Tennessee Valley Authority Kingston Fossil Plant Harriman, Roane County, Tennessee	**Perimeter Containment** **North Dredge Cell (Dike C) Segment 1** **Sta. A161+50 to A179+50**

Document Control Number	RDP-0113-E
Calculation Package	FPGKIFFESCDX00030020100006

Stantec

Exhibit 5
Long-Term Groundwater Levels

Purpose:

- Predict the equilibrium phreatic surface elevation within the landfill a long time after final closure.
- Results will be used to compute static pore water pressures for subsequent stability analyses.

Methods:

- 3D finite difference solution for groundwater seepage, accomplished using MODFLOW.
- Analyses included parametric variation studies on key input parameters.

Results:

- Predicted, long-term phreatic surface elevation within the closed dredge cell and ash pond, at locations across the site.

Calculation Performed by: Jacobs Engineering	
Prepared by:	*Reviewed by:*
Revisions:	

Variables for 3-D Groundwater Parametric Study

Material Name	Variables	Provided by Stantec [1]			Used by Jacobs [2]		
		Best Estimate	Max.	Min.	Best Estimate	Max.	Min.
Landfilled Ash	k_v (cm/sec)	5.00E-06	1.00E-05	1.00E-06	2.00E-05	1.00E-04	5.00E-06
	k_h/k_v Ratio	10	25	2	3	10	1
Sluiced Ash	k_v (cm/sec)	5.00E-05	1.00E-04	1.00E-05	2.00E-05	1.00E-04	5.00E-06
	k_h/k_v Ratio	20	50	1	3	10	1
Alluvial Clay	k_v (cm/sec)	1.00E-07	1.00E-06	1.00E-08	1.00E-07	1.00E-06	1.00E-08
	k_h/k_v Ratio	10	20	1	10	20	1
Alluvial Silt/Sand	k_v (cm/sec)	5.00E-06	1.00E-05	1.00E-06	5.00E-06	5.00E-05	1.00E-06
	k_h/k_v Ratio	20	50	2	3	10	1
Shale	k_v (cm/sec)	5.00E-07	1.00E-06	1.00E-07	5.00E-07	1.00E-06	1.00E-07
	k_h/k_v Ratio	5	10	2	3	10	1
Soilcrete - Ash	k_v (cm/sec)	5.00E-06	1.00E-05	1.00E-06	5.00E-06	1.00E-05	1.00E-06
	k_h/k_v Ratio	1	1	1	1	1	1
Soilcrete - Clay	k_v (cm/sec)	2.00E-08	1.00E-07	5.00E-09	2.00E-08	1.00E-07	5.00E-09
	k_h/k_v Ratio	1	1	1	1	1	1
Soilcrete - Silt/Sand	k_v (cm/sec)	1.00E-07	1.00E-06	5.00E-08	1.00E-07	1.00E-06	5.00E-08
	k_h/k_v Ratio	1	1	1	1	1	1
Infiltration Rate[3] (in./yr)		0.372	1.41	0.146	0.372	1.41	0.146

Notes: 1 - Parameters based on "Report of Geotechnical Exploration and Slope Stability for Dike C" (Stantec, Aug 2009)
Parameters for soilcrete based on bench tests by RECON for 2010 field demonstration test
2 - Revised parameter estimates used in the MODFLOW analyses
3 - Infiltration rates from HELP model predictions

CALCULATION COVER SHEET & ATTACHMENT

CALCULATION NO:	SUPERSEDES:	REV. NO.:	REV. DATE:
GW-001		0	01-26-11
CALCULATION TITLE: **Groundwater Flow Model Development and Modeling Analyses for the Proposed Dredge Cell Design at the TVA Kingston Fossil Plant Site, Tennessee**		PREVIOUS REV. NO:	PREVIOUS REV. DATE:

SYSTEM OR AREA:	Groundwater Model and Hydrogeologic Analysis
CALCULATION TITLE:	Groundwater Flow Model Development and Modeling Analyses for the Proposed Dredge Cell Design at the TVA Kingston Fossil Plant Site, Tennessee

PURPOSE / DESCRIPTION OF CALCULATION:

A groundwater flow model was constructed for the proposed Ash disposal Cell based on the proposed design parameters.

The primary purpose of the modeling analysis based on constructed model was to predict the groundwater conditions within the planned ash disposal cells. Specifically, the model were used to evaluate the following aspects of designs:

- Landfill cover design – clay cover vs. FML cover
- Stability wall impact on the water levels
- Wall design parameter variations
- Various design along the Stilling Pond on the water levels

PREPARED BY: Changsheng Lu DATE: 12/13/2010

CHECKED BY: [signature] DATE: 1/24/2011

ENGINEERING MANAGERS APPROVAL: [signature] DATE: 01/26/2011

CALCULATION HISTORY (INCLUDING REVISIONS):

PAGES AFFECTED BY REVISION	REVISED / ADDED / DELETED	DESCRIPTION OF REVISION

ASSUMPTIONS:

- Cell design and extent were provided by designer (Stantec) and based on the best estimate at the time (September 2010).
- Fixed boundary condition around the cell based on conservative groundwater head values (high river stage along the river and surface ditch elevation along the railroad) were used.
- Recharge rate was based on HELP model simulation according to design.
- Steady state (long-term) condition was conducted.

DESIGN INPUTS:

- Wall design, properties, and locations were provided by designer (Stantec)

SOFTWARE:

TITLE	DEVELOPER	VERSIONS	REVISION LEVEL
MODFLOW	USGS (McDonald, M. G. and Harbaugh, W)	MODFLOW-96	

CALCULATION SECTION:

A three-dimensional groundwater flow model was developed. MODFLOW (McDonald and Harbaugh 1988) model code was used to evaluate the hydrogeologic conditions and parameters in the proposed dredging cell.

MODFLOW is a modular, block-centered finite-difference groundwater flow code developed by the USGS. MODFLOW is capable of simulating both transient and steady-state saturated groundwater flow in one, two, or three dimensions. MODFLOW calculates potentiometric head distribution, flow rates, velocities, and water balances throughout an aquifer system. It also includes modules simulating recharge, flow towards wells, and groundwater into and drains and rivers. A number of different boundary conditions are available, including specified head, areal recharge, injection or extraction wells, evapotranspiration, drains, and streams or rivers. Aquifers can be simulated as unconfined, confined, or a combination of unconfined and confined. The finite-difference equations may be solved using many solutions, such as strongly implicit procedure (SIP), slice-successive

over-relaxation (SSOR), or preconditioned conjugate gradient (PCG) method.

MODFLOW was used for the analysis because it is in the public domain, is widely used by the industrial, scientific, and governmental communities, has been rigorously tested and verified, and a variety of software tools are publicly available for graphical preprocessing and post processing.

MODEL DISCRETIZATION

A couple versions of the models were developed during the model development. The final version of model used to conduct analysis cover the area if proposed dredge cell (see attachment #2). A uniform grid size of 10 feet x 10 feet was used for the model domain.

The model has 4 model layers. The top of the model Layer 1 reflects the existing topography (May 2010). The model layers represent the ash, alluvial clay, alluvial sand, and bedrock, respectively. The layer elevations were based on lithologic analysis based on site-specific boring logs. The model layers have variable thickness.

There are a total of 891,000 cells in the Model; 553,500 of the cells are active. Attachment #2 provides a summary for the model discretization information.

BOUNDARY CONDITIONS

The model has a no-flow boundary at the bottom of the bedrock and constant head boundary conditions around the four sides. The constant head condition was assumed for the Pine Ridge side and Plant side. For conservatism, bottom elevations of the surface ditches were used to define the highest possible groundwater levels (head). Along the river, The highest river level (742 ft-msl) was assumed.

Precipitation is the sole source of groundwater recharge for the model domain. Groundwater recharge is a function of precipitation, runoff, and evapotranspiration. Based on HELP model simulation fro the proposed FML cover design by Stantec, a 0.372 inch per year was used for base analysis.

HYDRAULIC CONDUCTIVITY FIELD

Four distinct hydraulic conductivity zones were used in the model to represent the materials presented in the site; ash, alluvial clay, alluvial sand, and bedrock unit. The hydraulic conductivity values and its distribution are presented in the table in Attachment #2.

ENGINEERING DESIGN FEATURE (WALLS)

Proposed stability walls were based on the design parameters provided by designer (Stantec). The walls were represented in the model by the wall package of the MIODFLOW. The wall thickness and its hydraulic property were also presented in the model.

MODEL ANALYSES AND RESULTS

After development of the model, the model was used to conducted the following four analyses:

1. Landfill cover design – clay cover vs. FML cover
2. Stability wall impact on the water levels

3. Wall design parameter variations
4. Various design along the Stilling Pond on the water levels

CONCLUSIONS / RECOMMENDATIONS:

Results of these analyses were presented in the four attachments of the report.

Attachment #1 shows the earlier model that was used to evaluate the landfill cover design and its results.

Attachment #2 summarizes the final flow model that was used for conducting detailed analysis of the proposed wall design. Extensive sensitivity analyses were conducted as shown the attachments.

Attachment #3 shows the results of wall designed parameter variations in term of wall thickness.

Attachment #4 shows the modeling results of impact from various trench designs between proposed ash cell and stilling pond.

REFERENCE:

McDonald, M. G. and Harbaugh, W., 1988. A modular Three-Dimensional Finite-Difference Groundwater Flow Model. Book 6, Modeling Techniques, Chapter A1, U.S. Geological Survey, Reston, Virginia

Schroeder, P. R., Dozier, T.S., Zappi, P. A., McEnroe, B. M., Sjostrom, J. W., and Peyton, R. L. 1994. The Hydrologic Evaluation of Landfill Performance (HELP) Model: Engineering Documentation for Version 3, EPA/600/R-94/168b, September 1994, U.S. Environmental Protection Agency Office of Research and Development, Washington, DC.

Attachments:

Model Summary and Results (previous presented and delivered files):

1. A1--GW modeling analysis on KIF landfill cover design.pdf (PDF)
2. A2--GW modeling analysis on KIF landfill design.pdf (PDF)
3. A3--GW modeling result- wall thickness effect.pdf (PDF)
4. A4--GW modeling result- stilling pond trench design analysis.pdf (PDF)

Groundwater Modeling Analyses on the Proposed KIF Landfill Design

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Analysis Objectives

A groundwater modeling analysis was conducted to evaluate the proposed KIF landfill design.

The purpose of the study is to predict the water levels within the landfill (with constructed stability walls) for two covered conditions.

To assist the analysis, a 3-D groundwater flow model for the planned landfill area was constructed.

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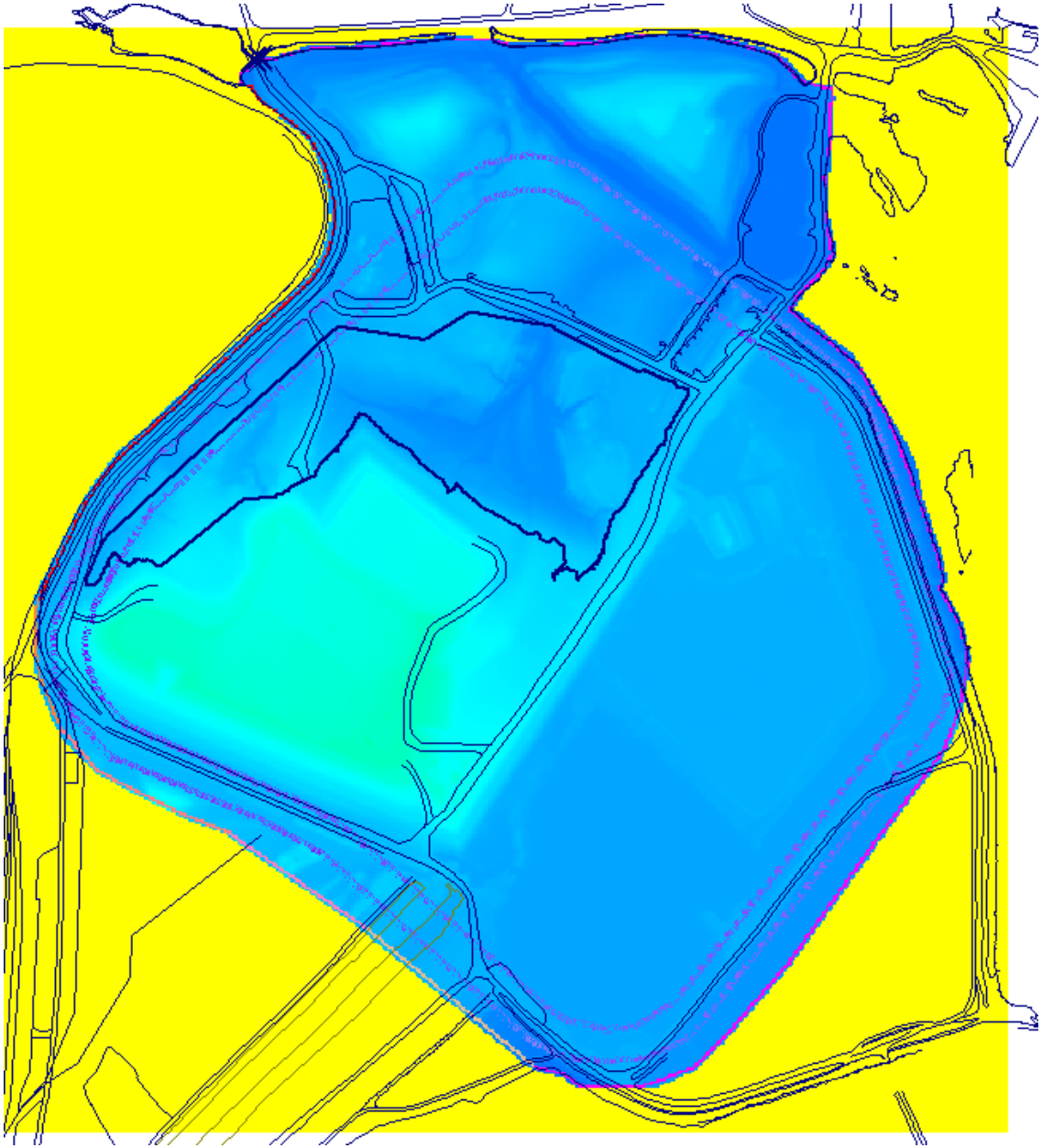
Model Information



