NEWFIELDS

TECHNICAL MEMORANDUM

TO: RENE FUENTES (EPA REGION 10)

FROM: PETER TOWNSEND (NEWFIELDS, LLC)

SUBJECT: SHORT-TERM WATER QUALITY MODELING

DATE: 7/30/2007

CC: ANNE SUMMERS (PORT OF PORTLAND); SEAN SHELDRAKE (EPA REGION 10)

INTRODUCTION

This memo describes the methodology, data input, and results of the short-term water quality predictions for the Confined Disposal Facility (CDF) at Port of Portland, Terminal 4. This memo is provided in response to EPA's request during the July 19 teleconference (Technical Meeting #11) to provide a summary of short-term water quality predictions.

METHODOLOGY

Numerical groundwater flow and solute transport modeling was performed to assess potential short-term water quality impacts of the proposed CDF on the Willamette River during the initial filling operation.

As described in BBL (2005), the alignment of the CDF is coincident with the general groundwater flow direction. To conservatively estimate groundwater quality COPC concentrations at the downgradient edge of the CDF berm, a two-dimensional (2-D) cross-sectional model was aligned along the groundwater flowpath and through the center of the CDF structure. Figure 1 illustrates the general layout and hydrologic components of the short-term cross-sectional model.

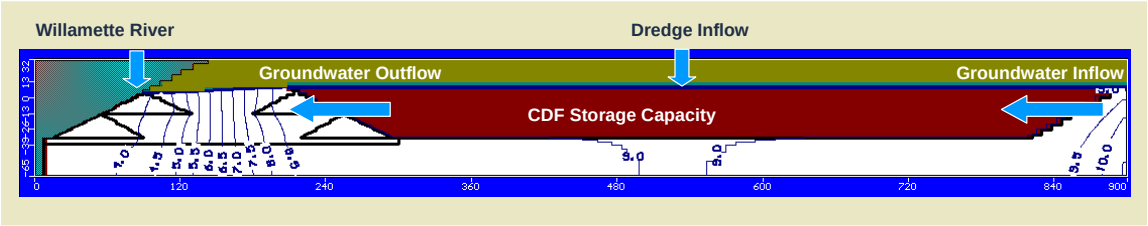

Figure 1: Cross-sectional model configuration for short-term water quality predictions.

The model domain extends 900 ft along the centerline cross-section of the CDF. Vertically, the model extends from elevation –65 ft to 32 ft NGVD. The model is discretized into 175 columns and

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31 layers. The top layer of the model corresponds to elevation 32 feet. The bottom of the CDF (i.e., the top of the underlying Unconsolidated Alluvial Deposits) corresponds to an elevation of -35 feet.

Visual Modflow[1] was used for model construction, execution, and visualization. All groundwater flow simulations were performed with MODFLOW-2000 (Harbaugh et. al., 2000). Contaminant transport simulations were performed with MT3DMS (Zheng, 1999).

MODEL INPUT

Three hydrologic boundary conditions are used in the short-term model:

- The CDF ponded water is represented by a time-varying constant head. This boundary condition represents an approximate elevation of the CDF ponded water during the initial filling period. Figure 3 illustrates the CDF ponded water elevation versus time. Development of this boundary condition is described in NewFields (2007a).

- The Willamette River is represented by constant head cells using the conservative 10-year monthly low elevation (3.8 ft. NGVD based on p = 0.1). River stage information was obtained from the U.S. Geological Survey National Stream flow Information Program, station number 14211720.

- The upland area is represented by a general head boundary. The general head was approximated using a boundary head of 14 ft at approximately 400 ft distance, and a hydraulic conductivity of 65 ft/day.

