Appendix A

Sample Calculations

A.1 Specified flux at the upgradient boundary

Figure A.1 was used to calculate the specified flux entering the model at the upgradient boundary. The Dupuit Equation was used to determine the distance to the groundwater divide, d, and the recharge rate, w, was estimated using published information about the site (Landmeyer et al., 1996).

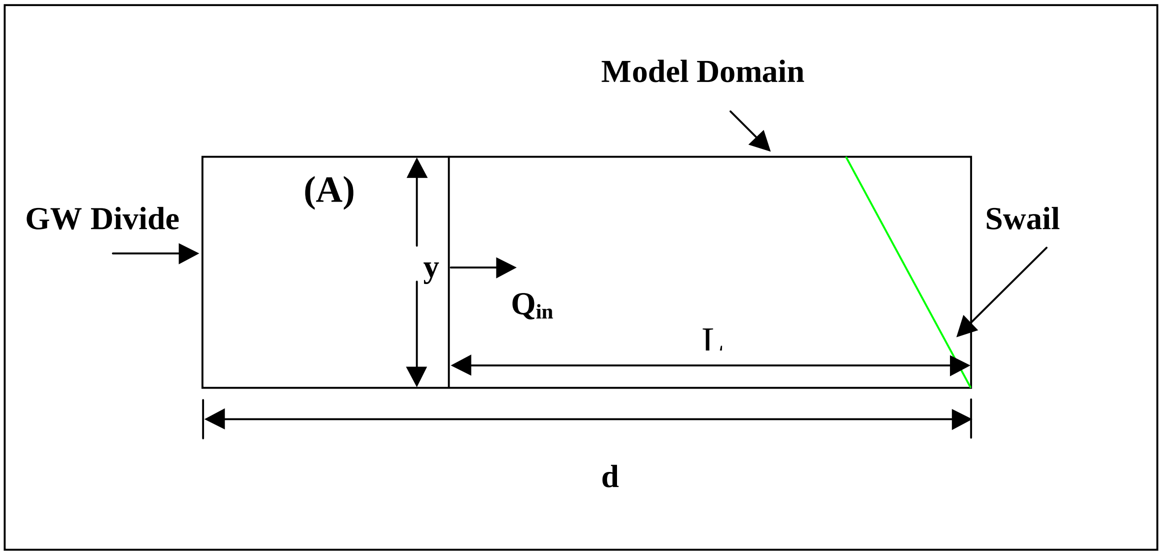

Figure A.1 Representation of method used to calculate groundwater inflow

$d = 620.5 \text{meters}$

$y = 98 \text{ meters}$

$L = 250 \text{ meters}$

$A = y(d - L) = 98(620.5 - 250) = 36{,}309 \text{ meters}^2$

$w = \text{recharge rate} = 0.0015 \text{ meters/day}$

$n = \text{number of cells along boundary} = 4(49) = 196$

$$Q_{in} = wA = 0.0015(36{,}309) = 54.5\ \text{meters}^3/\text{day}$$

$$Q_{per\ cell} = \frac{wA}{n} = \frac{0.0015(36{,}309)}{196} = 0.28\ \text{meters}^3/\text{day}$$

This flowrate was used in the bottom three layers. Since the water table in layer 1 did not reach the top of the layer, $Q_{per\ cell}$ was multiplied by a factor of 0.35 to get the flow into the cells in layer 1. That factor was found based on the assumption that the maximum head at the boundary would be 8.5 meters rather than 12 meters, or the top of each cell.

$$\text{factor} = \frac{8.5 - 6.75}{12 - 6.75} = 0.35$$

$$Q_{per\ cell,layer1} = 0.35(0.28) = 0.097\ \text{meters}^3/\text{day}$$

A.2 Cells Inactivated in Layer 1

The calculations used to determine the number of cells to inactivate in layer 1 to represent the sloping of the land surface near the swail were based on the elevation of the swail bottom, the land surface elevation and the width of the swail.

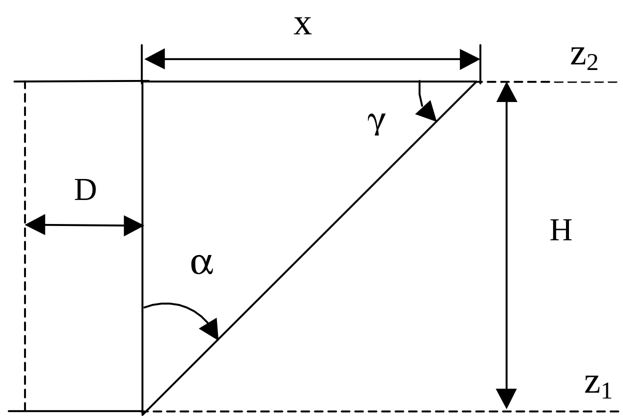

Figure A.2 Diagram for calculating cells inactivated in layer 1

$$x = \text{distance to inactivate}$$

$$D = \text{half the width of the swail} = \frac{30\text{ feet}}{2} = 15\text{ feet} = 4.57\text{ meters}$$

$$z_1 = \text{elevation of the swail bottom} = 17.5\text{ feet} = 5.33\text{ meters}$$

$$z_2 = \text{ground surface elevation} = 12\text{ meters}$$

$$H = z_2 - z_1 = 12 - 5.33 = 6.67\text{ meters}$$

$$\gamma = 9.4°$$

$$\alpha = 90° - \gamma = 90° - 9.4° = 80.6°$$

$$tan\,\alpha = \frac{x}{H}$$

$$x = H\,tan\,\alpha = 6.67\,tan\,80.6° = 40.3\text{ meters}$$

$$n = \text{number of cells to inactivate} = \frac{x}{\text{cell length}} = \frac{40.3}{2} = 20$$

A.3 Error Analysis Calculations

During calibration of the groundwater flow model, error analysis was performed. The mean error, mean absolute error, and root mean squared error of the hydraulic head values were calculated for each model simulation (Anderson and Woessner, 1992).

$$\text{Mean Error} = \frac{1}{n}\sum_{i=1}^{n}\left(h_m - h_s\right)_i$$

$$\text{Mean Absolute Error} = \frac{1}{n}\sum_{i=1}^{n}\left|\left(h_m - h_s\right)_i\right|$$

$$\text{Root Mean Squared Error} = \left[\frac{1}{n}\sum_{i=1}^{n}\left(h_m - h_s\right)_i^2\right]^{0.5}$$