Model Domain

(yellow area represents Inactive model cells)

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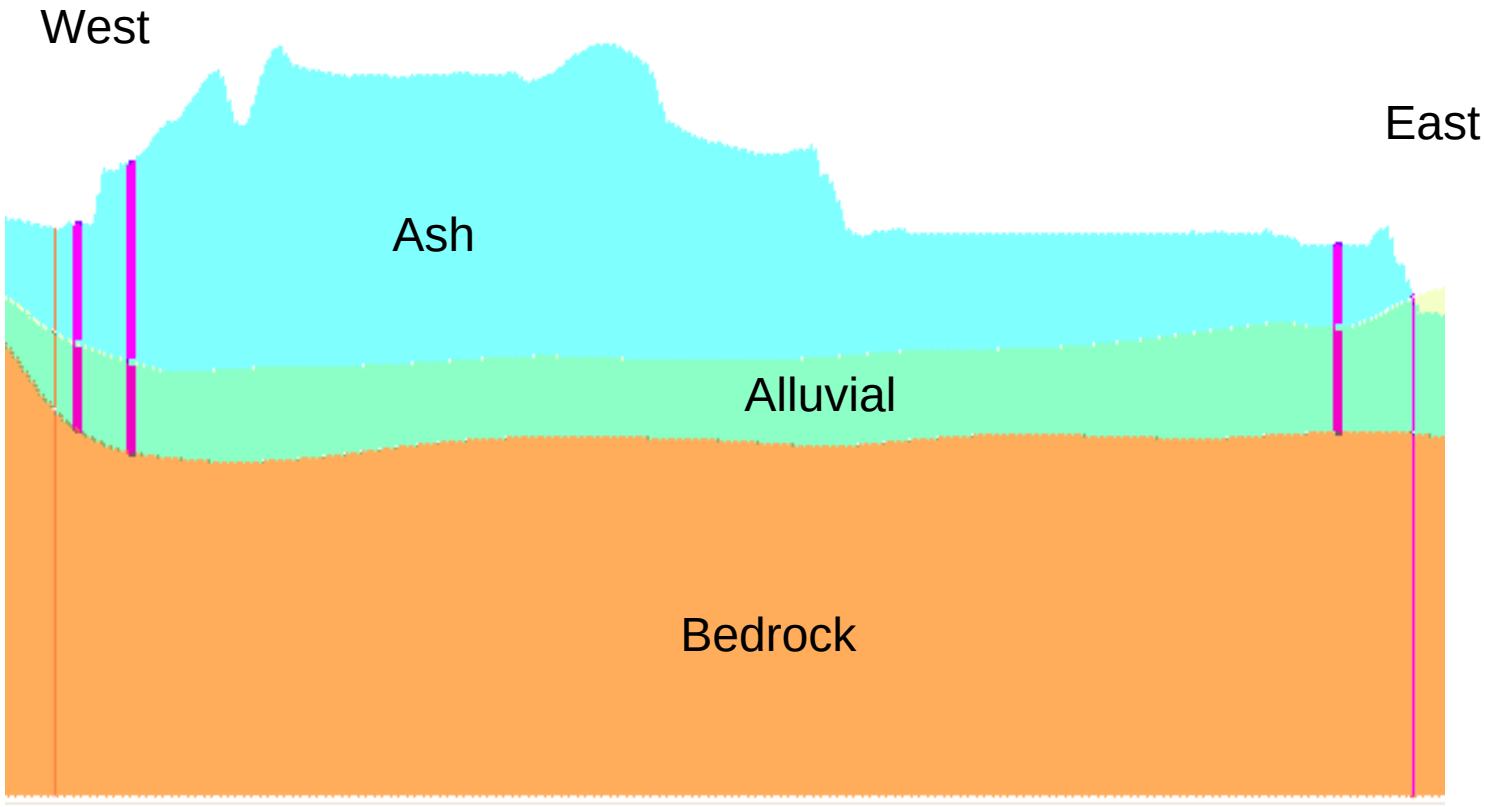
Model Information

Sub-surfaces are based on site-specific lithology analysis.

Model Vertical Layers



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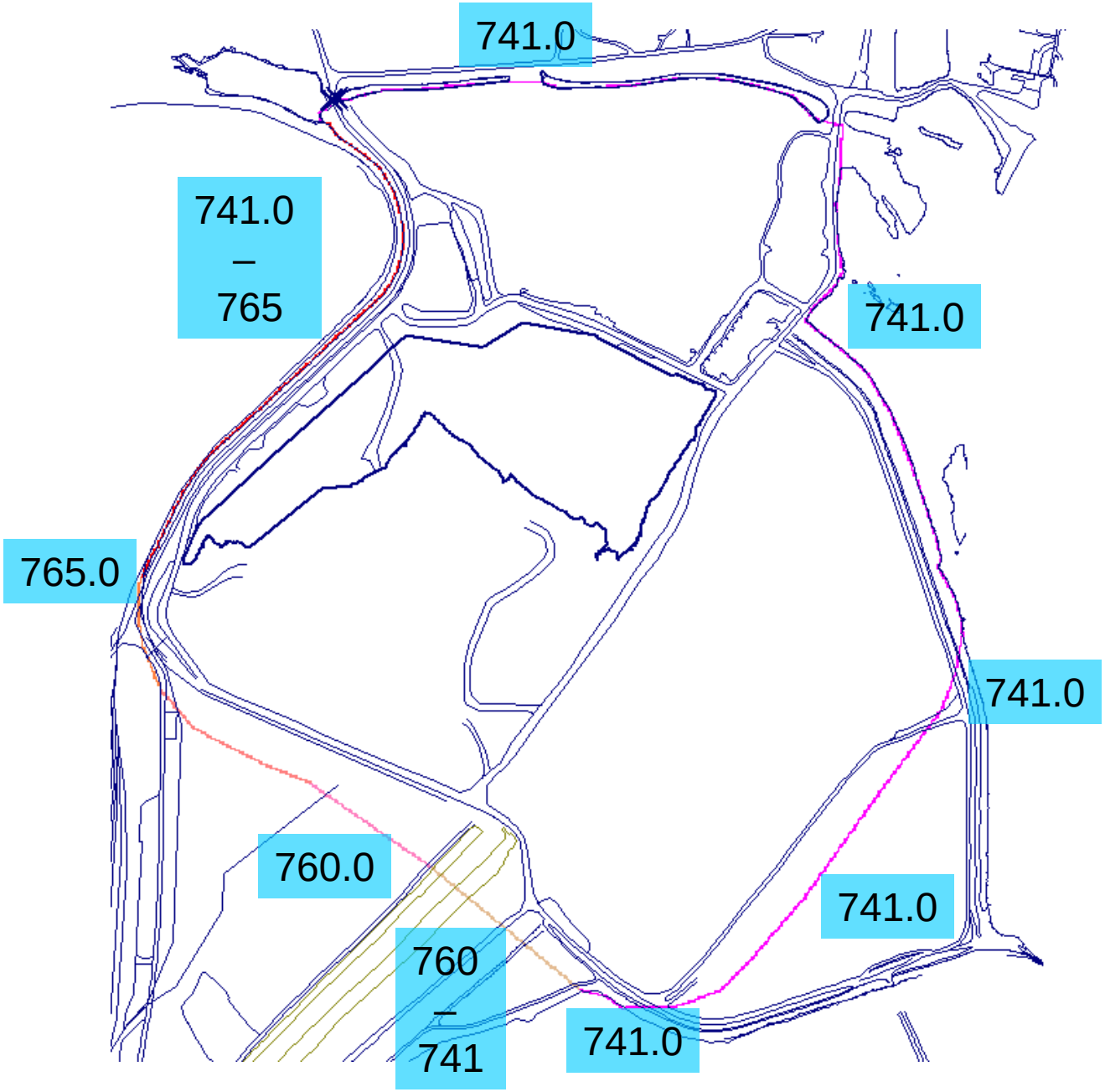
Model Information



Model Boundary Condition

(Constant Head)

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Model Information

Hydraulic Conductivities Summary of the KIF Site
(For bedrock, Oak Ridge data were also used)

	in cm/s	geomean	median	average	maximum	minimum	count
Fly Ash	Kh	5.35E-05	4.76E-05	1.41E-04	1.39E-03	3.70E-06	32
	Kv	3.82E-05	3.24E-05	1.03E-04	8.02E-04	3.60E-06	28
Bottom Ash	Kh	9.99E-05	1.19E-04	2.60E-04	1.39E-03	1.14E-05	8
	Kv	**9.30E-03**	**9.30E-03**	**9.30E-03**	**9.30E-03**	**9.30E-03**	**1**
Alluvial	Kh	2.83E-06	4.55E-06	1.85E-05	1.30E-04	6.60E-08	14
	Kv	4.00E-07	4.00E-07	1.21E-06	6.10E-06	4.40E-08	11
Bedrock	Kh	2.19E-05	4.06E-05	1.89E-04	2.50E-03	3.18E-09	163
	Kv						
Ash (combined)	Kh	6.06E-05	5.74E-05	1.65E-04	1.39E-03	3.70E-06	40
	Kv	3.82E-05	3.24E-05	1.03E-04	8.02E-04	3.60E-06	28
Wall		5.00E-06					

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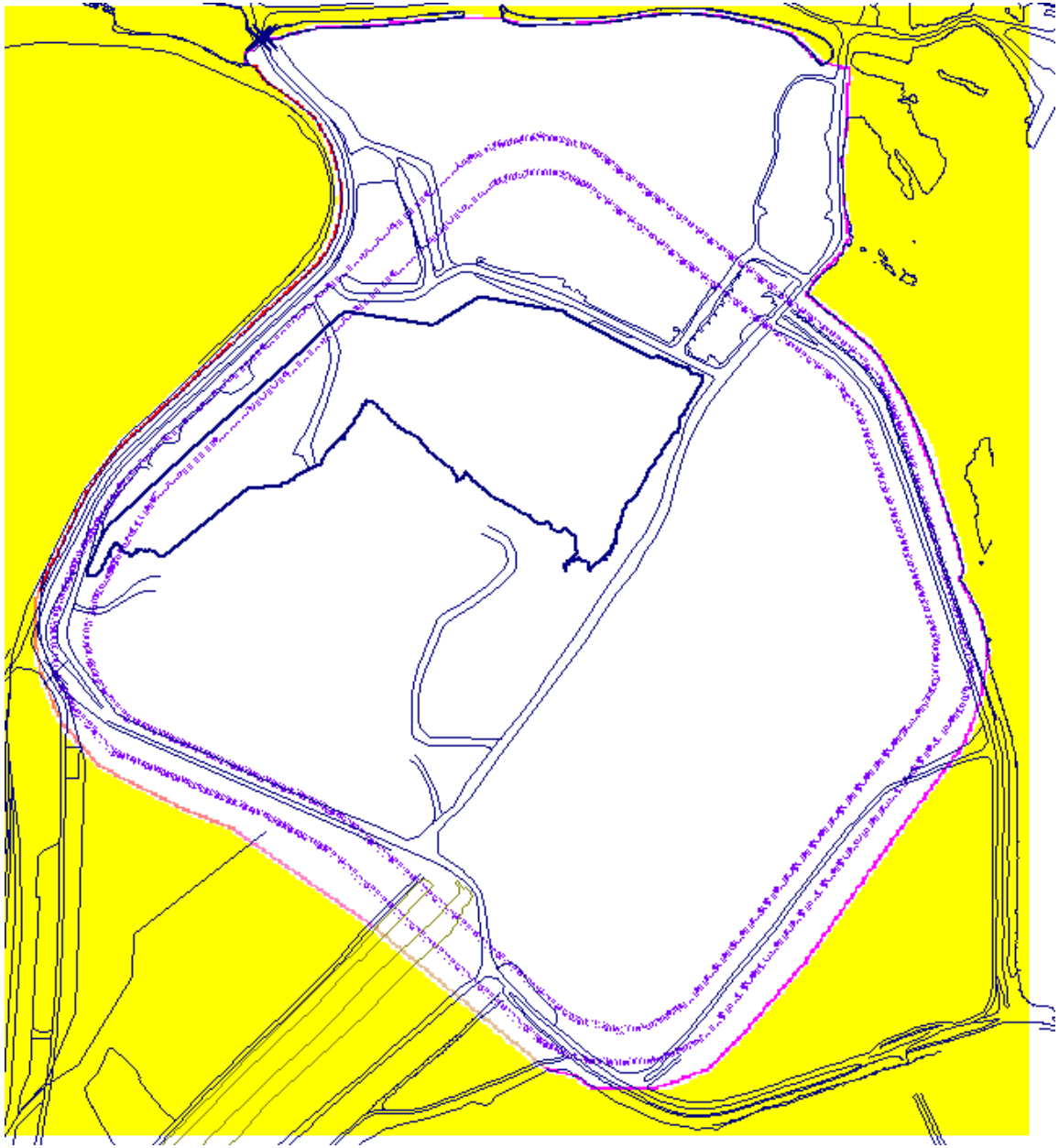
Model Information