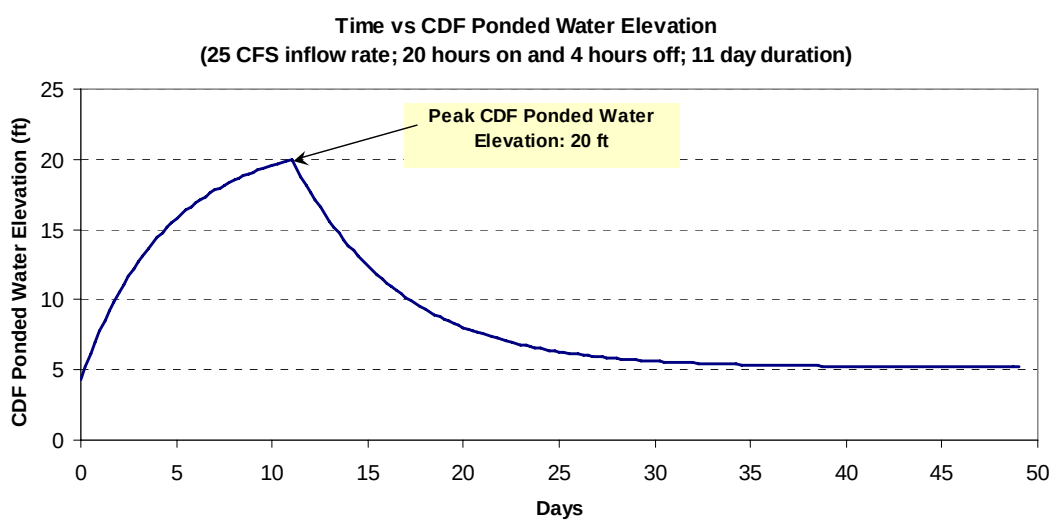

Figure 2: Time-varying constant head boundary in the CDF approximating CDF-ponded water elevation during filling.

[1] Version 4.2.0.151 (Waterloo Hydrogeologic, Inc)

Materials in the short-term model are:

- Berm select fill
- Training dikes (quarry spall)
- Unconsolidated Alluvial Deposits beneath the CDF.

Figure 3 shows the distribution of materials in the CDF structure (the berm) and the underlying alluvium. Hydraulic conductivity, porosity, fraction of organic carbon, and bulk density values were assigned to these materials. Table 1 lists the material properties. The values shown in Table 1 were developed cooperatively with EPA.

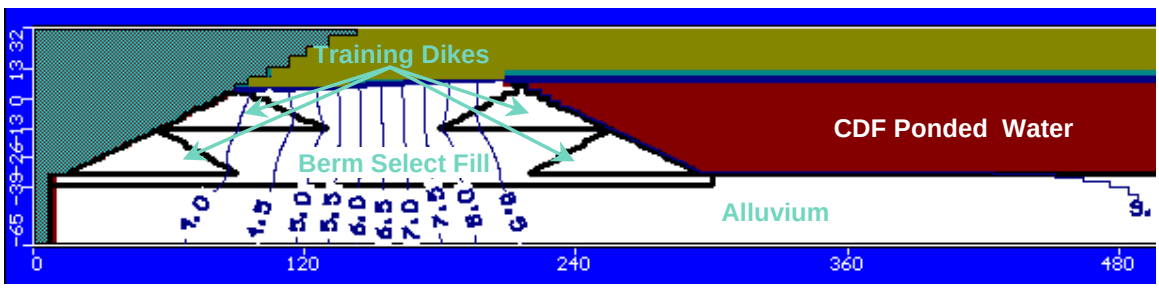

Figure 3: Distribution of material in model (enlargement of area near berm).

Table 1: Material properties for the short-term model.

Material	Units	Value
Berm select fill		
Fraction organic carbon	(-)	0.0006 [(a)]
Porosity	(-)	0.30
Hydraulic conductivity	ft/day	450 [(b)]
Bulk density	g/cm^3	2
Training dikes (quarry spall)		
Fraction organic carbon	(-)	≈0 [(c)]
Porosity	(-)	0.30
Hydraulic conductivity	ft/day	2800
Bulk density	g/cm^3	2.2
Aquifer		
Fraction organic carbon	(-)	0.003 [(d)]
Porosity	(-)	0.30
Hydraulic conductivity	ft/day	65
Bulk Density	g/cm^3	2

[a] Mean value from potential quarry sites.

[b] Berm specification indicates 10 to 25% passing 40-mesh sieve. D10 is to be in the fine sand range, between about 0.4 and 0.075 mm. Hazen's approximation of hydraulic conductivity results in a range of 16 to 450 ft/day.

