Groundwater Flow and Transport Model Development for Proposed Ash Landfill at Kingston Fossil Plant

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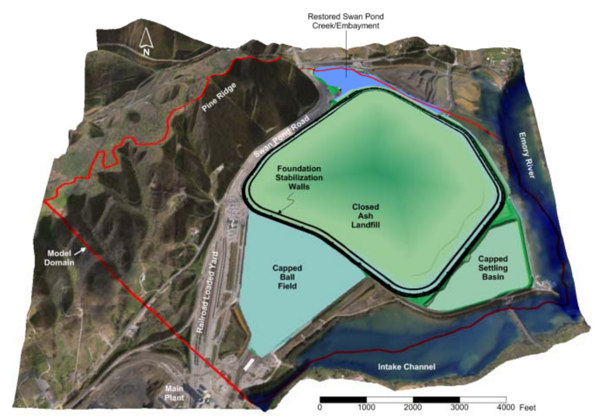

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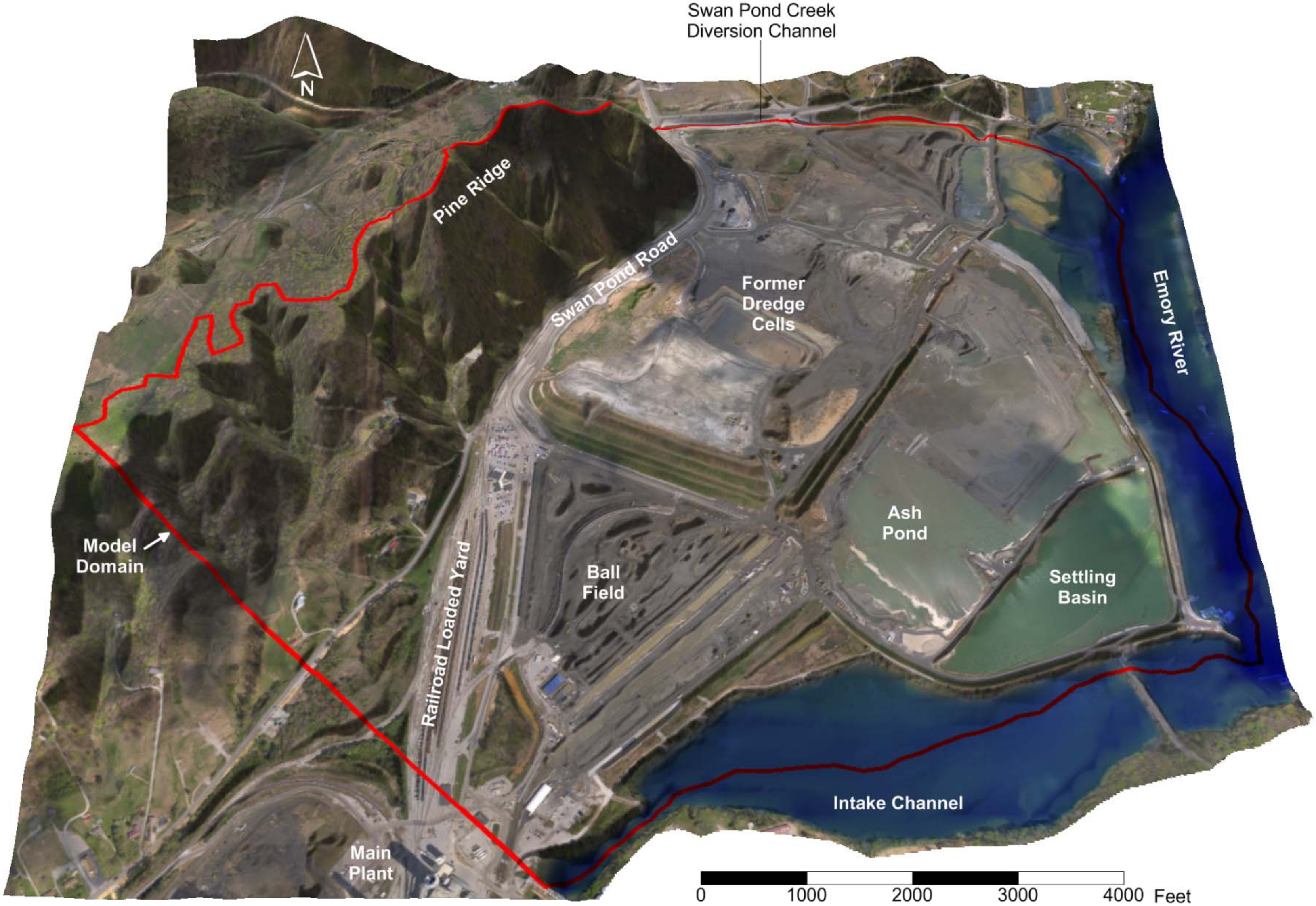
Three dimensional groundwater flow and transport models have been developed for the TVA Kingston Fossil Plant Ash Area to:

- **Predict the groundwater conditions at the site,**
- **Quantify ash-related constituent concentrations and mass fluxes entering the surface water bodies via groundwater seepage from ash source areas after proposed Ash Landfill construction.**

These predictions will be used in evaluating long-term risks to human and aquatic receptors.

2010 Site Conditions



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Model Development Steps

1. **Groundwater Flow Model for 2010 Conditions (MODFLOW)**
   - Model Parameter Estimation
   - Model Calibration and Verification
2. **Groundwater Flow Model for Future Conditions (MODFLOW)**
   - Predict Groundwater Condition for the Closed Ash Landfill Site
3. **Fate-Transport Model for Future Conditions (MT3D)**
   - Predict constituents of concern (COC) for fate and transport
   - Predict COC discharge (concentration and mass flux) to Surface Water Bodies

Major Tasks Performed During Model Development:

1. **Detailed lithologic 3-D mapping analysis**
   - Utilized all available borings (> 350) to map the distribution of lithologic units (ash, alluvial clay, alluvial sand, bedrock, residuum)
2. **Fly ash – bottom ash distribution analysis based on boring data**
3. **Groundwater / surface water level measurement (July 2010)**
   - Mapped the water levels in various layers and across the site
4. **Ash pore water and groundwater chemical sampling (2010)**
   - Mapped the 2010 distribution of COCs in groundwater
5. **Site-specific geotechnical analysis (2010)**
6. **Geochemical analysis (2010 – Leaching and column tests)**
7. **In-field hydraulic testing (2010 – in-situ hydraulic conductivity measurements and laboratory based tests on undisturbed samples)**
8. **Hydraulic property evaluation for all matrix based on existing data**
9. **Geochemical modeling to evaluate fate of potential COCs**