Wall representation

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Model Information

Model Summary

Grid

Rows	495
Columns	450
Layers	3
Total Cells	668250
Active Cells	404323

Coordinate Transformation

X Offset	2438500
Y Offset	553500
Rotation	0

Boundary Conditions

Constant Heads	5620
Wells	0
Rivers	0
Drains	0
GHBs	0
Streams	0
Walls	6392
Lakes	0
Wetlands	0
No Flow	263927
FHB	0

Target Types

Head	0
Head Difference	0
Drawdown	0
Concentration	0
Flux (node)	0
Flux (reach)	0
Prior Information	0
Constraints	0
Kx Pilot Point	0
Kz Pilot Point	0

Grid Spacings

	Minimum	Maximum
Rows (Delta-Y)	10	10
Columns (Delta-X)	10	10

Original File from GV Version 5: gv551

Analytic Elements

Wells	0
Line Boundaries	0
Circle Boundaries	0
Polylines	0
Polygons	0

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Model Assumptions

Constant head conditions for the Pine Ridge side and Plant side (for conservatism, bottom of the surface ditch will be used to define the head) and surface water bodies.

741 ft-msl surface water level is used at the Emory River, Pond, and Creek.

Two recharge (infiltration) rate through the cap (for the two cover design) were modeled.

Wall will have provided K (permeability) value and the Walls will be keyed to the (fresh) bedrock.

The landfill will have the profile of (from bottom up) Bedrock, Alluvial Sand/clay/silt, and Ash.

The general geometry of the these surfaces will be determined with available litho data analysis

The model is to predict the long-term water levels for the two cover designs - no model calibration will be conducted. But some sensitivity runs may be conducted for some of the parameters (recharge rate, aquifer materail hydraulic conductivities, and wall permeability)

A proper wall/cover construction sequence is assumed that there will not be extremely high water level in the landfill before landfill is closed.

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Model Analyses

All flow simulations were conducted used MODFLOW code.

Walls were modeled in two ways:

One is modeled as lower hydraulic conductivity zone (wall) and another way is as a Wall package in the MODFLOW simulation.

As shown later, the two methods yielded almost same results. Mathematically, they are treated almost same in the model.

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Model Simulation Summary

Modeling Run #	Recharge (in/y)	Ash			Alluvial			Bedrock			Walls		
		Kh	Kv	Kh/Kv	Kh	Kv	Kh/Kv	Kh	Kv	Kh/Kv	Kh	Kv	Kh/Kv
kif-sm-1	1.41	5.35E-05	3.82E-05	1.4	2.83E-06	1.42E-06	2.0	2.19E-05	2.19E-06	10.0	5.00E-06	5.00E-06	1.0
kif-sm-2	0.146	5.35E-05	3.82E-05	1.4	2.83E-06	1.42E-06	2.0	2.19E-05	2.19E-06	10.0	5.00E-06	5.00E-06	1.0
		Zone-1			Zone-2			Zone-3			Zone-4		
kif-sm-1a	1.41	5.35E-05	3.82E-05	1.4	2.83E-06	1.42E-06	2.0	2.19E-05	*1.10E-05*	*2.0*	5.00E-06	5.00E-06	1.0
kif-sm-2a	0.146	5.35E-05	3.82E-05	1.4	2.83E-06	1.42E-06	2.0	2.19E-05	*1.10E-05*	*2.0*	5.00E-06	5.00E-06	1.0
		Zone-1			Zone-2			Zone-5			Zone-4		
kif-sm-1b	1.41	5.35E-05	3.82E-05	1.4	*1.00E-05*	*5.00E-06*	2.0	2.19E-05	1.10E-05	2.0	5.00E-06	5.00E-06	1.0
kif-sm-2b	0.146	5.35E-05	3.82E-05	1.4	*1.00E-05*	*5.00E-06*	2.0	2.19E-05	1.10E-05	2.0	5.00E-06	5.00E-06	1.0
		Zone-1			Zone-6			Zone-5			Zone-4		
kif-sm-3b	*0.292*	5.35E-05	3.82E-05	1.4	*1.00E-05*	*5.00E-06*	2.0	2.19E-05	1.10E-05	2.0	5.00E-06	5.00E-06	1.0
		Zone-1			Zone-6			Zone-5			Zone-4		
kif-sm-4b	*0.584*	5.35E-05	3.82E-05	1.4	*1.00E-05*	*5.00E-06*	2.0	2.19E-05	1.10E-05	2.0	5.00E-06	5.00E-06	1.0
		Zone-1			Zone-6			Zone-5			Zone-4		
kif-sm-1c	1.41	5.35E-05	3.82E-05	1.4	*1.00E-05*	*5.00E-06*	2.0	2.19E-05	1.10E-05	2.0	*1.00E-05*	*1.00E-05*	1.0
		Zone-1			Zone-6			Zone-5			Zone-7		
kif-sm-1d	1.41	5.35E-05	3.82E-05	1.4	*1.00E-05*	*5.00E-06*	2.0	2.19E-05	1.10E-05	2.0	*NA*	*NA*	
		Zone-1			Zone-6			Zone-5			Zone-1 & 6		
kif-sm-w-1b	1.41	5.35E-05	3.82E-05	1.4	*1.00E-05*	*5.00E-06*	2.0	2.19E-05	1.10E-05	2.0	5.00E-06	5.00E-06	1.0
kif-sm-w-2b	0.146	5.35E-05	3.82E-05	1.4	*1.00E-05*	*5.00E-06*	2.0	2.19E-05	1.10E-05	2.0	5.00E-06	5.00E-06	1.0
		Zone-1			Zone-6			Zone-5			Wall		

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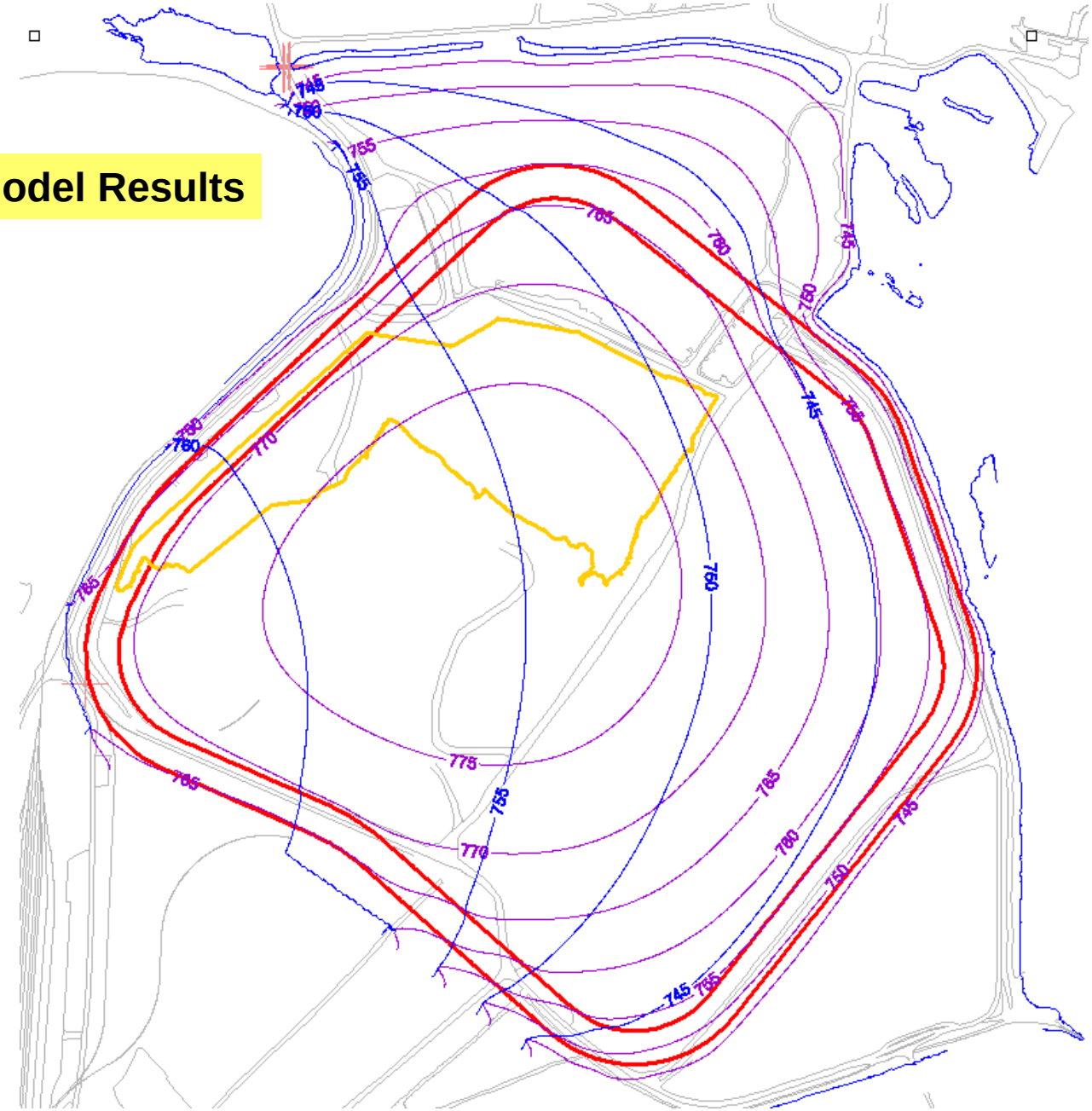
Model Results



Two initial runs

<u>Kif-sm-1</u> (purple – clay cover)

<u>Kif-sm-2</u> (blue – with FM liner)

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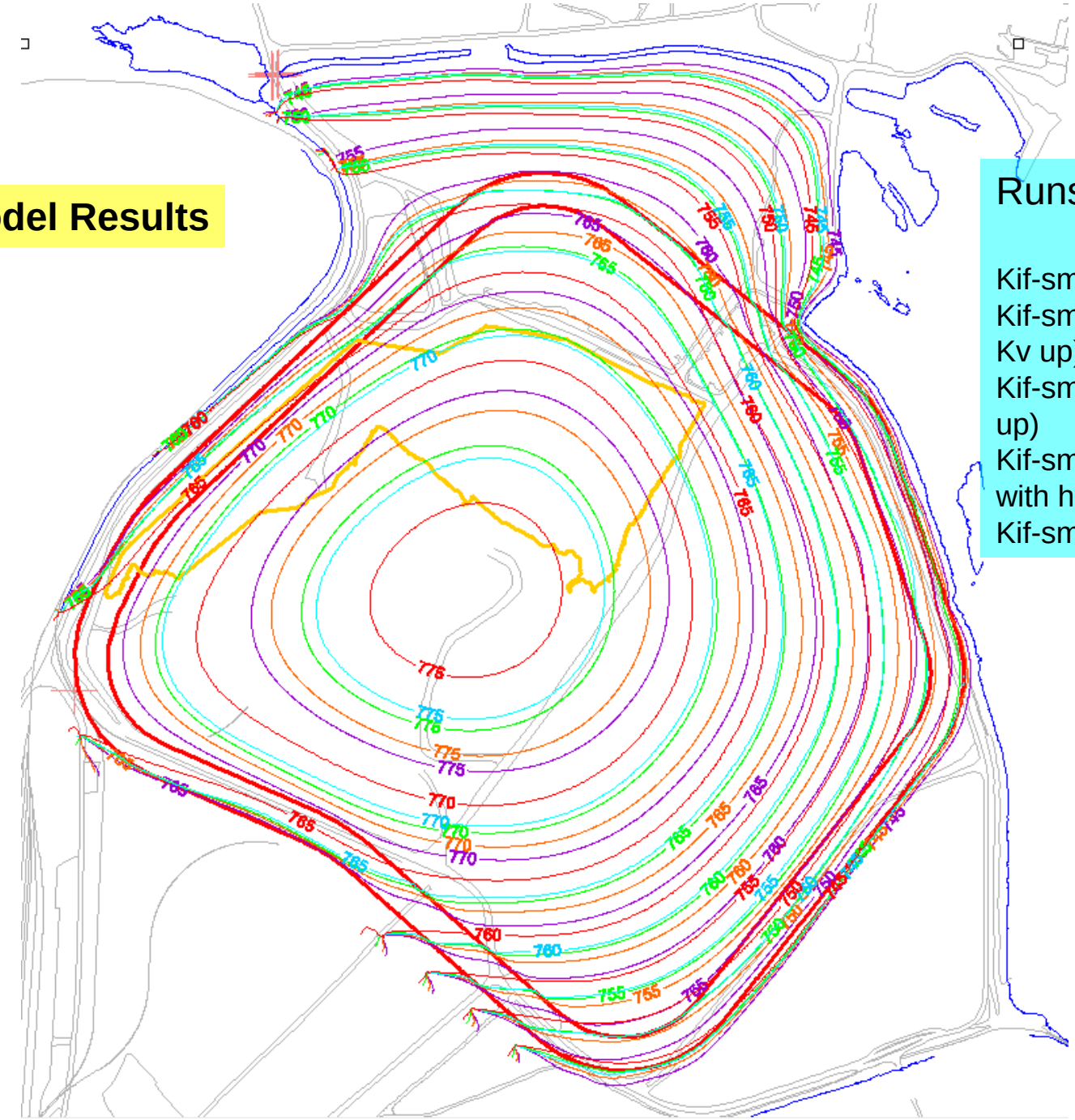
Model Results