[c] The fraction of organic carbon is assumed to be 0 (zero attenuation) for short-term predictions.

[d] An average foc for the underlying aquifer was obtained from TOC measurements in cores advanced in the bottom of Slip 1; the average value in the underlying aquifer was 0.3% based on sample locations VC03, VC04, VC05, VC06, VC07, VC08, VC09, VC11, VC12, VC14, VC15, and VC16

The CDF ponded water (dredge inflow) was represented with a constant concentration boundary condition. The concentration was based on the dissolved fraction (plus 0.5% of total suspended solid concentration) of the modified elutriate test (MET). Pb, Cu, Total DDT, and Total PCB were selected as COPCs for short-term water quality analyses. Constant concentrations used in the short-term model are shown in Table 4. Concentrations of CDF ponded water and COPC selection were developed cooperatively [2] with the EPA.

Adsorption distribution coefficients (K_d) for the metal COPCs were developed cooperatively with EPA. Metal K_d calculations are described in NewFields (2007b). Soil Organic Carbon-Water Partitioning Coefficient (K_{oc}) for Total DDT and Total PCB were also developed cooperatively with the EPA. Table 3 lists the mean and minimum values of K_d metals. Table 4 lists the mean and minimum values of K_{oc} for organics.

Table 2: Constant concentration boundary condition for CDF ponded water for Pb, Cu, Total DDT, and Total PCB.

COPC	MET Dissolved + 0.5% TSS (ug/L)	Chronic Water Quality Criteria (ug/L)
Copper	6	2.7
Lead	4.5	0.54
Total DDT	0.0019	0.001
Total PCB	0.0671	0.014

[2] Short-term source calculations are documented in the 7/16/2007 email from Todd Thornburg to Sean Sheldrake and Ken Fellows, titled "Recalculated Short-term Groundwater Source Concentrations (new MET)."

Table 3: Adsorption distribution (K_d) coefficient for Pb and Cu.

COPC	Material	K_d minimum (L/Kg)	K_d mean (L/Kg)
Copper	Berm & Alluvium	133 [a]	165 [a]
	Training Dike	≈0 [b]	≈0 [b]
Lead	Berm & Alluvium	109 [a]	179 [a]
	Training Dike	≈0 [b]	≈0 [b]

[a] NewFields, 2007b
[b] No attenuation is assumed to occur in the training dikes for short-term predictions.

Table 4: Soil Organic Carbon-Water Partitioning Coefficient (Koc) for Total DDT and Total PCB.

COPC	K_{oc} minimum (L/Kg)	K_{oc} mean (L/Kg)
Total DDT	303,000	703,000
Total PCB	599,000	1,550,000

RESULTS

The total simulation time for the short-term flow and transport model is 40 days, which corresponds to the time when the CDF ponded water elevation reaches steady state following filling (see Figure 2). For each COPC, the most conservative case is illustrated (minimum K_{oc} and K_d).

Figures 4, 5, 6, and 7 illustrate the predicted results for Pb, Cu, Total DDT, and Total PCB, respectively. Figures 4 through 7 show the predicted results with time-series graphs and color-shaded contours of COPC concentrations at 40 days. For each COPC, the blue-shaded color contour is $1x10^{-4}$ ug/L. For each COPC, concentration results are graphed for three locations. Location number one is the predicted concentration in groundwater at the Willamette River interface. The assumed concentration of the CDF ponded water and chronic water quality criteria are also illustrated.

As shown in Figures 4 through 7, COPC concentrations in groundwater at observation location number one do not exceed chronic water quality criteria at the Willamette River.

