Table 3-1. Off-Site Wells, Springs, and Public Water Supplies

Location Identifier	Location Description	Longitude (dg-mn-sc) est	Latitude (dg-mn-sc) est	Inside 1 mile radius	Outside 1 mile radius	Comment
Well 1	Swan Pond Rd south of Hwy 70	35-53-35 N	84-32-05.5 W		X	
Well 2	Swan Pond Rd south of Hwy 70	35-53-34 N	84-32-09 W		X	
Well 3	Swan Pond Rd south of Hwy 70	35-53-33 N	84-32-10.5 W		X	
Well 4	North of Hwy 70, South of I-40	35-53-41.5 N	84-32-14 W		X	
Well 5	Swan Pond Rd north of Hwy 70	35-53-44.5 N	84-32-09.5 W		X	
Well 6	Swan Pond Rd north of Hwy 70	35-53-45 N	84-32-06 W		X	
Well 7	Swan Pond Circle north of Swan Pond Rd	35-55-18 N	84-31-04.5 W	X		
Well 8	Swan Pond Rd north of Hwy 70	35-54-06 N	84-31-31 W	X		
Well 9	Swan Pond Rd north of Hwy 70	35-54-07 N	84-31-37 W	X		
Well 10	Swan Pond Rd north of Hwy 70	35-54-00.5 N	84-31-41 W	X		
Well 11	Swan Pond Rd north of Hwy 70	35-53-58.5 N	84-31-46 W	X		
Well 12	Swan Pond Rd north of Hwy 70	35-54-00.5 N	84-31-50.5 W	X		
Well 13	Swan Pond Rd north of Hwy 70	35-53-52 N	84-31-47 W	X		
Well 14	Swan Pond Rd north of Hwy 70	35-53-55 N	84-31-50 W	X		
Well 16	Swan Pond Rd north of Hwy 70	35-53-53 N	84-31-53 W		X	
Well 17	Swan Pond Rd north of Hwy 70	35-53-55 N	84-31-56 W		X	
Well 18	Swan Pond Rd north of Hwy 70	35-53-52 N	84-31-58.5 W		X	
Well 19	Swan Pond Rd north of Hwy 70	35-53-56 N	84-32-00 W		X	
Well 20	Swan Pond Rd west of Swan Pond circle	35-55-06.5 N	84-31-09 W	X		
Well 21	Swan Pond Rd north of Hwy 70	35-54-11 N	84-31-31.5 W	X		
Well 22	Swan Pond Rd north of Hwy 70	35-54-05 N	84-31-05 W	X		
Well 23	Hassler Mill Rd west of Swan Pond Rd	35-54-43 N	84-31-54 W	X		
Well 24	Sugar Grove Valley Road	35-54-34N	84-28-19W		X	
Well 25	Sugar Grove Valley Road	35-54-20N	84-28-59W		X	
Well 26	Sugar Grove Valley Road	35-54-03N	84-28-45W		X	
Well 27	Sugar Grove Valley Road	35-54-04N	84-28-44W		X	
Well 28	Sugar Grove Valley Road	35-54-53N	84-28-56W		X	
Well 29	Sugar Grove Valley Road	35-54-00N	84-28-49W		X	
Spring 1	Near intersection of Swan Pond Rd and Frost Hollow Rd (used for portion of municipal supply by City of Kingston)	35-55-07 N	84-31-54 W	X		
City of Kingston	Intake off Hwy 58 south of Kingston on Watts Bar Lake	n/a	n/a			Outside 2-mile radius
Swan Pond U. D.	Purchase water from City of Harriman	n/a	n/a			Outside 2-mile radius
Midtown Utilities	Purchase water from City of Rockwood	n/a	n/a			Outside 2-mile radius
Town of Harriman	Intake on Emory River Near Mile 13	n/a	n/a			Outside 2-mile radius
City of Rockwood	Intake on Watts Bar Lake near Post Oak Creek	n/a	n/a			Outside 2-mile radius

4. EVALUATION OF POTENTIAL WATER QUALITY IMPACTS

The potential impacts of proposed future coal-combustion byproduct (CCB) disposal on local groundwater and surface water resources are examined in this section. The focus of the evaluation is on the potential effect of disposal activities on stream water quality since all shallow groundwater originating on, or flowing beneath, the site ultimately discharges to streams without traversing private property. Separate evaluations are performed for future codisposal of ash and gypsum (Option A) and disposal of ash only (Option B). Comparisons of water quality impacts for facility designs with and without a constructed 3-ft geologic buffer are provided for each disposal option.

4.1 Contaminants of Concern

Representative chemical data for fly ash and flue-gas desulfurization (FGD)-derived gypsum leachate are presented in Table 4-1. The gypsum data represent average constituent concentrations for five leachate samples collected from the gypsum pond and slurry tank at Cumberland Fossil Plant (CUF) (Appendix E). Fly ash data were obtained from a single leachate sample collected from WP21 located in the KIF active ash pond on June 7, 2004.

Eight contaminants of concern (COC) were selected for evaluation including ammonia, arsenic, cadmium, copper, mercury, nickel, selenium, and zinc. These constituents exhibit mean concentrations that are significantly above primary drinking water MCL (e.g., As, Cd, Hg, Ni, and Se) or have potential aquatic toxicity (e.g., Cd, Cu, Ni, and Zn). Ash produced after May 2004 may contain a maximum of 226 mg/kg ammonia as a result of the recently installed NOx reduction system. Ammonia forms a residue on ash particle surfaces which is expected to be highly soluble. Residual ammonia dissolved by either sluice water or infiltrating precipitation would likely be in the form of the ammonium ion (NH_4^-). Interstitial water remaining in sluiced ash after mixing of ammoniated-ash with sluice water is estimated to contain 2.64 mg/L NH_3-N (TVA, 2002). The same ammonia content is conservatively assumed to apply to dry "dipped" ash (i.e., ash dredged from the ash pond and hauled by truck to the disposal site). Incident precipitation infiltrating through dry stacked fly ash would form leachate-containing ammonia as well as other ash-related constituents. The NH_3-N concentration of the dry ash leachate is estimated to be approximately 733 mg/L assuming complete leaching of ammonia from a unit volume of ash by one pore volume of infiltrating water. On entering the groundwater system beneath the disposal area, ammonia may be transformed by biological nitrification to nitrate and/or nitrite.

Table 4-1. Fly Ash and Gypsum Leachate Data

	Units	MCL	CCC	KIF Ash Leachate[1]	CUF Gypsum Leachate[2]
Aluminum	μg/L	200	150	<50	280.0
Antimony	μg/L	6		<3	9.3
Arsenic	μg/L	50		750	1.0
Barium	μg/L	2000		40	77.5
Beryllium	μg/L	4		<1	1.0
Boron	μg/L			730	42,500.0
Cadmium	μg/L	5	0.25	2	11.9
Chloride	mg/L	250		7.9	1,300.0
Chromium	μg/L	100	100	<1	2.3
Cobalt	μg/L			<1	9.5
Copper	μg/L	1300	9	<10	5.5
Fluoride	mg/L	4		0.57	13.1
Iron	μg/L	300		16000	205.0
Lead	μg/L	15	2.5	<1	1.0
Magnesium	μg/L			11	535.0
Manganese	μg/L	50		580	1,490.0
Mercury	μg/L	2	0.77	0.1	3.4
Nickel	μg/L	100	52	3	106.5
Selenium	μg/L	50	5	<1	137.0
Silver	μg/L	100	3.2	<10	5.2
Sodium	mg/L			5.7	19.5
TDS (180 deg)	mg/L	500		400	6,800.0
Strontium	μg/L			460	4,500.0
Sulfate	μg/L	250		130	3,020.0
Thallium	μg/L	2		<2	<2
Vanadium	μg/L			<10	<10
Zinc	μg/L	5000	120	<10	715.0

[1]*Data for filtered water sample from wellpoint WP-21 completed in Ash Pond.*
[2]*Average concentrations for 4 gypsum leachate samples given in Appendix E.*

4.2 Methods

4.2.1 Leachate Seepage Estimation

The potential impacts associated with each of the proposed CCB disposal areas during the period of active disposal operations were assessed individually since these facilities generally involve different wastes, spatially distinct areas, and will operate over different timeframes. The HELP landfill hydrologic water budget model (Schroeder et al., 1989 and 1994) was used to estimate CCB leachate seepage rates from landfill-type facilities not involving waste impoundments (e.g., dry ash stacks, inactive ash dredge cells, and inactive gypsum rim-ditch disposal operations). Typically, individual landfills were divided for purposes of HELP simulations into subregions based on waste thickness, surface cover, and surface slope. For example, Figure 4-1 shows the subregion and stratigraphic profile associated with the proposed Phase 1 addition of sluiced ash to existing Ash Dredge Cells 1-3. Subsequent stages of Phase 1 development of Cells 1-3 (e.g., capping with dipped ash and final closure) involved additional modeling steps. Subregion and profile diagrams for these models are given on Figures F-2 and F-3 of Appendix F.

Seepage estimates for CCB impoundment facilities (e.g., active ash dredge cells and gypsum sedimentation ponds) were performed by modeling a typical section through the disposal area using the USGS MODFLOW-2000 groundwater flow model (Harbaugh et al., 2000) in conjunction with the Visual MODFLOW modeling interface (Waterloo Hydrogeologic, Inc., 2004). The average steady-state seepage rate from the base of the facility along the section was then integrated over the full area of the facility to estimate total leachate seepage.

The various CCB disposal areas associated with Option A involved modeling of 25 separate landfill and impoundment subregions. Diagrams similar to Figure 4-1 describing the individual facility models for Option A are provided in Appendix F. Likewise, Appendix G contains diagrams of facility subregions associated with Option B. Note that proposed Phase 1 disposal facilities are the same for both Options A and B.