Runs with Clay Cover

Kif-sm-1 [purple]
Kif-sm-1a [orange] --(bedrock Kv up)
Kif-sm-1b [green] --(alluvial K up)
Kif-sm-1c [light blue] --(wall with higher K)
Kif-sm-1d [red] --(no walls)

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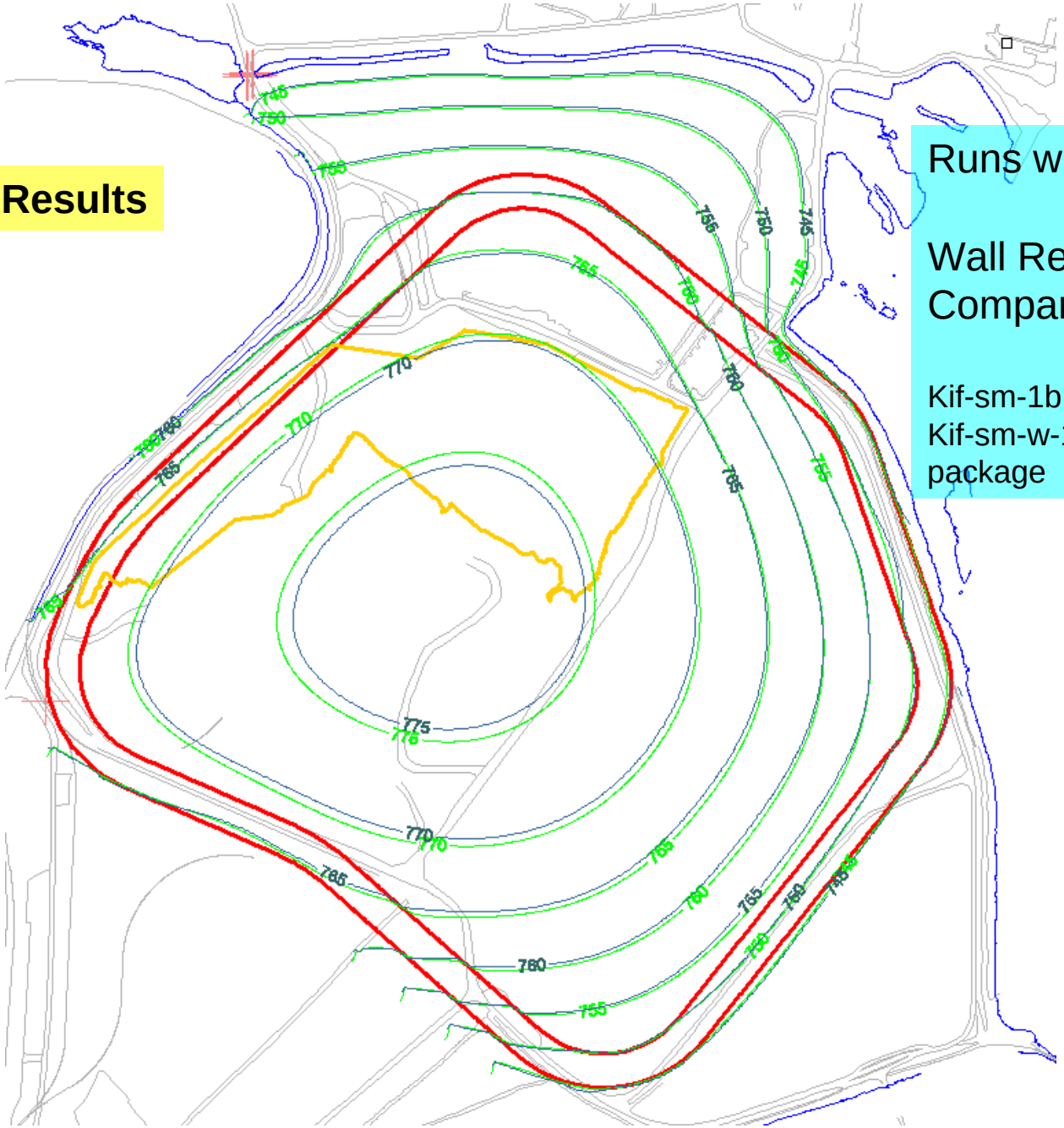
Model Results



Runs with Clay Cover

Wall Representation Comparison

Kif-sm-1b [green] – K zone
Kif-sm-w-1b [blue] – wall package

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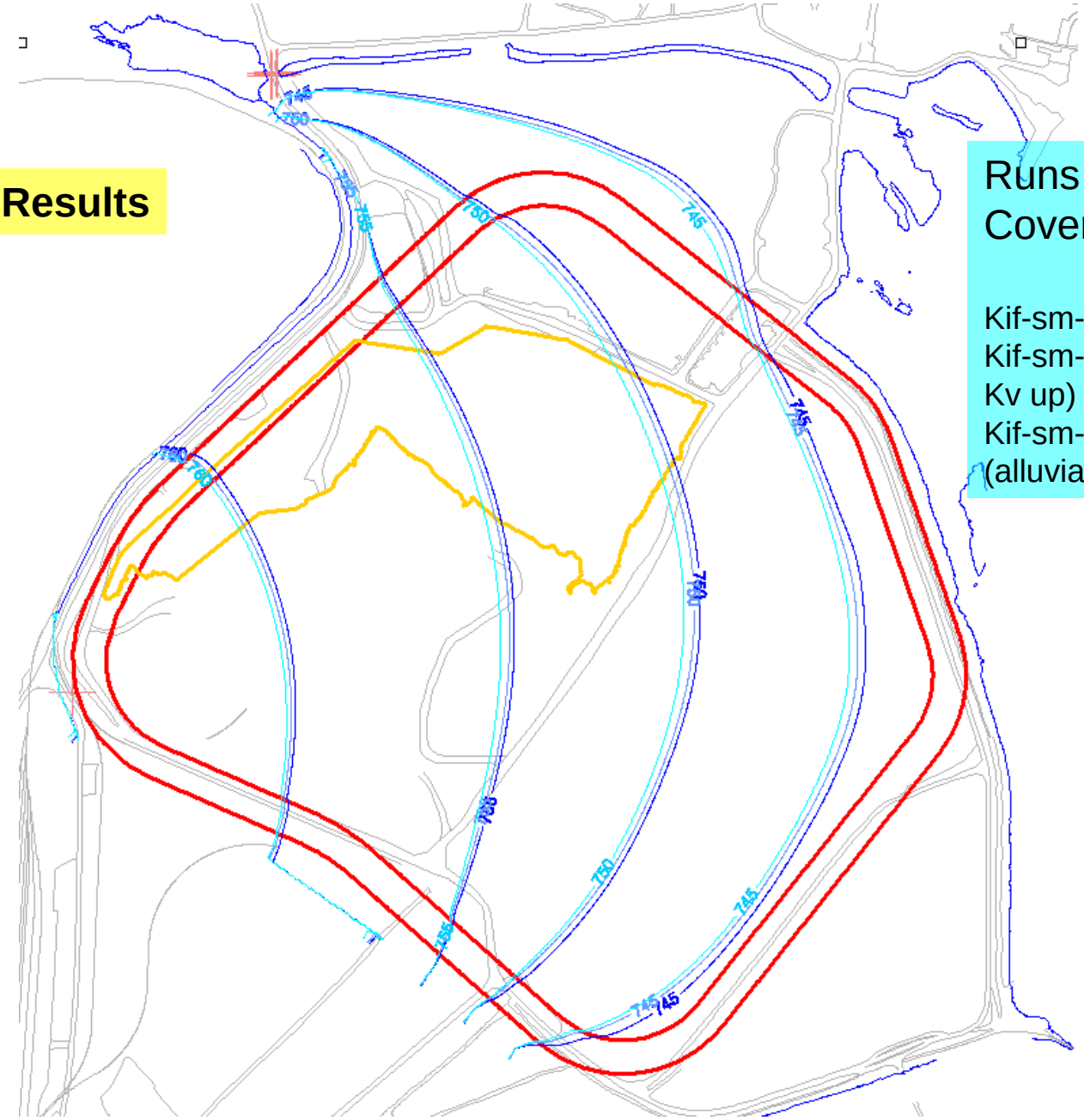
Model Results



Runs with FM liner Cover

Kif-sm-2 [dark blue]
Kif-sm-2a [blue] --(bedrock Kv up)
Kif-sm-2b [light blue] --(alluvial K up)

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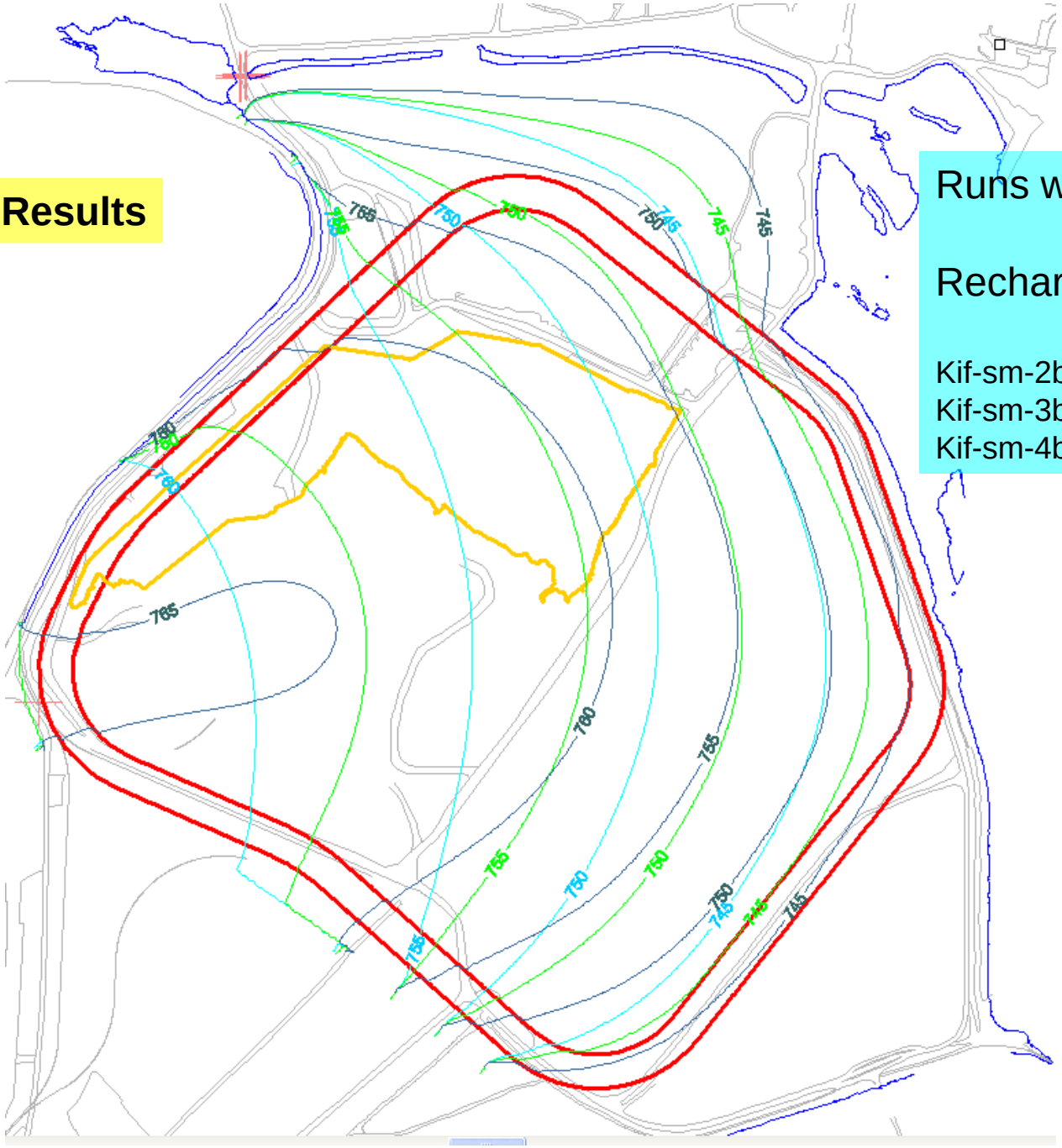
Model Results



