbons have not been identified migrating offsite and no groundwater uses other than possibly irrigation have been identified within a one-half mile radius of the subject property. The irrigation wells are located approximately 2,000 feet away from the subject property in an upgradient groundwater flow direction. (Fugro, June and September 1996)

Soil ingestion and dermal contact pathways have only been considered for construction workers because it is assumed that the source area will be covered with concrete or asphalt after construction. The representative concentrations for this pathway are those used for the subsurface soils (Table 1). The representative concentrations are based on the assumption that if a construction worker contacted the source area, it would be during initial grading and installation of underground utilities.

Considerations for Proposed Structure

As stated previously, this RBCA evaluation is based on the assumption that a commercial structure is proposed for the subject property. The final structure design, proposed building footprint or location of the building was not available to Fugro at the time this evaluation was completed. Fugro assumes that the source area will either be covered by an asphalt parking lot or the concrete foundation slab of the commercial structure. – need to make sure

For this evaluation, Fugro utilized ASTM default values for building parameters, and air parameters. The soil and groundwater parameters are a combination of default parameters and actual data collected during previous investigations. A complete list of applicable default values and site-specific values used for the SSTL calculations are shown on Output Table 1, Appendix A.

Potential Receptors

The potential receptors assumed for this evaluation are site workers and customers of the proposed retail center. Construction workers have also been considered assuming that they may come in contact with the residual soils during construction operations. A complete list of exposure parameters for human receptors are listed on Output Table 1 in Appendix A.

Calculations of SSTL Values

The GSI modeling software is designed to calculate SSTLs using data input from the user. The input data is either ASTM default values or site-specific data obtained from assessment activities at the subject property. The software runs the data through a series of calculations depending on the applicable exposure pathways. The calculations estimate cross-media transfer factors such as volatilization from soil to air.

Various assumptions are incorporated into the model that can effect the SSTL calculations. The key assumptions used in the calculations for each media transfer factor are:

Uniform Concentrations: Constituents levels uniformly distributed in soil and constant over exposure period (30 years).

No Decay of constituents: No biodegradation or other loss mechanism in soil or vapor phase.

Finite Source Term: Source term mass adjusted for constant volatilization over exposure period.

Default Building Parameters: Conservative default values for foundation crack and air exchange rates.

Appendix A contains GSI documentation that discusses cross-media factors and the applicable cross-media transfer equations and the assumptions used in the SSTL calculations.

RESULTS and CONCLUSIONS

Results of SSTL Calculation

SSTL values were calculated based on site-specific data including the extent of the source area, residual BTEX concentrations in the soil and groundwater, proposed development at the subject property and potential exposure pathways. The SSTLs were calculated using an individual carcinogenic target risk of 10E-5. The calculated SSTLs applicable to each complete pathway in Table 2.

Table 2. Applicable SSTL Values for Complete Exposure Pathways

Exposure Pathways	Applicable SSTL			
	Benzene	Toluene	Ethyl Benzene	Xylenes
Volatilization to ambient (outdoor) air from subsurface soils.	>Res	>Res	>Res	>Res
Volatilization to enclosed space from subsurface soils	1.5 mg/kg	>Res	>Res	>Res
Volatilization to ambient (outdoor) air from impacted groundwater	>Sol	>Sol	>Sol	>Sol
Volatilization to enclosed space from groundwater.	2.5 mg/l	300 mg/l	>Sol	>Sol
Direct ingestion or dermal contact of soil for construction workers.	33 mg/l	>Res	>Res	>Res

>Res = (Residual) Selected risk level is not exceeded for pure compound present at any concentration.
>Sol = (Solubility) Selected risk level is not exceeded for all possible dissolved levels

The equations used for volatilization from subsurface soil and groundwater to enclosed space, when used with ASTM default values for building parameters, tend to yield conservative result. Because of the conservatism, these SSTL values for enclosed space often represent the controlling or critical exposure pathway, as is the case with the subject property.

The calculated SSTL for the controlling pathway (enclosed space) is 1.5 mg/kg for benzene in soil and 2.5 mg/L in water. The SSTL for direct ingestion and dermal contact of source area soils is 33 mg/L. These SSTLs represent the maximum allowable concentration of the individual constituent in the source zone based on a specified target risk. When compared to the representative concentrations of BTEX used in this evaluation (Table 1), it is evident that the SSTL values were not exceeded for the specified pathway. Hence, the carcinogenic target risk of 10E-5 has not been exceeded.

SSTL values marked with a 'Res ' or 'Sol' indicate that the calculation software used for this evaluation did not calculate an actual value for SSTL because the SSTL value exceeded the solubility of the compound. Therefore, these SSTLs are greater than those with calculated numerical values.

Fugro's Conclusions Based on Results of RBCA Analysis

The Tier 2 RBCA evaluation performed for the subject property was meant to determine the risks associated with residual petroleum hydrocarbons, specifically benzene, that remain in a limited area beneath the existing building. The evaluation was designed assuming that the future development of the subject property would include commercial construction, namely a retail mall.

Fugro determined, through this evaluation, that the representative concentrations for the source area (Table 1) do not exceed the calculated SSTLs (Table 2) for the critical pathway (subsurface soils to enclosed space). These SSTLs were based on a target risk of 10E-5 for commercial property, as specified by the ACHED. Therefore, the maximum carcenogenic risk of the residual source area soils is not greater than 10E-5.

It is Fugro's opinion that the assumptions made for the calculation of SSTLs are conservative and the resulting SSTLs appropriately overestimate the risks. The primary assumptions are listed and discussed below.

- The source area is 330 square feet in area and the depth of impacted soils is 5 feet. The minimum representative concentration in the source area is that of benzene at 1.1 ppm.

Fugro conservatively estimated the source areas extends approximately 14 feet beneath the existing building or 330 square feet. Soil boring data, indicates that BTEX concentrations in the soils decrease to below 0.5 ppm over a distance of five feet under the building.

- The source area soils will remain intact throughout the proposed construction and be present at the current concentrations after the commercial building is completed.

This is considered conservative because site grading work may be necessary to prepare the site for building construction. The soil materials beneath the subject property consists of fill materials including clay and debris. It is likely that grading and fill work will be required to prepare the subject property for construction. If this occurs, the source area soils may be removed to certain depth and replaced with engineered fill thus reducing the source area.

- The entire source area contains the same representative concentration of BTEX. The source area concentrations will not biodegradate and will volatilize at a constant rate over the exposure period.

As indicated from soil sample results, the source area soil concentration decrease beneath the building indicating that the source area soils are not uniform. Natural biodegradation is expected to occur and thus, volatilization will not be constant.

Based on SSTLs calculated for this Tier 2 evaluation, it is Fugro's opinion that the future risks associated with the hydrocarbon impacted soil remaining beneath the existing warehouse building is low. However, if future improvements to the subject property involves development other than commercial/industrial construction a revised risk assessment may be necessary.

LIMITATIONS AND CLOSURE

The judgments, conclusions, and recommendations described in this report pertain to the conditions judged to be present or applicable at the time work was performed. Fugro's opinions were developed in accordance with accepted geologic, hydrogeologic, and engineering practices for this time and for this specific site. The interpretations and conclusions contained in this report represent our professional opinions. Other than this, no warranty is implied or intended.

