aqua science engineers inc.

April 3, 1997
(Ref. File No. 152.00)

ORIGINAL
RA

Alameda County Health Care Services, Hazardous Materials Division
1131 Harbor Bay Parkway, Suite 250
Alameda, CA 94052

Attn: Ms. Madhulla Logan

RE: Risk Assessment for Zima Center Corporation
2951 High Street, Oakland, CA

Dear Ms. Logan,

At your request, a Tier 2 Risk-Based Corrective Action (RBCA) has been performed for the above referenced site. The purpose of the RBCA was to calculate site-specific target levels for contaminant cleanup to protect human health due to exposure at the source or at points of exposure. This work is part of an Aqua Science Engineers, Inc. (ASE) Remedial Action Plan for the Zima Site, at the request of the Alameda County Health Care Services Agency (ACHCSA).

Background

One 300-gallon waste oil underground storage tank was removed from the site by Alpha Geo Services in September, 1993. Evidence of contamination was revealed and approximately 40 cubic yards of contaminated soil was removed from the tank pit vicinity. An initial site assessment consisted of four groundwater monitoring wells which were installed in February, 1995 by Soil Tech Engineering, Inc. These wells revealed groundwater contamination and indicated changeable flow directions to the north and south.

ASE continued site assessment by drilling and sampling five soil borings in June, 1995 which revealed more contamination. In December, 1996 and January, 1997 ASE drilled two soil borings and installed two additional monitoring wells for further contaminant plume definition. These wells suggested that some contaminants may be attributed to the existing underground fuel tank farm area. Groundwater flow appears anomalous for this site, with changeable flow directions, and a historically consistent flow trend has not yet been observed.

RBCA Scenarios

ASE has developed a Remedial Action Plan (RAP) for this site. As a part of that plan, the ACHCSA requested that a RBCA be performed for Benzene, Toluene, Ethylbenzene, Xylene and Methyl-tert-butyl-ether (BTEX, MTBE) fuel constituents.

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The following exposure scenarios were modeled:

Scenario 1. Vapors from groundwater which could enter a neighboring residence.
Scenario 2. Vapors from groundwater entering a commercial building on-site.
Scenario 3. Exposure of vapors from soil to construction workers on-site.

The purpose of this RBCA was to calculate cleanup Site Specific Target Levels (SSTLs) for the affected soil and groundwater. The calculation of these SSTLs was performed using site specific data available from previous site assessments. The computer models used to make the calculations was the Groundwater Services©, Inc., 1995 Tier 2 RBCA for Risk-Based Corrective Action. This computer model kit uses the guidelines described in the American Society of Testing Methods E-1739 *"Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites."* The ACHCSA is familiar with this computer model package and its use for RBCA.

The previous site assessment work summarized in the RAP effectively constitutes the Tier 1 Evaluation which identifies potential contaminant sources, transport pathways and exposure pathways. The Tier 2 data used in the models and calculations includes information on source zone characteristics, hydrogeologic conditions, relevant points of exposure and applicable risk goals as discussed below.

Source Zone. A known source was the waste oil underground storage tank which has been removed from the site together with contaminated soil. Additional contamination sources are suspected in the vicinity of the existing underground tank pit, possibly due to overspillage. The groundwater under the site has been affected and mapped with groundwater monitoring wells and soil borings. The historic maximum concentrations of the BTEX and MTBE constituents in soil and groundwater were used in all simulations. These concentrations were selected as the most conservative assumption to protect human health in the simulations (see concentrations listed in simulation output).

Hydrogeologic Conditions. The site is underlain by interbedded clayey silt and sandy sediment to depths of 30-feet. Groundwater was encountered at depths of about 22-feet below existing grade (beg) and current static water levels are about 7-feet beg. Groundwater movement is relatively slow and flow directions are changeable according to available site information.

Relevant Points of Exposure. At the request of the ACHCSA, the points of exposure are: vapor from groundwater entering a residence about 30-feet northwest of the site, vapor from groundwater entering a commercial building on-site, and vapor from groundwater and dermal exposure to construction workers excavating soils on-site.

Applicable Risk Goals. These are human health protection goals for individual and cumulative effects of exposure within the regulatory exposure limits and ecological standards. The groundwater under the site is not used for drinking water and water is supplied by East Bay Municipal Utility District. The site vadose zone soils are relatively low permeability, however default values were selected for soils as well as groundwater flow, which are conservative for these scenarios (that is, the model default values yield somewhat higher permeability and

conductivity values for water and vapor motion than anticipated or quantified subsurface conditions). The target risk health values were selected as 10^{-6} for Class A and B carcinogens and 10^{-5} for Class C carcinogens and a target hazard quotient of 1. Discussions with ACHCSA personnel indicate that these are reasonable data and exposure assumptions for the RBCA calculations.

Model Calculations

The model calculations were performed by inputting the appropriate on-site data, risk goals, exposure assumptions and model default parameters. Each scenario was then calculated for the SSTL and target cleanup level. Since the groundwater is not used for drinking, the CAL-EPA "correction factor" was not used in the model calculated numbers which are presented below.

Scenario 1.
This calculated the groundwater SSTL to protect an off-site residence from vapors emanating from groundwater into the residence. The highest concentrations observed in groundwater on-site were selected for this scenario. The simulation assumes 0.5% cracks in a slab-on-grade foundation. The model calculated a Benzene SSTL of 0.034 milligrams per liter (mg/l). The other TEX and MTBE constituents did not exceed SSTLs. A groundwater constituent reduction factor is indicated from this model, some cleanup is required.