Runs with FM liner Cover

Recharge Rate Change

Kif-sm-2b [light blue] -0.146 in/y
Kif-sm-3b [green] – 0.293 in/y
Kif-sm-4b [blue] – 0.586 in/y

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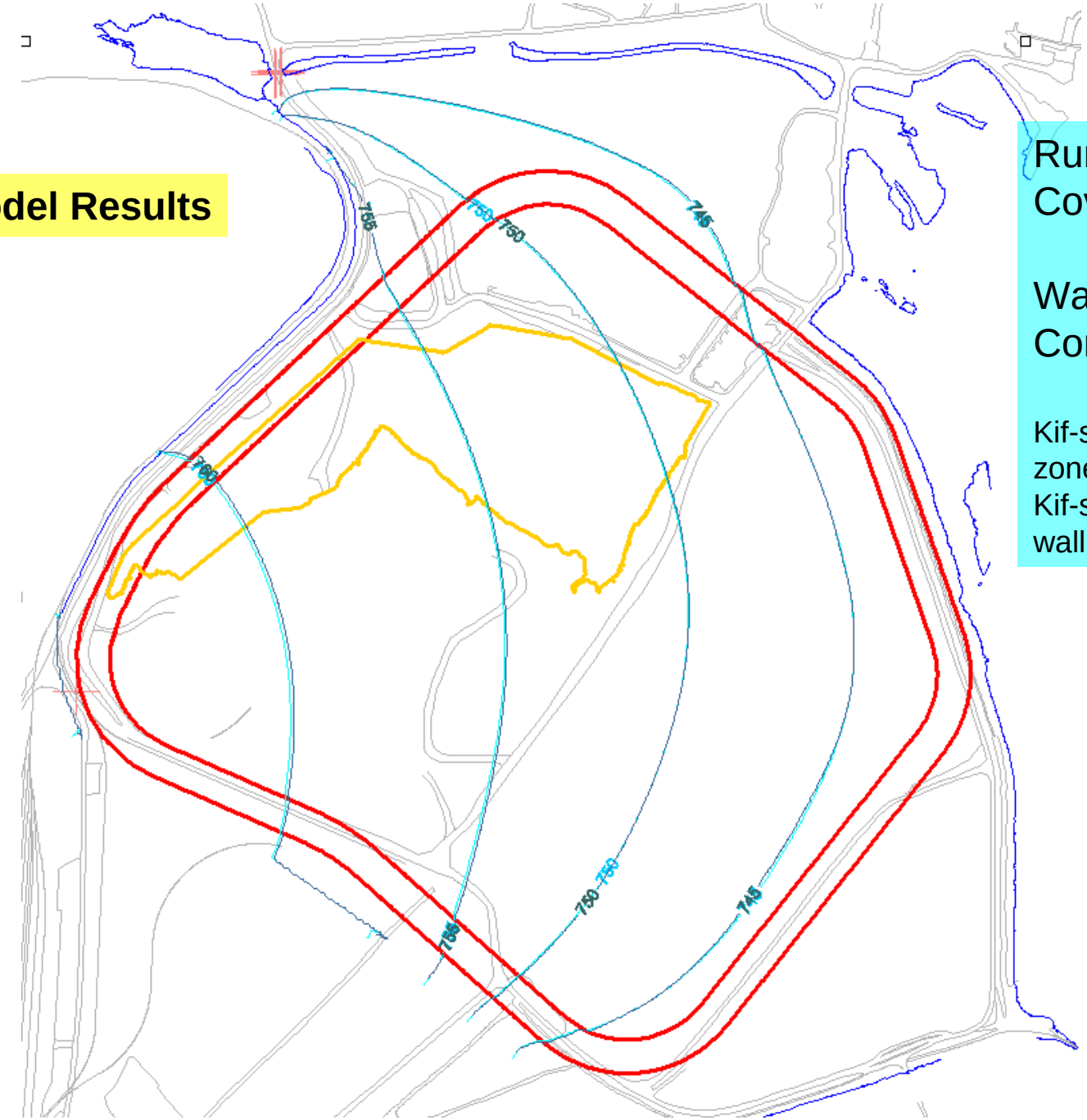
Model Results



Runs with FM liner Cover

Wall Representation Comparison

Kif-sm-2b [light blue] – K zone
Kif-sm-w-2b [dark blue] – wall package

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Groundwater Modeling Analyses on the Proposed KIF Landfill Design

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Modeling Run #	Recharge (in/y)	Ash			Alluvial			Bedrock			Walls			Note
		Kh	Kv	Kh/Kv	Kh	Kv	Kh/Kv	Kh	Kv	Kh/Kv	Kh	Kv	Kh/Kv	
kif-sm-1	1.41	5.35E-05	3.82E-05	1.4	2.83E-06	1.42E-06	2.0	2.19E-05	2.19E-06	10.0	5.00E-06	5.00E-06	1.0	
kif-sm-2	0.146	5.35E-05	3.82E-05	1.4	2.83E-06	1.42E-06	2.0	2.19E-05	2.19E-06	10.0	5.00E-06	5.00E-06	1.0	
		Zone-1			Zone-2			Zone-3			Zone-4			
kif-sm-1a	1.41	5.35E-05	3.82E-05	1.4	2.83E-06	1.42E-06	2.0	2.19E-05	*1.10E-05*	*2.0*	5.00E-06	5.00E-06	1.0	
kif-sm-2a	0.146	5.35E-05	3.82E-05	1.4	2.83E-06	1.42E-06	2.0	2.19E-05	*1.10E-05*	*2.0*	5.00E-06	5.00E-06	1.0	
		Zone-1			Zone-2			Zone-5			Zone-4			
kif-sm-1b	1.41	5.35E-05	3.82E-05	1.4	*1.00E-05*	*5.00E-06*	2.0	2.19E-05	1.10E-05	2.0	5.00E-06	5.00E-06	1.0	
kif-sm-2b	0.146	5.35E-05	3.82E-05	1.4	*1.00E-05*	*5.00E-06*	2.0	2.19E-05	1.10E-05	2.0	5.00E-06	5.00E-06	1.0	
		Zone-1			Zone-6			Zone-5			Zone-4			
kif-sm-3b	*0.292*	5.35E-05	3.82E-05	1.4	*1.00E-05*	*5.00E-06*	2.0	2.19E-05	1.10E-05	2.0	5.00E-06	5.00E-06	1.0	
		Zone-1			Zone-6			Zone-5			Zone-4			
kif-sm-4b	*0.584*	5.35E-05	3.82E-05	1.4	*1.00E-05*	*5.00E-06*	2.0	2.19E-05	1.10E-05	2.0	5.00E-06	5.00E-06	1.0	
		Zone-1			Zone-6			Zone-5			Zone-4			
kif-sm-1c	1.41	5.35E-05	3.82E-05	1.4	*1.00E-05*	*5.00E-06*	2.0	2.19E-05	1.10E-05	2.0	*1.00E-05*	*1.00E-05*	1.0	
		Zone-1			Zone-6			Zone-5			Zone-7			
kif-sm-1d	1.41	5.35E-05	3.82E-05	1.4	*1.00E-05*	*5.00E-06*	2.0	2.19E-05	1.10E-05	2.0	*NA*	*NA*		
		Zone-1			Zone-6			Zone-5			Zone-1 & 6			
kif-sm-w-1b	1.41	5.35E-05	3.82E-05	1.4	*1.00E-05*	*5.00E-06*	2.0	2.19E-05	1.10E-05	2.0	5.00E-06	5.00E-06	1.0	
kif-sm-w-2b	0.146	5.35E-05	3.82E-05	1.4	*1.00E-05*	*5.00E-06*	2.0	2.19E-05	1.10E-05	2.0	5.00E-06	5.00E-06	1.0	
		Zone-1			Zone-6			Zone-5			Wall			
kif-sm-w2-1b	1.41	5.35E-05	3.82E-05	1.4	*1.00E-05*	*5.00E-06*	2.0	2.19E-05	1.10E-05	2.0	5.00E-06	5.00E-06	1.0	new northern boundry
kif-sm-w2-2b	0.146	5.35E-05	3.82E-05	1.4	*1.00E-05*	*5.00E-06*	2.0	2.19E-05	1.10E-05	2.0	5.00E-06	5.00E-06	1.0	
		Zone-1			Zone-6			Zone-5			Wall			

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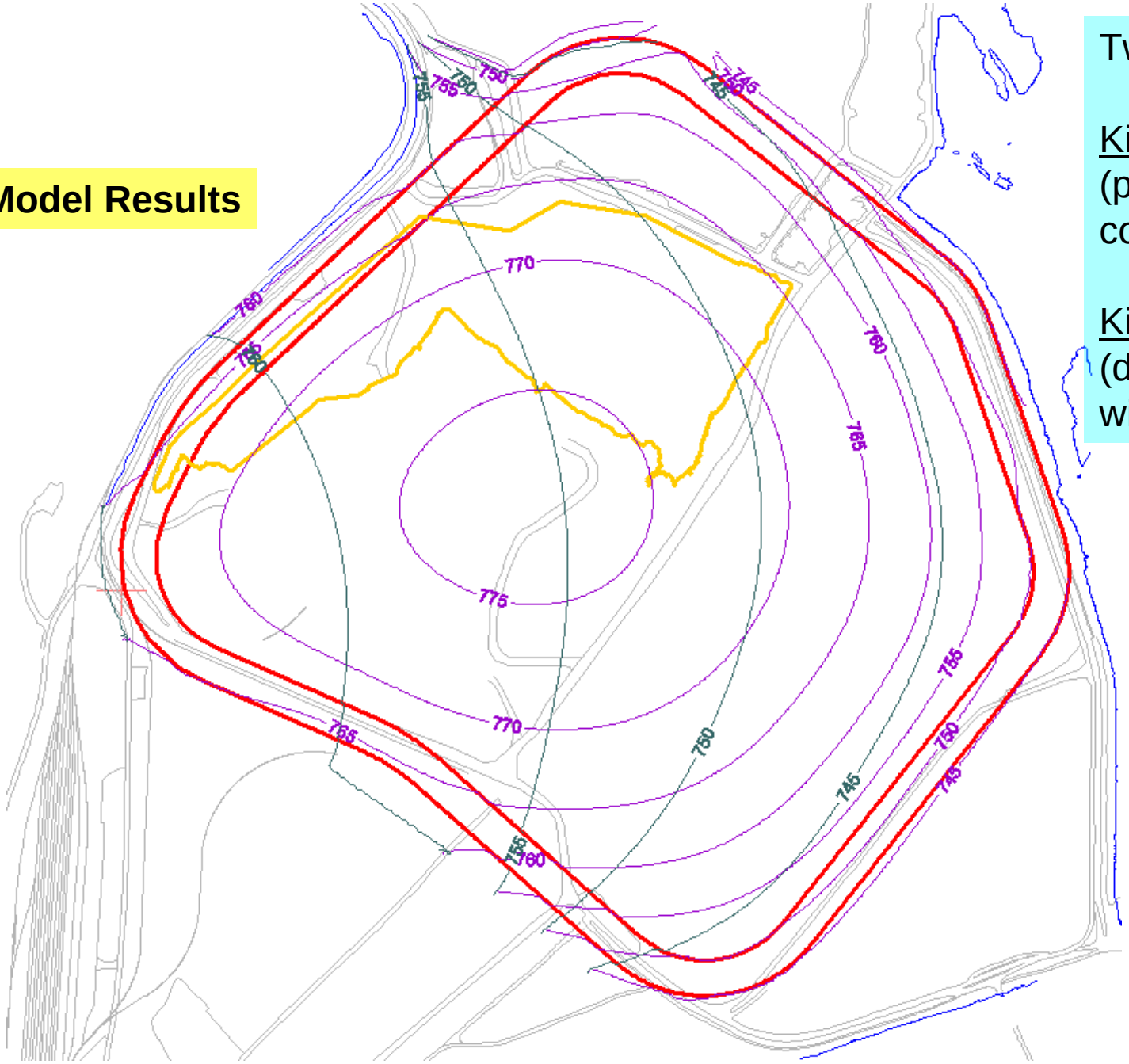
Model Results



Two new runs

<u>Kif-sm-w2-1b</u>
(purple – clay cover)

<u>Kif-sm-w2-2b</u>
(dark blue – with FM liner)

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Groundwater Modeling Analyses on the Proposed KIF Landfill Design

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Analysis Objectives

A groundwater modeling analysis was conducted to evaluate the proposed KIF landfill design.