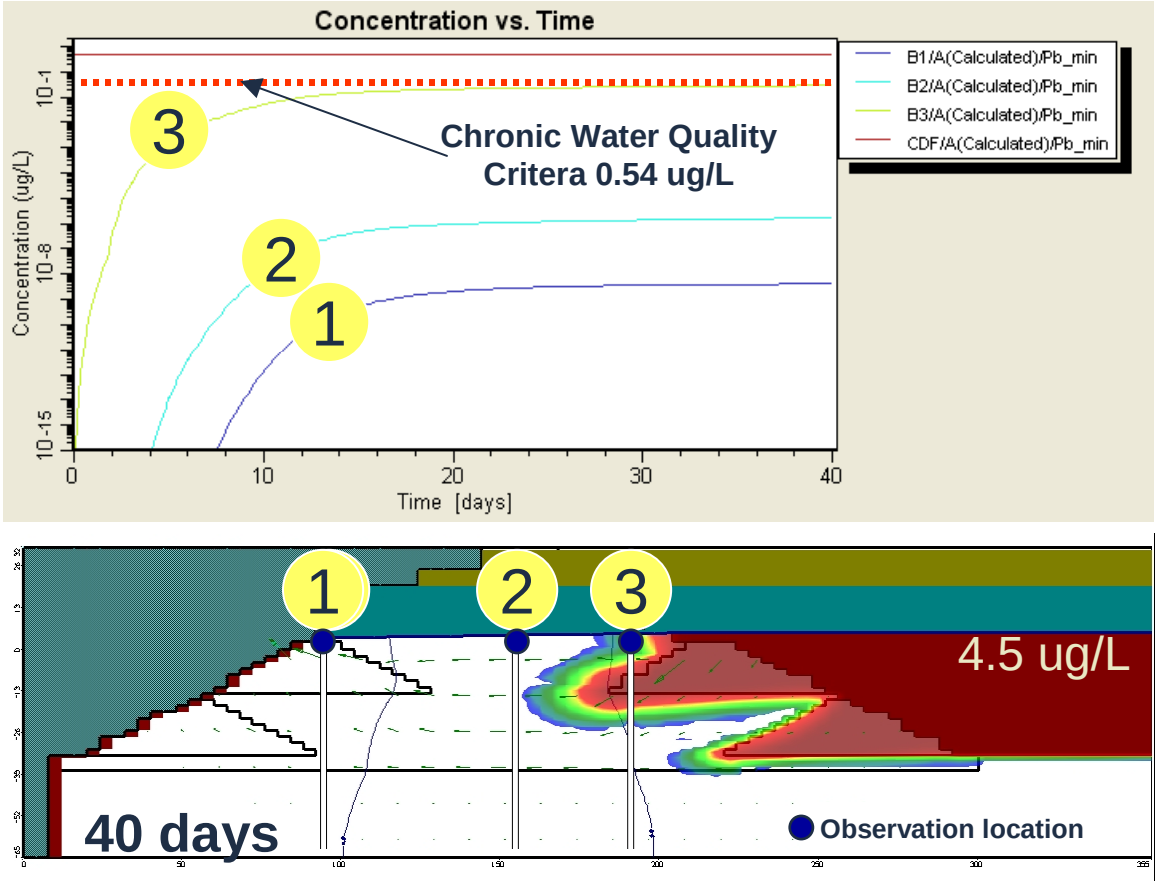

Figure 4: Short-term modeling results for Pb (minimum K_d). The blue-shaded color contour is $1x10^{-4}$ ug/L (time = 40 days). The concentration of the CDF ponded water is 4.5 ug/L