Scenario 2.
This calculated the groundwater SSTL to protect an on-site commercial building from vapors emanating from groundwater under the building. The highest concentrations observed in groundwater were selected for this scenario. This simulation assumes 0.5% cracks in a slab-on-grade foundation. The model calculated a Benzene SSTL of 0.110 mg/l. The other TEX and MTBE constituents did not exceed SSTLs. Since a groundwater constituent reduction factor is indicated from this model, some cleanup is required.

Scenario 3.
This calculated the soil SSTL to protect construction workers from vapors emanating from the soil, with the worker located in the contaminant source. The highest concentrations observed in soil below 3-feet deep were selected for this scenario. Dermal exposure was factored into the simulation. The model calculated a soil SSTL of 1.8 milligrams per kilogram (mg/kg). The carcinogenic risk at this concentration is less that 10^{-6}, hence a soil cleanup is not needed for further contaminant reduction.

Conclusions

A RBCA model was performed for three exposure scenarios as requested by ACHCSA as a part of the ASE RAP for the Zima site. The results of the model simulations show the following;

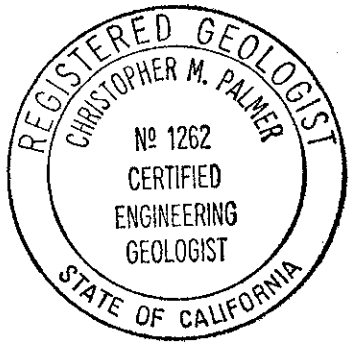
- A SSTL of 0.034 mg/l Benzene for the residential vapor point of exposure.
- A SSTL of 0.110 mg/l Benzene for the commercial building vapor point of exposure.

- o Exposure of construction workers to soil vapor did not exceed a soil SSTL.

Since Benzene is the constituent of concern which exceeds SSTLs in scenarios as noted above, some remedial groundwater cleanup work is required. ASE has proposed a remedial approach for this site to reduce the groundwater contaminants to reduce the potential exposures modeled above.

If you have any questions, please call.
Sincerely,

Christopher M. Palmer, C. E. G. 1262



Attachments:

Tier 1 Executive Summary Checklist
Tier 2 Executive Summary Checklist
Scenario 1. Groundwater SSTL Values and Output Table 1
Scenario 2. Groundwater SSTL Values and Output Table 1
Scenario 3. Subsurface Soil SSTL Values and Output Table 1

References

Aqua Science Engineers, Inc. report dated March 17, 1997 entitled, "Remedial Action Plan for Remediation of hydrocarbon Impacted Groundwater at Zima Center Corporation 2951 High Street, Oakland, CA (Draft)," 9 pages with attachments.

Aqua Science Engineers, Inc. report dated January 23, 1997 entitled, "Report of Soil and Groundwater Assessment ASE Job No. 3011 at Zima Center Corporation 2951 High Street Oakland, CA,"11 pages with attachments.

Groundwater Services©, Inc., 1995 Tier 2 RBCA for Risk-Based Corrective Action: computer models for soil, groundwater and vapor with accompanying texts.

Site Name: Zima Center Corp. Date Completed: March 31, 1997

Site Location: 2951 High Street, Oakland, CA Completed By: C. Palmer

TIER 1 EXECUTIVE SUMMARY CHECKLIST

VISUAL/HISTORICAL ASSESSMENT (■ TO SELECT)

Site size (acres)	■ <1	❑ <10	❑ >10
Site setting	❑ undeveloped	■ industrial	❑ residential
Site access	❑ capped	❑ fenced-in	■ open
Visual evidence of environmental impact	■ none	❑ limited	❑ extensive
Current site land use	❑ undeveloped	■ indust./comm.	❑ residential
Contaminant sources	■ tanks/spills	❑ trench/drums	❑ ponds/pits
Affected environmental media	❑ soil (>3 ft BGS)	■ groundwater	■ surficial soil (≤3 ft BGS)
Types of compounds likely to be present	■ petroleum hydrocarbons inorganic (nitrates) ❑	❑ metals ❑ other:(pesticides)	

BASELINE RECEPTOR IDENTIFICATION

Reasonable potential receptors (greatest concern)	❑ none	❑ ecological	■ human
Distance from fenceline to nearest off-site receptor (ft)	❑ >500	❑ 100 - 500	■ <100
Travel time to closest groundwater receptor (yr)	❑ >10	■ 2 - 10	❑ <2
Depth to first encountered groundwater (ft)	❑ >150	❑ 50 - 150	■ <50
Complete exposure pathways	❑ none	❑ ingestion	■ inhalation
	❑ ecological	■ dermal	❑ absorption

TIER 1 TASKS COMPLETED

❑ Visual / historical assessment	■ Initial (screening) site assessment	❑ Site prioritization / classification
■ Detailed site characterization	❑ RBSL comparison	❑ Initial ecological assessment
■ Corrective action planned ~~or implemented~~		

TIER 1 CLASSIFICATION EVALUATION

Classification No.	Scenario Description	Prescribed Interim Action	Date Implemented
	Underground storage tank removal and excavationof contaminated soil. Site Assessment by soil borings and groundwater wells.	Interim cleanup. Groundwater monitoring	Sept.-Oct., 1993 Feb. 1995-Present

TIER 1 CORRECTIVE ACTION CRITERIA

	Screening Level Criteria Exceeded? (■ if yes)						
Affected Medium	Risk-Based	Other (MCL)	Others: (specify) _____				None Exceeded
• Surface Soil (< 3ft BGS)	❑	❑	❑	❑	❑	❑	■
• Subsurface Soil (> 3ft BGS)	❑	❑	❑	❑	❑	❑	■
• Groundwater (potable/nonpotable)	■	■	❑	❑	❑	❑	❑
• Surface waters	❑	❑	❑	❑	❑	❑	■

NOTES: (List and discuss chemicals for which a Tier 1 exceedance is found.)