The purpose of the study is to predict the water levels within the landfill (with stability-enhancement walls) for proposed design.

To assist the analysis, a detailed 3-D groundwater flow model (with 10 x 10 ft grid) for the planned landfill area was constructed.

Extensive scenario/sensitivity runs were conducted to evaluate the impact from various design/nature parameters.

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Model Information

Model Domain

(yellow area represents Inactive model cells)

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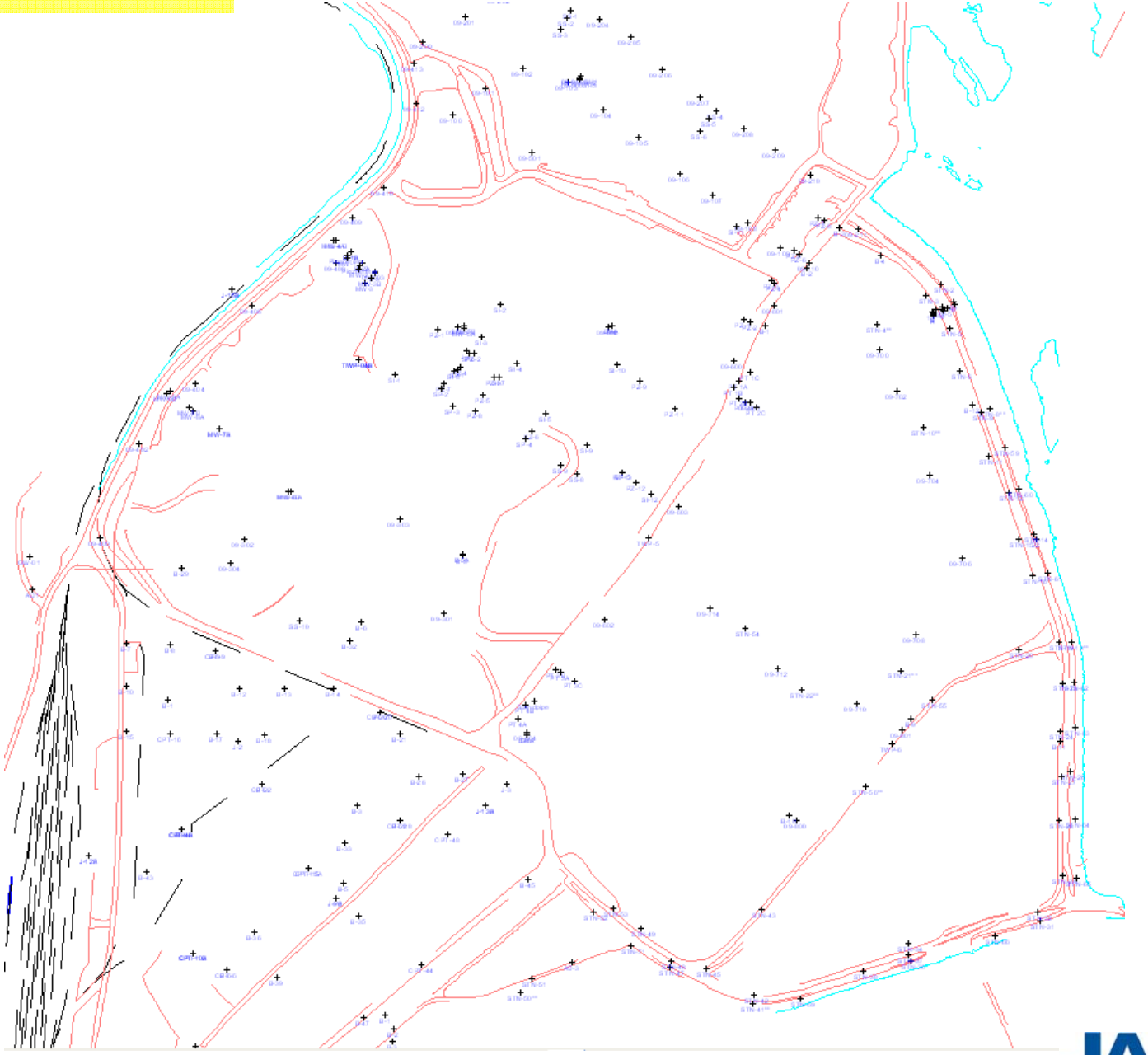
Model Information

Boring Locations used for 3-D lithologic Mapping analysis.



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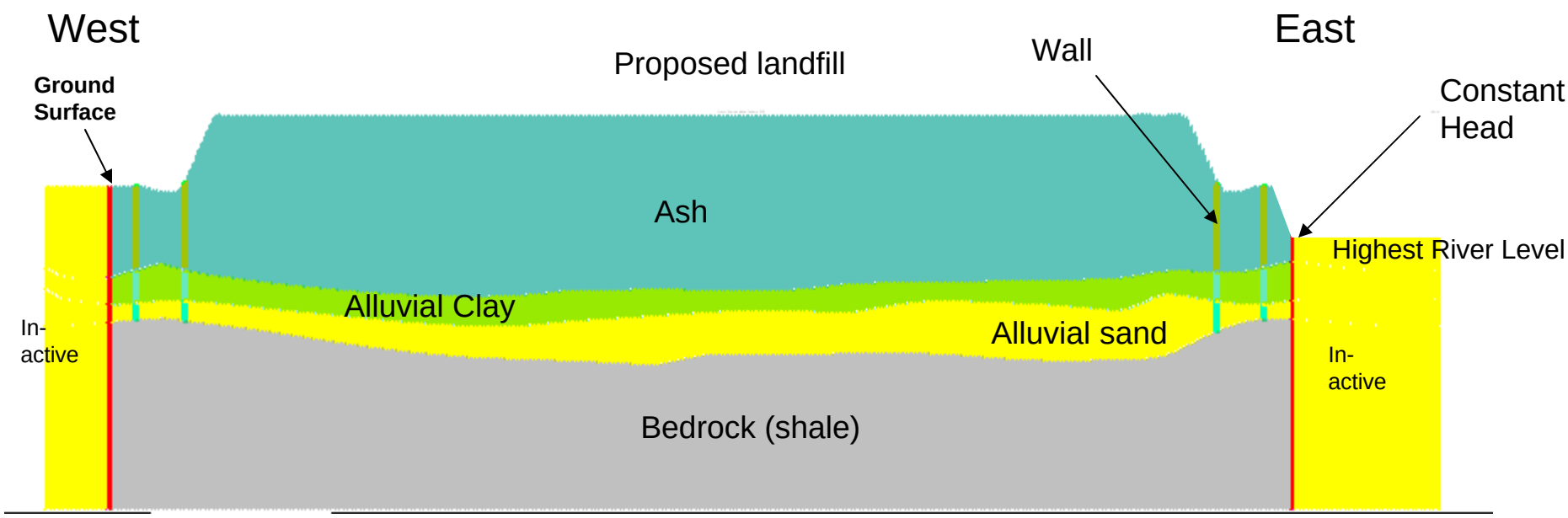
Model Information

Model Vertical Layers

Sub-surfaces are based on site-specific lithologic analysis.



Vertical Exaggeration 10/1

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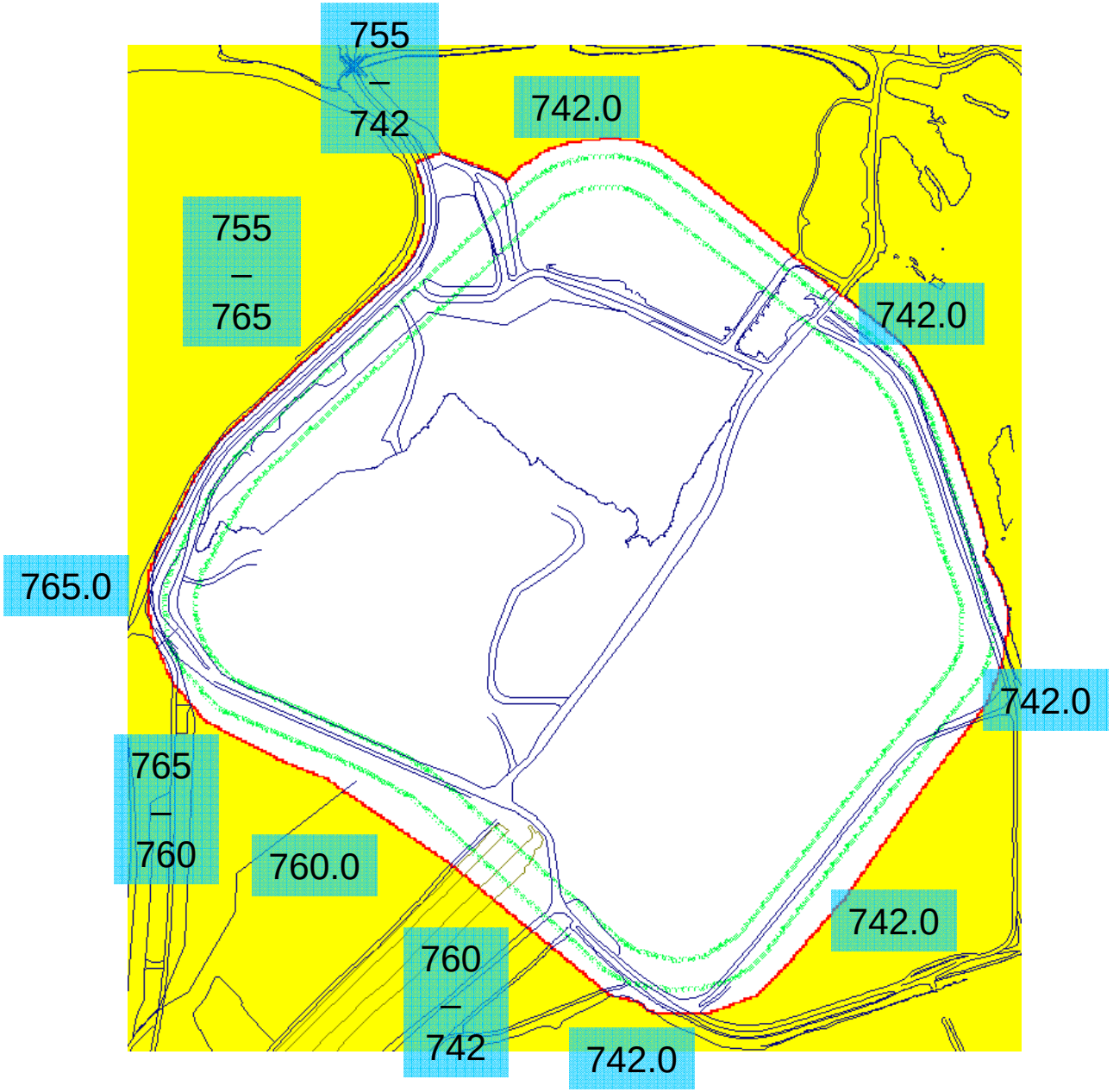
Model Information



Model Boundary Condition (Constant Head)

Most conservative (possible highest) water levels were assumed – <u>resulting in higher predicted groundwater levels – likely in the west side.</u>

Along the River, Highest River Level (742 ft-msl) is assumed.

Along the railroad side, the surface ditch elevations were used. The true groundwater levels may be many feet below the surface ditch.

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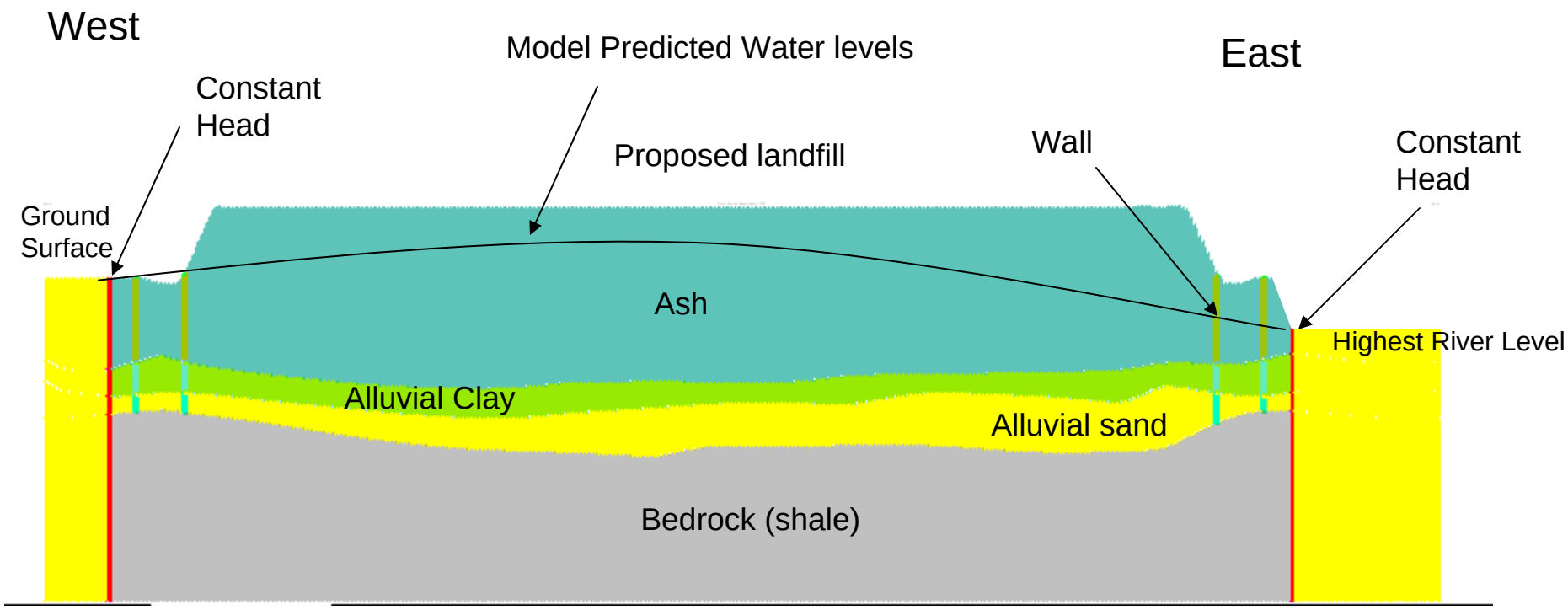
Model Information

The most conservative constant head (fixed water table) boundary conditions were used.