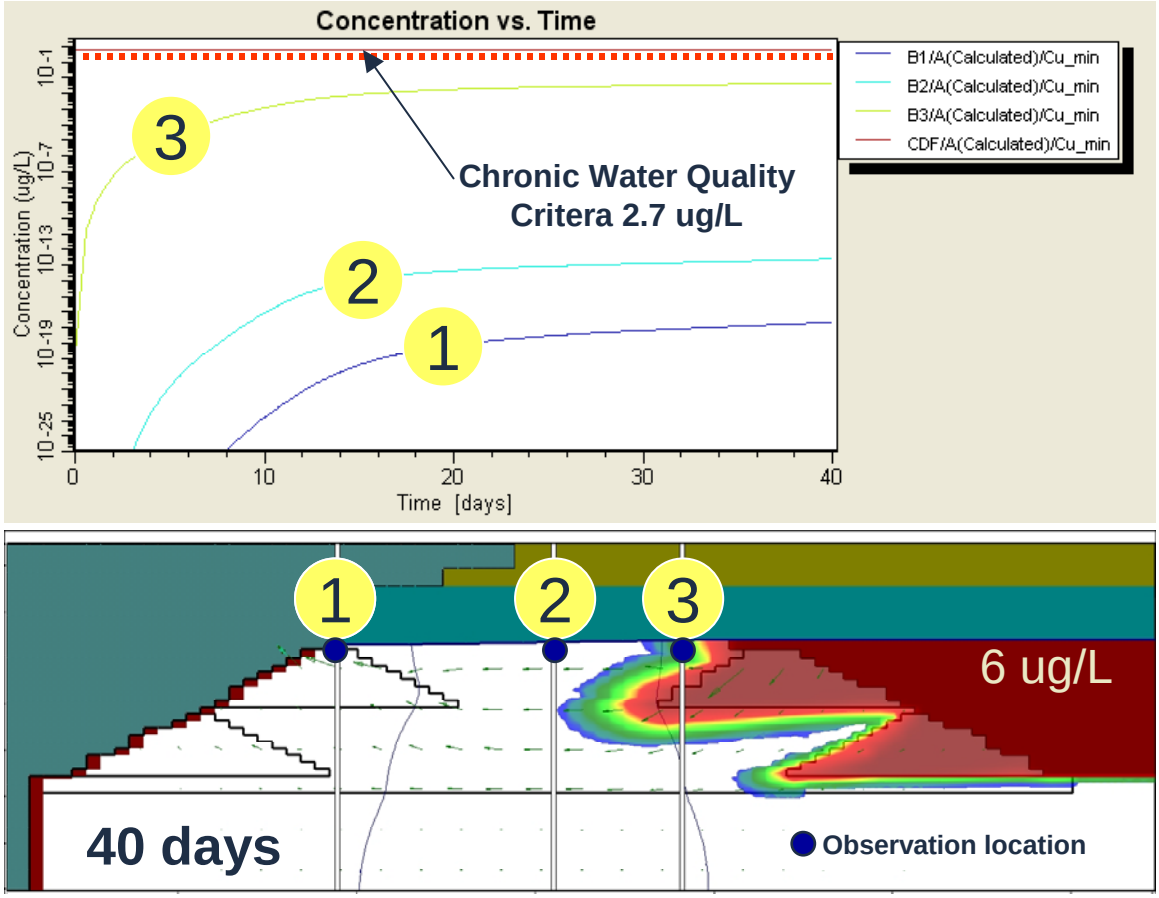

Figure 5: Short-term modeling results for Cu (minimum K_d). The blue-shaded color contour is $1x10^{-4}$ ug/L (time = 40 days). The concentration of the CDF ponded water is 6 ug/L

