

## AR TARGET SHEET

The following document was too large to scan as one unit, therefore, it has been broken down into sections.

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SECTION: 2 of 8

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TITLE: Draft RI/FS Report for  
1100-EM-1 OU, Hanford

Table 6-12. Hydraulic Flow Sensitivity Analysis

		TOTAL PRESSURE HEAD DIFFERENCE IN METERS		
RUN	TESTED PARAMETER	$\Delta$ @C15R22	$\Delta$ @C36R22	$\Delta$ @C52R22
0	1c60 Base*	0	0	0
1	1c61 $K_h' = K_h \times .50$ (all)	+0.156	+0.165	+0.119
2	1c62 $K_h' = K_h \times .25$ (all)	+0.300	+0.548	+0.500
3	1c63 $K_h' = K_h \times 2.0$ (all)	-0.096	-0.116	-0.085
4	1c64 $K_h' = K_h \times 4.0$ (all)	-0.155	-0.177	-0.123
5	1c65 $K_v' = K_v \times .50$ (all)	-0.040	-0.052	-0.018
6	1c66 $K_v' = K_v \times .25$ (all)	-0.066	-0.077	-0.018
7	1c67 $K_v' = K_v \times 2.0$ (all)	+0.032	+0.023	-0.014
8	1c69 Up Surf. Rech.' = 0 in./yr	-0.057	-0.026	-0.003
9	1c70 Up Surf. Rech.' = 4 in./yr	+0.015	+0.045	+0.036
10	1c71 Low Surf. Rech.' x .50	-0.020	-0.051	-0.050
11	1c72 Low Surf. Rech.' x 2.0	+0.041	+0.072	+0.099
12	1c73 Low Surf. Rech.' x 1.5	+0.021	+0.031	+0.049
13	1c74 Low Surf. Rech.' x .25	-0.031	-0.072	-0.074
14	1c75 Porosity' = Poros. x .25	0	0	0
15	1c76 Porosity' = Poros. x 4.0	0	0	0
16	1c77 $K_h' = K_h \times .25$ (Hanford)	+0.258	+0.333	+0.411
17	1c78 $K_h' = K_h \times .50$ (Hanford)	+0.112	+0.136	+0.147
18	1c79 $K_h' = K_h \times 2.0$ (Hanford)	-0.096	-0.134	-0.120
19	1c80 $K_h' = K_h \times 4.0$ (Hanford)	-0.174	-0.226	-0.185
20	1c81 $K_h' = K_h \times .25$ (Up Ringd)	-0.002	-0.020	-0.020
21	1c82 $K_h' = K_h \times .50$ (Up Ringd)	-0.005	-0.020	-0.015
22	1c83 $K_h' = K_h \times 2.0$ (Up Ringd)	-0.009	0	+0.016
23	1c84 $K_h' = K_h \times 4.0$ (Up Ringd)	-0.040	+0.009	+0.044
24	1c85 $K_h' = K_h \times .25$ (Silt)	-0.003	-0.001	-0.001
25	1c86 $K_h' = K_h \times 4.0$ (Silt)	-0.007	-0.003	-0.001
26	1c87 $K_h' = K_h \times .25$ (Lo Ringd)	+0.037	+0.020	-0.020
27	1c88 $K_h' = K_h \times 4.0$ (Lo Ringd)	-0.003	+0.008	+0.065

\*Base case used:  $K_{\text{Horiz. (Hanford)}}$  of 400 - 5000 m/d,  $K_{\text{Horiz. (Ringold)}}$  of 20 - 60 m/d,  $K_{\text{Horiz. (Silt)}}$  of 0.01 - 0.05 m/d, a horizontal-to-vertical conductivity ratio of 10:1, porosity of 0.20, storage coefficient of 0.20, upper surface recharge of  $1.0E-5$  m/d, and lower surface recharge of  $1.1E-3$  m/d. Base case elevations were 107.52, 106.42, and 105.32 meters.

**6.4.4.1 Hydraulic Flow Sensitivity.** The hydraulics portion of the model was ran repeatedly with the hydraulic parameters multiplied and divided by factors of 2 and 4 to determine model sensitivity. For recharge due to precipitation, the range was only varied from 0 to 4 inches per year. For each run, total pressure head deviations from the base case (calibrated average model) were determined in layer 12 at XY nodes (15,22), (36,22), and (52,22). All layers at a given XY node, representing the unconfined aquifer, have approximately the same total pressure head. Deviations are listed in table 6-12. There was only slight sensitivity to recharge due to precipitation, vertical hydraulic conductivity, and seepage (positive flux) into the bottom of the model. The unconfined aquifer pressure heads were not very sensitive to flux into the model's lower boundary due to the intervening silt aquitard, which tends to dampen effects of changes in the lower aquifer. Unconfined aquifer total pressure heads were not very sensitive to upper surface recharge (precipitation recharge) because of the high hydraulic conductivities in the upper part of the unconfined aquifer and due to the small range of possible precipitation recharge. Of the parameters tested, the model was most sensitive to changes in horizontal hydraulic conductivity. This is consistent with groundwater systems and groundwater models in general.

Model sensitivity to the primary factors influencing groundwater flow velocities is described above. A sensitivity analysis on the uncertainty associated with the delineation of stratigraphic boundaries was not performed mainly due to lack of a reasonable means of doing so. However, exact stratigraphic representation was not necessary to predict accurate contaminant travel times or dispersion rates since these are dependent on groundwater velocities which, in turn, depend mainly on hydraulic conductivities and total pressure head gradients. The modeling analysis emphasized calibration to observed hydraulic conductivities and total pressure head gradients, thus emphasizing the accuracy of predicted travel times, attenuation rates, and other velocity-dependent processes. Any error introduced by non-exact stratigraphic boundary definition has little effect on the velocity-dependent processes but has a greater effect on volume calculations such as those involved with predicting aquifer response to large scale pumping. Because of this, the greater the pumping rate of any simulated extraction-treatment scenario, the greater the associated uncertainty in predicted sustainable pumping rates and effects on groundwater gradients.

Although the grid mesh size was, by convention, adequate for the model applications in this study, the predictions of aquifer response to the extraction-treatment scenarios would be improved by increasing mesh density near the extraction wells.

Table 6-13. Contaminant Transport Sensitivity Analysis

Parameter Varied	1988 Max C (ppb)	1992 Max C (ppb)	2000 Max C (ppb)
Base Case*	180	80	30
R = 1.5	130	55	15
R = 4.0	180	80	30
SS = .1	180	80	30
SS = .4	180	80	30
$\eta_{\text{eff}} = .1$	110	30	3
$\eta_{\text{eff}} = .4$	220	130	75
$\eta_{\text{tot}} = .4$	180	80	30
$\eta_{\text{diff}} = .4$	180	85	30
$\alpha_{\text{long}} = 0$	180	80	30
$\alpha_{\text{long}} = 4$	160	76	28
$\alpha_{\text{trans}} = .001$	220	120	45
$\alpha_{\text{trans}} = .5$	20	5	0

\*Base case used: R = 2.0, SS = 0.2,  $\eta_{\text{eff}} = 0.20$ ,  $\eta_{\text{tot}} = 0.23$ ,  $\eta_{\text{diff}} = 0.20$ ,  $\alpha_{\text{long}} = 1.0$ ,  $\alpha_{\text{trans}} = 0.03$ , all in meters and days, where applicable.

**6.4.4.2 Contaminant Transport Sensitivity.** A contaminant transport sensitivity analysis was performed in which pertinent parameters were varied within reasonable ranges. Table 6-13 shows predicted maximum TCE concentrations for years 1988, 1992, and 2000 as a result of simulations using the parameters listed in the first column. The analysis indicated the model was most sensitive to effective porosity values, significantly sensitive to retardation and dispersivity values, and minimally sensitive to storage and diffusive porosity values.

The contaminant sensitivity analysis assisted in determining ranges of model input data sets, used in the analysis to represent unconservative (high attenuation) and conservative (low attenuation) simulations. The sensitivity of contaminant transport to a range of groundwater velocity fields was not tested. Such testing would require multiple calibrations of the flow portion of the model. The approach used in this analysis was to produce the best estimate of the velocity field by calibrating the flow provided to observed data, and then using this calibrated velocity field in the contaminant transport analysis.

#### 6.4.5 Calibration

The hydraulic flow and contaminant transport portions of the model were calibrated to observed site data. The purpose of the calibrations was to set model parameters consistent with site parameters so that model results better simulate actual site conditions. Without calibration, a model can produce results having little resemblance to what is observed in the field.

**6.4.5.1 Hydraulic Flow Calibration.** For the hydraulic flow portion of the model, calibration data was chosen from the observed groundwater levels reported in WHC, 1991b. Three data sets, June 25-27, February 27-March 2, and September 24 to 27, were chosen to represent the groundwater levels relating to the high-, average-, and low-river stage conditions. These calibrations were performed in the steady-state mode with boundary conditions and hydraulic conductivities adjusted until the model simulated the observed groundwater levels. Figures 6-21 through 6-23 show the observed and calibrated water surface contours superimposed. Table 6-14 lists the observed, computed, and the resulting difference for 22 wells in the area of interest. Maximum deviations of the computed from the observed elevations consistently occurs at well MW-13 which appears to be screened at a different depth or to have some other similar cause for its levels being consistently about 0.5 m (1.6 ft) higher than those of MW-14. Most other deviations are less than 0.1 m (0.3 ft) which indicates reasonably close calibrations.

The simulated river stages and inflowing flux values at the southern boundary were modified appropriately for each condition. The high-, average-, and low-river stages represent conditions where the river boundary was higher than 97, 48, and 7 percent of normally distributed river elevations. During the calibration process, horizontal and vertical hydraulic conductivities and boundary fluxes were adjusted until reasonable matches between observed and computed heads were obtained. Table 6-15 shows the calibrated hydraulic

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Table 6-14. Comparison of Observed Groundwater levels and Computed Total Pressure Heads for the High, Average, and Low River Stage Model Calibrations

WELL #	SEPTEMBER 24-27, 1990			FEB 27 - MARCH 2, 1990			JUNE 25 - 27, 1990		
	OBS meters	CALC meters	DIFF meters	OBS meters	CALC meters	DIFF meters	OBS meters	CALC meters	DIFF meters
399-1-17A	104.05	104.01	0.04	104.72	104.69	0.03	105.73	105.65	0.08
399-3-6	103.98	104.01	0.03	104.67	104.70	0.03	105.68	105.64	0.04
399-3-7	103.97	104.01	0.04	104.67	104.70	0.03	105.66	105.64	0.02
399-3-12	103.93	104.00	0.07	104.64	104.69	0.05	105.61	105.62	0.01
399-4-1	103.87	103.99	0.12	104.59	104.65	0.06	105.53	105.60	0.07
399-4-11	103.93	104.00	0.06	104.63	104.69	0.06	105.59	105.62	0.02
399-5-1	104.03	104.08	0.05	104.65	104.75	0.10	105.66	105.65	0.01
399-6-1	104.13	104.08	0.06	104.72	104.75	0.03	105.77	105.67	0.10
699-S27-E14	103.88	104.02	0.14	104.58	104.69	0.10	105.52	105.60	0.09
699-S29-E12	105.42	105.10	0.32	105.32	105.32	0.01	105.86	105.80	0.06
699-S30-E(MW-10)	106.34	106.26	0.08	106.22	106.31	0.09	106.28	106.51	0.23
699-S30-E(MW-11)	106.49	106.36	0.13	106.37	106.36	0.00	106.39	106.61	0.21
699-S30-E15A	103.84	104.09	0.25	104.80	104.74	0.06	105.65	105.57	0.09
699-S31-E(MW-08)	107.69	107.56	0.12	107.61	107.54	0.07	107.60	107.52	0.08
699-S31-E(MW-12)	106.22	106.29	0.07	106.09	106.32	0.23	106.16	106.53	0.37
699-S31-E(MW-14)	106.43	106.39	0.04	106.30	106.37	0.07	106.34	106.57	0.23
699-S31-E(MW-13)	107.01	106.39	0.62	106.88	106.42	0.45	106.92	106.62	0.30
699-S31-E(MW-15)	106.37	106.40	0.03	106.24	106.43	0.18	106.28	106.62	0.34
699-S31-E13	105.55	105.45	0.11	105.38	105.37	0.01	106.00	105.97	0.03
699-S32-E13A	105.65	105.45	0.21	105.47	105.63	0.16	106.05	106.03	0.02
699-S32-E13B	--	--	--	105.55	105.85	0.30	106.08	106.18	0.11
699-S34-E(MW-02)	107.70	107.72	0.01	107.40	107.46	0.06	107.43	107.48	0.04

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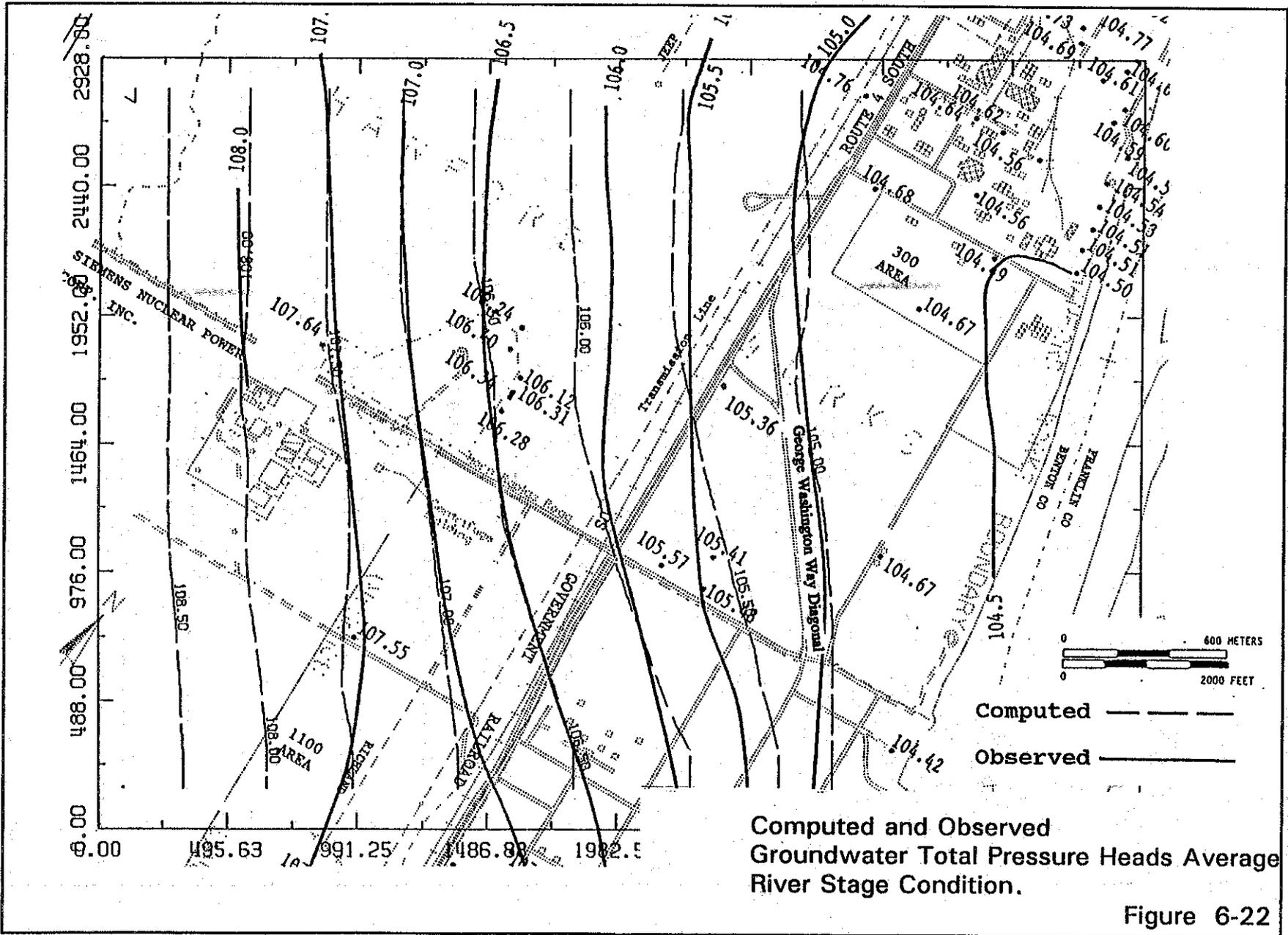
**Table 6-15. Model Zone Properties**

ZONE #	GEOLOGIC UNIT	HORIZON. HYDRAUL CONDUCT.	VERTICAL HYDRAUL CONDUCT.	EFFECTIVE POROSITY	DIFFUSIVE POROSITY	TOTAL POROSITY	STORE COEFF.
1	Lower Ringold (sand/gravel)	20. <sup>1</sup>	1.2	.20, .28 <sup>2</sup>	.20, .28	.23, .32	0.2
4	Upper Ringold (sand/gravel)	60.	3.400	.20, .28	.20, .28	.23, .32	0.2
5	Upper Ringold (silt)	0.01	0.001	.20, .24	.20, .24	.23, .27	0.2
7	Hanford (near river)	1000.	64.	.20, .28	.20, .28	.23, .32	0.2
8	Hanford (HRL vicinity)	400.	13.7	.20, .28	.20, .28	.23, .32	0.2
9	Ringold (ASH)	0.05	0.005	.20, .24	.20, .24	.23, .27	0.2
10	Hanford (near river)	5000.	50.	.20, .28	.20, .28	.23, .32	0.2

<sup>1</sup> Hydraulic conductivity values are in meters per day.

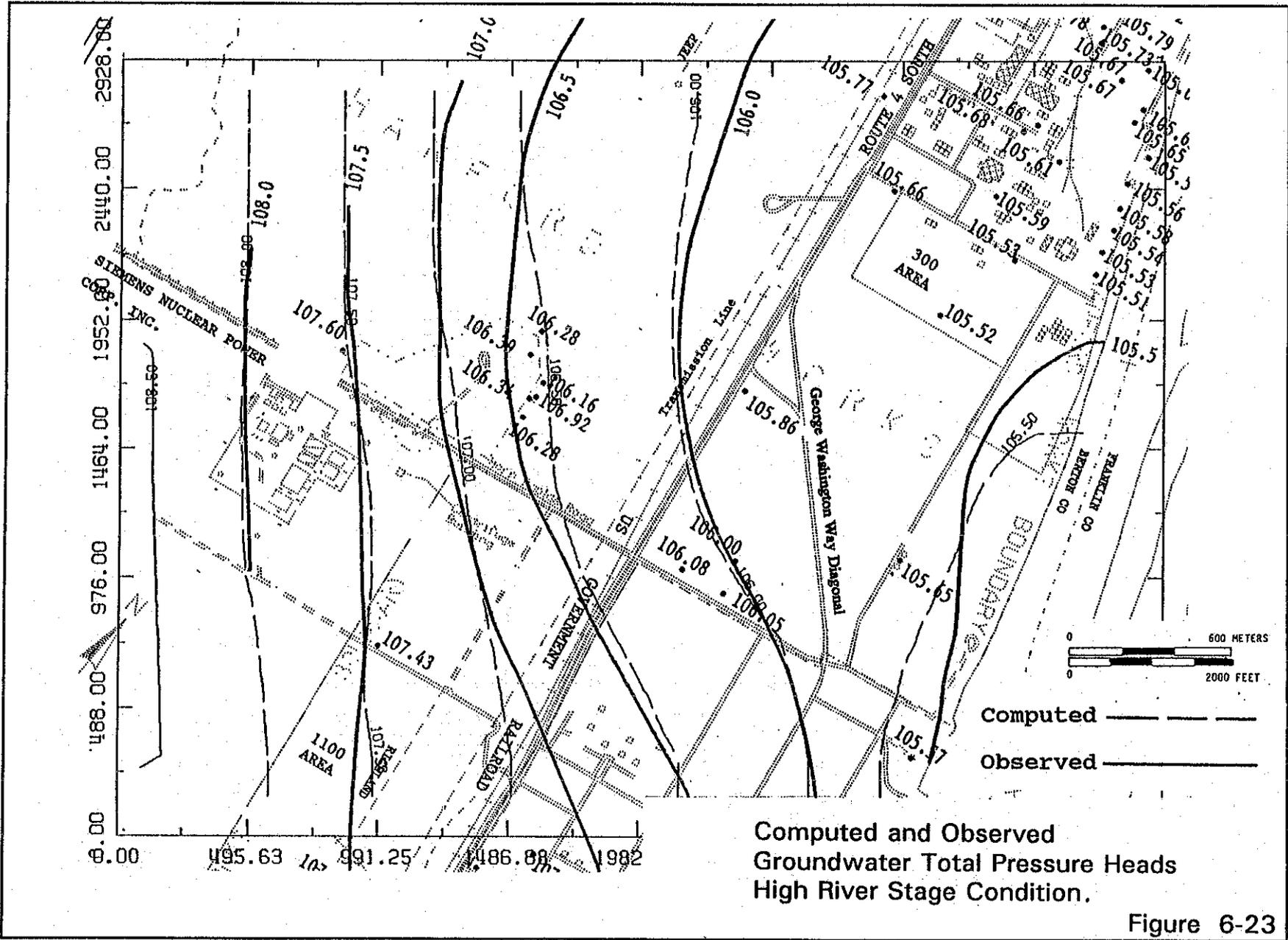
<sup>2</sup> The first and second values were used in the unconservative and conservative simulations, respectively.





Computed and Observed Groundwater Total Pressure Heads Average River Stage Condition.

Figure 6-22



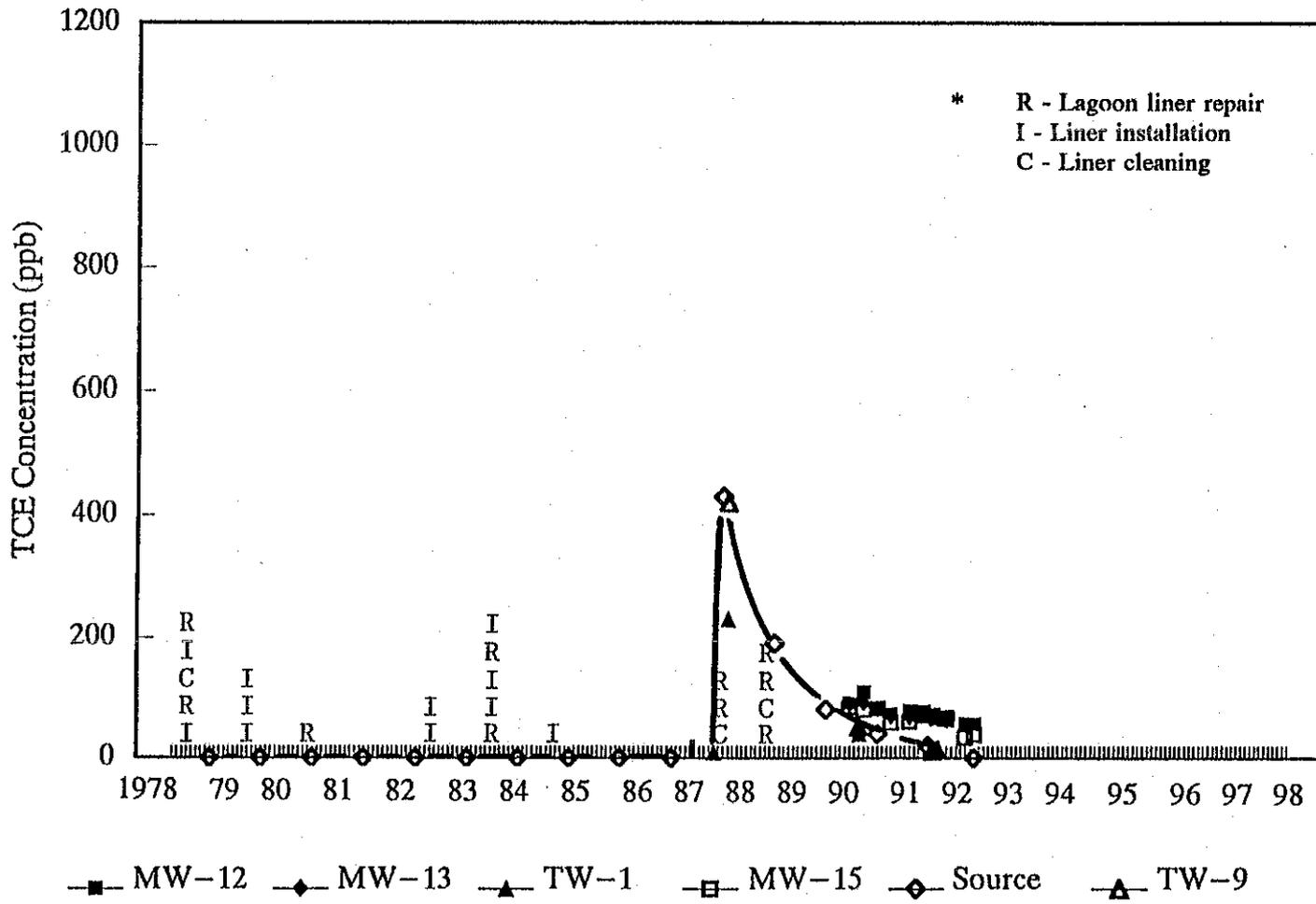
conductivities. The calibrated values for the Hanford formation and middle Ringold Formation correspond reasonably well to the pump test results [400 to 520 m/d (1,320 to 1,700 ft/d) at SPC and 10 to 72 m/d (33 to 236 ft/d) near the 300 Area].

The computed up-gradient influx to the portion of the model above the silt layer (unconfined aquifer) was 5620 m<sup>3</sup>/d (1.98E+05 ft<sup>3</sup>/d). Actual groundwater flow into the up-gradient boundary of the modeled area was estimated to be 4,600 to 8,000 m<sup>3</sup>/d (1.62E+05 to 2.82E+05 ft<sup>3</sup>/d) using the upper and lower bounds of the hydraulic conductivities in table 2-7, a .0021 m/m slope between the Yakima River and the SPC area, a saturated thickness of 7.0 m (23 ft), 2,928 m as the width of the modeled area, and the assumption that three-fourths of the unconfined thickness is dominated by Ringold material and one-fourth dominated by Hanford material. Influx estimates using the bounds of the conductivities reported from other studies at, or near, the 1100 Area (tables B-1 to B-6) resulted in influx estimates from 1,240 to 140,000 m<sup>3</sup>/d (4.38E+05 to 4.94E+06 ft<sup>3</sup>/d).

Sources for up-gradient inflow to the modeled area include recharge from the Yakima River, aquifer flow beneath the river, irrigation recharge, and precipitation recharge. A reasonable total recharge estimate could not be made because of the lack of information on, and the complexity of, the Yakima River/unconfined aquifer relationship. Recharge from up-gradient irrigation alone was estimated to be up to 1,940 m<sup>3</sup>/d (0.685E+05 ft<sup>3</sup>/d). About 4.6E6 m<sup>2</sup> (1150 acres) of irrigated land, and a net infiltration of .15 m/yr (.5 ft/yr) was used for this estimate, and provides a minimum for comparison purposes.

**6.4.5.2 Contaminant Transport Calibration.** Contaminant transport parameters were calibrated by matching simulated plume concentrations with observed contaminant levels. The model was used to determine an approximate source term that corresponds with TCE use at the site. Discrete spike source terms, with release timing correlating to periods of most intense lagoon repair and installation activity, were input to the model that was run iteratively until dispersion and retardation values produced calculated plumes matching observed plumes. This process began with an attempt to match the observed plume in a simulation having only one source spike in the summer of 1987. This was tried as a starting point because the observed data begins with a maximum December 1987 reading of 420 ppb as shown in figure 6-24. The TCE levels in well TW-1 suggest a release occurred between September and December of 1987, which implies the December levels approximate local maximums.

By comparing the simulated plumes, shown in figure 6-25, with those drawn from observed data shown in figure 6-14, it was determined that it was not possible, even with unreasonable input values, to match the observed data with only one source term occurring in 1987 (the time-series graphs, such as figure 6-25, are 2-dimensional slices of the computed, 3-dimensional contaminant plumes taken at the layer where the plume extends the farthest). Transport of significant quantities of TCE to the MW-12 area between 1987 and 1990 would require a source term far exceeding the observed concentrations at TW-1 and TW-9. In addition, such transport would require retardation and dispersion coefficients to be constrained to below their reasonable ranges. This assumes the calibrated velocity field is approximately correct.



Observed TCE Concentrations and Model Source Spike of 450 ppb.

Figure 6-24

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One additional source spike was added in 1983, at the next earlier period of increased TCE use because the simulation with one source spike did not match the observed data. The result is shown in figure 6-26. This simulation showed that additional, earlier, TCE introduction was still required for computed values to match the observed values. With one additional spike introduced in 1979 (shown in figure 6-27), near the earliest recorded use of TCE, the simulated values produced a reasonable match to observed values as shown in figure 6-28(a). Figures 6-28(b) and 6-28(c) show simulated and observed TCE levels at four locations.

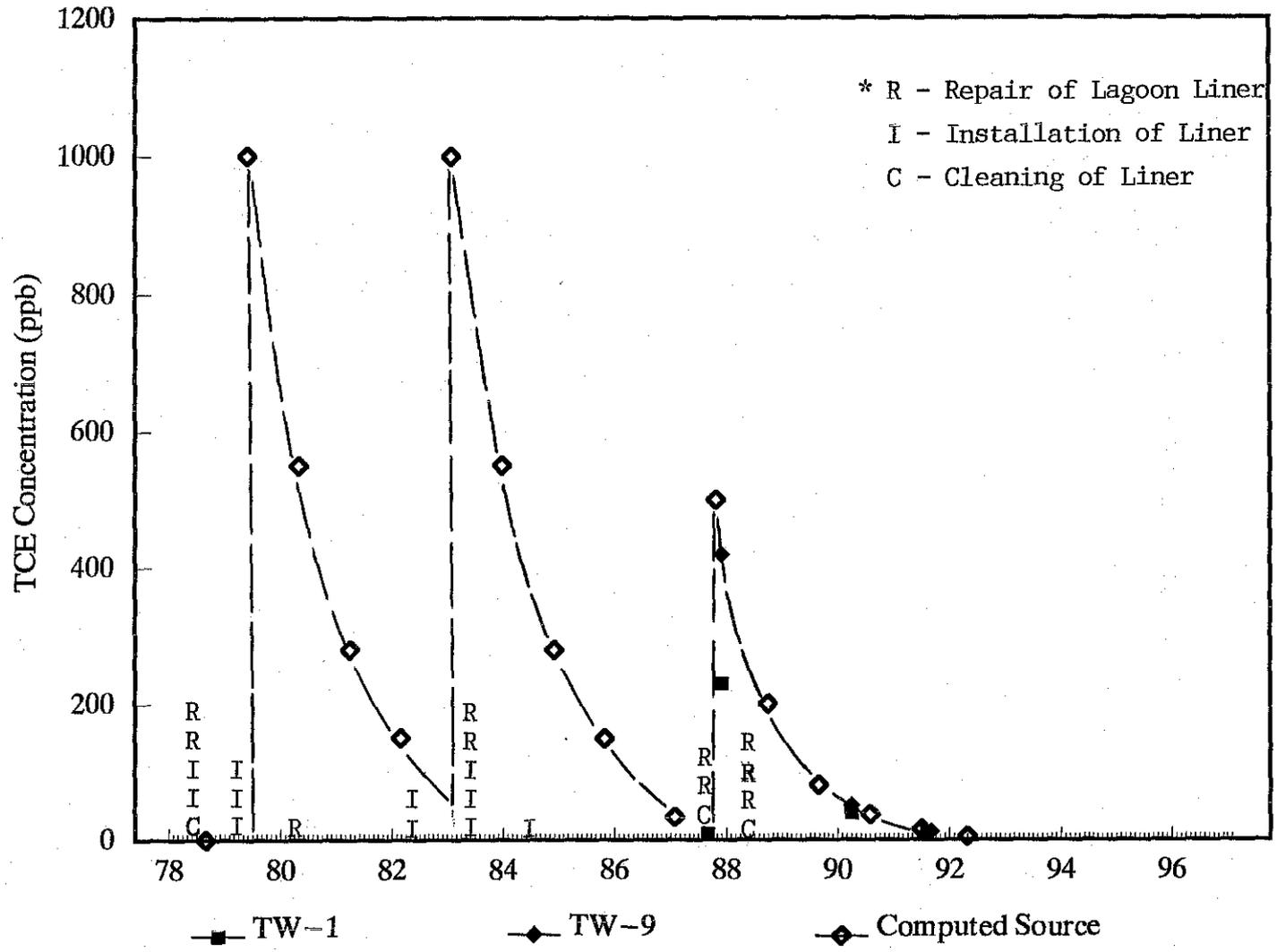
For this simulation, the TCE concentrations attenuated to below 5 ppb by the year 2007 with no concentrations above that level migrating across the George Washington Way diagonal line. This diagonal line, as shown in figure 6-13 and other figures of this section, is a construct defined by a straight line beginning at the intersection of George Washington Way and Horn Rapids Road, then running in a northwest direction along George Washington Way, and continuing in this same direction beyond the point where George Washington Way turns due west to eventually intersect with Stevens Drive. This construct defines a convenient line that is roughly parallel to the potentiometric contours and perpendicular to the prevailing groundwater flow (and the path of the contaminant plumes) in this area. Discussions dealing with the modeled plume migration and remediation scenarios will refer to this line (George Washington Way diagonal or George Washington Way diagonal line) to demarcate its movement.

The simulation discussed above is considered unconservative (the computed contaminant plume is less persistent than is actually the case) because, comparing the 1992 computed and observed plumes, the simulated concentrations in the source area appear to be dissipating faster than is occurring. The parameters used for this condition were: retardation factor ( $R$ ) = 2.0, total porosity ( $\eta_{tot}$ ) = 0.23, effective porosity ( $\eta_{eff}$ ) = 0.20, and longitudinal and transverse dispersivity factors of 1.0 and 0.03, respectively. Porosity values are for sand and gravel zones, the silt zone had  $\eta_{tot}$  and a  $\eta_{eff}$  of 0.24 and 0.28 assigned throughout. A conservative simulation (contaminant plume attenuates slower than actual) was found through repeated model runs. Results are presented in figure 6-29. The parameters used for this condition were: retardation factor ( $R$ ) = 2.55, total porosity ( $\eta_{tot}$ ) = 0.32, effective porosity ( $\eta_{eff}$ ) = 0.28, and longitudinal and transverse dispersivity factors of 0.3 and 0.01, respectively. For this simulation, the TCE concentrations attenuate to below 5 ppb by the year 2017 with no concentrations above that level migrating across the George Washington diagonal line. Because these contaminant transport parameters were more conservative, the source terms (figure 6-30) were reduced so the simulation would match the 1987 to 1992 observed data (*i.e.*, the more conservative transport parameters cause the simulated plume to remain at higher concentrations longer; so as the parameters become increasingly conservative, the source must be reduced proportionately in order to match the observed data). This simulation was the most conservative one found that provided a reasonable match of the observed data.

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\* R - Repair of Lagoon Liner  
 I - Installation of Liner  
 C - Cleaning of Liner

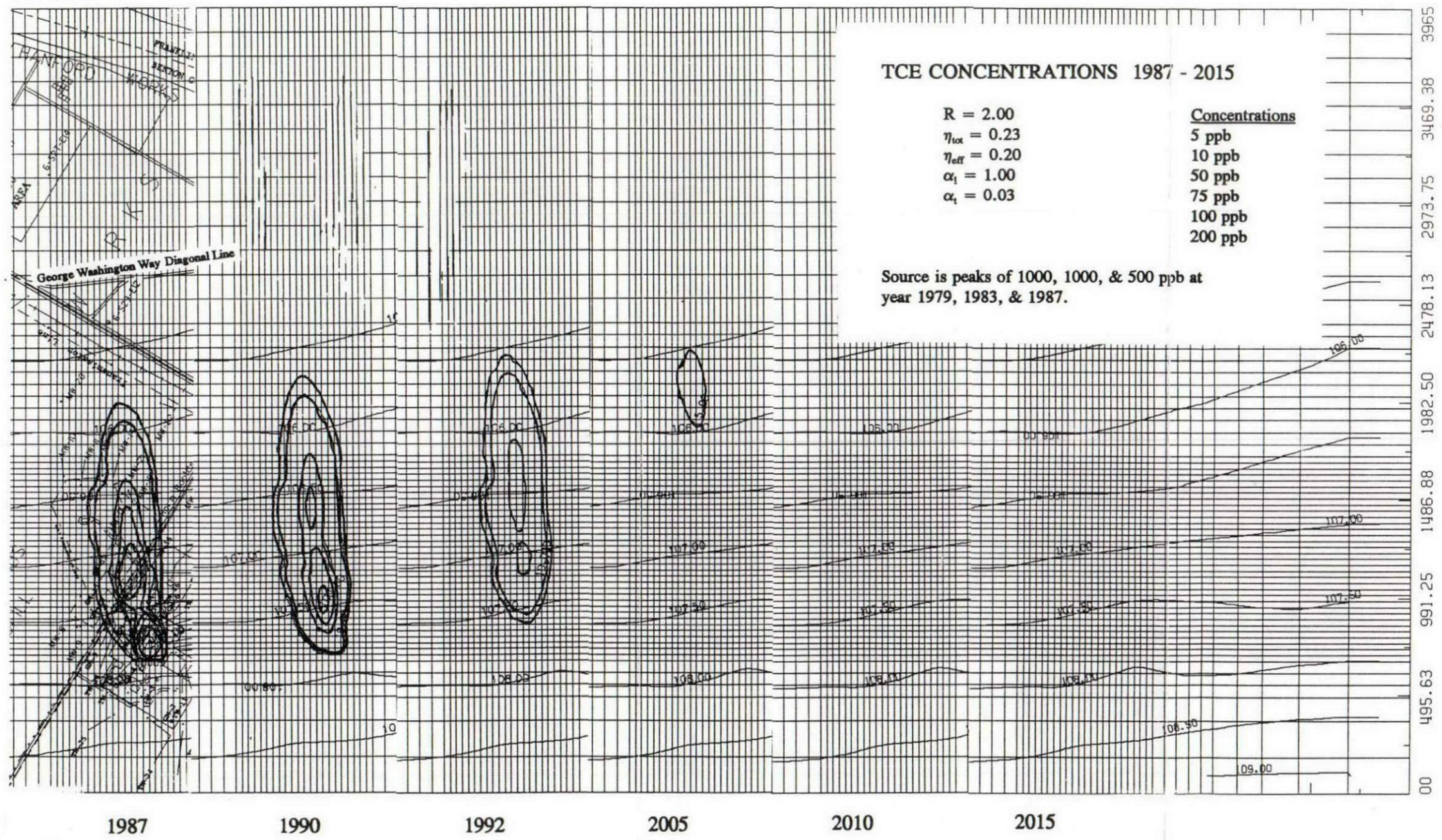
Observed TCE Concentrations and Model Source Spikes of 1000, 1000, and 500 ppb.

Figure 6-27

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Computed TCE Plumes With Source Peaks in 1979, 1983, and 1987. Unconservative Calibration.

Figure 6-28(a)

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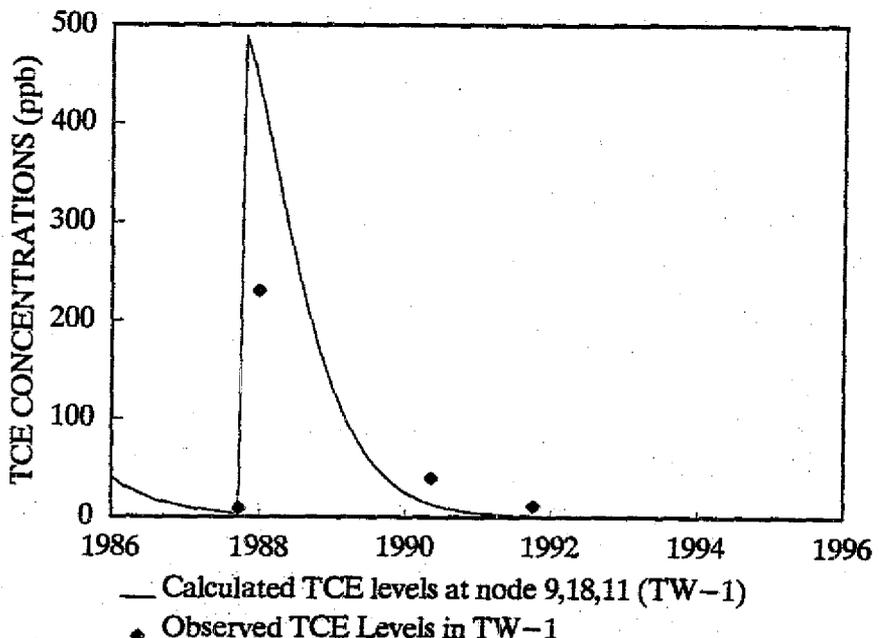
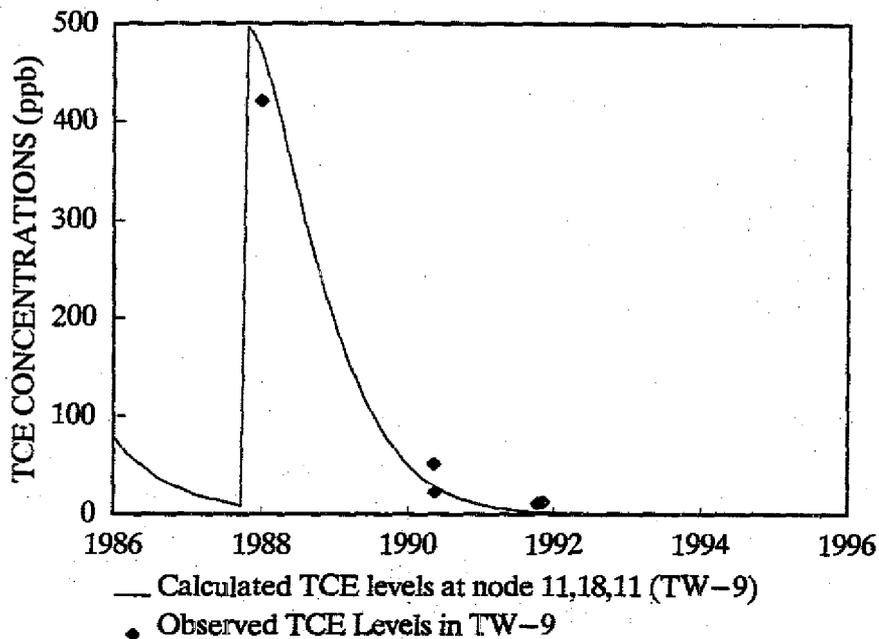


Figure 6-28(b). Calculated and Observed TCE levels at wells TW-1 and TW-9.