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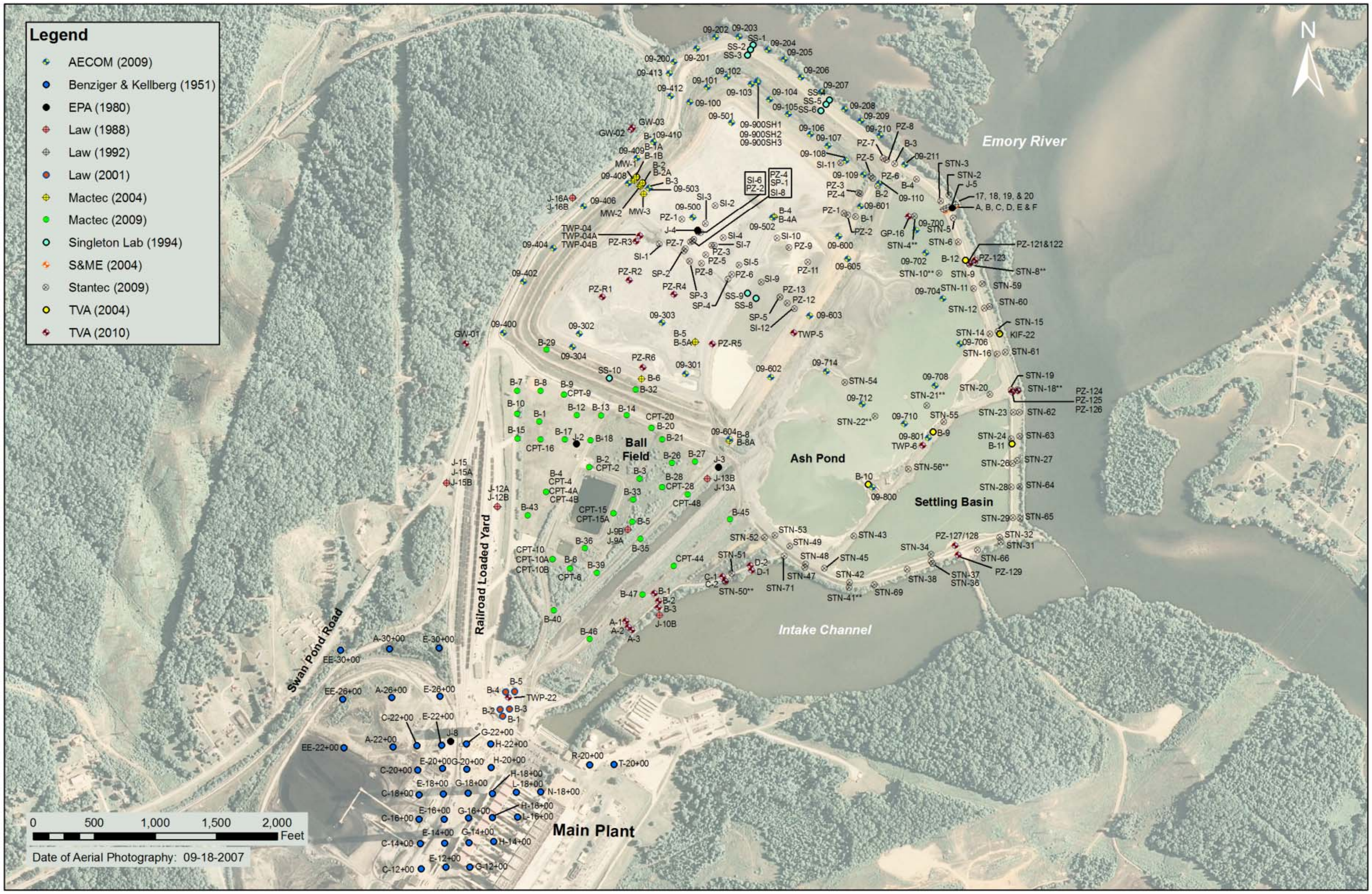
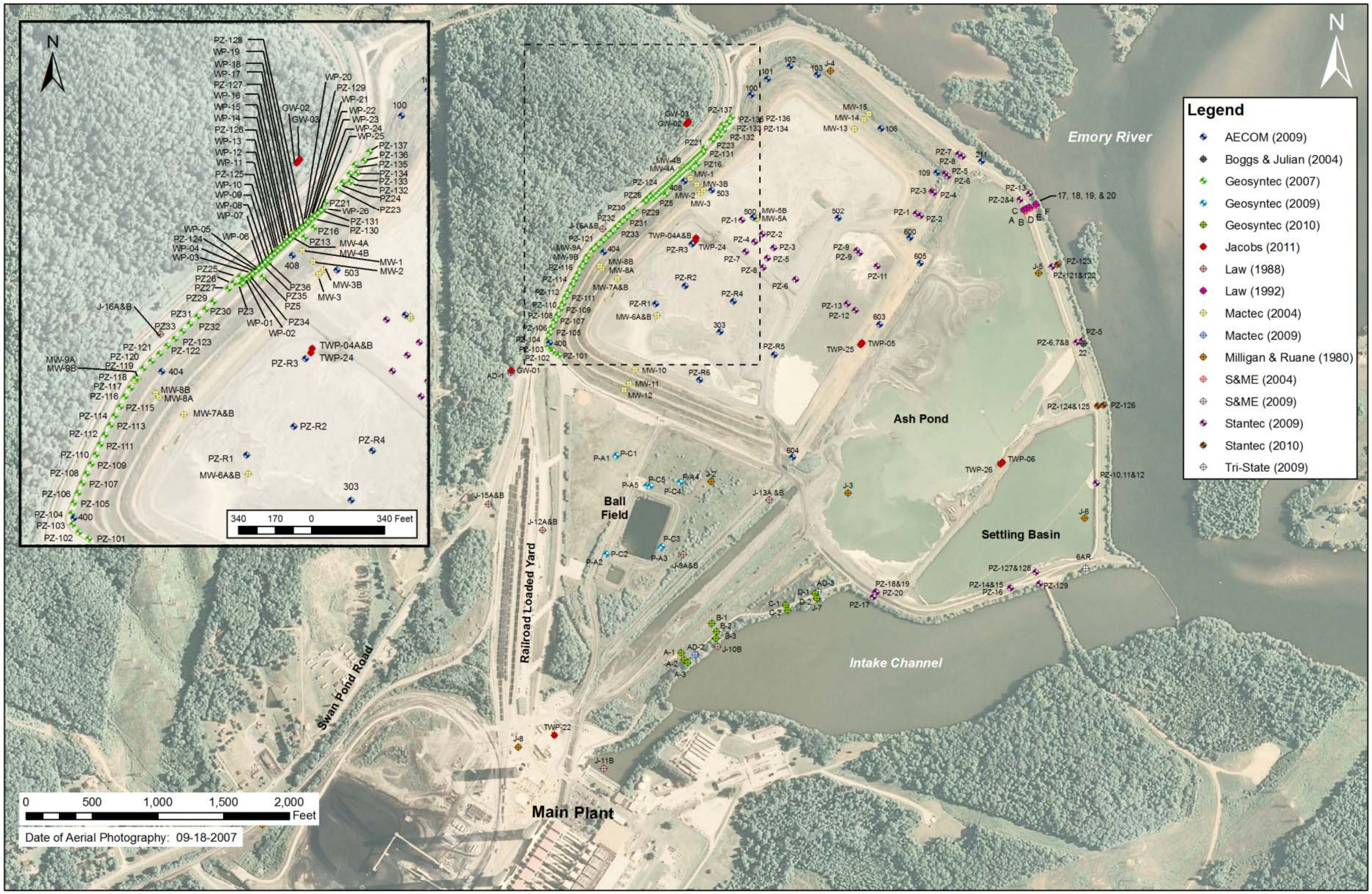
Borings Used for Lithologic Mapping Analysis



Wells Used for Lithologic Mapping Analysis



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Model for 2010 Conditions

GRID INFORMATION	
Number of Rows	680
Number of Columns	750
Number of Layers	8
Total Cells	4,080,000
Total Active Cells	2,261,144
Percent Inactive	55.4%
GRID DIMENSIONS	
Row Spacing	
Minimum Delta-Y (ft)	10
Maximum Delta-Y (ft)	10
Column Spacing	
Minimum Delta-X (ft)	10
Maximum Delta-X (ft)	10
MODEL BOUNDARY CONDITIONS (cells)	
Constant Heads	25,791
Rivers	34,665
Drains	4,213
No Flow	1,818,856
RECHARGE (inches/year)	
Ash/Dike	6
Residuum	8
Railroad Unloaded Yard	4
Pine Ridge	9

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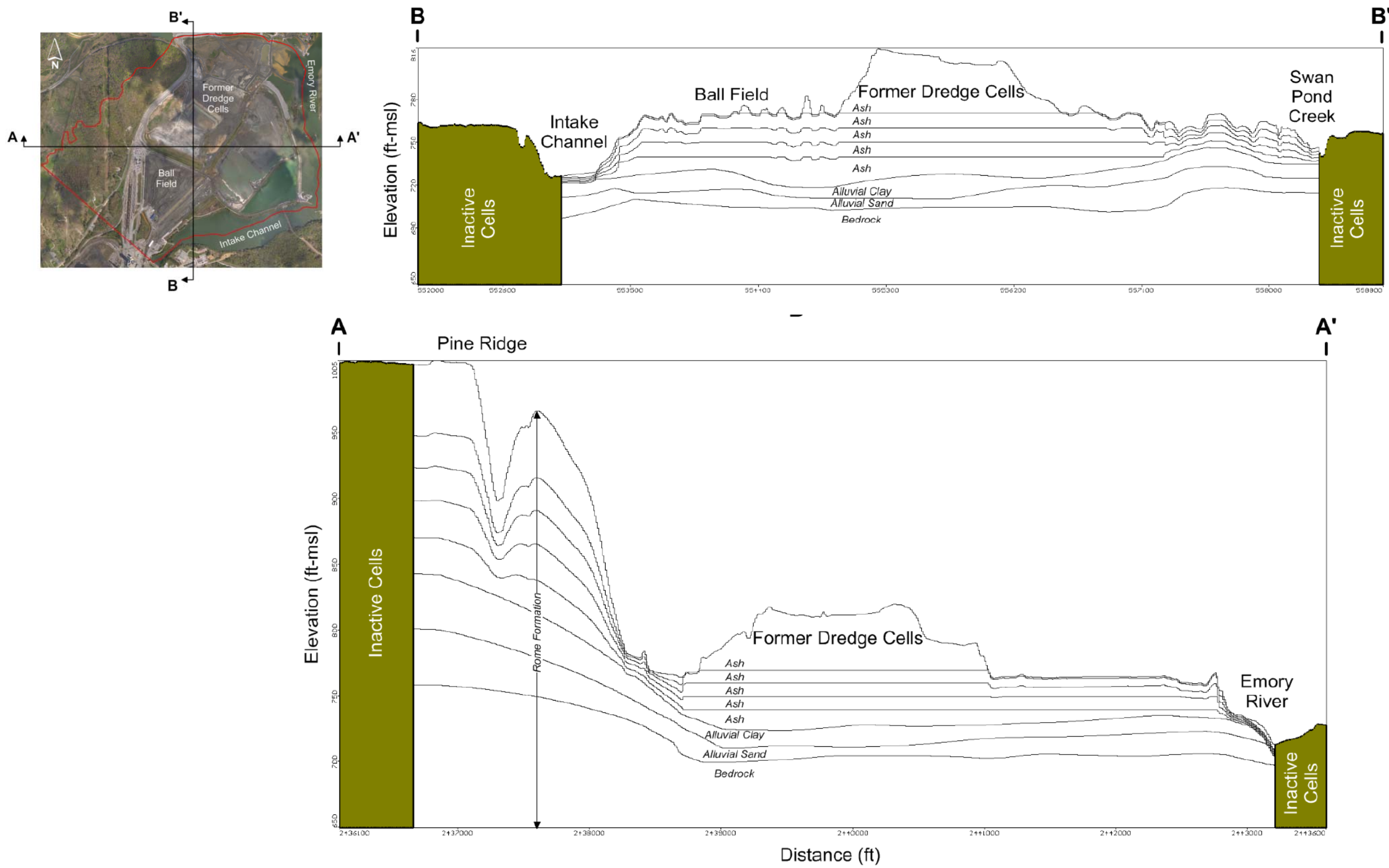
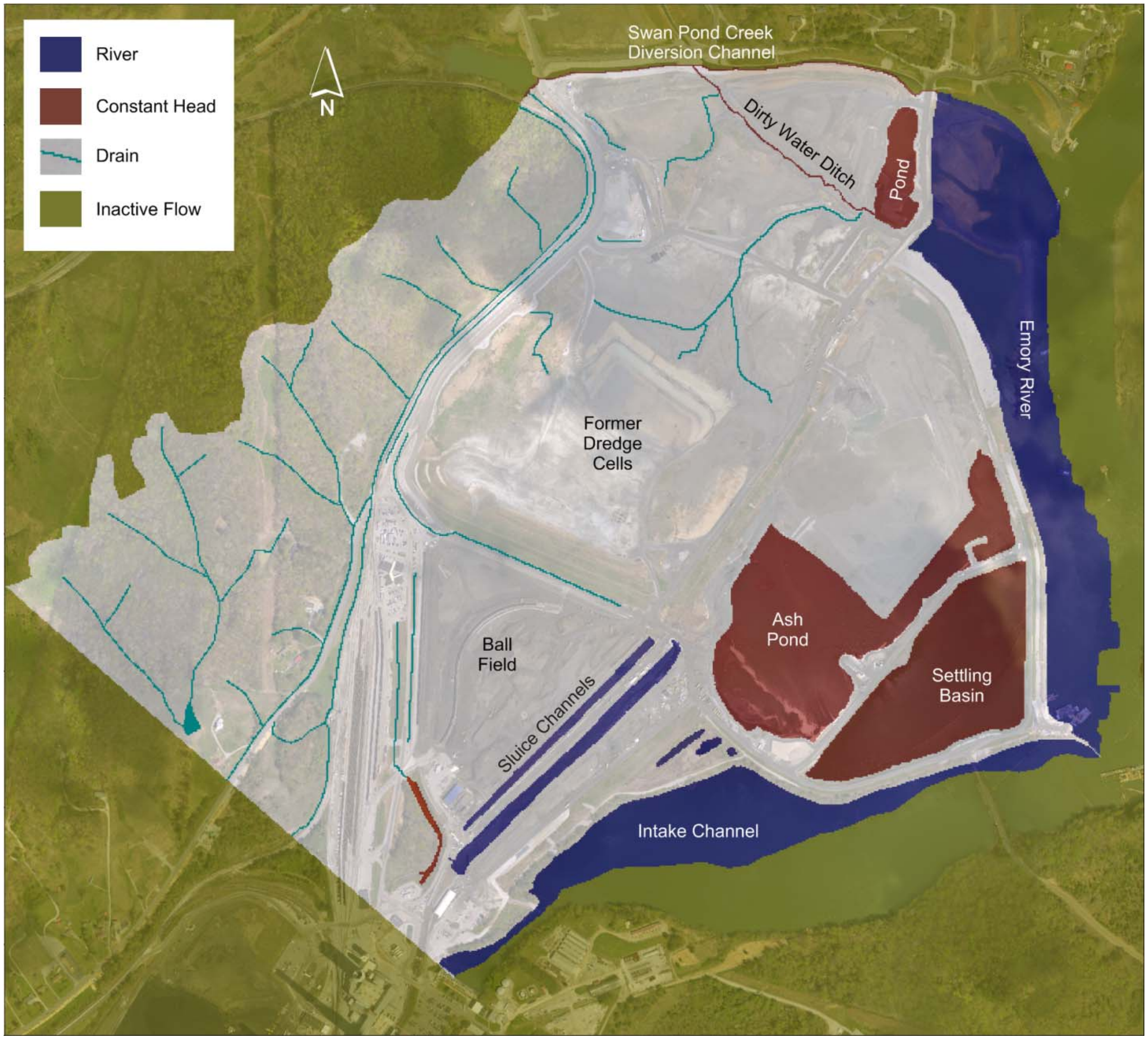


