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Environmental Systems & Technologies
A Division of Groundwater & Environmental Services, Inc.

**Assessment of Fate and Transport
of Constituents of Concern
for the
Proposed FGD Scrubber Residue Disposal Site
Belews Creek Steam Station
3195 Pine Hall Road
Belews Creek, North Carolina**



prepared for

Duke Power
526 South Church Street
Charlotte, North Carolina 28202

Prepared by

Environmental Systems & Technologies
A Division of Groundwater & Environmental Services, Inc.
1750 Kraft Drive, Suite 2700
Blacksburg, Virginia 24060

1300309-01-RF1
October 2005

APPROVED
DIVISION OF WASTE MANAGEMENT
SOLID WASTE SECTION
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1. Introduction

The following provides an overview of the approach and results for the fate and transport assessment conducted for the proposed Flue Gas Desulfurization (FGD) scrubber residue disposal site located near the Duke Power (Duke) Belews Creek Steam Station facility in North Carolina. The objective of the work scope is to determine if leachate infiltrating into the subsurface from the proposed landfill design will exceed the 15A NCAC 2L groundwater standards (2L standards). The landfill may also serve as a disposal site for clarifier waste. The constituents of concern (COCs) are sulfate, fluoride, boron, selenium, chloride, and arsenic. The proposed landfill will be in operation for a period of ten years and will be lined but uncovered during this period. The landfill will then be capped with a synthetic, engineered cover to minimize infiltration and leaching potential.

The fate and transport assessment was performed in three separate phases: (1) leachate modeling, (2) vadose zone flow and transport modeling, and (3) saturated flow and transport modeling. The first phase utilized the Hydrologic Evaluation of Landfill Performance (HELP) model to determine the infiltration rate of leachate from the landfill to the vadose zone during the operational and post-closure phases. The HELP modeling was performed by Duke, and the results were provided to ES&T for application in the vadose zone modeling. During the second phase, vadose zone flow and transport modeling was conducted to evaluate the COC concentrations reaching the water table. If the COC concentrations reaching the water table exceeded the 2L standards, then a third phase involving saturated zone flow and transport was performed to determine the fate of the COC within the aquifer.

The specific modeling activities involved a review of site data, conceptual model development, model selection, model construction, and model simulations. Details of the site conceptualization, modeling analyses, and results are described in the following sections.

2. Site Conceptualization

The site is located within the Milton belt of the Piedmont geologic province (S&ME, 2005). Typically within this region the bedrock consists of strongly foliated gneiss and schist with distinct layering. In general, the degree of weathering with depth decreases downward and a corresponding lithological change from residuum to saprolite to partially weathered rock is observed. Both depths to the lithologic units and the thicknesses of the units overlying the bedrock vary across the site. Bedrock occurs at depths ranging from 10.5 to 90 feet below ground surface (bgs). Bedrock is overlain by varying thicknesses of a highly weathered soil and rock mixture termed partially weathered rock (PWR). PWR is encountered at depths ranging from ground surface up to approximately 65 feet bgs. The PWR typically grades upward into saprolite, where weathering is more pronounced than the PWR, but the remnant structure of the bedrock is still evident. Saprolite is encountered at depths ranging from ground surface to 23.5 feet bgs. Above the saprolite, the further weathering of the strata results in soil, termed residuum, with no remnants of the parent structure.

The residual soil, saprolitic soils, and PWR typically have high porosity with low to moderate permeability. The potential for residuum and saprolite to transmit groundwater is dependant upon the particle size of the sediments and the amount of remnant structure present. Groundwater also occurs within the PWR and bedrock. Within the PWR groundwater occurs primarily within the clay, silt and sand in the weathered area. However, groundwater within the bedrock primarily occurs within fractures and joints. Fracture zones and foliations in bedrock, or that are retained in the PWR and saprolite, typically exhibit higher hydraulic conductivity and influence groundwater flow patterns.

The Siting Report (S&ME, 2005) further grouped the lithological units into hydrogeologic units so that soils with similar hydraulic conductivities would be considered part of the same unit when flow is considered. Four hydrogeologic units were identified based on hydraulic characteristics. At some locations, these hydrogeologic units cross lithologic boundaries, as described below:

Hydrogeologic Unit 1: Monitor wells BC-15, BC-19, BC-20, BC-21 and BC-22 were completed in residuum or saprolite with the water table occurring in either residuum or saprolite.

Hydrogeologic Unit 2: Monitor wells BC-2, BC-4, BC-8, BC-9, and BC-11 were completed in highly fractured, highly weathered rock, typically less competent than the underlying fractured bedrock. Rock cores collected from this hydrogeologic unit exhibited low sample recovery and obvious in-filling of weathered fractures. The water column in these wells primarily occurred in the PWR.

Hydrogeologic Unit 3: Monitor wells BC-1, BC-7, BC-8, BC-9, BC-10, BC-12, BC-14 and BC-18 were completed in PWR and/or shallow fractured rock. For the monitor wells screened within this hydrogeologic unit, the water column primarily occurs in the PWR or within bedrock less than 15 feet below auger refusal.

Hydrogeologic Unit 4: Monitor wells BC-16, BC-17 and BC-23A were completed in deep fractured rock with the water column primarily occurring in the bedrock, typically greater than 15 feet below auger refusal.

For the vadose modeling analyses, the first two hydrogeologic units were considered because they existed between the bottom of the proposed landfill and the top of the seasonal high water table. The saturated zone analysis was considered to occur within Hydrogeologic Units 1, 2 and 3. Unit 4 was considered a basal unit below the mixing zone, and was not considered in the saturated dilution model.

Groundwater levels at the site fluctuate seasonally in response to changes in precipitation, evaporation, and rainfall (recharge). Seasonal highs occur in April or May, while seasonal lows occur in November or December. Groundwater flow is generally radial from the northeast portion of the site. Groundwater flow directions appear to be influenced by site topography and Belews Lake. Groundwater elevations measured at the site range from approximately 728 feet above mean sea level (MSL) at BC-8 to approximately 782.5 feet MSL at BC-23A.

In order to determine the minimum depth from the bottom of the proposed landfill, a statistical analysis of the gauging data was performed to determine the estimated seasonal high groundwater (ESHG) elevation. The statistical analysis used data collected over 11 months at the site in conjunction with 15 years of data at the neighboring Pine Hall Road ash landfill. The results of the ESHG analysis predict that the ESHG ranges from approximately 784.9 feet MSL at BC-23A to approximately 736.3 feet MSL at BC-8 (*See Figure 22, S&ME, 2005*). The results of this analysis were used to determine the design elevation of the landfill bottom, and hence, the minimum vadose zone thickness across the site.

Landfill designs indicate that the base of the landfill will be constructed between 760 and 788 feet MSL. The base of the landfill will intersect the saprolite and PWR units, but maintain the regulatory separation between the landfill base grade and the water table, based on the ESHG (*S&ME, 2005*). The modeling assessment will consider flow and transport of the COCs from the base of the landfill through the vadose zone to the water table and subsequent flow and transport within the underlying aquifer.

3. Leachate Concentration Analyses

A laboratory leachate analysis was conducted to determine dissolved COC concentrations leaching from the scrubber waste that will be placed in proposed landfill. The analysis of the leachate potential was conducted by Battelle for Duke. Battelle measured contaminant concentrations in solution from five consecutive leaches for the two samples of FGD scrubber waste provided by Duke. These samples were labeled as HC Plant and Co Plant. The USEPA Synthetic Precipitation Leaching Procedure (SPLP, EPA SW846 1312) was used to determine the water soluble constituents in the waste. These concentrations were compared to the 2L standards for each COC to determine if any of the standards were exceeded in the leachate (Table 1).

The total dissolved solids and sulfate (SO_4) concentrations exceeded the 2L standards for both types of waste in all leachates by factors of approximately 4 and 6, respectively. The initial leaches from both waste types exceeded the fluoride (F) 2L standard by a factor of about 2; however, the fluoride concentrations decreased with subsequent leaches and either dropped below or were very close to the standard of 2 mg/L by the fifth leach. The arsenic (As) concentrations in all leachates started below the 2L standard of 0.01 mg/L, but the concentrations increased with subsequent leaches and exceeded the standard by a small amount in all cases after the second or third leach. No other constituents exceeded their respective 2L standards.

X-ray diffraction (XRD) analysis showed that the dominant mineral in the waste was gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). Saturation index calculations confirm that gypsum is controlling the calcium and sulfate concentrations in the leachate and producing the major ions in solution.

Additional SPLP analyses for three different clarifier waste samples were also considered in determining the COCs and their maximum leachate concentrations. Table 2 presents these data along with a comparison to the NCAC 2L groundwater standards. The leachate concentrations for chloride (Cl), fluoride (F), sulfate (SO_4), boron (B), and Selenium (Se) exceeded the 2L standard.

Table 3 summarizes the maximum leachate concentrations for the two waste types and all of the chemicals that exceeded the 2L standard. The maximum concentration of the two waste types was used in the vadose modeling for each chemical. Based on the results of the SPLP analysis and comparison to the 2L standards, the COCs utilized in the vadose zone modeling were three cations: arsenic, boron and selenium and three anions: fluoride, sulfate and chloride.

4. Vadose Zone Modeling Approach

A one-dimensional flow and transport model was selected for the vadose zone. The site hydrogeology was evaluated in relation to the proposed bottom of the landfill. Based on this analysis, two borings were selected for the vadose zone modeling. Table 4 lists the monitoring wells within the proposed landfill. The ground surface, measured groundwater elevation, estimated seasonal high groundwater elevation and the proposed subgrade elevation of the bottom of the landfill are presented to identify the minimum depth to water. The maximum potential for COCs to be transported through the vadose zone from the leachate exists where the depth to groundwater is shallowest beneath the landfill. As such, the location with the minimum depth to groundwater in each of the hydrogeologic units was selected for the analysis. Boring BC-18 was selected to represent the Hydrogeologic Unit 1 with a minimum depth to groundwater of 4.0 feet. Boring BC-16 was selected to represent the Hydrogeologic Unit 2 with a minimum depth to groundwater of 5.0 feet.

The fate and transport of the six COCs were simulated in these two soil profiles utilizing the maximum leachate concentrations from the SPLP analysis and the recharge rate derived from the HELP modeling of the proposed lined landfill design. The concentrations just beneath the landfill liner were predicted, the concentrations versus depth in the vadose zone were examined, and the predicted concentrations at the water table were compared to the 2L standards to determine if further modeling of the saturated zone was required.

4.1 Model Selection

HYDRUS-1D was selected to simulate the migration of the COCs in the leachate from the bottom of the proposed lined landfill to the top of the water table. HYDRUS-1D was developed by the United States Salinity Laboratory, United States Department of Agriculture (USDA), Agriculture Research Service (ARS) and is used to simulate one-dimensional water flow and the movement of solutes in variably-saturated soils. HYDRUS-1D uses the Richards' equation for simulating variably-saturated flow and Fickian-based convection-dispersion equations for heat and solute transport. Galerkin-type linear finite element schemes are used to solve the governing flow and transport equations.

4.2 Model Limitations

HYDRUS-1D does not handle preferential flow. HYDRUS-1D may fail for extremely nonlinear flow and transport problems. HYDRUS-1D neglects the effect of air phase on water flow. Numerical instabilities may develop for convection-dominated transport problems when no stabilizing options are used. Therefore, the implicit time weighting scheme and additional artificial dispersion were added to stabilize the numerical solution and avoid undesired oscillations in the Galerkin finite element results. The manual recommended value of 2.0 for the stability criterion involving $Pe \cdot Cr$ (Peclet number * Curant number) was applied in the simulations.

4.3 Model Construction

A one-dimensional column with a length equal to depth to water for each hydrogeologic unit was constructed. The number of nodes selected corresponded to a small cell width of 1 cm for each unit. In the modeling effort, input parameter values were defined from site data whenever possible. When site-specific data were not available, literature values were utilized to define model input values. The following describes the input parameters of the model and the values applied in the modeling effort.

Dissolved Species – Three cations: arsenic, boron and selenium and three anions: fluoride, sulfate and chloride were considered the constituents of concern in the model.

Leachate Concentrations – The maximum measured SPLP leachate concentrations for the six chemicals as shown in Table 3 were chosen to represent the dissolved concentrations leaving the bottom of the landfill and entering the underlying native soil.

Recharge Rate – Two recharge stress periods were used in the HYDRUS-1D modeling. The first represented the operational period before an engineered cover would be installed over the waste material. The second represented the condition after an engineered cap was installed. The operational rate was applied for the first 10 years of the simulation, and the post-cap rate was applied for the next 90 years. The rate at which recharge passes through the bottom of proposed landfill liner was estimated using HELP and provided by Duke (Miller, 2005). For the first stress period in the vadose zone modeling, the highest predicted recharge value of 0.03 inches per year was used. This HELP scenario considered a single 10-foot layer of sludge above the liner. The HELP estimated post-cap rate of 0.001 in/yr was used as the recharge rate for the second stress period.

Soil-water Distribution Coefficient – For each constituent, the model requires a linear adsorption coefficient for each soil type. The soil-water distribution coefficient (K_d) was measured for five saprolite and five PWR samples as part of a site-specific K_d study. These values are shown in Table 5 (Daniels, 2005) for the constituents of concern. To be conservative, the minimum measured K_d value for each constituent and soil type was used in the modeling.

Porosity – Total porosity is the ratio of void volume to total volume in the aquifer. Table 6 and Table 7 present the soil laboratory data from the samples in Hydrogeologic Units 1 and 2. The average measured porosity of 0.429 and 0.431 for the final sample conditions was used for Hydrogeologic Units 1 and Unit 2, respectively.

Soil Bulk Density – The soil bulk density (ρ_b) is the mass of dry soil relative to the bulk soil volume. Several bulk samples taken from the upper ten feet of the native soil provided a site-specific measurement for the two hydrogeologic units. Tables 6 and 7 present these data and reports the average value in the units of pounds per cubic foot. The values for Hydrogeologic Units 1 and 2 correspond to soil bulk densities of 1.69 g/cm³ and 1.77 g/cm³, respectively.

Particle Size Distribution – The particle size distribution describes the soil in terms of the percent sand, percent silt and percent clay. These are used in the Rosetta DLL (Dynamically Linked Library) within HYDRUS-1D to estimate the van Genuchten water retention parameters

and the residual water content. The average measured particle size distribution of 43.1% sand, 42.8% silt and 14.1% clay from the samples in Hydrogeologic Unit 1, as shown on Table 6, were used in conjunction with the unit type specific bulk density to estimate the water retention parameters applied in the modeling. The average measured particle size distribution of 62.0% sand, 32.9% silt and 5.1% clay from the samples in Hydrogeologic Unit 2, as shown on Table 7, were used in conjunction with the unit type specific bulk density to estimate the water retention parameters applied in the modeling.

van Genuchten Water Retention Parameters (α , N) – As mentioned above, the van Genuchten water retention parameters, α and N , were estimated by Rosetta within HYDRUS-1D based on particle size distribution and bulk density. Alpha values of 0.0178 and 0.0567 cm^{-1} were calculated for Hydrogeologic Units 1 and 2, respectively. Van Genuchten N values of 1.36 and 1.31 were calculated for Hydrogeologic Units 1 and 2, respectively.