HELP Simulations – Hydraulic properties used in the HELP simulations are presented in Table 4-2. Fly ash data represent average characteristics derived from laboratory testing of three Kingston fly ash samples (Young et al., 1993). The bottom ash hydraulic conductivity given in Table 4-2 is based on test results for a KIF bottom ash sample reported by MACTEC (2004). All other bottom ash parameters are based on lab testing of a sample of CUF bottom ash (D.B. Stephens, 1991). Since no gypsum has yet been produced at KIF, average properties for two gypsum samples from Shawnee Fossil Plant (SHF) were used (D.B. Stephens, 1991). The values for top soil were those presented by Schroeder et al. [1989] for a soil loam. The field capacity, wilting point, and porosity for the clay cap and clay buffer were those given by Schroeder et al. [1989] for a soil liner.

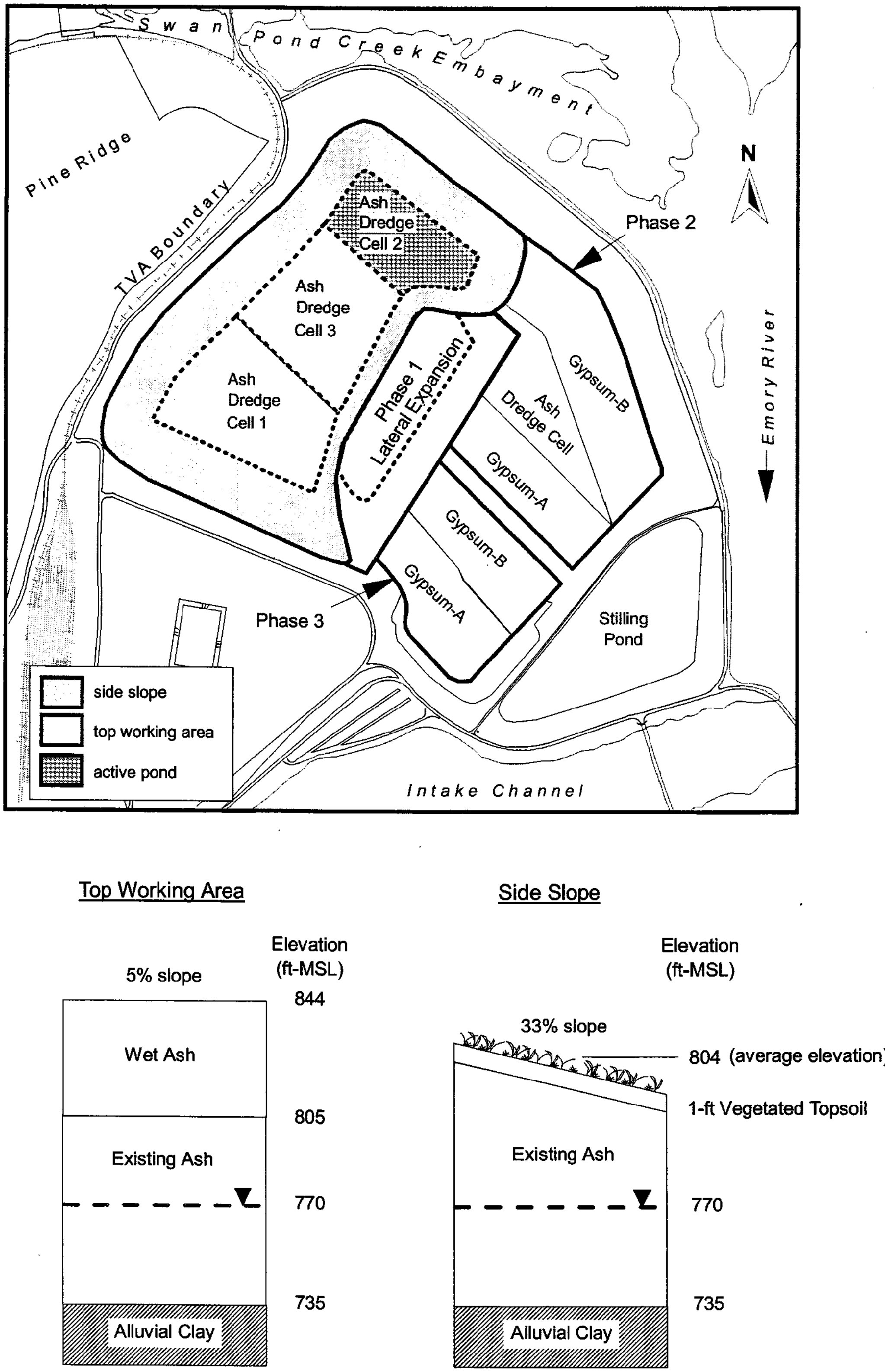


Figure 4-1. Conceptual Model of Ash Dredge Cells 1-3

Table 4-2. Hydraulic Properties Applied in HELP Simulations

Media Type	Total Porosity	Field Capacity[1]	Wilting Point[2]	Initial Volumetric Moisture Content (%)	Hydraulic Conductivity (cm/s)
Top Soil	0.46	0.23	0.12	0.23	3.7×10^{-4}
Clay Cap	0.43	0.37	0.28	0.37	1.0×10^{-7}
Fly Ash	0.47	0.40	0.12	0.22 - 0.32	2.0×10^{-5}
Gypsum	0.68	0.54	0.28	0.50	5.1×10^{-5}
Bottom Ash	0.53	0.15	0.06	0.10	9.3×10^{-3}
Geologic Buffer	0.43	0.37	0.28	0.37	1.0×10^{-6}

[1]Moisture content at pressure head of -0.33 bar.

[2]Moisture content at pressure head of -15 bars.

The design maximum hydraulic conductivity of the clay cap is 10^{-7} cm/s while that of the clay buffer is 10^{-6} cm/s. Initial volumetric moisture contents for the top soil, clay buffer, and clay cap were arbitrarily set at field capacity for all simulations involving these materials. The design moisture content of dry-stacked fly ash at the time of emplacement will be 0.22, whereas an initial moisture content of 0.26 was applied to existing fly ash. Initial moisture contents for gypsum and bottom ash were estimated from in situ data measured at SHF and CUF.

Soil Conservation Service curve numbers (CN), used by HELP to estimate surface runoff, were determined on the basis of vegetative cover and soil texture relationships provided by Schroeder et al. (1994, Figure 7, p. 39). CN values of 90 were used for bare fly ash and gypsum surfaces. Temporary cover consisting of top soil and a fair grass cover was assigned a CN of 80 and a leaf area index (LAI) of 2.2. Final cover applied at facility closure and consisting of top soil with a good grass cover was assigned a CN of 80 and an LAI of 3.3.

Evaporation parameters required by HELP include the evaporation coefficient and the evaporation depth. Foust and Young (1993) demonstrated by laboratory experiments and numerical simulations using fly ash from TVA's Kingston and Colbert Plants that the evaporation depth can approach several feet. For HELP simulations involving bare fly ash surfaces, a conservative evaporation depth of 30 inches was used. The measured evaporation coefficient of 14.6 mm/day$^{0.5}$ for KIF fly ash reported by Foust and Young (1993) was used for bare fly ash surfaces. For bare gypsum surfaces, an evaporation depth of 18 inches was assumed in conjunction with an evaporation coefficient of 8 mm/day$^{0.5}$ derived from a 15-month field lysimeter study involving SHF gypsum (Boggs et al., 1990). All cases involving top soil cover assumed 12-inch evaporation depths and an evaporation coefficient of 5.1 mm/day$^{0.5}$ in accordance with guidance provided by Schroeder et al. (1994).

Meteorological data was compiled from a NOAA station located in Oak Ridge, Tennessee. This station was selected because of its close proximity to KIF and because high quality data was available for a continuous 20-year period. The data include daily rainfalls and mean daily temperatures from 1968 to 1987. In order to provide 30 years of rainfall/temperature data for the water budget simulation, data for years 1968-77 were added to the end of the 1968-87 record. Daily solar radiation values were generated using a HELP subroutine that incorporates several factors including latitude and daily rainfall.

MODFLOW Simulations-- Steady-state leachate seepage from the gypsum and ash ponds were obtained from two-dimensional profile models oriented normal to the river as shown in the example on Figure 4-2. The figure depicts the finite difference model grid, subsurface hydrogeologic units, and constructed waste layers associated with the initial Phase 2 gypsum/ash impoundments. The upper model shown in Figure 4-2 represents an impoundment design without a geologic (clay) buffer, while the lower model represents an impoundment which incorporates a geologic buffer. In this example, constant-head boundary conditions of 765 ft and 740 ft are applied at the left and right model boundaries, respectively, to represent the approximate pre-impoundment ambient hydraulic gradient toward the river. The lower boundary represents approximate top of bedrock elevation and is assigned zero flux. Constant heads of 784 ft are assigned to model cells representing the upper surface of the impoundment to represent an assumed 4-ft water depth. Perimeter drains indicated in the bottom ash drainage layers were assigned fixed heads equal to the average elevation of the layer. Stratigraphic units, including the existing fly ash, alluvial clay, and alluvial sand, were assigned uniform average thicknesses based on available boring data. Table 4-3 provides the media hydraulic properties assigned to the models. In order to estimate the total steady rate of seepage through the base of the entire impoundment, the computed average flux rate across the lower side of the lowest drainage blanket for the 2D model was multiplied by the total surface area of the impoundment.