A.4 Hydraulic Gradient and Flow Direction Calculation and Use in Calibration

The hydraulic head levels were used to calculate the hydraulic gradients and flow directions, β, predicted by the model and observed in the field. Five triangles running along the entire length of the model were used to determine the gradients and flow directions. These triangles were composed of wells LB-EX-19, LB-EX-20, and LB-EX-21; LB-EX-3, LB-EX-4, and LB-EX-5; LB-EX-14, LB-EX-16, and LB-EX-20; LB-EX-13, LB-EX-15, and LB-EX-7; and wells LB-EX-13, 15, and LB-EX-1. The gradients and flow directions were calculated for the average, minimum, and maximum head measurements taken in the field, and an average of those three was found. This value was used as a basis for comparing the model values with those seen in the field. A ranking system was established to determine which set of model parameters best simulated field conditions. A simulation received a ranking of 1 if it was the closest to the measured values. Each simulation was ranked 10 times, once for every gradient and β in each of the five triangles used for comparison. The results were summed to obtain a final value for each simulation.

The hydraulic gradients, i, and flow directions, β, were calculated using the method shown on the following page (Widdowson, 1999). The calculations are for Triangle 1, which was made up of LB-EX-19, LB-EX-20, and LB-EX-21, using the model simulated results.

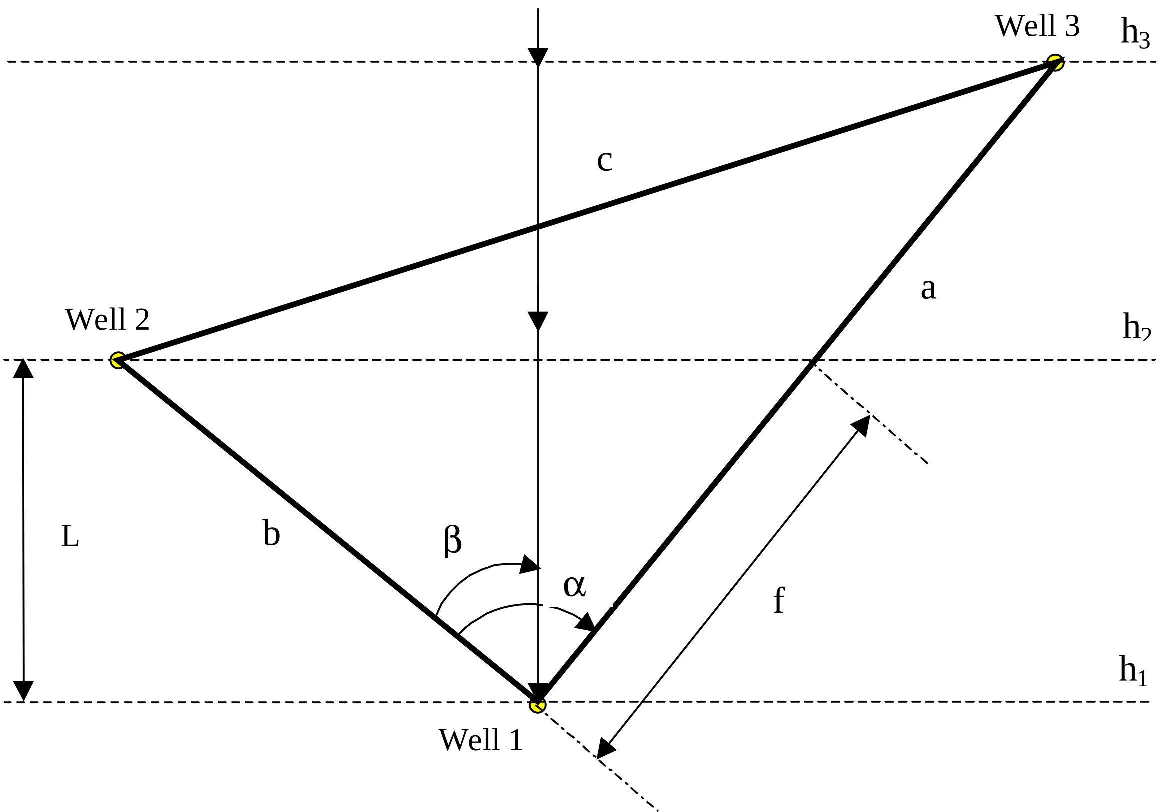

Figure A.3 Diagram for calculating the gradient magnitude, *i*, and direction, β

$\text{Well1} = \text{LB} - \text{EX} - 21$	$\text{a} = 42.9\ \text{meters}$	$\text{h}_1 = 6.02\ \text{meters}$
$\text{Well2} = \text{LB} - \text{EX} - 20$	$\text{b} = 29.7\ \text{meters}$	$\text{h}_2 = 6.92\ \text{meters}$
$\text{Well3} = \text{LB} - \text{EX} - 19$	$\text{c} = 26.6\ \text{meters}$	$\text{h}_3 = 7.07\ \text{meters}$

$$\alpha = cos^{-1}\left[\frac{\text{a}^2 + \text{b}^2 - \text{c}^2}{2\text{ab}}\right] = cos^{-1}\left[\frac{(42.9)^2 + (29.7)^2 - (26.6)^2}{2(42.9)(29.7)}\right] = 0.66$$

$$\beta = tan^{-1}\left\{\frac{1}{sin^{-1}}\left[\frac{(\text{h}_2 - \text{h}_1)\text{a}}{(\text{h}_3 - \text{h}_1)\text{b}} - cos\,\alpha\right]\right\} = tan^{-1}\left\{\frac{1}{sin^{-1}}\left[\frac{(6.92 - 6.02)42.9}{(7.07 - 6.02)29.7} - cos\,0.66\right]\right\} = 0.64$$

$$i = \frac{\text{h}_3 - \text{h}_1}{\text{a}\,cos\,\beta} = \frac{7.07 - 6.02}{42.9\,cos(0.64)} = 0.0304\ \text{meters per meter}$$

A.5 NAPL Mass Loading Rates

The NAPL mass loading rates were determined based on methodology used by Waddill and Widdowson (1998).

The velocity of the NAPL, $v_{NAPL,}$ was estimated as follows:

$$v_{NAPL} = M_o \frac{dZ_{ao}}{dx} \tag{A.1}$$

where

M_o is the oil mobility factor; and

dZ_{ao}/dx is the gradient in the air-oil table which can be estimated as equal to the water table gradient.

This value was found for the Laurel Bay site by Waddill and Widdowson (1997) to be 0.032 meters/day.