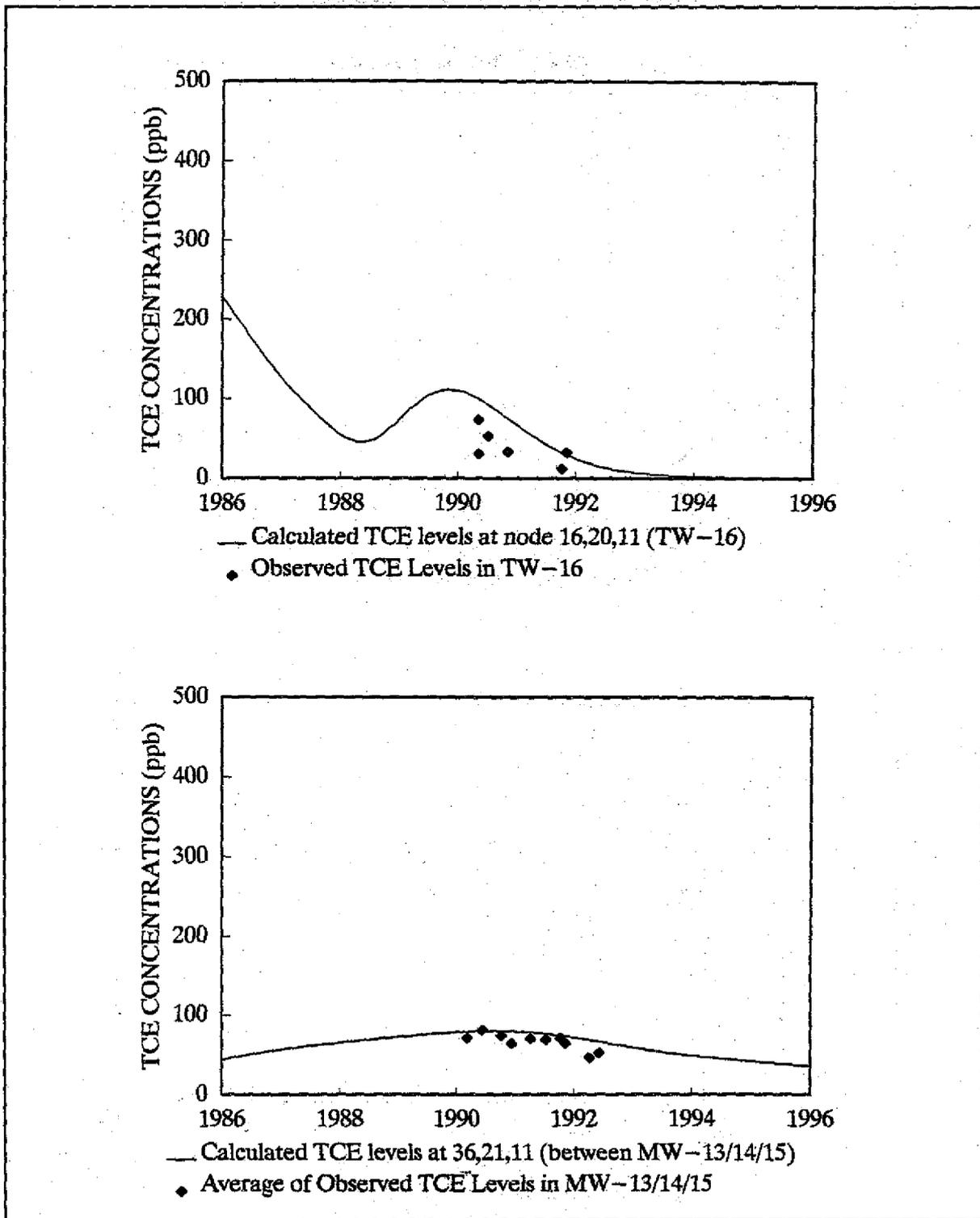
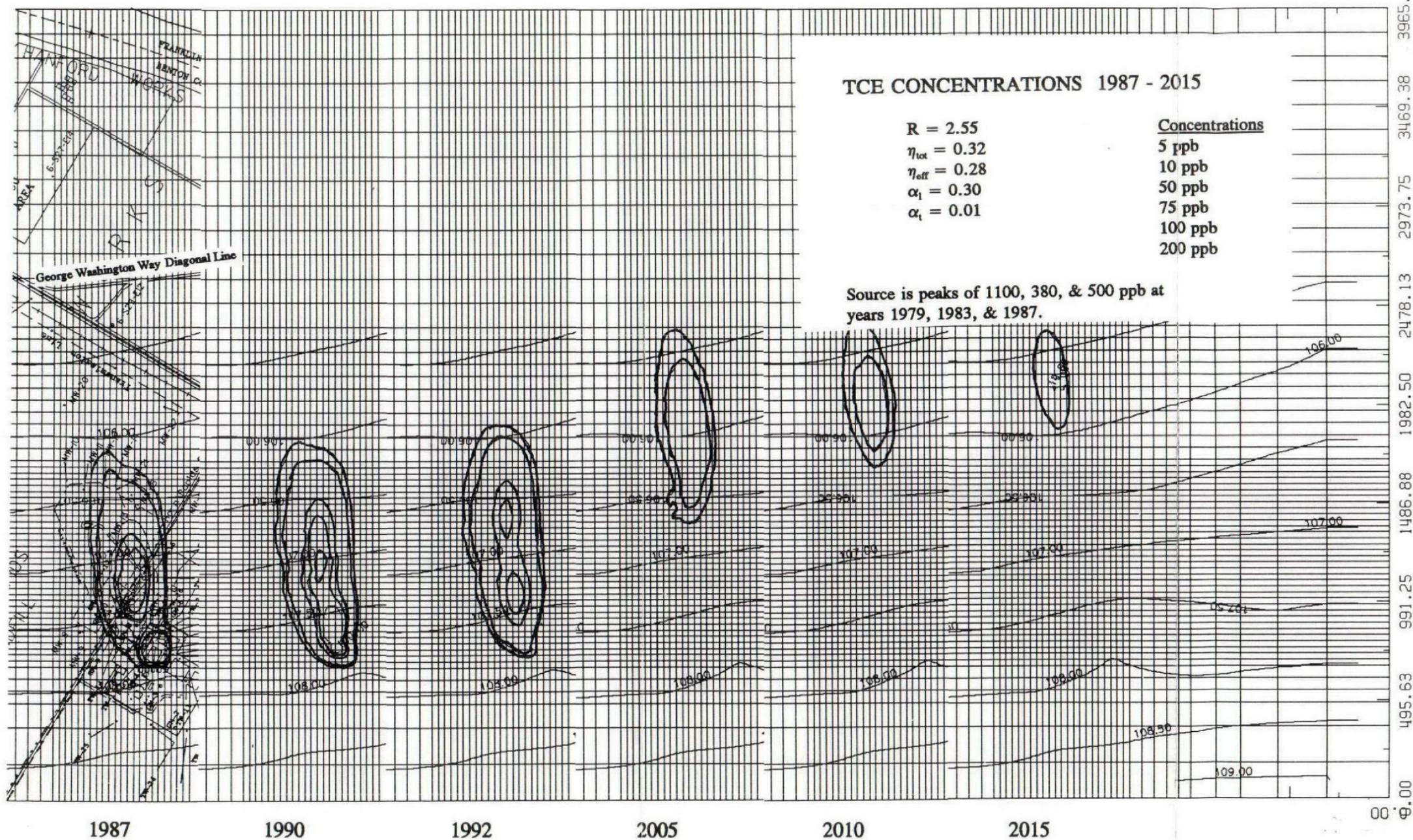


Figure 6-28(c). Calculated and Observed TCE Levels at Well TW-16 and Average of MW-13/14/15.

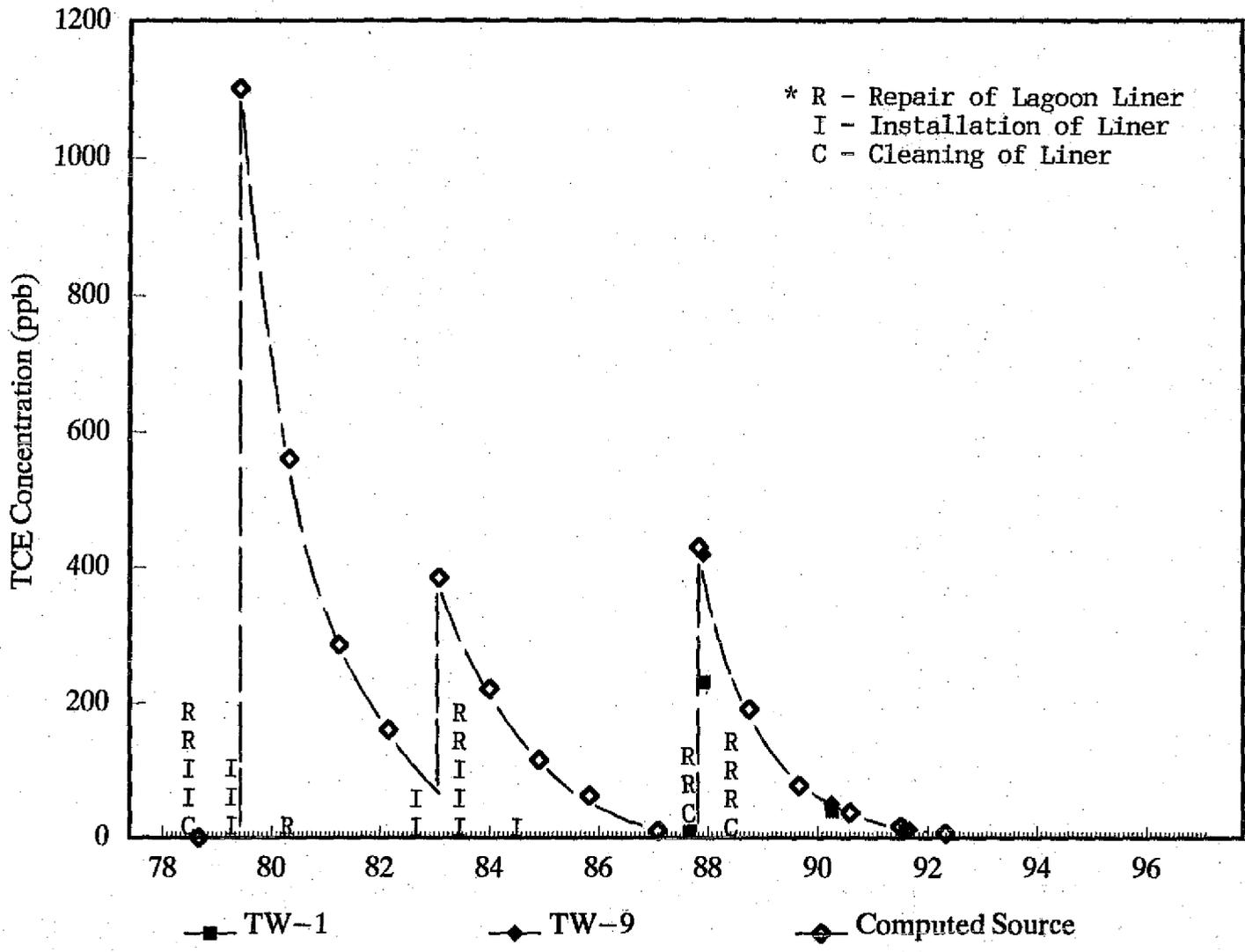
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Computed TCE Plumes with Source Peaks in 1979, 1983, and 1987. Conservative Calibration.

Figure 6-29

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Figure 6-30  
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Observed Tce Concentrations and Model Source Spikes of 1500, 380, and 420 ppb.

Figure 6-30

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The modeled source term and an estimate of the actual source amount were compared. The model used source amounts of 125 and 91 L (33 and 24 gal) for the unconservative and conservative simulations, respectively. The amount of actual source material is not documented and is not evident from the observed concentrations in the plume because of losses due to adsorption, degradation, and dispersion of TCE in concentrations below detection limits. However, an estimate of the amount of TCE in the groundwater plume was made by multiplying TCE concentration levels with their corresponding plume volumes and found to be about 57 to 83 L (15 to 22 gal) for the 1992 data (section 4.7.2).

For the purposes of determining the sensitivity of the modeled results to the contaminant transport parameters, additional simulations were made with retardation, dispersion, and porosity values stretched to more conservative degrees with results being shown in figures H-16 through H-18 in appendix H. These simulations do not match the 1987 to 1992 observed data well enough to be considered calibrated, but do demonstrate that the model results are not extremely sensitive to transport parameters. In other words, even when out-of-range porosity, retardation, and dispersivity values were used, TCE concentrations approached 5 ppb at about the same time (2015 to 2020) as the calibrated conservative simulation discussed earlier.

Reported contaminant transport values, for another groundwater modeling study involving TCE migration at the Fort Lewis, Washington site (USACE, 1990), were: retardation factor (R) of 3.0, dispersivity factors of 0.75 ( $\alpha_l$ , longitudinal) and 0.075 ( $\alpha_t$ , transverse), and porosity values ( $\eta$ ) of 0.25. These values compare fairly closely with the conservative simulation factors of  $R = 2.55$ ,  $\alpha_l = 0.30$ ,  $\alpha_t = 0.01$ , and  $\eta = 0.28$  to 0.32. Reported retardation values were assigned to the Hanford and Ringold Formations' gravel and sand deposits; the retardation for the silt layer was set at 10 because of its low hydraulic conductivity.

**6.4.5.3 Model Uncertainty.** The model is a simplified representation of a complex process (contaminant transport) in a complex setting (varied three-dimensional geology). Accordingly, uncertainty about how closely the simulations represent actual conditions is present. The model contains uncertainty from the lack of detailed definition of the following: site geology (e.g., hydrofacies boundaries), hydrofacies properties, particularly hydraulic conductivities, groundwater volume inflows and outflows, contaminant source definition, plume extent, and contaminant transport properties. The contaminant source term, although matching the period of TCE usage at SPC, was extrapolated from post-1987 data using reasonable contaminant transport parameters. Actual source amounts and timing were not known, and the source term used in the model is an approximation. Simplifications necessary to construct a PORFLOW™ model, such as using stepped horizontal layers to represent smooth inclined surfaces and the lack of a free watertable surface, also contribute to uncertainty in the results. The PORFLOW™ software also limited the lateral and vertical dispersion coefficient to a single value. This would not present a difficulty if lateral and vertical grid spacing were approximately the same. However, in this model, reasonable representation of the hydrofacies required close vertical grid spacing, and practical limitations on model size required wider lateral spacing. The result was that lateral dispersion was somewhat under-predicted in this model.

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The degree of uncertainty in the simulations cannot be easily quantified because of the complexity of the model. The sensitivity analysis provides some indication of the relative influence of the model parameters. Some parameters have a relatively narrow range, thus limiting the associated uncertainty. In the calibration process, the best estimates of site parameters were used while those with the most uncertainty were adjusted until observed site conditions were matched by the model. As a result of calibration, the model parameters were balanced relative to each other. Other combinations could potentially be found that also produce reasonable simulations of observed conditions. However, there is a limit to how much model parameters can be adjusted and still achieve calibration. When one parameter of a calibrated model is adjusted, in order to reestablish the calibration, other parameter(s) must also be adjusted to compensate. If this were done, the parameters adjusted to compensate would be moved away from their best estimates and potentially out of reasonable ranges.

This analysis dealt with the uncertainty by using the best estimates of site conditions, calibrating to observed data and, for contaminant transport, using the most conservative combination of parameters that still produced a reasonable calibration. Nevertheless, the model results contain uncertainty, particularly as a result of lacking data on the source term, plume extent, and site hydraulic conductivities.

Further sampling rounds, and the installation of monitoring wells between HRL and Stevens Drive, will allow for reduced uncertainty in future analyses.

#### 6.4.6 Model Simulation Results

The calibrated contaminant transport model was used to determine TCE persistence and migration extent for the baseline (no active remediation) and for three remediation scenarios the selection of which was determined by an optimization analysis.

**6.4.6.1 Baseline Scenario Results.** The migration of TCE was simulated using both the unconservative and conservative contaminant transport parameters with results shown in figures 6-28 and 6-29, respectively. These simulation results predict that the TCE plume will attenuate to below 5 ppb between the years 2007 and 2017 and will not cross the George Washington Way diagonal line in concentrations above 5 ppb. The maximum predicted concentration level of TCE reaching the Columbia River will be approximately 1 ppb. Other potential simulations providing results to the contrary and still matching the observed data were not found. The analysis assumed no future additional TCE source introduction.

The above results were checked in a simulation that used the conservative parameters and ran the high, average, and low river stage boundary conditions in a cyclical series. This series followed a pattern so that the average condition was used 50 percent of the time and the high and low conditions were each used 25 percent of the time. Figure 6-31 shows the time series plots for this simulation and shows that the results are similar whether or not the river boundary was set at the average river stage or allowed to fluctuate.

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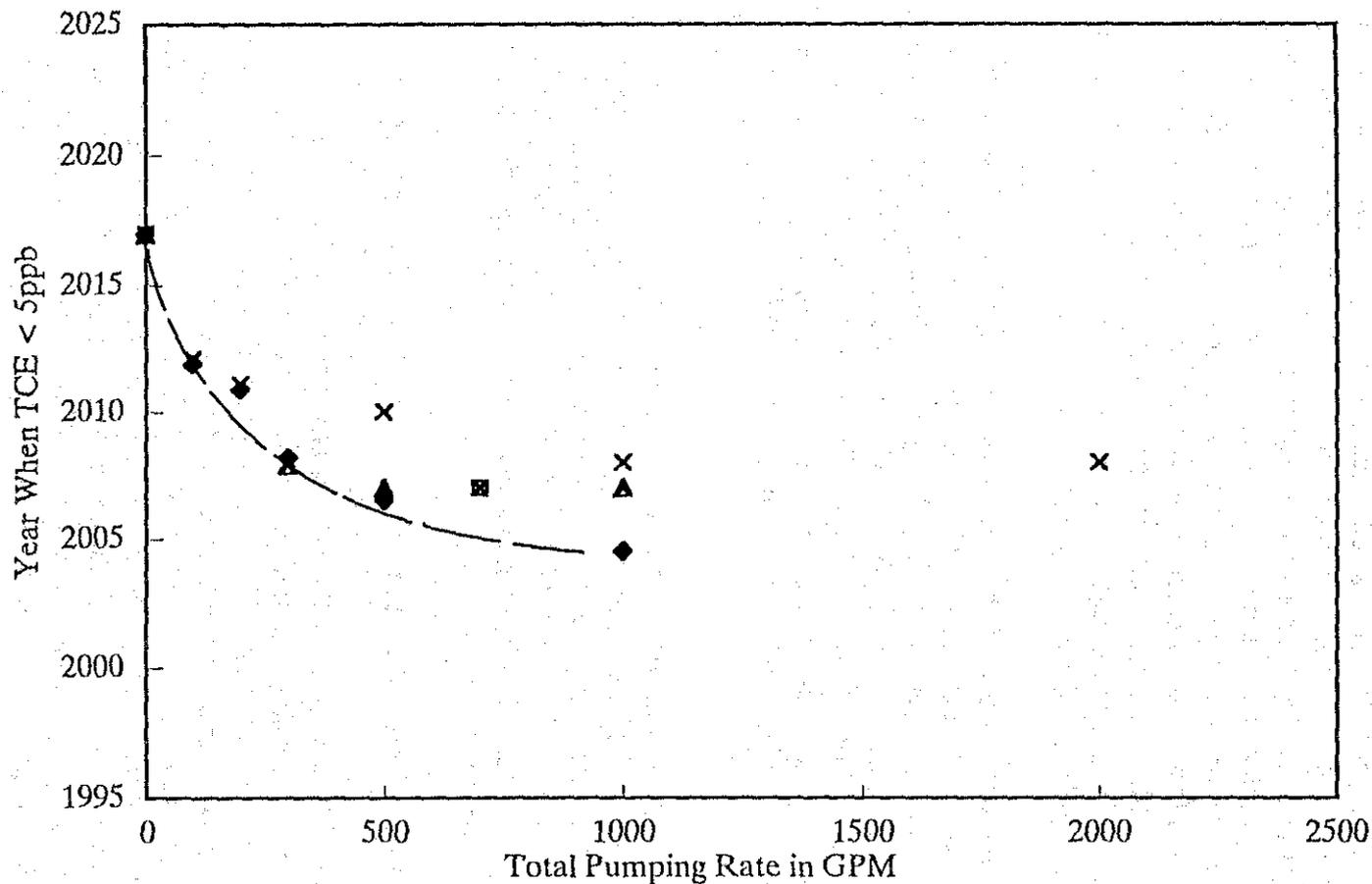


**6.4.6.2 Remediation Scenario Results.** The RI/FS study included consideration of extraction-treatment-infiltration (pump and treat or extraction-infiltration) scenarios which were the only action remediation scenarios analyzed with the model. A preliminary optimization of possible site extraction-infiltration scenarios was conducted to select a limited number of scenarios for further analysis. The results of the optimization simulations are shown in figure 6-32. The graphed data points represent the dates when maximum plume concentration dropped below 5 ppb for the pumping rates and well configurations simulated. The results predict the greatest TCE reductions with the first few wells [between 379 and 1,136 l/min (100 and 300 gal/min) total extraction rate] and decreasing reductions thereafter. Only a small amount of contaminant is reduced for total extraction rates greater than 1,894 l/min (500 gal/min). This effect occurs because the first well can be located in the most optimum place, wells added thereafter could only be placed in increasingly less effective locations. This, and effects from low permeability areas and the adsorption and desorption process, preclude a linearly effective extraction of contaminants.

Based on the preliminary optimization, three extraction-infiltration scenarios were identified for further analysis: (1) a single well system extracting 379 l/min (100 gal/min), (2) a three well, T-configuration system extracting 300 gpm, and (3) a 10 well, longitudinally linear system extracting 3,788 l/min (1000 gal/min). Figure 6-33 shows these three configurations, each being the most effective configuration for their respective extraction rates. For each, the treated water is infiltrated, in a near-surface trench, just down-gradient of the extraction wells. The model simulated extraction wells screened in the unconfined aquifer.

The effectiveness of these scenarios was evaluated in two ways: (1) using the calibrated hydraulic flow portion of the model only, the area of the aquifer captured by the extraction wells was identified and compared to the observed extent of the plume, and (2) using the calibrated flow and contaminant transport model functions, the migration of the plume, with the features of extraction of contaminated water and infiltration of clean water, was run in a time-series (transient) mode.

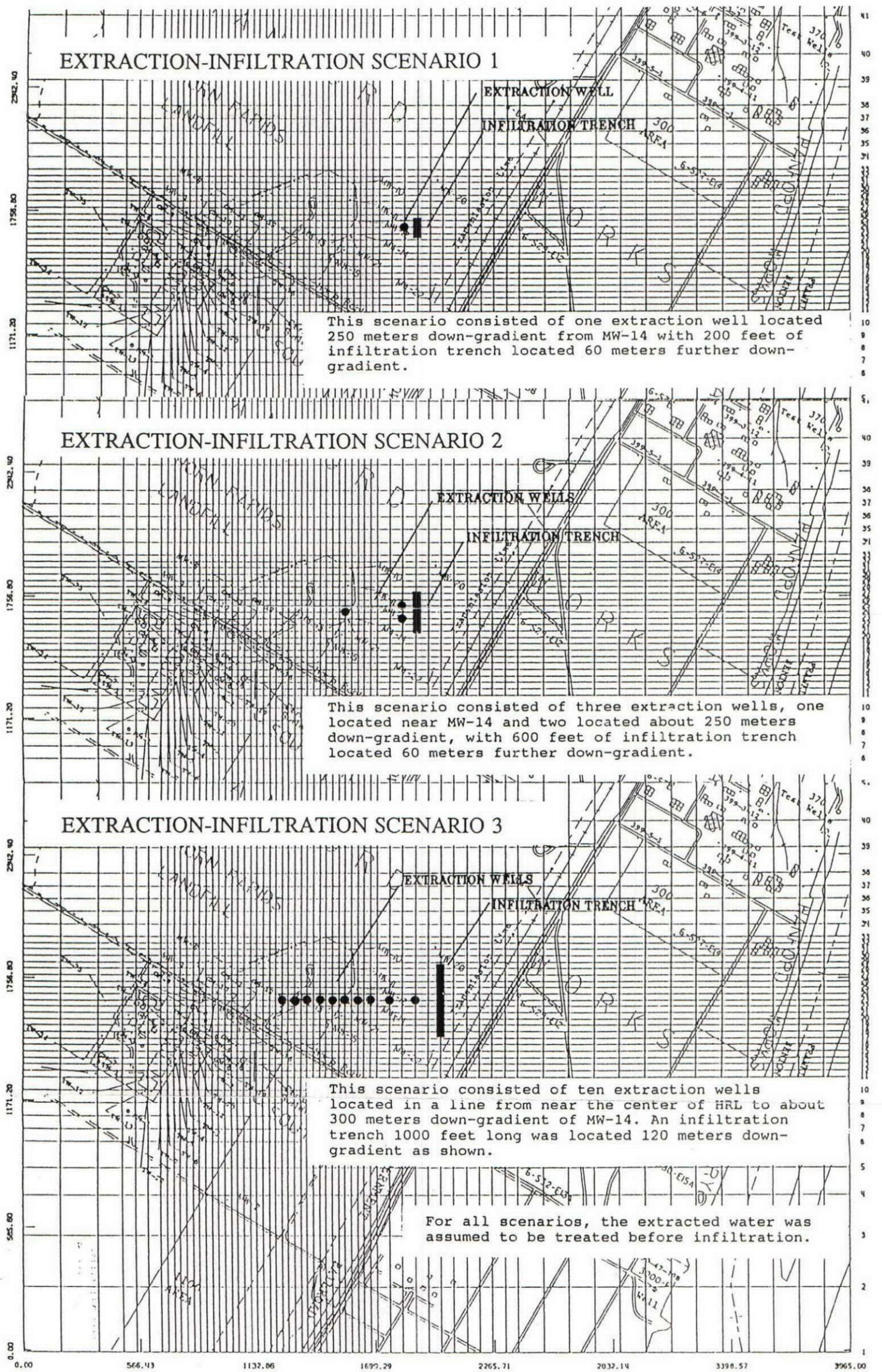
Figure 6-34 shows the predicted capture zones (shaded areas) for the three scenarios. Comparison of these zones with the 1992 TCE plume shown in figure 6-14, shows that scenario 1 would capture only the most highly concentrated portion of the plume (levels above approximately 35 ppb), scenario 2 would just capture the 5 ppb plume, and scenario 3 would capture the 5 ppb plume and about 100 percent additional water outside the 5 ppb plume. If scenario 3 were implemented and operated continually until clean-up standards were achieved, most of the water treated would be already below the TCE MCL. Likewise for scenario 2, although it captures the current 5 ppb plume almost exactly, after a few years of operation, its capture zone would also include water with below 5 ppb concentrations. From an efficiency standpoint, the optimum scenario treats the most highly concentrated portion of the plume with the untreated portion attenuating to MCL about the same time the treated portion achieves MCL. The capture zone analysis indicates that the optimum pump and treat scenario for this site would include wells extracting between 379 and 1,136 l/min (100 and 300 gal/min) (one to three wells).



- transverse line
- ◆ longit. line
- ▲ T-config.
- × T w/wells at plume front

Results of a Preliminary Extraction-Infiltration Well Configuration Optimization

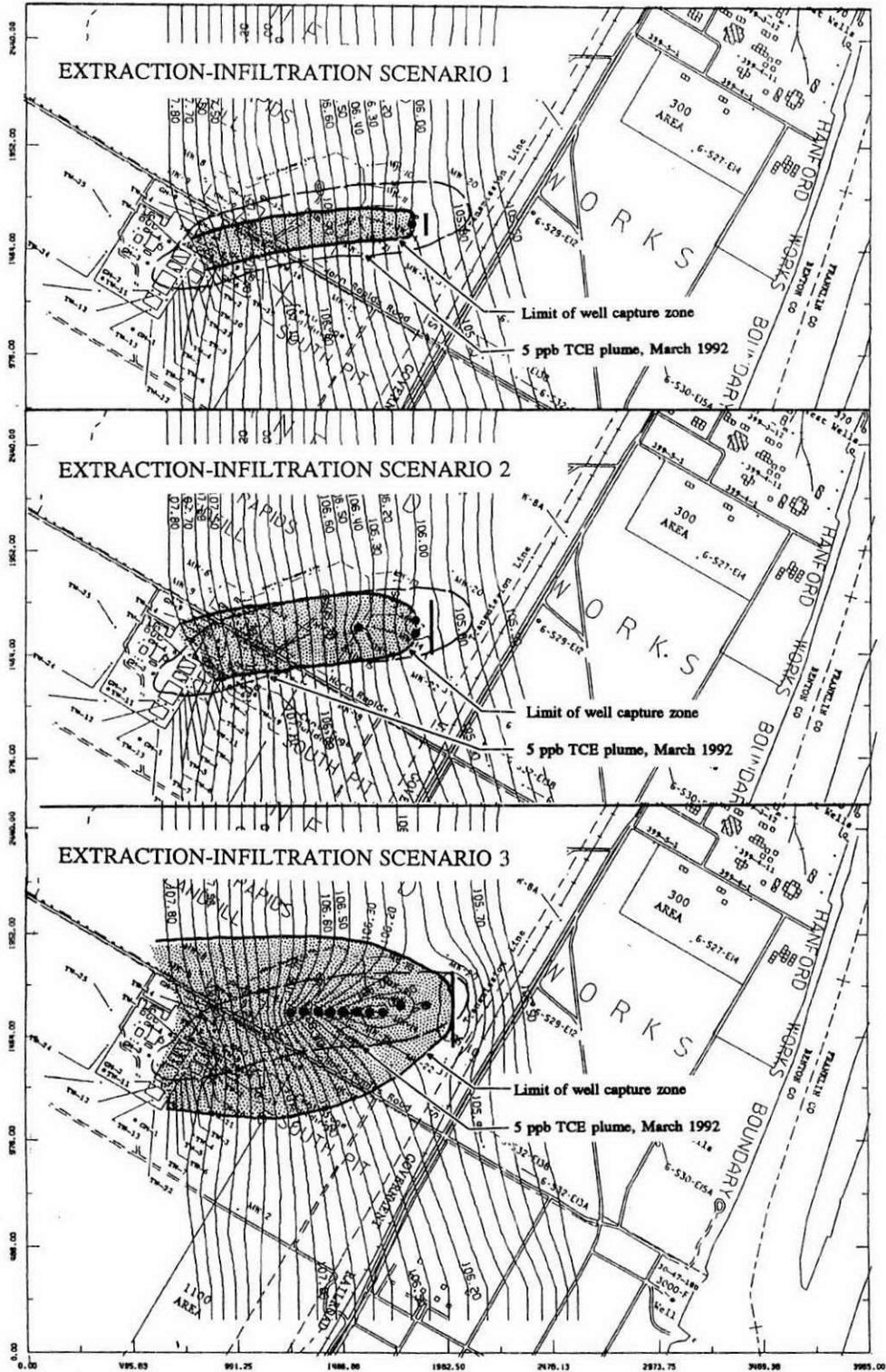
Figure 6-32.



Well Configurations for Extraction-Infiltration Scenarios 1-3.

Figure 6-33

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Well Capture Zones for Extraction-Infiltration Scenarios 1-3.

Figure 6-34

The three extraction-infiltration scenarios were also analyzed in the contaminant transport mode using the conservative parameters discussed earlier. Figures 6-35 through 6-37 show the time series results. Predicted dates when TCE concentrations are reduced to below 5 ppb are years 2012, 2008, and 2004 for scenarios 1, 2, and 3, respectively. These dates compare to the predicted baseline clean-up date of 2017 for the conservative condition. Simulations were not made using the unconservative transport parameters, but would result in earlier dates than those above. Table 6-16 lists these results for the baseline and the three pump and treat scenarios.

As discussed earlier in the sensitivity analysis section, the scenario with the largest pumping rate also has the largest uncertainty in terms of predicted aquifer response. The uncertainty results mainly from the relatively steep drawdown near the wells and from stratigraphic uncertainty. Further simulation, with finer grid mesh density near the extraction wells, is recommended if more detailed pump and treat designs, beyond the scope of this RI/FS, are desired.

A rough simulation of nitrate migration predicted nitrate attenuation to below 10 ppm before the year 2005. These results are given in appendix H and were derived using conservative transport parameters (with no retardation) and the assumption of no future nitrate source introduction. This simulation was calibrated to the observed nitrate data but had greater uncertainty than the TCE simulations because of the lack of a reasonable plume delineation and less information about the source term. Nitrate was considered a conservative solute and is subject to greater dispersion than TCE. Because of this, and because the nitrate concentrations are closer to MCL's than TCE, nitrate was predicted to attenuate to MCL's faster than TCE, both for the baseline and active remediation scenarios. However, if a remediation scenario included pump and treat for nitrate, the optimum well placement would be different than those shown in the TCE pump and treat scenarios because the two plumes do not appear to be aligned.

The results for the baseline scenario are reported as a range, and the results for the remediation scenarios are reported as expected upper limits, because of the uncertainty associated with the source terms and the contaminant transport parameters. This uncertainty was dealt with by setting the conservative condition transport parameters to their maximum limits while still matching the observed 1987 to 1992 data (*i.e.*, the conservative simulated contaminant plume was slightly more persistent than the observed plume so that predictions beyond 1992 are considered expected upper limits). Also, the simulations did not include biodegradation and volatilization losses, making the results more conservative.

Some predictions of TCE attenuation at other sites, particularly at pump and treat project sites, have been shown to be overly optimistic due to uncertainty concerning the amount of TCE available for desorption back into the groundwater. At some sites, the concentrations resulting from desorption alone leveled off above clean-up levels and are anticipated to remain so for a long time, implying long operation times and limited effectiveness of pump and treat in reaching low target concentration levels (Doty, 1991). This is not expected to be the case for this site because of the smaller TCE amount and relatively low concentration levels (50 ppb compared to 1,000 and 10,000 ppb at other sites), and a

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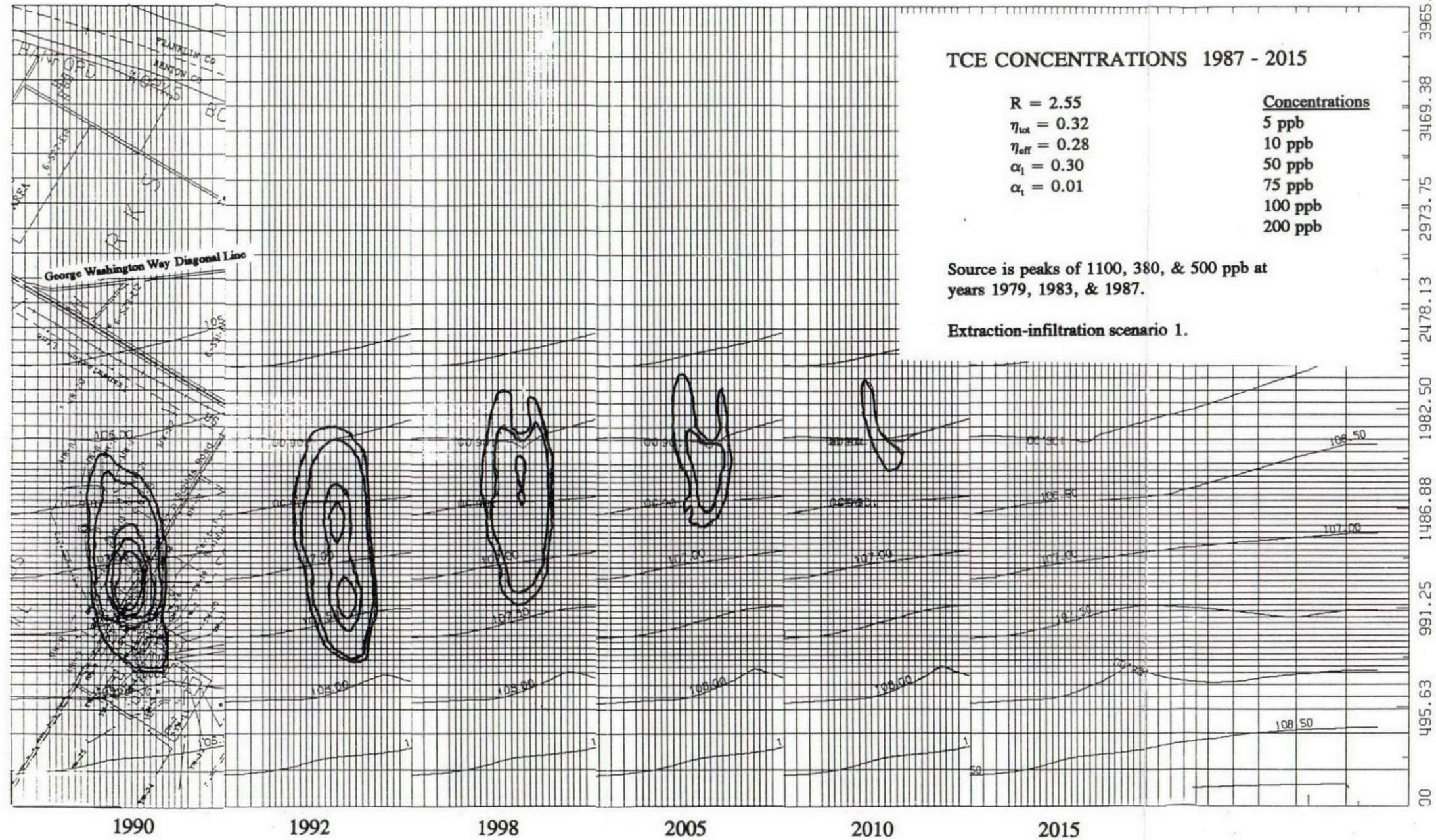
relatively rapid attenuation that does not appear to be leveling off. As discussed earlier, if current reduction rates in the MW-12 area wells were to continue, the concentrations would attenuate to 5 ppb by about the year 2000. This simple extrapolation does not account for the plume movement or the adsorption-desorption relationship over time, but does add to the credibility of the 2007 to 2017 range predicted by the model that did include these factors.

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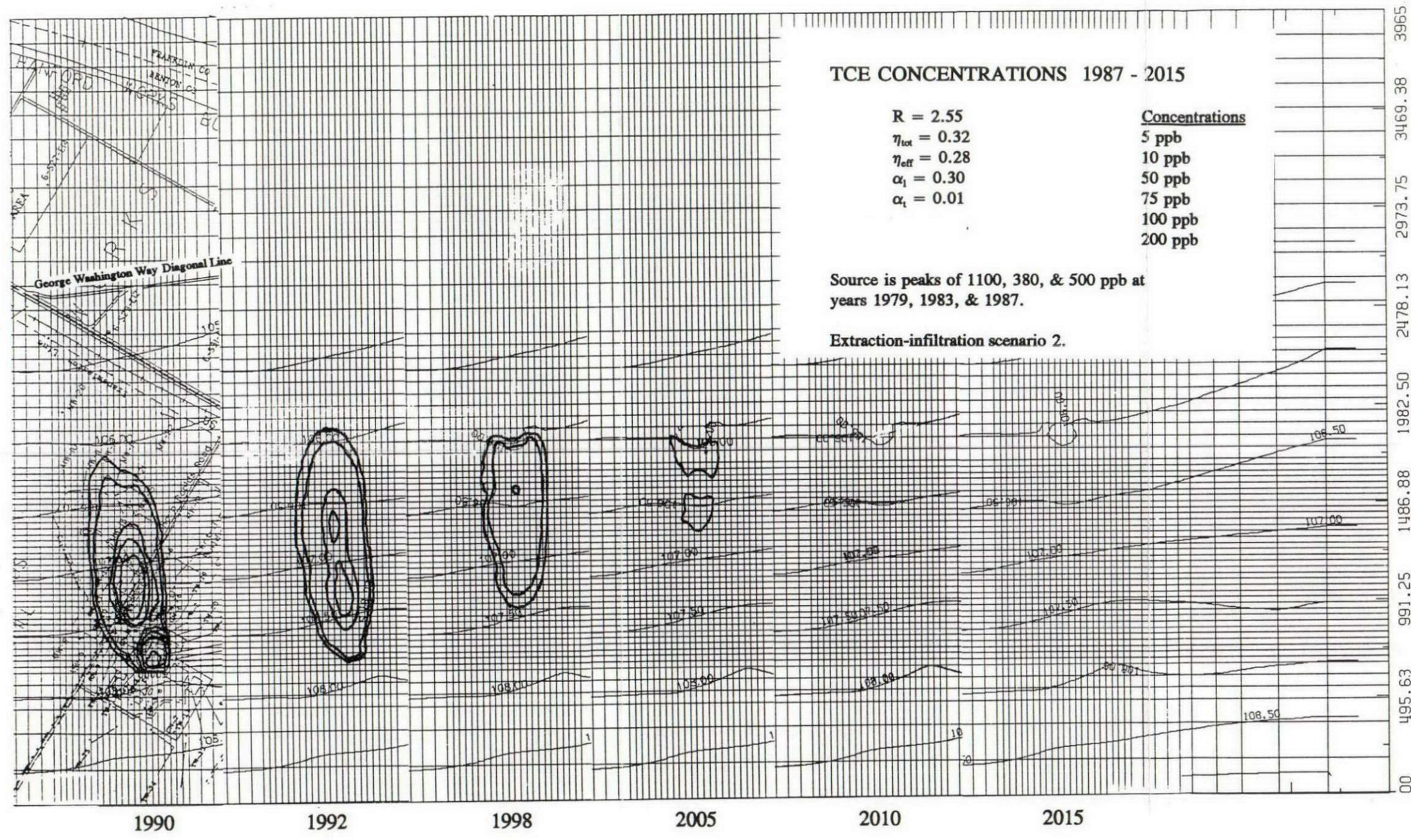
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Computed TCE Plumes for Extraction-Infiltration Scenario 1.

Figure 6-35

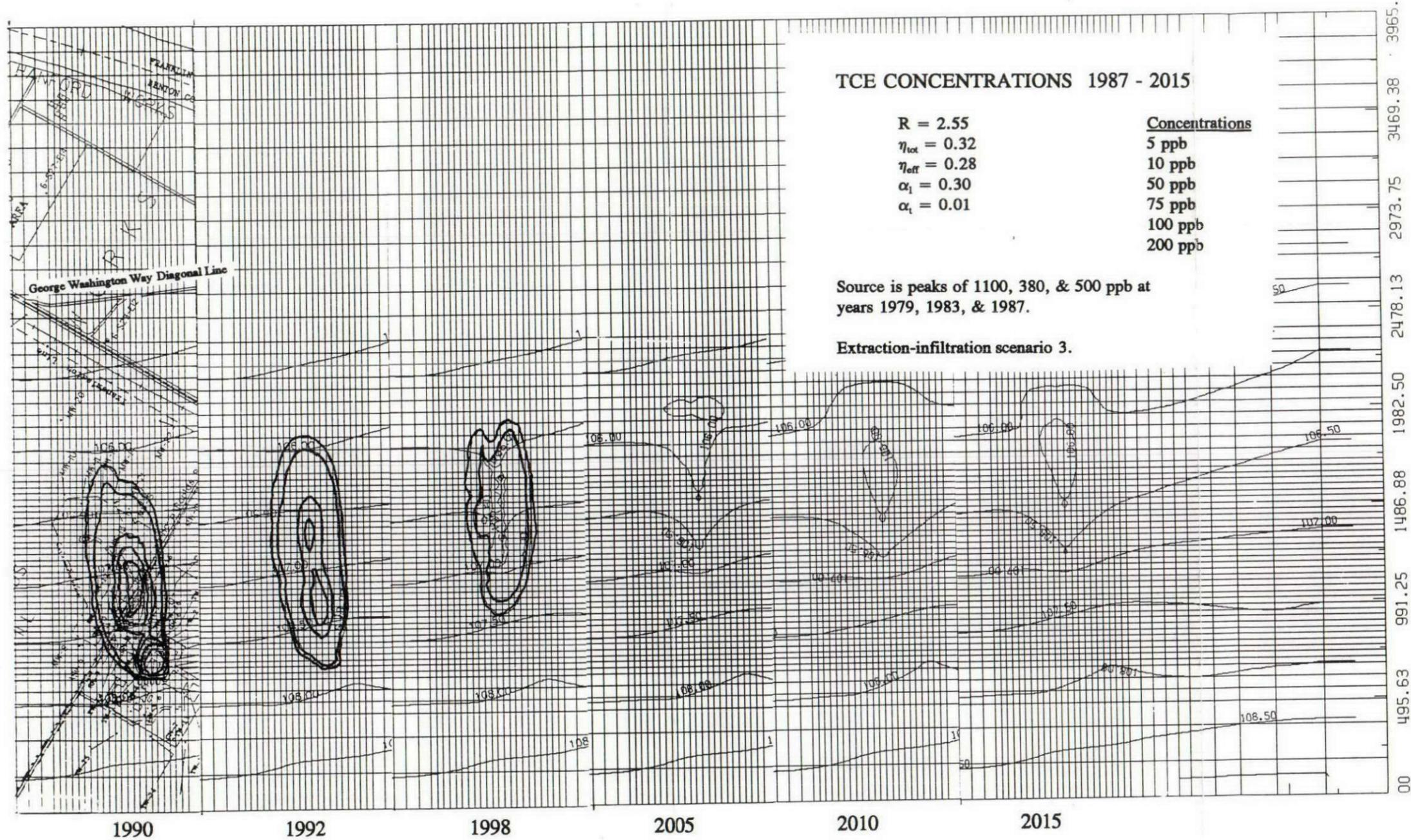
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Computed TCE Plumes for Extraction-Infiltration Scenario 2.

Figure 6-36

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Computed TCE Plumes for Extraction-Infiltration Scenario 3.

Figure 6-37

**Table 6-16. Clean-up Times and Operation Duration for the Baseline and Selected Remediation Scenarios**

	<u>Start of Operation</u>	<u>Treatment Rate, # Wells</u>	<u>Predicted End of Operation</u>	<u>Predicted Date when Conc. &lt; 5 ppb</u>
1. Baseline Scenario (no active remediation)	NA	NA	NA	2007 - 2017
2. Scenario 1	Jan 1995	100 gpm, 1	< 2012	< 2012 <sup>1</sup>
3. Scenario 2	Jan 1995	300 gpm, 3	< 2008	< 2008
4. Scenario 3	Jan 1995	1000 gpm, 10	< 2004	< 2004

<sup>1</sup> < arrow indicates that the value indicated was a result of a simulation using the conservative parameters and is a upper limit of the predicted range.

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## 7.0 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

The objectives of this section are to identify and screen a range of waste management technologies. Appropriate technologies should ensure the protection of human health and the environment and should involve the complete elimination or destruction of hazardous substances at the site, the reduction of concentrations of hazardous substances to acceptable health-based levels, prevention of exposure to hazardous substances via engineering or institutional controls, or some combination of the above. The process for identifying and screening technologies consists of six steps, which are discussed below (EPA, 1988).

1) Develop remedial action objectives (RAO's) specifying contaminants and media of interest, exposure pathways, and preliminary remediation goals. Preliminary remediation goals are based on chemical-specific ARAR's, when available, other pertinent information (e.g., carcinogenic slope factors), and site-specific, risk-related factors.

2) Develop general response actions for each medium of interest defining containment, treatment, excavation, pumping, or other actions that may be taken, singularly or in combination, to satisfy the remedial action objectives for the site.

3) Identify volumes or areas to which general response actions might be applied, taking into account the requirements for protectiveness as identified in the remedial action objectives and the chemical and physical characterization of the site.

4) Identify and screen technologies applicable to each general response action and eliminate those that cannot be technically implemented at the site.

5) To the extent possible, identify and evaluate the retained technologies and select one representative process for each technology type retained for consideration. These processes are intended to represent the broader range of process options within a general technology type.

6) Assemble the representative processes into alternatives that represent a range of treatment and containment combinations, as appropriate.

### 7.1 REMEDIAL ACTION OBJECTIVES

RAO's are site specific goals that define the extent of cleanup necessary to achieve the specified level of remediation at the site. The RAO's include preliminary remediation goals derived from ARAR's, the points of compliance, and the restoration timeframe for the remedial action. These goals are formulated to meet the overall goal of CERCLA, which is to provide protection to overall human health and the environment.

This section describes the RAO's for the 1100-EM-1 Operable Unit. Contaminants of potential concern were identified based on a statistical and risk-based screening process in site-affected media. The potential for adverse effects to human health and the environment

were initially identified in the Phase I RI report (DOE-RL-90-18), and are further evaluated in the BISRA and the BRSRA (appendix K). Findings of these assessments are summarized below. There are no contaminants that pose risks to ecological receptors that are distinguishable from the baseline conditions (section 5 and appendix L).

### 7.1.1 Land Use

A key component in the identification of RAO's is the determination of current and potential future land use at the site. The current use and long range planning by the city, county, and Hanford Site planners show the 1100-EM-1 Area as light industrial (appendix J). Area planners expect that the current land use patterns will remain unchanged as long as the Hanford Site exists. If control of the site is relinquished by the Government, land use in the vicinity of the Operable Unit would be expected to remain unchanged due to the presence of established commercial and industrial facilities that could be readily utilized by the private sector.