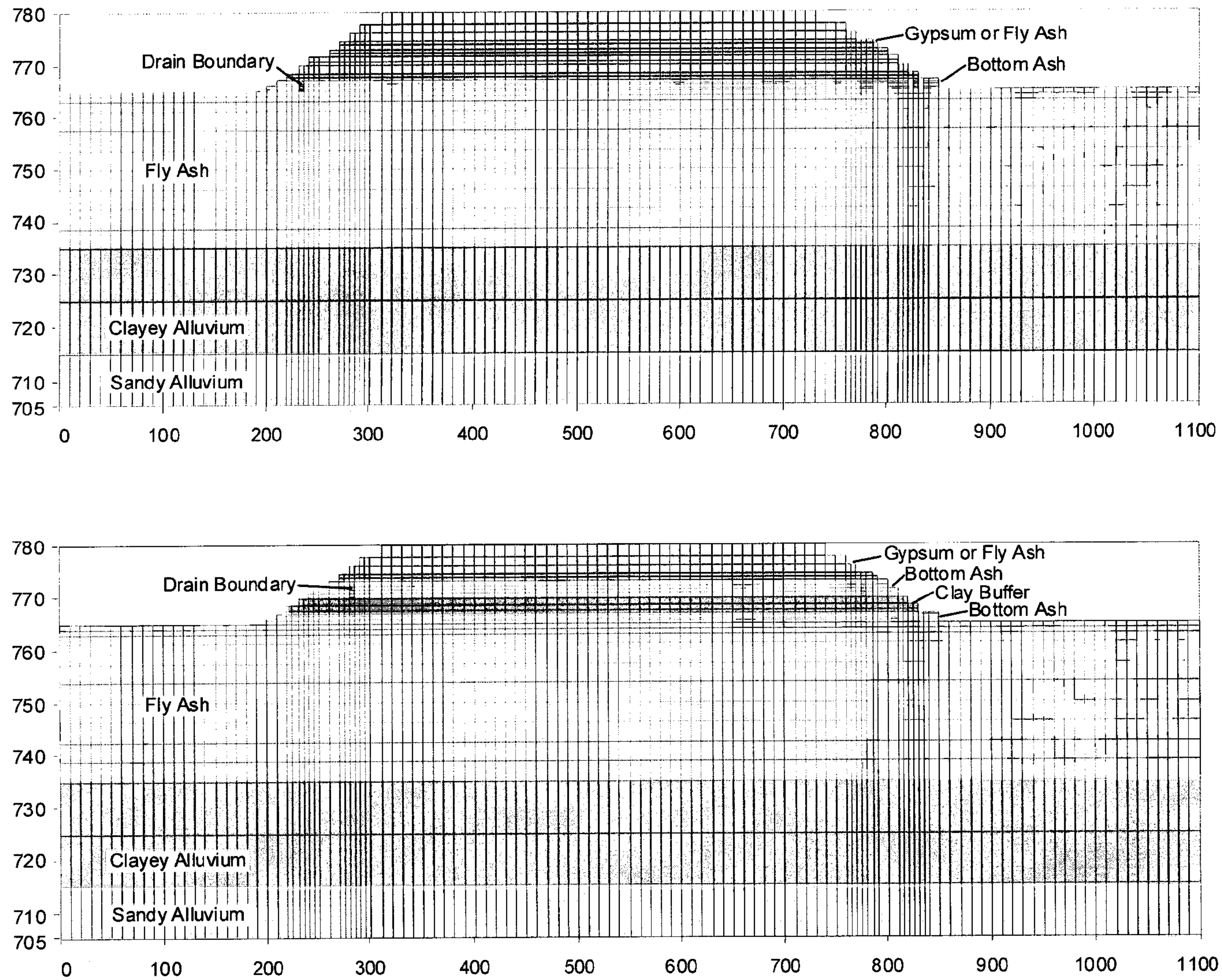


Figure 4-2. Profile View of MODFLOW Models Used for Pond Seepage Estimation

Table 4-3. Hydraulic Properties Applied in MODFLOW Simulations

Media Type	Thickness (ft)	Vertical Hydraulic Conductivity (cm/s)	Horizontal Hydraulic Conductivity (cm/s)
New Fly Ash	(varies)	2.0×10^{-5}	1.0×10^{-4}
New Gypsum	(varies)	5.1×10^{-5}	5.1×10^{-4}
Bottom Ash	2.0[a], 3.0[b]	9.3×10^{-3}	1.0×10^{-2}
Geologic (Clay) Buffer	3.0	1.0×10^{-6}	1.0×10^{-5}
Existing Fly Ash	30.0	2.0×10^{-5}	1.0×10^{-4}
Alluvial Clay	20.0	4.0×10^{-7}	9.0×10^{-6}
Alluvial Sand	10.0	1.0×10^{-4}	1.0×10^{-3}

[a]Thickness of bottom ash drainage layer above fly ash base
[b]Thickness of bottom ash drainage layer above geologic (clay) buffer

4.2.2 Stream Loading Estimation

Depending on their location and mode of disposal (i.e., either landfill or impoundment), leachate seepage from the CCB disposal areas will be transported by shallow groundwater to SPC embayment, Emory River, or the plant intake channel. Groundwater flow patterns based on water levels measured in shallow monitoring wells shown on Figure 2-6 indicate that, in the absence of sluicing to Ash Dredge Cells 1-3, leachate emerging from the base of Cells 2, 3, and most of Cell 1 would be transported by ambient groundwater flow to SPC. Leachate seepage from Phase 1 Lateral Expansion Area and from the Phase 2 and 3 Areas would ultimately discharge in the Emory River or the intake channel. The presence of impoundment disposal facilities during different phases of disposal operations would to some extent alter groundwater flow patterns and ultimate leachate discharge points. For example, incorporating the potentiometric heads associated with active Cell 2, ash pond, and stilling pond (Figure 2-7) indicates leachate seepage to SPC would be limited to Cell 2, while leachate from the remaining cells would discharge to the river and intake channel. For conservatism, all leachate seepage produced from Ash Dredge Cells 1-3 is assumed to ultimately discharge to SPC, whereas leachate from all other areas discharges to the Emory River.

In estimating worst-case in-stream COC concentrations, no credit was taken for mixing and dilution of leachate by ambient groundwater during transport or for geochemical attenuation. The mean leachate seepage rate estimated using HELP or MODFLOW for each facility during the active disposal period, along with the initial COC concentrations given in Table 4-1, were used to compute the mass loading (in kg/day) to the stream for each COC. To estimate COC concentrations in the stream, complete mixing of predicted mass loadings with the appropriate low stream flow was assumed. The 7Q10 stream flow was applied to in-stream concentration estimates for ammonia, whereas the 1Q10 was used for other COC constituents in accordance with TDEC guidance. Note that estimates of the maximum COC in-stream concentrations for the Emory River account for the cumulative contributions of COC mass loadings from multiple CCB disposal areas and from tributary SPC. On the other hand, the existing Ash Dredge Cells 1-3 represent the only area contributing COC mass to SPC. In this case the maximum concentrations for SPC were estimated using the highest stream load predicted for any future operational phase at Cells 1-3, including the post-closure phase.

Because no historical stream flow data are available for SPC, 1Q10 and 7Q10 low flows were estimated on the basis of continuous flow data (1935-70) for Whites Creek near Sharps Chapel, Tennessee. Whites Creek watershed (above the gauging station) is approximately 2.7 mi^2 and is closest in size of any of the gauged streams in the region to the 4.1 mi^2 watershed area of SPC. The 1Q10 and 7Q10 for Whites Creek are reported to be 0.216 and 0.240 cfsm (cubic feet per second per square mile). Applying the Whites Creek unit flows to the SPC watershed yields 1Q10 and 7Q10 estimates of 0.89 and 0.96 cfs.

Emory River 1Q10 and 7Q10 flows of 0.40 and 0.68 cfs are reported for the USGS gauging station at Oakdale located approximately 16 miles upstream of KIF (Flohr et al., 1993). However, flow of the Emory River in the immediate vicinity of KIF is controlled by upstream releases from Melton Hill Dam and plant intake withdrawals which average approximately 2200 cfs. Numerical flow-temperature simulations indicate that under worst-case low flow conditions (i.e., low natural inflow from the Emory River upstream and no releases from Melton Hill Dam) the flow toward the plant intake from the upstream reach of the Emory adjacent to the ash pond is approximately 84 cfs (personal communication, 5/6/02, Ming Shiao of the TVA Hydrothermal Team). The plant-controlled low flow of 84 cfs was used in stream loading analyses instead of the traditional 1Q10 and 7Q10 flows.

4.3 Option A - Future Codisposal of Coal Ash and FGD-Derived Gypsum

4.3.1 Facility Description

Figure 4-3 provides the schedule of CCB disposal operations proposed under Option A. Phase 1 operations will involve sluiced fly ash disposal in the existing Ash Dredge Cells 1-3 and in the Phase 1 Dredge Cell Lateral Expansion Area between 2004 and 2015. Approximately 4.034 million CY will be deposited in these areas bringing the grade elevation to approximately 844 ft in Cells 1-3 and to elevation 810 ft in the Lateral Expansion Area. Between 2015 and 2017 approximately 951,200 CY of dipped ash will be placed atop Cells 1-3 raising the final grade to a maximum elevation of 858 ft.