In regions close to leaking tanks where there are high volumes of free NAPL per unit volume of soil, M_o reaches a constant maximum value known as M_o^{max}.

$$M_o^{\max} = \frac{\rho_{ro} K_s}{\eta_{ro} \theta} \tag{A.2}$$

where

K_s is the saturated hydraulic conductivity of water;

ρ_{ro} is the specific gravity of oil;

η_{ro} is the ratio of oil to water viscosity; and

θ is the effective porosity.

Based on research done by Parker et al. (1994), it has been shown that for gasoline, $\rho_r \cong 0.8$ and $\eta_{ro} \cong 0.6$. θ was estimated as 0.35 during site investigations by ABB Environmental Services in 1993. Equation (A.2) was used with $\rho_r \cong 0.8$, $\eta_{ro} \cong 0.6$, $\theta = 0.35$, and $K_s = 3.386$ meters/day (the average hydraulic conductivity at the site), and a value of 13.3 meters per day was calculated for M_0^{max} (Landmeyer et al., 1996).

Equation (A.1) was used with a $M_o = M_o^{max}/2$ and a water table gradient of 0.0046 representing dZ_{ao}/dx , and ν_{NAPL} was found to be 0.032 meters per day. ν_{NAPL} was used to estimate the length of time it would take for the NAPL to travel through one of the cells in the model grid.

$$t = \frac{x}{v_{NAPL}} = \frac{2}{0.032} = 62.5 \text{ days} \tag{A.3}$$

This value was used to determine the mass scheduling in each of the mass loading regions. The results can be seen in Table 3.10.

The final input parameter needed to simulate mass loading was the actual mass rate entering each cell. Residual NAPL saturations in sandy soils range from 0.05 to 0.20 (Wilson et al., 1990). Therefore, the NAPL saturation in the cells where the leak originated was set to the maximum value of 0.20 for a worst case simulation. In the cells farthest from the leak, the saturation was assumed to be the minimum value of 0.05 with the assumption being that the saturation will decrease over time and distance. The concentration of NAPL can be calculated using:

$$C_{NAPL} = \frac{\rho_{NAPL}}{\rho_{soil}}(sat)\theta \tag{A.4}$$

where

ρ_{NAPL} is the density of the NAPL ;

ρ_{soil} is the soil bulk density;

sat is the saturation; and

θ is the effective porosity.

ρ_{NAPL} was estimated as 0.8 x 10^6 g/m^3. ρ_{soil} was estimated as 1.6 x 10^6 g/m^3, and the effective porosity at the site was estimated as 0.35. Using the maximum and minimum saturation estimates, Equation (3.4) was used to determine maximum and minimum concentrations of the NAPL in the soil. The maximum concentration was found to be 0.035 g_{NAPL} per g_{soil} and the minimum concentration was found to be 0.00875 g_{NAPL} per g_{soil}.

The maximum NAPL mass could be calculated knowing the concentration and the volume in which it was contained. Near the source, it was assumed that the NAPL was spread over the upper 1.5 meters of the aquifer, so the mass of NAPL in each of the cells could be calculated using:

$$Mass = C_{NAPL}(\rho_{soil})volume \qquad \text{(A.5)}$$

where

volume is the cell volume over which the contaminant is spread.

volume was calculated to be 6 m^3. As a result, the maximum mass in the cells near the source would be 336 kg.

Equation (3.5) could also be used to calculate the maximum mass in the cells in the loading regions furthest from the source. It was assumed that the NAPL was only spread over 1 meter of the aquifer is this region, so *volume* decreased to 4 m^3. Using these values, it was found that the maximum mass would be 56 kg.

The maximum masses in the remaining regions were calculated by assuming the NAPL concentrations decreased linearly as distance from the source increased. For all the cells aside from those in the immediate source area, it was assumed the NAPL was spread over only 1 meter of the aquifer. Since the NAPL concentrations measured in the field were at least an order of magnitude less than those calculated above, fractions of those values were used to determine the amount of mass loading.

Appendix B

SEAM3D Equations

The equations used by the SEAM3D contaminant transport model are presented in this appendix. They are all taken from the technical report on the program by Waddill and Widdowson (1997).

B.1 Transport Equations

For each hydrocarbon substrate, the aqueous phase transport was described using the advection-dispersion equation:

$$-\frac{\partial}{\partial x_i}(\bar{v}_i S_{ls}) + \frac{\partial}{\partial x_i}(D_{ij} \frac{\partial S_{ls}}{\partial x_j}) + \frac{q_s}{\theta} S_{ls}{}^* - R^{bio}_{\sin k,ls} + R^{NAPL}_{source,ls} = R_{ls} \frac{\partial S_{ls}}{\partial t} \qquad \text{(B.1)}$$

where

S_{ls} is the aqueous phase substrate concentration [M_{ls} L^{-3}] for ls=1,2,…,NS;

S_{ls}^* is the substrate point source concentration [M_{ls} L^{-3}];

$\bar{v}_i$ is the average pore water velocity [L T^{-1}];

x_I is distance [L];

D_{ij} is the tensor for hydrodynamic dispersion coefficient [L^2 T^{-1}];

$R^{bio}_{\sin k,ls}$ is the substrate biodegradation sink term [M_{ls} L^{-3} T^{-1}];

$R^{NAPL}_{source,ls}$ is a substrate source term due to non-aqueous phase liquid (NAPL) dissolution [M_{ls} L^{-3} T^{-1}];

R_{ls} is the retardation factor for substrate ls [L°];

t is time [T]; and

q_s is the volumetric flux of water per unit volume of aquifer [T^{-1}] with $q_s > 0$ for sources and $q_s < 0$ for sinks.

Nonbiodegradable tracers such as MTBE are simulated using a first order decay term replacing the biodegradation sink term in equation (B.1).

Transport for each aqueous phase electron acceptor follows:

$$-\frac{\partial}{\partial x_i}(\bar{v}_i E_{le}) + \frac{\partial}{\partial x_i}(D_{ij}\frac{\partial E_{le}}{\partial x_j}) + \frac{q_s}{\theta} E_{le}{}^{*} - R^{bio}_{\sin k, le} = \frac{\partial E_{le}}{\partial t} \qquad \text{(B.2)}$$

where

E_{le} is the electron acceptor concentration [M_{le} L^{-3}] for *le*=1,2, and 5;

E^{*}_{le} is the electron acceptor point source concentration [M_{le} L^{-3}]; and

$R^{bio}_{\sin k,le}$ is the EA biodegradation sink term [M_{le} L^{-3} T^{-1}].