PROPOSED TIER 1 ACTION

❑ *No Action:* Site does not exceed Tier 1 criteria. - Apply for closure.

❑ *Interim Corrective Action:* Site exceeds some Tier 1 criteria. - Propose interim corrective action and reprioritize site.

■ *Final Corrective Action:* Site exceeds some Tier 1 criteria. - Propose corrective action to achieve Tier 1 criteria.

❑ *Tier 2 Evaluation:* Site exceeds some Tier 1 criteria. - Re-evaluate corrective action goals per Tier 2 risk assessment.

Site Name: Zima Center Corp. Date Completed: March 31, 1997

Site Location: 2951 High Street, Oakland, CA Completed By: C. Palmer

TIER 2 EXECUTIVE SUMMARY CHECKLIST

TIER 2 SSTL CALCULATION METHOD (■ OR ● TO SELECT)

SSTL Calculation Option

- ■ Option 1: Site-Specific Screening Levels
- ☐ Option 2: Individual Constituent SSTL Values
- ☐ Option 3: Cumulative Constituent SSTL Values

NAF Calculation Method

- ☐ Fate and Transport Modeling:
  - ○ RBCA Spreadsheet System
  - ○ Other Model(s)
- ☐ Empirical NAF Calculation

SITE DATA INVENTORY

Source Zone Investigation Complete:

- ■ Surface Soil (e.g., ≤ 3 ft BGS)
- ■ Subsurface Soil (e.g., > 3 ft BGS)
- ■ Groundwater

Exposure Pathway Information Compiled:

- ■ Air Pathway
- ■ Groundwater Pathway
- ■ Soil Pathway
- ☐ Surface Water Pathway
- ☐ Land Use Classification (on-site and off-site)

TIER 1 WORKSHEETS 1.3 - 4.2 AND 5.2 - 5.6 HAVE BEEN UPDATED TO INCLUDE NEW TIER 2 INFORMATION.

TASKS COMPLETED

- ■ Tier 1 Evaluation
- ☐ Tier 1 Interim Corrective Action
- ■ Tier 2 Evaluation
- ☐ Tier 2 Interim Corrective Action
- ☐ Tier 2 Final Corrective Action
- ☐ Tier 3 Evaluation

CURRENT SITE CLASSIFICATION

Classification No.	Scenario Description	Prescribed Interim Action	Date Implemented
	Leaking underground tank. Site Assessment.	Tank source and contaminated soil removal, Subsurface assessment of soil and groundwater plume definition.	Sept.-Oct., 1993 Feb., 1995-Present

TIER 2 CORRECTIVE ACTION CRITERIA

Affected Medium	Tier 2 SSTL Exceeded?		Applicable Excess Risk Limits (specify value)				Other Applicable Exposure Limit
	Yes	No	Indiv. Risk	Total Risk	Hazard Index	Hazard Quotent	*(specify, if any)*
• Surface Soil (≤ 3ft BGS)	☐	☐	N/A	N/A	N/A	N/A	None
• Subsurface Soil (> 3ft BGS)	☐	☐	Below SSTL	Below SSTL	1	1	None
• Groundwater	☐	☐	see each	Above SSTL	1	1	None

PROPOSED ACTION

- ☐ ***No Action:*** Tier 2 SSTLs not exceeded. Apply for closure.
- ☐ ***Interim Corrective Action:*** Address principal, near-term risks sources.
- ■ ***Final Corrective Action:*** Remediate/control site to meet Tier 2 criteria.
- ☐ ***Tier 3 Evaluation:*** Improve baseline risk and SSTL estimates.

NOTE:

Rationale for proposed action documented on Worksheet 9.3 attached.

RBCA SITE ASSESSMENT — Tier 2 Worksheet 9.3

Site Name: Zima Center Corp.
Site Location: 2951 High Street, Oakland, CA

Completed By: Chris Palmer
Date Completed: 3/21/1997

GROUNDWATER SSTL VALUES

Target Risk (Class A & B) 1.0E-6
Target Risk (Class C) 1.0E-5
Target Hazard Quotient 1.0E+0

☐ MCL exposure limit?
☐ PEL exposure limit?