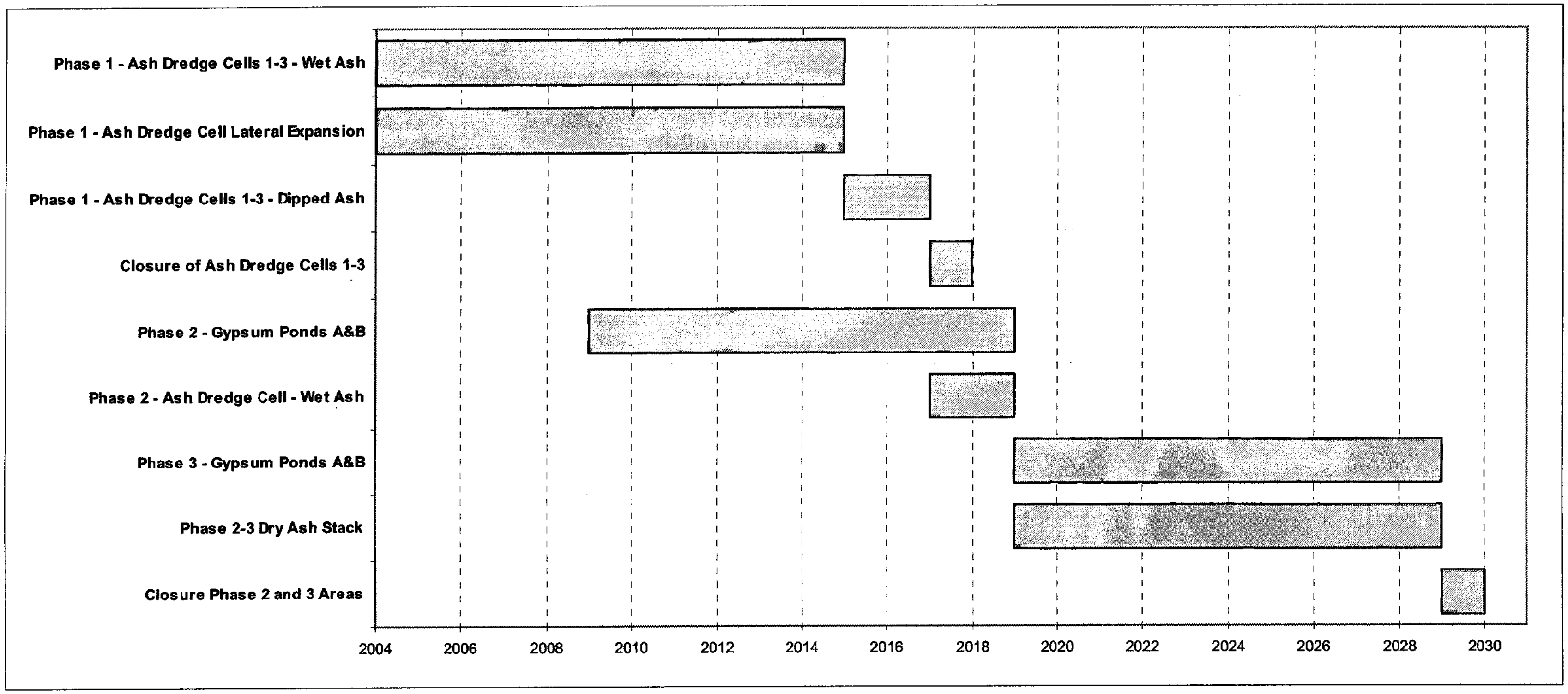


Figure 4-3. Option A – Schedule of Facility Operations

Dredge Cells 1-3 will be partially closed in 2017 by construction of a 1-ft thick clay cap having maximum hydraulic conductivity of 10^{-6} cm/s followed by 1 ft of vegetated top soil. The cap will extend over the entire Cells 1-3 area with the exception of the southeast-facing side slopes which will be left uncovered to allow for subsequent contiguous Phase 2 and 3 disposal operations. Maximum surface elevation of the closed facility will be approximately 860 ft.

Gypsum byproduct disposal in the Phase 2 area is expected to begin in 2009 when flue-gas scrubbers are scheduled for operation. Wet gypsum will be alternately sluiced to rim-ditch systems in Ponds A and B until 2019 when the stack reaches elevation 870 ft. At that point, gypsum byproduct will be directed to rim-ditch systems in the Phase 3 area. Stacking of dry fly ash in the region between the Phase 2 and 3 areas will also begin in 2019. Gypsum disposal in the Phase 3 area is expected to continue until 2029 when the stack reaches elevation 870 ft. Total volumes of gypsum deposited in the Phase 2 and 3 areas are estimated at approximately 3.27 million CY and 3.60 million CY, respectively.

Dry fly ash stacking will continue above the gypsum stacks until approximately 2029. The total volume of dry ash deposited in the Phase 2 and 3 areas will be approximately 5.7 million CY. Closure of the Phase 2 and 3 areas will involve placement of a clay cap and vegetated top soil over the entire area. Design of the cap and cover will be the same as that applied to the Phase 1 area.

4.3.2 Leachate Seepage Results

Average leachate seepage estimates for each of the proposed disposal facilities considered under Option A are presented in Table 4-4. Detailed seepage data for all disposal facility subregions are given in Appendix H, along with information regarding estimation methods.

The mean leachate seepage rate during the period (2004-14) of wet sluicing of ash to Dredge Cells 1-3 is estimated at approximately 425,000 liters per day (Lpd) (Table 4-5). This estimate conservatively assumes active ash sluicing to Cell 2 (closest to SPC embayment) and exposure of working surfaces of inactive Cells 1 and 3 to incident precipitation. Approximately 37% of the total seepage is derived from seepage below the assumed impoundment in Cell 2 as estimated with MODFLOW (Appendix H). Seepage from the remaining area was estimated using the HELP model. The average seepage rate outside of Cell 2 represents approximately 22% of average precipitation, and reflects the relatively high infiltration rates associated with exposed ash surfaces and the interim topsoil on side slope areas. Capping and closure of Dredge Cells 1-3 in 2018 is predicted to reduce the average seepage rate by 32 % to approximately 287,400 Lpd.

Table 4-4. Option A – Facility Leachate Seepage Estimates

Facility	Start Date	End Date	Waste	Mean Leachate Seepage (Lpd)	Seepage Difference Buffer vs. No Buffer
Phase 1 - Ash Dredge Cells 1-3	2004	2014	wet ash	425,135	NA
Phase 1 - Ash Dredge Cells 1-3	2015	2016	dipped ash	243,499	NA
Closure of Ash Dredge Cells 1-3	2017	2046	mixed ash	287,409	NA
Phase 1 - Dredge Cell Lateral Expansion Area	2004	2014	wet ash	56,936	NA
Phase 2 - Gypsum Ponds A&B - NO BUFFER	2009	2018	gypsum	62,287	
Phase 2 - Gypsum Ponds A&B - BUFFER	2009	2018	gypsum	41,506	33%
Phase 2 - Ash Dredge Cell - NO BUFFER	2009	2018	wet ash	21,844	
Phase 2 - Ash Dredge Cell - BUFFER	2009	2018	wet ash	17,370	20%
Phase 3 - Gypsum Ponds A&B - NO BUFFER	2019	2028	gypsum	60,733	
Phase 3 - Gypsum Ponds A&B - BUFFER	2019	2028	gypsum	37,798	38%
Phase 2&3 Dry Ash Stack - NO BUFFER	2019	2028	dry ash	10,268	
Phase 2&3 Dry Ash Stack - BUFFER	2019	2028	dry ash	8,243	20%
Closure of Phase 2&3 Areas - NO BUFFER	2029	2058	ash/gypsum	179,456	
Closure of Phase 2&3 Areas - BUFFER	2029	2058	ash/gypsum	177,878	1%

Table 4-5. Option A - Predicted Worst-Case Stream Loadings and In-Stream Concentrations

Constituent	MCL	CCC	Swan Pond CreekEmbayment		Emory River - No Buffer Case		Emory River - Buffer Case	
			Maximum Loading (kg/day)	Maximum Concentration (mg/L)	Maximum Loading (kg/day)	Maximum Concentration (mg/L)	Maximum Loading (kg/day)	Maximum Concentration (mg/L)
Ammonia-N	10/1	(**)	4.24E-01	0.15221	5.14E+01	0.25018	5.10E+01	0.24800
Arsenic	0.05	0.15	1.57E-03	0.00061	6.38E-02	0.00031	6.32E-02	0.00031
Cadmium	0.005	0.00021	4.25E-04	0.00016	1.88E-03	0.00001	1.59E-03	0.00001
Copper	1.3	0.0072	1.08E-02	0.00414	9.55E-03	0.00005	9.28E-03	0.00005
Mercury	0.002	0.00077	2.55E-04	0.00010	6.28E-04	0.00000	5.04E-04	0.00000
Nickel	0.1	0.0422	1.98E-02	0.00763	2.92E-02	0.00014	2.46E-02	0.00012
Selenium	0.05	0.005	4.25E-04	0.00016	1.72E-02	0.00008	1.33E-02	0.00006
Zinc	5	0.0957	8.89E-02	0.03424	1.60E-01	0.00078	1.29E-01	0.00063

***See Table 4-6*

Leachate seepage rates from the Phase 2 and 3 Gypsum and Ash Disposal Areas were conservatively estimated for the maximum sedimentation pond surface areas which occur during the early stage of disposal operations. A working surface elevation of 780 ft was assumed for the gypsum and ash disposal areas. Net seepage from Phase 2 Gypsum Ponds A and B is estimated to be approximately 62,300 Lpd for the no-buffer case and 41,500 Lpd for the buffer design, indicating a 33% overall reduction in seepage provided by the clay buffer. The Phase 3 Gypsum Disposal Area showed similar results with the buffer providing a 38% reduction in seepage generation. Incorporating artificial clay buffers below the Phase 2 Ash Dredge Cell and the dry ash stack situated between the Phase 2 and 3 areas decreased seepage by approximately 20% in both cases.

Average leachate seepage rates predicted during 30-year post-closure simulations of the combined Phase 2 and 3 areas were approximately 179,500 Lpd for the no-buffer design and 177,900 Lpd with a clay buffer (Table 4-4). The 1-ft, 10^{-6} cm/s clay cap constructed over the disposal area at closure would largely control net infiltration through the CCB materials. Since the hydraulic conductivity of the clay cap and buffer would be the same, the buffer would provide essentially no (i.e., less than 1%) additional containment of leachate seepage. Overall, results indicate that while modest seepage reductions of 20 to 38% could be expected by the addition of a clay buffer during active disposal operations, the long-term benefit of a buffer would be negligible.

4.3.3 Predicted COC Concentrations in Swan Pond Creek Embayment

The only disposal area that would contribute COC-containing leachate to SPC would be Ash Dredge Cells 1-3, as discussed in Section 4.2.2. Except for ammonia, future ash leachate generated from this area is expected to be chemically similar to current leachate. Therefore, future loadings of COC other than ammonia would not be expected to differ significantly from current loadings to SPC.