The transport of the biodegradation products follows:

$$-\frac{\partial}{\partial x_i}(\bar{v}_i P_{lp}) + \frac{\partial}{\partial x_i}(D_{ij}\frac{\partial P_{lp}}{\partial x_j}) + \frac{q_s}{\theta} P_{lp}{}^{*} - \lambda_{lp} P_{lp} + R^{bio}_{source,lp} = R_{lp}\frac{\partial P_{lp}}{\partial t} \qquad \text{(B.3)}$$

where

P_{lp} is the aqueous phase product concentration [M_{lp} L^{-3}] for *lp*=1,2,…NP;

P^{*}_{lp} is the product point concentration [M_{lp} L^{-3}];

λ_{lp} is the product first order decay coefficient [T^{-1}];

R^{bio}_{source} is a biodegradation source term [M_{lp} L^{-3} T^{-1}]; and

R_{lp} is the retardation factor for product *lp* [L°].

The sink term for each substrate degraded by microcolony x follows:

$$R_{\sin k,ls}^{bio} = \sum_{x} \frac{M_x}{\theta} r_{x,ls} \qquad (B.4)$$

where

M_x is the microbial biomass concentration [M_b L_{pm}^{-3}] for x=1,2,…,NM;

θ is effective transport porosity [L°]; and

$r_{x,ls}$ is the utilization rate of substrate ls in microcolony x [M_{ls} M_b^{-1} T^{-1}].

The sink term for each electron acceptor follows:

$$R_{\sin k,le}^{bio} = \sum_{x} \frac{M_x}{\theta} r_{x,le} \qquad (B.5)$$

where

$r_{x,le}$ is the utilization rate of electron acceptor le in microcolony x [M_{le} M_b^{-1} T^{-1}].

The source term for the product CH_4 is

$$R_{source,CH_4}^{bio} = \sum_{ls} \xi_{x,ls} \frac{M_x}{\theta} r_{x,ls} \qquad (B.6)$$

where $\xi_{x.ls}$ is the product generation coefficient [M_{lp} M_{ls}^{-1}] with x = le = 6 for CH_4 production.

The source term for the electron acceptor products follows:

$$R_{source,le}^{bio} = \sum_{ls} \xi_{x,le} \frac{M_x}{\theta} r_{x,le} \qquad (B.7)$$

where

x = le =2 for N_{user}, x = le = 3 for Mn(II), x = le = 4 for Fe(II), and x = le = 5 for H_2S.

B.2 NAPL Dissolution Equations

The NAPL dissolution term for a particular substrate *ls* follows:

$$R_{source,ls}^{NAPL} = \max[0, k^{NAPL}(S_{ls}^{eq} - S_{ls})]. \tag{B.8}$$

where

k^{NAPL} is the mass transfer rate coefficient;

S_{ls} is the aqueous phase concentration; and

S_{ls}^{eq} is the equilibrium concentration.

The equilibrium concentration is calculated as follows:

$$S_{ls}^{eq} = f_{ls} S_{ls}^{sol} \tag{B.9}$$

where

f_{ls} is the mole fraction of the substrate *ls* in the NAPL [$mol_{ls}\ mol_{NAPL}^{-1}$]; and

S_{ls}^{sol} is the solubility of the pure substrate *ls* in water.

f_{ls} is found for each time step using

$$f_{ls} = \frac{S_{ls}^{NAPL} / \omega_{ls}}{I^{NAPL} / \omega_I + \sum_{ls=1}^{NS} S_{ls}^{NAPL} / \omega_{ls} + \sum_{lt=1}^{NT} T_{lt}^{NAPL} / \omega_{lt}} \tag{B.10}$$

where

S_{ls}^{NAPL} is the NAPL mass of substrate *ls* per unit mass of dry soil [$M_{ls}\ M_{solid}^{-1}$];

I^{NAPL} is the NAPL concentration of the inert contaminants [$M_I\ M_{solid}^{-1}$];

T_{lt}^{NAPL} is the NAPL concentration of the nonbiodegradable tracer [$M_{ls}\ M_{solid}^{-1}$]; and

ω_j is the molecular weight of NAPL constituent *j*.

S_{ls}^{NAPL} is updated with each time step using

$$\frac{dS_{ls}^{NAPL}}{dt} = -\frac{\theta}{\rho_b} R_{source,ls}^{NAPL} \tag{B.11}$$

where

ρ_b is the bulk density of the porous medium [$M_{solid}\ L_{pm}^{-3}$].

B.3 Utilization Equations

The utilization of substrate within a given microcolony x follows:

$$r_{x,ls} = \sum_{le} \nu_{x,ls,le} \tag{B.12}$$

where

$\nu_{x.ls.le}$ is the specific rate of substrate utilization for microcolony *x* growing on substrate *ls* and electron acceptor *le* [M_{ls} M_b^{-1} T^{-1}].

The utilization of each electron acceptor follows:

$$r_{x,le} = \sum_{ls} \gamma_{x,ls,le} \nu_{x,ls,le} \tag{B.13}$$

where

$\gamma_{x,ls,le}$ is the electron acceptor use coefficient [M_{le} M_{ls}^{-1}].

For Mn(IV) and Fe(III), transport is not considered since they are assumed to be attached to the solid phase and utilization follows:

$$-\frac{M_x}{\rho_b} r_{x,le} = \frac{dE_{le}}{dt} \tag{B.14}$$

where

x = *le* = 3 for Mn(IV) and x = *le* = 4 for Fe(III); and

E_{le} is the solid phase concentration [M_{le} M_{solid}^{-1}].

Modifying the Monod kinetic equations to account for nutrient and electron acceptor availability, $v_{x,ls,le}$ can be written as:

$$v_{x,ls,ls} = v_{x,ls,le}^{\max}\left[\frac{\overline{S}_{ls}}{\overline{K}_{x,ls,le}^{s} + \overline{S}_{ls}}\right]\left[\frac{\overline{E}_{le}}{\overline{K}_{x,le}^{e} + \overline{E}_{le}}\right] N_x I_{le,li} \qquad \text{(B.15)}$$

where

$\overline{K}_{x,ls,le}^{s}$ is the effective half saturation constant for each substrate *ls* utilizing electron acceptor *le* [M_{ls} L^{-3}];

$\overline{K}_{x,le}^{e}$ is the effective half saturation constant for electron acceptor *le* [M_{le} L^{-3}];

$\overline{S}_{ls}$ is the effective concentration of substrate *ls* [M_{ls} L^{-3}];

$\overline{E}_{le}$ is the effective concentration of electron acceptor *le* [M_{le} L^{-3}]; and

N_x is a Monod function that describes nutrient limitations.