Fugro has prepared this report for the Housing Authority of the City of Alameda for their property located at 1916 Webster Street, in Alameda, California. Use of this report is provided to the Housing Authority of the City of Alameda solely for their exclusive use and shall be subject to terms and conditions of the contract between the Housing Authority of the City of Alameda and Fugro West, Inc. Any reliance on this report by third parties shall be at such parties' sole risk.

FUGRO WEST INC

Peter B. Hudson
Project Geologist

Stephen J Boudreau
Regional Branch Manager
Senior Environmental Engineer

RBCA TIER 1/TIER 2 EVALUATION

Output Table 1

Site Name: Alameda Housing Authority
Site Location: 1916 Webster St. Alameda
Job Identification: 96371311
Date Completed: 11/13/96
Completed By: Fugro West
Software: GSI RBCA Spreadsheet
Version: v 1.0

NOTE: values which differ from Tier 1 default values are shown in bold italics and underlined.

DEFAULT PARAMETERS

Exposure Parameter	Definition (Units)	Residential Adult	Residential (1-6yrs)	Residential (1-16 yrs)	Commercial/Industrial Chronic	Commercial/Industrial Constrctn
ATc	Averaging time for carcinogens (yr)	70				
ATn	Averaging time for non-carcinogens (yr)	30	6	16	25	1
BW	Body Weight (kg)	70	15	35	70	
ED	Exposure Duration (yr)	30	6	16	25	1
EF	Exposure Frequency (days/yr)	350			250	180
EF.Derm	Exposure Frequency for dermal exposure	350			250	
IRgw	Ingestion Rate of Water (l/day)	2			1	
IRs	Ingestion Rate of Soil (mg/day)	100	200		50	100
IRadj	Adjusted soil ing. rate (mg-yr/kg-d)	1.1E+02			9.4E+01	
IRa.in	Inhalation rate indoor (m^3/day)	15			20	
IRa.out	Inhalation rate outdoor (m^3/day)	20			20	10
SA	Skin surface area (dermal) (cm^2)	5.8E+03		2.0E+03	5.8E+03	5.8E+03
SAadj	Adjusted dermal area (cm^2-yr/kg)	2.1E+03			1.7E+03	
M	Soil to Skin adherence factor	1				
AAFs	Age adjustment on soil ingestion	FALSE			FALSE	
AAFd	Age adjustment on skin surface area	FALSE			FALSE	
tox	Use EPA tox data for air (or PEL based)	TRUE				
gwMCL?	Use MCL as exposure limit in groundwater?	FALSE				

Matrix of Exposed Persons to Complete Exposure Pathways		Residential	Commercial/Industrial Chronic	Commercial/Industrial Constrctn
Groundwater Pathways:				
GW.i	Groundwater Ingestion	FALSE	FALSE	
GW.v	Volatilization to Outdoor Air	FALSE	TRUE	
GW.b	Vapor Intrusion to Buildings	FALSE	TRUE	
Soil Pathways				
S.v	Volatiles from Subsurface Soils	FALSE	TRUE	
SS.v	Volatiles and Particulate Inhalation	FALSE	TRUE	TRUE
SS.d	Direct Ingestion and Dermal Contact	FALSE	TRUE	TRUE
S.l	Leaching to Groundwater from all Soils	FALSE	FALSE	
S.b	Intrusion to Buildings - Subsurface Soils	FALSE	TRUE	

Matrix of Receptor Distance and Location on- or off-site		Residential Distance	Residential On-Site	Commercial/Industrial Distance	Commercial/Industrial On-Site
GW	Groundwater receptor (cm)		FALSE		FALSE
S	Inhalation receptor (cm)		FALSE		TRUE

Matrix of Target Risks		Individual	Cumulative
TRab	Target Risk (class A&B carcinogens)	***1.0E-05***	
TRc	Target Risk (class C carcinogens)	1.0E-05	
THQ	Target Hazard Quotient	1.0E+00	
Opt	Calculation Option (1, 2, or 3)	2	
Tier	RBCA Tier	2	

Surface Parameters	Definition (Units)	Residential	Commercial/Industrial Chronic	Commercial/Industrial Construction
t	Exposure duration (yr)	30	25	1
A	Contaminated soil area (cm^2)	***3.1E+05***		***3.1E+05***
W	Length of affected soil parallel to wind (cm)	***6.1E+02***		***6.1E+02***
W.gw	Length of affected soil parallel to groundwater (c			
Uair	Ambient air velocity in mixing zone (cm/s)	2.3E+02		
delta	Air mixing zone height (cm)	2.0E+02		
Lss	Definition of surficial soils (cm)	***6.1E+01***		
Pe	Particulate areal emission rate (g/cm^2/s)	2.2E-10		

Groundwater	Definition (Units)	Value
delta.gw	Groundwater mixing zone depth (cm)	2.0E+02
I	Groundwater infiltration rate (cm/yr)	3.0E+01
Ugw	Groundwater Darcy velocity (cm/yr)	***9.1E+02***
Ugw.tr	Groundwater Transport velocity (cm/yr)	***2.4E+03***
Ks	Saturated Hydraulic Conductivity(cm/s)	3.2E-03
grad	Groundwater Gradient (cm/cm)	9.0E-03
Sw	Width of groundwater source zone (cm)	
Sd	Depth of groundwater source zone (cm)	
BC	Biodegradation Capacity (mg/L)	
BIO?	Is Bioattenuation Considered	FALSE
phi.eff	Effective Porosity in Water-Bearing Unit	3.8E-01
foc.sat	Fraction organic carbon in water-bearing unit	1.0E-03

Soil	Definition (Units)	Value		
hc	Capillary zone thickness (cm)	***3.0E+01***		
hv	Vadose zone thickness (cm)	***1.1E+02***		
rho	Soil density (g/cm^3)	***2.01***		
foc	Fraction of organic carbon in vadose zone	***0.001***		
phi	Soil porosity in vadose zone	0.38		
Lgw	Depth to groundwater (cm)	***1.4E+02***		
Ls	Depth to top of affected soil (cm)	***6.1E+01***		
Lsubs	Thickness of affected subsurface soils (cm)	***9.1E+01***		
pH	Soil/groundwater pH	6.5		
		capillary	**vadose**	**foundation**
phi.w	Volumetric water content	0.342	0.12	0.12
phi.a	Volumetric air content	0.038	0.26	0.26

Building	Definition (Units)	Residential	Commercial
Lb	Building volume/area ratio (cm)	2.0E+02	3.0E+02
ER	Building air exchange rate (s^-1)	1.4E-04	2.3E-04
Lcrk	Foundation crack thickness (cm)	1.5E+01	
eta	Foundation crack fraction	0.01	

Dispersive Transport Parameters	Definition (Units)	Residential	Commercial
Groundwater			
ax	Longitudinal dispersion coefficient (cm)		
ay	Transverse dispersion coefficient (cm)		
az	Vertical dispersion coefficient (cm)		
Vapor			
dcy	Transverse dispersion coefficient (cm)		
dcz	Vertical dispersion coefficient (cm)		