Estimates of the mass loading of each COC produced by leachate seepage from future disposal operations are presented in Table H2 (Appendix H). These estimates are subsequently used in estimating the cumulative COC loadings to SPC and the Emory River shown on Figures 4-4 and 4-5, and worst-case in-stream COC concentrations presented in Table 4-5. To illustrate the method of computing the facility mass loadings, consider the following example calculation for ammonia. From Table 4-4 the mean leachate seepage rate during the period (2004-14) of wet sluicing to Ash Dredge Cells 1-3 is 425,135 Lpd. The volume-weighted average NH_3-N concentration of 1.00 mg/L for leachate generated from Cells 1-3 shown in Table H2 is based on 4.034 million CY of new sluiced ash (above elevation 805 ft) having a pore water NH_3-N concentration of 2.64 mg/L and 6.652million CY of existing ash (between elevations 760 and 805 ft) having a zero NH_3-N concentration. Applying the weighted-average pore water NH_3-N

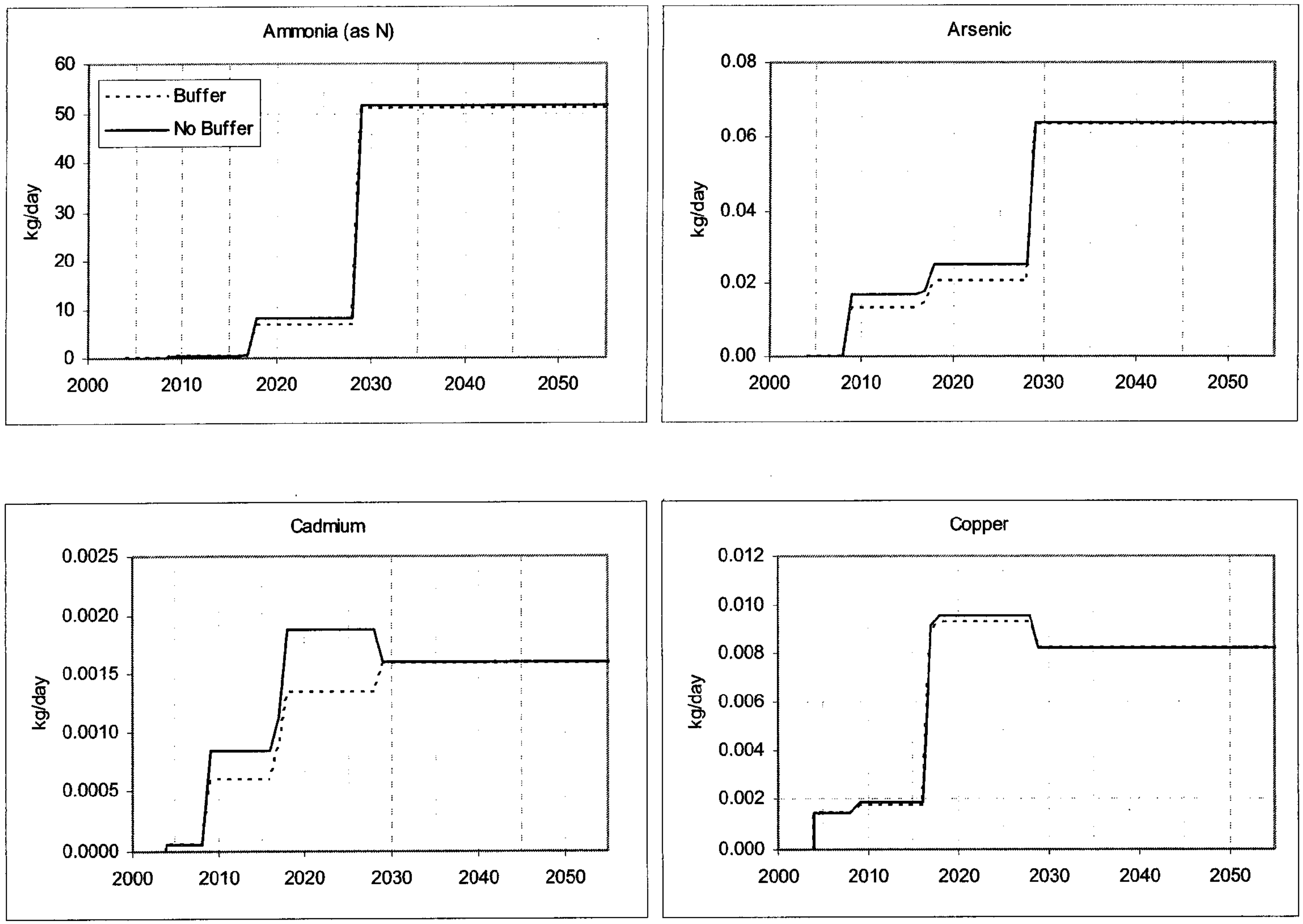


Figure 4-4. Option A – Cumulative COC Mass Loading for Emory River (Ammonia, Arsenic, Cadmium, and Copper)

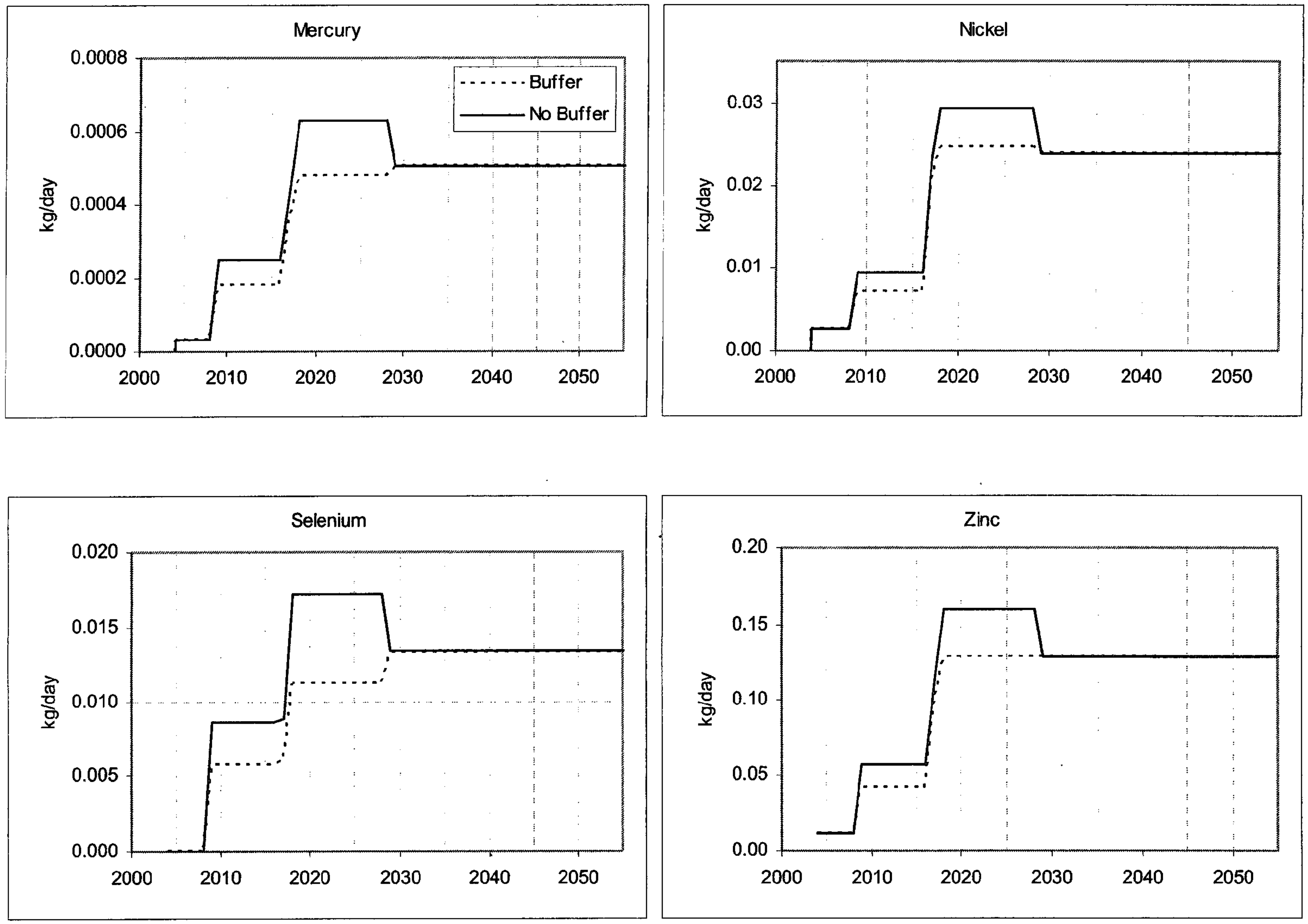


Figure 4-5. Option A – Cumulative COC Mass Loading for Emory River (Mercury, Nickel, Selenium, and Zinc)

concentration to the predicted seepage rate yields a mass loading of 0.424 kg/day. Since SPC discharges into the Emory River a short distance downstream, the NH_3-N loading to the Emory River is also 0.424 kg/day. Loadings of other ash-related COC to SPC were computed using historical mean groundwater quality data for monitoring wells 4A, 4B, 5, 5A, and 5B (Appendix I). As shown on Figure 2-6, these wells are situated downgradient of existing ash disposal areas, and provide representative COC concentrations of ash leachate currently entering SPC.