DOE recognizes that these long range land use plans are not predictors of long-term land use (beyond 20 to 30 years) and should not be used as predictors of land use beyond reasonable lengths of time nor for land use changes resulting from longer term events (for example, the potential excessing of 1100-EM-1 OU land after cleanup). DOE maintains that the current land use is light industrial, and will continue such use for the present and near-term future, even after the site is remediated.

DOE also recognizes that there is not universal agreement on land use for the 1100-EM-1 OU, nor for most of the Hanford site. To that end, the Hanford Future Site Users Working Group (the Working Group) was convened in April of 1992 to develop recommendations concerning the potential use of lands after cleanup. These recommendations are to be used as input into the Hanford Remedial Actions Environmental Impact Statement (HRA-EIS) which is not expected to be published until 1995 or later. The Working Group issued their report in December 1992 and proposed that the cleanup options at the 1100 Area be based on eventual non-restricted land use.

This proposal is in direct contrast with existing land use, planned land use by DOE, and current city/county land use of adjacent land which are all industrial. However, DOE views this divergence as an opportunity to implement a land use strategy at this OU which will lead to cost effective remedial alternatives protective of human health and the environment. This strategy is: (1) that contaminated sites which would exist indefinitely (beyond any reasonable time for assured institutional control) would be cleaned up for standards of unrestricted use where practicable, and (2) that institutional controls (such as land and groundwater restrictions) be implemented for sites associated with low risks where it can be shown that the contaminant would degrade or attenuate within a reasonable period of time or, for sites where contaminants would remain in place above unrestricted use cleanup goals, where it can be shown that meeting the more stringent cleanup goal is not practicable. For this OU, DOE considers that a reasonable period of time is that identified by the Working Group as "as soon as possible (by 2018)" which coincides with the TPA date for completion of cleanup actions. This time frame also approximates the upper limit of

reliability on long range land use plans which have been used by DOE to determine the near-term site use.

### 7.1.2 Chemicals and Media of Concern

Risks from soil and groundwater contaminants of concern identified in appendix K are at levels that exceed the EPA risk threshold and may, therefore, pose a potential threat to human health. The NCP requires that the overall incremental cancer risk (ICR) at a site not exceed the range of  $1E-06$  to  $1E-04$ . The State of Washington's Model Toxics Control Act (MTCA) is more stringent and requires that this risk not exceed  $1E-06$  to  $1E-05$ . For systemic toxicants or noncarcinogenic contaminants, acceptable exposure levels shall represent levels to which the human population may be exposed without adverse effect during a lifetime or part of a lifetime. This is represented by a hazard quotient (HQ). For sites in the state of Washington where the cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use is less than  $1E-045$ , and the noncarcinogenic HQ is less than 1, action generally is not warranted unless there are adverse environmental impacts. However, if MCL's or nonzero MCLG's are exceeded, action generally is warranted (EPA, 1991).

Two independent risk assessments were performed for contaminants of potential concern at the 1100-EM-1 OU. The BISRA was done to identify the risks due to the existing and perceived near-term land use at the OU. The BRSRA was done to identify potential risks at the OU due to the long-term uncertainty of future residential land use. Contaminants of potential concern (COPC) were identified through risk based screening using the maximum concentrations of the contaminants found in each subunit. Those contaminants identified as having an ICR greater than  $1E-06$  or a HQ of greater than 1 were then reevaluated using the contaminant concentration represented by the 95% UCL. A contaminant of concern (COC) was identified as one whose incremental cancer risk was still greater than  $1E-06$  or whose hazard quotient was still greater than 1 under any risk scenario using the 95% UCL.

For soils, overall risks due to exposure via inhalation, ingestion and dermal contact were calculated. The BISRA identified COC in three subunits while the BRSRA identified four subunits containing COC. These subunits and a comparison of the COC identified in each are presented in table 7-1. It should be noted that the garden produce pathway was evaluated in the BRSRA, however, site risk managers have determined that this pathway overestimates the reasonable maximum exposure and is highly conservative. Factors which influenced this decision are: 1) the uncertainty of the future land use as residential; 2) the conservative uptake factors used to estimate concentrations of contaminants in plants; and 3) the fact that actual subunit soil conditions could effect this uptake. Based on these factors this pathway was considered unreasonable and risks resulting from this exposure were not considered as a basis for risk management decisions.

TABLE 7-1. COMPARISON OF CONTAMINANT HAZARD QUOTIENTS (HQ) AND INCREMENTAL CANCER RISKS (ICR)

Operable Subunit	Contaminant	ICR Based on BISRA				ICR Based on BRSRA			
		Max Conc		95-percent UCL		Max Conc		95-percent UCL	
		HQ	ICR	HQ	ICR	HQ	ICR	HQ	ICR
1100-3	Arsenic	--	--	--	--	0.04	9E-06	--	--
UN-1100-6	BEHP	0.4	3E-05	0.3	2E-05	5.1	7E-04	3.4	4E-04
	Chlordane	0.02	4E-07	0.01	4E-07	0.3	9E-06	0.2	7E-06
Ephemeral Pool	Chlordane	0.03	6E-07	0.02	4E-07	0.4	--	0.3	--
	PCB's	--	6E-05	--	2E-05	--	1E-03	--	4E-04
HRL	Arsenic	0.006	1E-06	0.001	2E-07	0.08	2E-05	0.02	4E-06
	Beryllium	0.00007	5E-07	--	--	0.001	9E-06	0.0004	4E-06
	Chromium	0.07	3E-05	0.005	2E-06	0.9	6E-05	0.07	4E-06
	Lead <sup>1</sup>	--	--	--	--	--	ND	--	ND
	PCB's	--	1E-04	--	5E-05	--	3E-03	--	1E-03
	TCE <sup>2</sup>	--	--	--	--	--	4E-05	--	3E-05
	Nitrate <sup>2</sup>	--	--	--	--	1	--	0.8	--

<sup>1</sup> Lead was evaluated using EPA's Uptake Biokinetic (UBK) Model and was determined not to be present at levels which would cause adverse human health effects.

<sup>2</sup> Groundwater contaminants.

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The Phase II RI has confirmed the presence of groundwater contaminants at the site. These contaminants do not present any risk to human health under the current and future industrial land use scenarios for the site because: (1) downgradient users are supplied by Richland's water distribution system, and (2) the Phase I and II RI determined that the North Richland well field is not impacted by the HRL contaminant plume and is not at risk. The uncontrolled land use future uncertainty assessment using residential exposure indicates a higher risk than the industrial scenario. However, that risk (3E-05) is within the acceptable risk range established by the NCP but is higher than that prescribed by MTCA.

TCE in groundwater was calculated to have an ICR of 3E-05 for the uncertainty risk assessment. Generally, where groundwater is a potential source of drinking water, clean up requirements are set at levels which reduce the ICR to 1E-06 or to MCL's. Because of the uncertain use of the aquifer as a potential source of drinking water in the long-term future, TCE was identified as a contaminant of concern. The hazard quotient (HQ) associated with nitrate in the groundwater for the uncertainty risk assessment was calculated to be 0.8. Typically, a contaminant of concern has a HQ of 1 or greater. However, nitrate is present at levels above MCL's making it a contaminant of concern. The MCL is based on preventing methemoglobinemia through the ingestion of water containing nitrates in infants under 6 months old. Because the primary risks are to a minority of the population in the event of residential land use, which is associated with much uncertainty, site risk managers have determined that nitrate is not a risk driver at this OU. If nitrate were the lone groundwater contaminant, remedial actions addressing it would not be justified under this scenario. Nitrate in groundwater is considered a contaminant to be addressed only in conjunction with remedial actions targeted for TCE.

A summary of the chemicals and media of concern, and the risks associated with each is provided in section 5.0 of this report.

### 7.1.3 Exposure Routes

The exposure routes and receptors that may be affected by the currently identified chemicals of concern are discussed by medium in the following paragraphs.

**7.1.3.1 Soils.** Contaminants of concern are identified in surface and near-surface soils of the three subunits. Primary receptors include people with direct site access and job duties pertaining to the Discolored Soil Site, HRL, and the Ephemeral Pool. Receptors could be exposed through dermal contact, incidental ingestion, or inhalation of fugitive dust. Additional details on risk and pathway discussions can be found in appendix K.

The Phase II RI study looked at the potential for leaching of soil contaminants from the HRL soils to the aquifer. As discussed in section 4 of this report, and in further detail in sections 5.2 and 5.3 of the Phase I RI (DOE/RL-90-18), the potential for migration of inorganic or organic contaminants is minimal. In summary, this conclusion is based on the following factors: the predominantly low concentrations of contaminants in surface and subsurface soils; the infrequency of detection of the contaminants throughout the site; the low rainfall due to the desert climate; the low infiltration rate to the groundwater table identified

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in section 6 of this report [approximately between 1.04 and 3.46 cm/year (0.41 and 1.36 in/year)]; the hydrophobic nature of the organic contaminants of concern; the low solubility of the inorganic contaminants identified as contaminants of concern; depth to the groundwater table (20 to 25) feet; and the fact that no soil contaminants have been detected at elevated levels in the groundwater monitoring network at the HRL, some 20 years since its closure. Based on these facts, this pathway was not considered under existing land- and water-use conditions.

**7.1.3.2 Groundwater.** Primary exposure routes for groundwater are through the ingestion of drinking water and the inhalation of contaminants released through the household use of water. However, no known or expected groundwater users presently exist and are unlikely to be present within the next 20 years (appendix J).

#### **7.1.4 Applicable or Relevant and Appropriate Requirements**

In addition to the baseline risk assessment, section 121 of the Superfund Amendments and Reauthorization Act (SARA) provides a framework for selection of remedial actions and evaluation of cleanup standards for Superfund sites. This section of the statute sets forth the need for appropriate remedial actions, consistent with the National Oil and Hazardous Substances Pollution Contingency Plan, 40 CFR, part 300 (NCP), that provide a cost-effective response. Subsection (d) of section 121, generally requires that remedial actions attain a level or standard of control at least equivalent to ARAR's promulgated under Federal or state laws.

Identification of ARAR's is done on a site-specific basis and involves a two-part analysis: first, determining whether a given requirement is applicable; and second, if a given requirement is not applicable, determining whether it is relevant and appropriate. When the analysis determines that a requirement is relevant and appropriate, substantive compliance is the same as if it were applicable.

Applicable standards are those cleanup or control standards and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or state law that specifically address a hazardous substance, pollutant, contaminant, remedial action location, or other circumstance at a CERCLA site. Relevant and appropriate standards refer to those cleanup or control standards, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or state law that, while not applicable, address problems or situations sufficiently similar to those encountered at a CERCLA site that their use is well-suited to the particular site. Nonpromulgated advisories or guidance documents issued by Federal or state governments do not have the status of potential ARAR's. However, they are to be considered (TBC) in determining the necessary level of cleanup for protection of human health and the environment. The EPA has identified three categories of ARAR's:

- Chemical specific;
- Location specific (*e.g.*, wetland limitations or historical sites); and
- Action specific (*e.g.*, performance and design standards).

Chemical-specific requirements set health or risk-based concentration limits or ranges in various environmental media for specific hazardous substances, pollutants, or contaminants. These requirements may set protective cleanup levels for the chemicals of concern in the designated media, or may indicate an acceptable level of discharge (*e.g.*, air emission or wastewater discharge) where it occurs in a remedial activity.

There are a limited number of chemical-specific requirements; therefore, it is frequently necessary to use chemical-specific advisory levels, such as carcinogenic slope factors or reference doses (RfD's). While not ARAR's, these chemical-specific advisory levels may factor into the establishment of protective cleanup goals (EPA, 1988).

Location specific ARAR's are requirements based on the physical location, such as a floodplain, where an action may take place. Based on referenced descriptions, there are no cultural resource areas such as archaeologic and/or historic sites; no endangered or threatened species and their critical habitats; nor environmentally important natural resource areas such as floodplains, wetlands, important farmlands, and/or aquifer recharge zones in the areas evaluated for remedial actions. Therefore, potential location specific ARAR's addressing remedial actions at these sites are not pertinent.

Action specific ARAR's are requirements placed on particular remedial actions as they relate to the management of hazardous wastes. Typically these include requirements for transportation, storage, or disposal of hazardous wastes.

The ARAR's and TBC's for the operable unit are comprehensively discussed in appendix M.

### 7.1.5 Preliminary Remediation Goals (PRG's)

PRG's are goals that when achieved will both comply with ARAR's and result in residual risks that fully satisfy the NCP requirements for the protection of human health and the environment. Chemical-specific PRG's establish concentration goals for contaminants in medias of concern based on the land use at the site. For the 1100-EM-1 Operable Unit, chemical-specific PRG concentrations are determined by ARAR's. Those ARAR's include concentration levels set by Federal or state environmental regulations. PRG's for this report are either based on MCL's set under the Safe Drinking Water Act (SDWA) or clean-up levels determined under the State of Washington's Model Toxics Control Act (MTCA).

**7.1.5.1 Media Specific PRG's.** PRG's for the ingestion and dermal contact exposure pathways for contaminated operable unit soils were derived using the MTCA (WAC) 173-340. For these exposure pathways, the points of compliance for contaminated soil sites will be throughout the subunit from ground surface to a depth of 15 feet. The migration of contaminants to surface water or groundwater is not considered an operative pathway and PRG's based on these contaminant migration pathways were not calculated.

Selection of the appropriate ARAR's for the determination of these PRG's is discussed in appendix M. Consistent with DOE's land use strategy for this OU, PRG's for the Discolored Soil Site and the Ephemeral Pool are based on unrestricted future land use. This determination was based on the following practicability factors: the relatively small volume of material contaminated at each site; the availability of technologies which can attain these cleanup levels; the low risks to remedial workers when instituting these actions; and the high probability of achieving unrestricted closure. For the Discolored Soil Site, the MTCA Method B cleanup goal was determined to be 71 mg/kg for BEHP in soil. For the Ephemeral Pool, because there is only one contaminant of concern, the MTCA Method A cleanup goal of 1 mg/kg of PCB's in soil was evaluated.

MTCA Method C was used to determine the PRG of 5.2 mg/kg for PCB's at the HRL. While a consensus as to the long-term future use of the 1100 Area as a whole cannot be reached, it is very unlikely that the land use at the HRL will be anything but restricted. This judgement is based on the fact that the PCB hot spot lies within a larger area which was used as a landfill for construction debris and office wastes. The landfill contains a large volume of waste with relatively low levels of contamination. It also contains asbestos which requires management through long-term institutional controls (access restrictions and capping). Therefore, Method C was considered to be appropriate for this subunit.

The goals put forth in EPA and MTCA guidance are to return usable groundwaters to their beneficial uses in a timeframe that is reasonable given the particular circumstances of the site. PRG's for groundwater were based on the most stringent of applicable Federal or state requirements, which were determined to be SDWA MCL's. MCL's for TCE and nitrate as nitrogen are 5  $\mu\text{g}/\text{l}$  and 10 mg/l, respectively. The points or alternate points of compliance with MCL's will be as determined by EPA and Ecology. Proposed points of compliance are discussed in section 8.0 as part of the selection of alternative remedies.

Tables 7-2 and 7-3 summarize the PRG's associated with each media and exposure pathway for the contaminants of concern at each operable subunit.

**7.1.5.2 Remediation Timeframe.** Soil and groundwater remediation will generally be accomplished in timeframes that are appropriate for the risks associated with the site. Promising innovative technologies may require a longer timeframe to implement than more proven technologies. However, because the immediate site risk is low, innovative technologies were not screened out on this basis alone. The overall goal is to select a remediation alternative that will both be effective and that can be implemented in a reasonable timeframe given the particular circumstances.

**TABLE 7-2. RESIDUAL RISKS ASSOCIATED WITH SOIL PRG'S**

Operable Subunit	Contaminant	PRG Conc (mg/kg)	Soil Ingestion		Fugitive Dust		Dermal Exposure		Contaminant Totals		Subunit Totals	
			HQ	Risk	HQ	Risk	HQ	Risk	HQ	Risk	HQ	Risk
UN-1100-6 Discolored Soil Site <sup>1</sup>	BEHP	71 <sup>2</sup>	0.013	2E-06	--	2E-09	0.002	2E-07	0.015	2E-06	0.015	2E-06
Ephemeral Pool <sup>1</sup>	PCB's	1 <sup>3</sup>	--	1E-05	--	4E-08	--	2E-05	--	3E-05	--	3E-05
HRL	PCB's	5.2 <sup>4</sup>	--	4E-06	--	3E-07	--	4E-06	--	8E-06	--	8E-06
Maximum Site Risks										0.015	3E-05	

<sup>1</sup> Residual risk associated with residential scenario.  
<sup>2</sup> PRG for subsurface soils based on MTCA Method B.  
<sup>3</sup> PRG for subsurface soils based on MTCA Method A Table.  
<sup>4</sup> PRG for subsurface soils based MTCA Method C.

**TABLE 7-3. RESIDUAL RISKS ASSOCIATED WITH GROUNDWATER PRG'S (RESIDENTIAL SCENARIO)<sup>1</sup>**

Operable Subunit	Contaminant	PRG Conc (mg/l)	Water Ingestion		Inhalation of Household Release		Dermal Exposure		Contaminant Totals		Subunit Totals	
			HQ	Risk	HQ	Risk	HQ	Risk	HQ	Risk	HQ	Risk
Site-wide Groundwater	TCE	0.005	--	6E-07	--	1E-06	--	--	--	2E-06		
	Nitrate	10	0.17	--	--	--	--	--	0.17	--	0.17	2E-06
Site Totals										.17	2E-06	

<sup>1</sup> PRG's for groundwater are based on SDWA MCL's.

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### 7.1.6 Soil RAO's

RAO's have been identified for the contaminated near surface and subsurface soils at the Discolored Soil Site, the Ephemeral Pool, and HRL based on detected concentrations of chemicals of concern exceeding ARAR's. All RAO's shall minimize exposure to contaminated soils during remediation. These specific operable unit RAO's are:

- **UN-1100-6 Subunit (Discolored Soil Site)**

- a. Prevent the ingestion of and dermal contact with soils having BEHP concentrations greater than the MTCA B cleanup level of 71 mg/kg.
- b. For remedial actions that leave any contaminant in place above MTCA B levels, provide adequate institutional controls to monitor the site after remediation and to prevent potential future receptor exposure to contaminants.

- **Ephemeral Pool**

- a. Prevent the ingestion of and dermal contact with soils having PCB concentrations greater than the MTCA A cleanup level of 1 mg/kg.
- b. For remedial actions that leave any contaminant in place above MTCA A levels, provide adequate institutional controls to monitor the site after remediation and to prevent potential future receptor exposure to contaminants.

- **HRL**

- a. Prevent soil ingestion of and dermal contact with soils having PCB's at concentrations greater than the MTCA C cleanup level of 5.2 mg/kg.
- b. Prevent inhalation of fugitive dust from soils that may contain asbestos fibers.
- c. For remedial actions that leave any contaminant in place above MTCA C levels, provide adequate institutional controls to monitor the site after remediation and to prevent future receptor exposure to contaminants.

### 7.1.7 Groundwater RAO's

For the contaminated groundwater, the following RAO's based on chemical-specific ARAR's are identified.

- a. Minimize exposure to contaminated groundwater through existing institutional controls and the use of the domestic water supply system.

b. Attain the SDWA MCL of 5  $\mu\text{g/l}$  for TCE at the designated point of compliance. The point of compliance is to be defined by EPA and Ecology. Monitoring for compliance will be performed at the defined point.

c. Protect environmental receptors in surface waters by reducing groundwater contaminant concentrations in the plume to levels that are safe for biological and human receptors that may be affected at the groundwater discharge point to the Columbia River.

### 7.1.8 Residual Risks Post-Achievement of PRG's

Residual risks after meeting PRG's were calculated based on the uncertain residential land use scenario for soils at the Discolored Soil Site and the Ephemeral Pool, and the industrial land use scenario for soils at the HRL. The uncertain residential land use scenario was used to determine residual risks for groundwater. These risks are presented in tables 7-2 and 7-3. Site risks from contaminated soils are reduced from 4E-04 to 2E-06, 4E-05 to 3E-05, and 5E-05 to 8E-06, for 99.5, 92.5, and 84-percent reductions in incremental cancer risk at the Discolored Soil Site, the Ephemeral Pool, and HRL, respectively. Groundwater residual risks were calculated using the uncertain residential scenario. For nitrates, remediation to the PRG gives a hazard quotient of 0.17 compared to a 95-percent UCL based hazard quotient of 0.8. For TCE, the total incremental cancer risk due to inhalation and ingestion is reduced from 3E-05 based on the 95-percent UCL to 2E-06 for a 93-percent reduction in risk.

Not included in these are the potential risks to human health and the environment associated with remedial activities at the site. An example would be the remediation of any soils within the HRL. Because there is a significant presence of asbestos in landfill soils, fugitive dust poses a health threat to remedial workers. Any activities conducted must include the suppression of fugitive dust.

## 7.2 GENERAL RESPONSE ACTIONS

These paragraphs describe general response actions that satisfy the remedial action objectives, with a range of response actions presented for soil and groundwater contamination. These response actions should ensure the protection of human health and the environment, maintain protection over time, and minimize untreated waste (40 CFR 300). Each general response action, with appropriate technology and process options, is more fully evaluated in paragraph 7.3 and section 8.0. The following paragraphs describe the general response actions, and include identification of areas and volumes of contaminated soils and groundwater.

### 7.2.1 Areal Extent and Volume of Contaminated Media

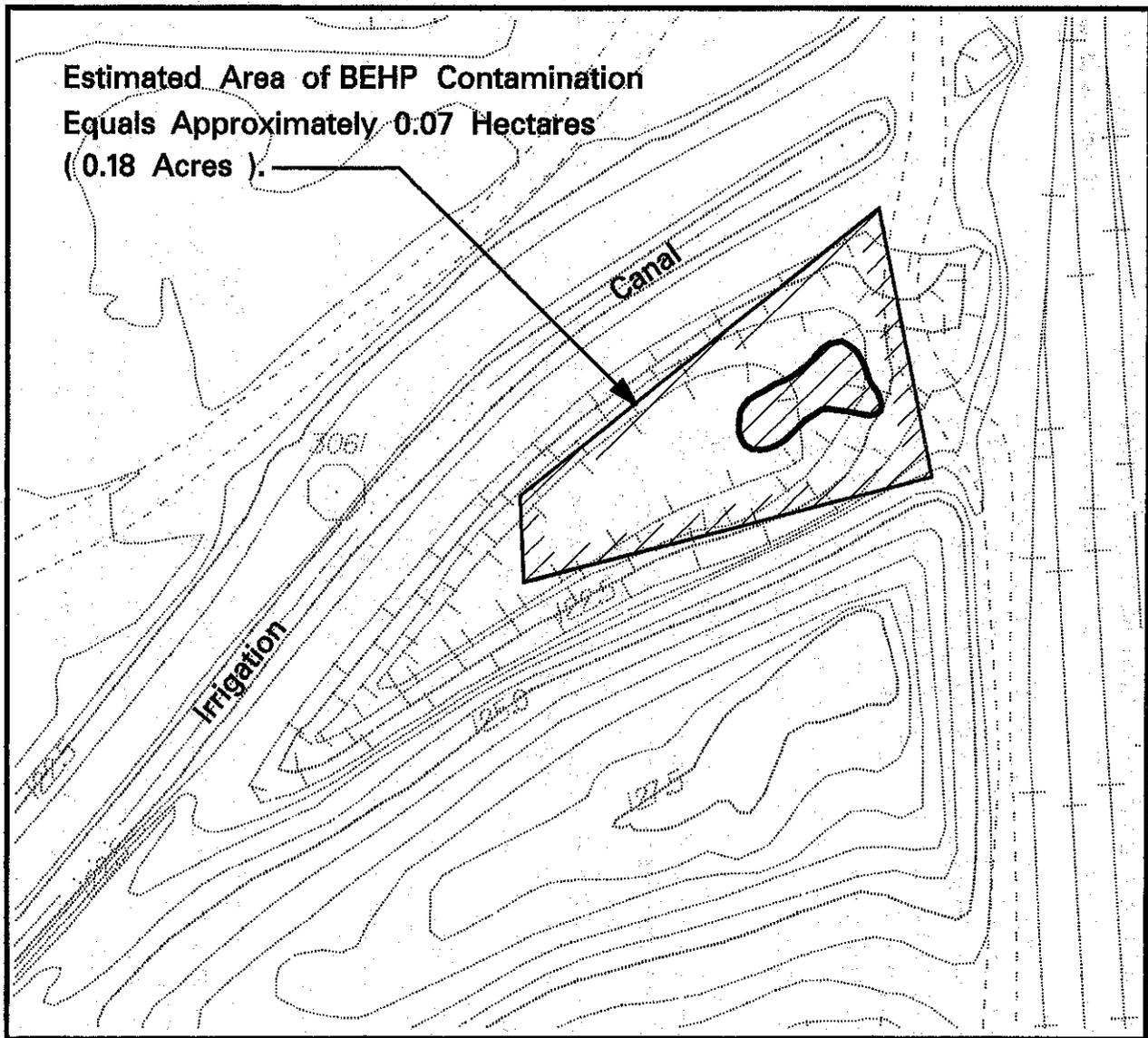
The areal extent and volumes of contaminated soil, and the areal extent of and the volume of contaminant in groundwater are estimated in the following sections. In the case of soils, estimates are based on the results of Phase I and II RI soil sampling. It should be noted that there is a significant amount of uncertainty in any volume calculation which relies on limited soil sampling results. Further compounding the uncertainty at this operable unit is the fact that the majority of samples taken were surface samples; there is very little information concerning the depth of the contaminants. However, because of the insoluble nature of the contaminants of concern and their presumed origin, contamination is expected to be confined to near surface soils. The areal extent of contamination at all subunits used in the following estimates were conservatively assumed by either setting the boundaries of the contaminated areas at sample locations at which no contaminant was detected, or by extrapolating from sample locations at which contaminants were detected to points at which the level of contamination was presumed to be zero. For groundwater, the estimates are based on modelling results that used Phase I and II RI groundwater sampling results as input.

**7.2.1.1 Extent and Volume of Soil Contamination.** Soil contamination is believed to be restricted to surface and near surface soils. As discussed in section 4.0, the origin of the BEHP at the Discolored Soil Site appears to be the result of one, and possibly several, incidents where containers of liquid organic material were dumped onto the ground. The origin of the PCB contamination at the Ephemeral Pool is unknown. The PCB contamination at HRL is believed to have originated either as a release of hydraulic fluid from heavy machinery or from an incident where containers of liquids containing PCB's were dumped. The extent and volume of these contaminated areas are estimated as follows:

- UN-1100-6 subunit (Discolored Soil Site)--A grid was established and 15 soil samples were taken at this site (samples A6141S through A6155S on figure 4-3). Of these, BEHP was only detected in samples A6150S through A6155S. These sample locations are within or in close proximity to the area of the soil discoloration. Because of the transport mechanisms of BEHP (section 6.0), the soil contamination is believed to be confined to this area. A conservative estimate of the areal extent of the contamination is made by considering the contaminated area to be bounded by the sample points, which did not detect any BEHP. This area is shown in figure 7-1 and measures 0.07 hectares (0.18 acres). The depth to which discolored soils can be distinguished is less than 0.25 m (10 in). Since BEHP is strongly sorbed to soils, the depth of contamination is not anticipated to extend much past this point. Contamination is conservatively assumed to extend from the surface to a depth of 0.46 m (1.5 ft). The volume of contaminated material is thus calculated to be 340 m<sup>3</sup> (440 yd<sup>3</sup>).

- Ephemeral Pool--Six surface soil samples were taken during the Phase II RI along the bottom of the surface depression that constitutes the Ephemeral Pool (figure 4-7). PCB's contamination was detected at only two of these locations (E2 and E3). Because no PCB's contamination was detected at location E4, it is used as the southern most boundary of the contaminated area. The northern boundary of the contamination is chosen as the point in the depression that is equal in elevation to that of E4, which is 122.4 m (401.5 ft) amsl.

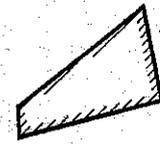
**LEGEND :**



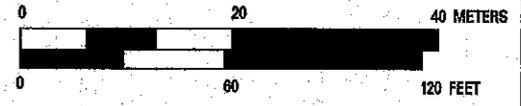
Estimated Area of BEHP Contamination  
 Equals Approximately 0.07 Hectares  
 (0.18 Acres).



Approximate Area of  
 Soil Discoloration.



Estimated Area of  
 BEHP Contamination.



Estimated Area of BEHP Contamination at the  
 UN - 1100 - 6 Operable Unit.

Figure 7-1

This point was chosen because, under the worst case scenario, it is hypothesized that a pool of PCB contaminated liquid with a uniform surface elevation may have existed. This area is depicted in figure 7-2 and averages 7.1 m (20 ft) in width and is 93 m (305 ft) long. The depth of contamination is assumed to be shallow as the PCB's should be confined to the fine sediments. Contamination is assumed to extend from the surface to a depth of 0.46 m (1.5 ft). The volume of contaminated soils associated with this site is 250 m<sup>3</sup> (340 yd<sup>3</sup>).

- HRL--HRL was investigated in both the Phase I and Phase II RI's. These investigations are summarized in section 3.0. Sampling concentrated on areas of the landfill known to have been actively used. Because access to the landfill was uncontrolled, it is difficult to determine what other areas may have been used. As a result of this unknown, the active area of the landfill is assumed to be bounded by physically undisturbed topological features. The outline of this area is shown in figure 7-3 and the area calculated by planimetry is approximately 10.1 hectares (25 acres). The exception is the southwest portion of the site that appears to have been used as a source of borrow material. Soil sampling in this area gave no indication of contamination that is distinguishable from background.

Only one contaminant, PCB, is present at levels that may pose a risk to human health. The PCB's are concentrated around boring HRL-4 (figures 7-3 and 7-4) from which samples were analyzed during the Phase I RI. PCB's (> 1 mg/kg) were detected in soils from the surface to a depth of 0.85 m (2.8 ft). Very small concentrations (< 1 mg/kg) of PCB's were detected in two samples at depths greater than 1.52 m (5 ft). Additional surface and near surface samples were taken during two separate soil sampling events during the Phase II RI (figure 4-24) in an effort to delineate the areal extent of the contamination. All samples were taken within an area approximated by a 8.5 m by 8.5 m (28 ft) square centered around HRL-4. Samples taken during the last sampling event, at the vertices of this square, contained detectable concentrations of PCB's. In order to determine the approximate areal extent of the contamination, straight line extrapolations were made from the presumed center of the boring, along the diagonals of the sampled area, to a point where PCB concentrations would be zero. Using the most conservative of these extrapolations, the contaminated area is estimated to be bounded by a 17.3 m by 17.3 m (57.75 ft) square centered around HRL-4. Using 1.52 m (5 ft) as the depth of the contamination gives a volume of 460 m<sup>3</sup> (600 yd<sup>3</sup>).

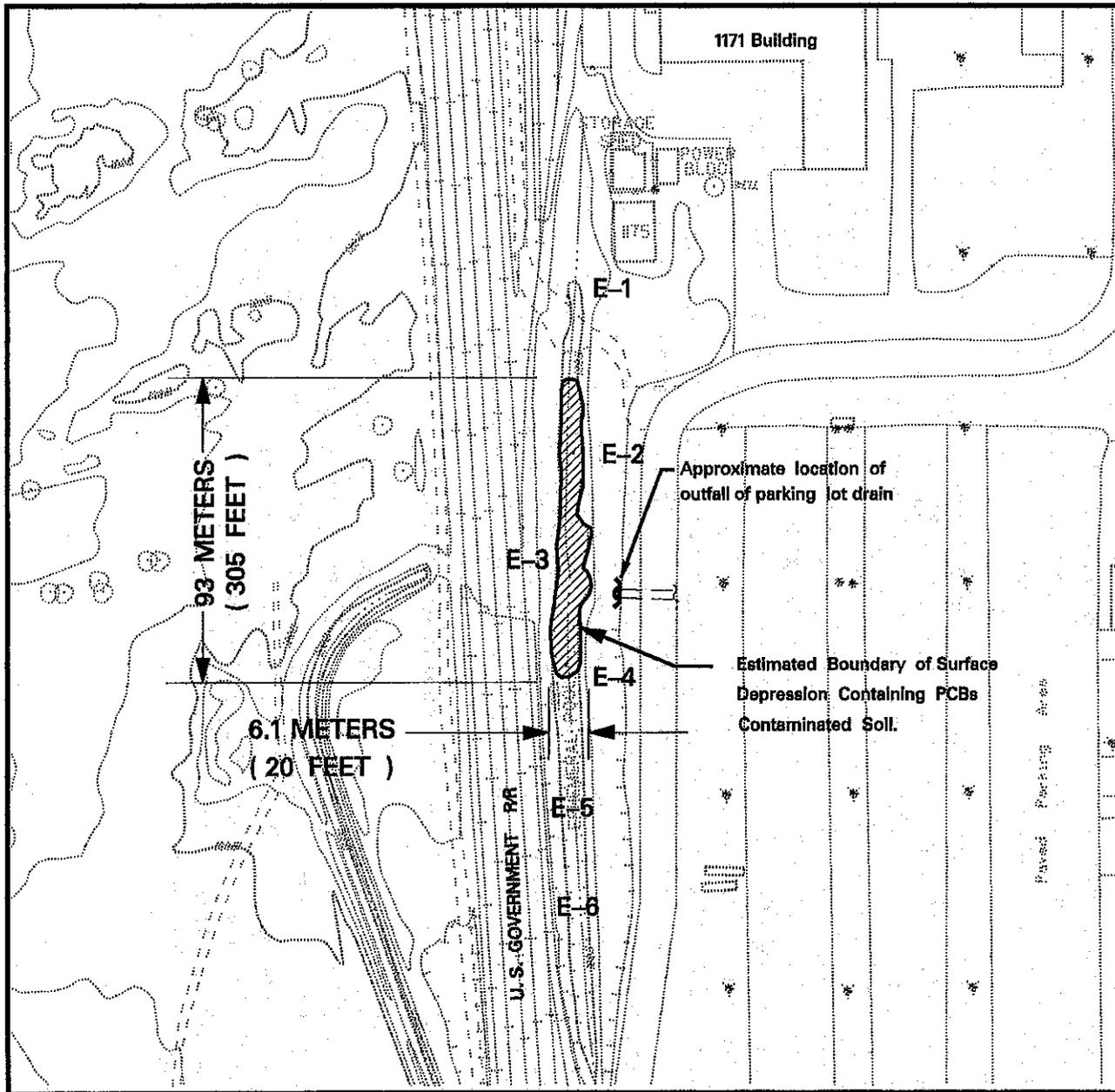
### 7.2.2. Extent and Volume of Groundwater Contamination

The source of groundwater contamination at and downgradient of the HRL is believed to have originated from activities conducted offsite. The present length and width of the TCE plume is 1.6 km (1 mi) and 0.3 km (0.2 mi), respectively. The estimated volume of TCE in groundwater is 75-115 L (20-30 gal). This volume does not account for the amount of TCE which may be adsorbed onto saturated zone soils. The length of the nitrate plume is 2 km (1.3 mi) and its width is 0.8 km (0.5 mi). The TCE and nitrate plumes are shown in figure 6-12 of section 6.0.

LEGEND :

E-2 Soil Sampling Location and Number.

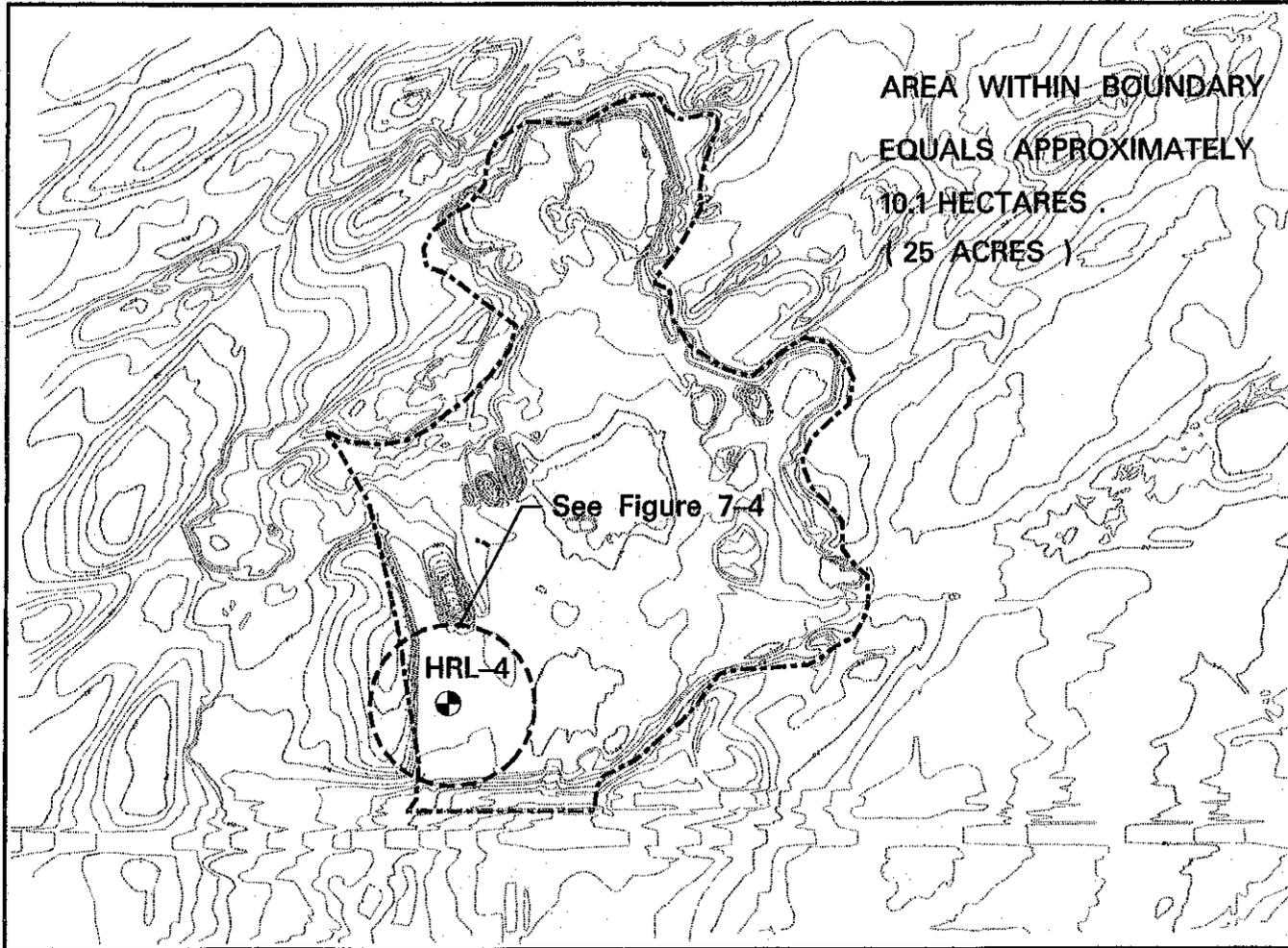
Estimated Area of PCBs Contamination.



Estimated Area of PCBs Contamination at the Ephemeral Pool Operable Subunit.

Figure 7-2

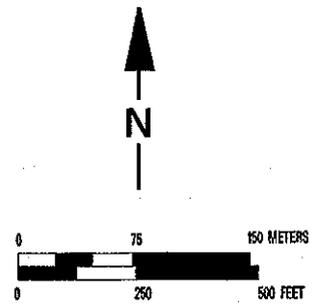
9 3 1 2 9 3 3 0 3 9 5



**LEGEND :**

HRL-4  
 Location and Designation of Borehole.

 Horn Rapids Landfill Boundary of Actively Used Area. ( Estimated )



Contour Interval is 0.5 meter.

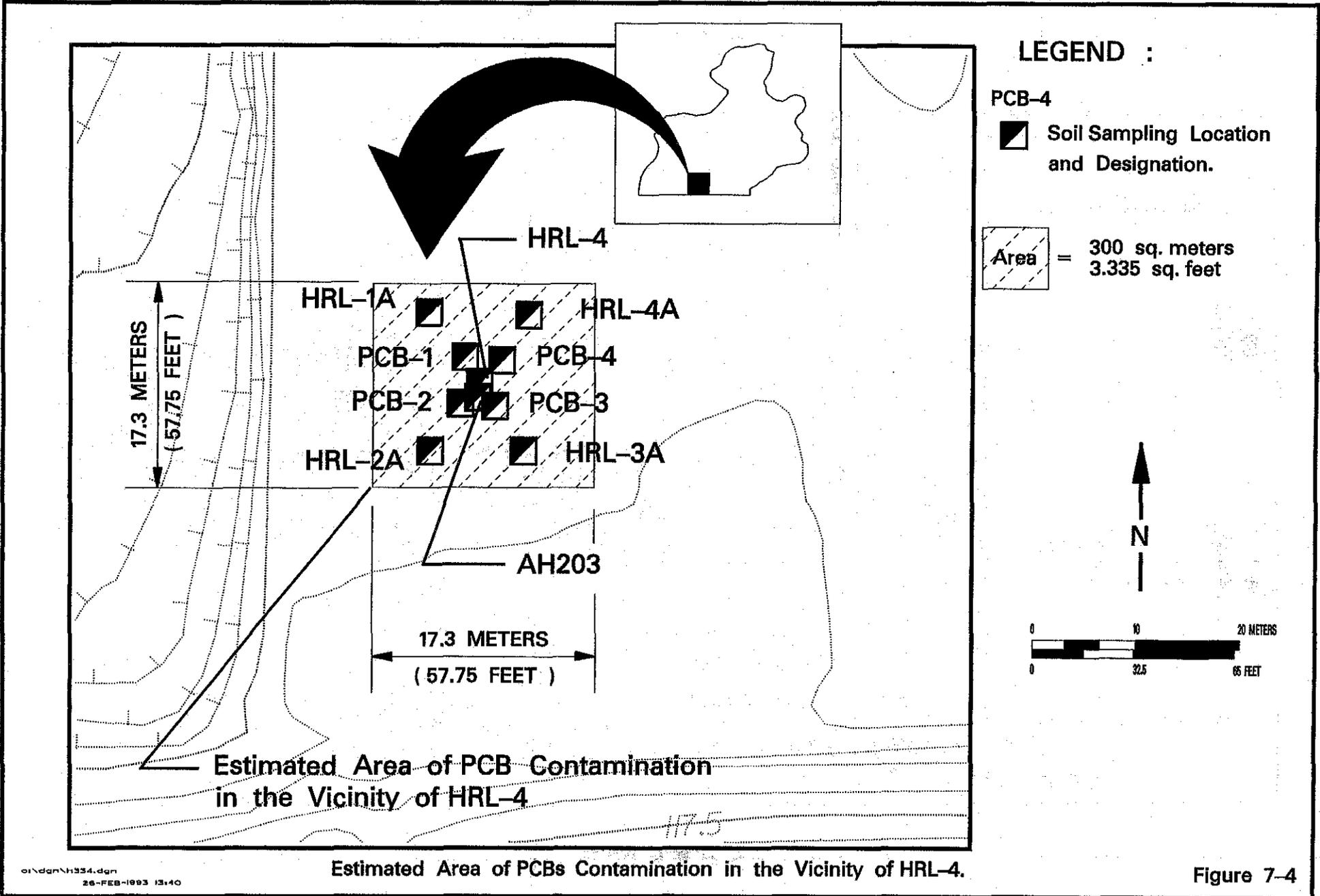
Estimated Boundary of the Actively Used Area of the Horn Rapids Landfill Operable Subunit.

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Estimated Area of PCBs Contamination in the Vicinity of HRL-4.

Figure 7-4

### 7.2.3 General Response Actions for Soils and Groundwater

General response actions for soils and groundwater are classes of actions that will satisfy either one or more of the remedial action objectives described in paragraph 7.1. Appropriate response actions include no action, institutional controls, containment, excavation/treatment/disposal for soils, extraction/treatment/discharge for groundwater, and in-situ treatment, all of which may be used alone or in combination. General response actions have been determined for the Discolored Soil Site, the Ephemeral Pool, HRL, and the groundwater beneath the HRL, and are discussed in paragraphs 7.2.3.1 through 7.2.3.6.

**7.2.3.1 No Action.** This alternative is required by the NCP and has been retained for baseline comparison with other alternatives. Because no remedial activities would be implemented, long-term human health and environmental risk for the site would be those identified in the baseline risk assessments (appendixes K and L).

**7.2.3.2 Institutional Controls.** Institutional controls include fencing, posting of signs, land-use restrictions, and other controls that restrict future access to, and use of, contaminated soils and groundwater. Continued monitoring of air and groundwater quality would also be implemented to assess the migration of contaminants offsite.

**7.2.3.3 Containment.** Containment actions usually involve capping contaminated soils with a protective barrier, such as clay, concrete, or plastic liners, or isolating contaminated soils by placing an in-situ barrier, such as a bentonite slurry wall. These barriers limit infiltration, prevent plants and animals from being exposed to contaminated soils, prevent fugitive dust, and provide long-term stability with relatively low maintenance requirements.

Containment options for groundwater prevent the further migration of contaminants offsite. Typically, this is achieved through the use of vertical barriers such as a bentonite slurry wall or by controlling the hydraulic gradient using a series of extraction and injection wells. Impervious caps are also sometimes used to prevent infiltration and aquifer recharge.

**7.2.3.4 Excavation/Treatment/Disposal for Soils.** Excavation/treatment/disposal actions include excavation and disposal of untreated soils at an offsite landfill; excavation, offsite contaminant destruction, immobilization, or other treatment, and disposal at an offsite landfill; and excavation, onsite contaminant destruction, immobilization, or other treatment, and onsite disposal. Typical treatment options include biological landfarming, thermal processing, soils washing/dechlorination, and stabilization/fixation.