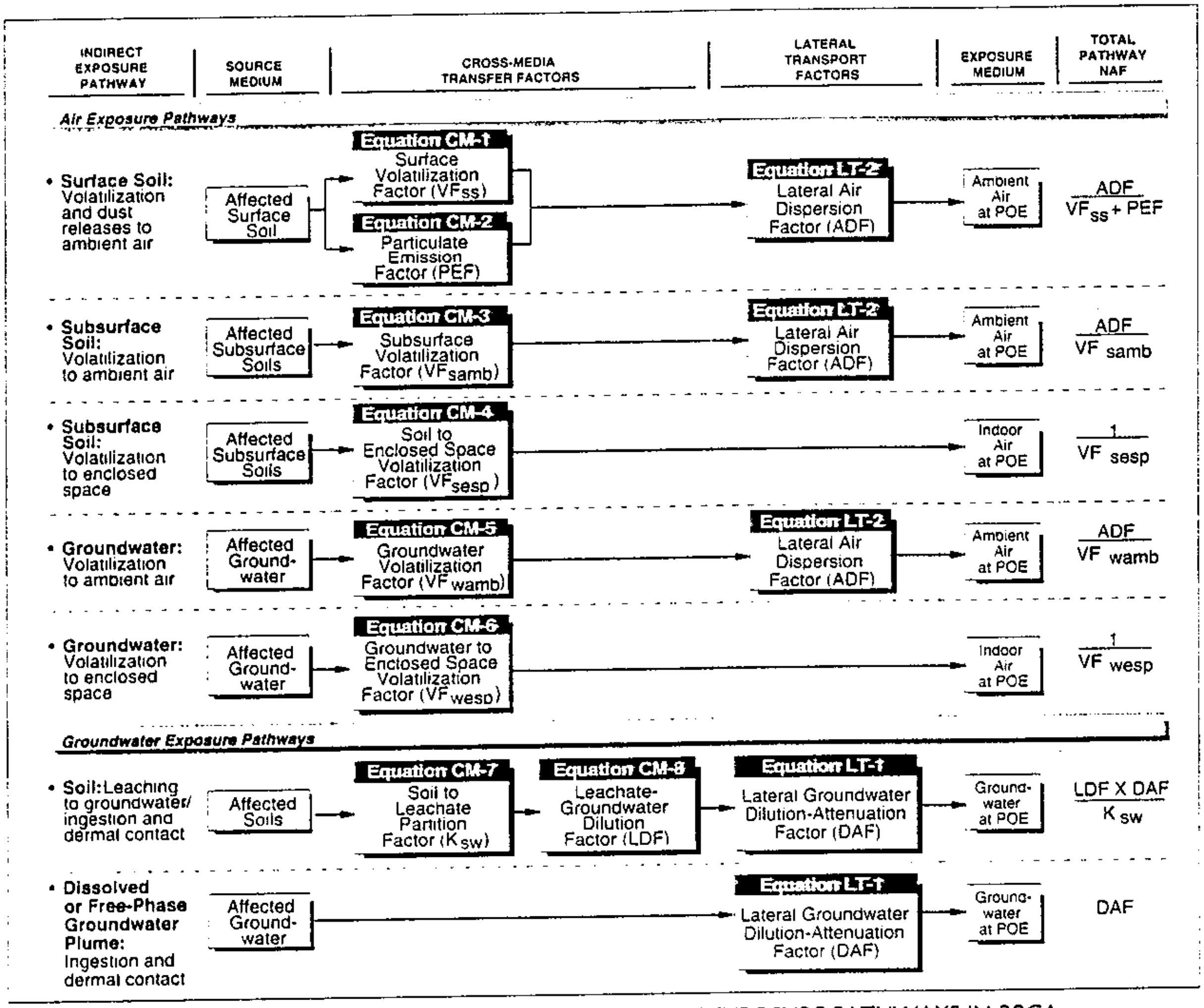


FIGURE A.2. NAF CALCULATION SCHEMATIC FOR INDIRECT EXPOSURE PATHWAYS IN RBCA SPREADSHEET SYSTEM

- ***VF_{SS}: Surface Soil Volatilization Factor (Equation CM-1)***

  The surface volatilization factor is the steady-state ratio of the concentration of an organic constituent in the ambient air breathing zone to the source concentration in the surface soil. The surface volatilization factor incorporates two cross-media transfer elements: i) organic vapor flux from the surface soil mass to ground surface and ii) mixing of soil vapors in the ambient air breathing zone directly over the affected surface soil. For each site, the applicable VF_{SS} value corresponds to the lesser result of two calculation methods (termed CM-1a and CM-1b on Figure A.3, page A-11). Equation CM-1a typically controls for low-volatility organics, as it assumes there is an infinite source of organics in the surface soils and uses a volatilization rate based primarily on chemical properties. Equation CM-1b, which typically controls for volatile organics, is based on a mass balance approach. In this equation, a finite amount of organics is assumed to be present in the surface soil (based on the representative COC concentration), volatilizing at a constant rate over the duration of the exposure period (e.g., 25-30 years). Both expressions account for the dilution of organics in ambient air above the source zone due to mixing with ambient air moving across the site. A simple box model is used for this dilution calculation, based on the following adjustable default assumptions: 2-meter mixing zone height and 225 cm/sec (5 mph) lateral wind speed. The length of the mixing zone is set equal to the lateral dimension of the exposed affected surface soil area parallel to the assumed wind direction.

Key assumptions used in this model and their effect on the SSTL calculation are as follows:

KEY ASSUMPTIONS: VF_{ss}	EFFECT ON CLEANUP STANDARD
• **Uniform COC Concentrations**: Constituent levels uniformly distributed in soil and constant over exposure period.	-----
• **No COC Decay**: No biodegradation or other loss mechanism in soil or vapor phase.	⇩
• **Finite Source Term**: Source term mass adjusted for constant volatilization over exposure period.	-----

- ***PEF: Soil Particulate Emission Factor (Equation CM-2)***
  The Particulate Emission Factor (PEF) is the steady-state ratio of the concentration of organics in particulates in the ambient air breathing zone to the source concentration of organics in the surface soil. The factor incorporates two cross-media transfer elements: i) the release rate of soil particulates (dust) from ground surface and ii) mixing of these particulates in the ambient air breathing zone directly over the affected surface soil. The particulate release rate is commonly matched to a conservative default value of 6.9 x 10^{-14} g/cm^2-sec (approximately 0.2 lbs/acre-year), unless a more appropriate site-specific estimate is available. (If the site is paved, the particulate release rate and resultant PEF value for the covered soil area will be zero.) Particulates are assumed to be diluted by lateral air flow directly over the source zone. For this purpose, a simple box model is employed, based on the following adjustable default assumptions: 2-meter mixing zone height and 225 cm/sec (5 mph) lateral wind speed. The length of the mixing zone is matched to the lateral dimension of the exposed affected surface soil area parallel to the assumed wind direction.