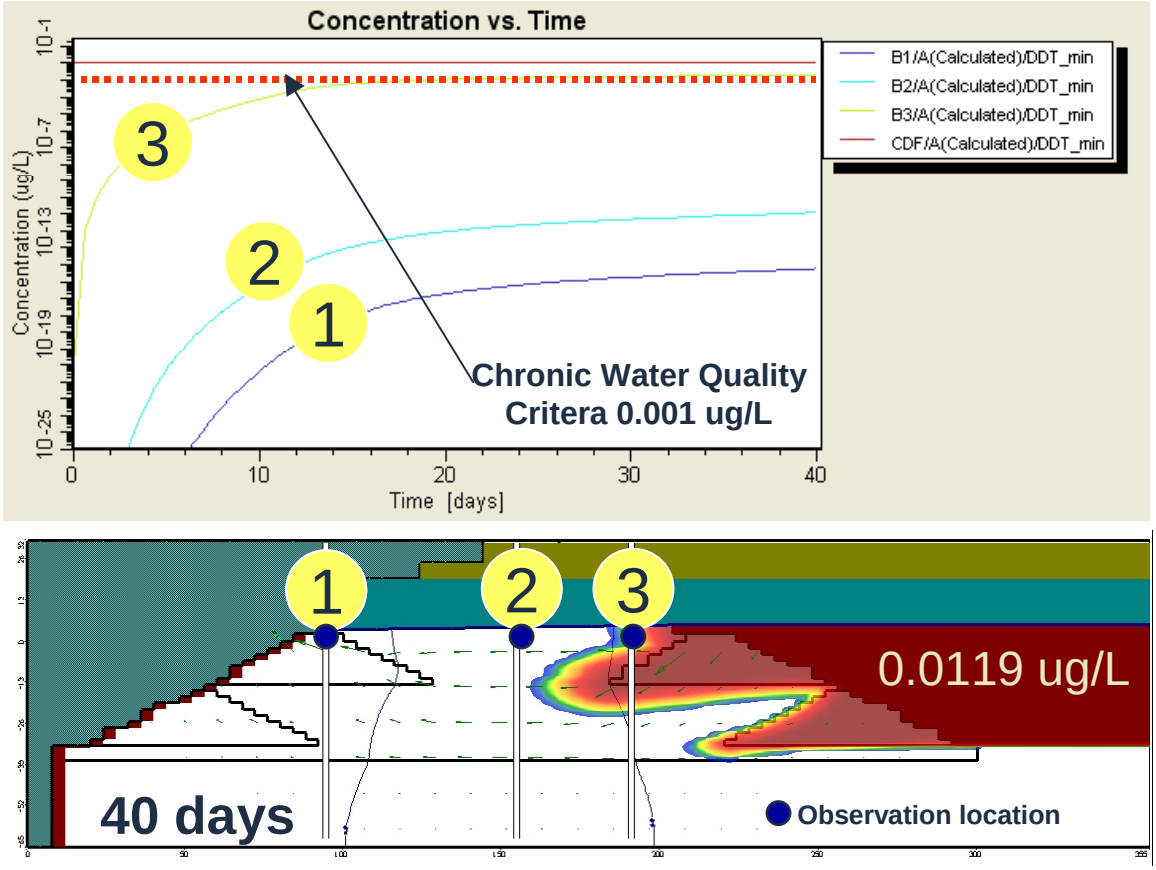

Figure 6: Short-term modeling results for Total DDT (minimum K_d). The blue-shaded color contour is $1x10^{-4}$ ug/L (time = 40 days). The concentration of the CDF ponded water is 0.0119 ug/L