Residual Water Content – The residual water content was estimated by Rosetta within HYDRUS-1D based on particle size distribution and bulk density. The values applied in the modeling were 4.16% and 2.83% for Hydrogeologic Units 1 and 2, respectively.

Longitudinal Dispersivity – Hydrodynamic dispersion is the term applied to the combined effects of mechanical dispersion and molecular diffusion in causing a plume to spread within a water system. For this modeling effort, a longitudinal dispersivity of 10 cm was assumed.

Horizontal Hydraulic Conductivity – Slug tests were performed on selected wells to determine the horizontal hydraulic conductivity in each hydrogeologic unit. A summary of the slug test results is provided in Table 8. The geometric mean of the horizontal hydraulic conductivity for each hydrogeologic unit was used in HYDRUS-1D.

Vertical Hydraulic Conductivity – The vertical hydraulic conductivity was estimated from laboratory measurements at soil borings. The vertical hydraulic conductivity for Hydrogeologic Unit 1 of 2.55E-4 cm/s was calculated using the average horizontal hydraulic conductivity and an anisotropy ratio of 9.84 derived from the ratio of the slug test measured value and the laboratory measured value at BC-19. This was the only pair of laboratory measured and slug test measured conductivity values within the same hydrogeologic unit. The vertical hydraulic conductivity for Hydrogeologic Units 2 through 4 was assumed to equal the average horizontal hydraulic conductivity as measured by the slug tests.

4.4 Vadose Zone Model Results and Conclusions

Model simulations were performed for each COC using the minimum thickness locations for Hydrogeologic Units 1 and 2. Model results are presented for the three cations and the three anions of concern as the predicted concentration over time at the top of the vadose zone (i.e., depth equals zero) and as a concentration profile with depth through the vadose zone at 10, 50 and 100 years. When the maximum predicted leachate concentration at the bottom of the vadose zone exceeded the 2L standard over the 100 years, an additional data series showing the concentration at the top of the water table was added to figure for that chemical.

Arsenic – For both of the modeling scenarios, the predicted maximum arsenic concentrations are less than the 2L standard of 0.01 mg/L (Figures 1a and 1b). The maximum predicted concentrations are 8.8×10^{-5} mg/L and 2.0×10^{-4} mg/L for Hydrogeologic Units 1 and 2, respectively. Migration through the vadose zone of these limited concentrations appears to reach a depth of approximately 0.4 feet after 100 years.

Boron – The predicted maximum boron concentrations exceed the 2L standard of 0.315 mg/L (Figures 2a and 2b) at the top of the vadose zone for both of the modeling scenarios. Boron has the lowest K_d and the highest ratio of the maximum leachate concentration to the 2L standard. As a result, the concentrations at the top of the water table are also shown. These concentrations also exceed the 2L standard prior to 100 years. The maximum predicted concentrations after 100 years entering the aquifer are 1.93 and 1.97 mg/L for Hydrogeologic Units 1 and 2, respectively.

Selenium – The predicted maximum selenium concentrations are less than the 2L standard of 0.050 mg/L (Figures 3a and 3b). The maximum predicted concentrations are 9.3×10^{-4} mg/L and 0.003 mg/L for Hydrogeologic Units 1 and 2, respectively. Migration through the vadose zone of appreciable concentrations appears to reach a depth of approximately 0.5 feet after 100 years.

Fluoride – For both of the modeling scenarios, the predicted maximum fluoride concentrations are less than the 2L standard of 2 mg/L (Figures 4a and 4b). The maximum predicted concentrations for Hydrogeologic Units 1 and 2 are 0.029 and 0.018 mg/L, respectively. Migration through the vadose zone of these limited concentrations appears to reach a depth of approximately 0.4 feet after 100 years.

Sulfate – Migration of sulfate through the vadose zone appears to reach a depth of approximately 1.3 feet after 100 years. The predicted maximum selenium concentrations are less than the 2L standard of 250 mg/L (Figures 5a and 5b), with maximum predicted concentrations of 49.7 mg/L and 105.8 mg/L for Hydrogeologic Units 1 and 2, respectively.

Chloride - The predicted maximum chloride concentrations are less than the 2L standard of 250 mg/L (Figures 6a and 6b). The maximum predicted concentrations are 16.7 mg/L and 35.5 mg/L for Hydrogeologic Unit 1 and Unit 2, respectively. Migration through the vadose zone of these limited concentrations appears to reach a depth of approximately 1.3 feet after 100 years.

Long-term – In Figures 2a and 2b, the boron concentrations at the top of the saturated zone were shown to be steadily increasing over time. To determine the highest possible concentration entering the saturated zone, a long-term boron simulation for 100,000 years was performed through Hydrogeologic Unit 1. Figure 7 depicts the boron concentration entering the saturated zone over this long period of time. The concentration entering the top of the saturated zone reaches 99% of the leachate concentration in the landfill after approximately 44,000 years.

In summary, only boron exceeded the 2L standard at the top of the water table in the first 100 years of the landfill operation. However, as evidenced by the long-term predicted concentrations of boron in Hydrogeologic Unit 1 (Figure 7), given unlimited time, the concentration in water reaching the water table will approach the concentration in the landfill material. As such, it is necessary to perform modeling to determine the fate and transport of groundwater concentrations that correspond to the anticipated leachate flux.

5. Saturated Zone Dilution Modeling

The results of the vadose zone modeling indicate that given ample time, the COC concentrations infiltrating through the vadose zone and to the water table ultimately reach the maximum leachate concentrations. Although the concentrations take an inordinate amount of time to reach the theoretical maximum, simulations of the maximum leachate concentrations were performed to determine the potential for them to exceed the corresponding 2L standard beneath the landfill and at the compliance boundary located 250 feet down-gradient from the edge of the landfill.

5.1 Model Selection

MYGRT was selected to simulate the mixing of leachate with groundwater in the unconfined aquifer beneath the landfill. MYGRT Version 3 (EPRI, 1998) predicts the migration of both inorganic and organic solutes in the unsaturated and saturated zones, down-gradient and beneath sources (i.e., waste disposal sites or spills). The processes included are advection, dispersion, retardation, and decay. The simulations can be performed in one, two or three dimensions using either horizontal or vertical views. MYGRT is used to simulate a single species solute migration through several pathways, starting from surface sources and migrating downward through the unsaturated zone, mixing with the underlying groundwater, and then migrating horizontally down-gradient through the aquifer. Each of the pathway models can be simulated individually or as an interconnected system of models. For this application, the MYGRT model was used to compute the concentration in the underlying aquifer as COC laden leachate mixed with the groundwater.

5.2 Model Limitations

The MYGRT model was used in 1D mode to simulate the mixing beneath the landfill of COC laden leachate with the groundwater in the underlying aquifer. The limitations of this approach are in the translation of a transient real-world, three-dimensional system to a one-dimensional approach. Care must be taken in selecting conservative input values in order to produce reliable results. The conservative approach to selecting parameters used in this application is evident in the selection of values for parameters in Section 5.3. For example, unattenuated leachate concentrations were applied directly to the water table.

5.3 Model Construction

MYGRT was applied as a 1D model to simulate the mixing of the leachate entering the aquifer with the native groundwater. For this analysis, a conservative approach was applied using site data. Groundwater flow was considered to predominantly occur within Hydrogeologic Units 1, 2 and 3, and aquifer properties were defined from available data for these units. Unit 4 was considered a basal unit below the mixing zone, and was not utilized in the saturated zone dilution model. Parameter values were selected with the intent to perform conservative modeling to ensure protectiveness of the 2L standards. Input parameter values were defined from site data whenever possible. When site-specific data were not available, literature values were utilized to

define model input values. The following describes the input parameters of the model and the values applied in the saturated zone modeling.

Dissolved Species – Sulfate, fluoride, arsenic, boron, selenium, and chloride were the constituents of concern considered in the model.

Leachate Concentrations – The maximum leachate concentrations for the six chemicals in the vadose zone modeling (Table 3) were selected to represent the dissolved concentrations entering the water table. This is the theoretical maximum concentration entering the aquifer, given unlimited time.

Recharge Rate – The HELP estimated post-cap flux of 0.001 in/yr was used as the recharge rate for the mixing solutions. This rate corresponds to the flux rate of the long-term leachate concentrations used in this analysis.

Soil-water Distribution Coefficient – The soil-water distribution coefficient (K_d) for the mixing model was defined as the lowest estimate based on measured values for each constituent over the Hydrogeologic Units 1, 2 and 3.

Porosity – To maintain the conservative approach, the smallest effective porosity from Hydrogeologic Units 1, 2 and 3 was selected. This value was selected to maximize potential down-gradient transport. An effective total porosity value of 0.20 corresponding to the PWR was used.

Soil Bulk Density – A value of 1.69 g/cm³, corresponding to saprolite in the vadose modeling, was used for saturated modeling analysis. This value is the lowest of Hydrogeologic Units 1, 2 and 3, and has the least potential for retarding the migration of the COCs.

Hydraulic Conductivity – The geometric mean of the horizontal hydraulic conductivity measured for Hydrogeologic Units 1, 2 and 3 was used. Insufficient information is available from wells beneath the landfill to compute a weighted average conductivity for this area. As such, a geometric mean of the values from the vadose zone modeling was used as a conservative value.

Hydraulic gradient – The hydraulic gradient for the saturated zone simulations was computed using the ESHG and flow paths from BC-10 to BC-21, BC-19 to BC-21, BC-18 to BC-8 and BC-9 to BC-20. The minimum gradient from these pairs was selected to produce the longest residence time, and hence, the highest corresponding concentrations. A gradient of 0.0294, corresponding to the flow path from BC-10 to BC-21 was selected.

Source Length Parallel to Flow Direction – The longest flow path across the landfill parallel to groundwater flow direction was determined to be approximately 800 feet. This value was selected for the transport model.

Aquifer Thickness and Mixing Depth – An aquifer thickness of 25 feet was selected. This value corresponds approximately to the average difference between the October 2004 water table

and the bottom of the well at borings within the landfill footprint (24.33 feet). A mixing depth of approximately 23 feet was computed by MYGRT.

5.4 Saturated Zone Model Results and Conclusions

Model simulations were performed for each COC using the mixing model. Model results indicate that after 1,000 years of simulating the direct application of unattenuated leachate concentrations to the underlying aquifer, the NCAC 2L groundwater standards are not exceeded for any COC (Table 9). Leachate concentrations range from 0.018 mg/L for arsenic to 1,710 mg/L for sulfate. Relative to the 2L standards, boron has the highest leachate concentration with approximately 216 times the 2L standard of 0.315 mg/L. Results indicate that for boron, the concentration beneath the landfill after mixing directly with groundwater is approximately 0.085 percent of its initial leachate concentration and 18.4 % of the 2L standard.

In summary, no exceedances of the 2L standard were predicted for any of the COCs directly beneath the landfill. As such, no exceedances of the 2L standard are indicated at the compliance boundary (250 feet down-gradient for the landfill). Therefore, the landfill design appears to be protective of NCAC 2L groundwater standards for the defined waste streams, including both the FCG scrubber residue and the clarifier sludge.

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Tables

Table 1
Scrubber Waste SPLP Results - All Leaches Comparison to NCAC 2L Groundwater Standards
Proposed FGD Scrubber Residue Landfill
Duke Energy - Belews Creek Steam Station
Belews Creek, Stokes County, North Carolina

Analyte	Units	NCAC 2L Groundwater Standard (mg/L)	Maximum Value from All Leaches	CO Plant #1	CO Plant #2	CO Plant #3	CO Plant #4	CO Plant #5	CO Plant Dup #1	CO Plant Dup #2	CO Plant Dup #3	CO Plant Dup #4	CO Plant Dup #5	HC Plant #1	HC Plant #2	HC Plant #3	HC Plant #4	HC Plant #5
pH	std units	6.5 to 8.5	7.35	7.35	6.80	6.89	7.11	7.04	7.31	7.07	6.99	7.08	7.29	7.14	7.10	7.30	6.97	7.18
Arsenic	mg/L	0.010	0.018	<0.010	<0.010	0.013	0.011	0.013	<0.010	0.015	0.013	0.018	0.015	<0.010	0.012	0.018	0.017	0.011
Barium	mg/L	2.000	0.059	0.041	0.046	0.047	0.044	0.044	0.043	0.048	0.042	0.042	0.046	0.051	0.044	0.054	0.051	0.059
Boron	mg/L	0.315	0.163	0.149	0.065	<0.040	0.061	0.073	0.162	0.059	0.069	0.081	0.078	0.130	0.163	0.147	0.136	0.152
Cadmium	mg/L	0.005	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002
Calcium	mg/L	n/a	622	597	603	605	599	586	614	579	607	595	601	612	580	622	589	591
Chloride	mg/L	250.00	5.33	5.33	<0.4	<0.4	<0.4	<0.4	4.98	<0.4	<0.4	<0.4	<0.4	3.67	<0.4	<0.4	<0.4	<0.4
Chromium	mg/L	0.050	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Copper	mg/L	1.000	0.0043	0.0031	<0.0030	0.0043	<0.0030	<0.0030	0.0035	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030	<0.0030
Fluoride	mg/L	2.00	4.45	4.45	3.98	3.86	3.06	2.02	4.02	3.88	3.73	3.03	1.88	3.05	3.18	2.61	1.77	1.21
Iron	mg/L	0.300	0.051	<0.020	<0.020	<0.020	<0.020	<0.020	0.051	<0.020	<0.020	<0.020	<0.020	0.026	<0.020	<0.020	<0.020	<0.020
Lead	mg/L	0.015	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
Magnesium	mg/L	n/a	1.730	1.600	0.237	0.228	0.184	0.159	1.730	0.215	0.200	0.197	0.175	1.230	0.155	0.138	0.127	0.131
Manganese	mg/L	0.050	0.0292	0.0286	0.0107	0.0133	0.0111	0.0092	0.0292	0.0108	0.0107	0.0105	0.0094	0.0187	0.0125	0.0127	0.0121	0.0109
Mercury	mg/L	0.0011	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020	<0.00020
Nickel	mg/L	0.100	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Potassium	mg/L	n/a	0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Selenium	mg/L	0.050	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Silver	mg/L	0.018	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Sodium	mg/L	n/a	2.83	0.93	0.58	<0.50	<0.50	0.55	0.94	0.70	0.59	0.87	0.51	2.83	1.08	0.76	0.70	0.73
Sulfate, SO₄	mg/L	250	1,510	1,490	1,500	1,510	1,460	1,490	1,500	1,500	1,510	1,460	1,480	1,510	1,470	1,470	1,450	1,500
TDS	mg/L	n/a	2200	2,160	2,090	2,130	2,140	2,140	2,180	2,190	2,190	2,150	2,200	2,200	2,150	2,200	2,110	2,100
Zinc	mg/L	2.1000	0.0206	0.012	0.0097	0.0134	0.0133	0.0171	0.0133	0.0091	0.0111	0.0148	0.0206	0.0157	<0.0050	0.0098	0.0138	0.0164

Notes:

Bold denotes concentrations greater than NCAC 2L groundwater standards

Source: Letter Report Regarding: Geochemical Evaluation of Flue Gas Desulfurization Scrubber Waste, Batelle, 2003.