$I_{le,li}$ is the inhibition function that has been defined by Widdowson et al. (1988) to be:

$$I_{le,li} = 1 \qquad \text{for } le = 1 \qquad \text{(B.16a)}$$

and

$$I_{le,li} = \prod_{li=1}^{le-1}\left[\frac{\kappa_{le,li}}{\kappa_{le,li} + \overline{E}_{li}}\right] \qquad \text{for } le = 2, 3, 4, 5, \text{ or } 6 \qquad \text{(B.16b)}$$

where

$\kappa_{le,li}$ is the electron acceptor inhibition coefficient [M_{le} L^{-3}].

The term $\bar{S}_{ls}$ is defined by:

$$\bar{S}_{ls} = \max\left(S_{ls} - S_{ls}^{t}, 0\right) \tag{B.17}$$

where

S_{ls}^{t} is the threshold concentration of the substrate *ls*.

Similarly, $\bar{K}_{x,ls,le}^{s}$ is defined as:

$$\bar{K}_{x,ls,le}^{s} = \max\left(K_{x,ls,le}^{s} - S_{ls}^{t}, 0\right) \tag{B.18}$$

where

$K_{x,ls,le}^{s}$ is the half saturation constant for the substrate *ls* utilizing electron acceptor *le* [M_{ls} TL^{-3}].

In a similar manner, $\bar{E}_{le}$ and $\bar{K}_{x,le}^{e}$ are both defined using E_{le}^{t} as the threshold concentration.

When E_{le} exceeds E_{le}^{t}, the expression for specific rate of substrate utilization becomes zero order with respect to the electron acceptor and can be expressed as:

$$v_{x,ls,le} = v_{x,ls,le}^{\max}\left[\frac{\bar{S}_{ls}}{\bar{K}_{x,ls,le}^{s} + \bar{S}_{ls}}\right] N_x I_{le,li} \tag{B.19}$$

B.4 Microbial Growth Equations

SEAM3D solves for the background growth rate, $G_x^{bk,0}$, as follows:

$$G_x^{bk,0} = Y_x^{bk} v_x^{\max,bk} \left[\frac{\overline{E}_{le}}{\overline{K}_{x,le}^{e} + \overline{E}_{le}} \right] N_x \tag{B.20}$$

where

$Y_x^{bk} = \frac{1}{NS} \sum_{ls} Y_{x,ls,le}$; and

$v_x^{\max,bk} = \frac{1}{NS} \sum_{ls} v_{x,ls,le}^{\max}$.

The mass balance equation describing the growth and death of microbial population *x* following contamination is:

$$\frac{1}{M_x} \frac{dM_x}{dt} = -k_{d_x} + G_{x,ls,le} \tag{B.21}$$

where

k_{d_x} is the "effective" death rate [T^{-1}]; and

$G_{x.ls.le}$ is the growth rate due to the hydrocarbon substrates.

The growth rate due to hydrocarbon substrates can be defined by:

$$G_{x,ls,le} = \sum_{le} \sum_{ls} Y_{x,ls,le} v_{x,ls,le} \tag{B.22}$$

where

$Y_{x,ls,le}$ is the biomass yield coefficient [$M_b\ M_{ls}^{-1}$].

The effective death rate is found as follows:

$$k_{d_x} = \max\left[0, k_{d_x}^{bk} - \left(G_x^{bk} + G_{x,ls,le}\right)\right] \tag{B.23}$$

where

G_x^{bk} is found using equation (B.20) with $\overline{E}_{le}$ and N_x being computed from the current concentrations in each cell in the grid.

Appendix C

Well Data

This section contains data on all the wells used as a basis for comparison in this modeling study. The data was compiled from multiple sources (ABB Environmental Services, 1993; Landmeyer et al., 1996; and personal correspondence between Dr. Mark. Widdowson and Dr. James Landmeyer, 1996-1998). It can be seen from the tables that there was limited information available for certain wells. When no information on the well was available, the symbol '--' was used in the table. ND and BD both indicate that the compound being measured was below the detection limit. NA and NS both indicate that the compound was not sampled.

Well LB-EX-1

Location in Model Grid	i-coordinate	21	**Top of Casing Elevation**	38.25 feet	
	j-coordinate	108	**Ground Surface Elevation**	38.49 feet	

		Feet	Meters
Water Table Elevation	Apr-93	28.73	8.76
	Mar-94	27.61	8.42
	Jan-97	26.59	8.10
	Jul-97	26.21	7.99
	Jan-98	--	--

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (µg/L)	Benzene	16000	8450	3.05	1.83	1.79	1000
	Toluene	43000	20600	18.6	14.1	19	15655
	Ethylbenzene	4000	<5	2.18	1.9	1.9	--
	Xylene	21000	13850	7.485	5.75	13.9	--
	MTBE	15000	15400	2814	--	--	577
Geochemical Indicator Concentrations (mg/L)	DO	--	0	0	0	0	--
	Sulfate	--	8.14	1.61	4.43	--	--
	Fe(II)	--	19.8	4.43	31.9	36.2	--
	Sulfide	--	ND	0.4	0.097	0.229	--
	Methane	--	BD	0.8	0.3	--	--

Well LB-EX-3

Location in Model Grid	i-coordinate	21		**Top of Casing Elevation**	40.5 feet	
	j-coordinate	113		**Ground Surface Elevation**	37.69 feet	

		Feet	Meters
Water Table Elevation	Apr-93	28.86	8.80
	Mar-94	27.62	8.42
	Jan-97	26.35	8.03
	Jul-97	25.95	7.91
	Jan-98	28.56	8.70

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (µg/L)	Benzene	ND	6.1	0.002	BD	NA	--
	Toluene	ND	22.2	0.007	BD	NA	--
	Ethylbenzene	ND	<5	0.095	BD	NA	--
	Xylene	10	258	0.213	0.012	NA	--
	MTBE	2.4	22.2	16.3	--	--	--
Geochemical Indicator Concentrations (mg/L)	DO	--	2.18	4.09	3.28	NS	--
	Sulfate	--	6.75	4.35	0	NS	--
	Fe(II)	--	0.7	0	0.01	NS	--
	Sulfide	--	ND	0	0.026	NS	--
	Methane	--	BD	BD	ND	NS	--