Calculation Option: 2

SSTL Results For Complete Exposure Pathways ("x" If Complete)

CONSTITUENTS OF CONCERN		Representative Concentration				X		X		Applicable SSTL	SSTL Exceeded ?	Required CRF
			Groundwater Ingestion			Groundwater Volatilization to Indoor Air		Groundwater Volatilization to Outdoor Air				
CAS No.	Name	(mg/L)	Residential: (on-site)	Commercial: (on-site)	Regulatory(MCL): (on-site)	Residential: (on-site)	Commercial: (on-site)	Residential (on-site)	Commercial: (on-site)	(mg/L	"■" If yes	Only if "yes" left
71-43-2	Benzene	4.6E+0	NA	NA	NA	3.4E-2	NA	1.1E+1	NA	3.4E-2	■	1.4E+02
100-41-4	Ethylbenzene	7.0E-1	NA	NA	NA	1.1E+2	NA	>Sol	NA	1.1E+2	☐	<1
1634-04-4	Methyl t-Butyl Ether	1.6E+1	NA	NA	NA	2.6E+3	NA	>Sol	NA	2.6E+3	☐	<1
108-88-3	Toluene	2.8E+0	NA	NA	NA	4.6E+1	NA	>Sol	NA	4.6E+1	☐	<1
1330-20-7	Xylene (mixed isomers)	2.7E+0	NA	NA	NA	>Sol	NA	>Sol	NA	>Sol	☐	<1

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Software: GSI RBCA Spreadsheet
Version: v 1.0

Serial: G-385-FVX-826

Scenario 1.

RBCA TIER 1/TIER 2 EVALUATION

Output Table 1

Site Name: Zima Center Corp. Job Identification: 3011
Site Location: 2951 High Street, Oakland, CADate Completed: 3/21/97
Completed By: Chris Palmer

Software: GSI RBCA Spreadsheet
Version: v 1.0

DEFAULT PARAMETERS

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

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		
BW	Body Weight (kg)	70	15	35		
ED	Exposure Duration (yr)	30	6	18		
EF	Exposure Frequency (days/yr)	350				
EF.Derm	Exposure Frequency for dermal exposure	350				
IRgw	Ingestion Rate of Water (l/day)	2				
IRs	Ingestion Rate of Soil (mg/day)	100	200			
IRadj	Adjusted soil ing. rate (mg*yr/kg*d)	1.1E+02			#DIV/0!	
IRa.in	Inhalation rate indoor (m^3/day)	15				
IRa.out	Inhalation rate outdoor (m^3/day)	20				
SA	Skin surface area (dermal) (cm^2)	5.8E+03		***2.0E+03***		
SAadj	Adjusted dermal area (cm^2*yr/kg)	2.1E+03			#DIV/0!	
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	TRUE	FALSE	
GW.b	Vapor Intrusion to Buildings	TRUE	FALSE	
Soil Pathways				
S.v	Volatiles from Subsurface Soils	TRUE	FALSE	
SS.v	Volatiles and Particulate Inhalation	FALSE	FALSE	FALSE
SS.d	Direct Ingestion and Dermal Contact	FALSE	FALSE	FALSE
S.l	Leaching to Groundwater from all Soils	FALSE	FALSE	
S.b	Intrusion to Buildings - Subsurface Soils	FALSE	FALSE	

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		FALSE

Matrix of Target Risks		Individual	Cumulative
TRab	Target Risk (class A&B carcinogens)	1.0E-06	
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		
A	Contaminated soil area (cm^2)	2.2E+06		1.0E+06
W	Length of affected soil parallel to wind (cm)	1.5E+03		1.0E+03
W.gw	Length of affected soil parallel to groundwater (cr	1.5E+03		
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)	1.0E+02		
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)	2.5E+03
Ugw.tr	Groundwater Transport velocity (cm/yr)	6.6E+03
Ks	Saturated Hydraulic Conductivity(cm/s)	
grad	Groundwater Gradient (cm/cm)	
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)	5.0E+00		
hv	Vadose zone thickness (cm)	3.0E+02		
rho	Soil density (g/cm^3)	1.7		
foc	Fraction of organic carbon in vadose zone	0.01		
phi	Soil porosity in vadose zone	0.38		
Lgw	Depth to groundwater (cm)	3.0E+02		
Ls	Depth to top of affected soil (cm)	1.0E+02		
Lsubs	Thickness of affected subsurface soils (cm)	2.0E+02		
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	***0.005***	

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)		

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Scenario 1.

RBCA SITE ASSESSMENT — Tier 2 Worksheet 9.3

Site Name: Zima Center Corp. (Zima 2)
Site Location: 2951 High St., Oakland, CA

Completed By: Chris Palmer
Date Completed: 3/10/1997

GROUNDWATER SSTL VALUES

Target Risk (Class A & B) 1.0E-6
Target Risk (Class C) 1.0E-5
Target Hazard Quotient 1.0E+0

❑ MCL exposure limit?
❑ PEL exposure limit?

Calculation Option: 1

SSTL Results For Complete Exposure Pathways ("x" If Complete)

CONSTITUENTS OF CONCERN		Representative Concentration		Groundwater Ingestion			X	Groundwater Volatilization to Indoor Air			Groundwater Volatilization to Outdoor Air		Applicable SSTL	SSTL Exceeded ?	Required CRF
CAS No.	Name	(mg/L)	Residential: (on-site)	Commercial: (on-site)	Regulatory(MCL): (on-site)		Residential: (on-site)	Commercial: (on-site)		Residential (on-site)	Commercial: (on-site)	(mg/L	"■" If yes	Only if "yes" left
71-43-2	Benzene	4.6E+0	NA	NA	NA		NA	1.1E-1		NA	NA	1.1E-1	■	4.3E+01
100-41-4	Ethylbenzene	7.0E-1	NA	NA	NA		NA	>Sol		NA	NA	>Sol	❑	<1
1634-04-4	Methyl t-Butyl Ether	1.3E+1	NA	NA	NA		NA	6.8E+3		NA	NA	6.8E+3	❑	<1
108-88-3	Toluene	2.8E+0	NA	NA	NA		NA	1.2E+2		NA	NA	1.2E+2	❑	<1
1330-20-7	Xylene (mixed isomers)	2.7E+0	NA	NA	NA		NA	>Sol		NA	NA	>Sol	❑	<1

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Software: GSI RBCA Spreadsheet
Version: v 1.0

Serial: G-385-FVX-826

Scenario 2.