Table 2
Clarifier Waste SPLP Results - All Leaches Comparison to NCAC 2L Groundwater Standards
Proposed FGD Scrubber Residue Landfill
Duke Energy - Belews Creek Steam Station
Belews Creek, Stokes County, North Carolina

Sample Description	MERCURY (CVAA) - WATER- ug/L	CHLORIDE (IC) mg/L	FLUORIDE (IC) mg/L	SULFATE (IC) mg/L	SILVER BY ICP (DIGESTED) mg/L	BORON BY ICP (DIGESTED) mg/L	BARIUM BY ICP (DIGESTED) mg/L	COPPER BY ICP (DIGESTED) mg/L	IRON BY ICP (DIGESTED) mg/L	MANGANESE BY ICP (DIGESTED) mg/L	ZINC BY ICP (DIGESTED) mg/L	ARSENIC BY ICP MASS SPEC (DIGESTED) ug/L	CADMIUM BY ICP MASS SPEC (DIGESTED) ug/L	CHROMIUM BY ICP MASS SPEC (DIGESTED) ug/L	NICKEL BY ICP MASS SPEC (DIGESTED) ug/L	LEAD BY ICP MASS SPEC (DIGESTED) ug/L	SELENIUM BY ICP MASS SPEC (DIGESTED) ug/L
BIG BEND CLARIFIER-SAMPLE A	< 1.00	356.0	< 1.00	1,560.0	< 0.005	67.49	0.075	0.022	0.024	0.020	0.023	7.13	< 0.50	1.30	3.89	< 2.00	150.0
BIG BEND CLARIFIER-SAMPLE B	< 1.00	338.0	1.30	1,710.0	< 0.005	69.14	0.066	0.010	0.012	0.010	< 0.020	7.78	< 0.50	1.16	3.62	< 2.00	152.6
CONEMAUGH CLARIFIER SLUDGE	< 0.50	573.6	4.87	158.8	< 1.50	54.01	0.080	0.031	0.037	0.029	0.029	< 6.00	< 1.50	< 3.00	< 6.00	< 6.00	125.5
NCAC 2L Groundwater Standard (units match SPLP results)	1.10	250.0	2.00	250.0	0.018	0.315	NA	1.000	0.300	0.050	2.100	10.00	5.00	50.00	100.00	15.00	50.0
Maximum		573.6	4.87	1,710.0	0.000	69.14	0.080	0.031	0.037	0.029	0.029	7.78	0.00	1.30	3.89	0.00	152.6

Notes:

NA = not available

Bold denotes concentrations greater than NCAC 2L groundwater standards

Table 3
Summary of Leachate Concentrations Used in Vadose Zone Modeling
Proposed FGD Scrubber Residue Landfill
Duke Energy - Belews Creek Steam Station
Belews Creek, Stokes County, North Carolina

Analyte	Units	NCAC 2L Groundwater Standard	Maximum Leachate from All Scrubber Leaches	Maximum Leachate from All Clarifier Leaches	Leachate Concentration Used in Vadose Modeling
Arsenic	mg/L	0.01	0.018	0.008	0.018
Boron	mg/L	0.315	0.163	69.14	69.14
Chloride	mg/L	250	5.33	573.6	573.6
Fluoride	mg/L	2	4.45	4.87	4.87
Selenium	mg/L	0.05	<0.010	0.1526	0.1526
Sulfate, SO ₄	mg/L	250	1,510	1,710	1,710

Notes:

Bold denotes concentrations greater than NCAC 2L groundwater standards

Table 4
Selection of the Locations for Vadose Zone Modeling Based on the Minimum Thickness for Each Hydrogeologic Unit
Proposed FGD Scrubber Residue Landfill
Duke Energy - Belews Creek Steam Station
Belews Creek, Stokes County, North Carolina

Monitor Well (within footprint of landfill)	Ground Surface	Groundwater Elevation (10/27/2004)	Estimated Seasonal High Groundwater Elevation (Predicted 95% CL)	Proposed Subgrade Elevation (approx.) (ft)	Depth to Water (ft)	Hydrogeologic Unit	Selected Boring for Vadose Modeling
BC-2	764.74	748.93	751.60	773.00	21.40	1	No
BC-9	775.54	756.66	761.54	767.00	5.46	1 & 2	No
BC-10	781.84	757.48	761.98	772.00	10.02	1	No
BC-11	785.15	750.32	753.44	765.00	11.56	1	No
BC-12	802.91	755.02	758.66	768.00	9.34	1 & 2	No
BC-16	833.77	762.47	766.97	772.00	5.03	2	Yes, minimum thickness for Hydrogeologic Unit 2
BC-18	780.97	757.63	762.63	766.60	3.97	1	Yes, minimum thickness for Hydrogeologic Unit 1
BC-19	813.09	775.81	780.31	787.00	6.69	1	No

Notes:

Monitor well BC-13 within the landfill footprint was dry on 10/27/04.

Source: *Geologic and Hydrologic Siting Report, FGD Scrubber Waster Residue Disposal Site Belews Creek Steam Station*
 S&ME, Inc., Raleigh, NC, - September 2005.

Table 5
Site-Specific Measured K_d Values
Proposed FGD Scrubber Residue Landfill
Duke Energy - Belews Creek Steam Station
Belews Creek, Stokes County, North Carolina

Belews Creek Soil Sample ID	K_d Values, mL/g					
	Cations			Anions		
	As	B	Se	F	SO ₄	Cl
Saprolite 1	91.88	1.11	94.73	500.00	6.26	
Saprolite 2	130.46	~0	149.29	500.00	6.57	
Saprolite 3	142.26	3.75	147.68	308.33	6.34	
Saprolite 4	176.19	~0	211.78	64.29	6.18	
Saprolite 5	222.34	0.30	274.58	375.00	5.56	
PWR 1	113.54	0.004	135.48	166.67	22.55	
PWR 2	59.75	0.10	68.56	500.00	1.97	
PWR 3	93.95	0.15	103.04	-	1.92	
PWR 4	55.61	0.11	30.13	> 100	1.52	
PWR 5	24.90	0.10	15.27	1166.67	2.23	
Saprolite (Minimum)	91.88	0.00	94.73	64.29	5.56	5.56*
PWR (Minimum)	24.90	0.004	15.27	166.67	1.52	1.52*

Note: *The K_d values for chloride are the minimum values measured from the anions tested.

Source: Daniels, J., 2005. Site Specific Distribution Coefficients (K_d Values) Belews Creek FGD Material Landfill, August 22, 2005, University of North Carolina – Charlotte, Charlotte, NC.

Table 6
Summary of Soil Laboratory Data Used in Vadose Zone Modeling for Hydrogeologic Unit 1
Proposed FGD Scrubber Residue Landfill
Duke Power - Belews Creek Steam Station
Belews Creek, Stokes County, North Carolina

Boring No.	Sample Type	Sample ID	Sample Depth (ft-bgs)	USCS Classification		Lithologic Unit	Natural Moisture Content (%)	Standard Proctor		Clay %	Silt %	% Finer No. 200	Sand %	Gravel %	Porosity		K (cm/sec)
				Symbol	Soil Description			Maximum Dry Density (pcf)	Optimum Moisture Content (%)						Final Sample Conditions		
BC-2	Bulk Sample	S-1	0 - 10	ML	Tan/brn fine sandy clayey SILT	Residuum	7.5	107	16.4	--	--	--	--	--	--	--	--
BC-3	Bulk Sample	S-1	0 - 10	ML	Brn. fine sandy clayey SILT	Saprolite	5.8	103.3	18.2	14.9	42.7	57.6	42.4	0.0	46.2	2.40E-05	
BC-6	Bulk Sample	S-1	0 - 10	MH	Red sandy clayey SILT	Residuum	27.6	96.3	23.4	--	--	--	--	--	--	--	--
BC-7	Bulk Sample	S-1	1 - 10	ML	Tan/brn sandy clayey SILT	Residuum	24.3	98.2	22.3	27.0	43.2	70.2	28.8	1.0	46.3	3.42E-06	
BC-8	Bulk Sample	S-1	0 - 10	ML	Tan/brn sandy clayey SILT	Saprolite	13.5	100.9	19.6	--	--	--	--	--	--	--	--
BC-10	Bulk Sample	S-1	1 - 10	SM	Yellow clayey silty SAND	Saprolite	9.3	109.1	14.9	7.9	31.6	39.5	57.5	3.0	37.1	9.06E-05	
BC-11	Bulk Sample	S-1	0 - 10	CL	Light red sandy CLAY	Fill/Residuum	27.6	108.4	17.6	--	--	56.6	41.4	2.0	40.4	1.67E-07	
BC-12	Bulk Sample	S-1	0 - 5	ML	Brown fine sandy clayey SILT	Saprolite	14.5	105	18.1	--	--	60.5	39.1	0.4	40.2	5.61E-06	
BC-13	Bulk Sample	S-1	0 - 10	ML	Tan/brn silty clayey sandy SILT	Saprolite	11.1	98.8	22.4	--	--	65.5	33.9	0.6	45.0	4.18E-06	
BC-14	Bulk Sample	S-2	10 - 20	ML	Brown fine sandy clayey SILT	Saprolite	18.0	103.0	19.1	--	--	60.8	39.2	0.0	41.8	8.65E-06	
BC-15	Bulk Sample	S-1	0 - 10	CL	Tan/brown fine sandy silty CLAY	Residuum	27.6	108.3	17.6	--	--	--	--	--	--	--	--
BC-16	Bulk Sample	S-1	0 - 5	SM	Tan silty SAND	Residuum	26.8	101.2	20.8	13.8	21.9	35.7	63.6	0.7	41.8	7.61E-06	
BC-17	Bulk Sample	S-1	0 - 5	SM	Tan brown silty SAND	Residuum	42.1	114.2	14.8	15.6	34.1	49.7	50.3	0.0	36.9	2.26E-05	
BC-19	Bulk Sample	S-1	0 - 6	MH	Red brown sandy clayey SILT	Residuum	21.3	104.2	19.5	36.0	48.2	84.2	15.8	0.0	40.6	1.79E-05	
BC-20	Bulk Sample	S-1	2 - 7	CL	Orange Brown Sandy silty CLAY	Residuum	37.1	87.8	32.4	53.0	30.8	83.8	15.2	1.0	51.3	4.61E-07	
BC-21	Bulk Sample	S-1	1 - 6	ML	Tan brown sandy clayey SILT	Residuum	10.5	114.6	15.3	12.2	38.1	50.3	47.3	2.4	37.3	2.03E-06	
BC-22	Bulk Sample	S-1	0 - 5	CL-ML	Tan brown sandy clayey SILT	Residuum	21.4	112.5	14.2	14.0	36.6	50.6	48.4	1.0	36.2	3.95E-06	
BC-23	Bulk Sample	S-1	0 - 5	CL	Tan brown sandy silty CLAY	Residuum	15.4	110.0	14.6	24.0	32.9	56.9	39.8	3.3	37.4	2.63E-04	
BC-6	Shelby Tube	ST-2	18 - 20	ML	Tan orange clayey silty SAND w/gravel	Residuum	2.7	118.7	12.2	4.3	20.6	24.9	60.1	15.0	34.1	4.40E-05	
BC-7	Shelby Tube	ST-2	14 - 16	ML	Tan/brn sandy clayey SILT	Saprolite	23.5	--	--	21.9	49.9	71.8	28.1	0.1	46	0	
BC-10	Shelby Tube	ST-1	12 - 14	MH	Tan sandy clayey SILT	Residuum	13.2	--	--	17.3	47.4	64.7	34.4	0.9	42.2	2.33E-04	
BC-11	Shelby Tube	ST-2	23 - 25	ML	Yellow/tan-brn sandy clayey SILT	Saprolite	41.2	--	--	12.0	67.9	79.9	20.1	0.0	56.0	8.15E-06	
BC-12	Shelby Tube	ST-2	27.0 - 28.7	ML	Tan/brn sandy clayey SILT	Saprolite	17.8	--	--	10.2	46.0	56.2	43.8	0.0	54.6	6.44E-06	
BC-17	Shelby Tube	ST-1	5.9 - 8.4	ML	Tan sandy clayey SILT	Saprolite	19.0	--	--	6.0	56.3	62.3	37.6	0.1	29.6	2.30E-05	
BC-19	Shelby Tube	ST-1	27 - 29	SC	Orange sandy clayey SILT	Residuum	25.3	--	--	23.5	53.5	77.0	23.0	0.0	58.0	4.26E-04	
BC-3	Split Spoon	SS-5	18.5 - 19.4	ML	Brown clayey SAND	Saprolite	20.2	--	--	7.0	34.9	42.1	57.8	0.1	53.9	3.29E-04	1.23E-04
					Tan fine clayey sandy SILT	Saprolite	--	--	--	9.7	49.5	59.2	40.8	0.0	--	--	--

Table 7
Summary of Soil Laboratory Data Used in Vadose Zone Modeling for Hydrogeologic Unit 2
Proposed FGD Scrubber Residue Landfill
Duke Power - Belews Creek Steam Station
Belews Creek, Stokes County, North Carolina

Boring No.	Sample Type	Sample ID	Sample Depth (ft-bgs)	USCS Classification		Lithologic Unit	Natural Moisture Content (%)	Standard Proctor		Clay %	Silt %	% Finer No. 200	Sand %	Gravel %	Porosity (%)		K (cm/sec)
				Symbol	Soil Description			Maximum Dry Density (pcf)	Optimum Moisture Content (%)						Final Sample Conditions		
BC-9	Bulk Sample	S-1	0 - 10	ML	Tan sandy clayey SILT	PWR	6.6	110.8	13	--	--	--	--	--	--	--	--
BC-1	Split Spoon	SS-2	3.5 - 3.83	SM	Tan fine clayey silty SAND	PWR	--	--	--	4.5	25	29.5	70.5	0	--	--	--
BC-18	Split Spoon	SS-4	18.5 - 18.8	SM	Brown silty SAND	PWR	--	--	--	4.7	26	30.7	63.1	6.2	--	--	--
BC-23	Split Spoon	SS-13	63.5 - 64.9	SC	Tan-brown clayey SAND	PWR	--	--	--	4.8	42.5	47.3	52.3	0.4	--	--	--
BC-2*	Split Spoon	SS-6	23.5-25.0														
BC-2*	Split Spoon	SS-7	28.5-28.7							3	27.8	30.8	65.3	3.9	42		--
BC-2*	Split Spoon	SS-8	33.5-33.7														
BC-2*	Split Spoon	SS-9	38.5-38.6														
B-4*	Split Spoon	SS-9	38.5-38.7							8	51	59	40.9	0.1	44		--
B-4*	Split Spoon	SS-10	43.5-43.6														
BC-9	Split Spoon	SS-1	0-0.4	SC-SM	Tan silty clayey medium to fine SAND	PWR	--	--	--	7.5	39.7	47.2	52.8	0	44		--
BC-10*	Split Spoon	SS-8	28.5-28.9							4	23.2	27.2	52.7	20.1	43		--
BC-10*	Split Spoon	SS-9	33.5-33.85														
BC-11*	Split Spoon	SS-11	48.5-49.0														
BC-11*	Split Spoon	SS-12	53.5-53.9														
BC-11*	Split Spoon	SS-13	58.5-59.0														
BC-12*	Split Spoon	SS-10	38.5-39.0														
BC-12*	Split Spoon	SS-11	43.5-44.0														
BC-12*	Split Spoon	SS-12	48.5-50.0														
BC-12*	Split Spoon	SS-13	53.5-55.0														
BC-18*	Split Spoon	SS-5	23.5-24.3														
BC-18*	Split Spoon	SS-6	28.5-28.8														
BC-19*	Split Spoon	SS-9	43.5-44.0														
BC-19*	Split Spoon	SS-10	48.5-48.9														
						Averages	6.6	110.8	13.0	5.1	32.9	38.1	56.7	5.3	43.1		

Notes: CL: Low Plasticity Clays pcf: Pounds per Cubic Foot
 CH: High Plasticity Clays ft-bgs: Feet Below Ground Surface
 ML: Low Plasticity Silts K: Hydraulic Conductivity
 SC: Clayey Sands cm/sec: Centimeters per Second

%; Percentage of water by volume in the sample
 % Finer No. 200: Sum of the Clay % and Silt % by total volume in the sample
 *: indicates a composite sample was analyzed from split spoons
 PWR: Partially Weathered Rock

Source: *Geologic and Hydrologic Siting Report, FGD Scrubber Waste Residue Disposal Site Belews Creek Steam Station*
 S&ME, Inc., Raleigh, NC, - September 2005.