The period of wet sluicing of ash to Ash Dredge Cells 1-3 produces the largest ammonia loading to SPC of any of the future disposal activities in this area. Consequently, the worst-case NH_3-N concentration in SPC after full mixing of the predicted maximum loading (0.424 kg/day) with the 7Q10 low flow would be approximately 0.15 mg/L (Table 4-5). While there is no drinking water MCL for ammonia, conversion of ammonia to nitrate or nitrite is possible during groundwater transport, and these constituents have MCLs of 10 mg/L and 1 mg/L, respectively. Resulting NO_3-N or NO_2-N concentrations in SPC would be <0.15 mg/L for either constituent and would be below MCLs. Maximum allowable levels of ammonia for protection of aquatic life presented in Table 4-6 are dependent on stream pH and temperature. Although no historical pH data are available for SPC embayment, three measurements performed on July 21, 2004, indicated pH of approximately 8.0 to 8.1. The estimated NH_3-N level is below the aquatic life CCC for the expected range of stream pH and temperature conditions. Further examination of Table 4-5 indicates that the predicted maximum stream loadings for the remaining COC produce in-stream concentrations meeting applicable MCL and CCC standards.

Table 4-6. Maximum Allowable Ammonia Concentrations to Protect Aquatic Life[a]

	CMC (mg N/L)[b]				CCC (mg N/L)			
Temp[c] (°C)	pH=7.0	pH=7.5	pH=8.0	pH=8.5	pH=7.0	pH=7.5	pH=8.0	pH=8.5
15					5.73	4.23	2.36	1.06
20					4.15	3.07	1.71	0.77
25	36.09	19.89	8.41	3.20	3.01	2.22	1.24	0.55
30					2.18	1.61	0.90	0.40

[a] *Assumes Salmonids absent and fish early life stages present.*

[b] *CMC is not temperature dependent.*

[c] *Chronic values do not change with temperature below 14.6°C.*

4.3.4 Predicted COC Concentrations in Emory River

The summary of maximum COC stream loadings and concentrations for the Emory River presented in Table 4-5 account for the cumulative contributions of COC mass loadings from multiple CCB disposal areas and from SPC. The graphs shown on Figures 4-4 and 4-5 provide cumulative mass loading time-series for each COC based on the facility operational schedules and loading data derived from Table H2. These graphs provide a general indication of the temporal variation of stream loadings in response to proposed disposal activities.

Figure 4-4 shows that the cumulative ammonia loading to the Emory River is low for both the buffer and no-buffer cases until 2019, when disposal of dry ash, with its relatively high ammonia content, begins in the region between the Phase 2 and 3 areas. The cumulative loads peak at closure (2029) after the maximum quantity of dry ash has been placed between and over the Phase 2 and 3 gypsum stacks. The worst-case NH_3-N loading estimated for the no-buffer design is 51.4 kg/day, resulting in an in-stream concentration of approximately 0.250 mg/L under low-flow conditions (Table 4-5). The clay buffer design slightly reduces the predicted in-stream concentration to 0.248 mg/L. These results suggest a negligible environmental advantage to the clay buffer, particularly since the in-stream NH_3-N concentration in both cases is below MCL and CCC.

Predicted worst-case in-stream concentrations for the remaining COC are also well below human health and aquatic life criteria in all cases. Differences between the estimated COC concentrations for the no-buffer and buffer design cases are directly related to predicted seepage differences and are generally 22% or less. As expected, constituents strongly associated with gypsum (e.g., cadmium, mercury, nickel, selenium and zinc) show substantial increases in cumulative load during the Phase 2 and 3 gypsum disposal periods from 2009 to 2029 (Figures 4-4 and 4-5). Loadings decrease substantially in 2029 after closure of the Phase 2 and 3 areas in response to decreased surface infiltration provided by the low-permeability clay cap.

4.4 Option B - Future Disposal of Coal Ash Only

4.4.1 Facility Description

Figure 4-6 provides the schedule of CCB disposal operations proposed for the ash-only disposal option. Phase 1 ash disposal operations would be the same as those described in Section 4.3.1 including closure of Ash Dredge Cells 1-3 in 2018. Sluiced ash disposal in the Phase 2 area is expected to begin in 2017. Ash would be alternately sluiced to two or three dredge cells until 2029 when the stack reaches elevation 870 ft. At that point, dry ash disposal operations would begin in the Phase 3 area.

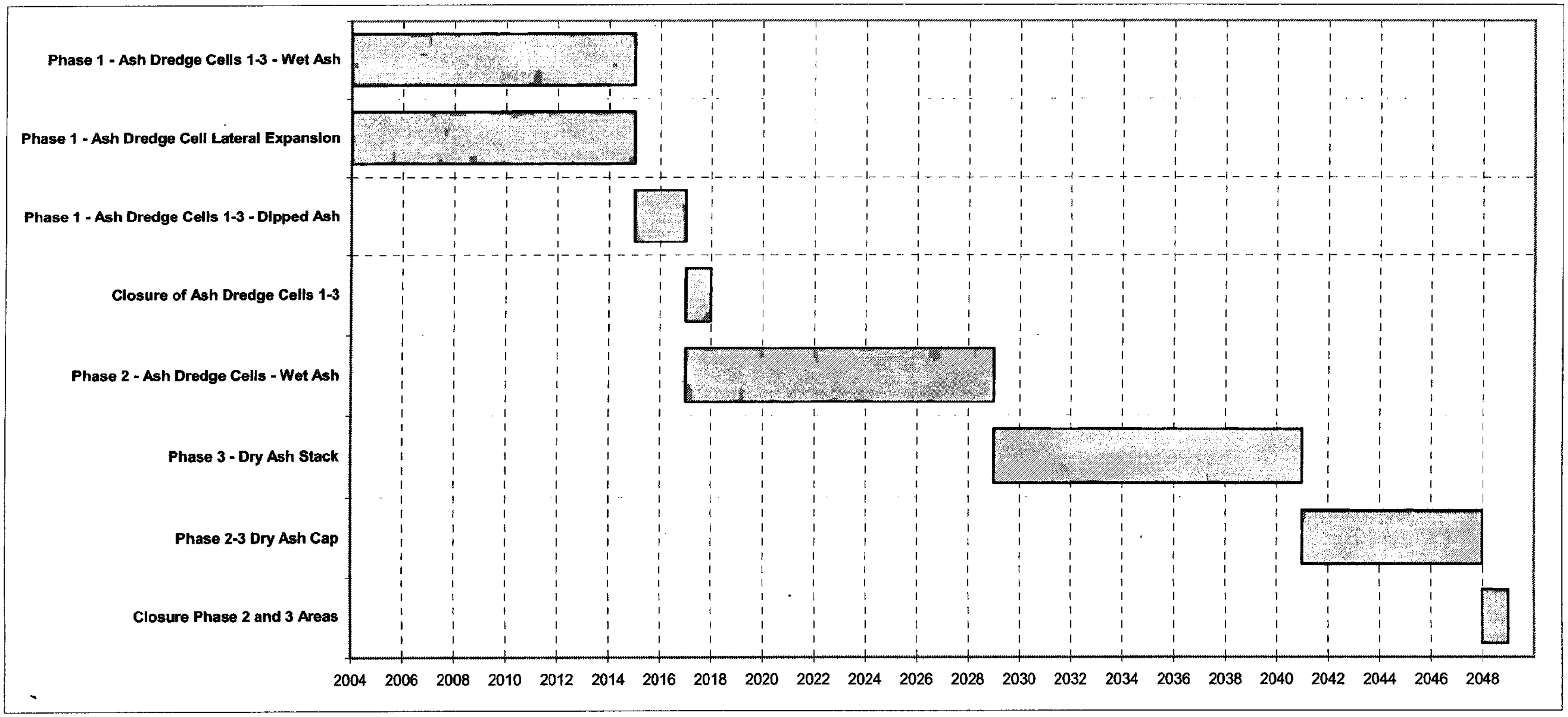


Figure 4-6. Option B – Schedule of Facility Operations

Dry ash stacking is expected to continue in the Phase 2 and 3 areas until 2048 when the stack attains a maximum elevation of 930 ft. Closure of the Phase 2 and 3 areas and the Phase 1 Lateral Expansion Area would occur in 2048 in the same manner described in Section 4.3.1 for Option A.

4.4.2 Leachate Seepage Results

Average leachate seepage estimates for each of the proposed disposal facilities considered under Option B are presented in Table 4-7. Detailed seepage data for all disposal facility subregions are given in Table J1 (Appendix J) along with information regarding estimation methods.

Leachate seepage estimates for Ash Dredge Cells 1-3 and the Lateral Expansion Area given in Table 4-7 are identical to those presented in Table 4-4 for Option A, since proposed disposal operations in these areas would be the same under both options. Results indicate that construction of an artificial clay buffer beneath the Phase 2 and 3 areas would reduce seepage during the active disposal period by 22 to 28%. As with Option A, 30-year post-closure simulations of the combined Phase 2 and 3 areas indicate essentially no difference between leachate production rates with or without a clay buffer.

4.4.3 Predicted COC Concentrations in Swan Pond Creek Embayment

Maximum COC stream loadings and concentrations for SPC embayment for Option B presented in Table J2 are identical to those presented for Option A (Table H2) , since future disposal operations affecting SPC are the same for both disposal options. Refer to Section 4.2.3 for discussion of potential water quality impacts to SPC.

4.4.4 Predicted COC Concentrations in Emory River

Except for ammonia, future ash leachate generated from existing ash disposal areas is expected to be chemically similar to current ash leachate. Therefore, future loadings of COC other than ammonia would not be expected to differ significantly from current loadings to the Emory River. Nevertheless, worst-case in-stream concentrations for the remaining COC are included in the analysis for consistency.