B'
A
A'
B
N
Former Dredge Cells
Emory River
Ball Field
Intake Channel
B
B'
Elevation (ft-msl)
Ball Field
Former Dredge Cells
Intake Channel
Swan Pond Creek
Ash
Ash
Ash
Ash
Ash
Alluvial Clay
Alluvial Sand
Bedrock
Inactive Cells
Inactive Cells
A
A'
Pine Ridge
Elevation (ft-msl)
Inactive Cells
Rome Formation
Former Dredge Cells
Ash
Ash
Ash
Ash
Ash
Alluvial Clay
Alluvial Sand
Bedrock
Emory River
Inactive Cells
Distance (ft)

2010 Model Boundary Conditions



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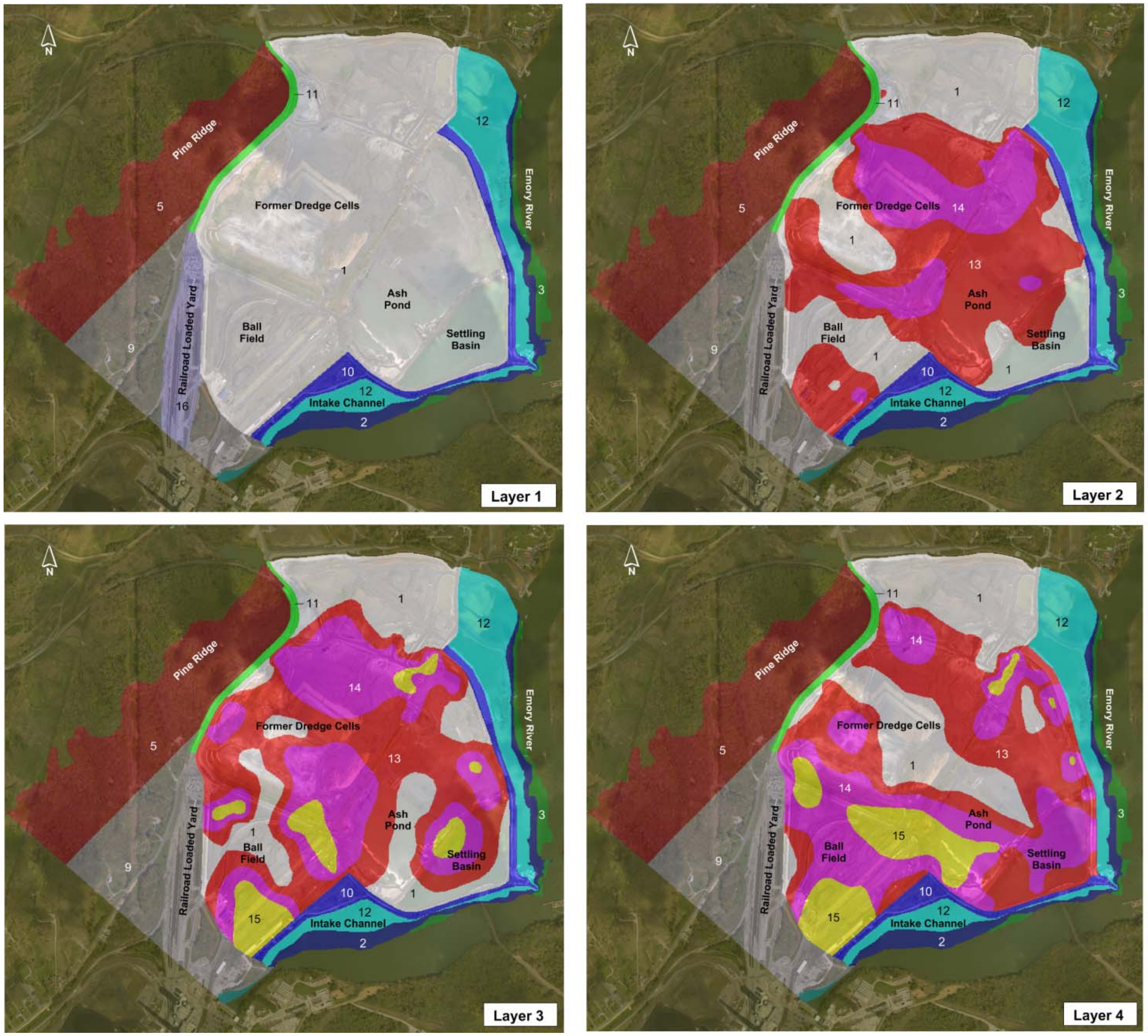
Model Hydraulic Conductivity Distribution (Layers 1-4)



Zone	Kx & Ky (cm/sec)	Kz (cm/sec)
1	5.4E-5	4.2E-5
2	5.0E-6	2.5E-6
3	5.0E-4	2.5E-4
4	5.0E-4	5.0E-4
5	8.0E-4	8.0E-4
6	2.0E-5	2.0E-5
7	4.0E-5	4.0E-5
8	7.9E-5	7.9E-5
9	5.0E-4	2.5E-4
10	8.0E-4	8.0E-4
11	1.0E-3	1.0E-3
12	8.0E-4	8.0E-4
13	3.4E-4	1.7E-4
14	6.2E-4	3.1E-4
15	9.0E-4	4.5E-4
16	9.0E-4	9.0E-4
Inactive Flow		