Table 8
Horizontal and Vertical Hydraulic Conductivity Values Grouped by Hydrogeologic Unit
Proposed FGD Scrubber Residue Landfill
Duke Energy - Belews Creek Steam Station
Belews Creek, Stokes County, North Carolina

Well ID	Hydrogeologic Unit	Monitor Well Geometric Mean Horizontal Hydraulic Conductivity ¹ (cm/sec)	Hydrogeologic Unit Geometric Mean Horizontal Hydraulic Conductivity ¹ (cm/sec)	Hydrogeologic Unit Assumed Vertical Hydraulic Conductivity (cm/sec)
BC-15 BC-18 BC-19 BC-20 BC-21 BC-22	1	2.25E-03 1.22E-03 1.21E-03 7.28E-03 3.55E-03 2.92E-03	2.51E-03	2.55E-04
BC-2 BC-4 BC-8 BC-9 BC-11	2	5.93E-05 1.24E-06 6.67E-06 2.47E-06 5.37E-05	9.17E-06	9.17E-06
BC-7 BC-10 BC-12 BC-14	3	1.12E-05 1.60E-05 6.80E-05 3.02E-05	2.46E-05	2.46E-05
BC-16 BC-17 BC-23A	4	1.64E-04 1.93E-05 5.55E-05	5.60E-05	5.60E-05

Notes:

- Horizontal conductivity estimated from slug test at wells.
- Vertical hydraulic conductivity estimated from laboratory measurements at soil borings.
- The vertical hydraulic conductivity for Hydrogeologic Unit 1 of 2.55E-4 cm/s was calculated using the average horizontal hydraulic conductivity and an anisotropy ratio of 9.84 derived from the ratio of the slug test measured value and the laboratory measured value at BC-19. This was the only pair of laboratory measured and slug test measured conductivity values within the same hydrogeologic unit.
- The vertical hydraulic conductivity for Hydrogeologic Units 2 through 4 was assumed to equal the average horizontal hydraulic conductivity as measured by the slug tests.
- cm/sec = centimeters per second

¹Source: *Geologic and Hydrologic Siting Report, FCD Scrubber Waster Residue Disposal Site Belews Creek Steam Station* S&ME, Inc., Raleigh, NC, - September 2005.

Table 9
Summary of MYGRT Predicted Aquifer Concentrations
Proposed FGD Scrubber Residue Landfill
Duke Energy - Belews Creek Steam Station
Belews Creek, Stokes County, North Carolina

Analyte	Units	NCAC 2L Groundwater Standard (mg/L)	Leachate Concentration Used at Top of Water Table (mg/L)	Aquifer Concentration Beneath Landfill (mg/L)
Arsenic	mg/L	0.01	0.018	1.53E-05
Boron	mg/L	0.315	69.14	0.059
Chloride	mg/L	250	573.6	0.487
Fluoride	mg/L	2	4.87	0.004
Selenium	mg/L	0.05	0.1526	1.29E-04
Sulfate, SO4	mg/L	250	1,710	1.451

Notes:

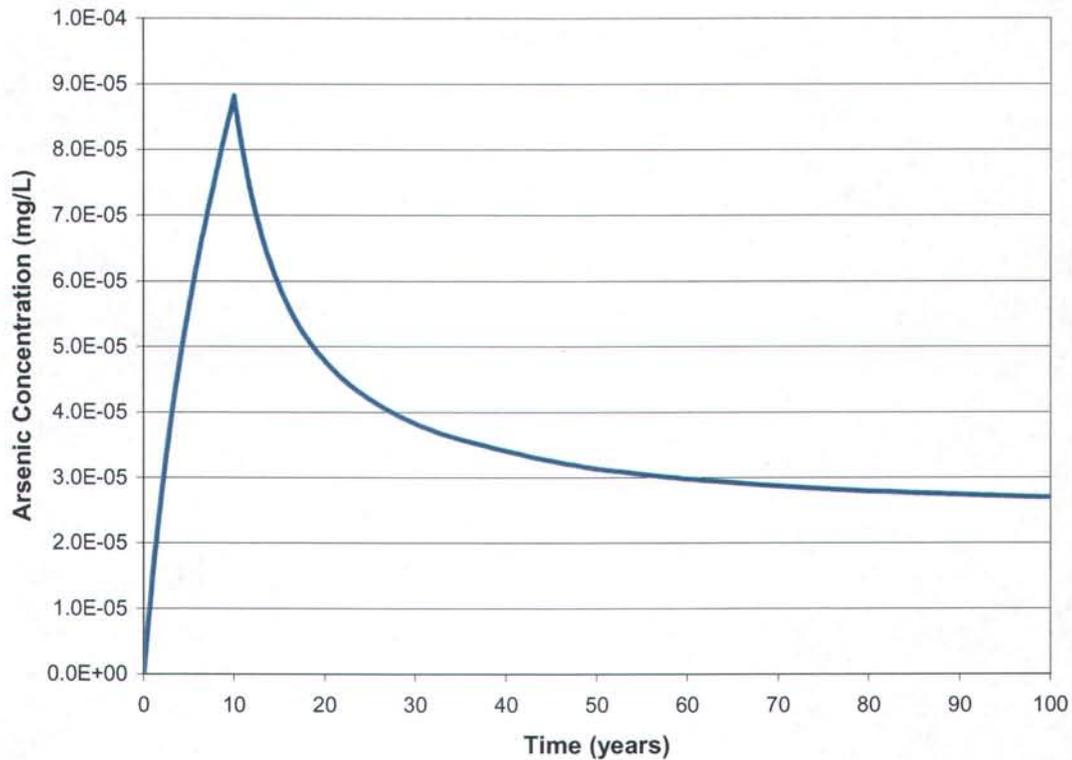
Concentrations are the maximum values calculated during a 1,000 year simulation.

Bold denotes concentrations greater than NCAC 2L groundwater standards

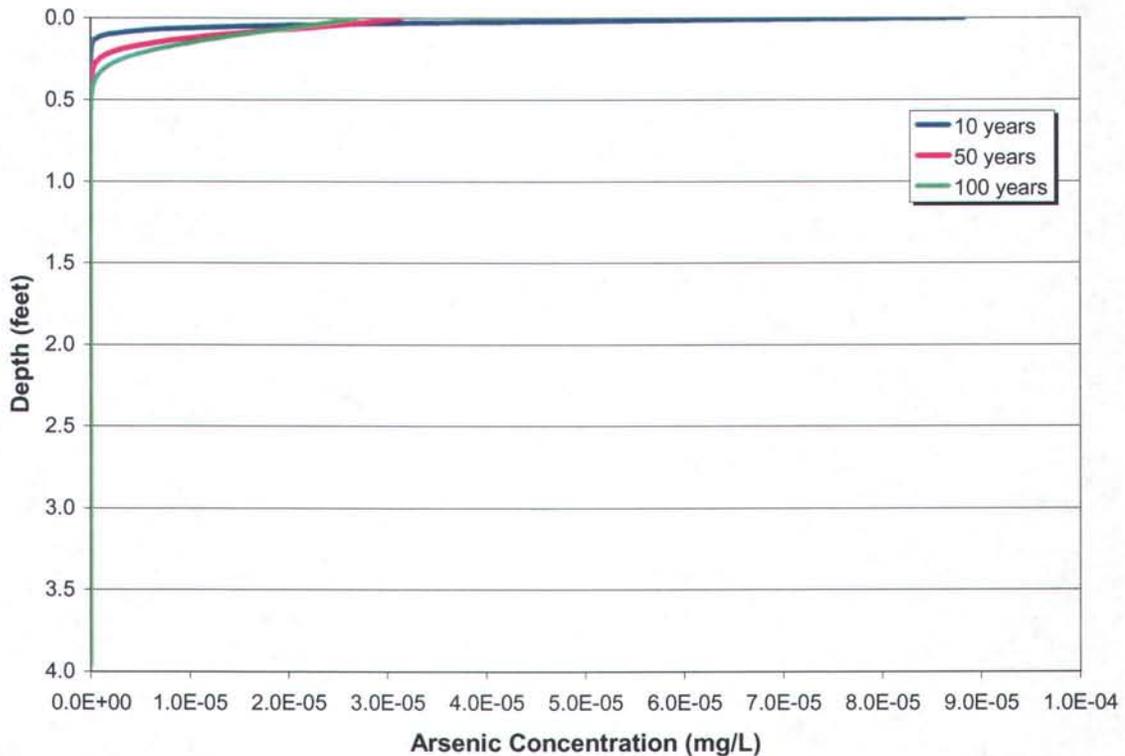
Figures

Arsenic Concentrations in Hydrogeologic Unit 1

Concentrations Over Time at Top of Vadose Zone (Depth = 0 ft)



Concentrations from Top of Vadose Zone to Water Table



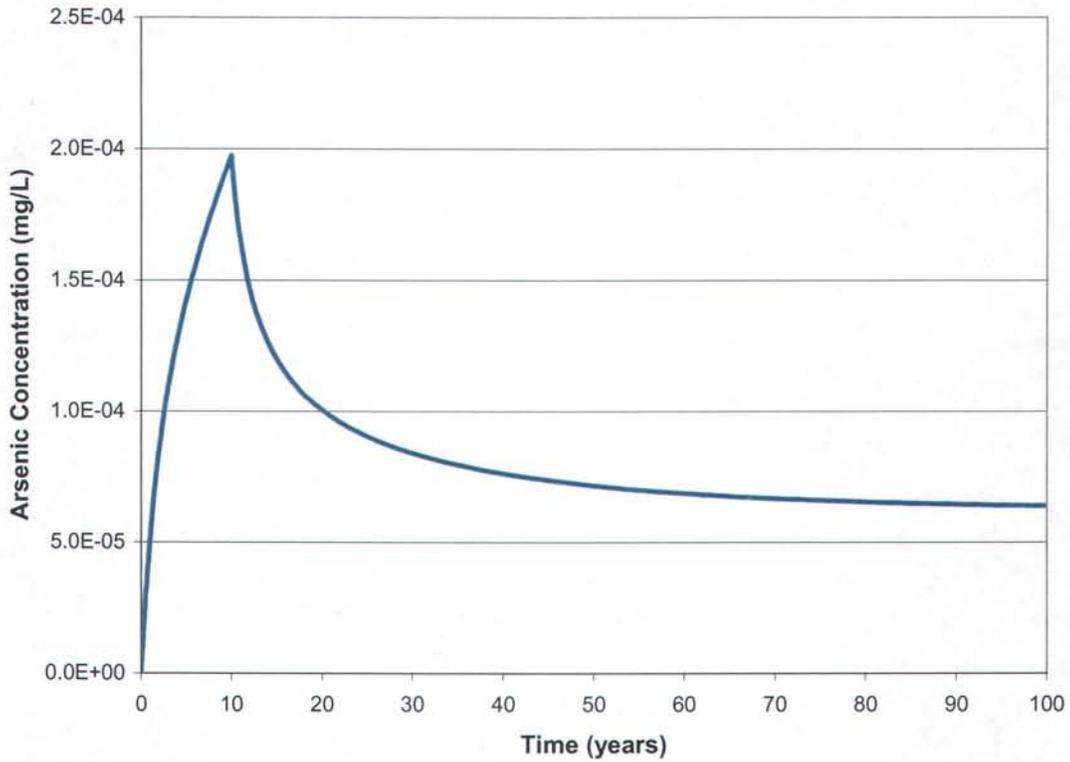
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Date: 10-03-05
Drafter: MJN
Approved: DRB/MAP

Figure 1a. Predicted Arsenic Concentrations in Hydrogeologic Unit 1.

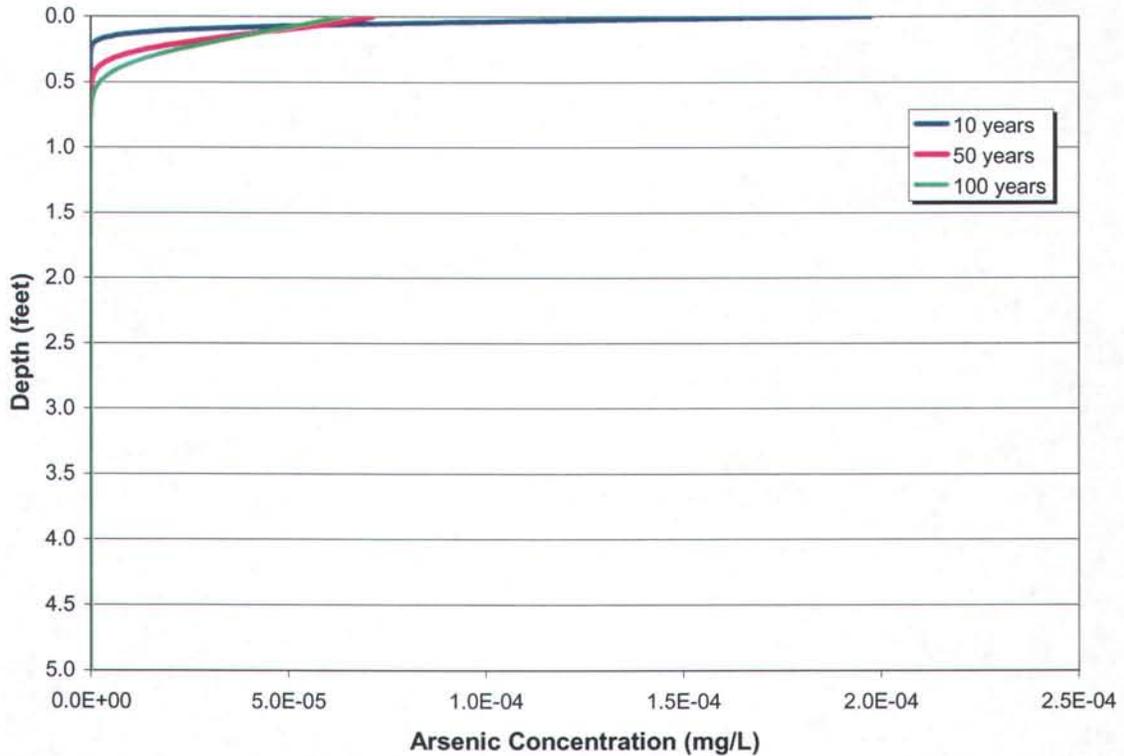


Arsenic Concentrations in Hydrogeologic Unit 2

Concentrations Over Time at Top of Vadose Zone (Depth = 0 ft)