Table 4-7. Option B – Facility Leachate Seepage Estimates

Facility	Start Date	End Date	Waste	Mean Leachate Seepage (Lpd)	Seepage Difference Buffer vs. No Buffer
Phase 1 - Ash Dredge Cells 1-3	2004	2014	wet ash	425,135	NA
Phase 1 - Ash Dredge Cells 1-3	2015	2016	dipped ash	243,499	NA
Closure of Ash Dredge Cells 1-3	2017	2046	mixed ash	287,409	NA
Phase 1 - Dredge Cell Lateral Expansion Area	2004	2014	wet ash	56,936	NA
Phase 2 - Ash Dredge Cells - NO BUFFER	2017	2028	wet ash	125,956	
Phase 2 - Ash Dredge Cells - BUFFER	2017	2028	wet ash	92,002	27%
Phase 3 - Dry Ash Stack - NO BUFFER	2029	2040	dry ash	111,158	
Phase 3 - Dry Ash Stack - BUFFER	2029	2040	dry ash	80,042	28%
Phase 2&3 - Dry Ash Cap - NO BUFFER	2041	2047	dry ash	88,160	
Phase 2&3 - Dry Ash Cap - BUFFER	2041	2047	dry ash	68,837	22%
Closure of Phase 2&3 Areas - NO BUFFER	2048	2077	ash	230,944	
Closure of Phase 2&3 Areas - BUFFER	2048	2077	ash	229,223	1%

Facility COC mass loadings for Option B are provided in Table J2, while Figures 4-7 and 4-8 show predicted cumulative COC mass loading time series for the Emory River. The ammonia loading to the Emory River is low for both buffer and no-buffer cases until 2029, when dry ash disposal, with its relatively high ammonia content, begins in the Phase 3 Area. The ammonia load decreases following facility closure (2048) in response to reduced infiltration through the clay cap. Table 4-8 indicates the worst-case cumulative NH_3-N loading estimated for the no-buffer design is approximately 119 kg/day, resulting in an in-stream concentration of approximately 0.58 mg/L for the Emory River low-flow condition (Section 4.2.2). The clay buffer reduces the predicted in-stream concentration by 19% to approximately 0.47 mg/L. For both buffer and no-buffer cases, potential ammonia-derived nitrate or nitrite byproduct concentrations would be well below drinking water limits during low flow conditions. Predicted ammonia levels would also be below the CCC under typical pH conditions for the Emory River (Figure 4-9). Potential adverse aquatic impacts could occur under coincident conditions of extreme pH, temperature, and low flow in the Emory River (i.e., pH>8.0 and temperature ≥30°C). Historical data for Oakdale (RM 18.3) show that river pH exceeds 8.0 less than 8% of the time, whereas temperatures of 30°C or more occur less than 3% of the time. Disregarding the probability of the Emory River low flow condition at the plant for which data are unavailable, the joint probability of the extreme pH and temperature conditions would be less than 0.3%.

Worst-case in-stream concentrations for the remaining COC are also well below human health and aquatic life criteria in all cases. Differences between the estimated COC concentrations for the no-buffer and buffer design cases are directly related to predicted seepage differences and are generally less than 13%.

4.5 Potential Impacts to Groundwater Users

There are currently 13 residential wells and one public water supply spring located within approximately one mile of the proposed disposal area (Figure 3-1). Wells 7 and 20 lie north of Swan Creek embayment and are hydrologically isolated from the disposal site. Similarly, the public water supply spring (Spring 1) and well 23 are hydrologically isolated from the site by Pine Ridge. The ten remaining wells, located to the southwest along Swan Pond Road, are situated indirectly upgradient of the site. There is no indication of groundwater movement from the proposed disposal site toward any off-site wells or springs. No adverse off-site groundwater impacts associated with the proposed CCB disposal facilities are anticipated under present or future conditions.

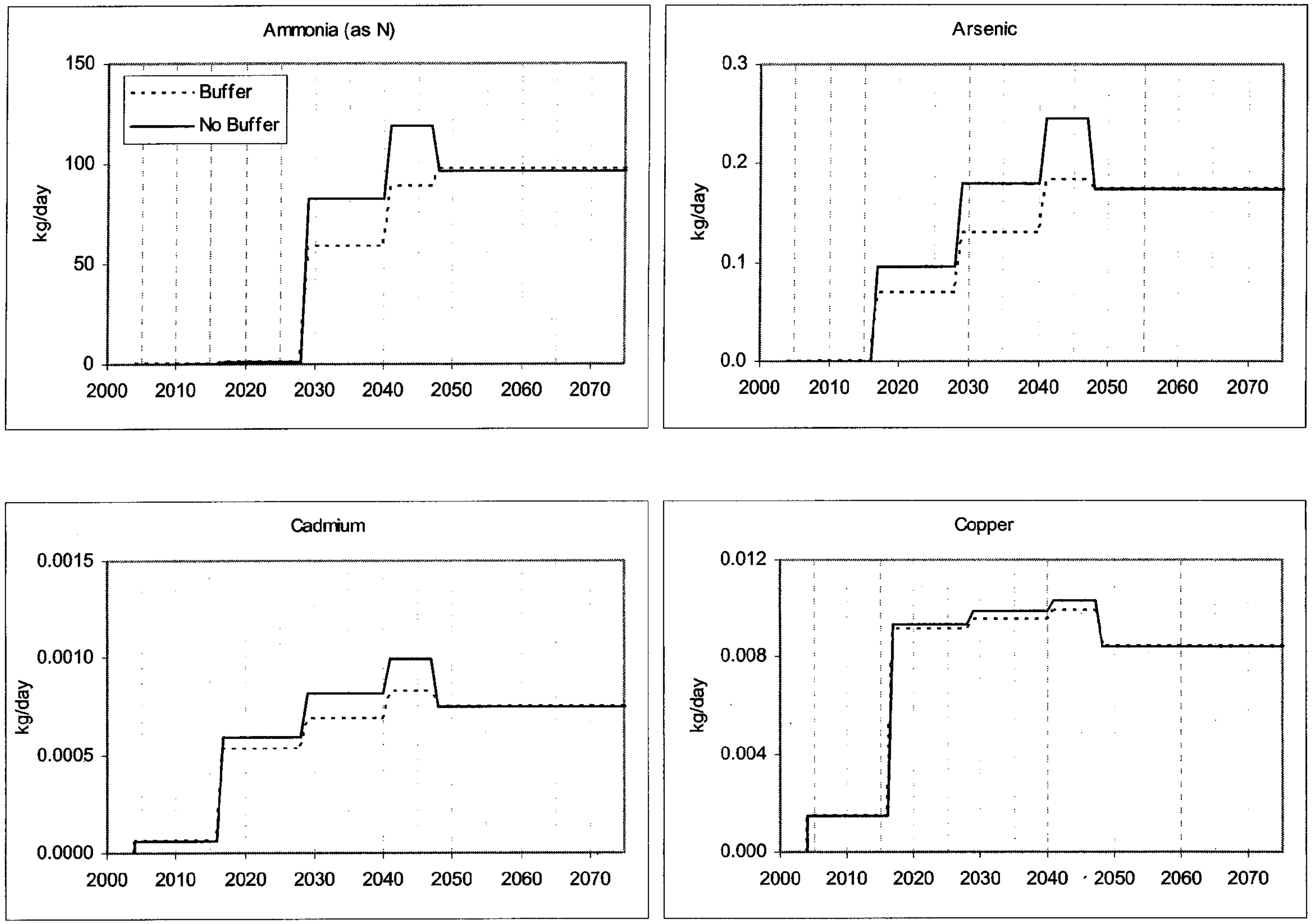


Figure 4-7. Option B – Cumulative COC Mass Loading for Emory River (Ammonia, Arsenic, Cadmium, and Copper)