**7.2.3.5 Extraction/Treatment/Disposal for Groundwater.** Extraction wells are used to collect contaminated groundwater for treatment. Treatment options consist of physical, chemical, and biological processes. Physical treatment processes include carbon adsorption, air stripping, and reverse osmosis. Chemical oxidation, ultraviolet radiation, irradiation, and ion exchange are several of the chemical processes. The use of aerobic and/or anaerobic bacteria to degrade the contaminants are the basis of biological processes. Treated groundwater is discharged either back into the aquifer through injector wells or discharge trenches, to storm or sanitary sewers, or directly to surface waters.

**7.2.3.6 In-Situ Treatment.** In-situ technology types can include biological, chemical, physical, and thermal processes. In-situ treatment for soil includes aerobic or anaerobic biological processes, surfactant soils washing, vapor extraction, chemical oxidation, radio-frequency heating, stabilization/fixation, and in-situ vitrification. These treatments attempt to either destroy, immobilize, physically remove or chemically alter the contaminant(s) to minimize harmful impacts to the groundwater or surface environment.

For groundwater, in-situ treatment includes aerobic or anaerobic biological processes, aeration, heating, and chemical oxidation or reduction. These treatments attempt to destroy, physically remove, or chemically alter the groundwater to minimize the potential risks to human health and the environment.

### **7.3 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS**

In these paragraphs, the universe of potentially applicable technology types and process options are identified. The process options are screened with respect to technical implementability, and the candidate list is reduced to reflect only those options that can be implemented at the site. Site specific information obtained during the Phase I and II RI is used as a basis for screening. This information includes contaminant types, concentrations, and volumes, and site soil and hydrogeological characteristics.

The Phase I and II FS's (DOE/RL-90-32) initially developed alternatives for remedial actions at the Discolored Soil Site and the HRL. Contamination at the Ephemeral Pool and of groundwater beneath the HRL was not addressed. For the Discolored Soil Site, alternatives that were retained included no action, institutional controls, excavation and treatment by incineration, and in-situ biological treatment. For the HRL, no action, institutional controls, excavation and treatment by incineration, dechlorination, or stabilization, and excavation and offsite disposal were the alternatives retained. The process options that comprise these alternatives are reevaluated in this report.

Technology types and process options are selected within each general response action to satisfy the remedial action objectives for the site. Appropriate technologies were identified and screened using the following references: *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA, 1988), *Handbook for Stabilization/Solidification of Hazardous Waste* (EPA, 1986a), *Guide to Treatment Technologies for Hazardous Wastes at Superfund Sites* (EPA, 1989c), *Handbook on In-Situ Treatment of Hazardous Waste-Contaminated Soils* (EPA, 1990b), *Innovative Treatment Technologies: Overview and Guide to Information Sources* (EPA, 1991b), *Treatment Technologies Second Edition* (GII, 1991), and *Water Treatment Principles and Design* (JMM, 1985).

### 7.3.1 Identification and Screening of Soil Technologies and Process Options

The initial screening of soil technologies and process options is summarized in table 7-4. Capping is the only technology type retained for the containment general response action. Other containment alternatives are infeasible because of the extent and depth of the contamination (specifically at HRL). In-situ thermal treatment is also rejected as a technology type because of the low volatility of the organic contaminants and the non-homogenous nature of HRL. A summary of the technology types and process options retained after initial screening is provided in table 7-5.

### 7.3.2 Identification and Screening of Groundwater Technologies and Process Options

Table 7-6 summarizes the groundwater technologies and process options initially screened. Hydraulic gradient control is the only process option retained for the containment general response action. All other containment options are not feasible due to the areal extent and depth of the contaminant plume. In-situ chemical treatment is rejected as a technology type because chemical treatments are not applicable to the contaminants of concern or their concentrations, or because of the depth of the aquifer. Table 7-7 is a summary of the groundwater technology types and process options remaining after initial screening.

## 7.4 EVALUATION OF RETAINED PROCESS OPTIONS

In this section, process options that were retained after the initial screening are evaluated with respect to effectiveness, implementability, and cost. This evaluation focuses on the technologies and the general response actions they are intended to satisfy, and not of the site as a whole. A greater emphasis is placed on the effectiveness of the process option, with implementability and cost receiving less consideration. The goal of this step on the screening process is to select a representative process from each technology type to simplify the development and evaluation of alternatives to be accomplished in subsequent steps.

The effectiveness evaluation considers the following:

- The ability of the process option to effectively handle the estimated areas or volumes of contaminated media in meeting the RAO's;
- The risks to human health and the environment during the construction and implementation phase; and
- The demonstrated reliability of the process for the contaminants and conditions of the site.

The technical feasibility of implementing the process options was considered at initial screening. At this stage, the administrative feasibility of the process options are considered. The evaluation criteria used includes:

- The ability to obtain the necessary permits from the appropriate agencies for offsite actions;
- The ability to access and use treatment, storage, and disposal services;
- The availability of skilled workers and proper equipment to implement the technology; and
- The ability to meet ARAR's.

At this stage cost plays a limited role in screening of process options. Cost analysis is made on the basis of engineering judgement. Relative capital and operation and maintenance (O&M) costs are used in lieu of detailed estimates to compare costs within each technology type, and processes are evaluated as to whether costs are high, medium, or low.

A detailed narrative evaluation of each of the process options is provided in the following paragraphs.

## 7.5 SOIL PROCESS OPTIONS EVALUATION

Remaining process options for the remediation of contaminated soils are evaluated in the following paragraphs.

### 7.5.1 No Action

This alternative is required under the National Contingency Plan and is retained for comparison with other alternatives. Under this alternative, the site soils will not be disturbed and groundwater monitoring of existing wells in the Horn Rapids Landfill (HRL) would be continued to determine if potential downward percolation of soil contaminants is affecting groundwater quality. Groundwater monitoring is considered an "institutional control."

This alternative would not be effective in reducing the short- and long-term risks to human health and the environment. Risks would remain the same as those identified in the baseline risk assessments. Implementation of the plan would be difficult because applicable or relevant and appropriate requirements would not be achieved. The cost of this alternative would be low.

### 7.5.2 Institutional Controls

Institutional controls are actions which protect human health and the environment and assure continued effectiveness of a response action. These actions would prevent exposure to contaminated soils for onsite workers and would ensure that the contaminants are not migrating offsite. Access restrictions and long-term monitoring are the institutional controls considered.

9 3 1 2 9 3 3 0 4 0 1

TABLE 7-4  
INITIAL SCREENING OF SOIL TECHNOLOGIES AND PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comments
No Action	None	Not Applicable	Contaminated soils are left in place with no further disturbance of site.	Consideration required by NCP.
Institutional Controls	Access Restrictions	Administrative Controls	Regulations would be established to restrict the use of land in the area of concern.	Potentially feasible for all subunits.
		Deed Restrictions	Change of ownership deeds would require limitations on future land uses.	Potentially feasible for all subunits.
		Excavation Restrictions	Existing and future landowners would be restricted in new subsurface construction or excavation.	Potentially feasible for all subunits.
		Fences	Access to contaminated soil sites would be restricted by use of fence.	Potentially feasible for all subunits.
	Monitoring	Groundwater Monitoring	Sample and test groundwater on a regular basis.	Potentially feasible for all subunits.

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TABLE 7-4 (Continued)  
INITIAL SCREENING OF SOIL TECHNOLOGIES AND PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comments
Containment	Capping	RCRA Cap	Cap complying to RCRA standards for closure of landfills.	Potentially feasible for all subunits.
		MSWLF Cap	Cap complying to the Washington Administrative Code (WAC) for closure of municipal solid waste landfills (MSWLF) in arid regions.	Potentially feasible for all subunits.
		Asbestos Cap	Cap complying to the code of Federal regulation for closure of landfills containing asbestos.	Potentially feasible for HRL.
	Horizontal Barriers	Options Include: Grout Injection and Liners	A horizontal barrier is placed below the contaminated soil to prevent migration of contaminants to groundwater.	Not feasible due to extent and depth of contamination at HRL. Not feasible due to small volumes of material at the Discolored Soil Site and Ephemeral Pool.
		Vertical Barriers	Options Include: Slurry Walls, Grout Curtains, and Sheet Piling	A vertical barrier is placed to prevent contaminants from migrating.

TABLE 7-4 (Continued)  
 INITIAL SCREENING OF SOIL TECHNOLOGIES AND PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comments
Excavation/ Treatment/ Disposal	Excavation	Earth-Moving Equipment	Backhoes, loaders, bulldozers, dump trucks, etc. used to excavate and move contaminated soil to treatment area if required.	Potentially feasible at all subunits.
	Thermal Treatment	Rotary Kiln Incinerator	Slightly inclined, refractory-lined cylinder used for the controlled combustion of organic waste.	Potentially feasible for PCB's and BEHP contaminated soils.
		Infrared Incinerator	Silicon carbide elements are used to generate thermal radiation beyond the red end of the visible spectrum to combust organic waste.	Potentially feasible for PCB's and BEHP contaminated soils.
		Circulating Fluidized Bed Incinerator	Refractory-lined vessel containing a fluidized bed of inert, granular, sand-like material at high temperatures is used to combust organic waste.	Potentially feasible for PCB's and BEHP contaminated soils.
		Low Temperature Thermal Desorption	Low temperature treatment to remove volatile and semivolatile organic compounds from soil.	Not applicable to PCB's or BEHP.
		Vitrification	Contaminated soils are fed into a melter which destroys organics and melts inorganic constituents into a glass pool.	Potentially feasible for all subunits.

TABLE 7-4 (Continued)  
INITIAL SCREENING OF SOIL TECHNOLOGIES AND PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comments
Excavation/ Treatment/ Disposal (cont.)	Chemical Treatment	Dechlorination	Soils mixed with chemical reactant to destroy chlorinated compound such as PCB's.	Potentially feasible for PCB's.
		Fixation/Stabilization	Excavated soil is mixed with pozzolanic material to form leach-resistant blocks.	Potentially feasible. Effectiveness on PCB's and BEHP contaminated soils would require testing.
		Chemical Oxidation	Soils treated with ozone or hydrogen peroxide to oxidize organics.	Not applicable to non-water-soluble PCB's and BEHP contaminated soils. Partial degradation byproducts are toxic.
	Physical Treatment	Solvent Extraction	An organic solvent is used to extract organic contaminant from soil.	Potentially feasible for PCB's and BEHP contaminated soils.
		Supercritical CO <sub>2</sub> Extraction	Organics are extracted from contaminated soils by mass transfer to supercritical CO <sub>2</sub> .	Potentially feasible for PCB's and BEHP contaminated soils.
		Soil Washing	Mechanical processes are used to separate particles that contain contaminants.	Potentially feasible for PCB's and BEHP contaminated soils.

9 3 1 2 9 3 3 0 4 0 5

TABLE 7-4 (Continued)  
INITIAL SCREENING OF SOIL TECHNOLOGIES AND PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comments
Excavation/ Treatment/ Disposal (cont.)	Biological Treatment	Aerobic	Oxygen-utilizing bacteria destroy contaminants by oxidation.	Potentially feasible for PCB's and BEHP contaminated soils.
		Anaerobic	Cosubstrate is introduced to stimulate anaerobic bacteria to degrade contaminants.	Potentially feasible for PCB's and BEHP contaminated soils.
	Disposal	Onsite	Treated soils exhibiting no hazardous characteristics redeposited onsite.	Potentially feasible for all subunits.
		Offsite	Treated soils meeting RCRA BDAT criteria deposited in hazardous waste landfill.	Potentially feasible for all subunits.
In Situ Treatment	Thermal Treatment	Radio Frequency Heating	Electrodes are placed in contaminated soils and radio frequency energy is used to heat soils and volatilize organics.	Not feasible due to low volatility of PCB's and BEHP.
		In Situ Vitrification	Electrodes are placed in contaminated soils and resistive heating melts soil and forms stable glass.	Not feasible for nonhomogenous landfill soils at HRL or shallow contaminated soils at the Discolored Soil Site and Ephemeral Pool.

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TABLE 7-4 (Continued)  
INITIAL SCREENING OF SOIL TECHNOLOGIES AND PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comments
In Situ Treatment (cont.)	Chemical Treatment	Fixation/Stabilization	Stabilizing agents are mixed into soils to immobilize contaminants.	Potentially feasible for all subunits.
		Surfactant Enhanced Soil Washing	Surfactant solution is percolated through soil column to expedite removal of contaminants.	Not feasible due to areal extent of contamination at HRL and small volumes of material at the Discolored Soil Site and the Ephemeral Pool.
	Physical Treatment	Vacuum Extraction	Vertical and/or horizontal vents are used to extract volatile organic contaminants.	Not feasible due to low volatility of PCB's and BEHP.
	Biological Treatment	Aerobic	Nutrients and acclimated oxygen-utilizing bacteria are introduced into soils to stimulate biological degradation of contaminants.	Potentially feasible for PCB's and BEHP contaminated soils.
		Anaerobic	Cosubstrate and nutrients are introduced to subsurface and anaerobic bacteria are stimulated to degrade chlorinated organics.	Potentially feasible for PCB's and BEHP contaminated soils.

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TABLE 7-5  
SOIL PROCESS OPTIONS REMAINING  
AFTER INITIAL SCREENING

General Response Action	Remedial Technology Types	Process Options
No Action	None	Not Applicable
Institutional Controls	Access Restrictions	Administrative Controls Deed Restrictions Excavation Restrictions Fences
	Monitoring	Groundwater Monitoring
Containment	Capping	RCRA Cap MSWLF Cap Asbestos Cap (HRL only)
Excavation/Treatment/Disposal	Excavation	Earth-Moving Equipment
	Thermal Treatment	Rotary Kiln Incinerator Infrared Incinerator Circulating Fluid Bed Incinerator Vitrification
	Chemical Treatment	Dechlorination (PCB's contaminated soils only) Fixation/Stabilization
	Physical Treatment	Solvent Extraction Supercritical CO <sub>2</sub> Extraction Soil Washing
	Biological Treatment	Aerobic Anaerobic
	Disposal	Onsite Offsite
In Situ Treatment	Chemical Treatment	Fixation/Stabilization
	Biological Treatment	Aerobic Anaerobic

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TABLE 7-6  
INITIAL SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comments
No Action	None	Not Applicable	Contaminated groundwater will be attenuated naturally by dispersion, diffusion, and dilution. Additionally, biochemical reactions may degrade contaminants.	Consideration required by NCP.
Institutional Controls	Alternate Water Supplies	Municipal Water	Extend existing water supply system to future users.	Potentially feasible.
		Commercially Supplied	Supply commercially bottled water to future users.	Potentially feasible.
		Surface Water	Use surface water to supply future users.	Not feasible because there is currently a moratorium on new surface water withdrawals from the Columbia River.
	Point of Entry/ Point of Use Treatment	Activated Carbon Adsorption	Adsorb contaminants onto activated carbon by passing water through carbon column.	Potentially feasible only for removal of TCE.
		Filtration	Remove suspended solids by straining and adsorption onto filter media.	Not effective for removal of TCE or nitrates.
		Ion Exchange	Hazardous anions and/or cations are removed by passing water through ion exchange resins.	Potentially feasible for removal of nitrates only.
	Reverse Osmosis	Water is forced through a membrane under high pressure to filter out contaminants.	Potentially feasible, for TCE and nitrates.	

TABLE 7-6 (Continued)  
 INITIAL SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comments
Institutional Controls (cont.)	Point of Entry/ Point of Use Treatment (cont.)	Distillation	Miscible liquids are separated.	Not feasible due to low concentration of TCE.
		Ozonation	Ozone used as an oxidant to destroy contaminant.	Not feasible for residential use.
		Ultraviolet Radiation	Ultraviolet radiation used to oxidize contaminant.	Not feasible for residential use.
		Electrodialysis	Electric energy is used to transfer ions and anions in water through selective membranes leaving behind purified water.	Not feasible for residential use.
	Access Restrictions	Administrative Controls	Regulations would be established to restrict the use of groundwater in the area of concern.	Potentially feasible.
		Deed Restrictions	Property deeds would include restrictions on wells.	Potentially feasible.
		Fences	A fence around the groundwater plume would be installed to restrict access.	Not feasible due to extent of contamination and potential for further migration.

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TABLE 7-6 (Continued)  
INITIAL SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comments
Institutional Controls (cont.)	Monitoring	Monitoring Wells	Test groundwater samples on a regular basis.	Potentially feasible.
Containment	Capping	Various Options Include: Clay and Soil, Geomembrane, Asphalt, Concrete, and Multimedia Caps	Cap over areas of groundwater contamination to prevent infiltration from rainwater and further spread of contaminant plume. Capping options are only effective in combination with vertical barriers.	Not feasible due to extent of contaminant plume.
	Vertical Barriers	Various Options Include: Grout Curtains, Sheet Piling, and Slurry Walls	Vertical walls would be constructed around the contaminant plume to prevent further migration.	Not feasible due to extent of contaminant plume.
	Hydraulic Gradient Barrier	Hydraulic Gradient Control	Groundwater flow patterns are altered through use of extraction and recharge points to prevent migration of the contaminant plume.	Not feasible due to extent of contaminant plume.
	Horizontal Barriers	Various Options Include: Grout Injection and Liners	A horizontal barrier is placed below the contaminated plume to prevent downward migration.	Not feasible due to extent of contamination.

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TABLE 7-6 (Continued)  
 INITIAL SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comments
Containment (cont.)	Surface Controls	Grading	Regrade area above contaminated plume to provide drainage for runoff and reduce infiltration of rainwater.	Not feasible due to extent of contaminant plume.
Extraction/ Treatment/ Discharge	Extraction	Deep Wells	Submersible pump used to pump water from a deep well.	Potentially feasible.
		Ejector Wells	Medium depth wells are pumped using a jet pump.	Potentially feasible.
		Well Points	Groups of wells are connected to a common header pipe or manifold and pumped by suction lift or vacuum pumps.	Not feasible due to depth of aquifer.
		Trench Drains	Excavated ditch backfilled with coarse gravel.	Not feasible due to depth of aquifer.
		Tile/Perforated Pipe Drains	Collection trench excavated, tile or perforated pipe placed, and trench backfilled with coarse gravel.	Not feasible due to depth of aquifer.
		Infiltration Galleries	Horizontally laid screens connected to a well to improve extraction capacity.	Not feasible due to depth of aquifer.

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TABLE 7-6 (Continued)  
INITIAL SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comments
Extraction/ Treatment/ Discharge (cont.)	Extraction (cont.)	Sumps	Excavated area to collect water at central location.	Not feasible due to depth of aquifer.
		Enhanced Extraction	Extraction/injection process to increase flow to extraction well.	Potentially feasible.
	Physical Treatment	Adsorption	Organics adsorbed onto the surface of a media (activated carbon).	Potentially feasible for TCE.
		Air Stripping	Mass transfer of VOC from liquid to air in a packed column by mixing high volumes of air with water.	Potentially feasible for TCE.
		Steam Stripping	Mass transfer of VOC from liquid to steam in a packed column by mixing high volumes of steam with water.	Potentially feasible for TCE.
		Reverse Osmosis	Water is forced through a membrane under high pressure to filter out contaminants.	Potentially feasible for TCE and nitrates.
		Ultrafiltration	Liquid is forced through a membrane under pressure and large molecular weight contaminants are filtered out.	Not feasible due to low molecular weight of TCE and nitrates.

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TABLE 7-6 (Continued)  
 INITIAL SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comments
Extraction/ Treatment/ Discharge (cont.)	Physical Treatment (cont.)	Electrodialysis	Electric energy is used to transfer ions and anions in water through selective membranes, leaving behind purified water.	Potentially feasible for the removal of nitrates.
		Solvent Extraction	Contaminated water is mixed with a solvent and mass transfer of the contaminant from the liquid to the solvent occurs.	Not feasible due to low concentration of TCE.
		Supercritical Fluid Extraction	Supercritical fluid is used to dissolve organic wastes and extract them from contaminated water.	Not feasible due to low concentration of TCE.
		Distillation	Miscible liquids are separated.	Not feasible due to low concentration of TCE.
		Freeze Crystallization	Separates contaminated water into separate phases by freezing.	Not feasible due to low concentration of TCE.
		Coagulation/ Flocculation	Suspended solids are aggregated to facilitate settling.	Not applicable to TCE or nitrates.
		Dissolved Air Flotation	Air is forced into the contaminated liquid under pressure and suspended solids are floated to the water surface.	Not applicable to dissolved contaminants.

TABLE 7-6 (Continued)  
 INITIAL SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comments
Extraction/ Treatment/ Discharge (cont.)	Physical Treatment (cont.)	Centrifugation	Separation process by which contaminants are separated from water through rapid rotation of the water.	Not applicable to the separation of TCE or nitrates from water.
		Evaporation	The concentration of solutions of nonvolatile solutes through heat-induced vaporization of the water.	Not applicable to TCE or nitrates.
	Chemical Treatment	Chemical Oxidation	An oxidizing agent is mixed into the contaminated water and the contaminant is oxidized.	Potentially feasible for TCE.
		Reduction	Metal ions are reduced to solid form.	Not applicable for TCE or nitrates.
		Hydrolysis	Destruction of organic molecules by adjusting pH to acidic or basic conditions.	Not applicable due to low concentration of TCE.
		Chemical Dechlorination	High temperatures and pressures used to remove chlorine atoms from contaminant.	Not applicable to dilute aqueous waste streams.
		Ultraviolet Radiation/ Photolysis	Contaminants are oxidized using ultraviolet radiation or sunlight.	Potentially feasible for TCE.
		Irradiation	Chemical reactions are initiated by exposing the contaminated water to gamma irradiation.	Potentially feasible for TCE.

TABLE 7-6 (Continued)  
 INITIAL SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comments
Extraction/ Treatment/ Discharge (cont.)	Chemical Treatment (cont.)	Neutralization	Acidic or basic waters are neutralized by adding acid or base.	Not applicable to groundwater contaminated with TCE or nitrates.
		Precipitation	Metals are converted to an insoluble form and precipitated.	Not applicable to TCE or nitrate removal.
		Ion Exchange	Hazardous anions and/or cations are removed by passing water through ion exchange resins.	Potentially feasible for removal of nitrates.
	Biological Treatment	Aerobic	Bacteria requiring oxygen for metabolism oxidize contaminant in groundwater.	Potentially feasible for TCE.
		Anaerobic	Bacteria which do not require oxygen for metabolism oxidize contaminants in groundwater.	Potentially feasible for TCE and nitrates.
	Sewage Treatment Plant	Onsite Sewage Treatment Plant	Extracted groundwater pumped to an onsite sewage treatment plant.	Not feasible because there is no onsite plant.

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TABLE 7-6 (Continued)  
 INITIAL SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comments
Extraction/ Treatment/ Discharge (cont.)	Sewage Treatment Plant (cont.)	Offsite Sewage Treatment Plant	Extracted groundwater is treated at a publicly owned sewage treatment plant.	Not feasible due to unwillingness of local POTW to accept wastewater for various reasons.
		Discharge	Sanitary Sewer	Treated water discharged to sanitary sewer and conveyed to publicly owned treatment plant.
		Storm Sewer	Treated water discharged to storm sewer.	Not feasible because there is no storm sewer network in this proximity.
		Surface Water	Treated water discharged to surface water (Columbia River).	Potentially feasible.
		Reuse/Recycle	Treated water reused or recycled onsite.	Potentially feasible.
		Recharge	Treated water recharged into the ground.	Potentially feasible.
In Situ Treatment	Physical	Aeration	Air is pumped into the contaminated aquifer in order to volatilize contaminants.	Potentially feasible for TCE.
		Heating	Contaminants are volatilized through the addition of heat to the aquifer	Potentially feasible for TCE.

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TABLE 7-6 (Continued)  
INITIAL SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Description	Screening Comments
In Situ Treatment (cont.)	Physical (cont.)	Treatment Trenches	Trenches are excavated downgradient of the contamination and backfilled with activated carbon to adsorb the contaminant.	Not feasible due to depth of aquifer.
		Chemical	Hydrolysis	Destruction of organic molecules by adjusting pH to acidic or basic conditions.
	Oxidation	Addition of oxidizing chemicals to aquifer to oxidize contaminant.	Not applicable due to depth of aquifer and inability to adequately mix reagent and groundwater.	
	Reduction	Addition of chemicals to aquifer to reduce metal ions to solid form.	Not applicable to TCE or nitrates.	
	Neutralization	An acid or base is added to the aquifer to neutralize the groundwater.	Not applicable to groundwater contaminated with TCE or nitrates.	
	Biological	Aerobic	Aerobic bacteria oxidize contaminants.	Potentially feasible for TCE.
		Anaerobic	Anaerobic bacteria oxidize contaminants.	Potentially feasible for TCE and nitrates.

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TABLE 7-7  
GROUNDWATER PROCESS OPTIONS REMAINING  
AFTER INITIAL SCREENING

General Response Action	Remedial Technology Types	Process Options
No Action	None	Not Applicable
Institutional Controls	Alternate Water Supplies	Municipal Water Commercially Supplied
	Point of Entry/Point of Use Treatment	Activated Carbon Adsorption Ion Exchange (nitrates only) Reverse Osmosis (TCE and nitrates)
	Access Restrictions	Administrative Controls Deed Restrictions
Containment	Monitoring	Monitoring Wells
	None Remaining After Screening	Not Applicable
Extraction/Treatment/Discharge	Extraction	Deep Wells Ejector Wells Enhanced Extraction
	Physical Treatment	Adsorption (TCE only) Air Stripping (TCE only) Steam Stripping (TCE only) Reverse Osmosis (TCE and nitrates) Electrodialysis (nitrates only)
	Chemical Treatment	Chemical Oxidation (TCE only) Ultraviolet Radiation/Photolysis (TCE only) Irradiation (TCE only) Ion Exchange (nitrates only)
	Biological Treatment	Aerobic (TCE only) Anaerobic (TCE and nitrates)

TABLE 7-7 (Continued)  
 GROUNDWATER PROCESS OPTIONS REMAINING  
 AFTER INITIAL SCREENING

General Response Action	Remedial Technology Types	Process Options
Extraction/Treatment/ Discharge (cont.)	Discharge	Surface Water Reuse/Recycle Recharge
In Situ Treatment	Physical	Aeration (TCE only) Heating (TCE only)
	Biological	Aerobic (TCE only) Anaerobic (TCE and nitrates)

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**7.5.2.1 Access Restrictions.** Access controls are measures that would restrict the access to or activity in the contaminated areas. Administrative controls such as land use zoning could be utilized to restrict the use of the land. Currently, the 1100-EM-1 Operable Unit is zoned for industrial use and this land use is anticipated to continue for at least the next 20 years (appendix J). Administrative controls are retained as an option for at least the near-term future.

Restrictions limiting land use could be attached to deeds if and when the Department of Energy (DOE) relinquished ownership of parts or all of the sites. Similarly, excavation restrictions would prevent future land owners from engaging in construction activities that would disturb the sites. These restrictions are usually not effective because they are difficult to enforce. Also, they are not implementable because it is the policy of the Federal government to dispose of only those properties which have unrestricted use. Therefore, each operable subunit must be fully remediated before it can be disposed of and the need for deed restrictions would be eliminated. For this reason, deed and excavation restrictions are not considered further.

Perimeter fencing at the sites would be effective in restricting public access and reducing the potential for exposure. Fencing is readily implementable with moderate capital and low operation and maintenance (O&M) costs. Fencing is a viable process option which may be used in combination with other alternatives and is retained for consideration.

**7.5.2.2 Monitoring.** Monitoring of groundwater may be required whether or not remedial actions are taken. This option is used in combination with all remedial alternatives for which contaminants remain onsite and is carried forward to be evaluated in the alternative selection process.

### **7.5.3 Containment**

Capping is the only containment option which is retained after initial screening. Because of the limited areal extent and volume of the contaminated material at the Discolored Soil Site and the Ephemeral Pool subunits, containment options at these sites were not considered. Capping is only considered as an option at the HRL subunit. A final capping system would prevent direct contact with soils and emissions of fugitive dust and/or minimize any long-term potential for migration of liquids (leaching potential) through the contaminated soil site.

The Resource Conservation and Recovery Act (RCRA) cap requirement (EPA, 1989d) is a multi-layered system consisting of:

- A top layer of at least 60 cm (2 ft) of soil, either vegetated or armored at the surface;
- A granular or geosynthetic drainage layer with a hydraulic transmissivity of no less than  $3E-05$  cm<sup>2</sup>/sec (0.0209 ft/day); and,

- A two-component low-permeability layer comprised of 1) a flexible membrane liner installed directly on 2) a compacted soil component with an hydraulic conductivity no greater than  $1E-07$  cm/sec (3 feet in 30 years).

The Washington Administrative Code (WAC) 173-304-460 (Landfilling Standards) allows a municipal solid waste landfill (MSWLF) cap of reduced design for installations in arid regions such as Hanford [ $< 18$  cm (7 inches) rainfall per year]. This cap would consist of:

- A top layer of at least 15 cm (6 inches) of soil;
- An impermeable layer consisting of a 50 mil thick geomembrane.

Installation of either cap would be effective in minimizing infiltration. The RCRA cap also provides a means for collecting water that is able to penetrate the cap. The potential for leaching of contaminants to the groundwater would be minimal for either option. However, the contaminants of concern at the Discolored Soil Site (BEHP), Ephemeral Pool (PCB's), and the HRL (PCB's) are generally insoluble and are tightly bound to the soil. As stated in paragraph 7.1.2.1, the existing potential for vadose zone contaminant migration to the aquifer is considered minimal. Caps designed to limit infiltration are not a remedial action objective. Of these two caps, only the MSWLF cap is retained for further evaluation in the alternative selection process to provide a conservative containment option that addresses uncertainty.

An alternate landfill closure option has been used at many sites that contain wide areas of contaminated soils at low concentrations, such as found at the HRL. For these closures, cover requirements are less stringent because the wastes being contained do not pose a threat to groundwater. Direct contact and fugitive dust threats can be adequately addressed with a soil cover. Long-term management at these sites would include site and cover maintenance, access controls, land use restrictions, and long-term monitoring. At sites where RCRA requirements for closure are "relevant and appropriate", these hybrid closure requirements can be used (53 FR 51446 and EPA, 1988b).

One such option that would meet these hybrid closure requirements is a cap designed to prevent the emission of fugitive dust containing asbestos from the HRL. For inactive disposal sites containing asbestos, minimum cap requirements are either (40 CFR 61):

- (1) A compacted 15 cm (6-inch), non-asbestos-containing soil cover with an established and maintained vegetative cover; or
- (2) A compacted 60 cm (2-foot), non-asbestos-containing soil cover maintained to prevent exposure to asbestos-containing soil; or

- (3) A compacted 15 cm (6-inch), non-asbestos-containing soil cover with an additional 3-inch layer of non-asbestos-containing crushed rock to prevent erosion.

All the above options would be effective in minimizing fugitive dust emission. Option (1) would not be implementable because of the desert environment. Options (2) and (3) are both implementable with the cost of each being comparable and moderate. To simplify future alternative evaluations, option (2) will be carried forward.

#### 7.5.4 Excavation/Treatment/Disposal

The excavation/treatment/disposal general response action encompasses all process options to remediate the contaminated soil sites ex situ. These are discussed in the following sections.

**7.5.4.1 Excavation.** Excavation of soils for processing will be done using conventional earthmoving equipment (backhoes, front-end loaders, dump trucks). Confirmatory sampling and analyses will be conducted to determine if and when cleanup goals are met and excavation is complete. This method is effective and implementable. A key consideration will be the control of fugitive dust during these operations to prevent short-term risks to onsite remediation workers. Safety precautions, such as the use of respirators, protective clothing and the misting of soil for dust control, may be required. Additionally, ambient air quality monitoring and restrictions on operations during moderate to high wind conditions may be required. The cost of the operations may increase substantially based on the level of protection determined to be protective of human health. This option is retained for further consideration.

**7.5.4.2 Thermal Treatment.** Thermal treatment processes use high temperatures to thermally destroy organic contaminants. Four thermal process, three of which are incinerators, were retained after initial screening and are discussed further in the following paragraphs.

**7.5.4.2.1 Incineration--Rotary kiln incinerators** are slightly inclined, refractory-lined cylinders used for the controlled combustion of organic waste under net oxidizing conditions (EPA, 1991b, and EPA, 1991c). Wastes and auxiliary fuel are fed into the high end of the kiln and passed through the combustion zone by gravity. Turbulence is created by the rotation of the combustion chamber and improves burnout of the solids. Organics which may volatilize and reside in the gases are destroyed in a secondary combustion chamber. Residuals from this process include ash, flue gases, and brine solution from the ash quench, and wet scrubber.

Infrared processing systems use electrical resistance heating elements or indirect fuel-fired radiant U-tubes to generate thermal radiation beyond the red end of the visible spectrum (EPA, 1991b and EPA, 1991c). Waste is fed into the combustion chamber by conveyor belt and exposed to the radiant heat. Exhaust gases are passed through a secondary combustion chamber. Residuals are the same as those for the rotary kiln incinerator.

Circulating fluidized bed incinerators use high air velocities to suspend and circulate fuel/waste particles in a refractory-lined combustion vessel (EPA, 1991b and EPA, 1991c). Fluidized beds can be operated at lower temperatures than other incinerators because the increased turbulence aids combustion. Flue gas is separated from heavier particles in a solids separation cyclone. Limestone is used to capture acid gases, thus eliminating wet scrubbers and one of the residual process waste streams.

The effectiveness of each of these incinerators in destroying organic contaminants is demonstrated by removal efficiencies of greater than 99.9 percent (EPA, 1991). Based on the 95 percent upper tolerance limit concentrations of 18,000 mg/kg BEHP at the Discolored Soil Site, 15 mg/kg PCB's at the Ephemeral Pool, and 38 mg/kg PCB's at the HRL, residual concentrations in incinerator ash would be 18, < 0.1, and < 0.1 mg/kg, respectively, for each operable subunit. These concentrations are well below the remedial action objectives.

Rotary kiln incineration is readily implementable. Soil feed size up to 12 inches in diameter can readily be handled (EPA, 1991). Size reduction would be required for both the fluidized bed and infrared units as they require waste feed material to be less than 2 inches in diameter (EPA, 1991). Soils at the operable subunits typically contain gravels greater than 2 inches in diameter. All processes being equally effective, only the rotary kiln incinerator is retained because it does not require special handling of feed soils. Because of the small volume of contaminated material onsite, a small mobile incineration unit is required. Units which process five tons per day are available at moderate mobilization and O&M costs.

Additional costs may be required for permitting, compliance monitoring and for the disposal of residuals. Also, the public reaction to onsite incineration has not always been favorable at other sites and the public may not accept this process option. The process is carried forward to be incorporated into alternatives, however, because it is proven effective in destroying the organic contaminants of concern.

7.5.4.2.2 Vitrification--A Joule heated ceramic melter is used to vitrify soils at temperatures up to 1500° C (2700° F). Organic contaminants present in the feed stream are destroyed by pyrolysis and/or combustion at these high operating temperatures (PNL, 1988). Final system design can assure effective destruction of BEHP and PCB's in the soil. Any inorganic contaminants in soils from the HRL would be incorporated into the glass matrix of the final product and isolated from the environment upon final disposal.

Waste materials and glass frit are fed into a high-temperature furnace where the organics decompose and any residual oxides and ash material melt to form a glass product. The glass frit typically consists of silica, soda ash, and lime. Contaminated soils are fed either on top of or below the molten glass surface of the melter. Waste particles undergo pyrolysis and organics are thermally degraded. Off gases are readily burned in the plenum space or in a secondary combustion chamber. The molten mixture is discharged into disposal containers or quenched in water to produce a granular product for bulk disposal (PNL, 1988).

The process is not readily implementable because the technology is not yet mobile. Pacific Northwest Laboratories (PNL) had planned to construct a mobile unit that could

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process five tons of contaminated soils per day but the project was suspended (PNL, 1992). An engineering scale vitrification plant is planned in the 300 Area, which will process 250 kg/day. This system will be permitted to process up to 1,000 kg of waste from any source. This facility could possibly be used to process a small quantity of these contaminated soils as a demonstration of the effectiveness of the technology.

If a fixed vitrification plant were operating and readily available, the cost of treatment would be moderate. However, because the technology is not yet on-line, this process option is not considered further. Vitrification should be revisited in the design phase if the DOE decides to proceed with a site-wide vitrification plant for the treatment of hazardous waste.

**7.5.4.3 Chemical Treatment**—Dechlorination and stabilization/solidification were the chemical treatment processes retained after initial screening and are evaluated further here.

**7.5.4.3.1 Dechlorination**—Chemical dechlorination is the process by which hazardous chlorinated wastes are destroyed or detoxified by substitution of the contaminant chlorine atoms with other atoms (predominantly hydrogen). This process is potentially effective for the treatment of PCB's. Contaminated soils are heated and mixed with an alkali metal hydroxide-based polyethylene glycol reagent in a mobile batch reactor (EPA, 1991).

Soils are first processed by screening to remove the large rocks and debris in order to avoid jamming of the reactor mixer blades. Reagent is then mixed well with the soil in the reactor to obtain efficient treatment. The mixture is heated to between 100° and 180° C and reactions are carried out for 1 to 5 hours depending on the type, quantity, and concentration of the contaminants. The treated mixture is then processed in a separator where the reagent is removed and recycled (EPA, 1991c).

Vaporized water resulting from the reaction is condensed and collected for further treatment or recycled through the washing process. Carbon filters are used to capture volatile organics that are not condensed. The treated soil is washed and neutralized by the addition of acid, dewatered, and then disposed of onsite if regulatory requirements are met.

A key process residual that may effect the overall cost of the treatment is the waste washwater. Typically, this residual contains only trace amounts of contaminants and reagents, and is expected to meet discharge standards that would allow it to be discharged to a publicly-owned treatment works. If the washwater does require treatment, typical methods are carbon adsorption, chemical oxidation, biodegradation and/or precipitation.

Field performance data suggests that dechlorination is effective in reducing PCB concentrations to below 2 parts per million (ppm) in treated soil (EPA, 1991b and EPA, 1990c). Initial soil concentrations cited were much higher than the PCB concentrations at the 1100-EM-1 Operable Unit. It is expected that by adjusting batch mixing time, temperature, and reagent ratio, soils can be treated to below the 1 ppm level.

The process is readily implementable with a number of vendors able to provide treatment units. Costs are moderate in comparison to other technologies which treat PCB's (*i.e.*, incineration). However, information from one vendor suggests that these systems are

cost effective only when at least 10,000 tons of soil are processed (Galson, 1992). Because of the limited amount of material to be processed at the site, dechlorination as an innovative and cost-effective technology is not carried forward in the evaluation process.

7.5.4.3.2 Stabilization/Solidification--Stabilization and solidification processes achieve one or more of the following results (EPA, 1986):

- Improve the handling and physical characteristics of the waste;
- Decrease the surface area of the waste mass across which transfer or loss of contaminants can occur; and/or,
- Limit the solubility of any hazardous constituents of the waste such as by pH adjustment or sorption phenomena.

Stabilization limits the solubility or mobility of the contaminants without necessarily changing the physical characteristic of the waste. The process usually involves the addition of a reagent that maintains the hazardous contaminant in its least mobile or toxic form.

Solidification produces a solid block of waste material with high structural integrity. The contaminants are mechanically locked in the solidified matrix. Migration of the contaminant is limited by the reduction of surface area exposed to the environment and/or by isolating the contaminants by microencapsulation.

Typically, portland cement and pozzolan materials (*e.g.*, fly ash) are blended with contaminated soils to produce a stronger waste/concrete composite. Contaminants are contained in the concrete matrix by microencapsulation. Other reagents are also used; however, most reagents have been found to be ineffective in immobilizing organic constituents (EPA, 1990b). A 1988 evaluation of a proprietary reagent gave inconclusive evidence on its ability to immobilize PCB's (EPA, 1990b).

While this process option is readily implementable at a moderate cost, its effectiveness in stabilizing the organic soil contaminants is questionable. The process is proven to be effective in immobilizing metals. Because leaching of contaminants to the groundwater aquifer at the HRL is not a pathway of concern at this site, stabilization/solidification methods are not pursued further.

**7.5.4.4 Physical Treatment.** Physical treatment processes involve the separation of the contaminant from the soil. Three process options were retained after initial screening and each is evaluated further here.

7.5.4.4.1 Solvent Extraction--In this process, hazardous contaminants are extracted from soils using an organic solvent. A solvent, which preferentially removes organic contaminants, is mixed with contaminated media, and transfer of the contaminants from the media to the solvent phase occurs. A change in temperature or pressure is then used to separate the contaminant from the solvent. This process is one of waste reduction; contaminants are not destroyed but are concentrated in their liquid forms. This concentrate

will require further treatment. Processed soils can be redeposited onsite if they meet regulatory criteria.

The process has demonstrated effectiveness in removing PCB's from sediments at an efficiency rate of between 84 to 98 percent (EPA, 1991). It should be noted that removal efficiencies increased with the increase in number of passes made through the reactor. It is reasonable to expect that 99 percent removal efficiencies can be achieved; however, the costs associated with this level of treatment will be comparatively high. The effectiveness of the process on BEHP removal is not proven, but the process is demonstrated to be effective on nonhalogenated semivolatile compounds.

The process is readily implementable with a number of vendors who are able to provide treatment units. Special material handling is required because units can only process materials 1/8 to 1 inch in diameter.

Because of the many passes required to increase removal efficiencies, the material handling considerations, and the requirement for post treatment of the extract, the cost of solvent extraction relative to other treatments for the small amount of contaminated soil is high. For these reasons, solvent extraction is not considered further.

7.5.4.4.2 Supercritical CO<sub>2</sub> Extraction--This extraction process uses supercritical carbon dioxide as the solvent to extract organic constituents from soils. The process operates at the critical temperature and pressure of carbon dioxide. At these conditions, carbon dioxide is at its critical density. The process is extractive and further treatment of the extract is required to destroy hazardous contaminants.

Near the critical point, the density of a supercritical fluid is typically  $10^2$  to  $10^3$  times greater than that of the gas at ambient temperatures. By increasing the density, the solvent strength of the supercritical fluid increases. Because carbon dioxide has a low critical temperature (31.1°C), extractions are performed at thermally mild conditions and the soil structure is not destroyed. Also, because carbon dioxide is a gas at room temperature, concentration of the extract is simplified.

Supercritical fluids have higher solute diffusivities than solvents used in conventional extraction techniques. Thus, removal efficiency is increased. This eliminates the multiple passes required in conventional systems.

The Westinghouse Hanford Corporation (WHC) has recently completed initial bench scale studies evaluating this process (WHC, 1992b). In these studies, contaminated soils from the UN-1100-6 and from the HRL were used. Preliminary results indicate that BEHP can be extracted from the UN-1100-6 soil at efficiencies of about 97 percent. While this is not sufficient to remediate soils to meet Model Toxics Control Act levels, these results are encouraging. Further bench scale studies that alter either the pressure or temperature under which the reactions are carried out will be conducted to determine optimal removal efficiencies. Removal efficiencies for the HRL soils containing PCB's were greater than 99 percent.

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Although this technology is not yet available on a full scale for soil remediation, it is carried forward to the next step in the process because it is an innovative technology.

**7.5.4.4.3 Soil Washing**--Soil washing is a volume reduction process used for pretreatment. The process is applicable to contaminants that are concentrated in the fine fraction of the soil (silt, clay, and soil organic matter) and to contaminants associated with the coarse soil fraction (sand and gravel), which are surficial. The goal of this separation process is to concentrate the contaminants in a smaller volume of material separate from a washed soil product. The washed product will meet cleanup standards and can be redeposited at the cleanup site.

Many of the unit processes are common to that of the mineral processing industry. Soils are first screened to remove the large debris (> 2 inches). Process steps can include mixing trommels, pug mills, vibrating screens, froth flotation cells, attrition scrubbing machines, hydrocyclones, screw classifiers, and various dewatering operations (Biotrol, 1992). The soils are mixed with washwaters to remove contaminants from the soil. Sometimes, organic solvents, chelating compounds, surfactants, acids, or bases are used to enhance the extraction of the contaminant from the soil. The soil and washwater are then separated, and the soil is rinsed with clean water resulting in a clean soil as a product. Suspended soil particles in the washwater are recovered as a sludge by discrete settling using gravity or by flocculation through the use of a polymer. This sludge consists of the fine fraction of the original soil and should contain most of the contaminants. The sludge is dewatered and then sent on for further treatment to destroy the contaminants. Processed washwater is usually recycled after biological or physical treatment.

The soil washing process has proven to be effective in reducing the volume of soils contaminated with PCB's. Although not directly cited in literature, its effectiveness for BEHP removal should be similar. Destruction of these contaminants would require additional treatment.

Soil washing would be readily implementable for the soils at the 1100-EM-1 sites. The technology is available from various vendors, and the process has been seen as favorable by the public at other sites.

For sites with a small volume of contaminated soil, the costs of soil washing are high. One vendor reports that for sites with less than 10,000 tons of contaminated soils, the process is not cost effective (Biotrol, 1992). These high costs are only associated with volume reduction of the soils and do not take into account added costs for treatment and destruction of the contaminant. For these reasons, soil washing is deemed not to be cost effective at this site and is not carried forward for further consideration.

**7.5.4.5 Disposal.** Both onsite and offsite disposal options were retained after initial screening and are evaluated further in the following sections.

**7.5.4.5.1 Onsite Disposal**--Onsite disposal is considered for all soils treated by onsite process options. These soils will be subject to the RCRA Land Disposal Restrictions that require treatment of wastes to the best demonstrated available technology (BDAT) levels

prior to land disposal. The ability to meet these requirements is dependent on the treatment process option chosen. In some instances, as in the use of innovative technologies, alternative treatment levels may be selected if a treatability variance establishing these levels is obtained.

The site remediation goal would be to meet BDAT levels and redeposit treated soils at the respective subunits. The treated soils would then be capped with 2 feet of random fill material and regraded. This process is effective in handling treated soils and should not increase risks to human health or the environment. It is easily implementable, has a relatively low cost, and will be considered for inclusion in the remedial action alternatives.