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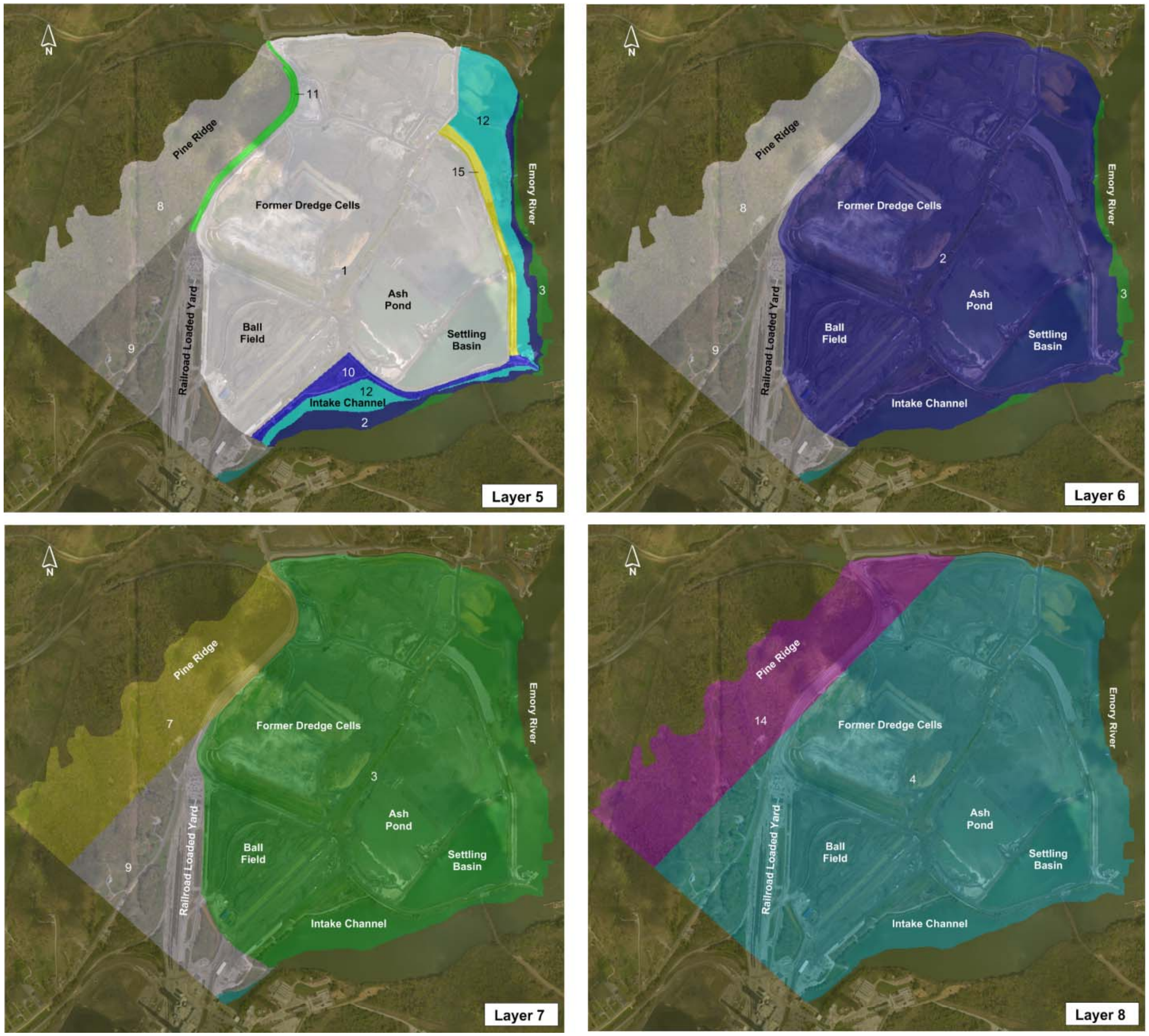
Model Hydraulic Conductivity Distribution (Layers 5-8)



Zone	Kx & Ky (cm/sec)	Kz (cm/sec)
1	5.4E-5	4.2E-5
2	5.0E-6	2.5E-6
3	5.0E-4	2.5E-4
4	5.0E-4	5.0E-4
5	8.0E-4	8.0E-4
6	2.0E-5	2.0E-5
7	4.0E-5	4.0E-5
8	7.9E-5	7.9E-5
9	5.0E-4	2.5E-4
10	8.0E-4	8.0E-4
11	1.0E-3	1.0E-3
12	8.0E-4	8.0E-4
13	3.4E-4	1.7E-4
14	6.2E-4	3.1E-4
15	9.0E-4	4.5E-4
16	9.0E-4	9.0E-4
	Inactive Flow	

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Predicted Water Table for Calibrated Model 2010 Conditions

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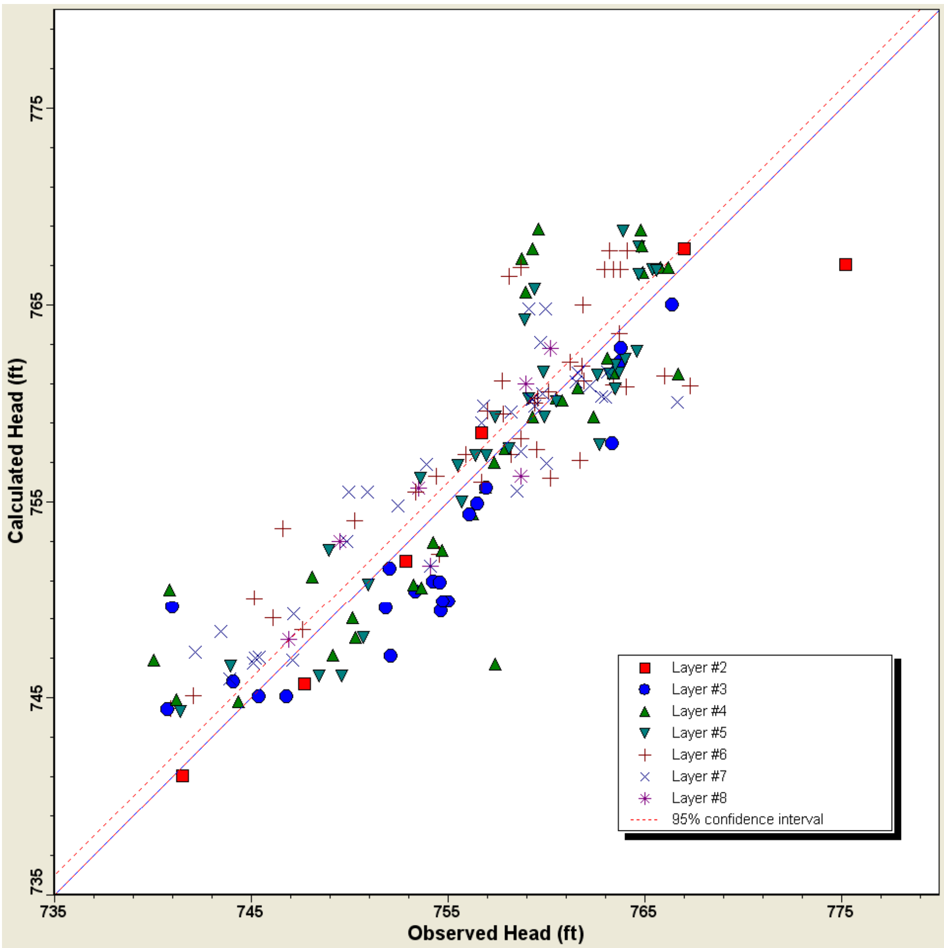
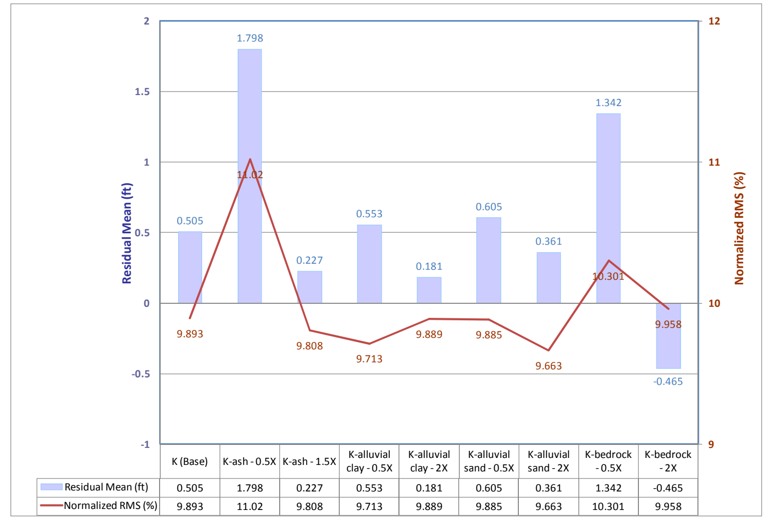
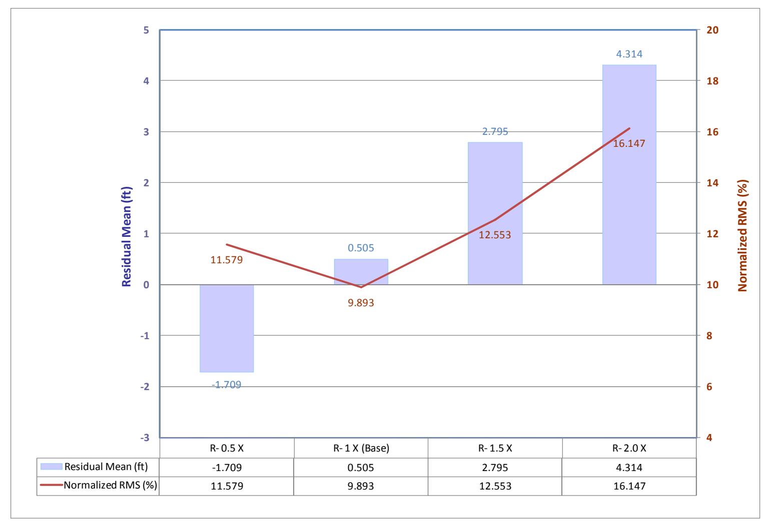
Model Calibration and Sensitivity Analysis