Concentrations from Top of Vadose Zone to Water Table



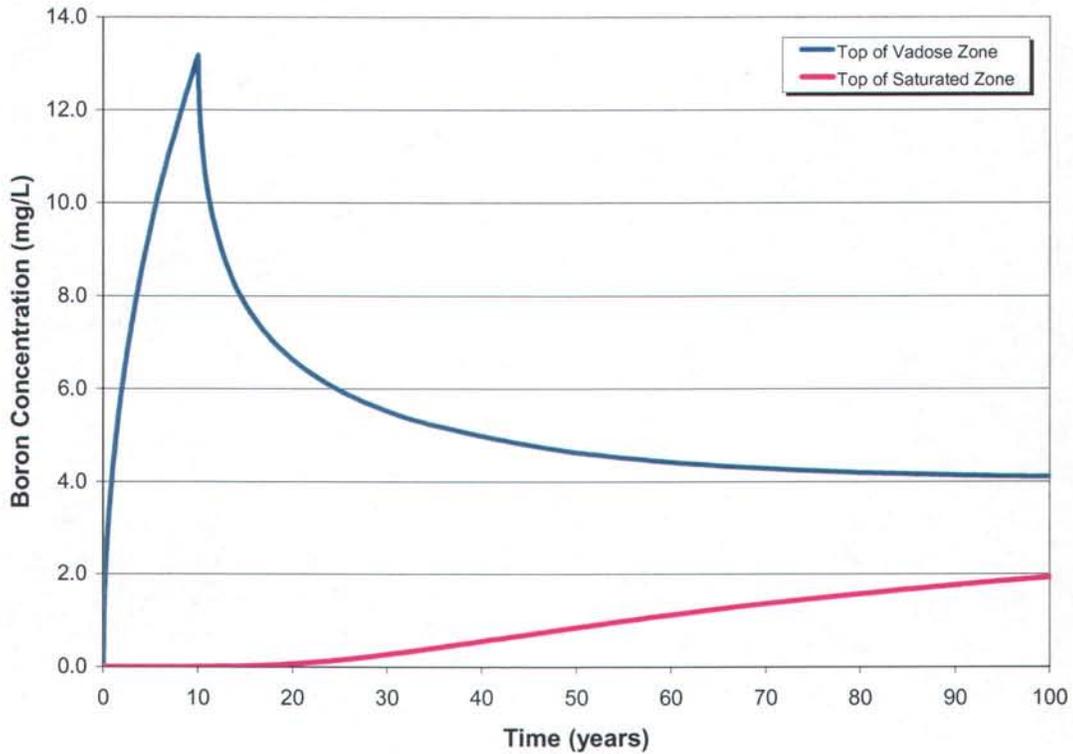
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Approved: DRB/MAP

Figure 1b. Predicted Arsenic Concentrations in Hydrogeologic Unit 2.

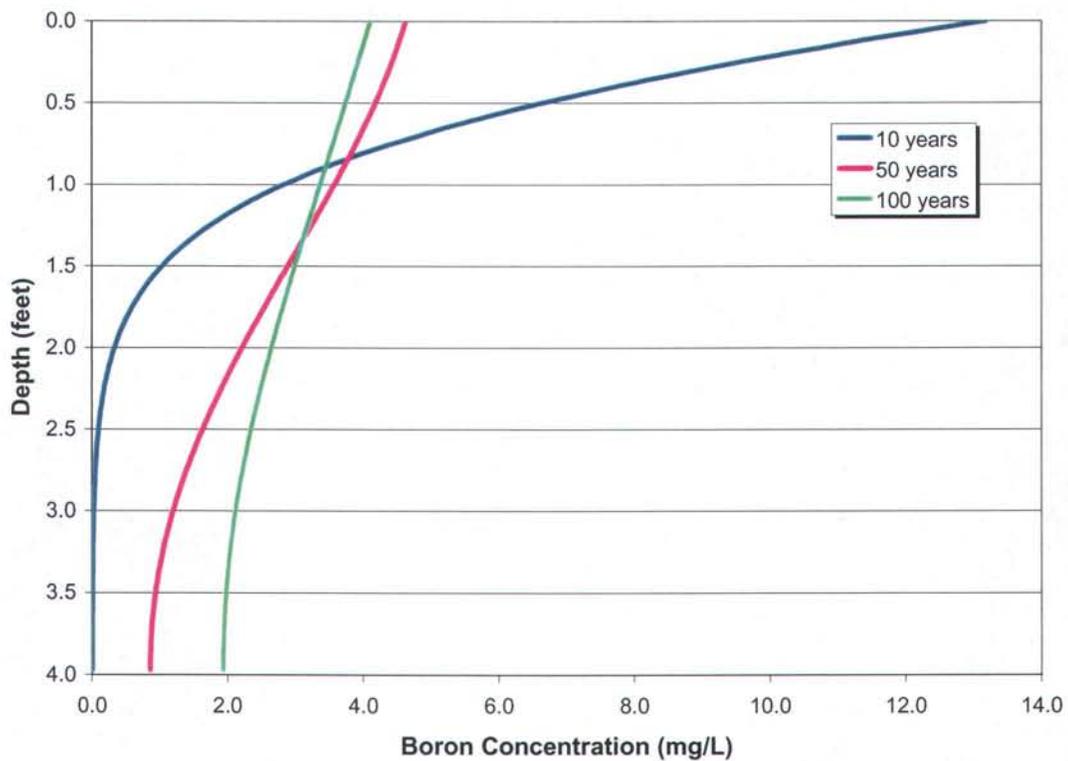


Boron Concentrations in Hydrogeologic Unit 1

Concentrations Over Time at Top of Vadose Zone (Depth = 0 ft)



Concentrations from Top of Vadose Zone to Water Table



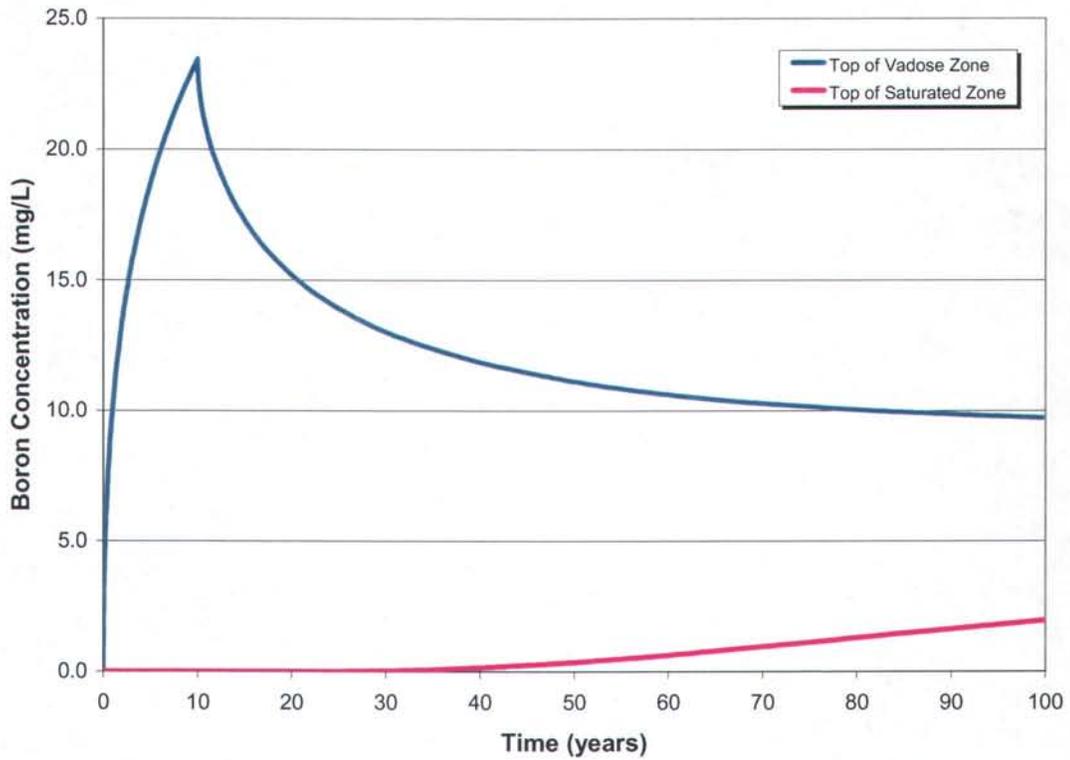
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Figure 2a. Predicted Boron Concentrations in Hydrogeologic Unit 1.

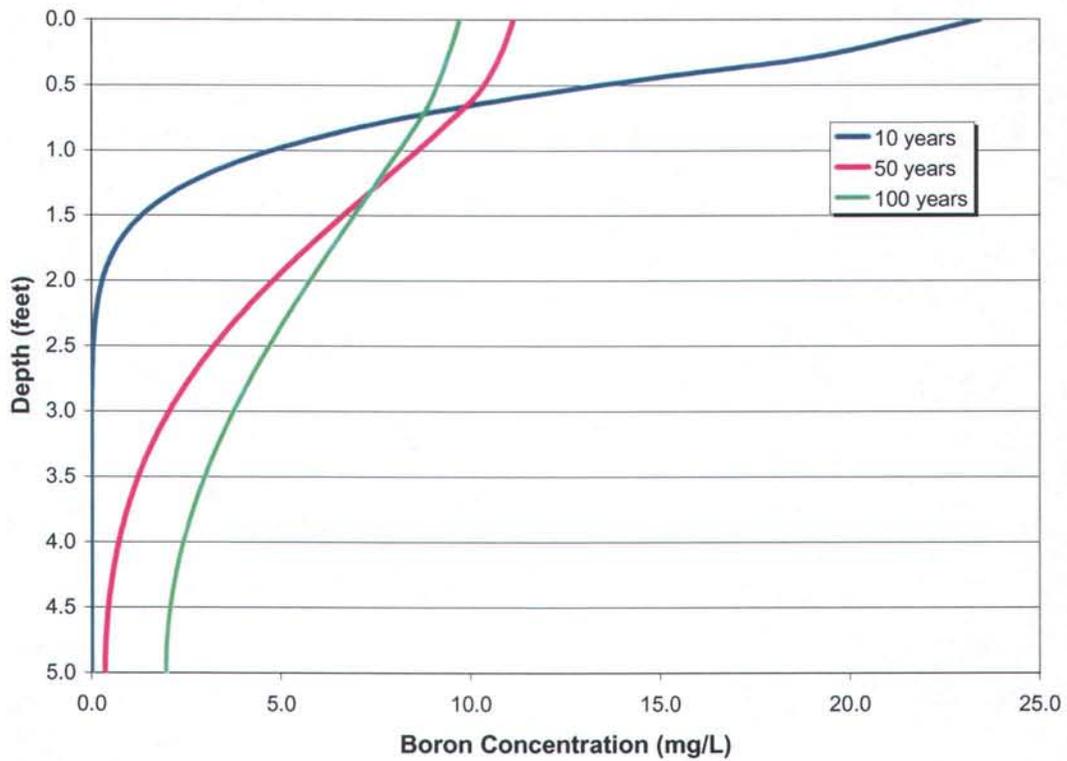


Boron Concentrations in Hydrogeologic Unit 2

Concentrations Over Time at Top of Vadose Zone (Depth = 0 ft)



Concentrations from Top of Vadose Zone to Water Table



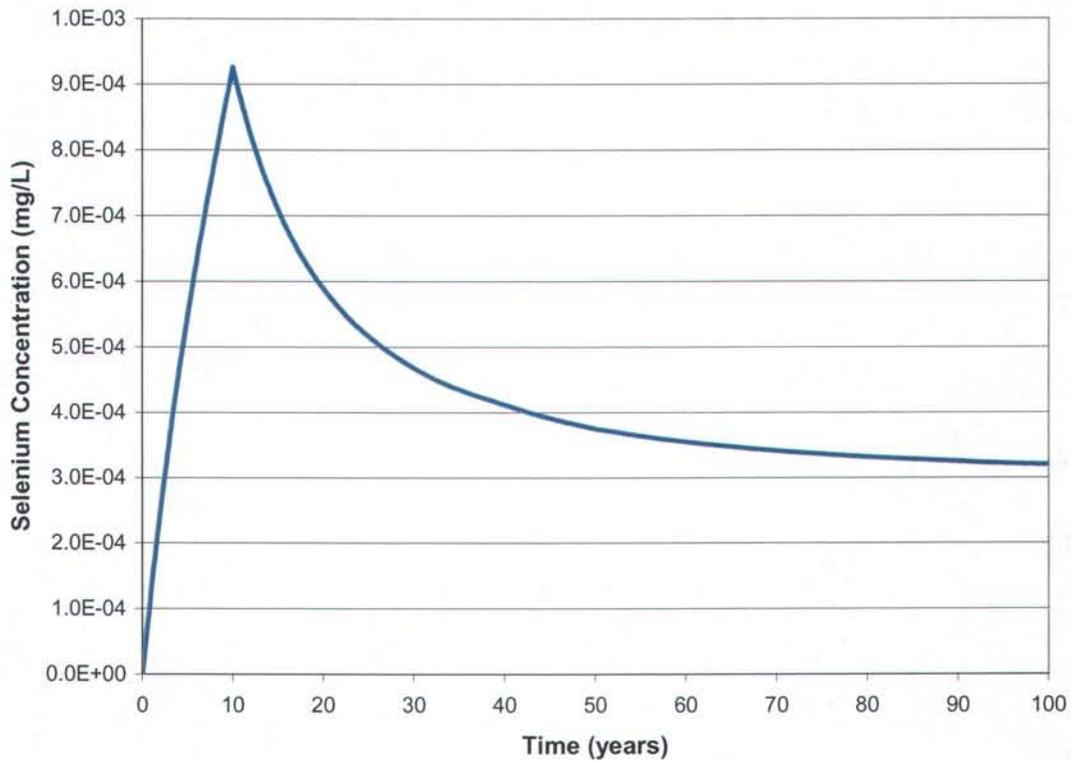
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Figure 2b. Predicted Boron Concentrations in Hydrogeologic Unit 2.