7.5.4.5.2 Offsite Disposal—Soils contaminated with BEHP are land banned under the third-third RCRA Land Disposal Restrictions. Offsite disposal of these soils cannot be considered unless the soils are treated to BDAT levels. The use of a Toxic Substance Control Act (TSCA)-approved disposal facility is considered for disposal of untreated PCB soils. Under TSCA, PCB-contaminated soils with concentrations up to 500 ppm may be disposed of in a licensed hazardous waste landfill.

This method is not effective in destroying the contaminant. PCB's are immobilized by containerization and the containers are deposited in the landfill. The landfill is built to specific requirements that prevent future migration of the contaminant. This disposal method is implementable with an approved facility within 180 miles of the site. The cost of this disposal option is moderate. This process option will be used in the development of alternatives.

### 7.5.5 In-Situ Treatment

Stabilization/Solidification is the only in-situ process option retained after initial screening. This process is similar to the ex-situ process except that soil cutting and mixing blades are used to blend soils in situ while stabilizing agents are being injected. Soils to depths of 9 m (30 ft) can easily be stabilized. The process is proven for the immobilization of metal soil contaminants; its effectiveness on organic contaminants is not well documented and treatability studies would be required to determine its ability to immobilize PCB's and BEHP.

Deep soil mixing augers and pressurized slurry-injection systems specifically built for this type of work are readily available. This equipment is most effective where there are sandy, relatively dry soils. Buried debris and concrete rubble, as might be encountered at the HRL, significantly hamper the process and may make the use of this technology infeasible for this site. The cost of the process is moderate.

This process is not carried on for further consideration because it may not easily be implemented at the HRL and its effectiveness on organic contaminants is uncertain. Additionally, contaminant migration from the vadose zone to the groundwater has been dismissed as an operative pathway making further immobilization of the contaminants unwarranted.

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### 7.5.6 Biological Treatment

Biological treatment refers to the use of microorganisms to decompose contaminants. This occurs under both aerobic conditions (in the presence of oxygen) and anaerobic conditions (devoid of oxygen), depending on the nature of the microbes. Sometimes decomposition is direct (the microbe consumes the contaminant as a source of carbon or other nutrient needed for growth) or the microbe may produce enzymes that catalyze a chemical change in the contaminant (cometabolism). The presence of existing microbes in the soil, suited to the decomposition of the contaminant, is beneficial. Otherwise, the microbes that are needed can be genetically derived or isolated in the laboratory. Regardless of the microbial origin, treatability studies are conducted to be sure that the desired decomposition of the contaminant can be achieved without the production of hazardous byproducts.

In order to stimulate the growth of the decomposing organisms, air and nutrients (aerobic biodegradation) or methane and nutrients (anaerobic biodegradation), must be supplied. The quantities of these inducers are determined stoichiometrically.

Contaminated soil can be treated in place or excavated and treated at a remote location. In-situ treatment of contaminated soil promotes and accelerates the natural biodegradation process in the undisturbed soil. Generally, it consists of a water recirculation system with above-groundwater treatment and conditioning of the infiltration water with nutrients and an oxygen source. The system is usually designed to allow uncontaminated groundwater to enter the zone of contamination, but prevents groundwater from leaving the contaminated zone (EPA, October 1991). For small sites containing contaminated soils at shallow depths, in-situ treatment is not economical. Therefore, in-situ bioremediation of soils is not carried forward for further consideration.

Ex-situ biological treatment of contaminated soil includes three general technologies: 1) slurry phase, 2) land treatment, and 3) contained land solid phase. In the slurry phase, the soil is excavated, mixed with water, and slurried to the bioreactor where the biological conversion takes place. Once treated, the soil is dewatered and disposed.

Land treatment is also called land farming. Using this method, the soil is excavated and placed in a prepared, lined treatment bed. Using standard farm equipment, a large area can be treated.

Contained solid phase generally refers to above-ground composting of the soil with appropriate soil amendments to stimulate microbial decomposition of the contaminant.

There is some evidence that bioremediation of BEHP may be possible. Waste Stream Technology (WST) has reported that they have isolated a microbe that can obtain energy for growth from BEHP (WST, 1992). WST has also reported that BEHP was among several contaminants biotreated in situ at the Pittsburgh Airport in Allegheny County, Pennsylvania. During construction of the Pittsburgh Airport expansion project, an abandoned garbage dump

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was discovered. BEHP was among the contaminants of concern at the site. The concentrations of BEHP were on the order of 1,000 to 2,000 mg/kg. After biotreatment, the concentrations of BEHP were below the target levels.

The potential effectiveness of biotreatment on the BEHP at this Pennsylvania site is unclear. There is reason to suggest that dilution by mixing, rather than biotreatment may explain the reduced concentrations in post treatment samples. The dump area was excavated and placed in a temporary stockpile where it was biologically treated. Since only isolated samples taken at the dump site contained concentrations of BEHP, it is possible that the BEHP was diluted during excavation, transport, and placement in the stockpile.

The fact that microbes have been isolated that utilize BEHP as their energy source is encouraging. A treatability study would be required to confirm that in-situ biotreatment of BEHP is feasible at the UN-1100-6 site. Bioremediation of BEHP through landfarming practices is carried forward as an innovative technology.

Biodegradation of PCB's in both aerobic and anaerobic realms has been investigated. Positive results have been achieved in bench scale testing of the biotreatability of PCB's. In a series of studies (Unterman *et al.*, 1988), soil from New York State contaminated with Aroclor 1242 (similar to Aroclor 1248) was sampled for biodegradation testing. Resting cell studies using the contaminated soil have shown substantial PCB biodegradation (Unterman *et al.*, 1988). These studies also included work on genetically engineered bacteria designed specifically for biodegradation of Aroclor 1242-contaminated soil. Additionally, PCB-degrading bacteria were isolated.

Dechlorination of Aroclor 1242 under anaerobic conditions has been attempted. At a project on the upper Hudson River, New York, PCB- (Aroclor 1242) contaminated sediments were dechlorinated by microorganisms under anaerobic conditions in a bench scale test (ATTIC-RM00468, 1992). Dechlorination occurred primarily from the para and meta positions; congeners that were substituted only in the ortho positions were accumulated (ATTIC-RM00468, 1992). These dechlorination products are both less toxic and more readily degraded by aerobic bacteria (ATTIC-RM00468, 1992). Again, treatability studies would be required to confirm biodegradation of PCB's at the 1100 sites is possible.

Successful PCB degradation in field studies has not been documented in the literature surveyed. To date, degradation has only been demonstrated in bench scale studies where input variables were closely controlled. Although bioremediation of PCB's in the field is an emerging technology, it has not been demonstrated and its use is not considered further here.

## 7.6 GROUNDWATER PROCESS OPTIONS

Groundwater process options remaining after initial screening are evaluated further in the following paragraphs.

### 7.6.1 No Action

Under this scenario, no remedial action would be taken on the HRL groundwater and contaminant levels would be naturally attenuated by dispersion, diffusion, and dilution. This alternative is required under the NCP to establish a baseline condition to compare to other alternatives and will be considered in the development of alternatives.

Currently, there is no use of this groundwater as a drinking water source. Domestic water is supplied through the city of Richland distribution network. Therefore, there is no current risk to human health or the environment. This alternative still may not be acceptable to regulators or the public because contaminants are left in place and are not actively remediated.

### 7.6.2 Institutional Controls

Institutional controls are actions that reduce the exposure of receptors to contaminated groundwater and that monitor the spread and level of contamination. Process options were retained after initial screening in the four technology types and are evaluated here.

**7.6.2.1 Alternate Water Supplies and Point of Entry/Point of Use Treatment.** For domestic consumption, alternate water supplies would be provided through Richland's distribution network or by commercially supplied (bottled) water. Richland's distribution network already serves the current industrial user in the area and can be readily accessed at low cost. It is the only alternate water supply that will be carried forward.

Point of entry/point of use treatment would be used by domestic consumers to purify water prior to ingestion. These systems would require maintenance and monitoring to ensure their effectiveness. Again, since Richland's distribution network is available, these types of process options are not considered further.

**7.6.2.2 Access Restrictions.** Access restrictions are actions that would prevent consumption of the contaminated water until it is remediated. Administrative controls would consist of regulations that would require owners to abandon wells or prevent the use of these wells. These controls are usually difficult to implement. There are currently no domestic consumers downgradient of the contaminated plume and the need for these restrictions is nonexistent. Deed restrictions could be imposed that would prohibit development of wells by new owners, upon disposal of the land by DOE. If this land would come under private ownership, deed restrictions could be difficult to implement. Deed restrictions are not pursued further.

Future use and the development of new wells can be controlled by both DOE, who owns the land, and Ecology, through which water well permits must be attained. These administrative controls are easily implementable and should be used until the groundwater is remediated. The cost of this option is low.

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**7.6.2.3 Monitoring.** Monitoring wells are valuable in identifying the extent, spread, and concentration of contaminants. Additionally, they are used to evaluate the effectiveness of the remedial activity. Installation of wells involves standard practices. Initial capital costs, O&M costs, and sampling and analytical costs are high when compared to other institutional controls. Monitoring is carried forward to the development of alternatives.

### 7.6.3 Extraction/Treatment/Discharge

This is the group of active remediation scenarios that would withdraw and treat contaminants prior to discharge. Extraction is by the use of a variety of wells and well configurations. Treatment includes physical, chemical, and biological processes. For the treatment of nitrates several process options are available and are discussed in the sections that follow. However, because nitrate is not a risk driver at the 1100-EM-1 OU, only one treatment option will be carried forward into the detailed analysis of alternatives. This is done to reduce the number of possible alternatives requiring detailed analysis. For the purposes of this FS, the nitrate treatment option selected is intended to represent a technology that has been demonstrated as effective, is implementable, and for which costs are easily quantified. Should groundwater pump and treat be selected as the appropriate remedial action, a value engineering study will be conducted in the remedial design phase to reevaluate nitrate treatment options. Several discharge scenarios are also evaluated.

**7.6.3.1 Extraction.** Deep well pumps have their impellers close enough to the water surface to avoid cavitation. The motor may be at ground level with a long shaft connecting it to the impellers, or it may be at the bottom of the well, below and directly adjacent to the impellers. These pumps efficiently move large volumes of water and are effective in aquifers with high hydraulic conductivities. Ejector well pumps are primarily used in aquifers with low hydraulic conductivity. They are designed to be operated intermittently and generally have lower efficiencies than deep well pumps. The HRL aquifer has a high hydraulic conductivity and the use of deep well pumps is most appropriate. This extraction method will be used for the development of alternatives.

Installation of well casing and pumps is readily implementable. Initial capital costs and O&M costs for a deep well pumping system are relatively low.

Enhanced extraction is the process where water is discharged to the aquifer in order to increase its hydraulic gradient and, thus, increase its capacity to flush contaminants. This procedure is most appropriately used where there is a known source area. The contaminants at HRL are widely dispersed and the benefits of this method would be minimal. Its use is not considered further.

**7.6.3.2 Physical Treatment.** Physical processes involve the separation of the contaminant from the groundwater. These processes exploit various physicochemical phenomena to remove the undesirable constituents. Five physical processes were retained following initial screening. Each is described and evaluated here. Viable physical processes for the removal of TCE are compared against each other in paragraph 7.6.3.2.6.

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7.6.3.2.1 Adsorption--Organics that are refractory and that are difficult to remove by conventional biological treatment processes are frequently removed by adsorption onto an active solid surface. Activated carbon is the most widely used adsorbent in these processes (Eckenfelder, 1989).

The underlying principle of adsorption is the mass transfer of an organic molecule from a liquid onto a solid surface. Adsorption occurs because there are forces that attract the organics to the solid surface from solution. In the case of activated carbon, the porous structure of the carbon attracts and holds (adsorbs) the organic contaminant. The contaminants are attracted either because: 1) they have a low solubility in the water; 2) they have a greater affinity for the carbon than for the water; or 3) a combination of the two (GII, 1991).

The carbon adsorption process usually consists of a series of columns that are packed with carbon. The contaminated water is passed through the vertical beds with either an upward or downward flow. The contaminants are most rapidly and effectively adsorbed by the carbon closest to the inlet of the bed. This carbon is in contact with the highest concentrations of the contaminated water. As treatment progresses, these carbon sites lose their adsorptive capacity and the adsorption zone progresses up or down the column. As this zone approaches the end of the carbon bed, effluent concentration approaches that of the influent. This is termed breakthrough. At this point the carbon bed is spent and no additional removal of the contaminant occurs. The carbon bed is then taken off line and the carbon is regenerated by thermal methods or replaced.

Carbon adsorption is demonstrated to reduce trichloroethene (TCE) concentrations in contaminated waters to below 1  $\mu\text{g/L}$ . Systems to handle the range of flows anticipated for this site are available from several vendors. Initial capital costs and annual O&M costs are typically high for these systems when compared to other physical processes.

7.6.3.2.2 Air Stripping--Air stripping is the physical process of transferring a volatile organic contaminant (VOC) from water into the air. This is normally done by passing water through a packed column countercurrent to a flow of air. The packing is usually an open structured, chemically inert material (plastic) that is selected to provide high surface areas that facilitate mass transfer of the contaminant from the water to the gas phase. This process is affected by the contact area, the solubility of the contaminant, the diffusivity of the contaminant in air and water, and the temperature (Eckenfelder, 1989). Besides the diffusivity and temperature, these parameters are dependent on the air- and water-flow rates and the packing media selected. The efficiency of the process in removing a contaminant is directly related to the Henry's Law constant of the organic compound and the mass transfer coefficient of the packing.

TCE has a Henry's Law constant of  $0.01 \text{ atm}\cdot\text{m}^3/\text{gmole}$ . Air stripping is usually applicable to contaminants with Henry's Law constants greater than  $0.003 \text{ atm}\cdot\text{m}^3/\text{gmole}$ . Generally the greater the Henry's Law constant, the easier the contaminant is removed from the liquid phase.

Typically a process unit consists of a cylindrical tower containing packing which disrupts the flow of the liquid thus renewing the air and water interface. Water is pumped to the top of the unit and flows countercurrent to a forced draft provided by a blower. The system is characterized by high interfacial area compared to the volume of water in the column. Principal design parameters are the volumetric air flow ratio, the packing type, size and depth, column diameter, water and air loading rates, and the gas pressure drop.

One consideration with stripping towers is the emission of the stripped VOC's to the atmosphere. VOC's are designated air pollutants whose emissions are controlled. However, because of the low concentration of TCE at the site, attaining air quality standards is not anticipated to be a problem.

Air stripping technology is readily available from multiple vendors. The process has been proven to remove TCE to below maximum contaminant levels (MCL's). The capital and O&M costs of a stripping system are moderate compared to other physical processes.

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7.6.3.2.3 Steam Stripping--Steam stripping is generally used to increase the efficiency of a stripping process. Heating of the contaminated water raises the Henry's Law constant of the contaminant thus making it more strippable. TCE is readily stripped at temperatures of 20° C. Steam stripping is an energy intensive process that would not be of great benefit for use at this site. This process is not considered further.

7.6.3.2.4 Reverse Osmosis--Reverse osmosis (RO) is a membrane process in which hydrostatic pressure is used to drive the feedwater through a semipermeable membrane while a major portion of the contaminant remains behind and is discharged as waste (reject). The process has shown some promise in removing VOC's, however, removal efficiencies for TCE were found to be between 30 and 69 percent (Clark *et al.*, 1984). New membranes are being developed that may increase these removal efficiencies.

RO is also applicable to the removal of nitrates. The development of thin filmed composite spiral wound membranes have made this process cost effective. Additionally, the reject can be flash evaporated leaving behind a solid residual that can easily be handled and disposed. This has advantages over other nitrate removal processes that have treatment residuals that are costly to treat (Culligan, 1992). RO is retained for further consideration for these reasons.

7.6.3.2.5 Electrodialysis--Electrodialysis (ED) is a membrane process that is used to transfer ions from the contaminated water through the membrane, leaving behind a purified water. Use of ED for removal of organics is not documented in the literature; there is little documentation on its use solely for nitrate removal. ED processes remove nitrate-nitrogen at efficiencies of less than 50 percent (Sorg, 1978). Costs for ED processes are typically high compared to other nitrate removal options. ED is not considered further.

7.6.3.2.6 Comparison of Physical Processes for TCE Removal--The remaining physical processes are carbon adsorption and air stripping. Both processes have demonstrated high removal efficiencies from 90 to 99 percent. For the removal of TCE only, air stripping has proven to be far more economical over a wide range of influent concentrations and treatment

flows (Clark *et al.*, 1984). As treatment flows increase, the difference in capital costs between the two processes gets larger because the carbon-adsorption system must operate under high pressures that require special pressure vessels for the carbon beds (Westates Carbon, 1992). While these systems provide equivalent treatment, air stripping is carried forward because of the economics.

**7.6.3.3 Chemical Treatment.** Four chemical treatment processes for the treatment of TCE or nitrates in groundwater were retained after initial screening and are evaluated in greater detail here.

**7.6.3.3.1 Chemical Oxidation and Ultraviolet (UV) Radiation--**In this process oxidants are added to contaminated groundwater to oxidize pollutants to terminal end products or to intermediate products that are more readily biodegradable or more readily removed by adsorption. Common oxidants used are chlorine, ozone, hydrogen peroxide, and potassium permanganate. Of these, only ozone and hydrogen peroxide are reported to oxidize refractory organic compounds. However, under normal conditions, complete degradation of these compounds does not occur; and, research has shown that using an additional energy source in conjunction with these oxidants (*i.e.*, UV radiation) readily decomposes these refractory compounds (Eckenfelder, 1989). It is believed that the UV activates the oxidant molecule and that it may also activate the organic substrate. The processes described below use UV in conjunction with either ozone or hydrogen peroxide or both.

Ozone is usually generated onsite from dry air or oxygen by a high-voltage electric discharge. Oxygen usually yields twice the ozone concentration (0.5 to 10 wt percent) as air. Ozone oxidation systems typically mix ozone with the contaminated water in a reaction chamber. At the same time, the mixture is exposed to UV radiation. Ozone off gases are treated in a catalytic ozone decomposer and released to the air. The terminal end products of this reaction are CO<sub>2</sub> and H<sub>2</sub>O. Similarly, hydrogen peroxide is mixed with the contaminated water in a reactor and irradiated with UV light.

In a third oxidation process, ozone and hydrogen peroxide are added to the contaminated water in a reactor and the water is subjected to UV light. This process was demonstrated in the field in 1989 as part of the Superfund Innovative Technology Evaluation (SITE) program. Results from this demonstration showed that the process removed 98 to 99 percent of the TCE present in the influent groundwater (EPA, 1990d). Some of the TCE removal was due to stripping (10 percent).

Of the three oxidation processes, the ozone, hydrogen peroxide and UV system will be considered further. The system is available at moderate capital cost. O&M for the system is high.

**7.6.3.3.2 Irradiation--**Irradiation as a means of chemically decomposing organic compounds has been found to require longer reaction times and by itself, has not been demonstrated with high efficiencies. Irradiation is not considered further.

**7.6.3.3.3 Ion Exchange--**Ion exchange systems are commonly used in municipal water treatment systems for the removal of nitrates. In this process, negatively charged nitrate

anions are removed by an insoluble, strong base resin, which exchanges other like charged anions into the solution. This exchange occurs with no structural changes in the resin. The nitrates in solution rapidly diffuse into the network of the resin where exchange occurs. The exchanged ions proceed by the same path into solution. At some point an ion exchange equilibrium is reached and the resin must be regenerated (Benefield *et al.*, 1982).

Various operational modes of ion exchange systems exist. The fixed-bed system is the most common of these. The operating cycle for a fixed-bed system consists of four steps: service, backwash, regeneration, and rinse.

Fixed-bed systems for nitrate removal by strong base resins are operated in the upflow or downflow mode for service, and vice versa for regeneration. This is known as countercurrent operation. Typically for these systems the resin has a high affinity for the exchanged ion and requires a considerable excess of regenerant to regenerate the resin bed. The column typically experiences leakage at the start of the next service run (Benefield *et al.*, 1982).

Ion exchange systems are readily available from a number of water treatment equipment vendors and are an effective treatment method for nitrate removal. The operational requirements for handling the strong base regenerant (NaOH), and the column rinsate are great, which make the O&M costs for these systems high. Based on a comparative study for treatment of site groundwater for nitrate, reverse osmosis was determined to be the more economical method (Culligan, 1992). While both methods are equal in effectiveness, ion exchange is dropped from further consideration because of its higher cost. As stated earlier, a more detailed value engineering study will be performed to reevaluate nitrate treatment processes during the remedial design if pump and treat scenarios are selected.

**7.6.3.5 Discharge.** Three discharge alternatives were retained and are evaluated below.

**7.6.3.5.1 Surface Water--**Discharge to the Columbia River would entail the construction of a 1.61 km (1 mile) pipeline. Installation of a gravity-driven system would require extensive excavation. A pumped system would reduce excavation, but increase O&M costs. This system would have high initial capital costs when compared to other discharge systems and is not considered further.

**7.6.3.5.2 Reuse/Recycle--**After treatment, the water will meet MCL's and would be available for reuse or recycle. However, there currently is no demand for water and there is no expected future demand. Therefore, this discharge option is not pursued.

**7.6.3.5.3 Recharge--**Subsurface drains consist of perforated distribution pipes placed in a trench and surrounded by clean sand. Treated groundwater would be gravity fed or pumped to the pipes and the system would be sized to ensure that the flow out of each orifice would be equal to assure even distribution of the discharge. After being discharged, the effluent would percolate through site gravels and eventually would return to the aquifer. This system is readily implementable and very effective in homogenous aquifers with high permeability

such as found at the site. The cost of this system is low compared to other discharge systems and is retained for consideration.

#### 7.6.4 In-Situ Treatment

Two physical in-situ treatments were retained after initial screening and are discussed below. In-situ biological methods are discussed in paragraph 3.5.

**7.6.4.1 Aeration.** In-situ aeration involves the pumping of air into the aquifer to induce the mass transfer of volatile organics to the gas phase. Typically this is done in vertical wells that are used as air strippers. Horizontal wells have been used to strip groundwater in situ along a leaking pipeline. These systems can only treat limited areas of the plume (source or hot spots) efficiently. As the areal extent of the plume gets larger and the contaminant more dispersed, the number of wells required to effectively treat the area would be cost prohibitive. For these reasons this process option is not considered further.

**7.6.4.2 Heating.** In-situ heating would involve the injection of steam and air into the aquifer, again to induce the mass transfer of the organic contaminant into the gas phase. The principal here is that the contaminant is more readily strippable at higher temperatures. TCE is readily strippable without heating. This process option is dropped from consideration for the same reason as was in-situ aeration, which is that the areal extent of the plume is too great to economically employ this process.

#### 7.6.5 Biological Treatment

Biological treatment refers to the use of microorganisms to decompose contaminants. This occurs both under aerobic conditions (in the presence of oxygen) and anaerobic or anoxic conditions (devoid of oxygen), depending on the nature of the microbes. Sometimes decomposition is direct, in that the microbe consumes the contaminant as a source of carbon, or other nutrient needed for growth. Or the microbe may produce enzymes that catalyze a chemical change in the contaminant (cometabolism). It is beneficial if the microbes needed for decomposition already exist in the aquifer (indigenous). Otherwise the microbes that are needed can be genetically derived or isolated in the laboratory. Regardless of the microbial origin, treatability studies are almost always conducted to be sure that the desired decomposition of the contaminant can be achieved without the production of hazardous byproducts.

In order to stimulate the growth of the decomposing organisms, air and nutrients (aerobic) or methane and nutrients (anaerobic), must be supplied. The quantities of these inducers are determined stoichiometrically. When biological treatment is conducted in situ, these materials are injected into the aquifer. A dilemma that is almost always faced in in-situ treatment is the potential for fouling the injection well. The microorganisms tend to flourish at the injection point resulting in clogged injectors and/or aquifer pores. Another problem encountered is that the contaminant is forced away from the injection point, as the aquifer makes room for the injected materials.

Ex-situ treatment requires that the aquifer be pumped, treated and then re-injected. Ex-situ biological treatment is performed in a bioreactor. Similar to in-situ treatment, the inducers are injected into the reactor, which provides adequate mixing and detention time for decomposition of the contaminant to occur. Sludge is produced in the process. Consequently sludge handling facilities must be considered in the ex-situ scenario.

In-situ biological treatment of TCE under aerobic conditions shows some promise. Research has determined that TCE can be completely mineralized to carbon dioxide, water, and chlorine in an aerobic environment. Aerobic processes require the presence of an inducing compound (an aromatic compound such as toluene or phenol), which may not be present. TCE is epoxidated by the enzyme methane monooxygenase, emitted by methylotrophic bacteria as they consume methane for energy (Russell *et al.*, 1992). Epoxidated TCE is very unstable, so hydrolyzation to various by-products is rapid (half life = 12 seconds in phosphate buffer with pH 7.7) (Miller and Guengerich, 1982).

One concern in an aerobic in-situ scenario is that the methane needed to stimulate the methylotrophs may be inhibitory to the TCE epoxidation (Russell *et al.*, 1992). Potentially, only a portion of the TCE would be epoxidated before being transported away in a flow situation.

Decomposition of TCE under anaerobic conditions is described as reductive dehalogenation. Under anaerobic conditions, TCE can function as an electron sink and is readily reduced by electrons (or reducing equivalents) formed as a result of the metabolism (oxidation) of the organic electron donors by members of the methanogenic consortia (Russell *et al.*, 1990/91). By introducing electron donors into the contaminated environment, TCE can be reduced. However, in the absence of adequate oxidizable organic compounds (*e.g.*, toluene), there is the potential to produce dichloroethylene and vinyl chloride (Bouwer and McCarty, 1983, and Bouwer *et al.*, 1981). Dichloroethylene is a suspected carcinogen and vinyl chloride is a known carcinogen. Therefore, if in-situ biological treatment in the anaerobic realm was selected, careful monitoring would be required to ensure that these compounds, particularly vinyl chloride are not produced.

Based on the discussion above, biologically treating TCE is not recommended at this time. Although evidence indicates that TCE can be biologically destroyed (cometabolized in an aerobic environment; reduced in an anaerobic environment), the practicality of providing the needed nutrients and inducers necessary for biological treatment in an in-situ environment is uncertain. Further, the inducers necessary for biological treatment, such as toluene or phenol in an aerobic environment, and toluene or acetone in an anaerobic environment, are themselves toxic. These organic contaminants are not present in the groundwater at this site, and injecting them for removal of TCE is not recommended. Also, in the anaerobic environment, there is potential to produce dichloroethylene and vinyl chloride as by-products (Russell *et al.*, 1990/91; Bouwer and McCarty, 1983; Bouwer *et al.*, 1981). As noted above, dichloroethylene is a suspected carcinogen and vinyl chloride is a known carcinogen.

Nitrate is reduced by a process known as denitrification. Denitrification is accomplished by facultative anaerobic microorganisms in an anoxic environment (Metcalf and Eddy, 1991). Denitrification is a two step process: 1) the conversion of nitrate to nitrite,

and 2) production of nitric oxide, nitrous oxide and nitrogen gas. The last three compounds are gaseous compounds that can be released to the atmosphere.

An ex-situ demonstration project at Hanford was performed to investigate denitrification of nitrates (Brouns *et al.*, 1991). Both a continuous stirred-tank bioreactor and a fluidized bed bioreactor were used in the pilot scale test. Results of the study indicate that microorganisms native to the Hanford site are capable of reducing nitrates to below the drinking water standard when supplied with an electron donor such as acetate (Broun, *et al.*, 1991). In-situ denitrification is being investigated. A pilot scale study has been initiated at Hanford but no results have been reported to date.

The use of biological treatment for in-situ treatment of nitrates is still experimental. An organic inducer would be required to stimulate denitrification. Ex-situ treatment has been investigated with positive results. Should the aquifer be treated ex situ, bioremediation of nitrate may be possible. A pilot test has been completed at Hanford using both continuous stirred tank and fluidized bed reactors (Broun *et al.*, 1991). Both reactors were able to reduce the influent nitrate concentration to below the drinking water standard (10 mg/L), with the fluidized bed reactor showing the best results. However, biological denitrification has several undesirable features. First, the process requires careful control to prevent bacterial and organic inducer breakthrough. Commonly the inducer itself is a hazardous chemical and even though low concentrations would be needed, system failure could result in the discharge of this substance to the environment. Secondly, the biological mass takes considerable time to develop and stabilize; system upsets in which this mass is lost would cause extended shutdowns of the system. For these reasons, biological nitrate removal is not considered further for the purposes of this FS. Should pump and treat be selected as the remedial action, this promising technology will be reevaluated with other nitrate removal methods to determine the most cost effective process.

## 7.7 SUMMARY

Summaries of the evaluations of soil and groundwater process options are provided in tables 7-8 and 7-10. The process options remaining after this screening evaluation are presented in tables 7-9 and 7-11 for soils and groundwater, respectively. For soils, applicability of the process option to each specific subunit is also noted. The next step is to assemble the retained technologies into remedial action alternatives representing a range of treatment and containment combinations. This is presented in section 8.

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TABLE 7-8  
SUMMARY EVALUATION OF SOIL PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Effectiveness	Implementability	Relative Cost	Used to Develop Alternatives?
No Action	None	Not Applicable	Health risks for industrial land use would remain the same. Contaminants are persistent and would remain onsite.	Easily implemented, but ARAR's would not be met and this option may not be acceptable to the regulators or public.	---	Yes for all subunits.
Institutional Controls	Access Restrictions	Administrative Controls	Land use can be controlled in the near-term future (20 years). Risks to public remain the same unless site is remediated.	Existing zoning and land use plans are in place and currently are being implemented.	Low capital. Low O&M.	Yes for all subunits.
		Deed Restrictions	New owners could still be exposed to contaminated soils if they remain in place.	Not implementable because Government will not dispose of land which is contaminated.	Low capital. Low O&M.	No
		Excavation Restrictions	Owners could still excavate in contaminated soils which remain in place.	This restriction would be difficult to enforce if land use changes.	Low capital. Low O&M.	No
		Fences	Access to contaminated sites would be restricted. Contaminated soils would remain in place.	Easily implemented.	Moderate capital. Low O&M.	Yes for all subunits.

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TABLE 7-8 (Continued)  
SUMMARY EVALUATION OF SOIL PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Effectiveness	Implementability	Relative Cost	Used to Develop Alternatives?
	Monitoring	Groundwater Monitoring	Valuable to document conditions and monitor releases. Does not reduce risks.	Easily implemented.	High capital. High O&M.	Yes
Containment	Capping	RCRA Cap	Effective barrier to prevent infiltration and prevent fugitive dust.	Possible clay source nearby. Easily implemented.	High capital. Low O&M.	No
		WAC Cap	Effective barrier to prevent infiltration and prevent fugitive dust.	Easily implemented.	High capital. Low O&M.	Yes at HRL only.
		Asbestos Cap	Does not prevent infiltration. Effective in prevention of fugitive dust.	Easily implemented.	Moderate capital. Low O&M.	Yes at HRL only.
Excavation/ Treatment/ Disposal	Excavation	Earth-Moving Equipment	Effectiveness methods for excavation and hauling of contaminated soils.	Easily implemented. Operators may require protective clothing and respirators.	Moderate capital. Moderate O&M.	Yes for all subunits.

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TABLE 7-8 (Continued)  
SUMMARY EVALUATION OF SOIL PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Effectiveness	Implementability	Relative Cost	Used to Develop Alternatives?
Excavation/ Treatment/ Disposal (cont.)	Thermal Treatment	Rotary Kiln Incinerator	Effective in destroying organic contaminants.	Onsite and offsite technology readily available. May require some special material handling. Permits will be required for onsite processing.	Moderate capital. Moderate O&M.	Yes for PCBs and BEHP contaminated soils.
		Infrared Incinerator	Effective in destroying organic contaminants.	Onsite and offsite technology readily available. Will require special material handling. Permits will be required for onsite processing.	Moderate capital. Moderate O&M.	No
		Circulating Fluid Bed Incinerator	Effective in destroying organic contaminants.	Onsite and offsite technology readily available. Will require special material handling. Permits will be required for onsite processing.	Moderate capital. Moderate O&M.	No
		Vitrification	Effective in destroying organic contaminants.	Technology not readily available.	Moderate capital. Moderate O&M.	No

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TABLE 7-8 (Continued)  
SUMMARY EVALUATION OF SOIL PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Effectiveness	Implementability	Relative Cost	Used to Develop Alternatives?
Excavation/ Treatment/ Disposal (cont.)	Chemical Treatment	Dechlorination	Effective in dechlorinating PCB's.	Technology available. Large quantities (> 10,000 tons) required for cost effectiveness.	Moderate capital. High O&M.	No
		Stabilization/ Solidification	Effectiveness in stabilizing organic soil contaminants is not well proven.	Readily implementable with a number of stabilizing reagents available. Treatability tests required.	Moderate capital. Moderate O&M.	No
	Physical Treatment	Solvent Extraction	Removal efficiencies for PCB's between 84 to 98 percent. Not proven for BEHP but likely to be effective.	Readily implementable. Special handling considerations. Extract must be recycled or treated. Requires multiple treatment passes.	High capital. High O&M.	No
		Supercritical CO <sub>2</sub> Extraction	Has proven effective in bench scale studies for removal of organics.	Full scale technology not yet developed for HTW remediation. Extract must be recycled or treated.	No costs available.	Yes for PCB's and BEHP contaminated soils.

TABLE 7-8 (Continued)  
SUMMARY EVALUATION OF SOIL PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Effectiveness	Implementability	Relative Cost	Used to Develop Alternatives?
Excavation/ Treatment/ Disposal (cont.)	Physical Treatment (cont.)	Soil Washing	Effective in reducing contaminated soil volumes.	Readily implementable. Large quantities (> 10,000 tons) required for cost effectiveness. Residual soils require additional treatment.	High capital. High O&M.	No
	Biological Treatment	Aerobic	No field demonstrated remediation of PCB's. Biodegradation of BEHP reported but not conclusive.	Readily implementable. Would require treatability study. May not be able to achieve BDAT standards.	Moderate capital. Moderate O&M.	Yes for BEHP contaminated soils only.
		Anaerobic	Bench scale studies have demonstrated degradation of PCB's. No field results.	Would require treatability studies. Reactors for anaerobic conditions would be required.	High capital. High O&M.	No
	Disposal	Onsite Disposal	Effective for disposal of treated soils which meet the BDAT requirements for land disposal.	Readily implementable.	Low capital. Low O&M.	Yes for treated soils from all subunits.
		Offsite Disposal	Effective for disposal of PCB contaminated soils. No reduction in toxicity would be achieved.	Readily implementable with facility in close proximity.	Moderate capital. No O&M.	Yes for disposal of untreated PCB's contaminated soils.

TABLE 7-8 (Continued)  
SUMMARY EVALUATION OF SOIL PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Effectiveness	Implementability	Relative Cost	Used to Develop Alternatives?
In Situ Treatment	Chemical Treatment	Stabilization/Solidification	Effectiveness in stabilizing organic contaminants is not well proven.	Readily implementable technology. Debris and concrete at HRL will pose problems.	Moderate capital. Low O&M.	No
	Biological Treatment	Aerobic	No field demonstrated remediation on PCB's. Biodegradation of BEHP reported but not conclusive.	Readily implementable. Would require treatability studies. Ability to maintain favorable conditions for microorganisms is difficult.	Low capital. Moderate O&M.	No
		Anaerobic	Bench scale studies have demonstrated degradation of PCB's. No field results.	Maintenance of anaerobic conditions in field would be difficult.	Moderate capital. Moderate O&M.	No

TABLE 7-9  
SOIL PROCESS OPTIONS REMAINING  
AFTER EVALUATION OF PROCESS OPTIONS

General Response Action	Remedial Technology Types	Process Options
No Action	None	Not Applicable
Institutional Controls	Access Restrictions	Administrative Controls Fences
	Monitoring	Groundwater Monitoring
Containment	Capping	WAC Cap (HRL only) Asbestos Cap (HRL only)
Excavation/Treatment/Disposal	Excavation	Earth-Moving Equipment
	Thermal Treatment	Rotary Kiln Incinerator
	Chemical Treatment	None Remaining
	Physical Treatment	Supercritical CO <sub>2</sub> Extraction
	Biological Treatment	Aerobic (for Discolored Soil Site)
	Disposal	Onsite (for treated soils) Offsite (for untreated soils)
	Chemical Treatment	None Remaining
In Situ Treatment	Chemical Treatment	None Remaining

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TABLE 7-10  
SUMMARY EVALUATION OF GROUNDWATER PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Effectiveness	Implementability	Relative Cost	Used to Develop Alternatives?
No Action	None	Not Applicable	There is no current risk to human health because domestic water is supplied through the city of Richland's distribution network. The quality of the groundwater is not improved.	Easily implemented. This alternative may not be acceptable to regulators or the public.	---	Yes
Institutional Controls	Alternate Water Supplies	Municipal Water	Health risks to receptors are eliminated because all industrial and domestic users are supplied through the municipality.	The city of Richland currently supplies domestic and industrial users downgradient of the plume. Distribution network already in place.	Low capital. Low O&M.	Yes
		Commercially Supplied	Health risks are eliminated because domestic users drink bottled water.	Easily implementable. May be an inconvenience to users.	Low capital. Low O&M.	No
	Point of Entry/ Point of Use Treatment	Various (see Table 7-5)	Effective in treating water at the point of use to below MCL's.	Easily implemented. Would require maintenance of treatment units. May be an inconvenience to users.	Moderate capital. High O&M.	No

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TABLE 7-10 (Continued)  
SUMMARY EVALUATION OF GROUNDWATER PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Effectiveness	Implementability	Relative Cost	Used to Develop Alternatives?
Institutional Controls (cont.)	Access Restrictions	Administrative Controls	Effective in restricting future well drilling. No reduction in contaminant concentrations.	Easily implemented. Both DOE and Ecology can restrict well drilling.	Low capital. Low O&M.	Yes
		Deed Restrictions	Effective in preventing future well drilling. No reduction in contaminant concentrations.	Difficult to implement if land comes under private ownership.	Low capital. Low O&M.	No
	Monitoring	Monitoring Wells	Effective in identifying the extent, spread, and concentration of the contaminant plume. No reduction in contaminant concentrations.	Easily implemented.	High capital. High O&M.	Yes
Containment	None Remaining After Initial Screening	Not Applicable	---	---	---	---
Extraction/Treatment/Discharge	Extraction	Deep Wells	Effective in pumping large volumes of groundwater from aquifers with high hydraulic conductivities.	Easily implemented.	High capital. High O&M.	Yes

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TABLE 7-10 (Continued)  
SUMMARY EVALUATION OF GROUNDWATER PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Effectiveness	Implementability	Relative Cost	Used to Develop Alternatives?
Extraction/ Treatment/ Discharge (cont.)	Extraction (cont.)	Ejector Wells	Effective for intermittent pumping of aquifers with low hydraulic conductivities.	Easily implemented.	High capital. High O&M.	No
		Enhanced Extraction	Effective in flushing contaminants at a known source area.	Easily implemented. Injected water must meet ARAR.	High capital. High O&M.	No
	Physical Treatment	Adsorption	Effective in removing organic contaminants from groundwater to below MCL's.	Equipment available from multiple vendors. Large flow systems require special containment vessels.	High capital. High O&M.	No
		Air Stripping	Effective in removing organic contaminants from groundwater to below MCL's.	Equipment available from multiple vendors. TCE emissions may be a concern.	Moderate capital. Moderate O&M.	Yes for TCE only.
		Steam Stripping	Effective in removing organic contaminants that are not readily strippable in normal air stripping processes.	Equipment available. Requires large energy input.	High capital. Moderate O&M.	No

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TABLE 7-10 (Continued)  
SUMMARY EVALUATION OF GROUNDWATER PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Effectiveness	Implementability	Relative Cost	Used to Develop Alternatives?
Extraction/ Treatment/ Discharge (cont.)	Physical Treatment (cont.)	Reverse Osmosis	Not effective in removing TCE. Effective in reducing nitrate concentrations to below MCL's.	Equipment readily available. Must treat or dispose of brine.	High capital. High O&M.	Yes for nitrates only.
		Electrodialysis	Not effective for removal of TCE. Removal efficiencies for nitrates are less than 50%.	Equipment readily available.	High capital. High O&M.	No
	Chemical Treatment	Chemical Oxidation	Effective in oxidizing organic contaminants to terminal end products usually CO <sub>2</sub> and H <sub>2</sub> O.	Equipment readily available.	High capital. High O&M.	Yes for TCE only.
		Ultraviolet Radiation/ Photolysis	Effective when used in conjunction with chemical oxidation to destroy organic contaminants.	Equipment readily available. Influent water must have low turbidity.	Moderate capital. High O&M.	Yes for TCE only.
		Irradiation	Not effective by itself in treating organic contaminants.	Requires long reaction times.	Moderate capital. High O&M.	No

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TABLE 7-10 (Continued)  
SUMMARY EVALUATION OF GROUNDWATER PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Effectiveness	Implementability	Relative Cost	Used to Develop Alternatives?
Extraction/ Treatment/ Discharge (cont.)	Chemical Treatment (cont.)	Ion Exchange	Effective for treatment of nitrates to below MCL's. Not effective in treating TCE.	Equipment readily available. Regenerant requires treatment and disposal.	High capital. High O&M.	No
	Biological Treatment	Aerobic	Studies have shown that TCE can be treated effectively.	Easily implemented. Would require the introduction of organic inducers to stimulate process which may not be acceptable to regulators.	High capital. High O&M.	No
		Anaerobic	Effective in reducing TCE and nitrate concentrations.	Easily implemented. Intermediate byproducts (vinyl chloride) have greater risk to humans. Organic inducers are required to stimulate process.	High capital. High O&M.	No
	Discharge	Surface Water	Effective for discharge of treated groundwater.	Easily implemented. Would require NPDES permit. Pipeline would traverse two major arterials.	High capital. Low O&M.	No

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TABLE 7-10 (Continued)  
SUMMARY EVALUATION OF GROUNDWATER PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Effectiveness	Implementability	Relative Cost	Used to Develop Alternatives?
Extraction/ Treatment/ Discharge (cont.)	Discharge (cont.)	Reuse/Recycle	Effective for supplying treated water to end users.	Easily implemented. No end users exist.	Moderate capital. Moderate O&M.	No
		Recharge	Effective for discharge of treated groundwater.	Easily implemented. Must meet groundwater treatment standards.	Moderate capital. Moderate O&M.	Yes
In Situ Treatment	Physical Treatment	Aeration	Effective in volatilizing organics to the gas phase. Contaminant is not destroyed but transferred to separate phase for treatment.	Difficult to implement for large contaminant plumes.	High capital. High O&M.	No
		Heating	Effective in volatilizing organics which are not easily volatilized by the injection of air. Does not destroy, but transfers contaminants to separate phase for treatment.	Difficult to implement for large contaminant plumes. Requires significant energy input.	High capital. High O&M.	No

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TABLE 7-10 (Continued)  
SUMMARY EVALUATION OF GROUNDWATER PROCESS OPTIONS

General Response Action	Remedial Technology Type	Process Option	Effectiveness	Implementability	Relative Cost	Used to Develop Alternatives?
In Situ Treatment (cont.)	Biological Treatment	Aerobic	Studies have shown that TCE can be treated effectively.	Would require supplements of oxygen, nutrients, and organic stimulant. Difficult to treat large plumes.	High capital. High O&M.	No
		Anaerobic	Effective in reducing TCE and nitrate concentrations.	Would require supplements of nutrients and organic stimulant. Difficult to treat large plumes.	High capital. High O&M.	No

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TABLE 7-11  
GROUNDWATER PROCESS OPTIONS REMAINING  
AFTER EVALUATION OF PROCESS OPTIONS

Page 1 of 1

General Response Action	Remedial Technology Types	Process Options
No Action	None	Not Applicable
Institutional Controls	Alternate Water Supplies	Municipal Water
	Point of Entry/Point of Use Treatment	None
	Access Restrictions	Administrative Controls
	Monitoring	Monitoring Wells
Containment	None Remaining After Screening	Not Applicable
Extraction/Treatment/Discharge	Extraction	Deep Wells
	Physical Treatment	Air Stripping (TCE only) Reverse Osmosis (nitrate only)
	Chemical Treatment	Chemical Oxidation (TCE only) Ultraviolet Radiation/Photolysis (TCE only)
	Biological Treatment	None
	Discharge	Recharge
	In Situ Treatment	Physical
	Biological	None

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## 8.0 DEVELOPMENT AND SCREENING OF ALTERNATIVES

In this section, the retained process options are assembled into remedial action alternatives that offer varied degrees of treatment for the contaminated media at the site. The assembled alternatives are then evaluated and screened. The remaining alternatives are analyzed in detail in section 9.0.

### 8.1 PROCESS OVERVIEW

Alternatives are initially developed to meet a set of remedial action objectives for each medium of interest. The goal of this process is to assemble a wide range of response actions that achieve different degrees of cleanup, treat different volumes of the contaminated media, and achieve the cleanup in different timeframes. These alternatives should include appropriate containment and treatment options.

At this point in the process, alternatives are defined in sufficient detail to allow for the differentiation of each with respect to effectiveness, implementability, and cost. Also, volumes of media to be treated are well defined. The following information will be developed, as appropriate, for the various technology processes used in an alternative:

- Size and configuration of onsite extraction and treatment systems;
- Timeframe in which treatment, containment, or removal goals can be achieved;
- Rates or flows of treatment;
- Spatial requirements for constructing treatment or containment technologies or for staging construction materials or excavated soil or waste;
- Distances for disposal technologies; and
- Required permits for actions and imposed limitations.

The assembled alternatives are next screened using three broad criteria: effectiveness, implementability, and cost. These criteria are defined as follows (EPA, 1988a):

- **Effectiveness Evaluation**--Each alternative is evaluated as to its effectiveness in providing protection and the reductions in toxicity, mobility, or volume that it will achieve. Both long- and short-term components of effectiveness should be evaluated; long-term referring to the period after the remedial action is complete, and short-term referring to the construction and implementation period. Reduction of toxicity, mobility, or volume refers to changes in one or more characteristics of the hazardous substances or contaminated media by the use of

treatment that decreases the inherent threats or risks associated with the hazardous material.