  Key assumptions incorporated in this model and their effect on the SSTL calculation are as follows:

KEY ASSUMPTIONS: PEF	EFFECT ON CLEANUP STANDARD
• **Uniform COC Concentrations**: Constituent levels uniformly distributed in soil and constant over exposure period.	-----
• **No COC Decay**: No biodegradation or other loss mechanism in soil or vapor phase.	⇩
• **Default Emission Rate**: Conservative particulate emission rate.	⇩

- ***VF_{samb}: Subsurface Soil Volatilization Factor (Equation CM-3)***
  The subsurface soil volatilization factor is comparable to the surface volatilization equation, except that the algorithm has been adjusted to account for vapor flux from greater soil depths. The volatilization factor accounts for two cross-media transfer elements: i) organic vapor flux from the subsurface affected soil mass to ground surface and ii) mixing of soil vapors in the ambient air breathing zone directly over the affected soil zone. As with the surface soil volatilization factor, VF_{SS}, the applicable subsurface soil volatilization factor, VF_{samb}, corresponds to the lesser result of two calculation methods (termed CM-3a and CM-3b on Figure A.3, page A-12). Equation CM-3a, which corresponds to the expression given in Appendix X.2 of ASTM E-1739, assumes a constant source mass in the subsurface and can severely overpredict the soil vapor flux rate. To correct for this problem, Equation CM-3b, which accounts for a mass balance of the volatilized source mass over the exposure period (similar to Equation CM-1b) has been incorporated in the RBCA Spreadsheet. With either equation (CM-3a or CM 3-b), dilution of soil vapors in the ambient air breathing zone is estimated using the same box model described for Equation CM-1.

Key assumptions incorporated in this model and their effect on the SSTL calculation are as follows:

KEY ASSUMPTIONS: VF_{samb}	EFFECT ON CLEANUP STANDARD
• **Uniform COC Concentrations**: Constituent levels uniformly distributed in soil and constant over exposure period.	-----
• **No COC Decay**: No biodegradation or other loss mechanism in soil or vapor phase.	⇩
• **Finite Source Term**: Source term mass adjusted for constant volatilization over exposure period.	-----

- ***VF_{sesp}: Subsurface Soil-to-Enclosed-Space Volatilization Factor (Equation CM-4)***
  This factor is the steady-state ratio of the source concentration of an organic constituent in indoor air due to the concentration in underlying subsurface soils. Again, two expressions are evaluated: i) Equation CM-4a, which assumes an infinite source mass and is of the same form as Equation CM-3a with a term added to represent diffusion through cracks in the foundation of the building, and ii) Equation CM-4b which accounts for a finite source mass volatilizing at a constant rate over the exposure period. The applicable VF_{sesp} value corresponds to the lesser of these two expressions. The soil-to-enclosed-space volatilization factor incorporates two cross-media transfer elements: i) organic vapor flux from the underlying soil mass through the building floor and ii) mixing of soil vapors with indoor air. Tier 1 default assumptions in the software include: i) a 1% open crack space in the foundation allowing vapors to diffuse into the building and ii) a building air exchange rate of one exchange every 20 days. When used with these default values, the expression yields very conservative results and can represent the controlling pathway for SSTL calculations for many sites. In such case, users are advised to conduct direct air or soil vapor measurements prior to proceeding with remedial measures for this pathway.

Tier 2 RBCA

Key assumptions used in this model and their effect on the SSTL calculation are as follows:

KEY ASSUMPTIONS: VF_{sesp}	EFFECT ON CLEANUP STANDARD
• **Uniform COC Concentrations**: Constituent levels uniformly distributed in soil and constant over exposure period.	-----
• **No COC Decay**: No biodegradation or other loss mechanism in soil or vapor phase.	⇩
• **Finite Source Term**: Source term mass adjusted for constant volatilization over exposure period.	-----
• **Default Building Parameters**: Conservative default values for foundation crack area and air exchange rate.	⇩

- ***VF_{wamb}: Groundwater Volatilization Factor (Equation CM-5)***
  The groundwater volatilization factor is the steady-state ratio of the concentration of an organic constituent in ambient air to the source concentration in underlying affected groundwater. Vapor flux rates from groundwater to soil vapor and thence from soil vapor to ground surface are generally lower than those associated with direct volatilization from affected soils. Consequently, this groundwater-to-ambient-air volatilization factor is typically not significant in comparison to soil volatilization factors (i.e., Equations CM-1 or CM-3). This factor accounts for i) steady-state partitioning of dissolved organic constituents from groundwater to the soil vapor phase, ii) soil vapor flux rates to ground surface, and iii) mixing of soil vapors in the ambient air breathing zone directly over the plume. Dilution of organic vapors in the breathing zone is estimated using a box model, as described for Equation CM-1 above.

Key assumptions incorporated in this model and their effect on the SSTL calculation are as follows:

KEY ASSUMPTIONS: VF_{wamb}	EFFECT ON CLEANUP STANDARD
• **Vapor Equilibrium**: Soil vapor concentrations reach immediate equilibrium with groundwater source.	⇩
• **No COC Decay**: No biodegradation or other loss mechanism in groundwater or vapor phase.	⇩
• **Infinite Source**: COC mass in source term constant over time.	⇩

- ***VF_{wesp}*: *Groundwater to Enclosed Space Volatilization Factor (Equation CM-6)***
This factor is the steady-state ratio of the concentration of an organic constituent in indoor air to the source concentration in the underlying affected groundwater. The algorithm is equivalent to Equation CM-5, modified to address vapor diffusion through a building floor and enclosed space accumulation. Tier 1 default values are the same as those specified for Equation CM-4 and, as noted previously, can provide a relatively conservative (upper-range) estimate of indoor vapor concentrations. If this pathway produces the controlling (minimum) RBSL or SSTL value for a given site, the user is advised to conduct direct air or soil vapor measurements to evaluate the actual need for remedial measures.

Key assumptions used in this model and their effect on the SSTL calculation are as follows:

KEY ASSUMPTIONS: VF_{wesp}	EFFECT ON CLEANUP STANDARD
• **Vapor Equilibrium**: Soil vapor concentrations reach immediate equilibrium with groundwater source.	⇩
• **No COC Decay**: No biodegradation or other loss mechanism in groundwater or vapor phase.	⇩
• **Infinite Source**: COC mass in source term constant over time.	⇩
• **Default Building Factors**: Conservative default values for foundation crack area and air exchange rate.	⇩

- ***K_{sw}*: *Soil Leachate Partition Factor (Equation CM-7)***
The soil leachate partition factor is the steady-state ratio between the concentration of an organic constituent in soil pore water and the source concentration on the affected soil mass. This factor is used to represent the release of soil constituents to leachate percolating through the affected soil zone.

Key assumptions used in this equation and their effect on the SSTL calculation are as follows:

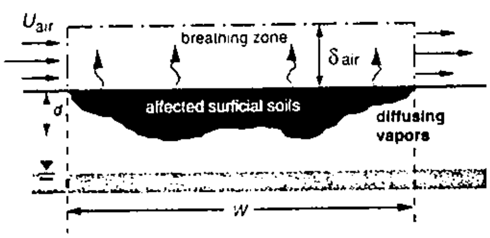
KEY ASSUMPTIONS: K_{sw}	EFFECT ON CLEANUP STANDARD
• **Leachate Equilibrium**: Leachate concentrations reach immediate equilibrium with affected soil source.	⇩
• **No COC Decay**: No biodegradation or other loss mechanism in soil or leachate.	⇩
• **Infinite Source**: COC mass in soil constant over time.	⇩

- ***LDF: Leachate-Groundwater Dilution Factor (Equation CM-8)***
  The LDF factor accounts for dilution of organics as leachate from the overlying affected soil zone mixes with groundwater in the underlying water-bearing unit. As indicated on Figure A.2, the leachate dilution factor (LDF) divided by the soil-leachate partition factor (K_{sw}) represents the steady-state ratio between the concentration of an organic constituent in the groundwater zone and the source concentration on the overlying affected soil. To estimate the leachate dilution factor, a simple box model is used to estimate mass dilution within a mixing zone in the water-bearing unit directly beneath the affected soil mass (see Equation CM-8, Figure A.3 on page A-13). The leachate volume entering the water-bearing unit is represented by the deep infiltration term, I, which typically falls in the range of 0.5% - 5% of annual site precipitation. For the Tier 1 RBSL calculation, a conservative default infiltration value of 30 cm/year is used, consistent with the example provided in ASTM E-1739, Appendix X.2. For many sites, this default value (equivalent to an annual rainfall rate of over 200 in/year) may significantly overestimate actual leachate rates.