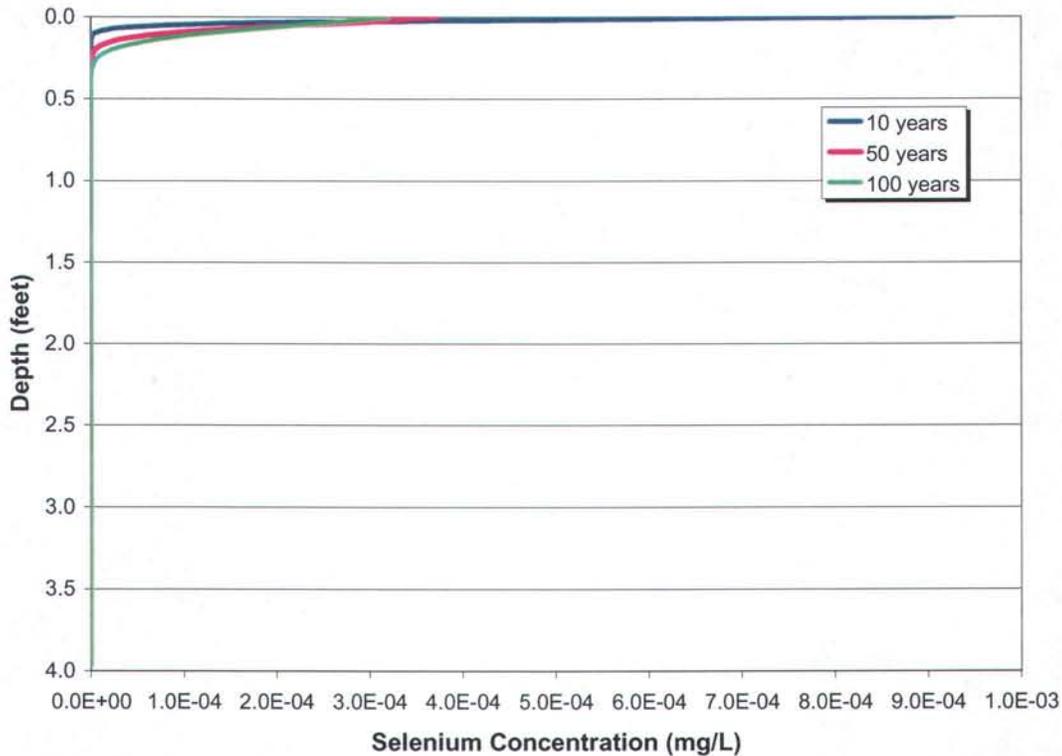


Selenium Concentrations in Hydrogeologic Unit 1

Concentrations Over Time at Top of Vadose Zone (Depth = 0 ft)



Concentrations from Top of Vadose Zone to Water Table



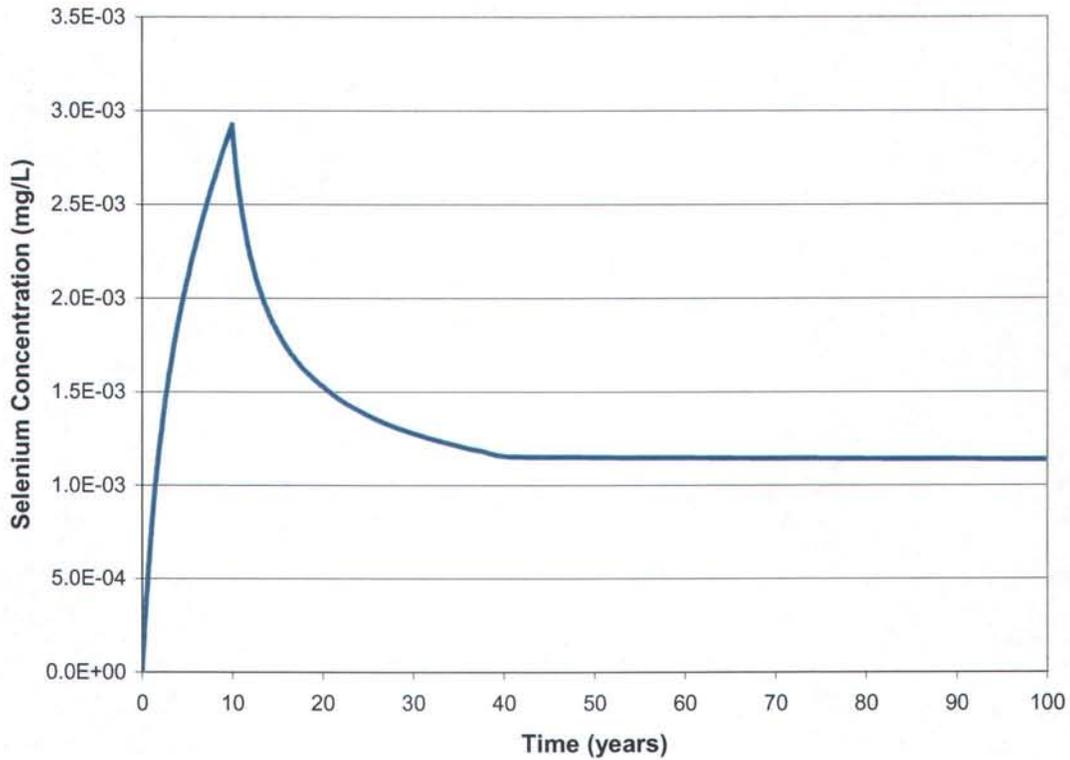
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Drafter: MJN
Approved: DRB/MAP

Figure 3a. Predicted Selenium Concentrations in Hydrogeologic Unit 1.

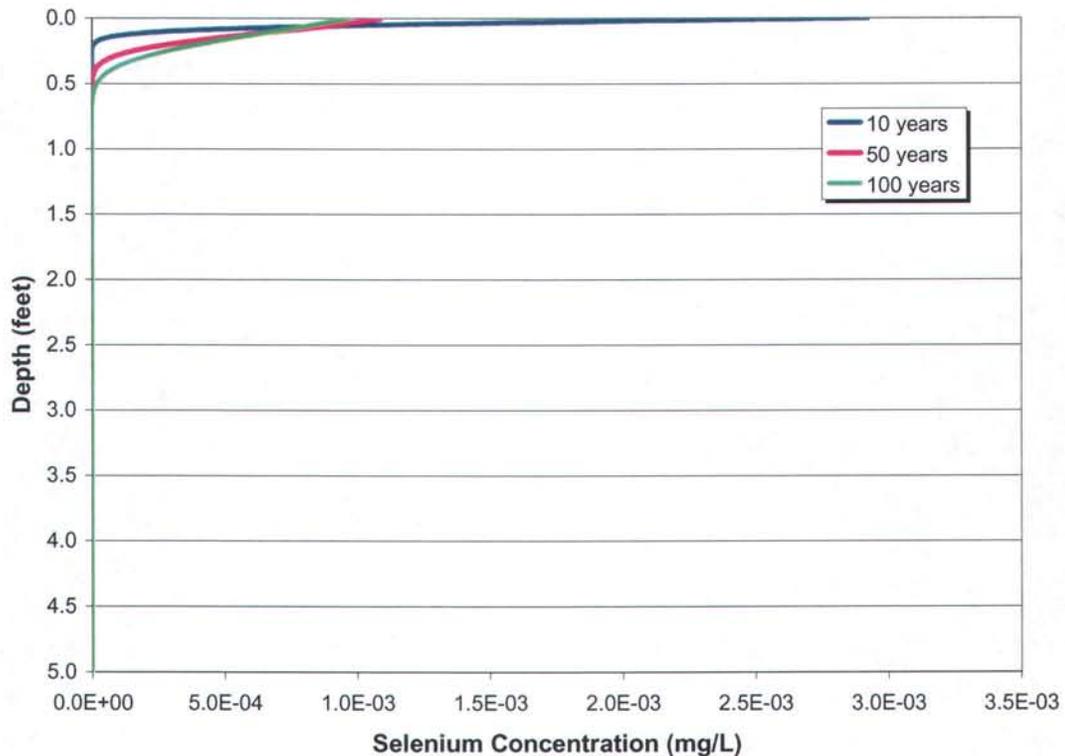


Selenium Concentrations in Hydrogeologic Unit 2

Concentrations Over Time at Top of Vadose Zone (Depth = 0 ft)



Concentrations from Top of Vadose Zone to Water Table



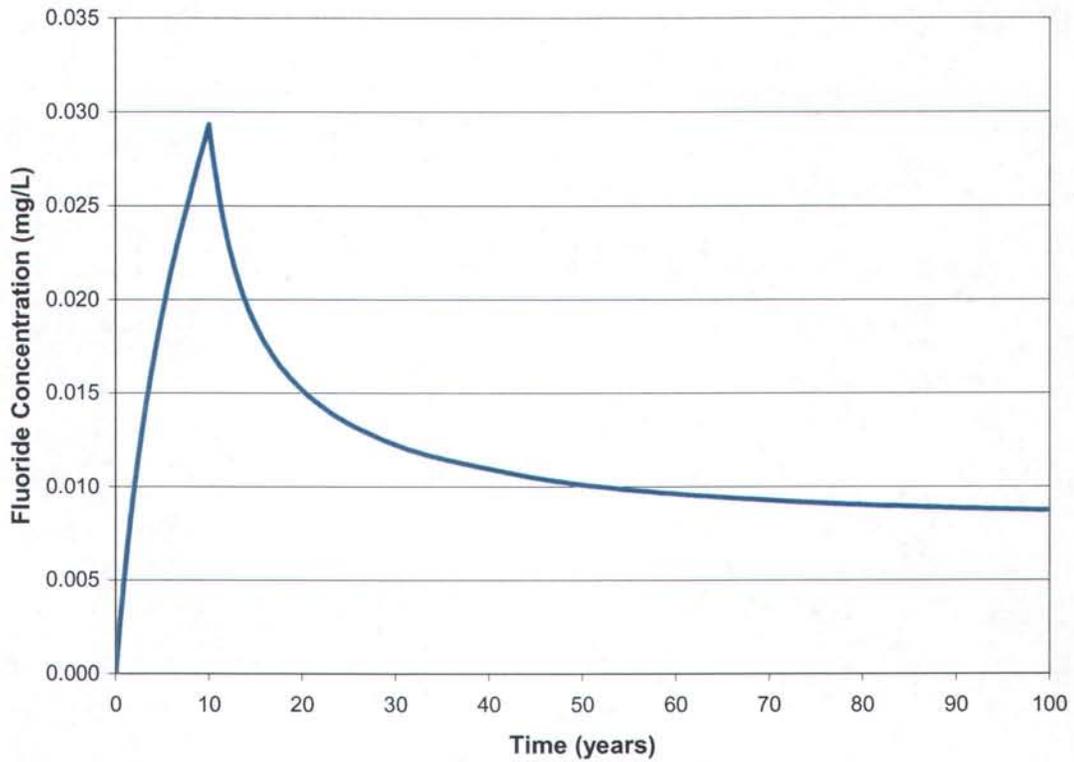
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Figure 3b. Predicted Selenium Concentrations in Hydrogeologic Unit 2.

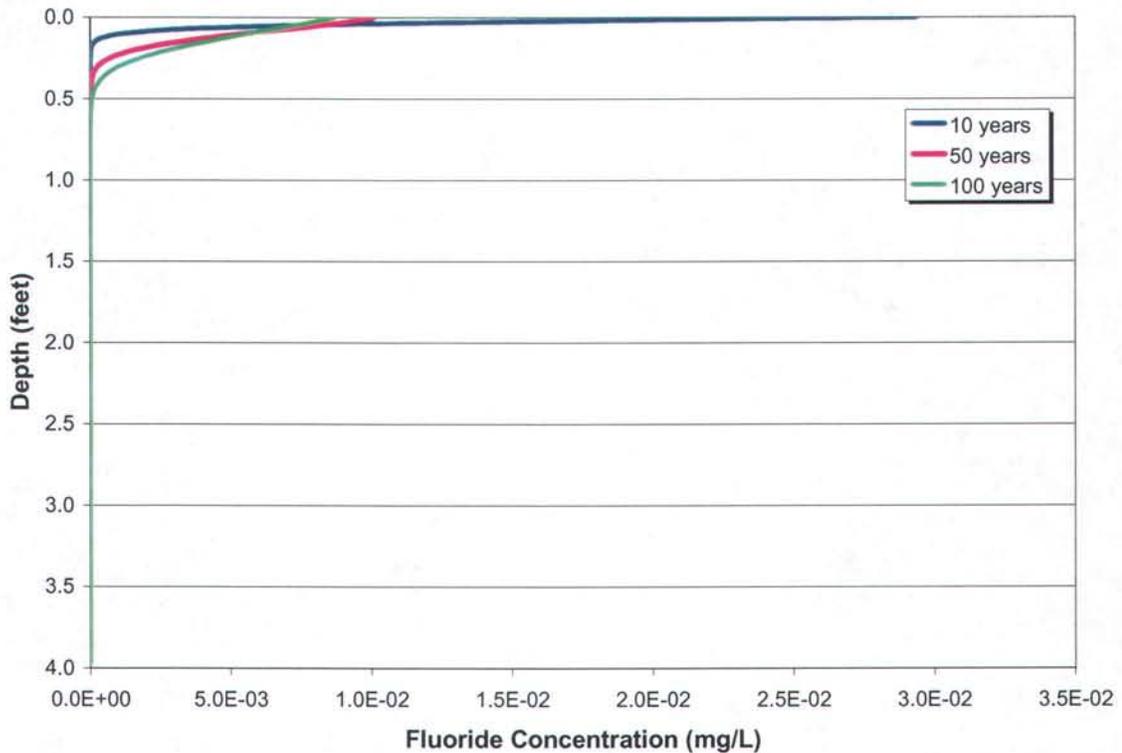


Fluoride Concentrations in Hydrogeologic Unit 1

Concentrations Over Time at Top of Vadose Zone (Depth = 0 ft)