- **Implementability Evaluation--**Implementability, as a measure of both the technical and administrative feasibility of constructing, operating, and maintaining a remedial action alternative, is used during this screening to evaluate the process options with respect to the conditions at the 1100-EM-1 Operable subunits. Technical feasibility refers to the ability to construct, reliably operate, and meet technology-specific regulations for process options until a remedial action is complete. Administrative feasibility refers to the ability to obtain approvals from the appropriate entities, the availability of treatment, storage, or disposal services and capacity, and the requirements for, and availability of, specific equipment and technical specialists.
- **Cost Evaluation--**Both capital and operation and maintenance (O&M) costs are considered. This evaluation will include those O&M costs that will be incurred as long as necessary, even after the initial remedial action is complete. Potential future remediation costs are considered to the extent that they can be defined. Present worth analysis should be used during this screening to evaluate expenditures that occur over different time periods. In this way, costs for different actions are compared on the basis of a single figure for each alternative.

Appendix N contains detailed cost estimates for the initial capital construction costs of each of the alternatives. Capital costs presented in the following paragraphs are taken from these estimates. Life-cycle O&M costs are estimated based on utility usage and historical costs supplied by various equipment vendors. These costs are reflected by a present worth cost using a annual discount rate of 5 percent used over the lifetime of the alternative.

There are several factors which may contribute to the uncertainty of the costs presented. In the case of soils, uncertainty in volume estimates due to limited sampling data could greatly influence costs. Quantity estimates in this report were based on conservative parameters. For groundwater, there are substantial annual O&M costs associated with the treatment of nitrates. Because nitrate is transported through the aquifer at rates much faster than TCE, nitrate levels in groundwater will probably fall below MCL's much sooner than levels for TCE. Substantial savings could be realized by turning off those components of the treatment system that specifically address nitrate removal. Life-cycle costs presented in this report may be overstated, as the entire treatment train was assumed to operate throughout the remedial action.

## 8.2 SOIL REMEDIAL ACTION ALTERNATIVES

Section 7.0 identified the viable process options for the specific contaminants in the contaminated media. Due to the small volume of contaminated soil at each subunit, the alternatives presented here address all contaminated soil rather than that of each subunit. Since treatment by one technology means one set of mobilization and set up costs, the net result is a reduction in cost per unit of treated soil. The mobilization and set up costs for two or three separate technologies would greatly increase these unit costs. Thus, economies of scale will dictate the actions taken at this operable unit and alternatives have been developed accordingly.

Soil remedial action alternatives are assembled from the various process options to present a range of treatment alternatives. These are represented by alternatives S-0 through S-5D in table 8-1. Alternatives with the same first two descriptors are similar except that the amount of material to be treated or the containment method are changed. Common components of each alternative are first described and evaluated, then the features which make each alternative unique, are described and evaluated against the screening criteria.

### 8.2.1 Common Components

Common components of each of the alternatives are discussed in the following paragraphs.

**8.2.1.1 Institutional Controls.** Institutional controls would consist of maintaining the current industrial land use, and restricting access and continuing groundwater monitoring hydraulically downgradient of sites on which contaminants remain in place. These controls would be both technically and administratively implementable. The cost of these controls would vary according to the cleanup level achieved and would be evaluated with respect to each alternative. For purposes of alternative comparison, it is assumed that the no action alternative would require continued monitoring of all presently monitored wells over the next 30 years. Using historical costs of \$52,150 per monitoring round, this has an estimated life-cycle present worth of \$802,000. For all other alternatives, removal or treatment options are assumed to obtain cleanup levels that facilitate clean closure, therefore, wells specifically installed to monitor releases from these remediated sites would no longer require sampling and the only monitoring requirements would be for the HRL. Pro-rated costs for this reduced monitoring effort are estimated at \$40,500 per annual sampling event. This has an estimated life-cycle present worth of \$623,000 over 30 years.

**8.2.1.2 Removal of PCB's at HRL.** Ten of the twenty-one proposed alternatives include the removal of all the PCB's contaminated soils, approximately 460 m<sup>3</sup> (600 yd<sup>3</sup>), at the identified hot spot at the HRL. As documented in section 7.0, a number of process options exist that would efficiently destroy the PCB's in soil to below required cleanup levels. Alternatives S-1A, S-1C, S-5A and S-5C include excavation and offsite disposal of these soils in a Toxic Substance Control Act (TSCA) permitted facility run by Chemical Waste Management Incorporated in Arlington, Oregon, approximately 145 km (90 miles) away. The excavated area would be regraded and covered with clean soil. Onsite incineration is the

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PROCESS OPTION	TABLE 8-1. SOIL REMEDIAL ACTION ALTERNATIVES																				
	S 0	S 1A	S 1B	S 1C	S 1D	S 2A	S 2B	S 2C	S 2D	S 3A	S 3B	S 3C	S 3D	S 4A	S 4B	S 4C	S 4D	S 5A	S 5B	S 5C	S 5D
No Action	•																				
Institutional Controls	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Bioremediation of BEHP		•	•	•	•																
Onsite Incineration /Disposal																					
• All Sites						•		•													
• UN-1100-6 and Ephemeral Pool							•		•												
Offsite Incineration /Disposal																					
• All Sites										•		•									
• UN-1100-6 and Ephemeral Pool											•		•								
• UN-1100-6																		•	•	•	•
Offsite Disposal																					
• HRL and Ephemeral Pool		•		•															•		•
• Ephemeral Pool			•		•														•		•
Supercritical CO <sub>2</sub> Extraction																					
• All Sites														•		•					
• UN-1100-6 and Ephemeral Pool															•		•				
Containment at HRL																					
• MSWLF Cap				•	•			•	•			•	•			•	•			•	•
• Asbestos Cap		•	•			•	•			•	•			•	•			•	•		

treatment technology used in alternatives S-2A and S-2C for the treatment of these soils. A small mobile incinerator capable of processing 4.5 metric tons (5-tons) of contaminated soil per day would be used (see paragraph 8.2.4 for additional details). Treated soils would be returned to the subunit and the area would be regraded and covered. Alternatives S-3A and S-3C include offsite incineration at a hazardous waste incinerator operated by Chemical Waste Management Incorporated located in Port Arthur, Texas, approximately 2,100 km (1,300 mi) away. Treated soils would be disposed of in the facility's ash disposal landfill. The excavation would be regraded and covered with soil. Supercritical CO<sub>2</sub> extraction would be the treatment method used for alternatives S-4A and S-4C. Contaminant would be extracted from the soils using CO<sub>2</sub> at a supercritical state which increases its solvating properties (section 7.0 and paragraph 8.2.6.1). Treated soils would be returned to the subunit and the area would be regraded and covered with clean soil.

Costs associated with the HRL PCB's removal are \$448,000 for alternatives S-1A, S-1C, S-5A and S-5C, which would use offsite disposal. Treatment of these soils utilizing onsite incineration, alternatives S-2A and S-2C, would cost \$1,514,000. A cost of \$2,679,000 is associated with the treatment of these soils at an offsite incinerator for alternatives S-3A and S-3C. No costs were calculated for treatment of HRL soils in alternatives S-4A and S-4C because supercritical CO<sub>2</sub> extraction is an innovative technology and cost parameters are not yet available.

Initial evaluation of these costs show that they are not prohibitive. However, when coupling these options with the capping options considered for all remedial alternatives at the HRL (except the no action), remedial costs are substantial. As stated in paragraph 7.1.1, DOE considers it very unlikely that the land use at the HRL will be anything but restricted. Also, the potential for migration of contaminants from the vadose zone to the groundwater aquifer is considered minimal (paragraph 7.1.3.1). Because capping and institutional control will reduce receptor exposure to the PCB's contaminated soil, further analysis was conducted to evaluate the effectiveness in removing these soils in terms of both risk reduction and cost.

Three relationships were evaluated: incremental cancer risk versus volume of soil removed; percent reduction in risk versus soil volume removed; and percent risk reduction versus total cost. The incremental cancer risk was calculated for the maximum contaminant level which would remain after a cleanup goal was achieved based on industrial risk assessment assumptions. Cleanup goals were set at 100 mg/kg corresponding to a no action alternative; 50 mg/kg corresponding to a level at which TSCA requirements would no longer be applicable to remaining contaminants; 38 mg/kg corresponding to the 95% UCL calculated for HRL PCB's contaminated soils; 25 mg/kg corresponding to the upper bound cleanup level in EPA's guidance for PCB's cleanup (EPA, 1990a); 5.2 mg/kg corresponding to the MTCA Method C cleanup goal; and 1 mg/kg corresponding to a MTCA Method A cleanup goal. The percent reduction in risk was calculated by taking the difference between the successive incremental cancer risk values corresponding to each cleanup goal, and dividing by the total reduction in risk possible at the site (*i.e.*, the risk reduction associated with remediating from 100 mg/kg down to 1 mg/kg). The extent of contamination was calculated by estimating the areal extent of the contamination between cleanup goals by extrapolation from the maximum sample concentration at each sampling location. Volumes were calculated by estimating the depth of excavation required to attain each cleanup goal

and multiplying by the associated areas. Total cost reflects only the cost for excavation and treatment of the soils at the site and as such, is used only to define cost trends. A graphical comparison of these parameters is shown in figure 8-1 and a discussion of each follows:

- **Risk versus Soil Volume**--Incremental cancer risk is reduced one order of magnitude from  $10^{-4}$  to the  $10^{-5}$  by removing the first  $24 \text{ m}^3$  ( $31 \text{ yd}^3$ ) of contaminated soil which corresponds to the estimated volume of material above the  $50 \text{ mg/kg}$  cleanup goal. An additional  $202 \text{ m}^3$  ( $265 \text{ yd}^3$ ) must be removed to decrease the risk to the  $10^{-6}$  range which represents the attainment of the MTCA C goal of  $5.2 \text{ mg/kg}$ . Further cleanup to the MTCA A goal of  $1 \text{ mg/kg}$  requires the removal of an additional  $233 \text{ m}^3$  ( $304 \text{ yd}^3$ ) which reduces the risk, although the order of magnitude remains at  $10^{-6}$ .
- **Percent Reduction in Risk versus Soil Volume**--Fifty percent of the reduction in risk is derived from the removal of the first  $24 \text{ m}^3$  ( $31 \text{ yd}^3$ ) of contaminated soil above  $50 \text{ mg/kg}$ . An additional 46-percent reduction in risk is achieved if the MTCA C goal is met and  $202 \text{ m}^3$  ( $265 \text{ yd}^3$ ) more soil is removed. Removing  $233 \text{ m}^3$  ( $304 \text{ yd}^3$ ) more soil to meet the MTCA A standard only achieves an additional 4-percent reduction in risk.
- **Percent Reduction in Risk versus Total Cost**--The costs to achieve a 50-percent reduction in risk is relatively low for all alternatives and corresponds to the cleanup of soils above  $50 \text{ mg/kg}$  PCB's. These costs increase at a slightly higher rate in proportion to the percent reduction in risk when considering cleanup goals between  $50$  and  $5.2 \text{ mg/kg}$  PCB's. Costs increase disproportionately with respect to risk reduction when cleaning up to the most stringent goal.

Based on these comparisons, it would be most effective to remove the first  $24 \text{ m}^3$  ( $31 \text{ yd}^3$ ) of soil from the PCB's hot spot at the HRL. A 50-percent reduction in risk would be achieved at a fraction of the cost associated with a MTCA A or C cleanup goal. Incremental cancer risks would be reduced to between  $10^{-4}$  to  $10^{-5}$ . When this action is taken in addition to the proposed capping of the landfill with access and institutional control, the risks to potential receptors would be further reduced.

Therefore, the removal of all the PCB's contaminated soil at the HRL is dropped from further consideration and alternatives S-1A, S-1C, S-2A, S-2C, S-3A, S-3C, S-4A, S-4C, S-5A and S-5C are eliminated. PCB's contaminated soils above  $50 \text{ mg/kg}$  will be removed and will be considered a part of all capping options. The method of treatment will be the same used for PCB's contaminated soils at the Ephemeral Pool for each specific alternative. Figure 8-2 depicts the HRL PCB's "hot spot" and shows the approximated areal extent of the soil contaminated with greater than  $50 \text{ mg/kg}$  PCB's. The anticipated excavation depth is  $0.91 \text{ m}$  ( $3 \text{ ft}$ ). Costs associated with the various treatment methods are  $\$95,000$ ,  $\$165,000$  and  $\$226,000$  for offsite disposal, onsite incineration, and offsite incineration, respectively. There are no costs available for supercritical  $\text{CO}_2$  extraction.

**8.2.1.3 Containment at the HRL.** Of the remaining 11 alternatives, 10 include some sort of capping option at HRL. The first would be a cap option designed in accordance with

Figure 8-1(a)  
Risk vs. Soil Volume

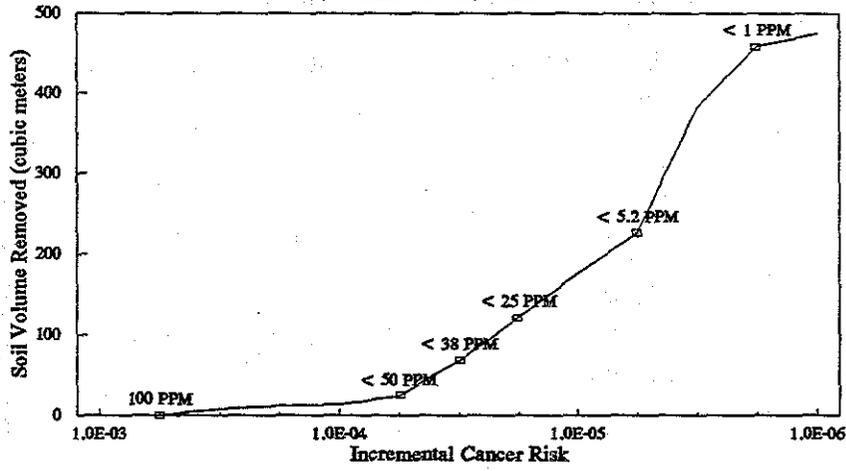


Figure 8-1(b)  
Percent Reduction in Risk vs. Soil Volume

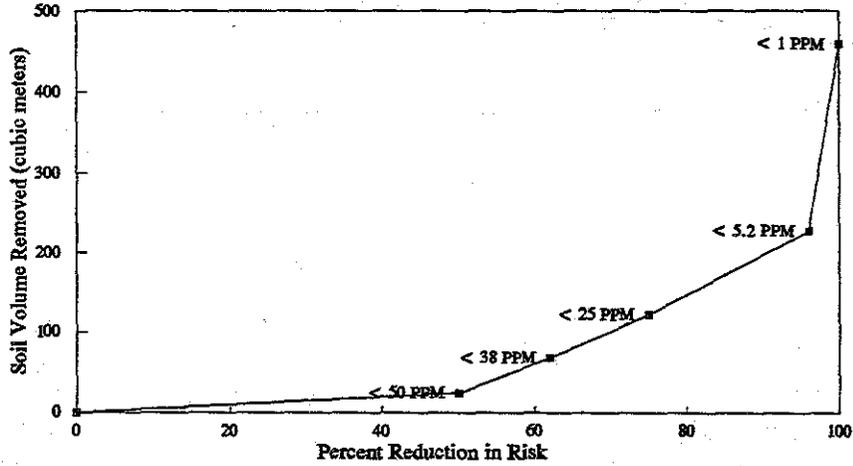


Figure 8-1(c)  
Percent Reduction in Risk vs. Total Cost

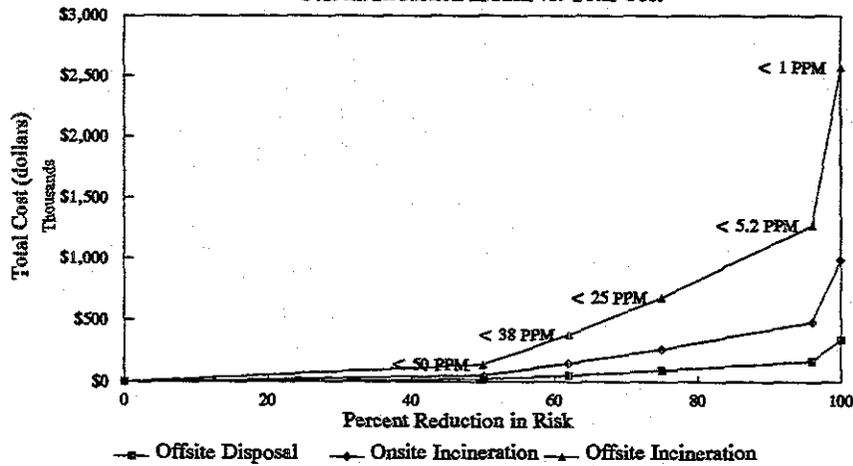
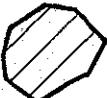
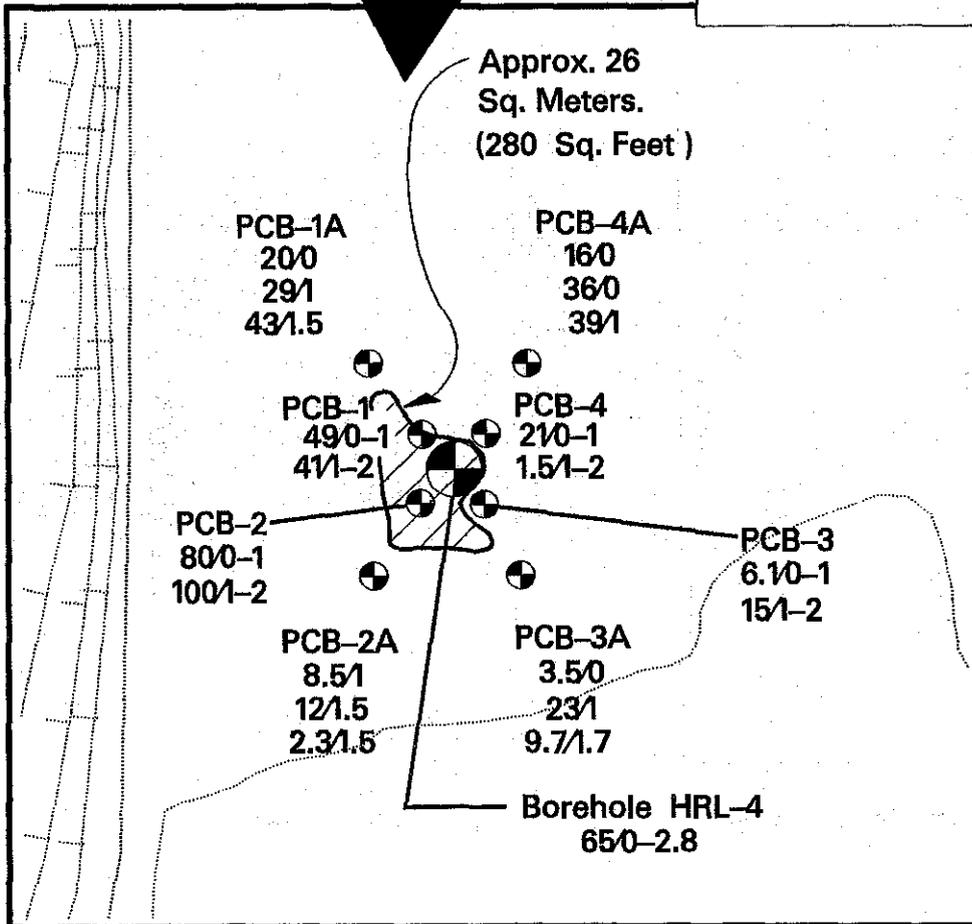


Figure 8-1. HRL PCB's PARAMETER ANALYSIS

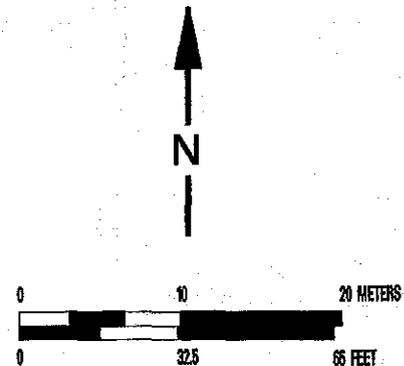
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LEGEND :

- 
**PCB-3**  
 Sample Location  
 Concentration PCBs ( mg/kg ) /  
 Sampling Depth.
- 
 Borehole Location.
- 
 Area Where PCBs Concentration  
 > 50 mg/kg.



Contour interval is 0.5 meter.



Horn Rapids Landfill – PCB Distribution PCB in mg/kg

0-8

DOE/RL-92-67

WAC 173-304-460 for the closure of municipal and solid waste landfills (MSWLF cap) in arid regions. As described in section 7.0, this would be an impermeable cap which exceeds the remedial action objectives for the subunit. This capping option was retained for evaluation to establish a baseline containment action that addresses uncertainty at the subunit. The second containment option would be a cap designed for the closure of inactive asbestos disposal sites under 40 CFR 61. Each is described and evaluated below. The capping options also include the limited removal of the HRL PCB's discussed in paragraph 8.2.1.2 and the removal and disposal or recycling of exposed discarded tires which are present in the landfill.

8.2.1.3.1 Description of the MSWLF Cap--The MSWLF cap would consist of a minimum of 15 cm (6 in) of topsoil over a 50-mil polyvinyl chloride (PVC) geomembrane. The cap would be placed over the 10.1 hectare (25 acre) area, which is estimated to be the extent of the actively used landfill. The cap would be designed to have a minimum 2-percent drainage slope to facilitate surface runoff. Because of the width of the landfill, intermediate drainage swales would be used to intercept this runoff. At these swales, 10 cm (4 in) diameter perforated pipe would be used for surface drainage collection and the intercepted runoff would be carried past the extent of the cap into a drain field where it would be allowed to percolate through the vadose zone.

The construction of the cap would require approximately 86,500 m<sup>3</sup> (113,000 yd<sup>3</sup>) of random fill material to be used in preparing an adequately sloped subgrade. Placement of the first 15 cm (6 in) of material would require special construction practices to prevent the exposure of remedial workers to possible asbestos-containing fugitive dust. A 15 cm (6 in) geomembrane bedding layer consisting of 2.54 cm (1 in) minus material would be placed on top of the random fill. Next, 87,900 m<sup>2</sup> (105,000 yd<sup>2</sup>) of geomembrane would be placed and covered with 15 cm (6 in) of topsoil. The capped area would be reseeded to establish a vegetative cover and 1.83 km (6000 ft) of perimeter fence would be constructed to restrict access to the site. Appropriate warning signs would be posted to inform the public that the area is a past landfill site that contains asbestos material. It is assumed that all earthwork materials would be obtained from offsite sources within a 16 km (10 mi) radius of HRL.

8.2.1.3.2 Evaluation of the MSWLF Cap--The MSWLF cap would be effective in preventing surface water intrusion into the landfill area and in preventing the migration of fugitive dust. Fencing around the landfill area would restrict access and would limit the potential of exposure to receptors. Contaminant volume and toxicity would not be reduced under this option; mobility of contaminated fugitive dust would be eliminated and the low potential for contaminant migration from the vadose zone to the groundwater would be reduced further. It should be noted that this action goes substantially beyond the RAO's for HRL, which are to prevent the ingestion of and dermal contact with PCB-contaminated soils, and to prevent the migration of fugitive dust containing asbestos. Short-term risks associated with the construction of the cap would be minimal and the long-term risks are substantially reduced. The long-term effectiveness of the cap would be dependent on the chemical and weather resistant properties of the geomembrane and would need to be periodically evaluated. The impact to the environment would be minimal as potential animal habitat would be disturbed during construction but would be enhanced by the placement of topsoil and a vegetative cover at the completion of cap placement.

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This option would be easily implemented. Construction of the cap would involve common methods used in industry. Earth materials are readily available near the site. There are a multitude of suppliers of geomembranes and numerous contractors who are qualified in the special methods required for their installation. Occupational Safety and Health Administration (OSHA) guidelines would have to be followed to protect workers from asbestos hazards until the initial cover layer was placed over the site.

The estimated initial capital cost for this option is \$5,445,000. O&M costs would involve periodic walkovers and visual evaluation of the cap system during its life, fence maintenance, and the maintenance of the surface drainage system. These costs are assumed to be negligible when considered over the lifetime of the cap. Additional annual costs would result from groundwater monitoring as described in paragraph 8.3.1.1.

8.2.1.3.3 Description of the Asbestos Cap--The asbestos cap would be constructed by placing 37,100 m<sup>3</sup> (48,500 yd<sup>3</sup>) of clean random fill material over the 10.1 hectare (25 acre) site which is estimated to be the area actively used as the landfill. Forty-five cm (18 in) of random fill material would be placed uniformly over the site following existing contours; no effort would be made to direct surface runoff off of the cap area. Placement of the first 15 cm (6 in) layer of this material would require the use of special construction practices to limit the exposure of remedial workers to fugitive dust. An additional 15 cm (6 in) topsoil layer would then be placed and seeded to dryland grasses. Total cap thickness would be 60 cm (2 ft). Access to the landfill area would be restricted by constructing 1.83 km (6,000 ft) of perimeter fence. Appropriate warning signs would be placed to notify the public that the area was used as a landfill and that it contains asbestos.

8.2.1.3.4 Evaluation of the Asbestos Cap--Placement of the cap would meet the RAO of preventing the migration of fugitive dust from the landfill. Construction of a perimeter fence would restrict site access and, therefore, the potential exposure to receptors would be reduced. Contaminant volume and toxicity would remain unchanged. Site risks would be reduced because there would be a significant reduction in the mobility of the asbestos. Because PCB's sorbed to soils have limited mobility within the vadose zone, a permeable cap system does not increase site risks. Because special construction practices would be employed during initial placement of the fill, short-term risks to remedial workers would be minimal. As discussed in section 7.0, this cap conforms to the "hybrid" closure requirements allowed by EPA at landfill sites with low levels of contamination.

Placement of the cap would involve standard earthwork practices and materials that are readily available within a 16 km (10 mi) radius of the site. OSHA standards would have to be followed until the initial cover layer was placed over the site to protect onsite workers from asbestos hazards. This option would be easily implemented.

An initial construction capital cost of \$2,131,000 is estimated for this option. O&M costs specific to the cap would include periodic walkovers and evaluation of the cap, and fence maintenance. These costs are assumed to be negligible over the life of the cap. Yearly groundwater sampling and analysis would be required because contaminants would be left in place. These costs are provided in paragraph 8.3.1.1 above.

**8.2.1.4 Offsite Disposal of Ephemeral Pool PCB's.** Four of the remaining options consider excavating the PCB's contaminated soil at the Ephemeral Pool and disposing of them in the TSCA permitted facility run by Chemical Waste Management Incorporated in Arlington, Oregon, approximately 145 km (90 mi) away. Under this option, approximately 250 m<sup>3</sup> (340 yd<sup>3</sup>) of contaminated soil would be removed and disposed of. Front end loaders would be used for excavation and hauling would be by Department of Transportation (DOT) approved hazardous waste haulers. The contaminated material would be hauled in bulk in approximately 28 ton truckloads. Removal of material would be in phases with confirmatory testing conducted between each phase. The RAO for this site is to remove all material to below the MTCA cleanup level of 1 mg/kg and to background levels if practicable. If this RAO was not achieved, or if any PCB's remain onsite (> 1 mg/kg) after the removal of 250 m<sup>3</sup> of material, additional soils would be removed until cleanup levels are met. If cleanup to background levels was achieved, the site would be closed without restrictions. At the completion of the removal action the site would be regraded and covered with 15 cm (6 in) of clean random fill material.

This option would reduce the mobility of PCB contaminated material at the site through removal actions; the volume and toxicity would not be reduced. Placement in a permitted offsite facility would ensure that controls are in place to prevent releases to the environment. The remedial action would be easily implemented as it requires basic earth moving equipment, DOT licensed haulers, and offsite landfill capacity, all of which are readily available. The short-term risks to remedial workers would be minimal as precautions would be taken to preclude worker exposure to contaminated material. If any PCB's remain onsite, access restrictions would prevent long-term exposure to onsite workers thus reducing risks.

The costs for this option are based on the assumption that the site would be remediated to background levels by removing a maximum of 250 m<sup>3</sup> of material. The estimated initial capital cost of this action is \$356,000. There would be no O&M costs associated with clean closure.

**8.2.1.5 Confirmatory Sampling and Analysis.** In order to determine if all contaminated soil above cleanup standards is removed, or to determine if contaminant residuals in treated soil meet cleanup standards, confirmatory sampling and analysis would be performed. Sampling and analysis costs are included as part of each remedial alternative that follows.

## **8.2.2 Alternative S-0 (No Action)**

**8.2.2.1 Description of Alternative.** This alternative is required by the NCP to establish a baseline condition to which other alternatives can be compared. Under this alternative, no action would be taken to remediate any of the contaminated soil sites. The current monitoring program would be revised to require annual sampling only over the next 30 years. During this period, if sample analysis indicates that conditions at the site are deteriorating, the program would be reevaluated. If at the end of 30 years, conditions at the site are unchanged or are improved, the monitoring program would be discontinued.

**8.2.2.2 Evaluation of Alternative.** This alternative would not reduce the toxicity, mobility, or volume of the contaminated media. If the current land use patterns of the site remain the same, the maximum incremental cancer risk of  $5E-5$  and hazard index of 0.3 for an onsite worker, as determined in appendix K based on the 95-percent UCL, would still exist. These levels are within the acceptable range set forth in the NCP but are slightly higher than those set forth in MTCA. As stated in appendix L, there are no risks to ecological receptors from the contaminants present that are distinguishable from the baseline conditions.

There are no technical requirements for the implementation of this alternative. Administratively, there may be some opposition to leaving contaminants in place by regulatory agencies and the public. The costs of this alternative would be those associated with continued site-wide monitoring as identified in paragraph 8.2.1.1.

### 8.2.3 Alternative S-1B and S-1D

**8.2.3.1 Description of Alternatives.** These alternatives consider the use of bioremediation for the BEHP contaminated soil at the Discolored Soil Site, removal and offsite disposal of the PCB's contaminated soil at the Ephemeral Pool, and either an asbestos cap (S-1A) or a MSWLF cap (S-1D) at HRL. Contaminated soil at the HRL above 50 mg/kg PCB's would be disposed of offsite. Bioremediation would be through the method of landfarming. A diked treatment area approximately 30.5 m by 36.6 m (100 ft by 120 ft) would be constructed onsite and lined with an impervious geomembrane. The contaminated soil, estimated to be a maximum of  $340 \text{ m}^3$  ( $440 \text{ yd}^3$ ), would be excavated and placed into the treatment area. A sprinkler system would deliver a mixture of water, nutrients, and microorganisms, specifically cultured for their ability to degrade BEHP, to the soils approximately twice a week. The soils would be tilled after each application of this mixture to provide additional mixing and aeration. Excess water would be collected and recycled. A bioreactor would be required onsite to culture the microorganisms. It was assumed that bioremediation would be conducted for 36 weeks a year with a suspension of operations during the colder winter months, which inhibit bacterial growth and respiration. The entire remediation process was assumed to take 2 years. However, this is a crude estimate and the actual time would be better estimated after treatability testing. After remediation, the soils would be placed back at the Discolored Soil Site and the area would be regraded and covered with 15 cm (6 in) of topsoil assuming that it meets the Land Disposal Restriction (LDR) Best Demonstrated Available Technology (BDAT) requirement of no more than 28 mg/kg of BEHP. If this requirement was not met, a land disposal treatability variance would be petitioned for.

**8.2.3.2 Effectiveness of Alternatives.** The effectiveness of bioremediation on BEHP soils is not well documented. At one site, BEHP in soils was reduced from 700 mg/kg to a few parts per million (WST, 1992). However, even with a treatment efficiency of 99 percent, for soils with a 95-percent UCL of 18,000 mg/kg, this treatment would not reduce contaminant levels to below the MTCA cleanup goal of 71 mg/kg. Treatability studies would better define the actual treatment levels that may be achieved. Therefore, it is difficult to predict the levels to which toxicity would be reduced. Unless the soils are

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remediated to background levels, which is unlikely, there would be no reduction in volume or mobility.

Landfarming would be an easily implemented treatment method. Initial construction of the facility would be simple. O&M would be somewhat difficult due to the sensitivity of the bacterial colonies, however, this would be overcome by initial operator training. The facility would have to meet RCRA guidelines for land treatment units.

The initial capital cost for each alternative, including offsite disposal of the Ephemeral Pool PCB's soil and capping of HRL is estimated at \$4,202,000 for alternative S-1B and at \$7,516,000 for alternative S-1D. These costs include the anticipated 2-year O&M costs of the landfarming operation. The life cycle present worth costs of annual monitoring were identified in paragraph 8.3.1.1.

#### 8.2.4 Alternatives S-2B and S-2D

**8.2.4.1 Description of Alternative.** These alternatives would use onsite incineration and disposal for the destruction of PCB's and BEHP at the Ephemeral Pool and the UN-1100-6 subunits, respectively. Alternative S-2B would use a cap designed for asbestos containment while, alternative S-2D would use a MSWLF cap at the HRL. Contaminated soil at the HRL above 50 mg/kg PCB's would also be incinerated onsite.

Onsite incineration would be accomplished by using a small mobile incinerator capable of processing approximately 4.5 metric tons (5-tons) of contaminated soil per day. Between the two operable subunits there would be approximately 1,100 metric tons (1,210 tons) of contaminated soils to be processed. Rotary kiln technology would be used to process materials as big as 5 cm (2 in) in diameter. Electricity would be used to power the combustion source. Combustion off gases would be treated to meet air quality standards for emissions through use of a secondary combustion chamber and wet scrubbers. Ashes would be quenched with water and the quench water would be recirculated. After incineration, the ash would be placed back at the operable subunit and the area would be regraded and covered with 15 cm (6 in) of topsoil.

Materials would be excavated using standard equipment for earthwork. Confirmatory testing would be conducted to ensure that all contaminated soils above cleanup levels are removed. A 30.5-m (100-ft) graded square pad would be required to house the incinerator. The pad would be located in an area that is central to the operable subunits. Precautions would be taken to ensure that material would not be spilled when transporting it from the site to the incinerator.

**8.2.4.2 Evaluation of Alternatives.** Incineration has been proven to be effective with 99.9 percent destruction efficiencies for PCB's and BEHP (EPA, 1991b). This option would reduce contaminant levels to below the MTCA requirements of 1 mg/kg for PCB's and 71 mg/kg for BEHP. Additionally, the LDR BDAT of 28 mg/kg for BEHP can be met. This method would significantly reduce the toxicity of the soils. The volume of soils would be slightly reduced, while the mobility of the contaminants that remain after incineration

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would stay the same. Soils redeposited after processing are likely to have some residual contaminants, however, these would be minimal and should not prohibit the delisting of the sites.

Mobile incinerator technology would be readily available making these alternatives easy to implement technically. Administratively, acquiring the approvals to operate the incinerator may be difficult due to public opposition. A test burn may be required to ensure that air emissions criteria are met and to evaluate the ash characteristics.

Specific evaluation of the capping options are as described above. Costs for these alternatives including the O&M costs for the incinerator and the capping costs for HRL, are estimated to be \$5,801,000 and \$9,115,000 for alternatives S-2B and S-2D, respectively. There would be no costs associated with O&M after incineration is complete.

## 8.2.5 Alternatives S-3B and S-3D

**8.2.5.1 Description of Alternatives.** In these alternatives, offsite incineration to destroy contaminants in subunit soils would be chosen as the remedial action. Approximately 1,100 metric tons (1,210 tons) of contaminated soils from the UN-1100-6 and Ephemeral Pool subunits would be excavated and shipped to an offsite incinerator. DOT licensed hazardous waste haulers would carry the contaminated soils in bulk truck loads of 18.2 metric tons (20 tons) to the Chemical Waste Management Incorporated RCRA licensed facility in Port Arthur, Texas, approximately 2,100 km (1,300 mi) away. After incineration, the ash would be disposed of in this facility's ash disposal landfill. Post action sampling and analyses of remaining subunit soils would be required to confirm the level of cleanup. At the completion of the removal action, the site would be regraded and covered with 15 cm (6 in) of clean random fill. These alternatives would require either an asbestos cap (alternative S-3B) or a MSWLF cap (alternative S-3D) as the containment option at HRL. An additional 45 metric tons (50 tons) of soil from the HRL (> 50 mg/kg PCB's) would be shipped to the incinerator.

**8.2.5.2 Evaluation of Alternatives.** The capping components of these alternatives were described previously. The efficiency of this option would be the same as that achieved for onsite incineration. In addition to reducing toxicity, this option reduces contaminant mobility because soils are removed from the site, treated, and placed in a controlled landfill. The volume of material would be slightly reduced in the incineration process.

There is both adequate incineration and transportation capacity to easily implement this alternative. Also, the public would be less likely to oppose treating and disposing of the soils offsite in an already permitted facility.

The estimated cost of alternative S-3B including the asbestos cap for HRL is \$6,325,000. A cost of \$9,639,000, which includes the MSWLF cap at HRL, is estimated for alternative S-3D. Life-cycle present worth and annual monitoring costs were identified in paragraph 8.3.1.1. There would be no O&M costs associated with these alternatives.

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## 8.2.6 Alternatives S-4B and S-4D

**8.2.6.1 Description of Alternatives.** Treatment for the Discolored Soil Site and Ephemeral Pool soils are accomplished through the use of supercritical CO<sub>2</sub> extraction under these alternatives. Again, alternative S-4B includes the asbestos cap at the HRL, and alternative S-4D includes the MSWLF cap, both of which have been previously described. HRL soils contaminated with PCB's above 50 mg/kg would also be treated through this process. This treatment technology has been retained to this point because it is innovative in nature and bench scale studies have shown promising results. Although this application is commonly used commercially for the decaffeination of coffee, equipment has not yet been developed for the decontamination of soil. The process is described in detail in section 7.0. Conceptually, contaminated soils would be fed into a reactor in which it would be subjected to a constant flow of supercritical CO<sub>2</sub> for a certain period of time determined through treatability testing. The treated soil would have the majority of contaminants removed and could possibly be redeposited at the sites. The extract would be brought back to ambient pressure and temperature and the CO<sub>2</sub> would return to its gaseous state. The remaining liquid would be free product of either PCB's or BEHP that could either be recycled or detoxified through some other treatment process.

**8.2.6.2 Evaluation of Alternatives.** Bench scale studies recently performed (WHC, 1992) on contaminated soils from both the Discolored Soil Site and the HRL site have shown 97-percent and 99-percent removal efficiencies through this process for BEHP and PCB's, respectively. Improved efficiencies may be possible by altering the temperature or pressure used in the process. Further bench scale studies will concentrate on these parameters to determine the most optimal extraction conditions.

Because this technology is only emerging, there is no equipment available to implement this treatment method. While bench scale tests have shown positive results, the actual design of material handling and process equipment has not been refined for the processing of soils. It is difficult to predict when the technology would even be available at a pilot scale. Because of the uncertain timeframe in its continued development, this technology is dropped from further consideration as a remedial alternative. However, because of the positive bench scale results, DOE will pursue the development of this technology for use in other areas at the Hanford site. This option should be reconsidered for this OU if development of this technology progresses significantly in the near future.

## 8.2.7 Alternatives S-5B and S-5D

**8.2.7.1 Description of Alternatives.** These alternatives would treat 619 metric tons (682 tons) of contaminated Discolored Soil Site soils using offsite incineration, dispose of 250 m<sup>3</sup> (340 yd<sup>3</sup>) of Ephemeral Pool soils in an offsite landfill, and use the asbestos cap (alternative S-5B) or the MSWLF cap (alternative S-5D) at HRL. Additionally, PCB-contaminated soil above 50 mg/kg would be disposed of offsite.

**8.2.7.2 Evaluation of Alternatives.** As previously discussed, offsite incineration for the treatment of BEHP soils would be effective in reducing contaminant toxicity and mobility.

Disposal of PCB contaminated soils in a TSCA landfill does not reduce volume or toxicity, however, mobility would be controlled through containment measures instituted by the facility. These options would reduce long-term exposure to onsite workers by removing contaminated materials. As indicated, these options would be easily implemented. The estimated initial capital cost of alternative S-5B is \$5,336,000. Alternative S-5D is estimated to have an initial capital cost of \$8,650,000. There are no O&M costs associated with this alternative. The yearly groundwater sampling and analyses cost and the life-cycle present worth cost, assuming clean closure of the Discolored Soil Site and Ephemeral Pool sites, would be as described in paragraph 8.3.1.1 for the 30 year period.

### 8.2.8 Summary of Remedial Alternative Costs

A summary of the retained remedial action alternative costs is provided in table 8-2. The detailed evaluation of these alternatives will be performed in section 9.0.

## 8.3 GROUNDWATER REMEDIAL ACTION ALTERNATIVES

The remaining groundwater process options are assembled to present a range of treatment alternatives. These are represented by alternatives GW-0 through GW-4B in table 8-3. Alternatives with the same first three descriptions are similar except that the treatment method for TCE differs. All pump and treat alternatives include the treatment of nitrates. As discussed in earlier sections, the treatment of nitrates is secondary to that for TCE. For this reason, only one nitrate treatment method is evaluated. Should pump and treat be selected as the remedial alternative, nitrate treatment methods will be re-evaluated during the remedial design. Common features of alternatives are first described and evaluated. Finally, complete alternatives are described and evaluated against the screening criteria.

### 8.3.1 Proposed Point of Compliance and Indicator Contaminant

An integral part of any groundwater remedial action is the establishment of a point of compliance (POC) at which the contaminants of concern must meet ARAR's. For groundwater at HRL, the George Washington Way diagonal, as described in section 6.0 (see figure 6-25) is proposed as the POC. The reasons for this proposal are: the diagonal is a conveniently oriented construct that is easily identified and is within DOE property boundaries; from modeling results, the outer edge of the TCE plume which is above MCL's is approximately 600 m (2,000 ft) upgradient of the proposed POC; and the 300 Area is approximately 300 m (1,000 ft) downgradient of the POC at its nearest point providing a buffer zone between the two areas.

The risks from groundwater at this site are a result of TCE contamination when calculated using the uncertain residential land use scenario. Even under this conservative scenario, nitrate contamination does not pose a significant risk. As discussed in section 7.0, the presence of nitrate alone in the groundwater at the reported levels would not trigger

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TABLE 8-2. SOIL REMEDIAL ALTERNATIVE COSTS

Alternative	S-0	S-1B	S-1D	S-2B	S-2D	S-3B	S-3D	S-5B	S-5D
Capital Cost	\$0	\$3,579,000	\$6,893,000	\$5,178,000	\$8,492,000	\$5,702,000	\$9,016,000	\$4,713,000	\$8,027,000
Annual Monitoring Cost	\$52,150	\$40,500	\$40,500	\$40,500	\$40,500	\$40,500	\$40,500	\$40,500	\$40,500
Lifecycle Present Worth of Annual Costs <sup>1</sup>	\$802,000	\$623,000	\$623,000	\$623,000	\$623,000	\$623,000	\$623,000	\$623,000	\$623,000
Total Present Worth Costs	\$802,000	\$4,202,000	\$7,516,000	\$5,801,000	\$9,115,000	\$6,325,000	\$9,639,000	\$5,336,000	\$8,650,000

<sup>1</sup> 30 year life.

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PROCESS OPTION	TABLE 8-3. GROUNDWATER REMEDIAL ACTION ALTERNATIVES							
	GW-0	GW-1	GW-2A	GW-2B	GW-3A	GW-3B	GW-4A	GW-4B
No Action	●	●						
Institutional Controls								
● Monitoring	●	●	●	●	●	●	●	●
● Points of Compliance with Contingency Plan		●						
Extraction-Infiltration								
● Scenario 1			●	●				
● Scenario 2					●	●		
● Scenario 3							●	●
TCE Treatment								
● Air Stripping			●		●		●	
● Chemical/UV Oxidation				●		●		●
Nitrate Treatment								
● Reverse Osmosis			●	●	●	●	●	●

remedial actions. Therefore, TCE is proposed as the indicator contaminant and the site would be out of compliance when TCE levels above MCL's are detected at the POC. As noted in section 6.0, nitrate has greater dispersion than TCE, which accounts for the bigger nitrate plume. It is not unreasonable to assume that nitrates (possibly above MCL's) would be detected at the proposed POC well in advance of TCE.

### 8.3.2 Common Components

The components that are common to a number of alternatives are described in the following paragraphs.

**8.3.2.1 Institutional Controls.** Institutional controls would consist of maintaining the existing land use, preventing the drilling of consumptive wells, and supplying future users through Richland's existing municipal distribution system. These controls would be both technically and administratively implementable. The costs of these controls would be minimal. Additionally, yearly groundwater sampling and analysis would be required until such time as contaminant levels equal background. For this evaluation, groundwater monitoring is assumed to be continued for 30 years for each alternative. The annual cost of sampling and analysis associated with the monitoring of HRL plume is estimated at \$40,500, which corresponds to a life-cycle present worth of \$623,000. It should be noted that these are the same monitoring wells used for the evaluation of releases from the contaminated soil sites. Therefore, to preclude accounting for these costs twice, they have not been considered as part of the groundwater alternative costs as they have already been considered in the soil alternatives.

**8.3.2.2 Extraction-Infiltration Scenario 1.** Under this scenario groundwater would be pumped at a rate of 0.38 m<sup>3</sup>/min (100 gpm) through one extraction well. The extracted water would be treated and then would be distributed to an infiltration system consisting of 61 m (200 ft) of 31 cm (12 in) diameter perforated pipe from which the treated water would be recharged into the ground. The extraction well would be approximately 18.3 m (60 ft) deep. The bottom 6.1 m (20 ft) would be screened. A 5 horsepower(hp)-pump would be used to push the water through 92 m (300 ft) of 8 cm (3 in) diameter pipe to the head of the treatment train. After treatment, the water would be pumped from a sump to the recharge system using a 1/2 hp pump. A general location of the well and recharge trench is shown in figure 6-33.

It is estimated that the plume would be remediated to below the MCL by the year 2012 under this pumping scenario. Capital costs are associated with the well, pumping, and piping networks. O&M costs are required mainly for power and occasional pump servicing. These costs are included in the evaluations to follow.