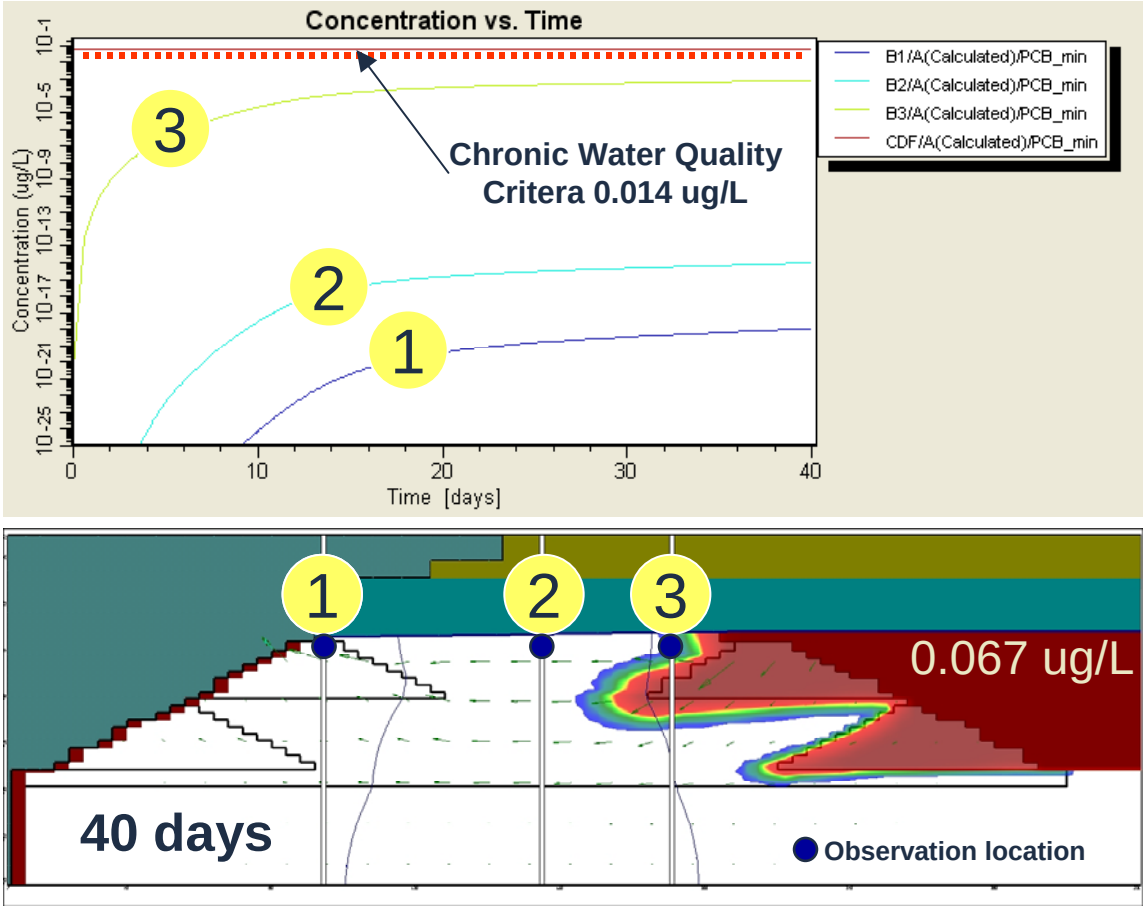

Figure 7: Short-term modeling results for Total PCB (minimum K_d). The blue-shaded color contour is $1x10^{-4}$ ug/L (time = 40 days). The concentration of the CDF ponded water is 0.067 ug/L

SUPPLEMENTAL INFORMATION

This section provides supplemental information requested by EPA and its contractors during the July 19 teleconference (Technical Meeting #11).

Retardation

This section reviews the concept of retardation and sorbed velocity of a solute in groundwater. For comparison purposes, retardation calculations are also provided to compare short-term COPCs and other common groundwater contaminants.

COPCs in soil and porewater are subject to a variety of physicochemical processes, including advective, dispersive and diffusive transport, adsorption to soil, biodegradation, and other mechanisms that may occur during transport. These processes may have a significant effect on COPC concentrations in groundwater and on a COPC's velocity in groundwater.

COPCs in groundwater often move at a slower rate than the groundwater due to the adsorption of the compounds to soil particles. This process is described as retardation of a given compound in the groundwater. The retardation factor varies for different compounds and for different soil organic carbon contents. Sorption refers to the chemical transport process whereby chemicals dissolved in groundwater partition preferentially to solid-phase aquifer materials.

The quantity of a chemical that can partition to solid phase materials is directly proportional to the affinity of the dissolved chemical to sorb to the solid-phase material. This affinity is described by the soil-water partition coefficient, K_d. The result of this process is that some quantity of the chemical mass is removed from groundwater during transport, and the rate of COPC migration in groundwater can be less than the average linear groundwater velocity. To more accurately evaluate the role that sorption plays in retarding the COPC plume migration rate relative to the average linear groundwater velocity, a COPC-specific retardation factor can be estimated based on the following equation:

$$R_c = 1 + \left[\frac{\rho_b \cdot K_d}{\phi} \right] \qquad \text{(Freeze and Cherry, 1979)}$$

where R_c is the retardation factor for a specific chemical (c), ρ_b is the bulk density of the soil, K_d is the chemical specific soil-water partition coefficient, and ϕ is the soil porosity. For organic COPCs, K_d can be described by $K_{oc} \times f_{oc}$ where K_{oc} is the chemical-organic carbon partition coefficient and f_{oc} is the fraction of organic carbon in the soil.

Site-specific K_d values can be developed for COPCs. Site-specific data, typical material properties, and chemical-specific literature values can be used in the calculation. Table 5 shows retardation calculations for the COPCs using the K_d and K_{oc} data described above for berm materials. The retardation factors in the berm range from 728 to 2,397. Table 6 shows retardation calculations for the COPCs using the K_d and K_{oc} data described above for training dike materials. The retardation factor in the training dike material is one.