RBCA TIER 1/TIER 2 EVALUATION

Output Table 1

Site Name: Zima Center Corp. (Zima 2) Job Identification: 3011
Site Location: 2951 High St., Oakland, CA Date Completed: 3/10/97
Completed By: Chris Palmer

Software: GSI RBCA Spreadsheet
Version: v 1.0

DEFAULT PARAMETERS

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

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			25	1
ATn	Averaging time for non-carcinogens (yr)				70	
BW	Body Weight (kg)				25	1
ED	Exposure Duration (yr)				250	180
EF	Exposure Frequency (days/yr)				250	
EF.Derm	Exposure Frequency for dermal exposure				1	
IRgw	Ingestion Rate of Water (l/day)				50	100
IRs	Ingestion Rate of Soil (mg/day)				#DIV/0!	
IRadj	Adjusted soil ing. rate (mg-yr/kg-d)	#DIV/0!			20	
IRa.in	Inhalation rate indoor (m^3/day)				20	10
IRa.out	Inhalation rate outdoor (m^3/day)				5.8E+03	5.8E+03
SA	Skin surface area (dermal) (cm^2)				#DIV/0!	
SAadj	Adjusted dermal area (cm^2-yr/kg)	#DIV/0!				
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				

Surface Parameters	Definition (Units)	Residential	Commercial/Industrial Chronic	Commercial/Industrial Construction
t	Exposure duration (yr)		25	1
A	Contaminated soil area (cm^2)	2.2E+06		1.0E+06
W	Length of affected soil parallel to wind (cm)	1.5E+03		1.0E+03
W.gw	Length of affected soil parallel to groundwater (cr	1.5E+03		
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)	1.0E+02		
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)	2.5E+03
Ugw.tr	Groundwater Transport velocity (cm/yr)	6.6E+03
Ks	Saturated Hydraulic Conductivity(cm/s)	
grad	Groundwater Gradient (cm/cm)	
Sw	Width of groundwater source zone (cm)	
Sd	Depth of groundwater source zone (cm)	
BC	Biodegradation Capacity (mg/L)	
BIO?	Is Bioattenuation Considered	TRUE
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)	5.0E+00
hv	Vadose zone thickness (cm)	3.0E+02
rho	Soil density (g/cm^3)	1.7
foc	Fraction of organic carbon in vadose zone	0.01
phi	Soil porosity in vadose zone	0.38
Lgw	Depth to groundwater (cm)	3.0E+02
Ls	Depth to top of affected soil (cm)	1.0E+02
Lsubs	Thickness of affected subsurface soils (cm)	2.0E+02
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

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	FALSE	
GW.b	Vapor Intrusion to Buildings	FALSE	TRUE	
Soil Pathways				
S.v	Volatiles from Subsurface Soils	FALSE	FALSE	
SS.v	Volatiles and Particulate Inhalation	FALSE	FALSE	FALSE
SS.d	Direct Ingestion and Dermal Contact	FALSE	TRUE	FALSE
S.l	Leaching to Groundwater from all Soils	FALSE	FALSE	
S.b	Intrusion to Buildings - Subsurface Soils	FALSE	FALSE	

Building	Definition (Units)	Residential	Commercial
Lb	Building volume/area ratio (cm)		3.0E+02
ER	Building air exchange rate (s^-1)		2.3E-04
Lcrk	Foundation crack thickness (cm)	1.5E+01	
eta	Foundation crack fraction	***0.005***	

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)		TRUE		TRUE
S	Inhalation receptor (cm)		TRUE		TRUE

Matrix of Target Risks		Individual	Cumulative
TRab	Target Risk (class A&B carcinogens)	1.0E-06	
TRc	Target Risk (class C carcinogens)	1.0E-05	
THQ	Target Hazard Quotient	1.0E+00	
Opt	Calculation Option (1, 2, or 3)	1	
Tier	RBCA Tier	2	

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)		

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Scenario 2.

RBCA SITE ASSESSMENT

Site Name: Zima Center Corp. (Zima 3)
Site Location: 2951 High Street, Oakland, CA

Completed By: Chris Palmer
Date Completed: 3/21/1997

Tier 2 Worksheet 9.2

SUBSURFACE SOIL SSTL VALUES (> 3 FT BGS)

Target Risk (Class A & B) 1.0E-6
Target Risk (Class C) 1.0E-5
Target Hazard Quotient 1.0E+0

❑ MCL exposure limit?
❑ PEL exposure limit?