**8.3.2.3 Extraction-Infiltration Scenario 2.** Three wells each being pumped at a rate of 0.38 m<sup>3</sup>/min (100 gpm) each, for a combined total of 1.14 m<sup>3</sup>/min (300 gpm), are the basis of this extraction scheme. Each well would be 18.3 m (60 ft) deep and would be screened over the bottom 6.1 m (20 ft). The water would be pumped by 5 hp pumps through 8 to 10 cm (3 to 4 in) diameter transmission line to the head of the treatment train. A total of

495 m (1,625 ft) of pipeline is required. After treatment, the effluent would be collected in a sump and a 3 hp pump would be used to discharge the effluent to a 183 m (600 ft) long infiltration trench containing 31 cm (12 in) diameter perforated pipe. The approximate locations of the wells and the recharge trench for this scheme are shown in figure 6-33.

Under this scenario, the contaminated plume would be remediated to below MCL's by the year 2008. Capital costs are based on the installation of new wells and the transmission piping system. O&M costs reflect the cost of annual monitoring and occasional pump maintenance. Evaluations that follow include these costs.

**8.3.2.4 Extraction-Infiltration Scenario 3.** This scenario represents the most aggressive pumping scenario considered. Ten wells, each extracting at a rate of 0.38 m<sup>3</sup>/min (100 gpm), for a total of 3.79 m<sup>3</sup>/min (1,000 gpm), would be installed. Each well would be equipped with a 7.5 hp pump. The water would be conveyed through a 8 to 20 cm (3 to 8 in) diameter transmission line to the head of the treatment train. Approximately 725 meters (2,375 ft) of transmission pipeline would be required. After treatment, the effluent would be collected in a sump and then pumped using a 20 hp pump to the infiltration system. The infiltration system consists of 610 m (2,000 ft) of 31-cm- (12-in)-diameter perforated pipe in a trench that would be 305 m long by 6.1 m wide (1,000 ft by 20 ft).

Alternatives employing extraction-infiltration scenario 3 (GW-4A and GW-4B) are predicted to remediate the aquifer in the least amount of time (9 years). However, as stated in section 6.0, 100 percent additional water outside the 5 ppb TCE plume would be captured and treated. Preliminary estimates indicate that treatment of this clean water more than doubles the costs of alternatives utilizing extraction-infiltration scenario 2 (GW-3A and GW-3B) and only reduces the remediation timeframe by 4 years. The capture zone analysis performed in section 6.0 indicates that the optimum pump and treat scenario would include wells extracting between 0.38 and 1.14 m<sup>3</sup>/min (100 and 300 gpm). For these reasons, alternatives GW-4A and GW-4B are dropped from further consideration.

**8.3.2.5 Additional Monitoring Wells.** In all alternatives (except GW-0, the no-action alternative), six additional wells would be installed in order that the contaminant plume can be more effectively monitored. Three wells would be installed just west of and parallel to the proposed POC. Three other wells would be installed at locations to be determined downgradient of HRL. The depth of these wells would be approximately 18.3 m (60 ft). Wells shall be cased using 10.2 cm (4 in) diameter stainless steel. The bottom 6.1 m (20 ft) of the well shall be screened with a 10-slot stainless steel well screen. The initial capital costs of the additional wells is estimated at \$685,000. Annual sampling and analyses costs for these additional wells would be \$24,300. Life-cycle present worth costs would vary according to the estimated life of the project.

### 8.3.3 Alternative GW-0

**8.3.3.1 Description of Alternative.** This is the "no action" alternative required by the NCP for the purpose of establishing a baseline remediation scenario to which all other alternatives can be compared. Under this alternative, no active measures would be undertaken to

remediate the TCE and nitrates in the groundwater. A long-term monitoring program would be implemented to characterize the migration of contaminants over time. Existing administrative controls would remain in place.

**8.3.3.2 Evaluation of Alternative.** It is estimated that the groundwater contaminants in the plume would naturally attenuate to below MCL's by the year 2017 and that no TCE above MCL's would cross the George Washington Way diagonal. Because there are no downgradient users, there would be no additional risks to humans during this remediation timeframe. This option does not reduce contaminant volume or mobility. Toxicity would be reduced through dispersion and dilution. Technically, this alternative would be easily implemented. Administratively, there may be some concern with leaving contaminants in place. The costs associated with this alternative are those required for yearly groundwater monitoring. There are no capital costs associated with this alternative.

### 8.3.4 Alternative GW-1

**8.3.4.1 Description of Alternative.** This alternative would be similar to Alternative GW-0 in that no active remedial action would be taken initially. Instead, six new monitoring wells will be installed and a point of compliance would be established along a line just west of and parallel to George Washington Way. Three of the new monitoring wells would be installed along this line and would provide information on contaminant migration to this point. In addition, a contingency plan would be developed in the event that TCE at levels above MCL's were detected at these wells.

**8.3.4.2 Evaluation of Alternative.** Under the most conservative groundwater modeling scenario, TCE at levels above MCL's do not migrate past The George Washington Way diagonal and naturally attenuate by the year 2017. Establishing the diagonal as a POC within the DOE site boundary, provides some insurance if the actual conditions differ from those modelled. If TCE above MCL's is detected at any of the three new wells along the diagonal, a contingency plan can be initiated. As in the no action scenario, there are no additional risks to human health during the anticipated remediation timeframe because there are no downgradient groundwater users. This alternative would be easy to implement technically and, administratively, may be better accepted because a contingency plan would be in place to trigger an appropriate response should conditions warrant. The costs of this alternative include the construction of six additional monitoring wells, and the yearly sampling and analysis required for monitoring. The initial capital cost and the present worth life-cycle costs of this alternative are estimated at \$1,059,000. This assumes that no remedial action would be necessary in the future based on modeling results.

### 8.3.5 Alternatives GW-2A Through GW-3B

**8.3.5.1 Description of Alternatives.** These alternatives would treat various flow rates of extracted groundwater using two separate treatment trains. Alternatives GW-2A and GW-3A treat 0.38 and 1.14 m<sup>3</sup>/min (100 and 300 gpm) flows, respectively, using air stripping for treatment of TCE and reverse osmosis for the treatment of nitrates. Alternatives GW-2B and

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GW-3B use an ultraviolet (UV)/oxidation system to treat TCE and reverse osmosis for the treatment of nitrates at these same respective flows.

8.3.5.1.1 Pretreatment Units--At the head end of each process train, high flow multi-media filters would remove sediments from the groundwater. This would prevent fouling of the air stripping media and of the osmotic membrane. Filters or a combination of filters are available to meet the proposed design flows (Culligan, 1992). Filters have been sized for flow rates of  $0.28 \text{ m}^3/\text{min-m}^2$  (7 gpm/ft<sup>2</sup>). The filters would require periodic backwashing to remove accumulated sediments. Because of the low turbidity of the groundwater, it is anticipated that backwashing would only be required a maximum of twice daily. Backwash flow rates are  $.80 \text{ m}^3/\text{min}$  (210 gpm) for each filter used. One filter is required for the  $.38 \text{ m}^3/\text{min}$  (100 gpm) system and two are required for the  $1.14 \text{ m}^3/\text{min}$  (300 gpm) system. Backwash cycles are 13 minutes in duration. Settling tanks of  $50 \text{ m}^3$  (4,000 gal) and  $100 \text{ m}^3$  (8,000 gal) would be used to settle solids. The tanks are sized so that one-third of their capacity is reserved for sludge storage. It is anticipated that these tanks have adequate capacity to store all sludge generated over the lifetime of the pump and treat systems. At the conclusion of operations, this sludge would require treatment prior to disposal. Overflow from the settling tanks would be pumped back to the head of the system for treatment.

8.3.5.1.2 Air Strippers--Air strippers are commonly used for the removal of TCE from groundwater. As described in section 7.0, stripping makes use of TCE's favorable Henry's Law Constant. Air would be passed countercurrent to water flow and the volatile organic contaminant would be transferred from the liquid phase to the gas phase. Air stripping units for the various flow rates would have the following design parameters (Hydro Group, 1992). Strippers are used in Alternatives GW-3A, GW-4A, and GW-5A.

<u>Parameter</u>	<u><math>0.38 \text{ m}^3/\text{min}</math></u>	<u><math>1.14 \text{ m}^3/\text{min}</math></u>
Height	7.63 m (25 ft)	7.63 m (25 ft)
Diameter	0.61 m (2 ft)	1.22 m (4 ft)
Packing Height	4.57 m (15 ft)	4.57 m (15 ft)
Blower Size	1 hp	3 hp

All units would be constructed of structural aluminum and would be free standing.

8.3.5.1.3 UV/Oxidation Units--The UV/oxidation process is described in section 7.0 and applies to the treatment of TCE (alternatives GW-2B and GW-3B). Typical processes would mix the contaminated water with ozone and hydrogen peroxide in a reaction chamber. This mixture would then be irradiated with UV light. Off gases would be treated in a catalytic ozone decomposer and then released to the air. Units, or a combination of units, are available to treat the range of design flows (ULTROX, 1992). System components would consist of an oxidation reactor, ozone generator, compressor, air dryer, air filter, hydrogen peroxide feed system, a vapor treatment unit, and associated programmable logic controls.

For the respective flow rates, 12.7 and 45.4 kilograms (kg) [28 and 100 pounds (lbs)] of ozone would need to be generated per day.

8.3.5.1.4 Reverse Osmosis--Reverse osmosis is chosen as the process option to remove nitrates to below MCL's. As described in section 7.0, hydrostatic pressure would be used to drive feedwater through a semipermeable membrane while a major portion of the contaminant content would remain behind and would be discharged as waste. This waste discharge would then be flash evaporated, leaving behind residue, which could easily be disposed of. Units, or a combination of units, are available to treat the range of flows proposed (Culligan, 1992). Standard systems would feature a thin-film composite spiral-wound-reverse osmosis membrane, fiberglass membrane housings, panel mounted and in-line instruments for monitoring of system performance, and a water quality monitor. These systems are assumed to operate with a 75-percent recovery rate.

8.3.5.2 Evaluation of Alternatives. Each of these alternatives would be effective in reducing the contaminant levels in the groundwater to below MCL's. Air stripping would transfer the TCE to the gas phase and would not reduce the overall volume or toxicity of the TCE. Mobility would be transferred from the liquid phase to the gas phase. Emissions of TCE to the atmosphere are not considered to be a substantial health risk at this site. TCE emissions for the proposed treatment rates are estimated to be 52.6 and 157.7 grams/day (0.12 and 0.35 lbs/day) based on the average TCE concentrations from eight rounds of sampling. Because TCE concentrations have been falling with each successive sampling round, this estimate is conservative. TCE would also degrade in the atmosphere after several days. The process would be easily implemented with a number of vendors available who can supply units. Administratively, obtaining approval for direct release of emissions to the atmosphere should not be difficult due to the low inherent risks.

The UV/oxidation system would destroy the TCE and convert it to CO<sub>2</sub> and water. The system would effectively reduce TCE concentrations to below MCL's. Volume, mobility, and toxicity of the contaminant would all be reduced. There is only one known vendor of this system, however, obtaining equipment should not pose a problem. Administratively, obtaining approval for the use of this system should not be a concern.

Reverse osmosis has proven effective in removing nitrates to below MCL's. Residuals from this process are easily disposed of. Volume would not be reduced, but toxicity and mobility are reduced as nitrate would remain as a constituent of a solid residue. This technology is readily available and would be easily implemented with a number of available equipment suppliers. There should be no administrative obstacle in using this technology.

Initial capital costs have been estimated and are summarized in table 8-4. Vendor quotes for all equipment were obtained. O&M costs are based on pumping, chemical, and energy requirements. Where possible, costs were obtained from the vendor, otherwise costs are approximate values.

Costs of all other retained alternatives are also summarized in table 8-4. Detailed evaluation of these alternatives will be conducted in section 9.0.

TABLE 8-4. GROUNDWATER REMEDIAL ALTERNATIVE COSTS<sup>1</sup>

Alternative	GW-0 <sup>2</sup>	GW-1 <sup>2</sup>	GW-2A <sup>3</sup>	GW-2B <sup>3</sup>	GW-3A <sup>4</sup>	GW-3B <sup>4</sup>
Capital Cost	\$0	\$685,000	\$1,536,000	\$2,072,000	\$3,557,000	\$4,228,000
Annual O&M Cost	\$0	\$0	\$232,000	\$238,000	\$481,000	\$514,000
Annual Monitoring for Six Additional Wells	\$0	\$24,300	\$24,300	\$24,300	\$24,300	\$24,300
Lifecycle Present Worth Cost of Annual Costs	\$0	\$374,000	\$2,890,000	\$2,957,000	\$4,747,000	\$5,057,000
Total Present Worth Costs	\$0	\$1,059,000	\$5,111,000	\$5,714,000	\$8,989,000	\$9,970,000
<sup>1</sup> Annual sampling and analysis cost of \$40,500 for existing wells are not included in these costs; they were previously considered for soil alternatives. <sup>2</sup> 30-year life. <sup>3</sup> 17-year life. <sup>4</sup> 13-year life.						

## 9.0 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

The candidate remedial alternatives are evaluated in detail in this section. The evaluation criteria used in this analysis are discussed in paragraph 9.2. Detailed descriptions of the alternatives were provided in section 8.0. After each alternative is individually assessed against these criteria, a comparative analysis is made to evaluate the relative performance of each alternative in relation to the specific evaluation criteria.

### 9.1 EVALUATION CRITERIA

Each alternative is evaluated against nine criteria. They are: the overall protection of human health and the environment; compliance with ARAR's; long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; cost; state acceptance; and community acceptance. The first two are considered "threshold criteria" and relate to statutory requirements. The next five are considered "balancing criteria" and consider a number of subcriteria to allow a more thorough analysis and evaluation. State and community acceptance are appropriately reviewed during the receipt of public comment and the development of the proposed plan. Evaluation of these two criteria are beyond the scope of this report. The criteria and subcriteria are those described in FS guidance (EPA, 1989) and are briefly summarized below.

#### 9.1.1 Criterion 1--Overall Protection of Human Health and the Environment

This evaluation criterion provides a final check to assess whether each alternative meets the requirements that it is protective of human health and the environment. The overall assessment of protection draws on the assessments conducted under other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARAR's.

This evaluation will focus on how an alternative achieves protection over time and how site risks are reduced. The analysis considers how each source of contamination is to be eliminated, reduced, or controlled for each alternative.

#### 9.1.2 Criterion 2--Compliance with ARAR's

This evaluation criterion is used to determine whether each alternative will meet the Federal and state ARAR's that have been identified. The analysis will summarize the requirements that are applicable or relevant and appropriate to the alternative and will describe how each is met. The following is addressed for the detailed analysis of ARAR's:

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- Compliance with chemical-specific ARAR's;
- Compliance with action-specific ARAR's; and
- Compliance with location-specific ARAR's.

### 9.1.3 Criterion 3--Long-Term Effectiveness and Permanence

The evaluation of alternatives under this criterion addresses the results of a remedial action in terms of the risks remaining at the site after response objectives have been met. The primary focus of this evaluation is the extent and effectiveness of the controls that may be required to manage the risk posed by treatment residuals and/or untreated wastes. The following sub-criteria are addressed:

- Magnitude of residual risk;
- Adequacy of controls; and
- Reliability of controls.

### 9.1.4 Criterion 4--Reduction of Toxicity, Mobility, or Volume Through Treatment

This evaluation criterion addresses both the Federal and state statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of the hazardous substance as their principal element. This preference is satisfied when treatment is used to reduce the principal threats at a site through the destruction of toxic contaminants, reduction of the total mass of toxic contaminants, irreversible reduction in contaminant mobility, or reduction in total volume of contaminated media.

The evaluation focuses on the following specific factors for a particular remedial alternative:

- The treatment processes the remedy will employ, and the materials they will treat;
- The amount of hazardous materials that will be destroyed or treated, including how the principal threat(s) will be addressed;
- The degree to which the treatment will be irreversible;
- The type and quantity of treatment residuals that will remain; and

- Whether the alternative would satisfy the statutory preference for treatment as a principal element.

#### 9.1.5 Criterion 5--Short-Term Effectiveness

This evaluation criterion addresses the effects of the alternative during the construction and implementation phase until remedial response objectives are met (*e.g.*, a cleanup target has been met), as well as the speed with which risks posed by the site are addressed. Alternatives are evaluated with respect to their effects on human health and the environment during implementation of the remedial action. The following factors will be addressed:

- Protection of the community during remedial actions;
- Protection of workers during remedial actions;
- Environmental impacts; and
- Time until remedial action objectives are met.

#### 9.1.6 Criterion 6--Implementability

The implementability criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during its implementation. The following factors are analyzed:

- Technical feasibility including construction and operation, reliability of technology, and the ease of undertaking additional remedial action;
- Administrative feasibility; and
- Availability of services and materials including offsite storage and treatment capacity, and the availability of equipment, services, and personnel.

#### 9.1.7 Criterion 7--Cost

The cost of each alternative is presented including estimated capital, annual costs, and present worth costs. The accuracy of all costs are within the plus 50-percent to minus 30-percent range specified in EPA guidance. Capital costs include the direct costs of equipment, labor, and materials necessary to install remedial alternatives. Annual costs are post-construction costs necessary to ensure effectiveness of the remedial action. Present worth costs are calculated to evaluate expenditures that occur over different time periods by

discounting all future costs and annual costs to a common base year. For this report a discount rate of 5 percent was used to determine present worth costs. Detailed costs are presented in section 8.0 with backup provided in appendix N.

### 9.1.8 Criterion 8--State Acceptance

State acceptance is assessed based on the evaluation of the technical and administrative issues and concerns that state regulatory agencies have regarding each of the alternatives. This criterion will be addressed in the Record of Decision (ROD) once comments on the RI/FS and the proposed plan are received.

### 9.1.9 Criterion 9--Community Acceptance

This assessment evaluates the issues and concerns the public may have regarding each of the alternatives. As with state acceptance, this criterion will be addressed in the Record of Decision once comments on the RI/FS and proposed plan are received.

## 9.2 EVALUATION OF SOIL REMEDIAL ALTERNATIVES

The remaining soil remedial alternatives are evaluated against the seven criteria that are possible to address at this time in the following paragraphs. At the conclusion of these individual evaluations a comparative analysis is made. A detailed description of each alternative is provided in paragraph 8.2.

### 9.2.1 Alternative S-0 (No Action)

Under this alternative, no action would be taken to remediate the site actively and annual monitoring of existing downgradient wells would be implemented.

**9.2.1.1 Criterion 1--Overall Protection of Human Health and the Environment.** The remedial action objectives for all the sites would not be satisfied. Continued exposure to contaminated soil by industrial onsite workers would be possible. Maximum site ICR to industrial workers is  $5E-05$  and the maximum HI is 0.3. For the uncertain long-term residential land use scenario, the maximum ICR is  $4E-04$  and the HI is 3.4 assuming that land use at the HRL remains restricted.

**9.2.1.2 Criterion 2--Compliance with ARAR's.** MTCA cleanup levels would not be achieved by this alternative.

**9.2.1.3 Criterion 3--Long-Term Effectiveness and Permanence.** Residual risks would be as stated above. Groundwater monitoring would be a reliable and adequate control to determine if contaminants are migrating offsite. Continued industrial land use would ensure

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that potential exposure would be limited to onsite workers; however, there is uncertainty as to industrial land use in the long-term future.

**9.2.1.4 Criterion 4--Reduction of Toxicity, Mobility, or Volume Through Treatment.**

There would be no reduction in the toxicity, mobility, or volume of the contaminants under this alternative.

**9.2.1.5 Criterion 5--Short-Term Effectiveness.** Because no active remedial actions would be undertaken there would be no short-term risks to remedial workers or the public. There would be no impacts to the environment due to construction or operation.

**9.2.1.6 Criterion 6--Implementability.** This alternative would be easily implemented. Monitoring would be conducted using established procedures. No permits, special equipment, or specialists would be required.

**9.2.1.7 Criterion 7--Cost.** The present worth cost of this alternative is estimated at \$802,000.

**9.2.2 Alternative S-1B**

Under this alternative soils at the Discolored Soil Site would be bioremediated, PCB-contaminated soil from the Ephemeral Pool would be removed and disposed of offsite, and HRL would be capped for the containment of asbestos. The PCB-contaminated soil above 50 mg/kg will also be disposed of offsite. Additionally, annual groundwater monitoring is conducted, access would be restricted to sites on which contaminants remain, and the current land use would be continued.

**9.2.2.1 Criterion 1--Overall Protection of Human Health and the Environment.** All of the remedial action objectives would be satisfied by this alternative. Potential receptor exposure to contaminated materials would be significantly reduced by either reducing the toxicity of the contaminants through bioremediation, removal of the contaminants offsite, or through the combined effects of containment and access restrictions.

**9.2.2.2 Criterion 2--Compliance with ARAR's.** Achievement of MTCA cleanup levels may not be possible for the bioremediation of BEHP at the Discolored Soil Site. Also, the operation of this facility would need to comply with RCRA requirements. A land disposal variance would have to be petitioned for if these soils did not meet RCRA Land Disposal Restriction Best Demonstrated Achievable Technology requirements prior to land disposal.

Achievement of MTCA cleanup levels would be attained at the Ephemeral Pool. Materials would be disposed of in a TSCA approved facility and transported according to DOT regulations.

MTCA cleanup levels for PCB's would not be achieved at HRL; however, the removal of the highly contaminated soils, containment, continued monitoring, and access restrictions would reduce exposure to the contaminant and would comply with Ecology's

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requirements for actions involving containment. The asbestos cap would comply with the requirement for capping inactive landfills containing asbestos. Installation of a soil cap would be consistent with the EPA policy for closure of landfills containing contaminants at low concentrations. Warning signs would alert the public to the potential hazards of the landfill as required.

**9.2.2.3 Criterion 3--Long-Term Effectiveness and Permanence.** Cleanup to the MTCA levels at the Discolored Soil Site and Ephemeral Pool subunits would reduce residual risks at those sites to the E-6 range and below. If bioremediation of the Discolored Soil Site soils does not reduce contaminant levels to below MTCA goals, risks would be higher and additional actions (removal, treatment, and/or containment) may be required. Risks from the PCB's at HRL would be reduced to the E-5 range assuming a restricted land use. Capping and restricting access at this site would be adequate and reliable controls which would also significantly reduce the potential for exposure. Continued yearly downgradient monitoring would determine if contaminants are migrating offsite and if additional remedial measures would be necessary.

**9.2.2.4 Criterion 4--Reduction of Toxicity, Mobility, or Volume Through Treatment.** The toxicity of the bioremediated Discolored Soil Site soil would be reduced under this alternative. Because residuals of the contaminant would still exist, volume and mobility would remain the same.

Offsite disposal of the PCB-contaminated soil at the Ephemeral Pool and the HRL would reduce the mobility of the contaminant onsite. Disposal in a controlled TSCA facility would limit the mobility of the contaminant offsite. The volume and toxicity of the contaminated soil would be unchanged.

The asbestos cap would not reduce either the toxicity, mobility, or volume of PCB-contaminated soil at HRL. The mobility of fugitive dust containing asbestos would be reduced.

**9.2.2.5 Criterion 5--Short-Term Effectiveness.** There would not be any short-term risks to the community during the implementation phase of this alternative. Control measures would be taken to control fugitive dust as part of any remedial action. Remedial workers would be required to wear protective coveralls to protect against dermal exposure. At HRL, special construction practices including dust suppression would be utilized to prevent worker exposure to asbestos.

During remediation, there would be some disruption of the environment due to earthmoving activities. However, after the sites are remediated, the areas would be regraded to restore the land to near original conditions. At HRL, topsoil would be provided and the area would be seeded to dryland grass to provide future habitat for birds and small mammals.

Bioremediation of the Discolored Soil Site is estimated to require about 2 years from the start of onsite activities. This remediation timeframe is not well constructed and can be better established after treatability studies are conducted. The removal action at the

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Ephemeral Pool and HRL can be completed within 3 months of beginning site work. Six months would be required to complete the capping and installation of the fence at HRL.

**9.2.2.6 Implementability.** Bioremediation is a commonly used technology that requires no special equipment. Initial operator training would be required to establish procedures for culturing the microorganisms and for supplementing and aerating the soil. Confirmatory testing would be required to determine when cleanup levels are achieved. If this treatment cannot achieve cleanup objectives, other methods described in this report can be readily instituted.

Removal of PCB's to an offsite facility would also be easy to implement. Excavation of material would be by using conventional earthmoving equipment. Confirmatory testing would be conducted to ensure that all material above the cleanup level is removed. An approved TSCA facility with more than sufficient capacity is located at Arlington, Oregon, approximately 145 km (90 miles) away. A number of licensed DOT hazardous waste haulers are available who could transport this material.

Construction of a cap to contain asbestos would require only conventional earthwork practices. Earth materials for fill are available within a 16.1-km (10-mile) radius of the site. No special permits would be required.

**9.2.2.7 Cost.** The total present worth cost of this alternative is estimated at \$4,202,000.

### 9.2.3 Alternative S-1D

This alternative would be similar to alternative S-1B except that a cap designed in accordance with WAC 173-304 would be used instead of the asbestos cap. Consequently, the evaluation that follows only considers this difference.

**9.2.3.1 Criterion 1--Overall Protection of Human Health and the Environment.** The use of a WAC cap in this alternative would satisfy the remedial action objectives. Potential receptor exposure to contaminants would be significantly reduced through the capping of the site and the imposition of access restrictions.

**9.2.3.2 Criterion 2--Compliance with ARAR's.** Again, MTCA cleanup levels for PCB's would not be achieved at HRL, however, exposure to the contaminant would be significantly reduced and the action would comply with Ecology's requirements for actions involving containment. The WAC cap conforms to state requirements for capping of landfills in arid climates. Warning signs would alert the public to the potential hazards of the landfill as required.

**9.2.3.3 Criterion 3--Long-Term Effectiveness and Permanence.** Removal of the PCB-contaminated soil above 50 mg/kg reduces the ICR to the E-5 range assuming restricted land use. Capping and access restrictions would also significantly reduce the likelihood of exposure and would be adequate and reliable controls. Continued annual monitoring of

downgradient wells would be used to evaluate the cap and to determine if additional measures would be necessary.

**9.2.3.4 Criterion 4--Reduction of Toxicity, Mobility, or Volume Through Treatment.**

The cap would not reduce the volume or toxicity of the PCB's. The cap would be impermeable thus infiltration would be reduced. This should further reduce the already limited mobility of the PCB's. The mobility of fugitive dust containing asbestos would be reduced.

**9.2.3.5 Criterion 5--Short-Term Effectiveness.** Construction of the cap would not pose a risk to the community. Special precautions would be taken to control fugitive dust that may contain asbestos to protect remedial workers. Construction would disturb 10.1 hectares (25 acres), that may currently be inhabited by wildlife. A topsoil cover seeded to dryland grass would be installed to provide habitat after construction is complete. Construction of the WAC cap would be completed within 6 months of starting work at the site.

**9.2.3.6 Criterion 6--Implementability.** The cap would be constructed using conventional practices and should be easily implemented. Geomembranes would be available from multiple vendors and there are a number of contractors that are qualified in their installation. Earth fill materials are readily available within a 16.1-km (10-mile) radius. No special permits would be required for construction.

**9.2.3.7 Criterion 7--Cost.** The total present worth cost of this alternative is estimated at \$7,516,000.

**9.2.4 Alternative S-2B**

This alternative considers the use of onsite incineration for the destruction of contaminants at the Discolored Soil Site and Ephemeral Pool subunits. Remedial action at HRL consists of capping for the containment of asbestos and the use of access restrictions. The capping option was evaluated as part of a previous alternative and is not reviewed here. Additionally, PCB-contaminated soil above 50 mg/kg will also be incinerated onsite. Annual downgradient groundwater monitoring would be employed to evaluate remedial actions.

**9.2.4.1 Criterion 1--Overall Protection of Human Health and the Environment.**

Remedial action objectives would be met through this alternative. At the Ephemeral Pool and the Discolored Soil Site, residual risks would be reduced to less than E-6 if cleanup levels are obtained; no residual risks from these contaminants would remain if clean closure is obtained. At the HRL, residual risks would be reduced to the E-5 range assuming restricted use.

**9.2.4.2 Criterion 2--Compliance with ARAR's.** The ARAR for MTCA cleanup levels would be met under this alternative at the Discolored Soil Site and Ephemeral Pool. MTCA cleanup levels would not be achieved at the HRL but the alternative would comply with Ecology's requirements for sites using containment. The onsite incineration facility would be required to meet RCRA standards for incineration facilities and also to meet regional air

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quality standards. Ash from the process would have little residual contaminant and should meet requirements to allow replacement at the subunits.

**9.2.4.3 Criterion 3--Long-Term Effectiveness and Permanence.** There should be little or no residual risks associated with remediation of this site as indicated above at the Discolored Soil Site and Ephemeral Pool. Risks from PCB's at the HRL would be reduced to the E-5 range. If contaminants above background remain, annual monitoring would provide reliable controls to establish if subsequent releases occur.

**9.2.4.4 Criterion 4--Reduction of Toxicity, Mobility, or Volume Through Treatment.** Toxicity of the contaminants would be significantly reduced as these processes typically have 99.9 percent destruction removal efficiencies. Incineration of soils would not reduce volume substantially. Mobility of the remaining residuals would remain the same.

**9.2.4.5 Criterion 5--Short-Term Effectiveness.** There should be no risk to the community during remediation if the incinerator is operating properly. Air quality would be monitored and the operation would not proceed if emissions do not meet standards. Remedial workers would require protective clothing to prevent dermal contact. Impacts to the environment would consist of the excavation of contaminated materials and the construction of a pad to house incineration facilities. After remediation these areas would be regraded to return the site to near original conditions.

**9.2.4.6 Criterion 6--Implementability.** Vendors are available to supply onsite incineration facilities that have proven effectiveness in remediating soils with similar contaminants. Operation of the incinerator would typically be done by vendor supplied operators. Ashes can be tested to determine if cleanup goals are being met. The incinerator must meet the requirements of RCRA and be approved by state agencies in accordance with the TPA.

**9.2.4.7 Criterion 7--Cost.** The present worth total cost of this alternative is estimated at \$5,801,000.

## 9.2.5 Alternative S-2D

This alternative is similar to alternative S-2B except that a WAC cap is employed for the containment at HRL. Evaluation of the first six criteria has previously been presented in the above discussions. The only criterion that differs is the present worth total cost which is estimated at \$9,115,000.

## 9.2.6 Alternative S-3B

This remedial alternative utilizes incineration at an offsite facility for the remediation of the Discolored Soil Site and Ephemeral Pool contaminated soils in conjunction with a cap for asbestos containment and access restrictions at HRL. Capping and access restrictions at HRL were previously considered and are not evaluated further here. Contaminated soils

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above 50 mg/kg at the HRL will also be incinerated offsite. Groundwater sampling would be conducted annually to monitor the effectiveness of the remedial actions.

**9.2.6.1 Criterion 1--Overall Protection of Human Health and the Environment.** This alternative would meet the site-wide remedial action objectives. Risks to human health from these specific contaminants would be reduced to below 1E-06 if MTCA cleanup levels are obtained and eliminated if the site attains clean closure at the Discolored Soil Site and Ephemeral Pool. Assuming a restricted land use at the HRL, risks will be reduced to the E-5 range.

**9.2.6.2 Criterion 2--Compliance with ARAR's.** All ARAR's would be met at the Discolored Soil Site and Ephemeral Pool. MTCA cleanup goals would not be achieved at the HRL but the alternative would comply with Ecology's requirements for actions involving containment. The contaminated material would be hauled by a licensed DOT hazardous waste hauler. The receiving facility would have a permit to operate a RCRA facility. Ash disposal would be in an RCRA-approved facility.

**9.2.6.3 Criterion 3--Long-Term Effectiveness and Permanence.** Long-term risks, as indicated above, would be significantly reduced through this action at the Discolored Soil Site and Ephemeral Pool. Risks at the HRL are reduced to the E-5 range. If contaminant residuals do remain, monitoring of groundwater would provide adequate controls to measure the effectiveness of the action.

**9.2.6.4 Criterion 4--Reduction of Toxicity, Mobility, or Volume Through Treatment.** Contaminant toxicity would be reduced due to the high destruction removal efficiencies associated with this process option. If residuals remain, their mobility would be unaffected. Volume would be only slightly reduced through the incineration of soils.

**9.2.6.5 Criterion 5--Short-Term Effectiveness.** There would be no risks to the community from the offsite incineration alternative. Risks to remedial workers would be minimized by requiring the use of protective clothing to prevent dermal exposure. Excavation of the contaminated material would disturb the relatively small sites. Post remediation activities would include regrading to return the area to near original conditions. The two subunits would be remediated within 3 months of commencing site activities.

**9.2.6.6 Criterion 6--Implementability.** This alternative would be easily implemented. A commercial incinerator is available in Port Arthur, Texas, approximately 2,100 km (1,300 miles) away. This incinerator accepts contaminated soils and has adequate capacity. Excavation of material would be by conventional equipment and transportation is readily available through a number of licensed haulers. There would be no administrative requirements for onsite activities. Confirmatory testing would be used to determine when cleanup levels are achieved.

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**9.2.6.7 Criterion 7--Cost.** The total present worth cost of this alternative is \$6,325,000.

### 9.2.7 Alternative S-3D

This alternative uses a WAC cap as the containment option at the HRL in lieu of the cap for asbestos containment thus distinguishing it from alternative S-3B. Evaluations of all the components that comprise this option have been discussed in previous sections. Cost is the only criterion that differs and the total present worth costs of this alternative is estimated at \$9,639,000.

### 9.2.8 Alternative S-5B

This alternative is a hybrid alternative that utilizes offsite incineration for the Discolored Soil Site soils contaminated with BEHP and, offsite disposal for the PCB's contaminated soils of the Ephemeral Pool. A cap for asbestos containment would be used at the HRL along with removal and offsite disposal of PCB-contaminated soil above 50 mg/kg, access restrictions, and continued annual groundwater monitoring. Each of these components were previously discussed and are not evaluated further. The present worth total cost of this alternative is estimated at \$5,336,000.

### 9.2.9 Alternative S-5D

Like Alternative S-5B, offsite incineration for Discolored Soil Site soils and offsite disposal for Ephemeral Pool soils would be utilized. This option, however, employs a WAC cap at HRL, along with removal and offsite disposal of PCB-contaminated soil above 50 mg/kg, access restrictions, and continued annual groundwater monitoring. The present worth total costs of this alternative is estimated at \$8,650,000.

### 9.2.10 Comparative Analysis

In the following analysis, the alternatives are evaluated in relation to one another for each of the evaluation criteria. The purpose of this analysis is to identify the relative advantages and disadvantages of each alternative.

**9.2.10.1 Criterion 1--Overall Protection of Human Health and the Environment.** All the alternatives would meet the remedial action objectives established at the site with the exception of alternative S-0. Protection of human health would be provided by reducing the risks associated with the dermal contact and ingestion pathways. Alternatives S-1B, S-1D, S-5B, and S-5D achieve protection by a combination of treatment, removal, and disposal, and containment options. Alternatives S-2B, S-2D, S-3B, and S-3D achieve protection by the same technology, incineration, except that the method (onsite or offsite) differs. Containment at HRL would be through one of two capping options.

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**9.2.10.2 Criterion 2--Compliance with ARAR's.** All actions except alternative S-0 have the potential of meeting ARAR's. For alternative S-0, MTCA cleanup levels would not be attained. Bioremediation may be less effective in reducing BEHP levels in alternatives S-1B and S-1D. The efficiency of cleanup would need to be determined in order to evaluate if MTCA cleanup levels can be met. Capping and treatment of the PCB-contaminated soils greater than 50 mg/kg at HRL would not address MTCA cleanup levels, however, capping of landfills containing contaminants at low concentrations is consistent with EPA policy and these actions would comply with Ecology's requirements for sites involving containment.

**9.2.10.3 Criterion 3--Long-Term Effectiveness and Permanence.** Alternatives S-2B, S-2D, S-3B, and S-3D offer the highest degrees of long-term permanence because these alternatives use treatment methods that permanently reduce toxicity at the Discolored Soil Site and Ephemeral Pool subunits. For Alternatives S-2B and S-2D, soils containing residuals would be disposed of onsite. Alternatives S-5B and S-5D also have high degrees of long-term permanence because contaminants would be either destroyed or removed offsite to a controlled facility. Alternatives S-1B and S-1D have the potential for long-term permanence if contaminants could be degraded to below cleanup levels. Otherwise, additional remedial actions may be necessary. No long-term maintenance would be required at these subunits.

The capping options would require periodic evaluation and maintenance to preserve their integrity. The asbestos cap would maintain its functionality provided that the asbestos material remains covered. Functionality of the WAC cap would be maintained as long as the geomembrane remains covered and is not ruptured. This cap option has the added benefit of reducing infiltration into the landfill area. Long-term monitoring would ensure that releases from HRL would not be occurring and would be critical for evaluating effectiveness. The reduction in exposure to receptors relies on maintaining access restrictions and current land uses.

Alternative S-0 would not reduce any residual site risks.

**9.2.10.4 Criterion 4--Reduction of Toxicity, Mobility, or Volume Through Treatment.** Toxicity would be reduced through alternatives S-2B, S-2D, S-3B, and S-3D. Alternatives S-1B, S-1D, S-5B, and S-5D reduce toxicity for BEHP contaminated soils at the Discolored Soil Site only.

Onsite mobility would be reduced through alternatives S-1B, S-1D, S-3B, S-3D, S-5B, and S-5D by removing materials offsite. However, mobilities of the contaminants at offsite facilities remain the same even though they may be controlled.

Alternatives utilizing incineration reduce soil volumes very little. All other alternatives do not reduce volume.

Capping options reduce the mobility of fugitive dust that may contain contaminants. Mobility of contaminants in the vadose zone remain the same (practically immobile) although, the WAC cap reduces infiltration that potentially could further reduce mobility.

Alternative S-0 would not reduce the toxicity, mobility, or volume of contaminated soils.

**9.2.10.5 Criterion 5--Short-Term Effectiveness.** All alternatives present relatively low risks to the community during implementation. Some fugitive dust emissions from cap construction activities would be anticipated although precautions would be taken to reduce these to protect both remedial workers and the community. Risks to remedial workers for all other alternatives would be reduced by using protective clothing.

The onsite biological treatment option for alternatives S-1B and S-1D is estimated to require approximately 2 years to complete. The onsite incineration option of alternatives S-2B and S-2D is estimated to take less than 1 year to complete. All offsite treatment options would be accomplished within 3 months of initiating field activities. The capping options in each of the alternatives would be constructed within 6 months of initiating field activities.

**9.2.10.6 Criterion 6--Implementability.** All alternatives would be technically easy to implement. Alternatives S-1B and S-1D require some operator training and knowledge of the process. Alternatives S-2B and S-2D require the mobilization, set up, and trial testing of the incinerator to ensure that applicable standards would be met. Operating personnel would be supplied by the vendor. The capping options would only require typical construction practices using readily available materials. Offsite disposal or treatment facilities considered in alternatives S-1B, S-1D, S-3B, S-3D, S-5B, and S-5D all have adequate capacity to receive these materials. Also, there are numerous licensed haulers who would be able to transport these materials.

**9.2.10.7 Criterion 7--Cost.** The no action alternative has the least total present worth costs. These costs are associated with annual groundwater monitoring for the next 30 years. O&M costs for all remaining alternatives would be the same because total cleanup of the Discolored Soil Site and Ephemeral Pool subunits is assumed and the only costs would be associated with the yearly monitoring of wells downgradient of HRL. Options that use the asbestos cap at HRL would be less costly than those that use the WAC cap. Alternatives that use a combination of treatment for soils at the UN-1100-6 subunit and offsite disposal of the soils from the Ephemeral Pool subunit would be less costly than alternatives that utilize either onsite or offsite incineration. A summary of estimated costs is presented in table 8-2.

**9.2.10.8 Summary of Soil Remedial Alternatives Evaluation.** Table 9-1 is a summary of the evaluation of groundwater alternatives versus the seven criteria against which they were evaluated.

### 9.3 EVALUATION OF GROUNDWATER REMEDIAL ALTERNATIVES

The remaining groundwater remedial alternatives are evaluated against the seven criteria that are possible to address at this time in the following sections. A comparative analysis is made at the conclusion of these individual evaluations. A detailed description of each alternative is provided in paragraph 8.3.

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**TABLE 9-1. EVALUATION OF SOIL REMEDIAL ALTERNATIVES**

<b>CERCLA CRITERIA</b>	<b>S-0 No Action</b>	<b>S-1B</b>	<b>S-1D</b>	<b>S-2B</b>	<b>S-2D</b>	<b>S-3B</b>	<b>S-3D</b>	<b>S-5B</b>	<b>S-5D</b>
Overall Protection	L/M	M/H							
Compliance with ARAR's	L	M/H	M/H	M/H	H	M/H	H	M/H	H
Long-Term Effectiveness and Permanence	L	M/H	H	M/H	H	M/H	H	M/H	H
Reduction of Toxicity, Mobility, Volume	L	L/M	M	M	M/H	M	M/H	M	M/H
Short-Term Effectiveness	L/M	M/H	M/H	M/H	M/H	H	H	H	H
Implementability	H	H	H	H	H	H	H	H	H
Cost (Present Worth) Thousands of Dollars	\$802K	\$4,202K	\$7,516K	\$5,801K	\$9,115K	\$6,325K	\$9,639K	\$5,336K	\$8,650K
<p>L = Low--Does not meet all elements of the Criterion adequately                      M = Medium--Does meet all elements of the Criterion adequately                      H = High--Meets all of the elements of the Criterion to a high degree</p>									

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### 9.3.1 Alternative GW-0

No active remedial measures would be undertaken under this alternative. Annual groundwater monitoring would be implemented to evaluate the migration of contaminants over time. Existing administrative controls that specify land use and restrict well drilling for consumptive purposes would remain in place. New facilities would receive water supplied through the City of Richland's distribution network.

**9.3.1.1 Criterion 1--Overall Protection of Human Health and the Environment.** This alternative would meet the remedial action objectives of the site. Overall risks to human health would be minimal because there are no current receptors. Continued use of the institutional controls would prevent future exposure. This alternative leaves contamination in place, that allows for further migration of the plume. However, groundwater modeling results have estimated that at no point in time would groundwater with TCE above MCL's cross the George Washington Way diagonal.

**9.3.1.2 Criterion 2--Compliance with ARAR's.** This alternative would attain SDWA MCL's by the year 2017 through natural attenuation as estimated by groundwater modeling. No other ARAR's apply to this alternative.

**9.3.1.3 Criterion 3--Long-Term Effectiveness and Permanence.** After natural attenuation to below MCL's is complete, the long term residual incremental cancer risk would be reduced to 1E-6 for TCE and the hazard quotient for nitrates would be 0.17. Groundwater monitoring would be a reliable control to determine the rate and concentration of plume migration.

**9.3.1.4 Criterion 4--Reduction of Toxicity, Mobility, or Volume Through Treatment.** The toxicity of contaminants would be reduced through the effects of diffusion, dispersion, dilution, and biodegradation. Mobility and volume would remain the same.

**9.3.1.5 Criterion 5--Short-Term Effectiveness.** There would be no additional risks to the community, environment, or remedial workers because no action will be taken. Assuming a common start date for all alternatives in the year 1995, the most conservative modeling estimate is that natural attenuation to below MCL's would be complete in 22 years.

**9.3.1.6 Criterion 6--Implementability.** This alternative would be easily implemented. The annual groundwater monitoring would be conducted under procedures already established for this site.

**9.3.1.7 Criterion 7--Cost.** There would be no costs associated with this alternative.

### 9.3.2 Alternative GW-1

This alternative would be similar to the no action alternative except that points of compliance would be established on a line just west and parallel to George Washington Way. Three monitoring wells would be installed along this line to monitor the plume migration.

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An additional three wells will be installed down-gradient of the HRL. A contingency plan would be implemented if TCE above MCL's is detected at any of these wells.

**9.3.2.1 Criterion 1--Overall Protection of Human Health and the Environment.** Site remedial action objectives would be accomplished under this alternative. Maintenance of institutional controls would ensure that there would be no receptors of the groundwater, thus making the risks to human health minimal. Again, contamination would be left in place and would be allowed to migrate. However, natural attenuation of the entire plume to below MCL's would be expected by the year 2017.

**9.3.2.2 Criterion 2--Compliance with ARAR's.** This alternative would comply with SDWA MCL's when attenuation is complete.

**9.3.2.3 Criterion 3--Long-Term Effectiveness and Permanence.** The residual incremental cancer risk associated with attenuation to MCL's would be  $1E-6$  and the hazard quotient would be 0.17. Groundwater monitoring would be a reliable control to determine if attenuation is complete. Natural attenuation is generally recommended when warranted because of site-specific conditions, *e.g.*, where groundwater is unlikely to be used in the foreseeable future and, therefore, can be remediated over an extended period of time, or where natural attenuation is expected to reduce the concentration of contaminants in the groundwater to the remediation goals in a reasonable time frame (55 FR 8734 and EPA, 1988d).

**9.3.2.4 Criterion 4--Reduction of Toxicity, Mobility, or Volume Through Treatment.** There would be no reduction in contaminant volume or mobility under this alternative. Contaminant toxicity would be reduced through dispersion, diffusion, and dilution.

**9.3.2.5 Criterion 5--Short-Term Effectiveness.** There would be no additional risks to the community or environment due to this action. Risks to remedial workers associated with monitoring well installation would also be low. There is no transfer of contaminants from one media to another. There is no transport of contaminants or disposal at another site. Natural attenuation to MCL's would be expected to be complete in 22 years under the most conservative modeling estimate.

**9.3.2.6 Criterion 6--Implementability.** This alternative would be technically easy to implement with the only new construction consisting of well development. Obtaining regulatory approval for setting the points of compliance and leaving contaminants in place would be required. Annual groundwater monitoring would reliably evaluate the effects of natural attenuation throughout the remediation timeframe. If TCE above the MCL is detected at the points of compliance, a contingency plan would be implemented to assure an appropriate response.