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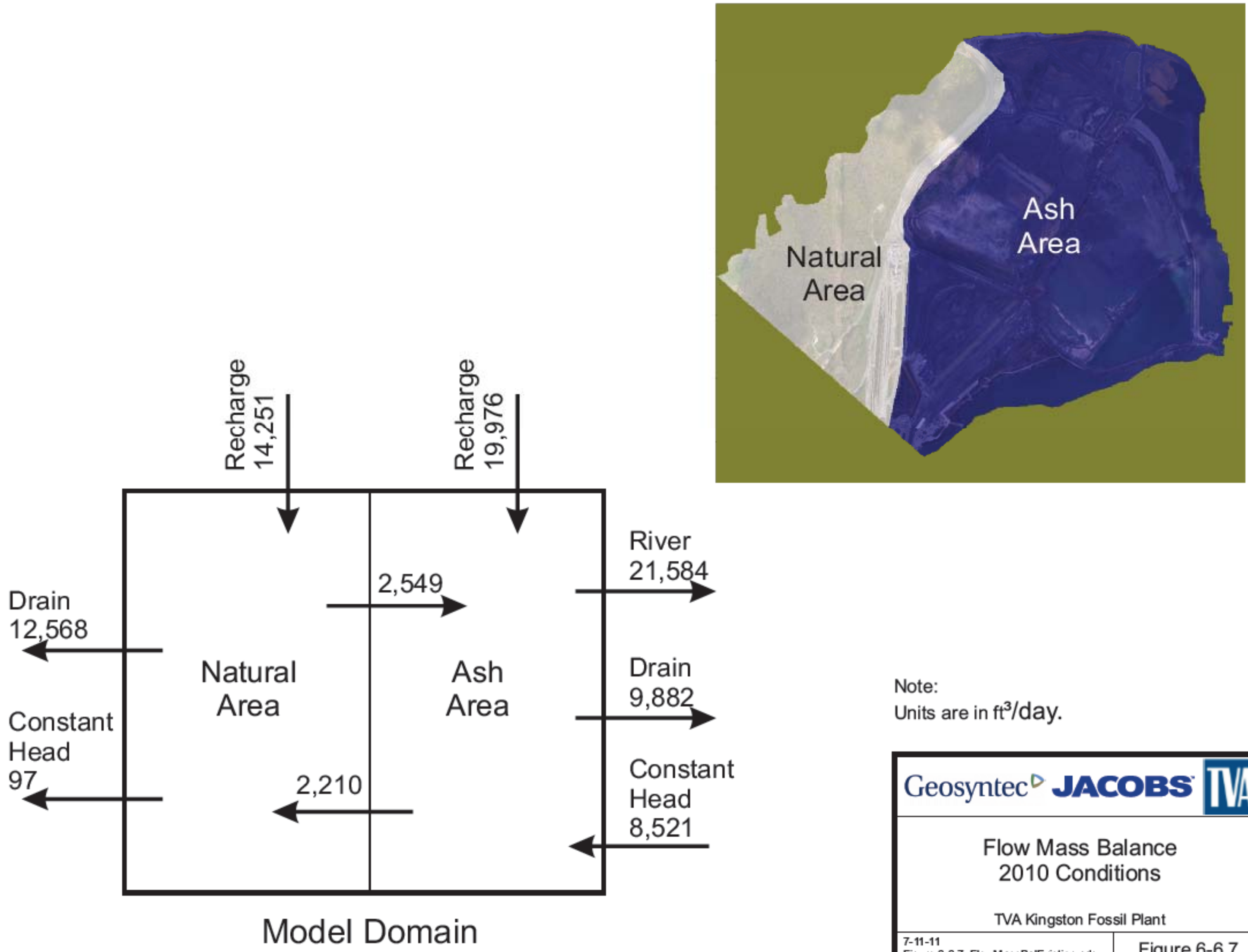


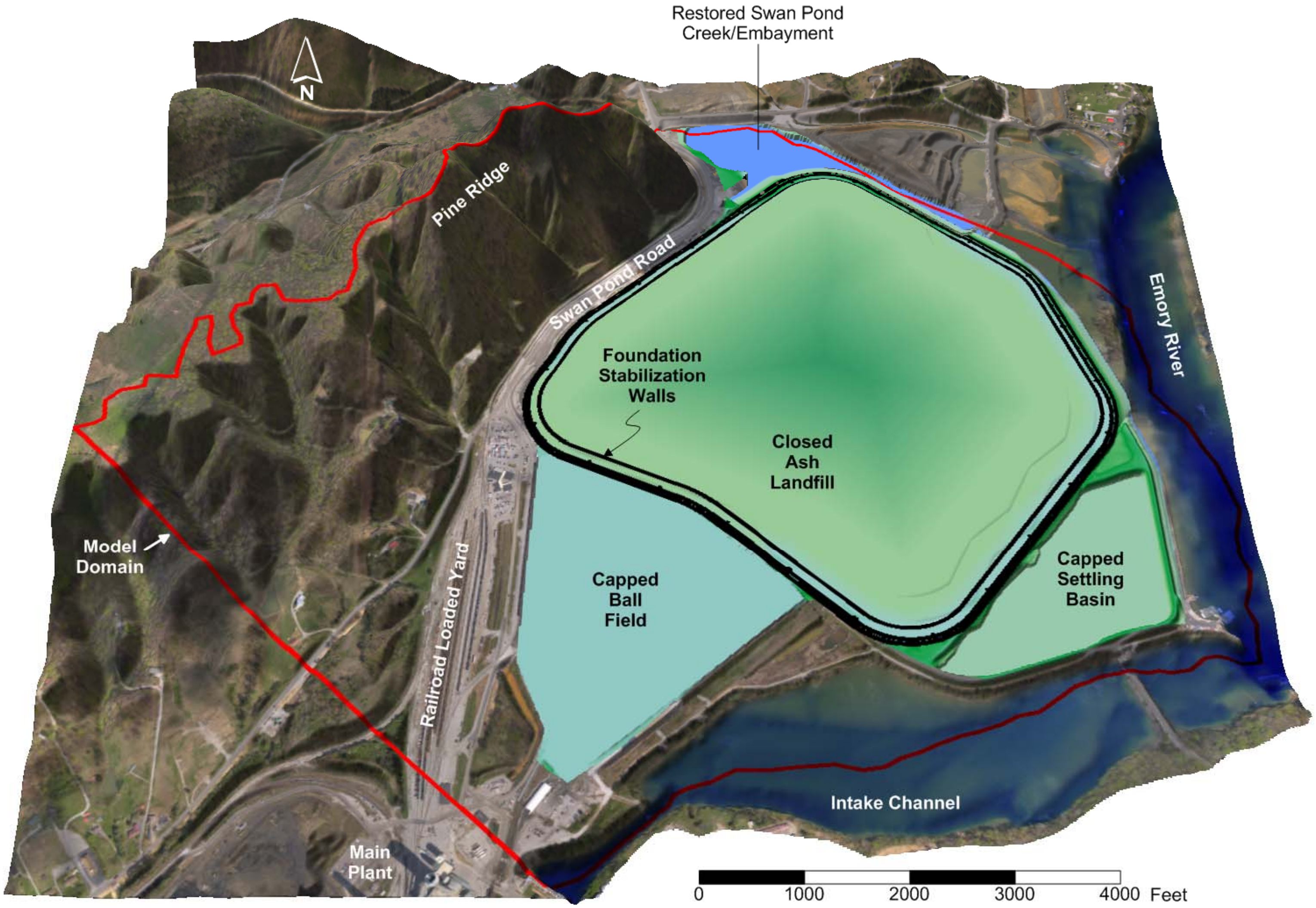
Flow Mass Balance
2010 Conditions

TVA Kingston Fossil Plant

7-11-11
Figure 6-6.7_FlowMassBalExisting.cdr

Figure 6-6.7

Future Conditions



Capped Ash Landfill with flexible membrane liner (FML)