Well LB-EX-4

Location in Model Grid	i-coordinate	25		**Top of Casing Elevation**	40.14 feet	
	j-coordinate	114		**Ground Surface Elevation**	37.39 feet	

		Feet	Meters
Water Table Elevation	Apr-93	28.88	8.80
	Mar-94	27.66	8.43
	Jan-97	26.39	8.04
	Jul-97	25.98	7.92
	Jan-98	28.59	8.71

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (µg/L)	Benzene	--	BD	BD	BD	NA	--
	Toluene	--	BD	BD	BD	NA	--
	Ethylbenzene	--	BD	BD	BD	NA	--
	Xylene	--	BD	BD	BD	NA	--
	MTBE	--	BD	BD	--	--	--
Geochemical Indicator Concentrations (mg/L)	DO	--	5.34	4.26	3.02	NS	--
	Sulfate	--	5.6	4.31	5.06	NS	--
	Fe(II)	--	0.6	0	0	NS	--
	Sulfide	--	ND	0	0.004	NS	--
	Methane	--	BD	BD	ND	NS	--

Well LB-EX-5

Location in Model Grid	i-coordinate	20	**Top of Casing Elevation**	39.93 feet
	j-coordinate	120	**Ground Surface Elevation**	37.09 feet

		Feet	Meters
Water Table Elevation	Apr-93	29.02	8.84
	Mar-94	27.72	8.45
	Jan-97	26.43	8.06
	Jul-97	26.02	7.93
	Jan-98	28.74	8.76

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (µg/L)	Benzene	--	BD	BD	BD	NA	--
	Toluene	--	BD	BD	BD	NA	--
	Ethylbenzene	--	BD	BD	BD	NA	--
	Xylene	--	BD	BD	BD	NA	--
	MTBE	--	BD	78.6	--	--	--
Geochemical Indicator Concentrations (mg/L)	DO	--	5.07	2.48	3.31	NS	--
	Sulfate	--	7.45	3.44	3.95	NS	--
	Fe(II)	--	BD	0.05	0.01	NS	--
	Sulfide	--	ND	0	0.003	NS	--
	Methane	--	BD	BD	BD	NS	--

Well LB-EX-6

Location in Model Grid	i-coordinate	35	**Top of Casing Elevation**	37.82 feet
	j-coordinate	109	**Ground Surface Elevation**	38.49 feet

		Feet	Meters
Water Table Elevation	Apr-93	28.78	8.77
	Mar-94	--	--
	Jan-97	--	--
	Jul-97	--	--
	Jan-98	--	--

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (µg/L)	Benzene	--	--	--	--	--	--
	Toluene	--	--	--	--	--	--
	Ethylbenzene	--	--	--	--	--	--
	Xylene	--	--	--	--	--	--
	MTBE	--	--	--	--	--	--
Geochemical Indicator Concentrations (mg/L)	DO	--	--	--	--	--	--
	Sulfate	--	--	--	--	--	--
	Fe(II)	--	--	--	--	--	--
	Sulfide	--	--	--	--	--	--
	Methane	--	--	--	--	--	--

Well LB-EX-7

Location in Model Grid	i-coordinate	17	Top of Casing Elevation	38.69 feet
	j-coordinate	102	Ground Surface Elevation	38.99 feet

Water Table Elevation		Feet	Meters
	Apr-93	28.65	8.73
	Mar-94	27.36	8.34
	Jan-97	26.14	7.97
	Jul-97	25.75	7.85
	Jan-98	--	--

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (µg/L)	Benzene	11000	9450	2.33	1.47	0.915	263
	Toluene	32000	22300	4.18	4.03	8.67	589
	Ethylbenzene	4000	3100	4.895	0.71	0.896	--
	Xylene	23000	15100	1.594	2	5.16	--
	MTBE	77000	251000	7012	--	--	550
Geochemical Indicator Concentrations (mg/L)	DO	--	0	0	0	0	--
	Sulfate	--	0.99	4.1	4.73	--	--
	Fe(II)	--	20	3.91	13.7	7.5	--
	Sulfide	--	ND	4.4	1.04	1.35	--
	Methane	--	BD	BD	ND	--	--

Well LB-EX-8

Location in Model Grid	i-coordinate	15	Top of Casing Elevation	40.81 feet
	j-coordinate	87	Ground Surface Elevation	38.56 feet

Water Table Elevation		Feet	Meters
	Apr-93	28.2	8.59
	Mar-94	26.93	8.21
	Jan-97	25.71	7.84
	Jul-97	25.36	7.73
	Jan-98	27.76	8.46

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (µg/L)	Benzene	1700	9180	5.03	9.45	0.937	201
	Toluene	4100	22500	14.8	3.09	3.67	--
	Ethylbenzene	920	2400	2.24	1.55	0.687	--
	Xylene	4600	19350	6.46	2.2	3.379	--
	MTBE	18000	26700	8161	--	--	727
Geochemical Indicator Concentrations (mg/L)	DO	--	0	0	0	0	--
	Sulfate	--	9.82	0.45	0.38	--	--
	Fe(II)	--	6.8	36.75	28.3	26.3	--
	Sulfide	--	ND	1	0.473	0.207	--
	Methane	--	BD	0.2	ND	--	--

Well LB-EX-9

Location in Model Grid	i-coordinate	5	**Top of Casing Elevation**	39.46	feet
	j-coordinate	108	**Ground Surface Elevation**	37.59	feet

		Feet	Meters
Water Table Elevation	Apr-93	28.73	8.76
	Mar-94	27.37	8.34
	Jan-97	26.13	7.96
	Jul-97	25.75	7.85
	Jan-98	28.44	8.67

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (μg/L)	Benzene	--	36.6	ND	BD	NA	--
	Toluene	--	132	ND	BD	NA	--
	Ethylbenzene	--	11.8	ND	BD	NA	--
	Xylene	--	60.7	ND	BD	NA	--
	MTBE	--	54.4	ND	--	--	--
Geochemical Indicator Concentrations (mg/L)	DO	--	4.11	2.08	2.52	NS	--
	Sulfate	--	12.12	4.54	5.85	--	--
	Fe(II)	--	BD	0	0.02	ND	--
	Sulfide	--	ND	0	0	NS	--
	Methane	--	BD	BD	ND	--	--