**9.3.2.7 Criterion 7--Cost.** The total present worth cost of this alternative is estimated at \$1,059,000, which assumes that natural attenuation would occur as modelled and that no additional remedial action would be necessary. This cost includes the capital cost of well construction and annual monitoring cost over a 30-year period.

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### 9.3.3 Alternative GW-2A

Groundwater would be actively remediated under this scenario. An extraction rate of 0.38 m<sup>3</sup>/min (100 gpm) would be used. Groundwater would be treated by air stripping (to remove TCE) and by reverse osmosis (to remove nitrates) to reduce contaminant levels to below MCL's. Effluent from the treatment train would be recharged through an infiltration trench. Current institutional controls would remain in place and six additional monitoring wells would be installed.

**9.3.3.1 Criterion 1--Overall Protection of Human Health and the Environment.** This alternative meets the remedial action objectives for the site. Risks to human health would be minimal because there are no current or potential consumptive users of the groundwater. Remediation to below MCL's would be expected by the year 2012.

**9.3.3.2 Criterion 2--Compliance with ARAR's.** The groundwater would be remediated to SDWA MCL's. TCE emissions from the air stripper would not be expected to be above levels that require treatment.

**9.3.3.3 Criterion 3--Long-Term Effectiveness and Permanence.** Remediation to MCL's reduces the site incremental cancer risk to below 1E-6 and the hazard quotient to 0.17. However, it should be noted that while case studies have shown pump and treat options to be effective in controlling contaminant migration, it is less effective in cleaning up an aquifer to MCL's (Doty, 1991 and paragraph 6.4.6.2). Groundwater monitoring would provide reliable controls to assess the effectiveness of the remedial action. Maintenance would be required for pumps and treatment units to ensure their proper operation.

**9.3.3.4 Criterion 4--Reduction of Toxicity, Mobility, or Volume Through Treatment.** This extraction scenario would only capture the portion of the TCE contaminant plume above 35 ppb. The rest of the plume would be allowed to migrate and naturally attenuate. Upon transfer of the TCE to the gas phase by stripping, its mobility would be increased. However, TCE would degrade naturally in the atmosphere after a number of days.

Likewise, only a portion of the nitrate plume would be captured and the remainder would be allowed to attenuate naturally. There would be no reduction of nitrate volume. However, toxicity and mobility would be reduced because nitrate would be contained in the solid residue remaining after treatment.

**9.3.3.5 Criterion 5--Short-Term Effectiveness.** The risks associated with TCE emissions to the community and environment would be minimal because of the low emission rate and the fact that there are no residential areas in close proximity. Risks to workers installing wells and the extraction system and operating the system would be low. There would be minor disruption of the environment for construction activities.

Remediation under this scenario would be expected to take 17 years. The environment would be minimally impacted by construction activities.

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**9.3.3.6 Criterion 6--Implementability.** This alternative would be implemented easily. The required equipment, materials, and construction techniques are common to industry. The treatment units should reliably meet remediation goals.

**9.3.3.7 Criterion 7--Cost.** The total present worth cost for this alternative, including additional monitoring wells and yearly sampling, is \$5,111,000.

#### **9.3.4 Alternative GW-2B**

This alternative would be similar to alternative GW-2A except that a UV/Oxidation treatment unit would be used in lieu of an air stripper for TCE treatment.

**9.3.4.1 Criterion 1--Overall Protection of Human Health and the Environment.** This alternative meets the remedial action objectives for the site. Risks to human health would be minimal because there are no current or potential consumptive users of the groundwater. Remediation to below MCL's would be expected by the year 2012.

**9.3.4.2 Criterion 2--Compliance with ARAR's.** SDWA MCL's would be met under this alternative. No other ARAR's were identified.

**9.3.4.3 Criterion 3--Long-Term Effectiveness and Permanence.** Remediation to MCL's reduces the site incremental cancer risk to below  $1E-6$  and the hazard quotient to 0.17. However, it should be noted that while case studies have shown pump and treat options to be effective in controlling contaminant migration, it is less effective in cleaning up an aquifer to MCL's. Groundwater monitoring would provide reliable controls to assess the effectiveness of the remedial action. Maintenance would be required for pumps and treatment units to ensure their proper operation.

**9.3.4.4 Criterion 4--Reduction of Toxicity, Mobility, or Volume Through Treatment.** This treatment scheme would destroy TCE and thus would reduce its volume. Again, only the portion of the plume above 35 ppb would be captured using this extraction scenario. The remainder of the plume would be allowed to naturally attenuate.

There would be no reduction in nitrate volume; toxicity and mobility would be reduced because nitrate exists in a solid state after treatment. Like TCE, only a portion of the nitrate plume would be captured and the remainder would be left to naturally attenuate.

**9.3.4.5 Criterion 5--Short-Term Effectiveness.** There would be minimal risks to the community and remedial workers during the implementation of this alternative. The environment would be slightly impacted by construction activities. It is estimated that the plume would be remediated to below MCL's in 17 years.

**9.3.4.6 Criterion 6--Implementability.** The treatment units required for this alternative would be available from vendors, and construction of the facilities requires only common practices. The treatment process would require review from the regulators and no difficulties are anticipated. Therefore, this alternative should be easily implemented.

**9.3.4.7 Criterion 7--Cost.** The total present worth cost of this alternative is \$5,714,000. The costs of institutional controls are included.

### 9.3.5 Alternative GW-3A

Under this alternative, groundwater would be extracted at a rate of 1.14 m<sup>3</sup>/min (300 gpm) through three extraction wells. The water would be treated through a treatment train similar to that of alternative GW-2A, except that it would be sized for the larger flow. Six additional monitoring wells would be installed and existing institutional controls remain in place.

**9.3.5.1 Criterion 1--Overall Protection of Human Health and the Environment.** This alternative meets the remedial action objectives for the site. Risks to human health would be minimal because there are no current or potential consumptive users of the groundwater. Remediation to below MCL's would be expected by the year 2008.

**9.3.5.2 Criterion 2--Compliance with ARAR's.** The groundwater would be remediated to SDWA MCL's. TCE emissions from the air stripper would not be expected to be above levels that require treatment.

**9.3.5.3 Criterion 3--Long-Term Effectiveness and Permanence.** Remediation to MCL's reduces the site incremental cancer risk to below 1E-6 and the hazard quotient to 0.17. However, it should be noted that while case studies have shown pump and treat options to be effective in controlling contaminant migration, it is less effective in cleaning up an aquifer to MCL's. Groundwater monitoring would provide reliable controls to assess the effectiveness of the remedial action. Maintenance would be required for pumps and treatment units to ensure their proper operation.

**9.3.5.4 Criterion 4--Reduction of Toxicity, Mobility, or Volume Through Treatment.** This extraction scheme captures the portion of the TCE plume that would be above the 5 ppb MCL. The remaining contaminants would be allowed to migrate and attenuate naturally. TCE mobility would be increased when it is stripped and transferred to the gas phase. However, TCE would degrade in the atmosphere after only a few days.

This alternative also would capture a larger portion of the nitrate plume. That portion that would not be captured would be allowed to migrate and naturally attenuate. There would be no reduction of nitrate volume. However, toxicity and mobility would be reduced because nitrate would be contained in the solid residue remaining after treatment.

**9.3.5.5 Criterion 5--Short-Term Effectiveness.** The risks to the community and environment associated with TCE emissions would be minimal because of the low emission rate and the fact that there would be no residential areas in close proximity. Risks to workers installing wells and the extraction system and operating the system would be low.

Remediation under this scenario would be expected to take 13 years. The environment would be minimally impacted by construction activities.

**9.3.5.6 Criterion 6--Implementability.** This alternative would be easily implemented. The treatment system would attain the MCL goals. Equipment, material, and skilled labor are all readily available. Review of the treatment process would be done by the regulators and approval should not be difficult.

**9.3.5.7 Criterion 7--Cost.** The total present worth cost of this alternative is estimated at \$8,989,000. This cost includes the cost of institutional controls.

### 9.3.6 Alternative GW-3B

Use of a UV/Oxidation treatment unit for TCE replaces the air stripping unit in alternative GW-3A to distinguish this alternative.

**9.3.6.1 Criterion 1--Overall Protection of Human Health and the Environment.** Risks to human health would be minimal because there would be no current or potential consumptive users of the groundwater. Remediation to below MCL's would be expected by the year 2008. Therefore, this alternative meets site remedial action objectives.

**9.3.6.2 Criterion 2--Compliance with ARAR's.** SDWA MCL's would be met under this treatment alternative. No other ARAR's were identified.

**9.3.6.3 Criterion 3--Long-Term Effectiveness and Permanence.** Site incremental cancer risks would be reduced to  $1E-6$  and the hazard quotient would be reduced to 0.17 when MCL's are attained. However, it should be noted that while case studies have shown pump and treat options to be effective in controlling contaminant migration, it is less effective in cleaning up an aquifer to MCL's. Maintenance would be required for pumps and treatment units to ensure their proper operation. Groundwater monitoring would provide reliable controls to assess the effectiveness of the remedial action.

**9.3.6.4 Criterion 4--Reduction of Toxicity, Mobility, or Volume Through Treatment.** This treatment scheme destroys TCE and thus reduces its volume. Again, only the portion of the plume above 5 ppb would be captured using this extraction scenario. The remainder of the plume would be allowed to attenuate naturally.

There would be no reduction in nitrate volume; toxicity and mobility would be reduced because nitrate exists in a solid state after treatment. Like TCE, only a portion of the nitrate plume would be captured and the remainder would be left to attenuate naturally.

**9.3.6.5 Criterion 5--Short-Term Effectiveness.** There would be minimal risk to the community and remedial workers during the implementation of this alternative. The environment would be slightly impacted by construction activities. It is estimated that the plume would be remediated to below MCL's in 13 years.

**9.3.6.6 Criterion 6--Implementability.** This alternative would be easily implemented. The treatment system would attain the MCL goals. Equipment, material, and skilled labor would all be readily available.

**9.3.6.7 Criterion 7--Cost.** The total present worth cost of this alternative, including institutional controls, is estimated at \$9,970,000.

### 9.3.7 Comparative Analysis

The purpose of this analysis is to identify the relative advantages and disadvantages of each alternative. The alternatives are evaluated in relation to one another for each of the evaluation criteria in the paragraphs that follow.

**9.3.7.1 Criterion 1--Overall Protection of Human Health and the Environment.** All alternatives protect human health and the environment by attaining the site RAO's for groundwater. There would be no current users of the groundwater and the continued use of institutional controls would ensure that consumptive use of the aquifer would not occur until remediation to below MCL's would be complete.

**9.3.7.2 Criterion 2--Compliance with ARAR's.** All alternatives attain the SDWA MCL's of 5  $\mu\text{g/L}$  for TCE and 10 mg/L for nitrate as nitrogen although the time required to reach these goals differs slightly. Alternatives GW-2A and GW-3A would produce TCE air emissions, however, these quantities of TCE released would be small and do not require regulation.

**9.3.7.3 Criterion 3--Long-Term Effectiveness and Permanence.** Alternatives GW-2B and GW-3B physically destroy a portion of the TCE and use natural attenuation to remediate the rest of the plume thus achieving the highest degree of permanence. All alternatives reduce the site incremental cancer risks to below  $1\text{E}-06$  and the hazard quotient to 0.17. Alternatives GW-0 and GW-1 use natural attenuation to meet the MCL's. Alternatives GW-2A and GW-2B transfer a portion of the TCE to the gas phase and use natural attenuation to remediate the rest of the plume. TCE would be naturally degraded in the atmosphere under these alternatives.

Alternatives GW-2A, GW-2B, GA-3A, and GW-3B require maintenance of the pumps and treatment trains throughout the remediation timeframe. All alternatives rely on annual groundwater monitoring to evaluate their effectiveness. Continued land use restrictions ensure that there would be no users of the groundwater.

**9.3.7.4 Criterion 4--Reduction of Toxicity, Mobility, or Volume Through Treatment.** Alternatives GW-0 and GW-1 reduce toxicity through natural attenuation. Alternatives GW-2A, GW-2B, GW-3A, and GW-3B reduce toxicity through treatment and natural attenuation.

Alternatives GW-2B and GW-3B would be the only alternatives that actively destroy TCE and reduce contaminant volumes. Alternatives GW-2A and GW-3A additionally rely on the natural degradation of TCE in the atmosphere to reduce volume of the contaminant.

TCE mobility would not be reduced under any alternative. In fact, TCE mobility would be increased by transfer to the gas phase under alternatives GW-2A and GW-3A.

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Nitrate mobility would be reduced under all options that utilize treatment trains because it would be incorporated in a solid residue after treatment.

**9.3.7.5 Criterion 5--Short-Term Effectiveness.** All alternatives present low remedial risks to the community and to onsite remedial workers with GW-0 and GW-1 presenting the lowest risk because contaminants are not extracted and, therefore, there is no potential for exposure. Emissions from the air strippers of alternatives GW-2A and GW-3A would be relatively low. The site would be distant from the community, therefore, posing minimal risk of exposure to emissions.

Alternatives GW-0 and GW-1 would remediate the site in 22 years. Alternatives GW-2A and GW-2B would remediate the site in 17 years. It would take an estimated 13 years to remediate the site under alternatives GW-3A and GW-3B.

**9.3.7.6 Criterion 6--Implementability.** All alternatives would be easy to implement technically. Alternatives GW-2A, GW-2B, GW-3A, and GW-3B require treatment units that would be available from multiple vendors. These alternatives also require that the processes be reviewed and approved by regulators. All alternatives would employ standard construction practices.

**9.3.7.7 Criterion 7--Cost.** Alternative GW-0 is the least costly. It is assumed that alternative GW-1 would not require additional remedial action in the future and it is estimated to be less costly than alternatives which actively treat the groundwater. Alternatives that treat 0.38 m<sup>3</sup>/min (100 gpm) would be less costly than those that treat 1.14 m<sup>3</sup>/min (300 gpm). For alternatives treating the same flows, those that use air stripping for TCE removal would be less costly than those utilizing UV/Oxidation for the destruction of TCE. A summary of these costs is presented in table 8-4.

**9.3.7.8 Summary of Groundwater Remedial Alternatives Evaluation.** Table 9-2 is a summary of the evaluation of groundwater alternatives versus the seven criteria against which they were evaluated.

## 9.4 SUMMARY

The next step in the RI/FS process is to assemble a comprehensive site remediation plan that addresses all the contaminated soil at each operable subunit and the groundwater at the HRL. This plan would combine a soil remedial alternative with a groundwater remedial alternative. Any number of comprehensive plans could be formed. From this group of comprehensive plans, one will be selected as the preferred alternative and will be put forth as the proposed plan.

**TABLE 9-2. EVALUATION OF GROUNDWATER REMEDIAL ALTERNATIVES**

<b>CERCLA CRITERIA</b>	<b>W-0 No Action</b>	<b>GW-1 Monitor</b>	<b>GW-2A Airstrip 100 GPM</b>	<b>GW-2B UV/Ox 100 GPM</b>	<b>GW-3A Airstrip 300 GPM</b>	<b>GW-3B UV/Ox 300 GPM</b>
Overall Protection	M	M	M	M	M	M
Compliance with ARAR's	M	M	M	M	M	M
Long-Term Effectiveness and Permanence	M	M	M	M	M	M
Short-Term Effectiveness	M	M	M	M	M	M
Reduction of Toxicity, Mobility, Volume	M	M	M	M/H	M	M/H
Implementability	H	H	H	H	H	H
Cost (Present Worth) Thousands of Dollars	\$0	\$1,059K	\$5,111K	\$5,714K	\$8,989K	\$9,970K
L= Low--Does not meet all elements of the Criterion adequately M = Medium--Does meet all elements of the Criterion adequately H = High--Meets all of the elements of the Criterion to a high degree						

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## 10.0 REFERENCES

- Allen, J., 1980, *The Ecology and Behavior of the Long-Billed Curlew in Southeastern Washington*, Wildlife Monographs, The Wildlife Society, Bethesda, Maryland.
- Amdur, M.O., J.D. Doull, and C.D. Klaassen, Editors, 1991, *Casarett and Doull's Toxicology: The Basic Science of Poison, 4th Edition*, Pergamon Press, New York, New York.
- Arlt, S., 1989, Meeting Minutes from 1100-EM-1 Exposure Assessment Data Collection; Richland Department of Water, Sewage, and Refuse and Golder Associates; November 28, 1989.
- Ash, J. and I. Ash, Editors, 1978, *A Formulary of Paints and Other Coatings, Volume 1*, Chemical Publishing Company, Inc., New York, New York.
- ATTIC - No. RM00468, *Reduction of Polychlorinated Biphenyls by Anaerobic Microorganisms from Sediments*, 1992.
- Baskett, R.L., 1983, *Fugitive Dust Emission Factors for the Mining Industry*, American Mining Congress, Washington, D.C.
- Benefield, L.D., J.F. Judkins, and B.L. Weand, *Process Chemistry for Water and Wastewater Treatment*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1982.
- Biotrol, 1992, Personal communications with Pamela Sheehan, Biotrol, Inc., Chaska, Minnesota, August, 1992.
- Bjornstad, B.N., 1984, *Suprabasalt Stratigraphy Within and Adjacent to the Reference Repository Location*, SD-BWI-DP-039, Rockwell Hanford Operations, Richland, Washington.
- Bouwer and McCarty, 1983, *Transformations of 1- and 2- Carbon Halogenated Aliphatic Organic Compounds Under Methanogenic Conditions*, Applied Environmental Microbiology, 45:1286-1294.
- Bouwer *et al.*, 1981, *Anaerobic Degradation of Halogenated 1- and 2- Carbon Organic Compounds*, Applied Environmental Microbiology, 15:596-599.
- Bower, 1992, Personal communication with J. Bower from Geraghty & Miller, Inc., Reston, Virginia, December 1992.
- Brady, N.C., 1974, *The Nature and Property of Soil, 8th Edition*, MacMillan Publishing Co., Inc., New York, New York.
- Brouns *et al.*, 1991, *Biological Treatment of Hanford Groundwater: Development of an Ex-Situ Treatment Process*, Gov. Doc. DE91010008.

- Bryce, R.W. and S.M. Goodwin, 1989, *Borehole Summary Report for Five Ground-Water Monitoring Wells Constructed in the 1100 Area*, PNL-6824, Pacific Northwest Laboratory, Richland, Washington.
- Campbell, G.S., 1985, *Soil Physics with BASIC*, Elsevier, New York.
- Clark, R.M., R.G. Eilers, and J.A. Goodrich, *VOCs in drinking Water: Cost of Removal*, Journal of Environmental Engineering, Vol. 110, No. 6, December 1984.
- Clark, R.M., G.A. Frank, and B.W. Lykins, Jr., *Removing Organic Contaminants from Groundwater*, Environmental Science and Technology, Vol. 22, No. 10, 1988.
- Clayton, G.D. and F.E. Clayton, Editors, 1981, *Patty's Industrial Hygiene and Toxicology*, John Wiley and Sons, New York, New York.
- Clement Assoc., 1988, *Multi-pathway Health Risk Assessment Input Parameter and Guidance Document*, Prepared for the South Coast Air Quality Management District, Contract Number 8798.
- Cowherd, C., Jr., G.E. Muleski, P.J. Englehart, and D.A. Gillette, 1985, *Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites*, EPA/600/8-85/002, U.S. Environmental Protection Agency, Office of Health and Environmental Assessment, Washington, D.C.
- Culligan, 1992, Personal communications with Frank Rouse from Culligan of Yakima, Washington, September and October 1992.
- Cushing, C.E., 1991, *Hanford Site National Environmental Policy Act (NEPA) Characterization*, Pacific Northwest Laboratories, PNL-6415, Revision 4, Richland, Washington.
- CWC-HDR, Inc., 1988, *Water Filtration Plant and North Richland Well Field Evaluation: City of Richland Water and Waste Utilities*, City of Richland, Richland, Washington.
- DNR, 1990, *Washington Natural Heritage Program, 1990, Endangered, Threatened, and Sensitive Vascular Plants of Washington*, Washington State Department of Natural Resources, Olympia, Washington.
- U.S. Department of Energy (DOE), 1987, *Disposal of Hanford Defense High-Level Transuranic and Tank Waste: Hanford Site, Richland, Washington (Final Environmental Impact Statement)*, DOE/EIS-0113, DOE, Richland, Washington.
- DOE/RL-88-23, 1989, *Remedial Investigation/Feasibility Study Work Plan for the 1100-EM-1 Operable Unit Hanford Site*, DOE, Richland, Washington.
- DOE/RL-89-90, 1990, *RI/FS Work Plan for the 300-FF5 Operable Unit*, DOE, Richland, Washington.

DOE/RL-90-18, 1990, *Phase I Remedial Investigation Report for the Hanford Site 1100-EM-1 Operable Unit*, DOE, Richland, Washington.

DOE/RL-90-32, 1990, *The Phase I and II Feasibility Study Report for the Hanford Site 1100-EM-1 Operable Unit*, DOE, Richland, Washington.

DOE/RL-90-37, 1992, *Remedial Investigation Phase II Supplemental Work Plan for the Hanford Site 1100-EM-1 Operable Unit*, DOE, Richland, Washington.

DOE/RL-91-44, 1991, *Description of Codes and Models to be Used in Risk Assessment*, Richland, Washington.

DOE/RL-91-45, 1992, *Hanford Site Baseline Risk Assessment Methodology*, DOE, Richland, Washington.

DOE/RL-92-05, *B Plant Source Aggregate Area Management Study Report*, DOE, Richland, Washington.

Doty, Carolyn, B., 1991, *The Effectiveness of the Pump and treat Method for Aquifer Restoration*, ASG, Inc., Oak Ridge, Tennessee.

Driver, C., 1990, Personal communications with C. Driver, Pacific Northwest Laboratory, Richland, Washington, June 1990.

Echenfelder, W.W., Jr., 1989, *Industrial Water Pollution Control*, McGraw-Hill Book Company, New York, New York.

Echroth, D., 1981, *Kirk-Othmer Encyclopedia of Chemical Technology, 3rd edition*, John Wiley and Sons, Inc., New York, New York.

Einan, D., 1991, U.S. Environmental Protection Agency (EPA), (letter to R. Stewart, DOE/RL), May 30, 1991.

Einan, D., 1992, EPA, (letter to R. Stewart, DOE/RL), January 16, 1992.

EPA, 1974, *Waste Oil Study, Report to Congress*, U.S. Environmental Protection Agency PB-257-693, Washington, D.C.

EPA, 1986a, *Handbook for Stabilization/Solidification of Hazardous Waste*, U.S. Environmental Protection Agency EPA/540/2-86/001, Washington, D.C.

EPA, 1986b, *Quality Criteria for Water 1986*, U.S. Environmental Protection Agency EPA 440/5-86-001, Washington, D.C.

EPA, 1986c, *Land Application and Distribution and Marketing of Sewage Sludge: Technical Support Document*, U.S. Environmental Protection Agency, Office of Water Regulation and Standards, Washington, D.C.

93129330509

- EPA, 1986d, *Superfund Public Health Evaluation Manual*, EPA/540/1-86/060 OSWER 9285.4-1, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.
- EPA, 1986e, *Air Quality Criteria for Lead*, June 1986 and Addendum September 1986. U.S. Environmental Protection Agency, Office of Research and Development and Office of Health and Environmental Assessment, Washington, D.C. and Environmental Criteria and Assessment Office, Research Triangle Park, North Carolina. EPA 600/8083-028AF, BF, CF, DF, EPA/602/8-83/028A.
- EPA, 1987, *Soil-Gas Sensing for Detection and Mapping of Volatile Organics*, U.S. Environmental Protection Agency, Environmental Monitoring and Systems Laboratory, Las Vegas, Nevada.
- EPA, 1988a, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, U.S. Environmental Protection Agency EPA/540/G-89/004, Washington, D.C.
- EPA, 1988b, *CERCLA Compliance with Other Laws - Draft Guidance*, U.S. Environmental Protection Agency EPA/540/G-89/006, Washington, D.C.
- EPA, 1988c, *Superfund Exposure Assessment Manual*, U.S. Environmental Protection Agency EPA-540/1-88/001, Washington, D.C.
- EPA, 1988d, *Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites*, U.S. Environmental Protection Agency, EPA/540/G-88/ 003, Washington, D.C.
- EPA, 1989a, *Risk Assessment Guidance for Superfund, Volume 2: Environmental Evaluation Manual*; Interim Final, EPA/540/1-89/001, United States Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.
- EPA, 1989b, *Health Effects Assessment Summary Tables (HEAST) - Fourth Quarter FY 1989*, OSWER (OS-230), ORD (RD-689), OERR 9200.6-303-(89-4), United States Environmental Protection Agency, Environmental Criteria and Assessment Office, Cincinnati, Ohio.
- EPA, 1989c, *Guide to Treatment Technologies for Hazardous Wastes at Superfund Sites*, U.S. Environmental Protection Agency EPA/540/2-89/052, Washington, D.C.
- EPA, 1989d, *Final Covers on Hazardous Waste Landfills and Surface Impoundments*, U.S. Environmental Protection Agency EPA 530-SW-89-047, Washington, D.C.
- EPA, 1989e, *Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites*, OSWER 9355.4-02, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C.

93129330510

- EPA, 1989f, *Exposure Factors Handbook*, EPA/600/8-89/043, U.S. Environmental Protection Agency, Office of Health and Environmental Assessment, Washington, D.C.
- EPA, 1989g, *Development of Risk Assessment Methodologies for Land Application and Distribution and Marketing of Municipal Sludge*, EPA/600-6-89/001, U.S. Environmental Protection Agency, Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, Office of Research and Development, Cincinnati, Ohio.
- EPA, 1990a, *A Guide on Remedial Actions at Superfund Sites with PCB Contamination*, U.S. Environmental Protection Agency OSWER Directive 9355.4-01 FS, Washington, D.C.
- EPA, 1990b, *Handbook on In Situ Treatment of Hazardous Waste-Contaminated Soils*, U.S. Environmental Protection Agency EPA/540/2-90/002, Washington, D.C.
- EPA, 1990c, *Chemical Dehalogenation Treatment: APEF Treatment*, U.S. Environmental Protection Agency EPA/540/2-90/015, Washington, D.C.
- EPA, 1990d, *Site Technology Profile - ULTROX International*, U.S. Environmental Protection Agency EPA/540/2-90/006, Washington, D.C.
- EPA, 1990e, *Methodology for Assessing Health Risks Associated with Indirect Exposure Combustor Emissions*, EPA/600/6-90/003, U.S. Environmental Protection Agency, Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, Office of Research and Development, Cincinnati, Ohio.
- EPA, 1991a, *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions*, Environmental Protection Agency, OSWER Directive 9355.0-30, Washington, D.C.
- EPA, 1991b, *Innovative Treatment Technologies: Overview and Guide to Information Sources*, U.S. Environmental Protection Agency EPA/540/9-91/002, Washington, D.C.
- EPA, 1991c, *Mobile/Transportable Incineration Equipment*, U.S. Environmental Protection Agency EPA/540/9-91/014, Washington, D.C.
- EPA, 1991d, *Standard Default Exposure Factors*, OSWER 9285.6-03, U.S. Environmental Protection Agency, Washington, D.C.
- EPA, 1991e, *Health Effects Assessment Summary Tables, Annual FY-1991*, OERR 9200.6-303(91-1), U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D.C.

- EPA, 1991f, *Users Guide for Lead: A PC Software Application of the Uptake/Biokinetic Model Version 0.50*, U.S. Environmental Protection Agency, Environmental Criteria and Assessment Office, and Office of Health and Environmental Assessment, Cincinnati, Ohio.
- EPA, 1991g, *Technical Support Document on Lead*, U.S. Environmental Protection Agency, Environmental Criteria and Assessment Office, and Office of Health and Environmental Assessment, Cincinnati, Ohio.
- EPA, 1992a, *Integrated Risk Assessment System*, Access date: March 1992, U.S. Department of Health and Human Services, National Library of Medicine Toxicology Data Network, Bethesda, Maryland.
- EPA, 1992b, *Health Effects Assessment Summary Tables: Annual FY-1992*, OHEA ECANOCIN-821, U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, D. C.
- EPA, 1992c, *Dermal Exposure Assessment: Principles and Applications*, EPA/600/8-91/011B, U.S. Environmental Protection Agency, Exposure Assessment Group, Washington, D.C.
- EPA-10, August 16, 1991, *Supplemental Risk Assessment Guidance for Superfund*, U.S. Environmental Protection Agency, Region 10, Seattle, Washington.
- Evans, J.C., 1 September 1989, *1100-EM-1 Soil Gas Survey Final Report*, WHC-MR-0072, Westinghouse-Hanford Company, Richland, Washington.
- Fayer, M.J. and T.L. Jones, 1990, *UNSAT-H Version 2.0: Unsaturated Soil Water and Heat Flow Model*, PNL-6779, Pacific Northwest Laboratory, Richland, Washington.
- Fayer, M.J., 3 June 1992, *Notes on UNSAT-H Operation with Input File HMET.INP*, Personal Memo to J. McBane, CENPW-EN-EE.
- Fecht, K.R. and J.T. Lillie, 1982, *A Catalog of Borehole Lithologic Logs from the 600 Area, Hanford Site*, RHO-LD-158, Rockwell International, Richland, Washington.
- Fecht, K.R., S.P. Reidel, and A.M. Tallman, 1985, *Paleodrainage of the Columbia River System on the Columbia Plateau of Washington State: A Summary*, RHO-BW-SA-318P, Rockwell Hanford Operations, Richland, Washington.
- Fitzner, R.E., 1980, *Behavioral Ecology of Swainson's Hawk (Buteo Swainsoni) in Washington*, PNL-2754, Pacific Northwest Laboratory, Richland, Washington.
- Folk, R.L., 1954, *The Distinction Between Grain Size and Mineral Composition in Sedimentary-Rock Nomenclature*, Journal of Geology, Vol. 62, pp. 344-359.

93129330512

- Franklin, J.F. and C.T. Dyrness, 1988, *Natural Vegetation of Oregon and Washington*, Oregon State University Press, Corvallis, Oregon.
- Freshley, M.D., M.P. Bergeron, N.J. Aimo, and A.G. Law, 1989, *Ground-Water Modeling Investigation of the North Richland Well Field and the 1100 Area*, Pacific Northwest Laboratory and Westinghouse Hanford Company, Richland, Washington.
- Galson, 1992, Personal communication with Robert Peterson, Galson Remediation Corporation, East Syracuse, New York, September 1992.
- Gaylord, D.R. and E.P. Poeter, 1991, *Geology and Hydrology of the 300 Area and Vicinity, Hanford Site, South-Central Washington*, WHC-EP-0500, Westinghouse Hanford Company, Richland, Washington.
- Gee, G.W., 1987, *Recharge at the Hanford Site: Status Report*, PNL-6403, Pacific Northwest Laboratory, Richland, Washington.
- GII, 1991, *Treatment Technologies Second Edition*, Government Institutes, Inc., Rockville, Maryland.
- Golder Associates, Inc., April 2, 1992 (Golder, 1992)--Section 6. *Contaminant Degradation Study at the 1100-EM-1, Operable Unit*.
- Golder Associates, Inc., 19 September 1991, *Report to Westinghouse Hanford Company on Geophysical Surveys at the Horn Rapids Landfill*, 903-1249, Redmond, Washington.
- Gosselin, R.E., R.P. Smith, and H.C. Hodge, 1984, *Clinical Toxicology of Commercial Products, 5th Edition*, Williams and Wilkins, Baltimore, Maryland.
- Hillel, D., 1980, *Fundamentals of Soil Physics*, Academic Press, Inc., New York, New York.
- Hulstrom, L.C., 1992, *Climatological Summary of the 300 Area for the 300-FF-5 Operable Unit Remedial Investigation*, WHC-SD-EN-TI-005, Westinghouse Hanford Company, Richland, Washington.
- Hunt, R.E., 1986, *Geotechnical Engineering Analysis and Evaluation*, McGraw-Hill Book Company, New York, New York.
- Jancquish, R.E. and P.J. Mitchell, (Editors), 1988, *Environmental Monitoring at Hanford for 1987*, PNL-6464, Pacific Northwest Laboratory, Richland, Washington.
- JMM, 1985, *Water Treatment Principles and Design*, James M. Montgomery Consulting Engineers, Inc., John Wiley and Sons, Inc., New York, New York.
- Jury, W.A., W.R. Gardner, and W.H. Gardner, 1991, *Soil Physics*, John Wiley and Sons, Inc., New York, New York.

- Kabata-Pendias, A. and H. Pendias, 1984, *Trace Elements in Soils and Plants*, CRC Press, Inc., Boca Raton, Florida.
- Life Systems, Inc., 1989, *Toxicological Profile for Di(2-ethylhexyl)phthalate*, ATSDR/RP88/15, Agency for Toxic Substances and Disease Registry, Atlanta, Georgia.
- Lindberg, J.W. and F.W. Bond, 1979, *Geohydrology and Ground-Water Quality Beneath the 300 Area*, Hanford Site, Washington, PNL-2949, Pacific Northwest Laboratory, Richland, Washington.
- Lindsey, K.A., D.R. Gaylord, and E.P. Poeter, 1989, *Sedimentary and Stratigraphic Examination of the Ringold Formation, Hanford Nuclear Reservation, Washington, Applied Lithofacies Analysis*, Geological Society of America, Abstracts with Programs, Vol. 21, No. 5.
- Lindsey, K.A., 1991, *Revised Stratigraphy for the Ringold Formation, Hanford Site, South-Central Washington*, WHC-SD-EN-EE-004, Rev. O, Westinghouse Hanford Company, Richland, Washington, 12 p.
- Lindsey, K.A. and D.R. Gaylord, 1990, *Lithofacies and Sedimentology of the Miocene-Pliocene Ringold Formation, Hanford Site, South-Central Washington*, Northwest Science, Vol. 64, No. 3, pp. 165-180.
- Mackay, D.M., et al., 1985, *Transport of Organic Contaminants in Groundwater*, Environmental Science Technology, Vol. 19, No. 5, pp. 384-392.
- McGhan, V.L., 1989, *Hanford Wells*, PNL-6907, Pacific Northwest Laboratory, Richland, Washington.
- Metcalf and Eddy, 1991, *Wastewater Engineering - Treatment, Disposal and Reuse, 3rd edition*, 1991.
- Miller, G.C., and F.P. Guengerich, 1982, *Oxidation of Trichlorethylene by Liver Microsomal Cytochrome P-450: Evidence for Chlorine Migration in a transition state not involving Trichlorethylene Oxide*, Biochemistry 21: 1090-1097.
- Mitchell, T.H. and J.R. Kunk, February 1991, *Geophysical Surveys at the 1100-EM-1 South Pit*, WHC-MR-0243, Richland, Washington.
- Myers, C.W. and S.M. Price, 1979, *Geologic Studies of the Columbia Plateau: A Status Report*, RHO-BWI-ST-4, Rockwell Hanford Operations, Richland, Washington.
- Myers, R.R. and J.S. Long, Editors, 1975, *Treatise on Coatings, Volume 4*, Marcel Dekker, Inc., New York, New York.

- Newcomb, R.C., 1958, *Ringold Formation of Pleistocene Age in the Type Locality, the White Bluffs, Washington*, American Journal of Science, Vol. 256, pp. 328-340.
- Newcomb, R.C., J.R. Strand, and F.J. Frank, 1972, *Geology and Groundwater Characteristics of the Hanford Reservation of the Atomic Energy Commission*, Washington, U.S. Geological Survey Professional Paper 717.
- NOAA, 1988, *National Oceanic and Atmospheric Administration Preliminary Natural Resource Study - Hanford: Finding of Fact*, U.S. National Oceanic and Atmospheric Administration, Seattle, Washington.
- Paustenbach, D.J., 1989, *The Risk Assessment of Environmental and Human Health Hazards: A Textbook of Case Studies*, John Wiley and Sons, New York, New York.
- PNL, 1988, *Vitrification Technologies for Weldon Springs Raffinate Sludges and Contaminated Soils Phase I Report: Development of Alternatives*, Pacific Northwest Laboratory, PNL-6704, Richland, Washington.
- PNL, 1989, *Ground-water Modeling Investigation of North Richland Well Field and the 1100 Area*, Pacific Northwest Laboratory, PNL Letter Report, M.D. Freshley, Richland Washington.
- PNL, 1992, Personal communications with Joe Perez, Pacific Northwest Laboratories, Richland, Washington, September 1992.
- Prentice, B.A., S.K. Fadeff, J.G. Kaye, E.A. Lepel, N.L. Wynhoff, E.J. Wyse, 1992, *1100-EM-1 Groundwater Characterization: Phase 1, Data Package/Report No. 1, Rev. 0*.
- PSPL, 1982, *Stratigraphic Investigation of the Skagit/Hanford Nuclear Project, Skagit/Hanford Nuclear Project Preliminary Safety Analysis Report*, Vol. 5, Appendix 2R, Puget Sound Power and Light Company, Bellevue, Washington.
- Reidel, S.P., R.W. Cross, and K.R. Fecht, 1983, *Constraints on Tectonic Models as Provided from Strain Rates*, in Preliminary Interpretation of the Tectonic Stability of the Reference Repository Location, Cold Creek Syncline, Hanford Site, RHO-BW-ST-19P, Rockwell Hanford Operations, Richland, Washington.
- Richard, J.L., Sr., 1992, *SAX's Dangerous Properties of Industrial Materials, Eighth Edition*, Van Nostrand Reinhold, New York, New York.
- Richards, L.A., 1931, *Capillary Conduction of Liquids in Porous Mediums*, Physics 1:318-333.
- Richardson, C.W. and D.A. Wright, 1984, *WGEN: A Model for Generating Daily Weather Variables*, U.S. Department of Agriculture, Agricultural Research Service, ARS-8.

- Rockhold, M.L., M.J. Fayer, G.W. Gee, and M.J. Kanyid, 1990, *Natural Groundwater Recharge and Water Balance at the Hanford Site*, PNL-7215, Pacific Northwest Laboratory, Richland, Washington.
- Russell, H.H., J.E. Matthews, and G.W. Sewell, Winter 1990-91, *Remediation of Sites Contaminated with TCE*, Remediation.
- Russell, H.H., J.E. Matthews, and G.W. Sewell, 1992, *TCE Removal from Contaminated Soil and Ground Water*, U.S. Environmental Protection Agency EPA/540/S-92/002, Washington, D.C.
- Ryan, E.A., E.T. Hawkins, B. Magee, and S.L. Santos, 1987, "Assessing Risk from Dermal Exposure at Hazardous Waste Sites," *Superfund 1987: Proceedings of the 8th National Conference*, Hazardous Materials Control Institute, Silver Springs, Maryland.
- Ryan, J.A., R.M. Bell, J.M. Davidson, and G.A. O'Connor, 1988, *Plant Uptake of Non-Ionic Organic Chemicals From Soils*, Chemosphere, Vol. 17, No. 12: 2299-2323.
- Sandness, G.A., E.V. Allen, and D.K. Larson, May 1989, *Report on Geophysical Surveys at Four Inactive Waste Burial Sites in the 100-EM-1 Operable Unit*, WHC-MR-0073; Richland, Washington.
- Schalla, R., R.W. Wallace, R.L. Aaberg, S.P. Airhart, D.J. Bates, J.V.M. Carlile, C.S. Cline, D.I. Dennison, M.D. Freshley, P.R. Heller, E.J. Jensen, K.B. Olsen, R.G. Parkhurst, J.T. Rieger, E.J. Westergard, 1988, *Interim Characterization Report for the 300 Area Process Trenches*, PNL-6716, Pacific Northwest Laboratory, Richland, Washington.
- Schroeder, P.R., Personal Communication, May 1992.
- Schroeder, P.R., B.M. McEnroe, R.L. Peyton, and J.W. Sjostrom, April 1992, *Hydrologic Evaluation of Landfill Performance (HELP) Model*, EL-92-1, Department of the Army, Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.
- Schwille, F. (Schwille, 1988), *Dense Chlorinated Solvents in Porous and Fractured Media*, Lewis Publishers, 1988.
- Shu, H.P., P. Teitelbaum, A.S. Webb, L. Marple, B. Brunck, D. DeiRossi, F.J. Murray, and D. Paustenbach, 1988, *Bioavailability of Soil-Bound TCDD: Dermal Bioavailability in the Rat*, *Fundamental and Applied Toxicology*, 10:335-343.
- Skidmore, E.L., and N.P. Woodruff, 1968, *Wind Erosion Forces in the United States and Their Use in Predicting Soil Loss*, Agricultural Handbook No. 346, U.S. Department of Agriculture, Agricultural Research Service.

93129330516

- Smoot, J.L., J.E. Szecsody, B. Sagar, G.W. Gee, and C.T. Kincaid, November 1989, *Simulations of Infiltration of Meteoric Water and Contaminant Plume Movement in the Vadose Zone at Single-Shell Tank 241-T-106 at the Hanford Site*, WHC-EP-0332, Richland, Washington.
- Sorg, T.J., February 1978, *Treatment Technologies to Meet the Interim Primary Drinking Water Regulations for Organics*, Journal of the American Water Works Association.
- SPC, 1992, May 22, 1992 - Section 4. *Substance Source Evaluation*, Siemens Nuclear Power Corporation, (Work Plan, Hazardous) Richland, Washington.
- Stone, W.A., J.M. Thorpe, O.P. Gifford, and D.J. Hoitink, 1983, *Climatological Summary for the Hanford Area*, PNL-4622, Pacific Northwest Laboratory, Richland, Washington.
- Summers, W.K. and G. Schwab, 1977, *Drillers' Logs of Wells in the Hanford Reservation*, ARH-C-00016, Atlantic Richfield Hanford Company, Richland, Washington.
- Swanson, D.A., T.L. Wright, P.R. Hooper, and R.D. Bentley, 1979, *Revisions in Stratigraphic Nomenclature of the Columbia River Basalt Group*, Bulletin 1457-G, U.S. Geological Survey, Washington, D.C.
- Tallman, A.M., J.T. Lillie, and K.R. Fecht, 1981, *Suprabasalt Sediments of the Cold Creek Syncline Area*, in *Subsurface Geology of the Cold Creek Syncline*, C.W. Myers and S.M. Price (Editors), RHO-BWI-ST-14, Rockwell Hanford Operations, Richland, Washington, p. 28.
- Terres, J.K., 1980, *The Audubon Society Encyclopedia of North American Birds*, Alfred A. Knopf, New York, New York.
- Tolan, T.L., S.P. Reidel, M. H. Beeson, J.L. Anderson, K.R. Fecht, and D.A. Swanson, 1989, *Revisions to the Estimates of the Areal Extent and Volume of the Columbia River Basalt Group*, in *Volcanism and Tectonism in the Columbia River Flood Basalt Province*, S.P. Reidel and P.R. Hooper (eds.), Geological Society of America Special Paper 239, pp. 1-20.
- Travis, C.C. and A.D. Arms, 1988, *Bioconcentration of Organics in Beef, Milk, and Vegetation*, Environmental Science and Technology, 22: 271-274.
- Unterman, et al., 1988, *Biological Approaches for Polychlorinated Biphenyl Degradation*, pp. 253-269. In: G.S. Omenn (ed.), *Environmental Biotechnology-Reading Risks from Environmental Chemicals through Biotechnology*, Plenum Press, New York, New York.

- U.S. Air Force (USAF), July 1989, *The Installation Restoration Program Toxicology Guide*, Volumes I-V, Prepared by Biomedical and Environmental Information Analysis, Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.
- U.S. Army Corps of Engineers, 1989, *Water Control Manual for McNary Lock and Dam, Columbia River, Oregon and Washington*, Walla Walla District, U.S. Army Corps of Engineers, Walla Walla, Washington.
- U.S. Army Corps of Engineers, 1990, *Feasibility Study Report, Fort Lewis Logistics Center Remedial Investigation/Feasibility Study, Depart of the Army*, Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.
- U.S. Department of Agriculture, *Water Erosion Prediction Model: Hillslope Profile Version, Weather Generator*, National Soil Erosion Research Laboratory Report No. 2. West Lafayette, Indiana 47907.
- U.S. Weather Bureau and SCS, 1962, *Evapotranspiration Maps for the State of Washington*, United States Weather Bureau, Office of the State Climatologist, Seattle, Washington.
- Westates Carbon, 1992, Personal communication with Charles Wells, Westates Carbon, Inc., Los Angeles, California, September 1992.
- Westinghouse Hanford Company (WHC), 27 August 1991, (a) *Soil Gas Sampling and Analysis of Permanent Monitoring Probes at the Horn Rapids (Third Quarter 1991)*, 903-1221, Richland, Washington.
- WHC by Golder Associates, Inc., 30 July 1991, (b) *Interim Groundwater Data Summary Report for the 1100-EM-1 Operable Unit for 1990*, No. 903-1215, Redmond, Washington.
- WHC, 1991, *1100-RM-1 Phase II Remedial Investigation Well Inventory*, WHC-MR-0295, Westinghouse Hanford Company, Richland, Washington.
- WHC, April 1992a, *Soil Gas Sampling and Analysis at the 1100-EM-1 Operable Unit*, WHC-MR-0378, Richland, Washington.
- WHC, April 1992b, *Soil Gas Sampling and Analysis of Permanent Monitoring Probes at the Horn Rapids*, WHC-MR-0379, Richland, Washington.
- WHC, 1992a, *Phase I Hydrologic Survey of the 300-FF-5 Operable Unit, 300 Area*, Westinghouse Hanford Company, Richland, Washington.
- WHC, 1992b, Personal communications with Tim Moody, Westinghouse Hanford Company, Richland, Washington, June through October 1992.

93129330518

Wisness, S., DOE-RL, Letter to P. Day, EPA and T. Nord, State of Washington, Department of Ecology, October 30, 1991.

Woodruff, N.P., and F.H. Siddoway, 1965, *Wind Erosion Equations*, Soil Science Society of America, Proceedings, Vol. 29, pp. 602-608.

WST, 1992, Personal communications with Brian Schepart, Waste Stream Technology, Buffalo, New York, September through October 1992.

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