Concentrations from Top of Vadose Zone to Water Table

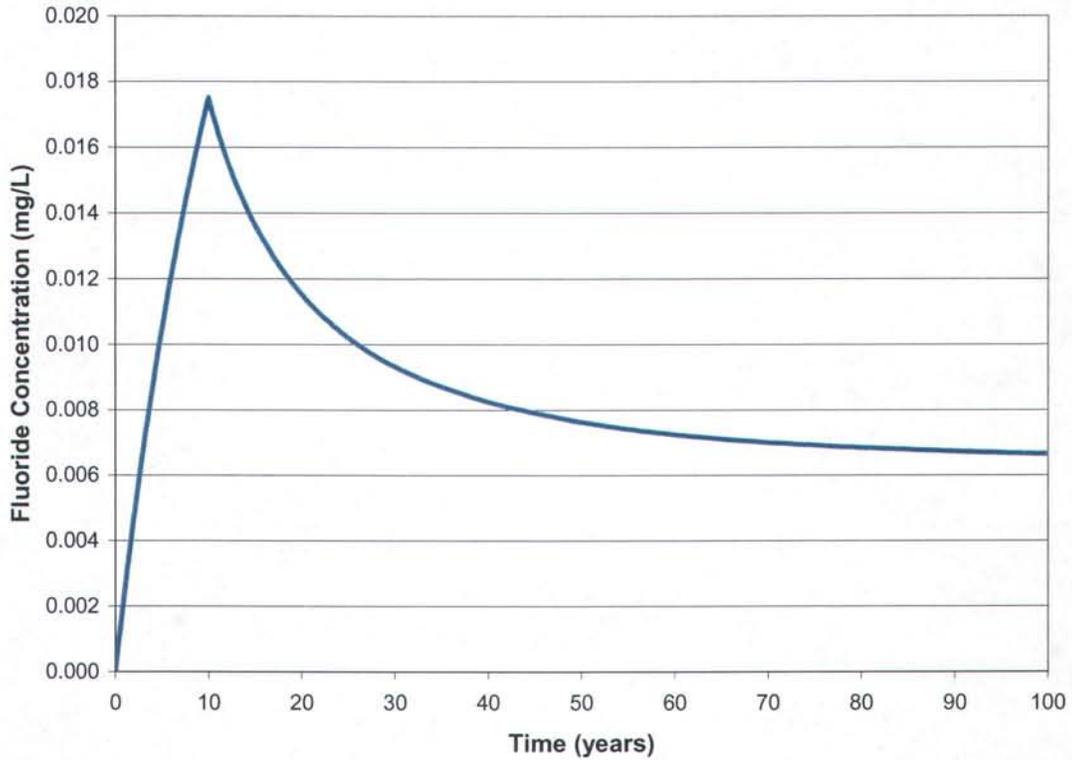


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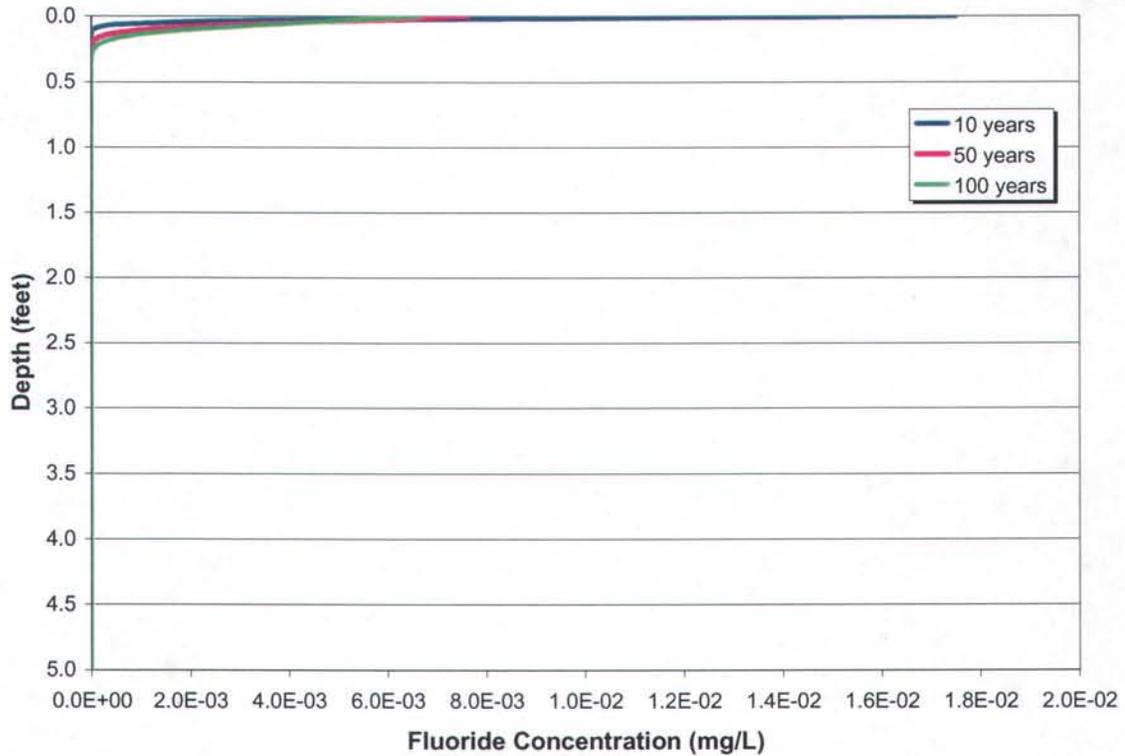
Figure 4a. Predicted Fluoride Concentrations in Hydrogeologic Unit 1.

Fluoride Concentrations in Hydrogeologic Unit 2

Concentrations Over Time at Top of Vadose Zone (Depth = 0 ft)



Concentrations from Top of Vadose Zone to Water Table



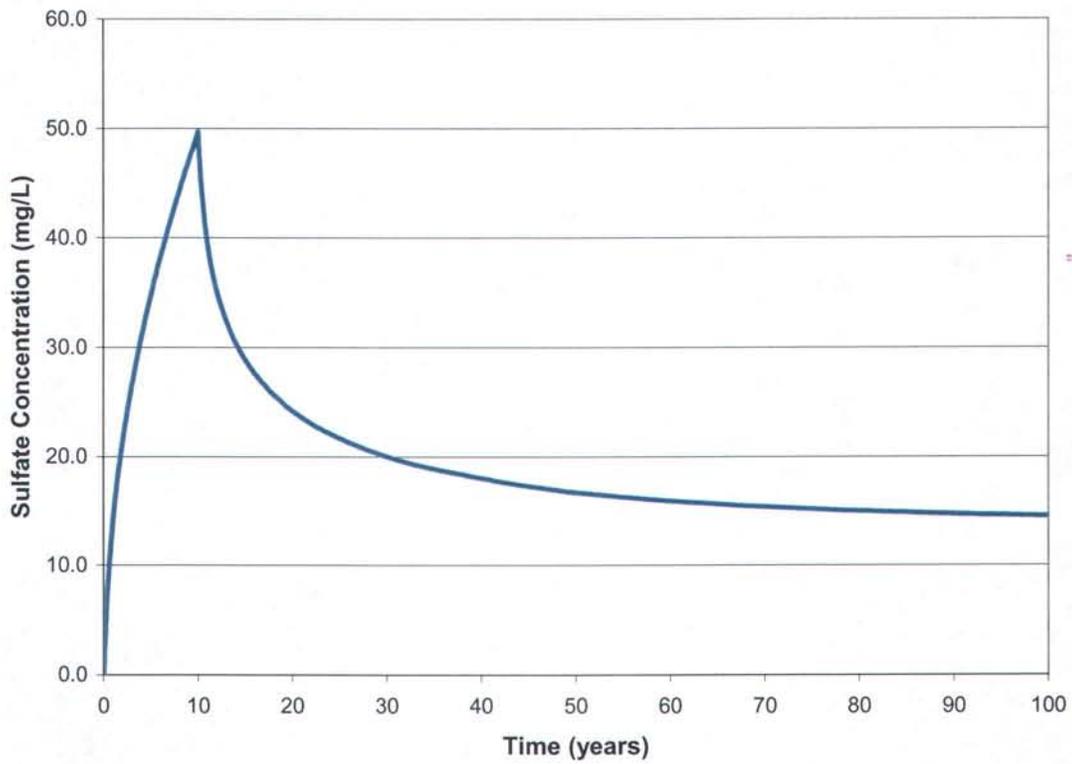
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Approved: DRB/MAP

Figure 4b. Predicted Fluoride Concentrations in Hydrogeologic Unit 2.

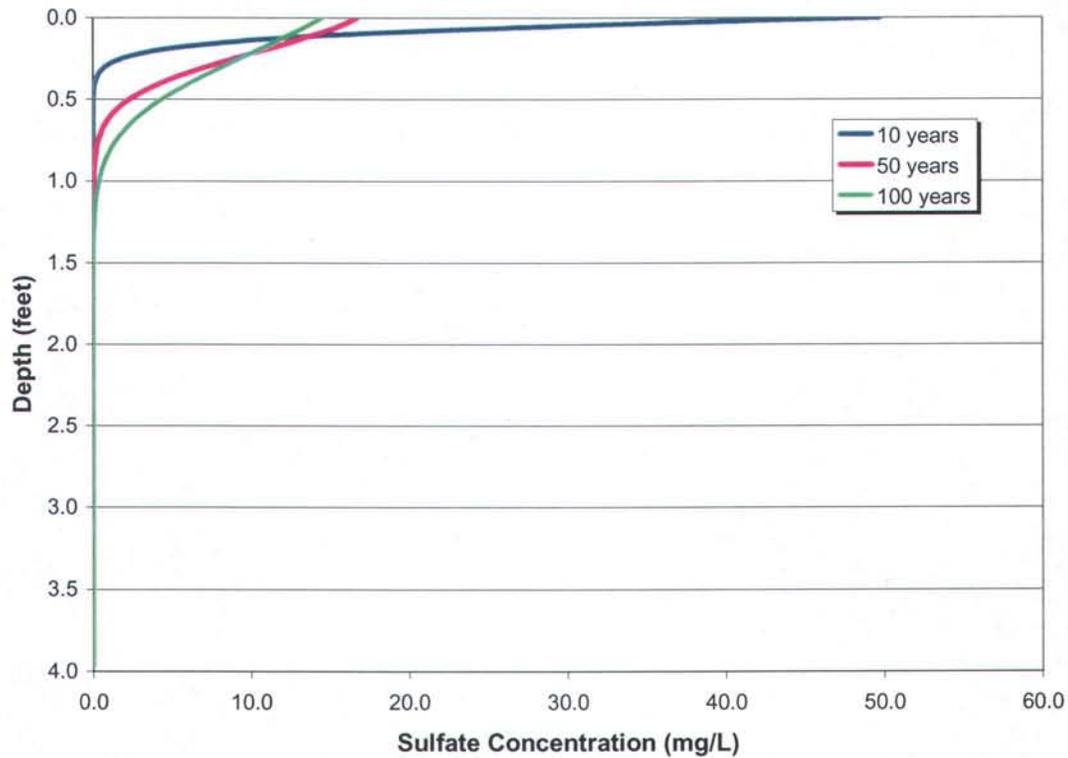


Sulfate Concentrations in Hydrogeologic Unit 1

Concentrations Over Time at Top of Vadose Zone (Depth = 0 ft)



Concentrations from Top of Vadose Zone to Water Table

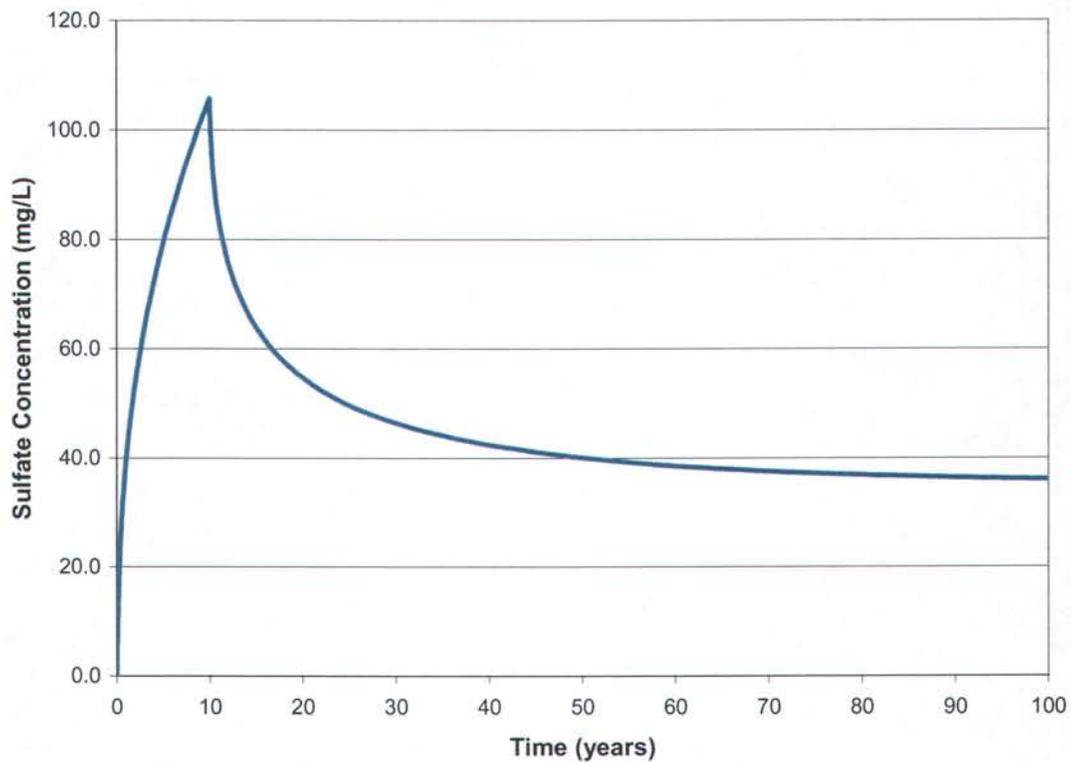


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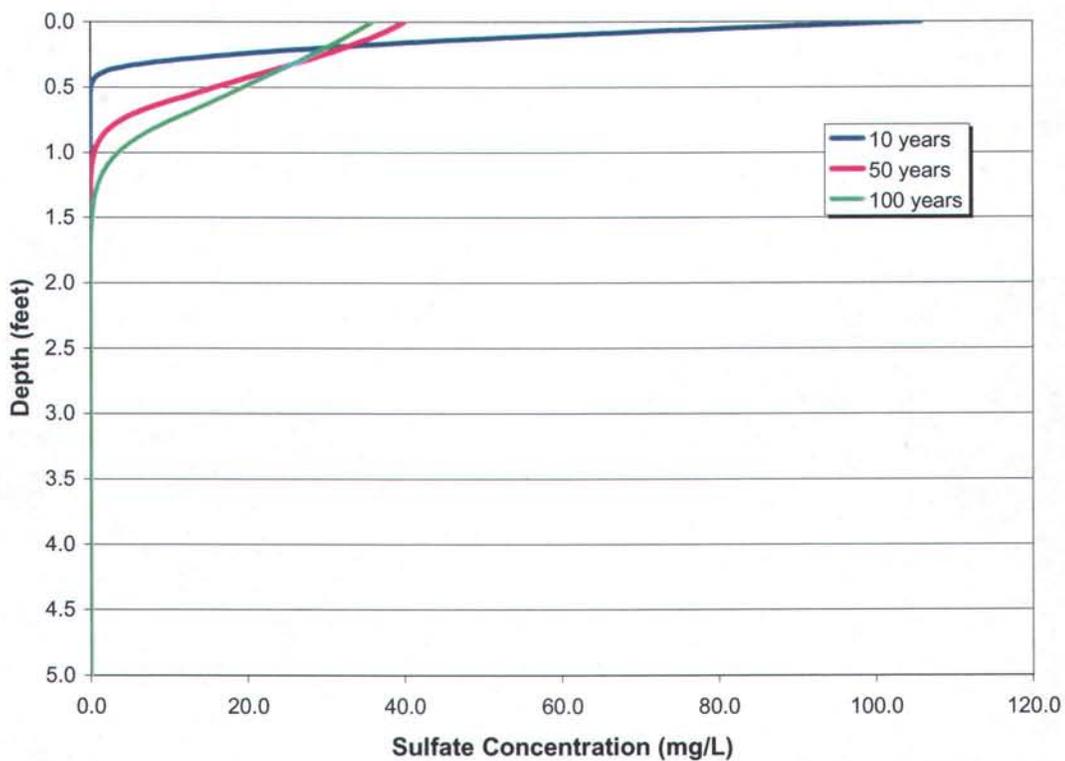
Figure 5a. Predicted Sulfate Concentrations in Hydrogeologic Unit 1.