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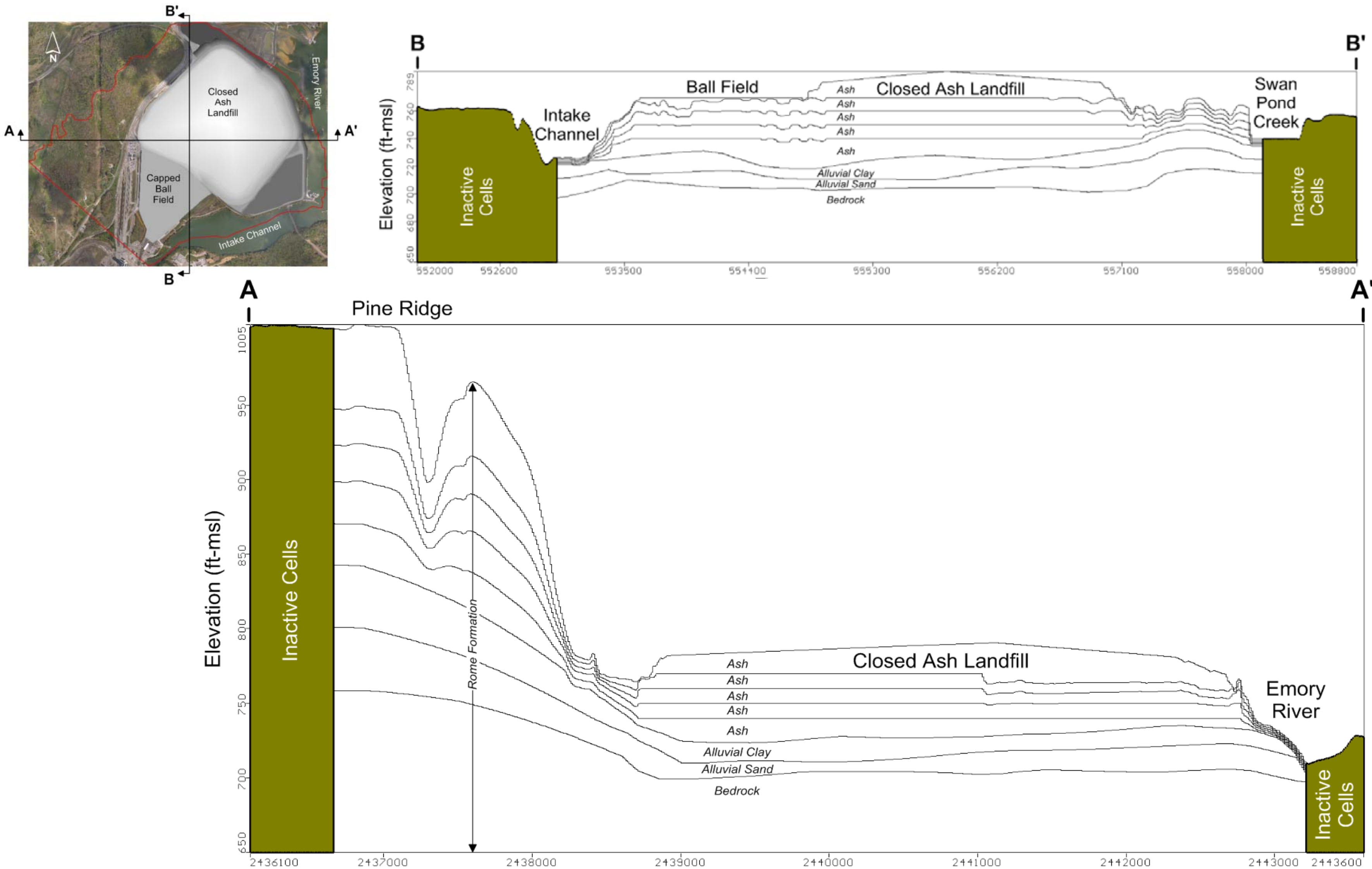
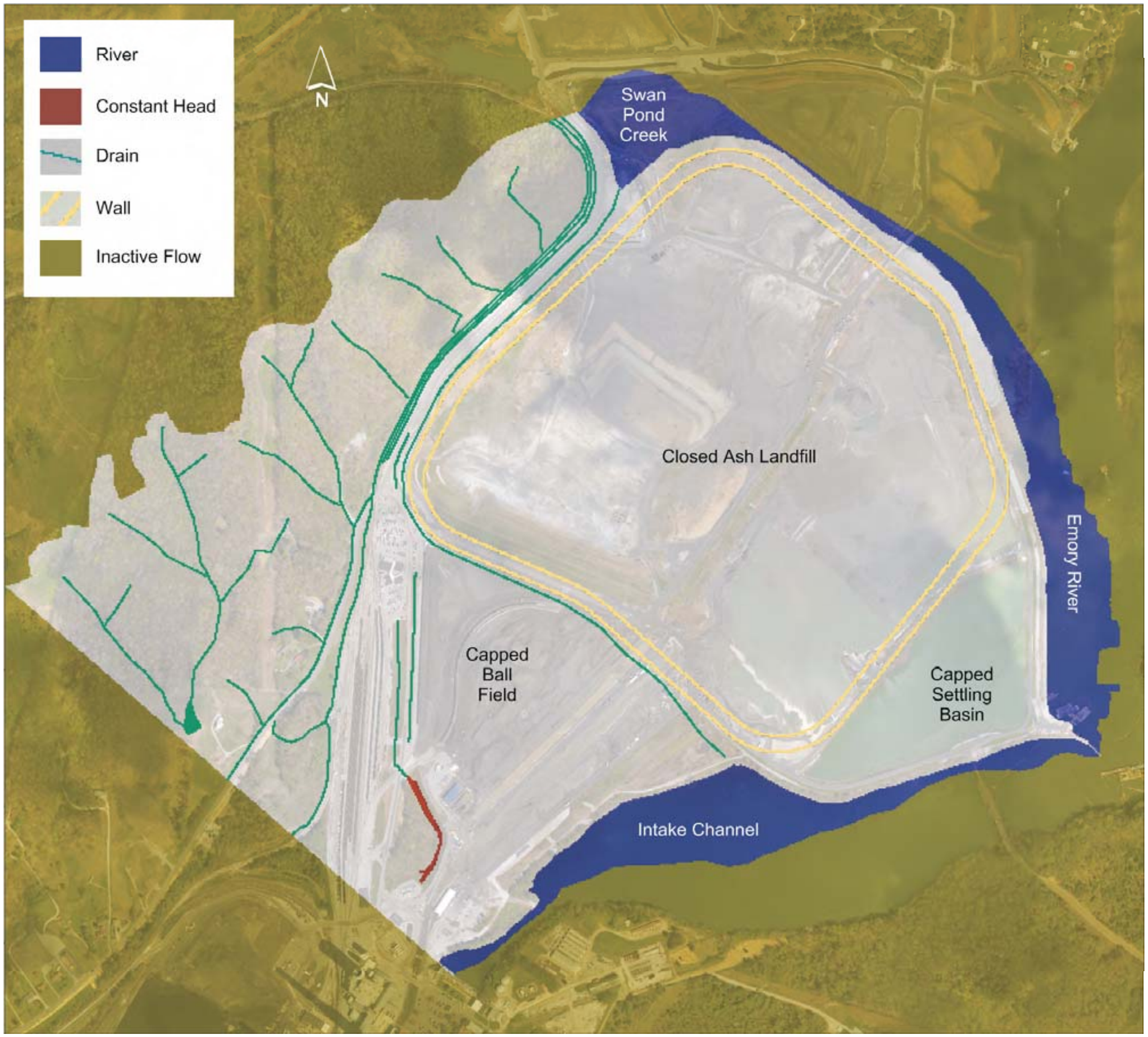


B'
B
A
A'
Closed Ash Landfill
Capped Ball Field
Emory River
Intake Channel
N
Elevation (ft-msl)
Inactive Cells
Intake Channel
Ball Field
Ash
Closed Ash Landfill
Swan Pond Creek
Alluvial Clay
Alluvial Sand
Bedrock
552000
552600
553500
554400
555300
556200
557100
558000
558800
Pine Ridge
Rome Formation
Emory River
2436100
2437000
2438000
2439000
2440000
2441000
2442000
2443000
2443600
1005
950
900
850
800
750
700
650

Future Model Boundary Conditions



Predicted Water Levels in Ash for Future Conditions

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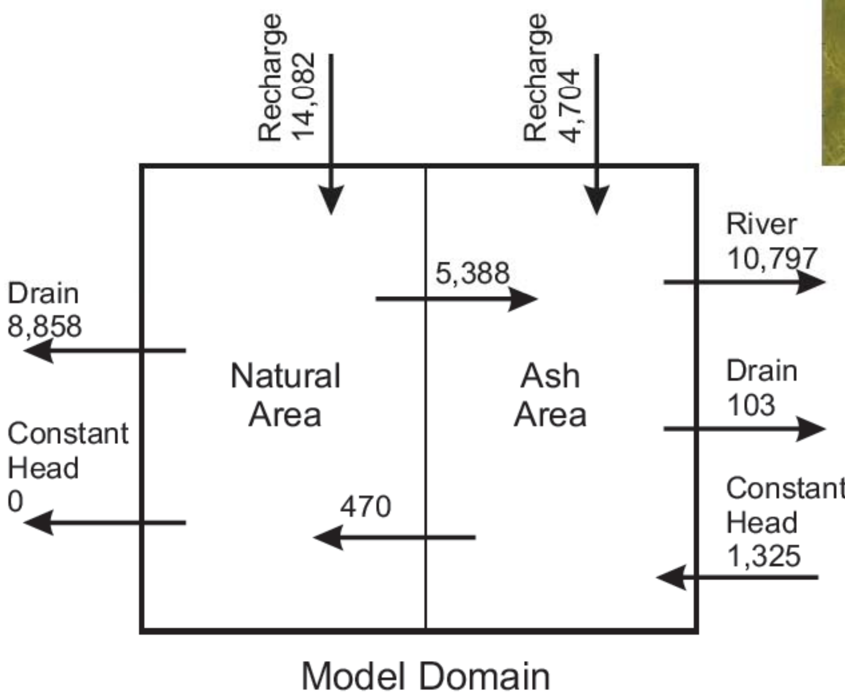

Note:
Units are in ft^3/day.

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Flow Mass Balance
Future Conditions

TVA Kingston Fossil Plant

7-11-11
Figure 7-6.5_FlowMassBalFuture.cdr

Figure 7-6.5

Fate-Transport Modeling

The constituents of concern (COCs) selected for final fate-transport modeling were <u>arsenic</u>, <u>selenium</u>, and <u>radium-226</u>.

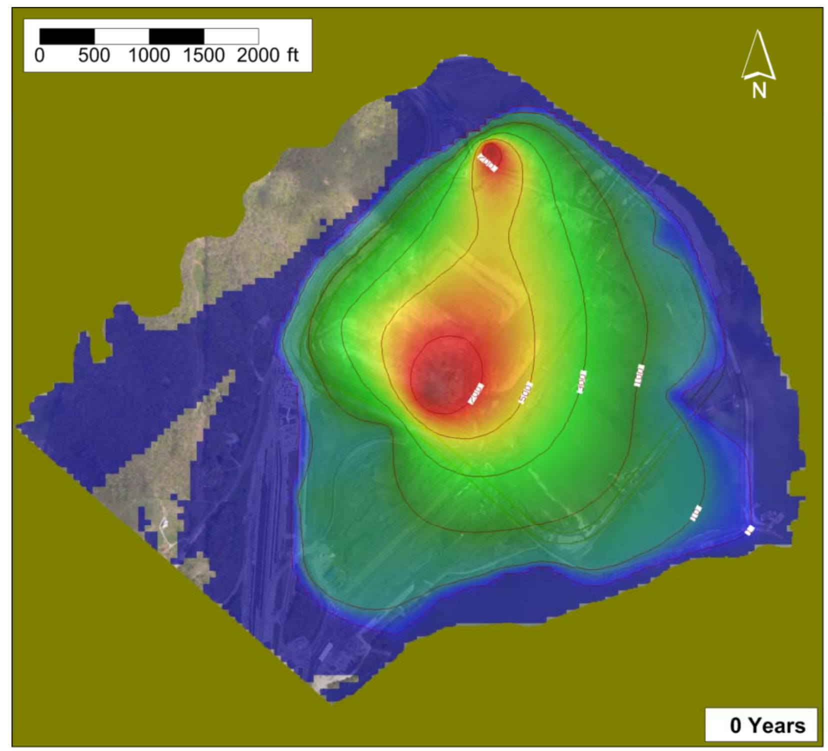
These constituents are naturally-occurring metals and radionuclides that have been concentrated in the ash through the coal combustion process.

These COCs are representative of the primary constituents in the ash that have been shown to contribute to potential risk in human and ecological receptors exposed to environmental media within the river system.

The fate and transport of the COCs within a <u>100-year</u> time frame were predicted.