Vertical Exaggeration 10/1

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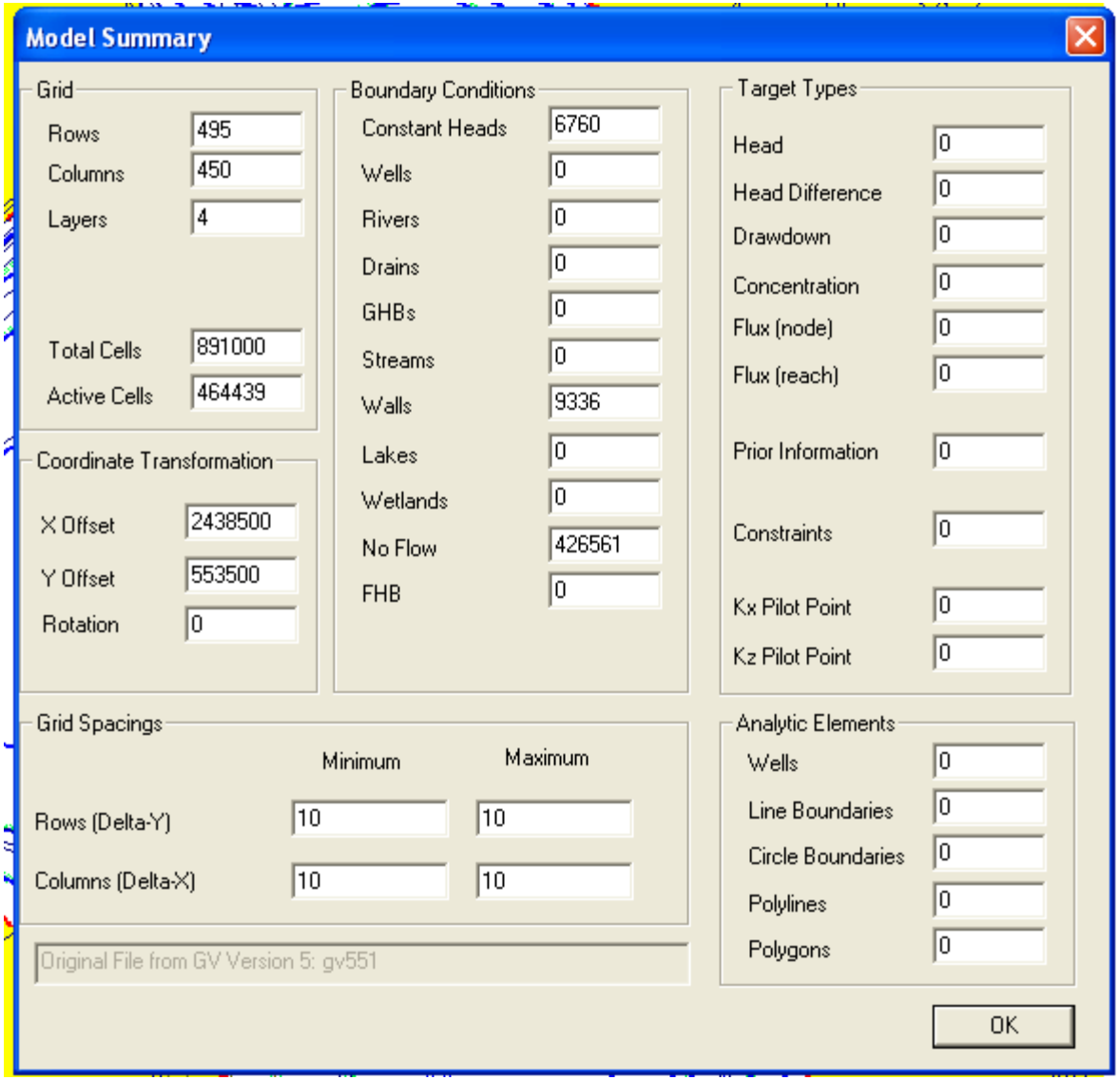
Model Information



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Model Code Used

All flow simulations were conducted used MODFLOW code - the most common applied groundwater code.

MODFLOW code is a finite-difference groundwater flow code developed by the USGS (1986). MODFLOW is capable of simulating both transient and steady state saturated groundwater flow in one, two, or three dimensions. A number of different boundary conditions are available, including specified head, areal recharge, injection or extraction wells, evapotranspiration, drains, and streams or rivers. The code simulates groundwater flow using a block-centered, finite-difference approach. Aquifers can be simulated as unconfined, confined, or a combination of unconfined and confined.

The application of a porous medium code (i.e., MODFLOW) to a fractured/weathered bedrock (shale) system, such as KIF, is termed the equivalent porous medium (EPM) approach. This approach assumes that the medium is fractured to the extent that it behaves hydraulically as a porous medium. Given the large scale of the flow model and the degree of fracturing of the geologic units underlying the site, the EPM approach is a reasonable modeling approach.

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Ranges of values for natural materials

Table of saturated hydraulic conductivity (*K*) values found in nature

Values are for typical fresh groundwater conditions — using standard values of viscosity and specific gravity for water at 20°C and 1 atm. similar table derived from the same source for intrinsic permeability values.[11]

K (cm/s)	10^2	10^1	$10^0=1$	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}
K (ft/day)	10^5	10,000	1,000	100	10	1	0.1	0.01	0.001	0.0001	10^{-5}	10^{-6}	10^{-7}
Relative Permeability	Pervious				Semi-Pervious				Impervious				
Aquifer	Good					Poor				None			
Unconsolidated Sand & Gravel	Well Sorted Gravel		Well Sorted Sand or Sand & Gravel			Very Fine Sand, Silt, Loess, Loam							
Unconsolidated Clay & Organic					Peat		Layered Clay			Fat / Unweathered Clay			
Consolidated Rocks	Highly Fractured Rocks				Oil Reservoir Rocks			Fresh Sandstone		Fresh Limestone, Dolomite		Fresh Granite	

Source: modified from Bear, 1972

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Model Parameter Summary

Variables		Best Estimate	Max.	Min.	Kv or Kh	Best Estimate	K Max.	K Min.	Kh/Kv Max.	Kh/Kv Min.
Ash	k_v, (cm/sec)	2.00E-05	1.00E-04	5.00E-06	**Kv**	2.00E-05	1.00E-04	5.00E-06	2.00E-05	2.00E-05
	k_h/k_v Ratio	3	10	1	**Kh**	6.00E-05	3.00E-04	1.50E-05	2.00E-04	2.00E-05
Alluvial Clay	k_v, (cm/sec)	1.00E-07	1.00E-06	1.00E-08	**Kv**	1.00E-07	1.00E-06	1.00E-08	1.00E-07	1.00E-07
	k_h/k_v Ratio	10	20	1	**Kh**	1.00E-06	1.00E-05	1.00E-07	2.00E-06	1.00E-07
Alluvial Silt/Sand	k_v, (cm/sec)	5.00E-06	5.00E-05	1.00E-06	**Kv**	5.00E-06	5.00E-05	1.00E-06	5.00E-06	5.00E-06
	k_h/k_v Ratio	3	10	1	**Kh**	1.50E-05	1.50E-04	3.00E-06	5.00E-05	5.00E-06
Shale	k_v, (cm/sec)	5.00E-07	1.00E-06	1.00E-07	**Kv**	5.00E-07	1.00E-06	1.00E-07	5.00E-07	5.00E-07
	k_h/k_v Ratio	3	10	1	**Kh**	1.50E-06	3.00E-06	3.00E-07	5.00E-06	5.00E-07
Soilcrete – Ash	k_v, (cm/sec)	5.00E-06	1.00E-05	1.00E-06						
	k_h/k_v Ratio	1	1	1						
Soilcrete – Clay	k_v, (cm/sec)	2.00E-08	1.00E-07	5.00E-09						
	k_h/k_v Ratio	1	1	1						
Soilcrete – Silt/Sand	k_v, (cm/sec)	1.00E-07	1.00E-06	5.00E-08						
	k_h/k_v Ratio	1	1	1						
Infiltration Rate	in./year	0.372	1.41	0.146						

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Model Run Summary

Case No.	Variables											
	Ash		Alluvial Clay		Alluvial Silt/Sand		Shale		Soilcrete-Ash	Soilcrete-clay	Soilcrete-Silt/Sand	Infiltration Rate
	kv	kh/kv	kv	kh/kv	kv	kh/kv	kv	kh/kv	kv	kv	kv	
1	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.
2	max.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.
3	min.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.
4	best est.	max.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.
5	best est.	min.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.
6	best est.	best est.	max.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.
7	best est.	best est.	min.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.
8	best est.	best est.	best est.	max.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.
9	best est.	best est.	best est.	min.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.
10	best est.	best est.	best est.	best est.	max.	best est.	best est.	best est.	best est.	best est.	best est.	best est.
11	best est.	best est.	best est.	best est.	min.	best est.	best est.	best est.	best est.	best est.	best est.	best est.
12	best est.	best est.	best est.	best est.	best est.	max.	best est.	best est.	best est.	best est.	best est.	best est.
13	best est.	best est.	best est.	best est.	best est.	min.	best est.	best est.	best est.	best est.	best est.	best est.
14	best est.	best est.	best est.	best est.	best est.	best est.	max.	best est.	best est.	best est.	best est.	best est.
15	best est.	best est.	best est.	best est.	best est.	best est.	min.	best est.	best est.	best est.	best est.	best est.
16	best est.	best est.	best est.	best est.	best est.	best est.	best est.	max.	best est.	best est.	best est.	best est.
17	best est.	best est.	best est.	best est.	best est.	best est.	best est.	min.	best est.	best est.	best est.	best est.
18	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	max.	best est.	best est.	best est.
19	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	min.	best est.	best est.	best est.
20	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	max.	best est.	best est.
21	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	min.	best est.	best est.
22	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	max.	best est.
23	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	min.	best est.
24	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	max.
25	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	min.
26	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	3.00E-07			best est.
27	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	5.00E-06			best est.
28	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	2.00E-08			best est.
29	best est.	best est.	best est.	best est.	best est.	best est.	best est.	best est.	NA			best est.