Calculation Option: 1

SSTL Results For Complete Exposure Pathways ("x" if Complete)

CONSTITUENTS OF CONCERN		Representative Concentration	Soil Leaching to Groundwater			Soil Volatilization to Indoor Air		X Soil Volatilization to Outdoor Air		Applicable SSTL	SSTL Exceeded ?	Required CRF
CAS No.	Name	(mg/kg)	Residential: (on-site)	Commercial: (on-site)	Regulatory(MCL): (on-site)	Residential: (on-site)	Commercial: (on-site)	Residential: (on-site)	Commercial: (on-site)	(mg/kg)	"■" If yes	Only if "yes" left
71-43-2	Benzene	1.7E+1	NA	NA	NA	NA	NA	NA	1.8E+1	1.8E+1	❑	<1
100-41-4	Ethylbenzene	3.9E+1	NA	NA	NA	NA	NA	NA	>Res	>Res	❑	<1
#######	Methyl t-Butyl Ether	7.6E+0	NA	NA	NA	NA	NA	NA	>Res	>Res	❑	<1
108-88-3	Toluene	6.9E+1	NA	NA	NA	NA	NA	NA	>Res	>Res	❑	<1
#######	Xylene (mixed isomers)	1.7E+2	NA	NA	NA	NA	NA	NA	>Res	>Res	❑	<1

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Software: GSI RBCA Spreadsheet
Version: v 1.0

Serial: G-385-FVX-826

Scenario 3.

RBCA TIER 1/TIER 2 EVALUATION

Output Table 1

Site Name: Zima Center Corp. (Zima 3) Job Identification: 3011
Site Location: 2951 High Street, Oakland, CADate Completed: 3/21/97
Completed By: Chris Palmer

Software: GSI RBCA Spreadsheet
Version: v 1.0

DEFAULT PARAMETERS

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

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			25	1
ATn	Averaging time for non-carcinogens (yr)				70	
BW	Body Weight (kg)				25	1
ED	Exposure Duration (yr)				250	180
EF	Exposure Frequency (days/yr)				250	
EF.Derm	Exposure Frequency for dermal exposure				50	100
IRgw	Ingestion Rate of Water (l/day)				#DIV/0!	
IRs	Ingestion Rate of Soil (mg/day)				20	
IRadj	Adjusted soil ing. rate (mg-yr/kg-d)	#DIV/0!			20	10
IRa.in	Inhalation rate indoor (m^3/day)				5.8E+03	5.8E+03
IRa.out	Inhalation rate outdoor (m^3/day)				#DIV/0!	
SA	Skin surface area (dermal) (cm^2)					
SAadj	Adjusted dermal area (cm^2-yr/kg)	#DIV/0!				
M	Soil to Skin adherence factor	1				
AAFs	Age adjustment on soil ingestion	FALSE			FALSE	
AAFd	Age adjustment on skin surface area	FALSE			***TRUE***	
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	FALSE	
GW.b	Vapor Intrusion to Buildings	FALSE	FALSE	
Soil Pathways				
S.v	Volatiles from Subsurface Soils	FALSE	TRUE	
SS.v	Volatiles and Particulate Inhalation	FALSE	FALSE	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	FALSE	

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)		TRUE		TRUE
S	Inhalation receptor (cm)		TRUE		TRUE

Matrix of Target Risks		Individual	Cumulative
TRab	Target Risk (class A&B carcinogens)	1.0E-06	
TRc	Target Risk (class C carcinogens)	1.0E-05	
THQ	Target Hazard Quotient	1.0E+00	
Opt	Calculation Option (1, 2, or 3)	1	
Tier	RBCA Tier	2	

Surface Parameters	Definition (Units)	Residential	Commercial/Industrial Chronic	Commercial/Industrial Construction
t	Exposure duration (yr)		25	1
A	Contaminated soil area (cm^2)	***1.5E+06***		1.0E+06
W	Length of affected soil parallel to wind (cm)	***1.2E+03***		1.0E+03
W.gw	Length of affected soil parallel to groundwater flow	1.5E+03		
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)	1.0E+02		
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)	
Ugw.tr	Groundwater Transport velocity (cm/yr)	
Ks	Saturated Hydraulic Conductivity(cm/s)	
grad	Groundwater Gradient (cm/cm)	
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)	5.0E+00
hv	Vadose zone thickness (cm)	3.0E+02
rho	Soil density (g/cm^3)	1.7
foc	Fraction of organic carbon in vadose zone	0.01
phi	Soil porosity in vadose zone	0.38
Lgw	Depth to groundwater (cm)	3.0E+02
Ls	Depth to top of affected soil (cm)	***1.5E+02***
Lsubs	Thickness of affected subsurface soils (cm)	***4.6E+02***
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)		

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Scenario 3.

APPENDIX B

ORC Procedures From Regenesis

REGENESIS
Bioremediation Products

DIRECTIONS FOR ORC® SLURRY MIXING

1. OPEN 5 GALLON BUCKET, AND REMOVE PRE-MEASURED BAG OF ORC.

2. MEASURE AND POUR WATER INTO THE 5-GALLON BUCKET ACCORDING TO THE FOLLOWING DESIRED CONSISTENCY:

   65% solids slurry — Mix .63 gallons of water per 10 pounds of ORC powder.
   Example: Mix 20 pounds of ORC with 1.26 gallons of water.
   Mix 30 pounds of ORC with 1.89 gallons of water.

   60% solids slurry — Mix .79 gallons of water per 10 pounds of ORC powder.
   Example: Mix 20 pounds of ORC with 1.58 gallons of water.
   Mix 30 pounds of ORC with 2.37 gallons of water.

   50% solids slurry — Mix 1.19 gallons of water per 10 pounds of ORC powder.
   Example: Mix 20 pounds of ORC with 2.38 gallons of water.
   Mix 30 pounds of ORC with 3.57 gallons of water.

3. ADD THE APPROPRIATE ORC QUANTITY TO THE WATER . Check weight of each bucket (see label). The 5 gallon shipping bucket weighs 2 pounds. An additional 4 pounds of ORC would require one additional quart of water, at the 65% solids level.