The sorbed velocity of solute can be calculated by dividing the average groundwater velocity by the retardation factor. In other words, the sorbed velocities of the COPCs are approximately 728 to 2,397 times slower than the average groundwater velocity in the berm material. Thus, attenuation is expected to limit the transport distance of COPCs in the berm during filling conditions. Attenuation is assumed not to occur in the training dike materials during filling conditions.

For comparison purposes, Table 7 shows retardation calculations for other common groundwater contaminants assuming berm material properties. The constituents illustrated in Table 7 provide a range of retardation in groundwater. As expected, some chemicals move readily in groundwater. Other constituents preferentially adsorb to soil.

Table 5: COPC calculated retardation factor (using minimum K_{oc} and K_d) in berm material.

COPC	Fraction Organic Carbon f_{oc} (-)	Partitioning Coefficient K_{oc} (L/Kg)	Adsorption Distribution Coefficient K_d (L/Kg)	Bulk Density ρ_b (Kg/L)	Porosity ϕ (-)	Calculated Retardation Factor R (-)
Cu	-	-	133 [a]	2	0.3	888
Pb	-	-	109 [a]	2	0.3	728
Total DDT	0.0006	303,000	182	2	0.3	1213
Total PCB	0.0006	599,000	359	2	0.3	2397

[a] NewFields, 2007b

Table 6: COPC calculated retardation factor (using minimum K_{oc} and K_d) in training dike material.

COPC	Fraction Organic Carbon f_{oc} (-)	Partitioning Coefficient K_{oc} (L/Kg)	Adsorption Distribution Coefficient K_d (L/Kg)	Bulk Density ρ_b (Kg/L)	Porosity ϕ (-)	Calculated Retardation Factor R (-)
Cu	-	-	≈0	2.2	0.3	1
Pb	-	-	≈0	2.2	0.3	1
Total DDT	≈0	303,000	≈0	2.2	0.3	1
Total PCB	≈0	599,000	≈0	2.2	0.3	1

Table 7: Calculated retardation factor for some other common groundwater contaminants, assuming berm material properties.

COPC	Fraction Organic Carbon f_{oc} (-)	Partitioning Coefficient K_{oc} [a] (L/Kg)	Adsorption Distribution Coefficient K_d (L/Kg)	Bulk Density ρ_b (Kg/L)	Porosity ϕ (-)	Calculated Retardation Factor R (-)
Aldrin	0.0006	2,450,000	1,470	2	0.3	9800
Benzene	0.0006	58.9	0.035	2	0.3	1.2
Dieldrin	0.0006	21,400	13	2	0.3	87
Pyrene	0.0006	105,000	63	2	0.3	420
TCE	0.0006	166	0.1	2	0.3	1.7

[a] USEPA, 2002, Exhibit C-1, Supplemental Guidance For Developing Soil Screening Levels For Superfund Sites, OSWER 9355.4-24, December 2002.

REFERENCES

Blasland, Bouck & Lee, Inc. (BBL), 2004. Characterization Report, Terminal 4 Early Action, Port of Portland, Oregon. September 17.

EPA 2005. Partition Coefficients For Metals In Surface Water, Soil, And Waste. EPA/600/R-05/074.

Harbaugh, A.W., Banta, E.R., Hill, M.C., and McDonald, M.G., 2000, MODFLOW-2000, the U.S. Geological Survey modular ground-water model -- User guide to modularization concepts and the Ground-Water Flow Process: U.S. Geological Survey Open-File Report 00-92, 121 p.

Freeze R.A. and Cherry J.A. 1979. Groundwater. Prentice Hall, Englewood Cliffs.

NewFields, 2007a, June 20, Technical Memorandum: Short-Term CDF Hydraulic Boundary Condition.

NewFields, 2007b, June 20, Technical Memorandum: Cadmium, Copper, and Lead Partition Coefficients for Berm Materials in T4 CDF Groundwater Transport Models

Zheng, Chunmiao, and P. Patrick Wang, 1999, MT3DMS, A modular three-dimensional multi-species transport model for simulation of advection, dispersion and chemical reactions of contaminants in groundwater systems; documentation and user's guide, U.S. Army Engineer Research and Development Center Contract Report SERDP-99-1, Vicksburg, MS, 202 p.