  Key assumptions used in this equation and their effect on the SSTL calculation are as follows:

KEY ASSUMPTIONS: LDF	EFFECT ON CLEANUP STANDARD
• **Rainfall Infiltration:** Deep percolation through affected soil assumed to reach water-bearing unit regardless of soil thickness or permeability.	⇩
• **No COC Decay:** No biodegradation or other loss in mechanism groundwater zone.	⇩
• **Default Dilution Parameters:** Conservative default value for infiltration rate.	⇩

Equation CM-1: Surface Soil Volatilization Factor (VFss)



CM-1a:

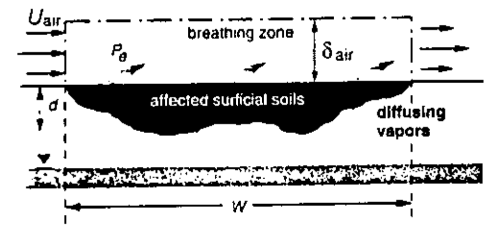
$$VF_{ss}\left[\frac{(mg/m^3-air)}{(mg/kg-soil)}\right]=\frac{2W\rho_s}{U_{air}\delta_{air}}\sqrt{\frac{D^{eff}H}{\pi\tau(\theta_{ws}+k_s\rho_s+H\theta_{as})}}\times 10^3$$

or CM-1b:

$$VF_{ss}\left[\frac{(mg/m^3-air)}{(mg/kg-soil)}\right]=\frac{W\rho_s d}{U_{air}\delta_{air}\tau}\times 10^3$$

whichever is less

Equation CM-2: Soil Particulate Emission Factor (PEF)

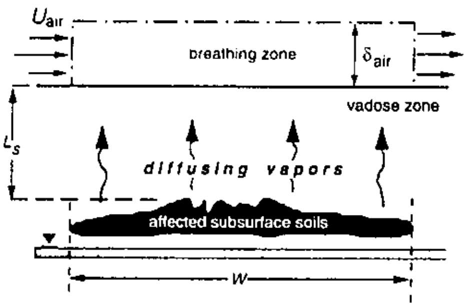


$$PEF\left[\frac{(mg/m^3-air)}{(mg/kg-soil)}\right]=\frac{P_e W}{U_{air}\delta_{air}}\times 10^3$$

FIGURE A.3 CROSS-MEDIA PARTITIONING EQUATIONS IN THE RBCA SPREADSHEET SYSTEM ***Continued***

Continued

Equation CM-3: Subsurface Soil Volatilization Factor (VFsamb)



CM-3a:

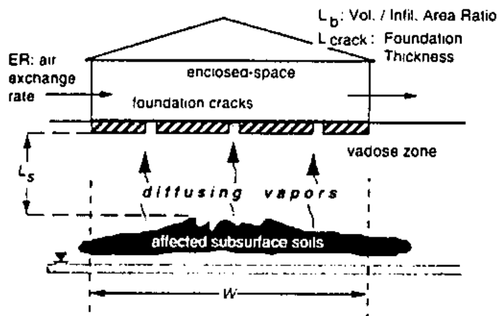
$$VF_{samb}\left[\frac{(mg/m^3-air)}{(mg/kg-soil)}\right]=\frac{H\rho_s}{\left[\theta_{ws}+k_s\rho_s+H\theta_{as}\right]\left[1+\frac{U_{air}\delta_{air}L_s}{D_s^{eff}W}\right]}\text{x}10^3$$

or CM-3b:

$$VF_{samb}\left[\frac{(mg/m^3-air)}{(mg/kg-soil)}\right]=\frac{W\rho_s d_s}{U_{air}\delta_{air}\tau}\text{x}10^3$$

whichever is less

Equation CM-4: Subsurface Soil to Enclosed Space Volatilization Factor (VFsesp)



CM-4a:

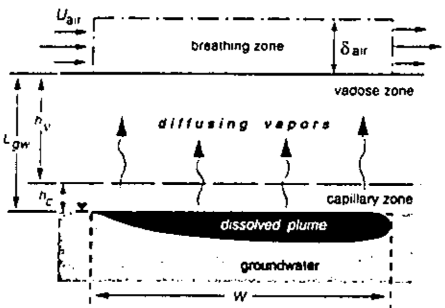
$$VF_{sesp}\left[\frac{(mg/m^3-air)}{(mg/kg-soil)}\right]=\frac{\frac{H\rho_s}{\left[\theta_{ws}+k_s\rho_s+H\theta_{as}\right]}\left[\frac{D_s^{eff}/L_s}{ER\ L_B}\right]}{1+\left[\frac{D_s^{eff}/L_s}{ER\ L_B}\right]+\left[\frac{D_s^{eff}/L_s}{\left(D_{crack}^{eff}/L_{crack}\right)\eta}\right]}\text{x}10^3$$

or CM-4b:

$$VF_{sesp}\left[\frac{(mg/m^3-air)}{(mg/kg-soil)}\right]=\frac{\rho_s d_s}{L_B ER\tau}\text{x}10^3$$

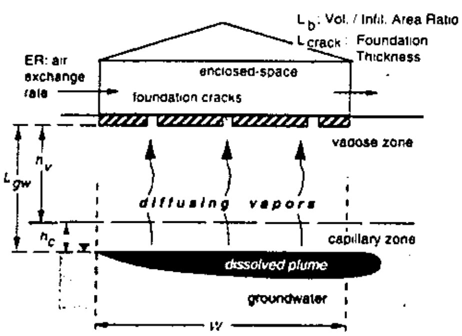
whichever is less

Equation CM-5: Groundwater Volatilization Factor (VFwamb)



$$VF_{wamb}\left[\frac{(mg/m^3-air)}{(mg/L-H_2O)}\right]=\frac{H}{1+\left[\frac{U_{air}\delta_{air}L_{GW}}{WD_{ws}^{eff}}\right]}\text{x}10^3$$