Well LB-EX-10

Location in Model Grid	i-coordinate	3	**Top of Casing Elevation**	40.3	feet
	j-coordinate	91	**Ground Surface Elevation**	38.16	feet

		Feet	Meters
Water Table Elevation	Apr-93	28.33	8.63
	Mar-94	27.03	8.24
	Jan-97	25.83	7.87
	Jul-97	25.46	7.76
	Jan-98	28.06	8.55

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (μg/L)	Benzene	--	BD	ND	ND	NA	--
	Toluene	--	BD	ND	ND	NA	--
	Ethylbenzene	--	BD	ND	ND	NA	--
	Xylene	--	BD	ND	ND	NA	--
	MTBE	--	BD	ND	--	--	--
Geochemical Indicator Concentrations (mg/L)	DO	--	2.93	3.28	3.5	NS	--
	Sulfate	--	14.75	7.17	6.81	--	--
	Fe(II)	--	BD	0.72	0	NS	--
	Sulfide	--	ND	0	0.004	NS	--
	Methane	--	BD	BD	ND	--	--

Well LB-EX-11

Location in Model Grid				Top of Casing Elevation	42.54 feet
	i-coordinate	9		Top of Casing Elevation	42.54 feet
	j-coordinate	72		Ground Surface Elevation	40.16 feet

Water Table Elevation		Feet	Meters
	Apr-93	27.53	8.39
	Mar-94	26.27	8.01
	Jan-97	--	--
	Jul-97	--	--
	Jan-98	29.92	9.12

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (µg/L)	Benzene	ND	BD	NA	NA	NA	--
	Toluene	ND	BD	NA	NA	NA	--
	Ethylbenzene	ND	BD	NA	NA	NA	--
	Xylene	ND	BD	NA	NA	NA	--
	MTBE	2.4	BD	NA	--	--	--
Geochemical Indicator Concentrations (mg/L)	DO	--	4.66	DRY	DRY	DRY	--
	Sulfate	--	14.84	DRY	DRY	--	--
	Fe(II)	--	BD	DRY	DRY	DRY	--
	Sulfide	--	ND	DRY	DRY	DRY	--
	Methane	--	BD	DRY	DRY	DRY	--

Well LB-EX-12

Location in Model Grid				
	i-coordinate	31	Top of Casing Elevation	39.61 feet
	j-coordinate	64	Ground Surface Elevation	39.66 feet

Water Table Elevation		Feet	Meters
	Apr-93	27.01	8.23
	Mar-94	25.86	7.88
	Jan-97	24.57	7.49
	Jul-97	24.25	7.39
	Jan-98	26.46	8.06

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (µg/L)	Benzene	--	BD	ND	BD	ND	--
	Toluene	--	BD	ND	0.008	ND	--
	Ethylbenzene	--	BD	ND	ND	ND	--
	Xylene	--	BD	ND	ND	ND	--
	MTBE	--	BD	ND	--	--	--
Geochemical Indicator Concentrations (mg/L)	DO	--	4.43	2.51	3.04	0.3	--
	Sulfate	--	12.13	15.25	15.92	--	--
	Fe(II)	--	BD	0	0.04	0.21	--
	Sulfide	--	ND	0	0.006	0.003	--
	Methane	--	BD	BD	ND	--	--

Well LB-EX-13

Location in Model Grid	i-coordinate	39	**Top of Casing Elevation**	38.68	feet
	j-coordinate	90	**Ground Surface Elevation**	38.96	feet

		Feet	Meters
Water Table Elevation	Apr-93	28.26	8.61
	Mar-94	27.22	8.30
	Jan-97	25.95	7.91
	Jul-97	25.58	7.80
	Jan-98	27.71	8.45

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (µg/L)	Benzene	--	BD	0.325	0.24	ND	--
	Toluene	--	BD	0.819	0.33	0.0171	--
	Ethylbenzene	--	BD	0.048	0.35	ND	--
	Xylene	--	BD	0.1572	0.51	0.0152	--
	MTBE	--	BD	846	--	--	--
Geochemical Indicator Concentrations (mg/L)	DO	--	5.91	3.52	3.66	1.5	--
	Sulfate	--	24.43	20.69	41.38	--	--
	Fe(II)	--	ND	0	0	0.14	--
	Sulfide	--	ND	0	0.005	0.002	--
	Methane	--	BD	BD	BD	--	--

Well LB-EX-14

Location in Model Grid	i-coordinate	44	**Top of Casing Elevation**	37.73	feet
	j-coordinate	73	**Ground Surface Elevation**	37.66	feet

		Feet	Meters
Water Table Elevation	Apr-93	27.73	8.45
	Mar-94	26.68	8.13
	Jan-97	25.22	7.69
	Jul-97	27.68	8.44
	Jan-98	--	--

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (µg/L)	Benzene	--	BD	0.029	ND	ND	--
	Toluene	--	BD	0.005	0.03	ND	--
	Ethylbenzene	--	BD	ND	0.008	ND	--
	Xylene	--	BD	ND	0.026	ND	--
	MTBE	--	BD	75	--	--	--
Geochemical Indicator Concentrations (mg/L)	DO	--	5.3	3.86	3.78	0.96	--
	Sulfate	--	9.93	11.17	10.05	--	--
	Fe(II)	--	ND	0	0.02	0	--
	Sulfide	--	ND	0	0.005	0	--
	Methane	--	BD	BD	ND	--	--

Well LB-EX-15

Location in Model Grid			Top of Casing Elevation	
	i-coordinate	27	Top of Casing Elevation	38.82 feet
	j-coordinate	73	Ground Surface Elevation	38.86 feet

Water Table Elevation		Feet	Meters
	Apr-93	27.67	8.43
	Mar-94	26.57	8.10
	Jan-97	25.24	7.69
	Jul-97	25.04	7.63
	Jan-98	27.22	8.30

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (µg/L)	Benzene	2.7	6.7	0.364	0.15	0.0096	--
	Toluene	ND	6.1	0.008	BD	0.0607	--
	Ethylbenzene	8.8	5.9	0.006	BD	0.0148	--
	Xylene	0.81	11.4	0.011	BD	0.0599	--
	MTBE	19	BD	4038	--	--	--
Geochemical Indicator Concentrations (mg/L)	DO	--	0.9	2.44	0.89	0.53	--
	Sulfate	--	27.88	33.49	32.71	--	--
	Fe(II)	--	2.8	0.02	0	0.03	--
	Sulfide	--	ND	0	0.005	0.005	--
	Methane	--	BD	0.1	ND	--	--