4. USE AN APPROPRIATE MIXING DEVICE TO THOROUGHLY MIX ORC AND WATER. A hand held drill with a "jiffy mixer" or a stucco mixer on it may be used in conjunction with a small paddle to scrape the bottom and sides of the container. Standard environmental slurry mixers may also be used, following the equipment instructions for operation. For small quantities a usable slurry can be mixed by hand, if care is taken to blend all lumps into the mixture thoroughly.

CAUTION: ORC MAY SETTLE OUT OF SLURRY IF LEFT STANDING. ALSO, ORC EVENTUALLY HARDENS INTO A CEMENT-LIKE COMPOUND, AND CANNOT BE RE-MIXED AFTER THAT HAS HAPPENED. THEREFORE:
Mix immediately before using. Do not let stand more than 30 minutes, and re-mix immediately before use, to be sure the mixture has not settled out. If a mechanical slurry mixer attached to a pump is being used, the material may be cycled back through the mixer to maintain slurry suspension and consistency.

5. CHECK SLURRY CONSISTENCY FOR POURABILITY. ADD WATER IF NECESSARY (IN 1 CUP INCREMENTS) TO ACHIEVE THE CORRECT CONSISTENCY .

27130A Paseo Espada, Suite 1407
San Juan Capistrano, CA 92675
Tel: (714) 443-3136
Fax: (714) 443-3140

• Registered trademark of **REGENESIS** Bioremediation Products

REGENESIS Bioremediation Products

ORC® Slurry Installation Instructions
Geoprobe® Injection into the Soil Matrix

SAFETY:

Pure ORC is shipped to you as a fine powder rated at -325 mesh (passes through a 44 micron screen). It is considered to be a mild oxidizer and as such should be handled with care while in the field. Field personnel should take precautions while applying the pure ORC. Typically, the operator should work upwind of the product as well as use appropriate safety equipment. These would include eye and respiratory protection, and gloves as deemed appropriate by exposure duration and field conditions.

Personnel operating the field equipment utilized during the installation process should have appropriate training, supervision and experience.

GENERAL GUIDELINES:

ORC may be installed in the contaminated saturated zone in the ground utilizing hand augered holes, Geoprobe® type hydraulic punch equipment, or hollow stem augers. This set of instructions is specific for Geoprobe equipment. Alternate instructions may be obtained from the Regenesis Technical Support Department.

For optimum results the ORC slurry installation should span the entire vertical contaminated saturated thickness, including the capillary fringe and "smear zone".

Two general installation approaches are available. The first is to backfill only the probe hole with slurry. This is a simple approach, in that it is easy, straightforward, and the location of the ORC slurry is precisely known after installation. However, this method requires significantly more probe holes than the alternative, and may take more time for the completion of the remediation process. A separate set of instructions for this method utilizing Geoprobe equipment is available from Regenesis.

The second method is to inject the slurry through the probe holes into the contaminated saturated zone. This method requires fewer probe holes, is less disruptive to the site, and aids the spread of oxygen by spreading the ORC source material. However, it may be difficult to know the exact, final disposition of the ORC installed with this method. This is the method described in these instructions.

Note: It is important that the installation method and specific ORC slurry point location be established prior to field installation. It is also important that the ORC slurry volume and solids

content for each drive point be predetermined. The Regenesis Technical Service Department is available to discuss these issues, and Helpful Hints at the end of these instructions offers relevant information. Regenesis also has available Technical Bulletins covering source treatments with ORC.

SPECIFIC INSTALLATION PROCEDURES:

1. Identify the location of all underground structures, including utilities, tanks, distribution piping, sewers, drains, and landscape irrigation systems.

2. Identify surface and aerial impediments.

3. Adjust planned installation locations for all impediments and obstacles.

4. Pre-mark the installation grid point locations, noting any that have special depth requirements.

5. Set up the Geoprobe unit over each specific point, following manufacturer recommended procedures. Care should be taken to assure approximate vertical probe holes.

6. Penetrate surface pavement, if necessary, following standard Geoprobe procedures.

7. Drive the 1 1/2" (one-and-one-half inch) pre-probe (part #AT-148B) with the expendable tip (part #AT142B) to the desired maximum depth. Standard 1" (one inch) drive rods (part #AT104B) should be used, after the pre-probe. (Hint: Pre-counted drive rods should be positioned prior to the installation driving procedure to assure the desired depth is reached.)

8. Disconnect the drive rods from the expendable tip, following standard Geoprobe procedures.

9. Mix the appropriate quantity of ORC slurry for the current drive point. (See separate "Directions for ORC® Slurry Mixing" and Helpful Hints). **Note: Do not mix more slurry than will be used within a 30 minute period.**

10. Set up and operate an appropriate slurry pump according to manufacturer's directions. Based on our experience, a Geoprobe model GS-1000 pump is recommended. Connect the pump to the probe grout pull cap (GS-1054) via a 1 inch diameter delivery hose. The hose is then attached to the 1" drive rod with its quick connector fitting. Upon confirmation of all connections add the ORC slurry to the pump hopper/tank.

11. Withdraw the pre-probe and drive stem 4'(four feet). (Also note Helpful Hints - Operations at end of instructions.)

12. Optional pretreatment step. (See Helpful Hints - Operations at end of instructions). Pump one to two gallons of tap water into the aquifer to enhance dispersion pathways from the probe hole.

13. Pump the predetermined quantity of ORC slurry for the depth interval being injected. Observe pump pressure levels for indications of slurry dispersion or refusal into the aquifer. (Increasing pressure indicates reduced acceptance of material by the aquifer).