Closed Ash Landfill Leaching Source

Starting (Arsenic) Distribution in GW



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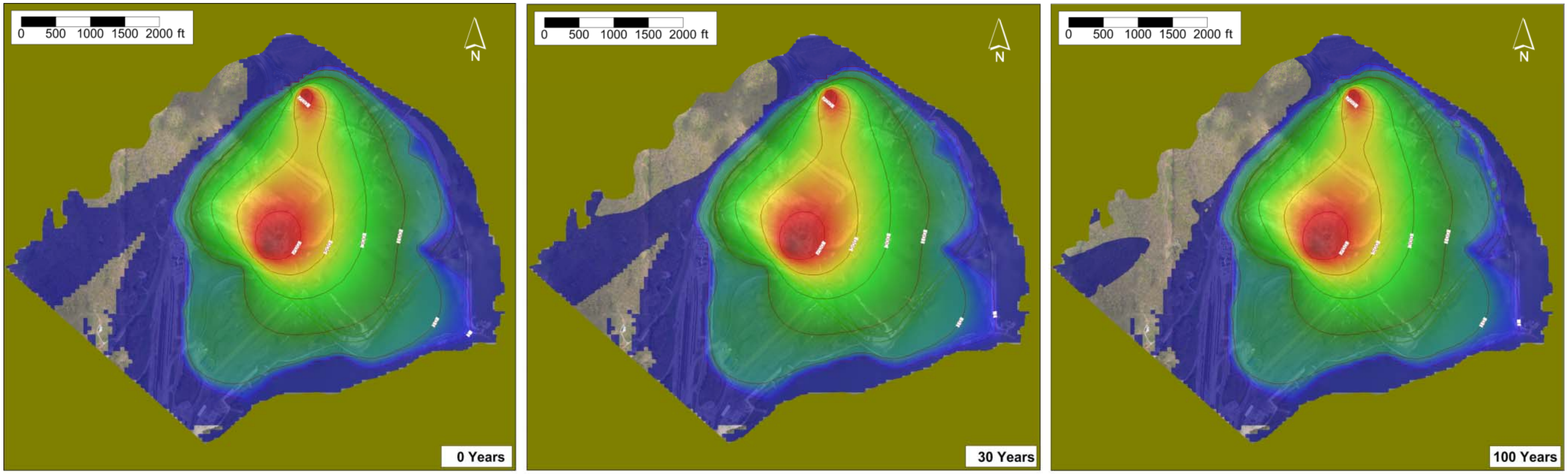
Modeled Scenarios – Sources and Kds

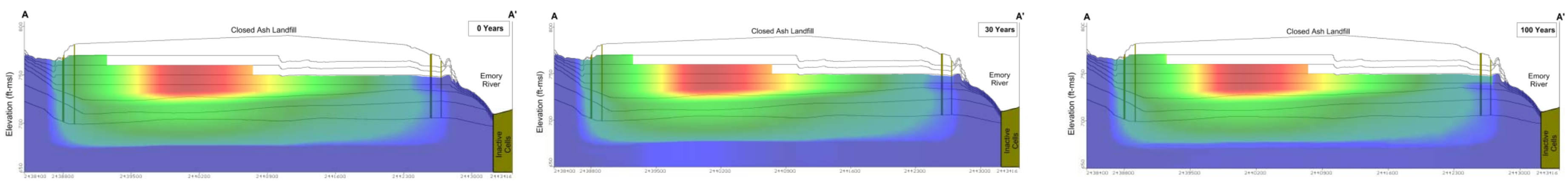
COC	Scenario	Media	Kd (L/kg)	Recharge Concentration (ug/L)
Arsenic	1	Ash	61.6	915
		alluvial clay	14.0	
		alluvial sand	17.0	
		residuum	379.3	
		bedrock	9.2	
	2	Ash	100.0	564
		alluvial clay	14.0	
		alluvial sand	17.0	
		residuum	379.3	
		bedrock	9.2	
	3	Ash	180.0	313
		alluvial clay	14.0	
		alluvial sand	17.0	
		residuum	379.3	
		bedrock	9.2	
Selenium	1	Ash	21.0	235
		alluvial clay	4.0	
		alluvial sand	4.0	
		residuum	4.0	
		bedrock	4.0	
	2	Ash	250.0	19.6
		alluvial clay	4.0	
		alluvial sand	4.0	
		residuum	4.0	
		bedrock	4.0	
Radium-226	1	Ash	3370.0	2.35 = 2.377E-06 (pCi/L = ug/L)
		alluvial clay	19.1	
		alluvial sand	19.1	
		residuum	282.0	
		bedrock	90.5	



Legend

As [µg/L] 0.33 1 10 100 300 500 700 900

Arsenic (in Ash)



Arsenic -- Kd = 61.1 L/kg

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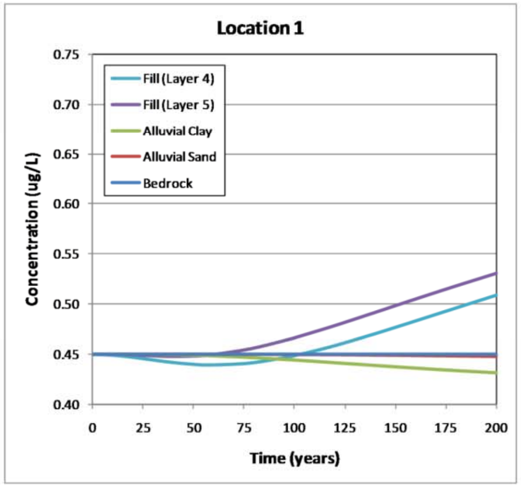

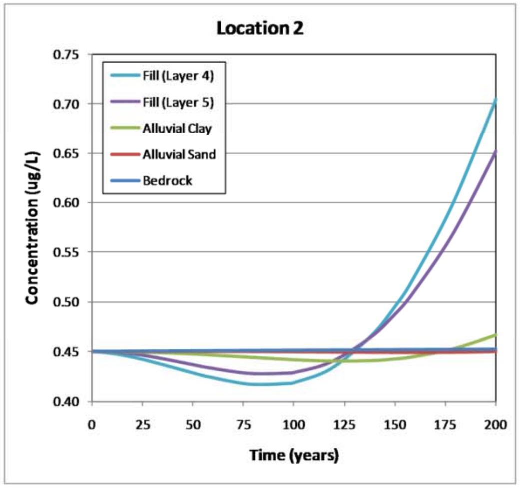

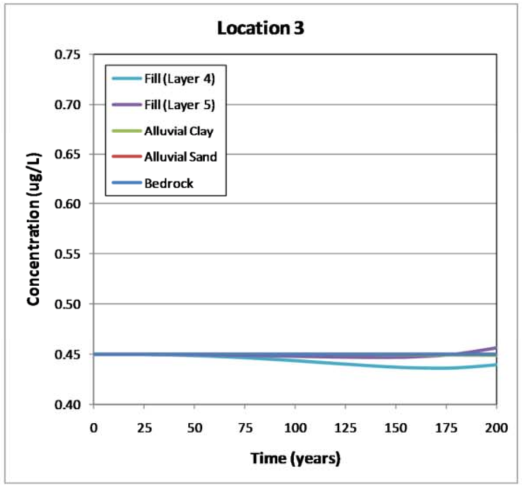

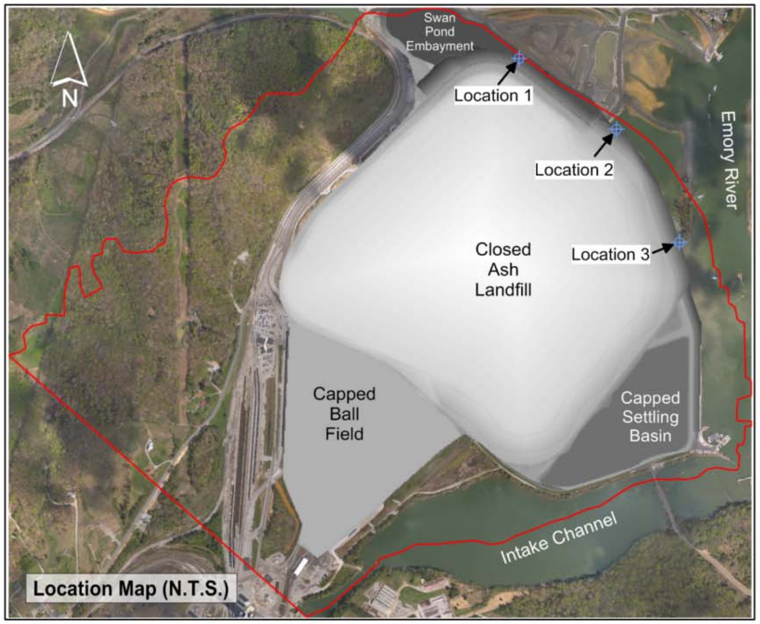

Arsenic -- Kd = 61.1 L/kg

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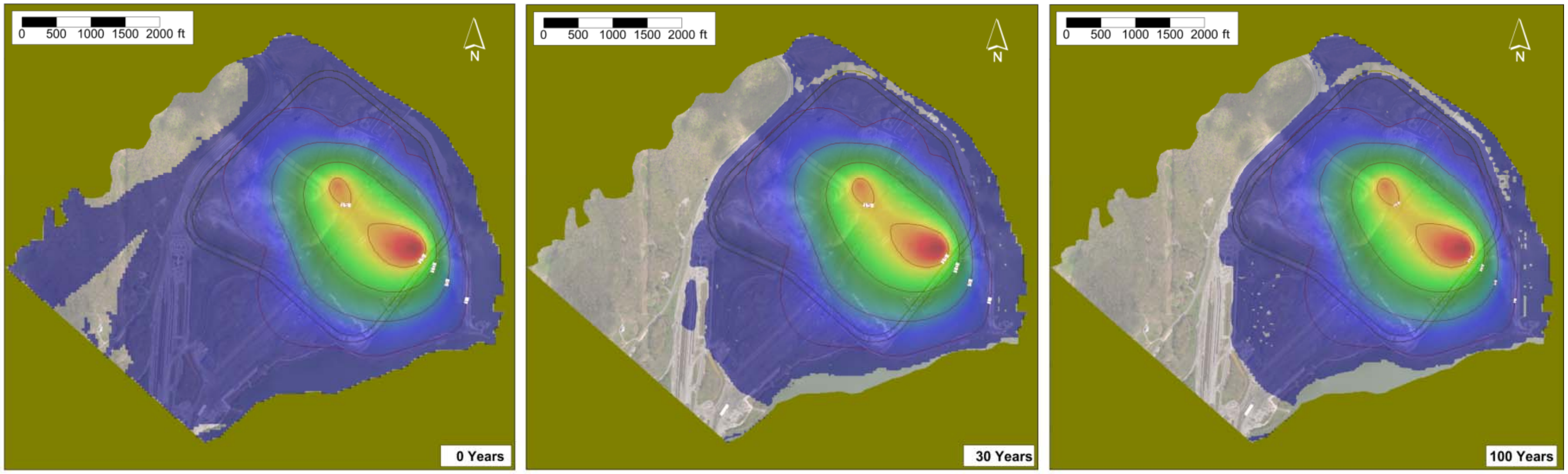
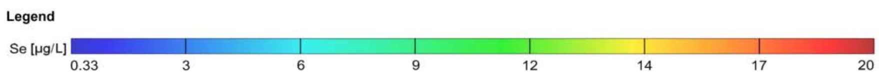
Modeling Discharge Results – Concentrations and Mass Flux (Arsenic)