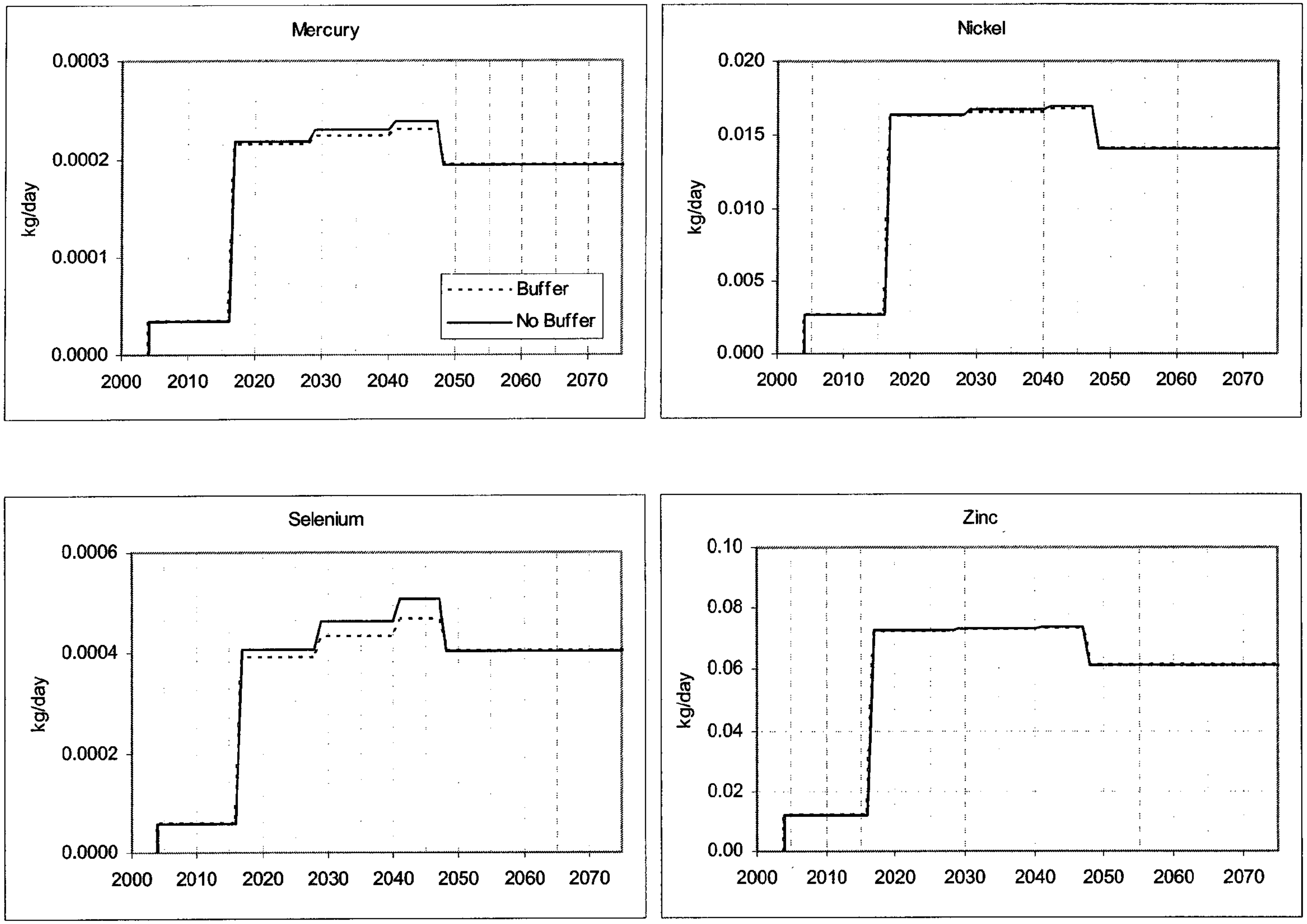
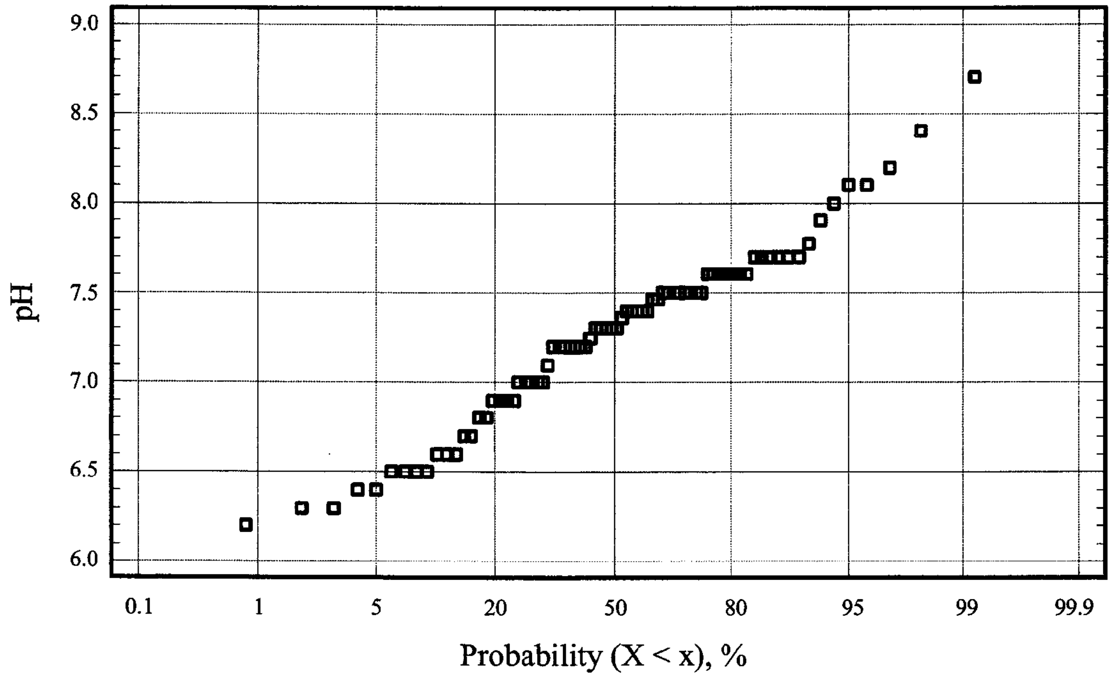


Figure 4-8. Option B – Cumulative COC Mass Loading for Emory River (Mercury, Nickel, Selenium, and Zinc)



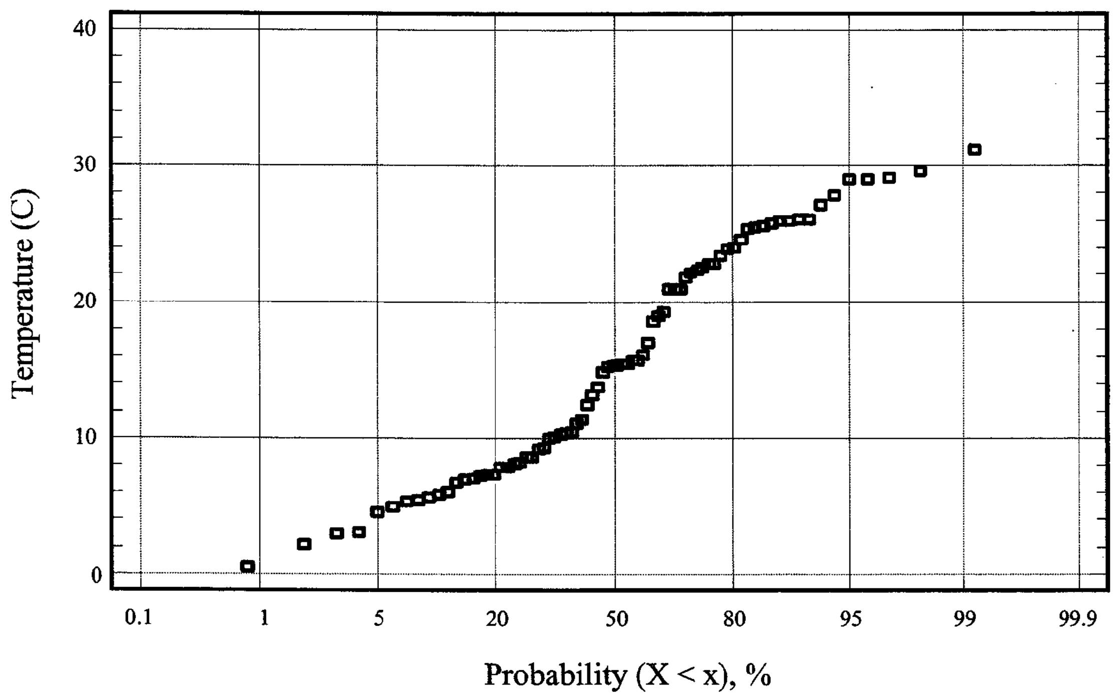


Figure 4-9. Emory River (RM 18.3) pH and Temperature Duration Data (1986-2001)

Table 4-8. Option B - Predicted Maximum Stream Loadings and In-Stream Concentrations

			Swan Pond Creek Embayment		Emory River – No Buffer Case		Emory River – Buffer Case	
Constituent	MCL	CCC	Maximum Loading (kg/day)	Maximum Concentration (mg/L)	Maximum Loading (kg/day)	Maximum Concentration (mg/L)	Maximum Loading (kg/day)	Maximum Concentration (mg/L)
Ammonia-N	10/1	(**)	4.24E-01	0.15221	1.19E+02	0.57939	9.67E+01	0.47043
Arsenic	0.05	0.15000	1.57E-03	0.00061	2.45E-01	0.00119	1.82E-01	0.00089
Cadmium	0.005	0.00021	4.25E-04	0.00016	9.95E-04	0.00000	8.26E-04	0.00000
Copper	1.3	0.00720	1.08E-02	0.00414	1.03E-02	0.00005	9.92E-03	0.00005
Mercury	0.002	0.00077	2.55E-04	0.00010	2.39E-04	0.00000	2.31E-04	0.00000
Nickel	0.1	0.04220	1.98E-02	0.00763	1.70E-02	0.00008	1.68E-02	0.00008
Selenium	0.05	0.00500	4.25E-04	0.00016	5.07E-04	0.00000	4.65E-04	0.00000
Zinc	5	0.09570	8.89E-02	0.03424	7.36E-02	0.00036	7.32E-02	0.00036

*** See Table 4-6*

4.6 Discussion and Conclusions

Modeling of leachate seepage from proposed CCB disposal facilities indicates that construction of an artificial 3-ft clay buffer having a hydraulic conductivity of 10^{-6} cm/s or less beneath the Phase 2 and 3 disposal areas would not provide a significant environmental benefit. During the operational phase, predicted leachate seepage rates for the no-buffer and buffer designs for Option A differed by 38% or less. Similar comparisons for Option B showed differences of 28% or less. In general, differences in seepage rates with and without the buffer are relatively small because hydraulic conductivity of the clay buffer is only an order of magnitude lower than that of CCB materials. Following facility closure, differences in seepage rates were 1% or less for both disposal options indicating essentially no long-term environmental benefit of an artificial clay buffer.

A conservative evaluation of leachate seepage effects on local stream water quality further supports the suitability of the site for the proposed disposal options without an artificial geologic buffer. Under Option A, maximum cumulative COC stream loadings predicted for the Emory River during low flow conditions would not produce in-stream concentrations exceeding the drinking water MCL or aquatic life criteria for either the buffer or no-buffer cases. Predicted COC concentrations for the Emory River low-flow condition under disposal Option B were below drinking water and aquatic life standards for all COC except ammonia. Worst-case NH_3-N concentrations of 0.58 and 0.47 mg/L estimated for the no-buffer and buffer designs pose no threat to human health, but could exceed the CCC under coincident conditions of extreme pH, temperature, and low flow in the Emory River. Historical data suggest the joint probability of such an occurrence would be less than 0.3%. The potential risk associated with ammonia under Option B can be addressed by future monitoring. Periodic sampling of ash ammonia content and groundwater downgradient of the facility could be performed to assure ammonia levels remain within the limits assumed in this evaluation.

The facility poses no risk to existing or future groundwater users. There are no existing groundwater wells downgradient of the proposed facility, and there is no potential for future development of such wells. All downgradient property between the disposal site and surface water boundaries lies within plant reservation boundaries.

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