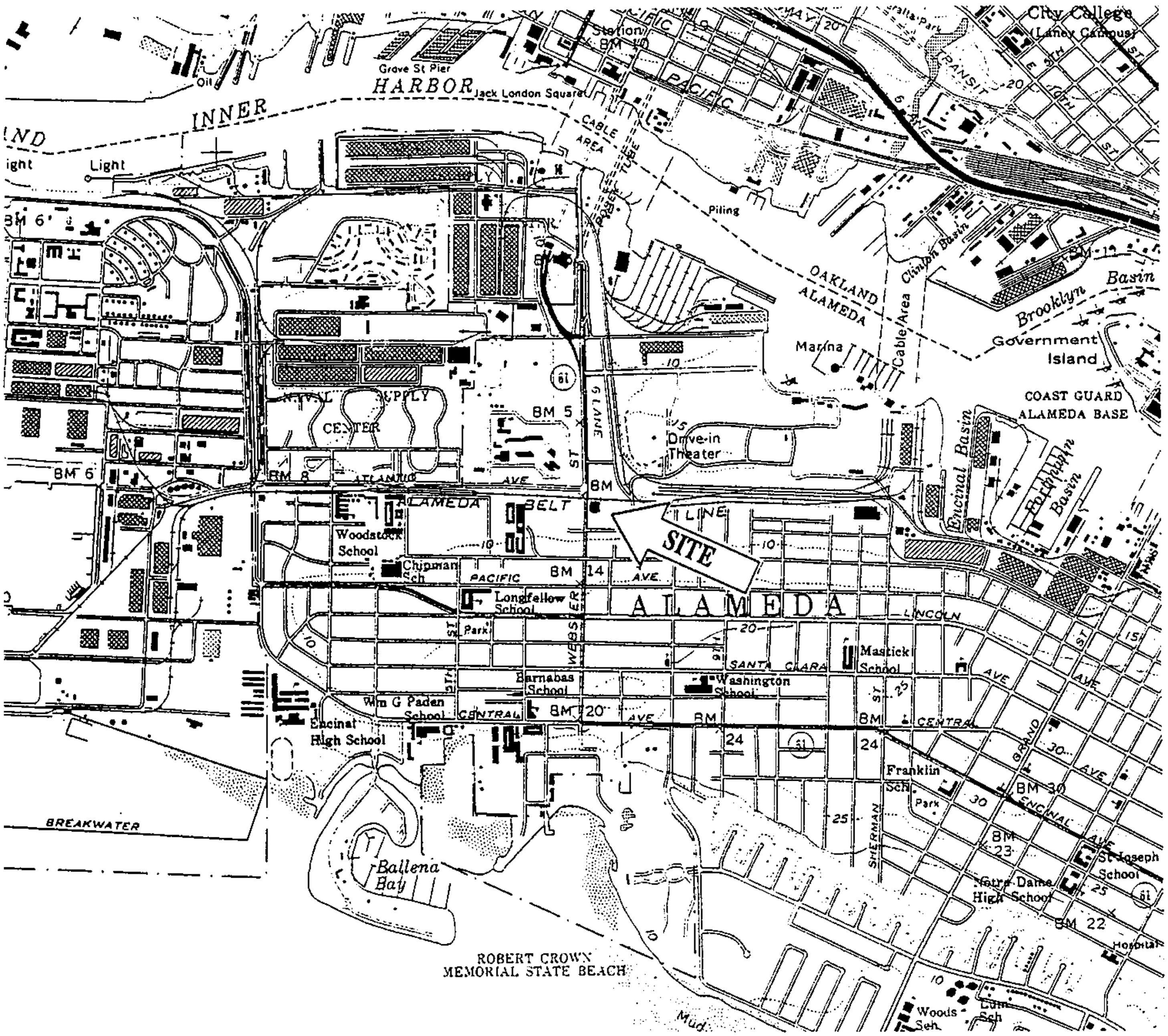
Equation CM-6: Groundwater to Enclosed Space Volatilization Factor (VFwesp)



$$VF_{wesp}\left[\frac{(mg/m^3-air)}{(mg/L-H_2O)}\right]=\frac{H\left[\frac{D_{ws}^{eff}/L_{GW}}{ER\ L_B}\right]}{1+\left[\frac{D_{ws}^{eff}/L_{GW}}{ER\ L_B}\right]+\left[\frac{D_{ws}^{eff}/L_{GW}}{\left(D_{crack}^{eff}/L_{crack}\right)\eta}\right]}\text{x}10^3$$

FIGURE A.3 CROSS-MEDIA PARTITIONING EQUATIONS IN THE RBCA SPREADSHEET SYSTEM *Continued*

FIGURES



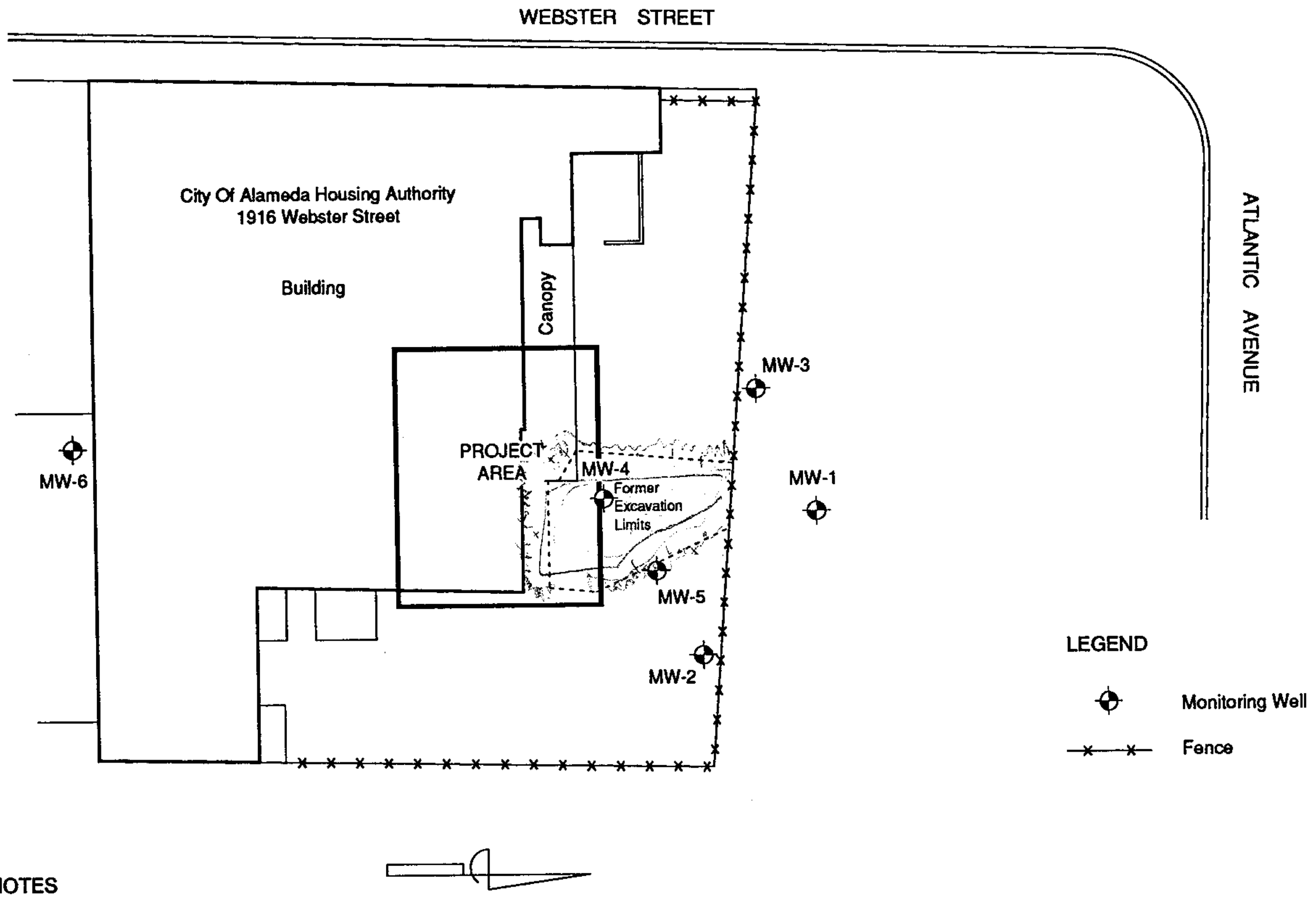
GENERAL NOTES:

BASE MAP FROM USGS
7.5 MINUTE TOPOGRAPHIC
OAKLAND WEST, CA

0 2000 4000
Approximate Scale in Feet

FUGRO

DRAWN BY: J. Paradis	SITE LOCATION MAP		FIGURE 1
DATE: September 19, 1996			
REVISED BY:	City of Alameda Housing Authority Property 1916 Webster Street Alameda, CA		PROJECT NUMBER: 95-37-1311
DATE:			



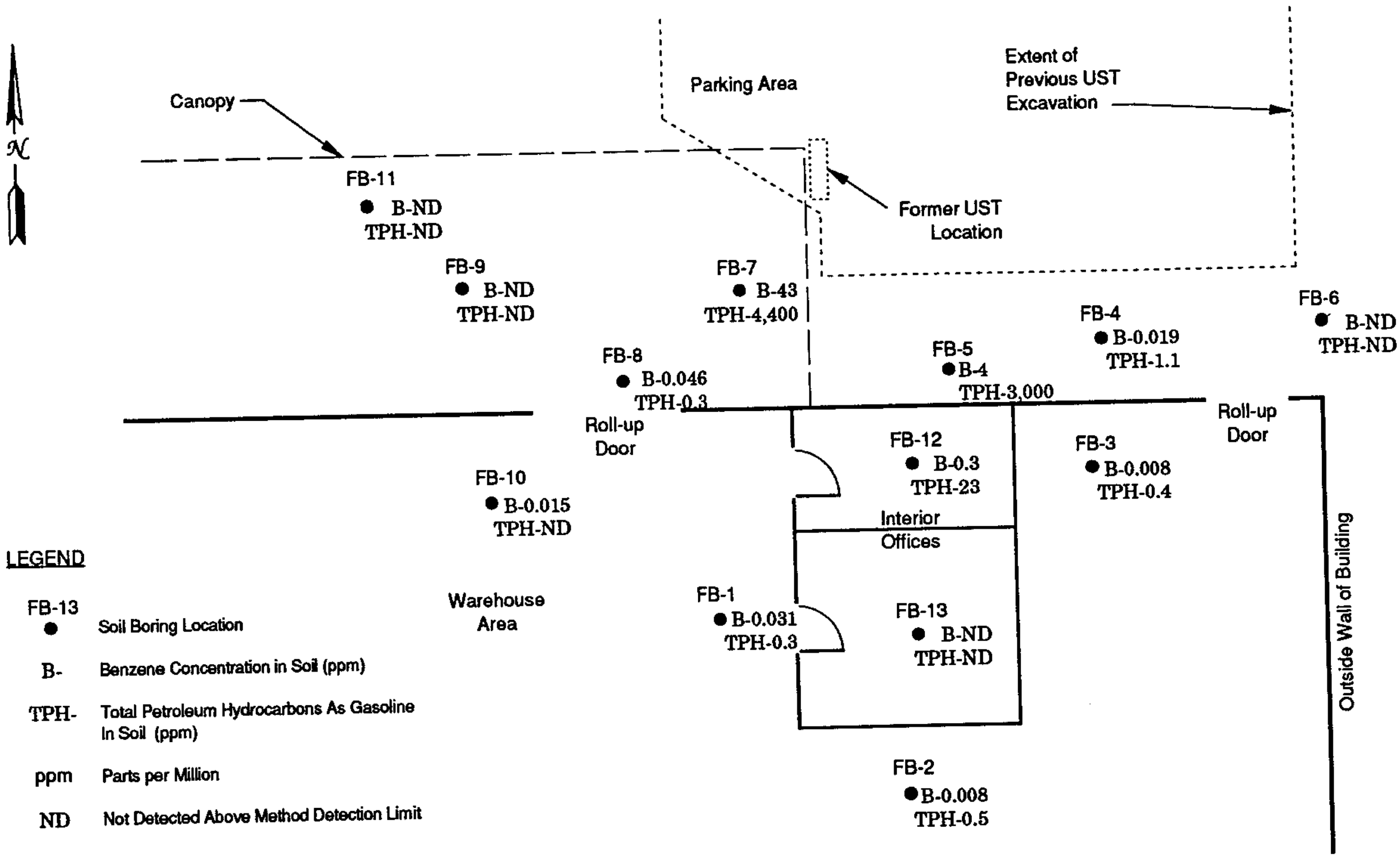
NOTES

Site Sketch After Map
By Ron Archer, Civil Engineer, Inc.

All Locations Are Approximate

0 50 100
Approximate Scale In Feet

FUGRO	DRAWN BY: D. Hada	SITE AND PROJECT AREA MAP	FIGURE 2
	DATE: April 17, 1996		
	REVISED BY: J. Paradis	City of Alameda Housing Authority Property 1916 Webster Street Alameda, CA	PROJECT NUMBER: 95-37-1311
	DATE: September 19, 1996		



NOTES:

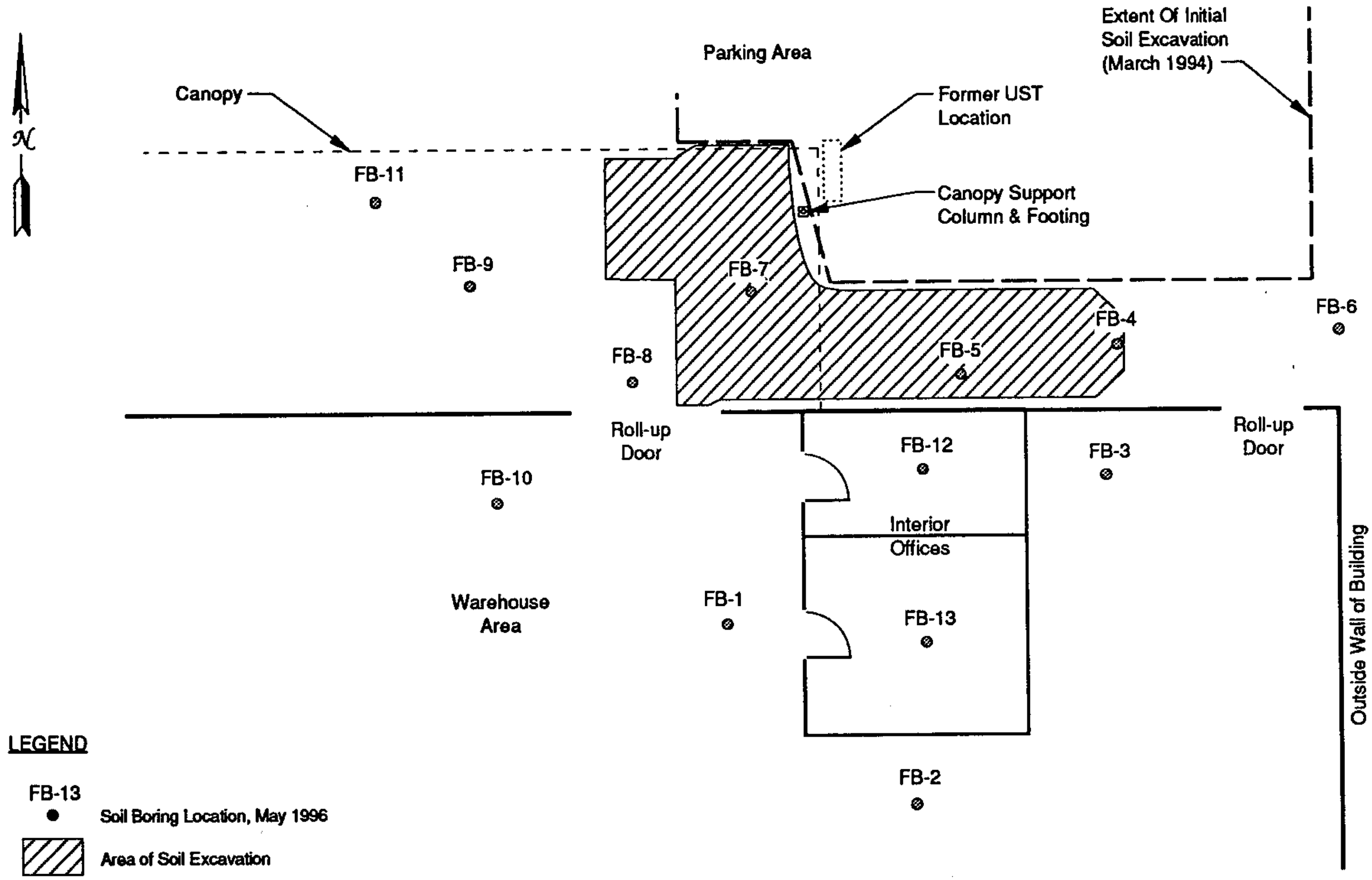
ppm = milligrams per kilogram (mg/kg)