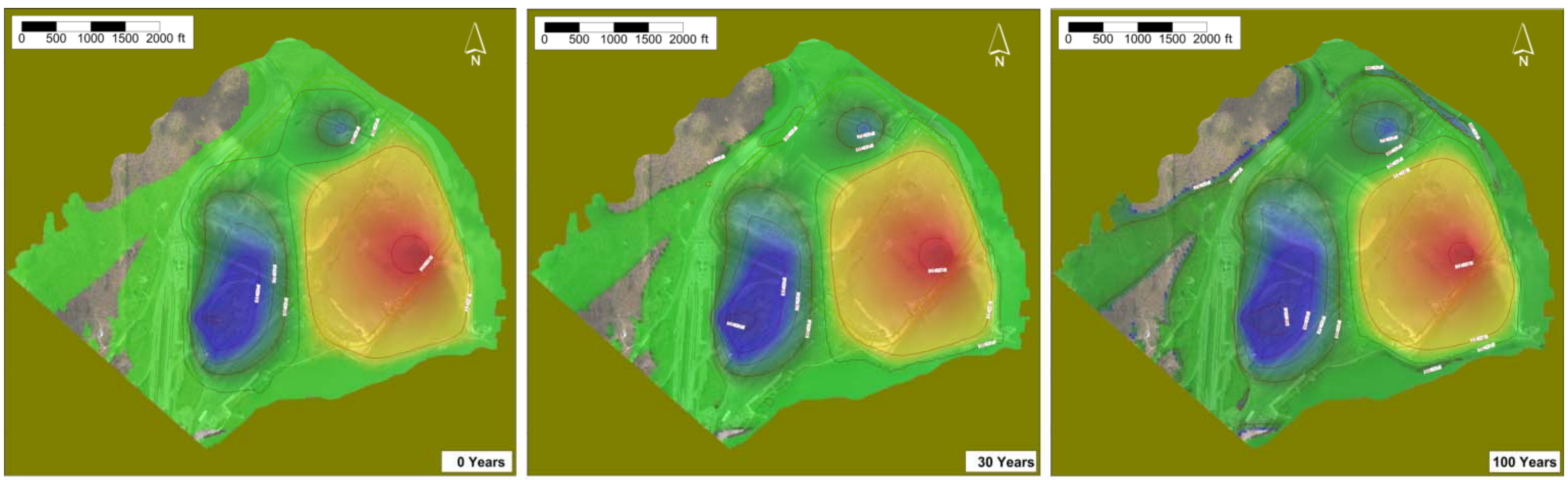
	Swan Pond Creek		Emory River		Intake Channel		Ash Kd (L/kg)
	30-Year	100-Year	30-Year	100-Year	30-Year	100-Year	
Minimum Concentration (ug/L)	0.37	0.38	0.31	0.22	0.40	0.30	61.6
Maximum Concentration (ug/L)	2.10	13.49	0.81	1.27	31.01	31.43	
Average Concentration (ug/L)	0.45	0.52	0.45	0.45	0.96	0.97	
Segment Mass Flux (gram/d)	0.028	0.072	0.026	0.026	0.099	0.105	
	30-Year	100-Year	30-Year	100-Year	30-Year	100-Year	
Minimum Concentration (ug/L)	0.37	0.38	0.31	0.22	0.40	0.30	100
Maximum Concentration (ug/L)	2.06	13.47	0.81	0.92	31.00	31.43	
Average Concentration (ug/L)	0.45	0.52	0.45	0.45	0.96	0.97	
Segment Mass Flux (gram/d)	0.028	0.072	0.026	0.025	0.099	0.105	
	30-Year	100-Year	30-Year	100-Year	30-Year	100-Year	
Minimum Concentration (ug/L)	0.37	0.38	0.31	0.22	0.40	0.29	180
Maximum Concentration (ug/L)	2.04	13.41	0.81	0.82	30.99	31.43	
Average Concentration (ug/L)	0.45	0.52	0.45	0.45	0.96	0.97	
Segment Mass Flux (gram/d)	0.028	0.071	0.026	0.025	0.099	0.105	

							Kd (L/kg)
Segment Mass Flux (gram/d)	2.794E-02	7.201E-02	2.558E-02	2.568E-02	9.909E-02	1.051E-01	61.6
Segment Mass Flux (gram/d)	2.783E-02	7.177E-02	2.558E-02	2.541E-02	9.905E-02	1.051E-01	100
Segment Mass Flux (gram/d)	2.777E-02	7.138E-02	2.559E-02	2.522E-02	9.900E-02	1.052E-01	180

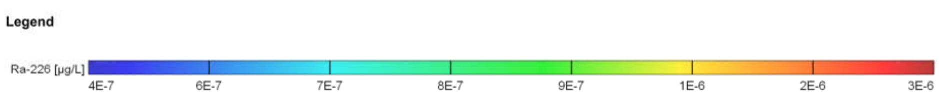


Selenium (in Ash)





Ra-226 (in Ash)



Modeled Results and Conclusions

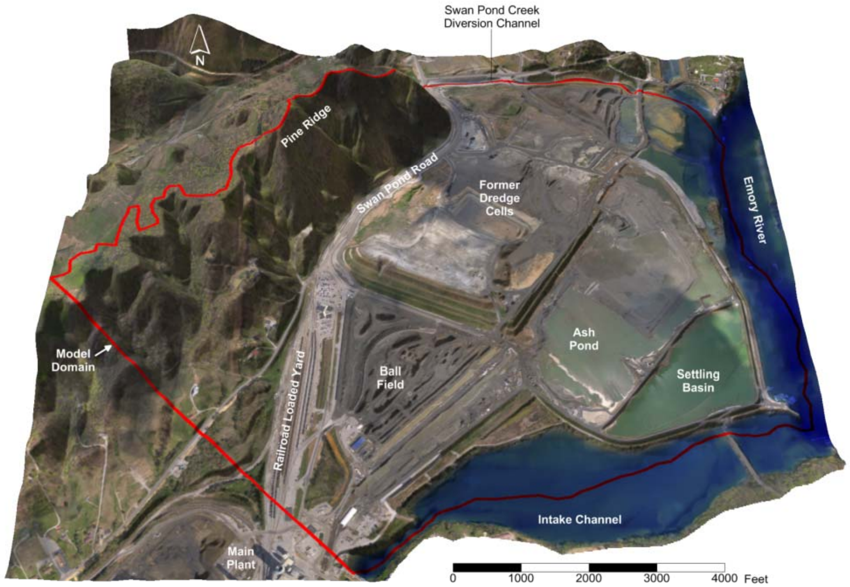
Using the assumptions and model parameters, the fate-transport of the COCs from the proposed Ash Landfill were predicted.

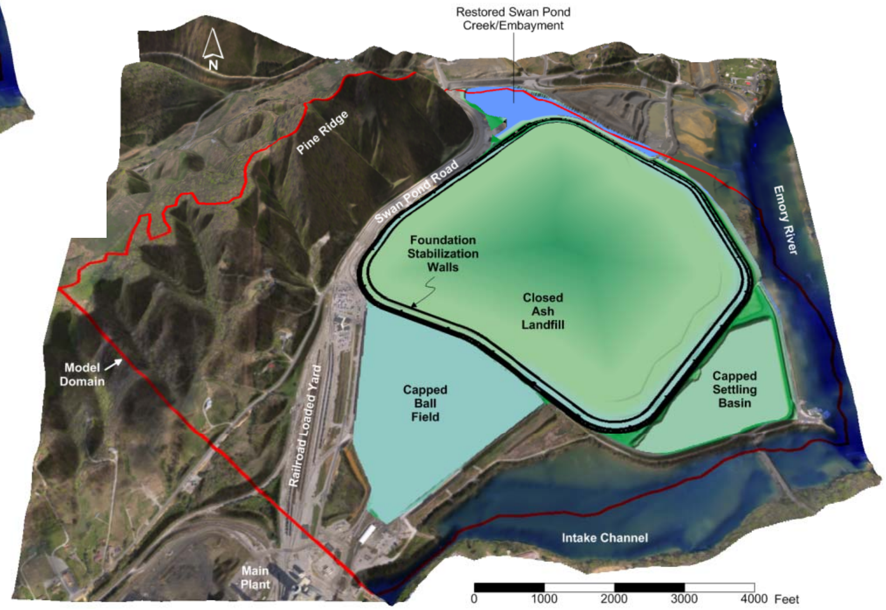
- **The predicted spatial distributions of arsenic over time exhibit little differences other than minor increases in arsenic concentrations laterally from the ash toward downgradient surface water boundaries. The mass fluxes discharging to the river only show minimal change over time.**

- **The spatial distributions of selenium and mass fluxes discharging to the river over time exhibit little differences.**

- **The distributions of radium-226 and mass fluxes discharging to the river over time also exhibit little differences.**

Questions ?





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