Well LB-EX-16

Location in Model Grid			Top of Casing Elevation	
	i-coordinate	20	Top of Casing Elevation	42.51 feet
	j-coordinate	60	Ground Surface Elevation	40.56 feet

Water Table Elevation		Feet	Meters
	Apr-93	26.7	8.14
	Mar-94	25.39	7.74
	Jan-97	24.26	7.39
	Jul-97	23.96	7.30
	Jan-98	25.93	7.90

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (µg/L)	Benzene	ND	6.5	0.007	0.101	0.115	12
	Toluene	ND	BD	ND	0.054	ND	--
	Ethylbenzene	ND	BD	ND	0.017	ND	--
	Xylene	ND	BD	0.0064	0.063	ND	--
	MTBE	17	800	3049	--	--	1550
Geochemical Indicator Concentrations (mg/L)	DO	--	4.92	3.49	1.82	0	--
	Sulfate	--	15.5	24.61	13.6	--	--
	Fe(II)	--	BD	2.15	0	1.57	--
	Sulfide	--	ND	0	0.001	0.003	--
	Methane	--	BD	BD	ND	--	--

Well LB-EX-17

Location in Model Grid	i-coordinate	18	**Top of Casing Elevation**	40.95	feet
	j-coordinate	85	**Ground Surface Elevation**	38.56	feet

Water Table Elevation		Feet	Meters
	Apr-93	--	--
	Mar-94	--	--
	Jan-97	25.45	7.76
	Jul-97	24.97	7.61
	Jan-98	--	--

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (µg/L)	Benzene	3.7	--	0.033	0.067	ND	ND
	Toluene	8.2	--	0.005	0.12	ND	ND
	Ethylbenzene	1.7	--	0.008	0.01	ND	--
	Xylene	7.4	--	0.012	0.046	ND	--
	MTBE	71	--	414	--	--	--
Geochemical Indicator Concentrations (mg/L)	DO	--	--	--	--	--	--
	Sulfate	--	--	--	--	--	--
	Fe(II)	--	--	--	--	--	--
	Sulfide	--	--	--	--	--	--
	Methane	--	--	--	--	--	--

Well LB-EX-19

Location in Model Grid	i-coordinate	21	**Top of Casing Elevation**	--	feet
	j-coordinate	36	**Ground Surface Elevation**	--	feet

Water Table Elevation		Feet	Meters
	Apr-93	--	--
	Mar-94	--	--
	Jan-97	22.8	6.95
	Jul-97	22.61	6.89
	Jan-98	24.21	7.38

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (µg/L)	Benzene	--	--	ND	BD	0.0108	ND
	Toluene	--	--	ND	0.007	0.0064	ND
	Ethylbenzene	--	--	ND	BD	0.0089	--
	Xylene	--	--	ND	BD	0.011	--
	MTBE	--	--	35.8	--	--	ND
Geochemical Indicator Concentrations (mg/L)	DO	--	--	4.9	4.48	2.2	--
	Sulfate	--	--	6.88	7.82	--	--
	Fe(II)	--	--	0.03	0	0.07	--
	Sulfide	--	--	0.1	0.005	0	--
	Methane	--	--	BD	ND	--	--

Well LB-EX-20

Location in Model Grid					
	i-coordinate	33	**Top of Casing Elevation**	--	feet
	j-coordinate	29	**Ground Surface Elevation**	--	feet

Water Table Elevation		Feet	Meters
	Apr-93	--	--
	Mar-94	--	--
	Jan-97	22.4	6.83
	Jul-97	22.19	6.76
	Jan-98	23.55	7.18

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (µg/L)	Benzene	--	--	ND	BD	ND	ND
	Toluene	--	--	ND	BD	ND	ND
	Ethylbenzene	--	--	ND	BD	ND	--
	Xylene	--	--	ND	BD	ND	--
	MTBE	--	--	ND	--	--	ND
Geochemical Indicator Concentrations (mg/L)	DO	--	--	0.69	1.35	0	--
	Sulfate	--	--	6.08	4.5	--	--
	Fe(II)	--	--	1.97	1.84	2.61	--
	Sulfide	--	--	0	0.012	0.013	--
	Methane	--	--	0.4	0.2	--	--

Well LB-EX-21

Location in Model Grid					
	i-coordinate	29	**Top of Casing Elevation**	--	feet
	j-coordinate	15	**Ground Surface Elevation**	--	feet

Water Table Elevation		Feet	Meters
	Apr-93	--	--
	Mar-94	--	--
	Jan-97	--	--
	Jul-97	20.57	6.27
	Jan-98	18.38	5.60

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (µg/L)	Benzene	--	--	1.47	2.36	1.28	1590
	Toluene	--	--	0.924	0.86	0.681	486
	Ethylbenzene	--	--	0.532	0.78	0.369	--
	Xylene	--	--	0.706	0.67	0.617	--
	MTBE	--	--	18500	--	--	15200
Geochemical Indicator Concentrations (mg/L)	DO	--	--	6.49	4.14	1.53	--
	Sulfate	--	--	7.01	2.13	--	--
	Fe(II)	--	--	0.04	0	0	--
	Sulfide	--	--	0	0.022	0.03	--
	Methane	--	--	0.3	0.3	--	--

Well LB-EX-RW

Location in Model Grid	i-coordinate	20	**Top of Casing Elevation**	39.47	feet
	j-coordinate	99	**Ground Surface Elevation**	39.39	feet

		Feet	Meters
Water Table Elevation	Apr-93	28.65	8.73
	Mar-94	27.27	8.31
	Jan-97	--	--
	Jul-97	26.07	7.95
	Jan-98	25.71	7.84

		Apr-93	Mar-94	Jun-96	Jan-97	Jul-97	Jan-98
Contaminant Concentrations (µg/L)	Benzene	--	9650	7.89	6.21	5.08	1060
	Toluene	--	16100	13.2	7.65	13.4	2830
	Ethylbenzene	--	BD	1.28	5.32	1.56	--
	Xylene	--	7900	3.77	6.8	7.53	--
	MTBE	--	70000	31583	--	--	262
Geochemical Indicator Concentrations (mg/L)	DO	--	0	0	0	0	--
	Sulfate	--	0.82	1.51	2.03	--	--
	Fe(II)	--	9.8	16.2	29.2	27.3	--
	Sulfide	--	<.02	0	0.93	0.0496	--
	Methane	--	BD	0.8	0.3	--	--