14. Remove one 4' section of the 1" drive rod. The drive rod will contain slurry. This slurry should be returned to the ORC bucket for reuse.

15. Repeat steps 11, 13, and 14 until treatment of the entire affected thickness has been achieved. It is generally recommended that the procedure extend to the top of the capillary fringe/smear zone.

16. Install an appropriate seal, such as bentonite, above the ORC slurry through the entire vadose zone. This helps assure that the slurry stays in place and prevents contaminant migration from the surface. Depending on soil conditions and local regulations, a bentonite seal can be pumped through the slurry pump or added via chips or pellets after probe removal.

17. Remove and decontaminate the drive rods and pre-probe.

18. Finish the probe hole at surface as appropriate (concrete or asphalt cap, if necessary).

19. Move to the next probe point, repeating steps 5 through 18.

HELPFUL HINTS:

A. Physical characteristics

A1. <u>Slurry</u>

The ORC slurry is made using the dry ORC powder (rated at -325 mesh). It makes a smooth slurry, with a consistency that depends on the amount of water used.

A thick, but pumpable, slurry that approaches a paste can be made by using 65-67% solids. This material would normally be used for back-filling a bore or probe hole. It is especially useful

where maximum density is desired such as where ground water is present in the hole or there are heaving sands.

Thinner slurries can be made by using more water. Typical solids for the thinner slurries content will range from 35% to 62%. Such slurries are useful for injecting through a probe or bore hole into the saturated aquifer.

As a rule, it is best to mix the first batch of slurry at the maximum solids content one would expect to use. It can then be thinned by adding additional water in small increments. By monitoring this process, the appropriate quantities of water for subsequent batches can be determined.

The slurry should be mixed at about the time it is expected to be used. It is best to not hold it for more than 30 minutes. Thinner slurries, especially, can experience a separation upon standing. All ORC slurries have a tendency to form cements when left standing. If a slurry begins to thicken too much, it should be mixed again and additional water added if necessary.

Care should be taken with slurry that may be left standing in a grout pump or hose. Problems can generally be avoided by periodically recirculating the slurry through the pump and hose back into the pump's mixing or holding tank.

A2. Equipment

Most geotechnical grout pumping equipment has a holding tank with a capacity sufficient for injection.

When applying measured volumes of ORC slurry to probe holes, it is sometimes useful to know the volumes and content of the delivery system lines. The following information may be useful in this regard:

Geoprobe pump: At the end of a pump stroke virtually no deliverable slurry remains in the pump.

5/8" O.D. connecting hose (10 feet long):	.2 gallons (26 fluid ounces).
Four foot (4') length of 1" drive rod:	.04 gallons (5 fluid ounces).
Three foot (3') length of 1 1/2" pre-probe:	.03 gallons (4 fluid ounces).

Cleaning and maintenance:

Pumping equipment and drive rods can be lightly cleaned by circulating clear water through them. Further cleaning and decontamination (if necessary due to subsurface conditions) should be performed according to the equipment supplier's standard procedures and local regulatory requirements.

B. Operating characteristics
B1. Operations - General

Judgment will be needed in the field when injecting ORC slurries. In general, it is relatively easy to inject ORC slurries into sandy soils, and this can usually be accomplished at very moderate pressures. Silts and clays require more pressure, and may accept less slurry.

Careful observation of pressure during slurry pumping is the best indication of the effectiveness of the slurry injection. To test the soil's ability to accept the slurry and to "precondition" the injection point for the slurry, it is sometimes useful to inject a small volume of plain water prior to the slurry. Normally, one-half (0.5) gallons to two (2) gallons would be appropriate.

During injection, increasing pressure and decreasing flow rate are signs of refusal by the soil matrix to accept the slurry. The site geologist should determine whether to increase pressure, and possibly fracture ("frac") the soil matrix to achieve ORC slurry installation in a tight site that has refused the slurry at lower pressures.

B2. Fill Volumes
Probe hole back-filling

Please see Table on Page 6

Probe hole capacities:

Per 10' (Ten Foot) length

	Theoretical Volume (Gallons/Fluid Ounces/Cubic Inches) Sand, Silts & Clay	Operating Volume (Gallons/Fluid Ounces) Sand	Operating Volume (Gallons/Fluid Ounces) Silts & Clay
1" Diameter	.41 gal/52 fl. oz./94.2 cu. in.	.61 gal/78 fl. oz	.51 gal/65 fl. oz.
1 1/2" Diameter	.92 gal/117 fl. oz./212.0 cu. in.	1.38 gal/176 fl. oz.	1.15 gal/146 fl. oz.
2" Diameter	1.63 gal/209 fl. oz./376.8 cu. in.	2.44 gal/313 fl. oz.	2.04 gal/261 fl. oz.
2 1/4" Diameter	2.06 gal/264 fl. oz./476.9 cu. in.	3.09 gal/396 fl. oz.	2.57 gal/330 fl. oz.

Note that the operating volumes include a 50% excess above the theoretical volume in sands and 25% in clays and silts. This is important to successful treatment. The additional material allows for a small degree of infiltration of the slurry into the surrounding soil and fractures, as well as hole diameter variability. It is important to assure that the entire contaminated saturated zone is treated (including the capillary fringe), since this is often the area of highest pollution concentration. Failure to treat this area due to improper installation can undermine an otherwise successful remediation effort.