Soil Sample Interval:
1.5-2.5 Foot Depth (typical)

All Locations Are Approximate

0 10 20
Approximate Scale In Feet

FUGRO		
DRAWN BY: J. Paradis	LOCATION OF SOIL BORINGS, DISTRIBUTION OF BENZENE AND GASOLINE CONCENTRATIONS IN SOIL MAY 1996	FIGURE 3
DATE: May 31, 1996		
REVISED BY: J. Paradis	City of Alameda Housing Authority Property 1916 Webster Street Alameda, CA	PROJECT NUMBER: 95-37-1311
DATE: September 19, 1996		



LEGEND

FB-13 ● Soil Boring Location, May 1996

Area of Soil Excavation

NOTES:

All Locations Are Approximate

0 10 20
Approximate Scale In Feet

FUGRO

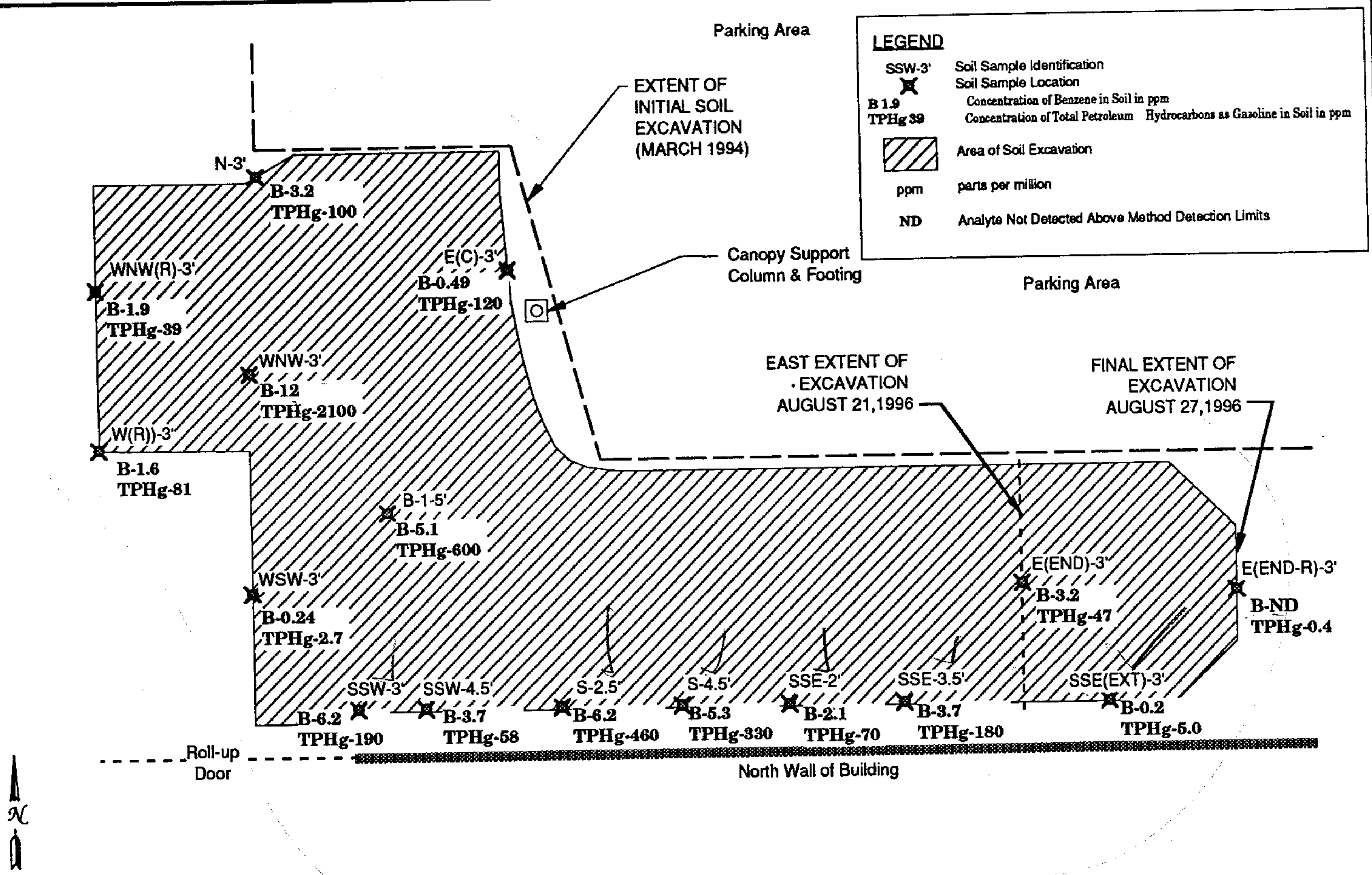
DRAWN BY:	J. Paradis
DATE:	May 31, 1996
REVISED BY:	J. Paradis
DATE:	September 19, 1996

EXCAVATION AREA MAP

City of Alameda Housing Authority Property
1916 Webster Street
Alameda, CA

FIGURE 4

PROJECT NUMBER: 95-37-1311



NOTES:

All Locations Are Approximate

0 4 8
Approximate Scale In Feet

FUGRO

DRAWN BY: J. Paradis	EXCAVATION SOIL SAMPLE LOCATIONS	FIGURE 5
DATE: May 31, 1996		
REVISED BY: J. Paradis	City of Alameda Housing Authority Property 1916 Webster Street Alameda, CA	PROJECT NUMBER: 95-37-1311
DATE: September 20, 1996		