Sulfate Concentrations in Hydrogeologic Unit 2

Concentrations Over Time at Top of Vadose Zone (Depth = 0 ft)



Concentrations from Top of Vadose Zone to Water Table



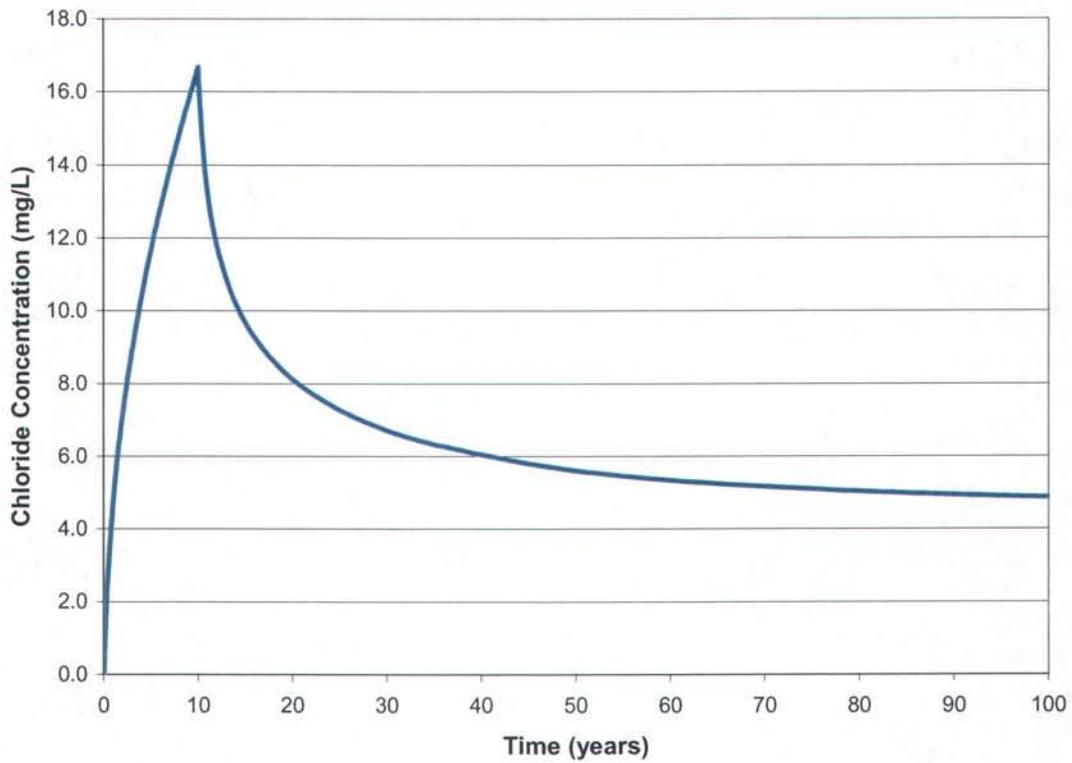
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Figure 5b. Predicted Sulfate Concentrations in Hydrogeologic Unit 2.

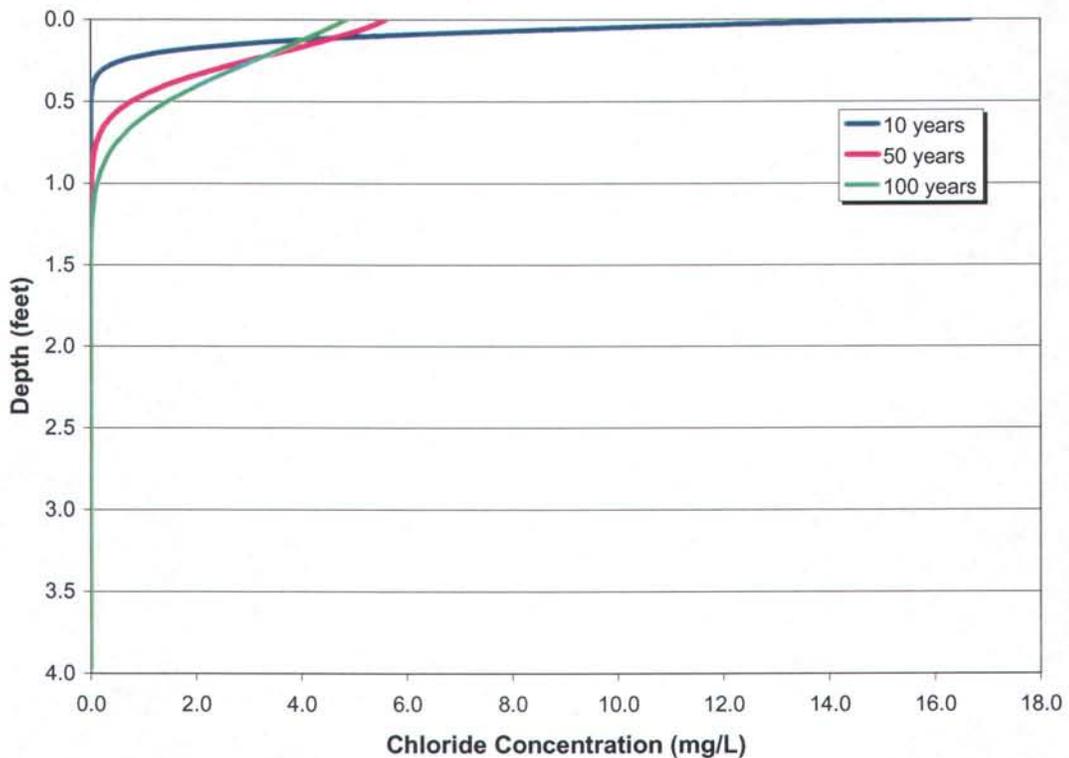


Chloride Concentrations in Hydrogeologic Unit 1

Concentrations Over Time at Top of Vadose Zone (Depth = 0 ft)



Concentrations from Top of Vadose Zone to Water Table

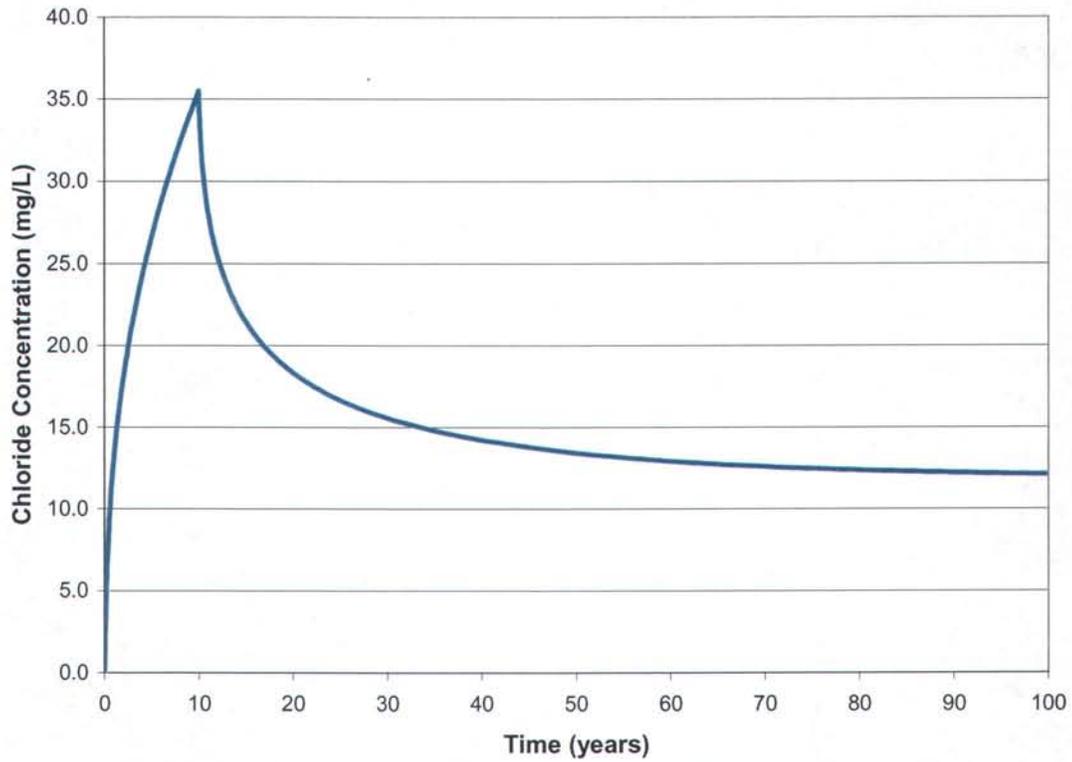


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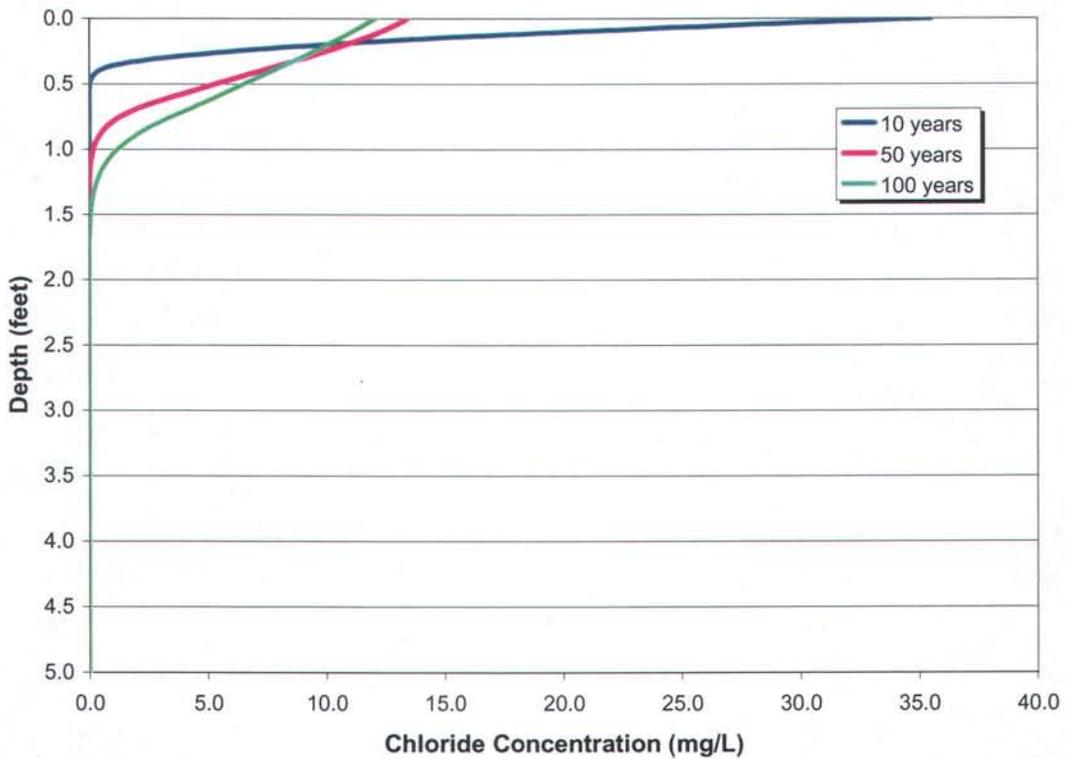
Figure 6a. Predicted Chloride Concentrations in Hydrogeologic Unit 1.

Chloride Concentrations in Hydrogeologic Unit 2

Concentrations Over Time at Top of Vadose Zone (Depth = 0 ft)



Concentrations from Top of Vadose Zone to Water Table

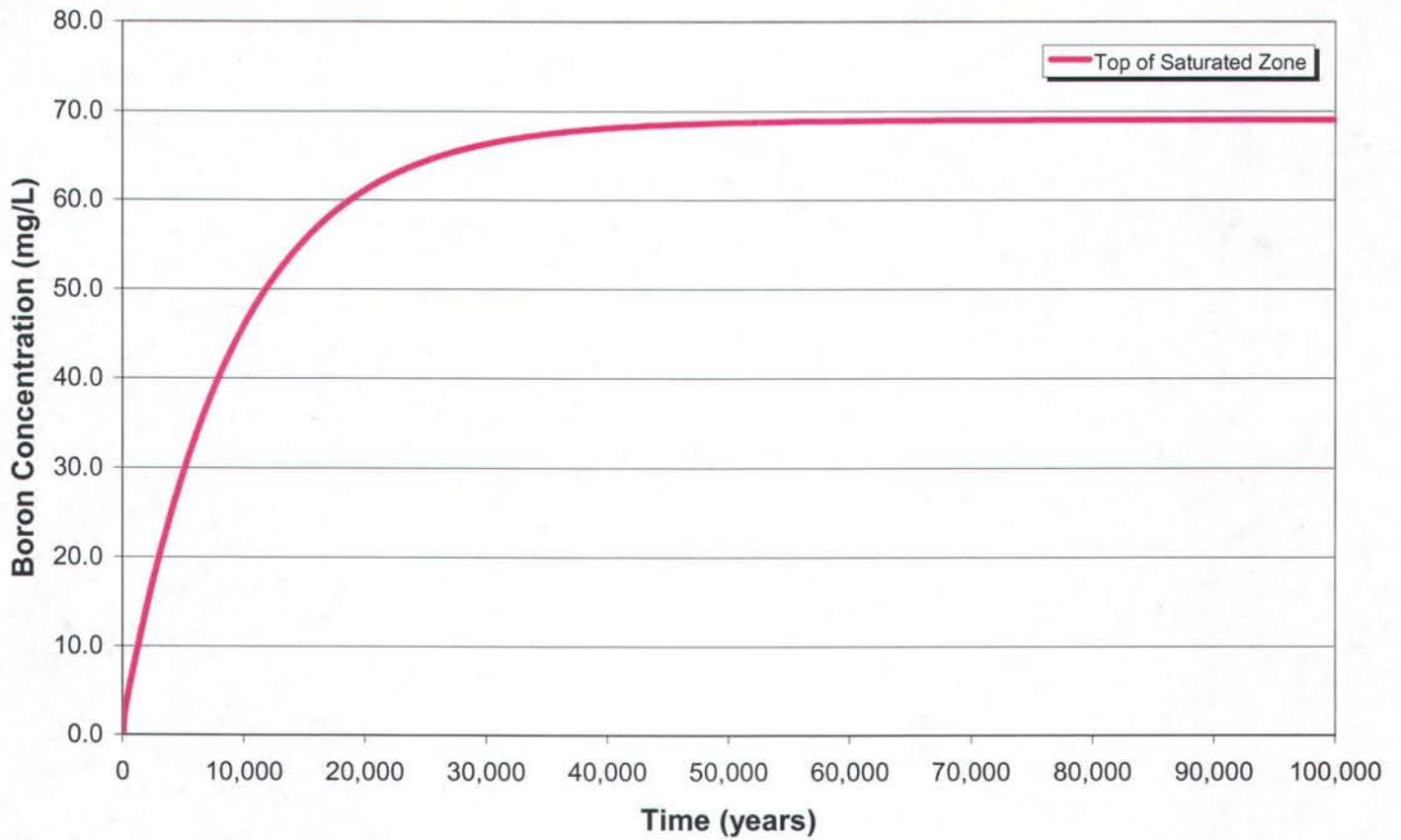


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Figure 6b. Predicted Chloride Concentrations in Hydrogeologic Unit 2.



Long-term Boron Concentrations Entering the Water Table



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Figure 7. Predicted Long-term Boron Concentrations Entering the Water Table.