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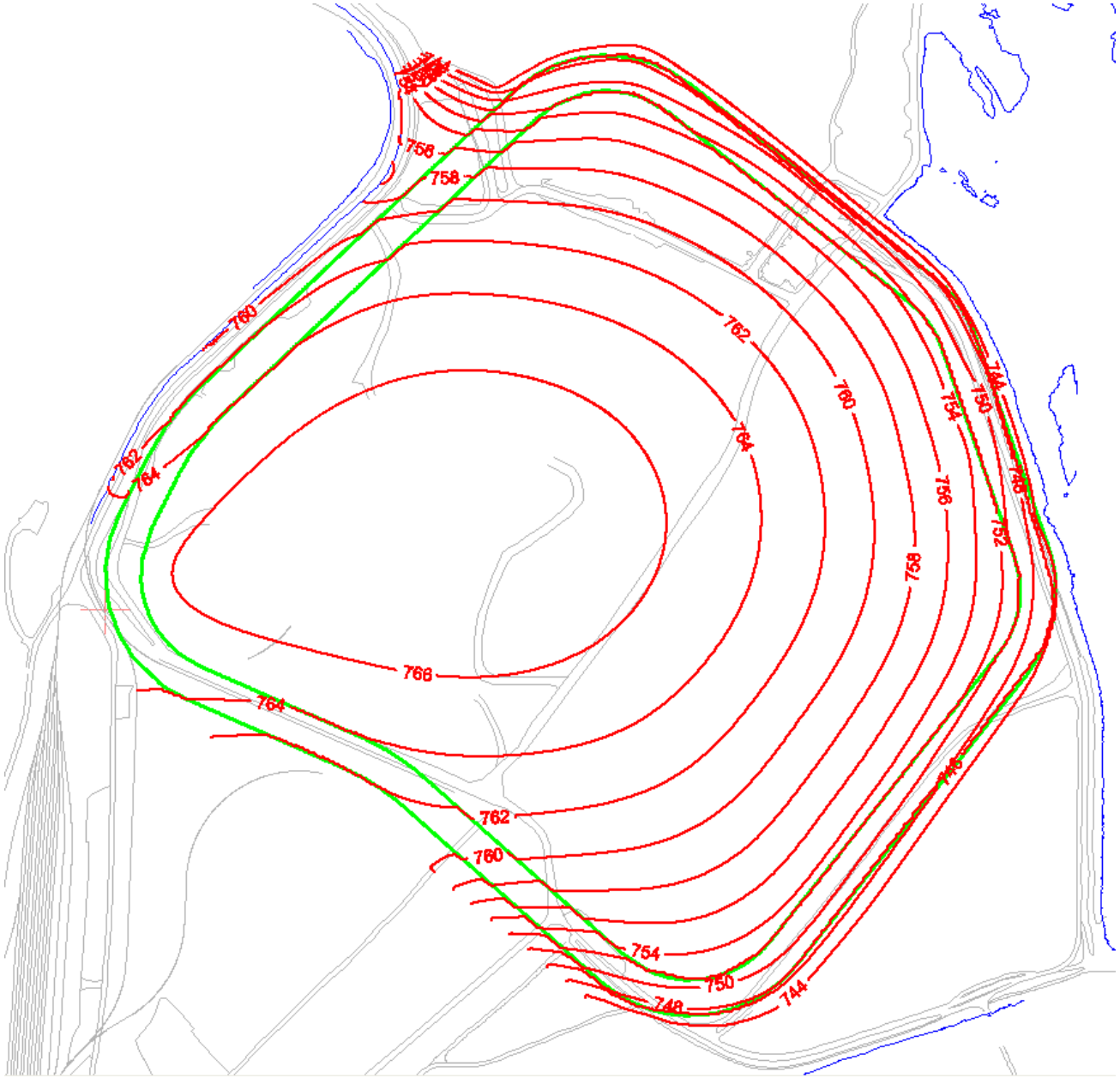

Model Results

Best Estimate (BE)

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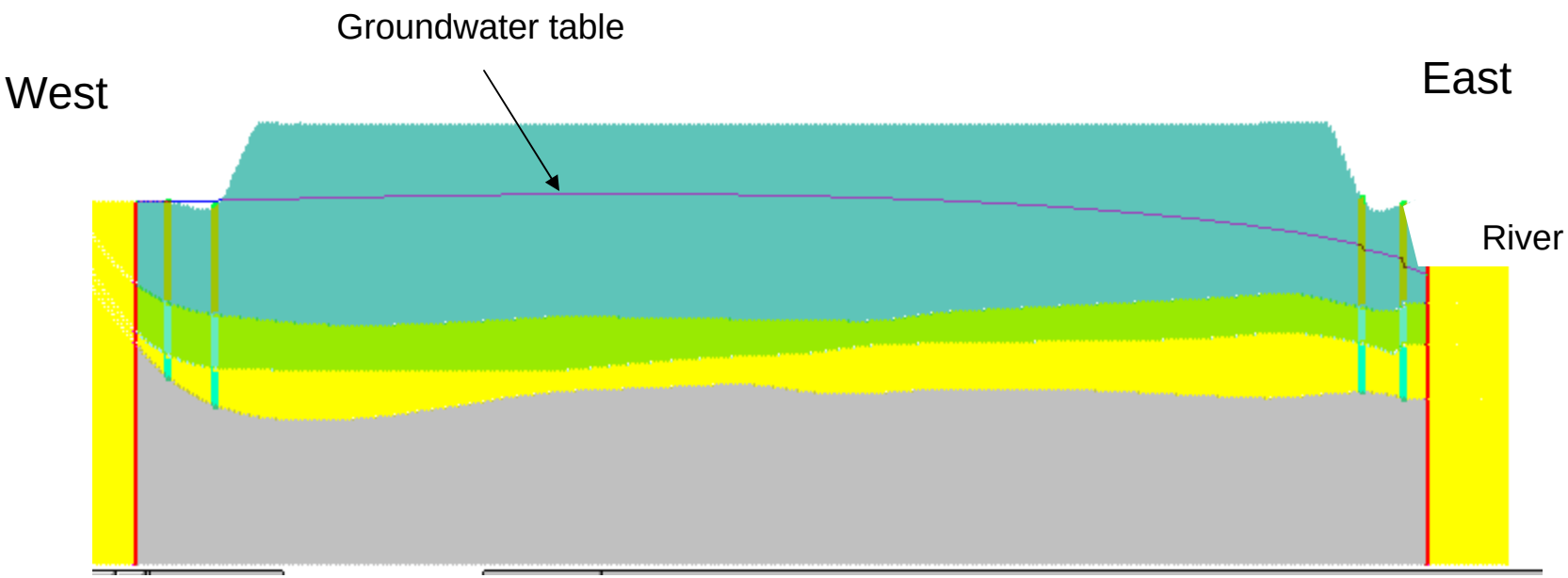
Model Results

Model predicted water table in X-section

Best Estimate (BE)



Vertical Exaggeration 10/1

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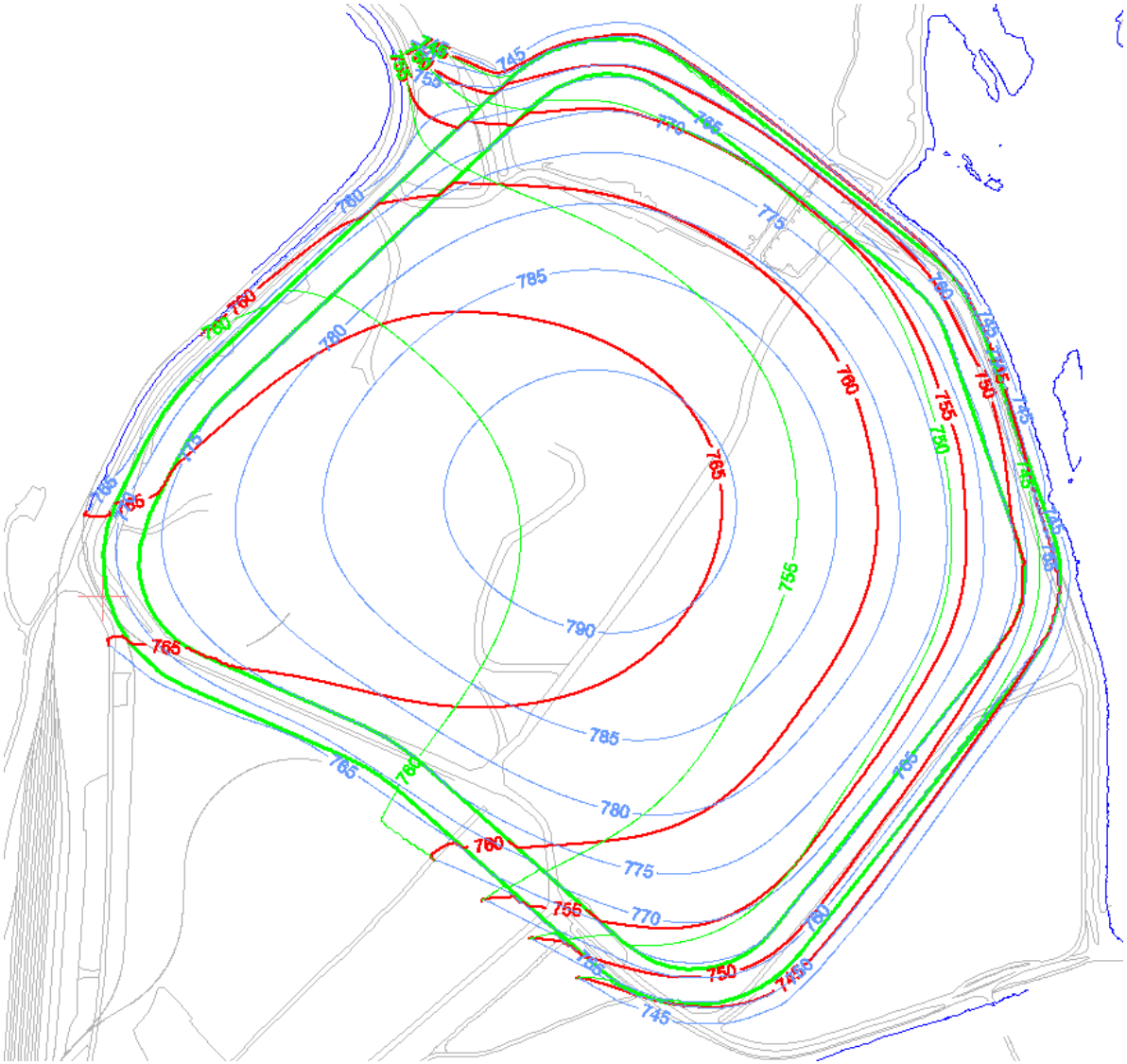
Model Results



Recharge Rate Impact

BE (red)
Max (blue)
Min (green)

Conclusion:

Higher recharge rate will cause higher water levels within the landfill.

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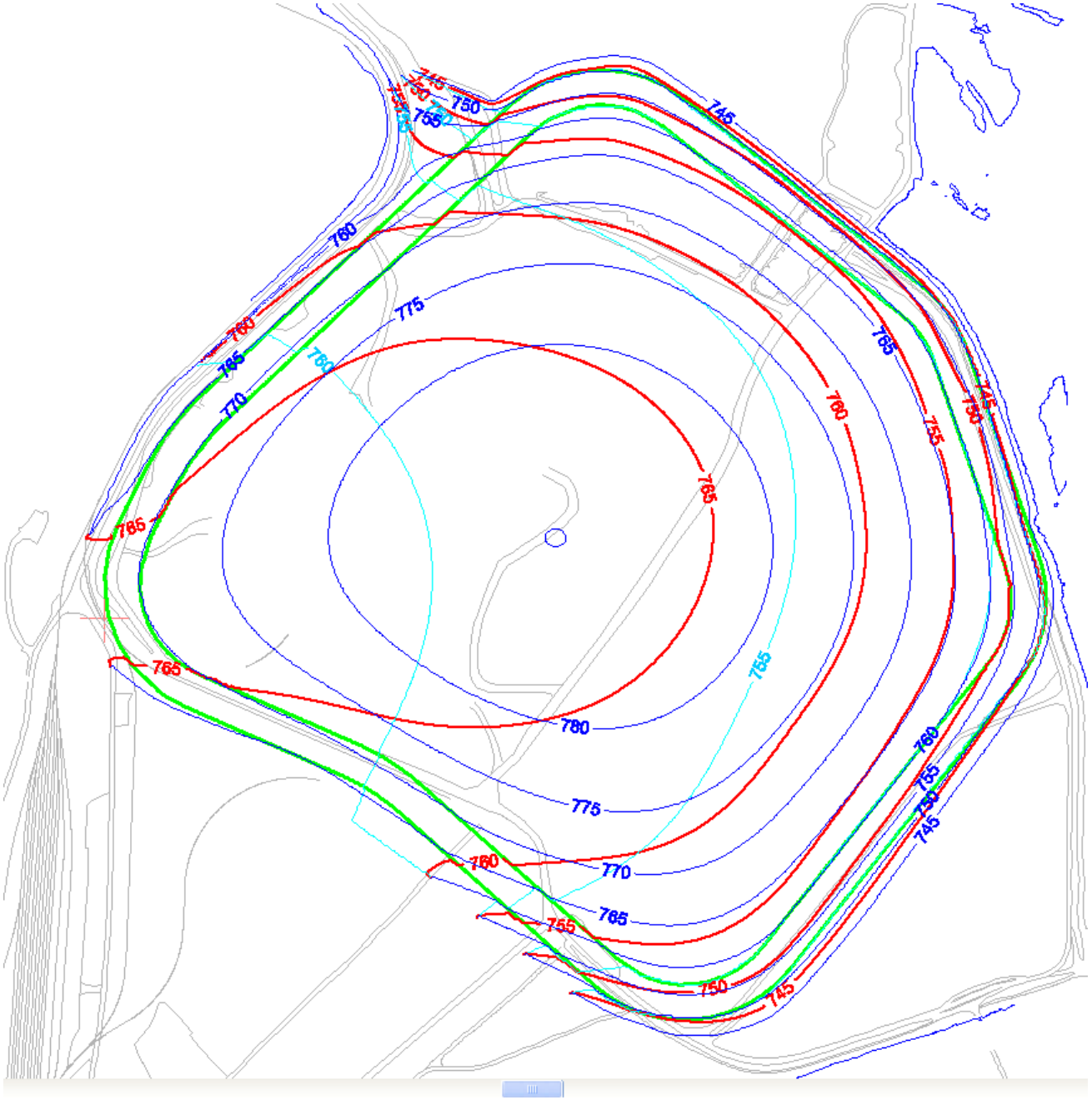

Model Results

Ash K Variation

BE (red)
Max (light blue)
Min (blue)

Conclusion:

Lower K (hydraulic conductivity) will result in higher water levels within the landfill.

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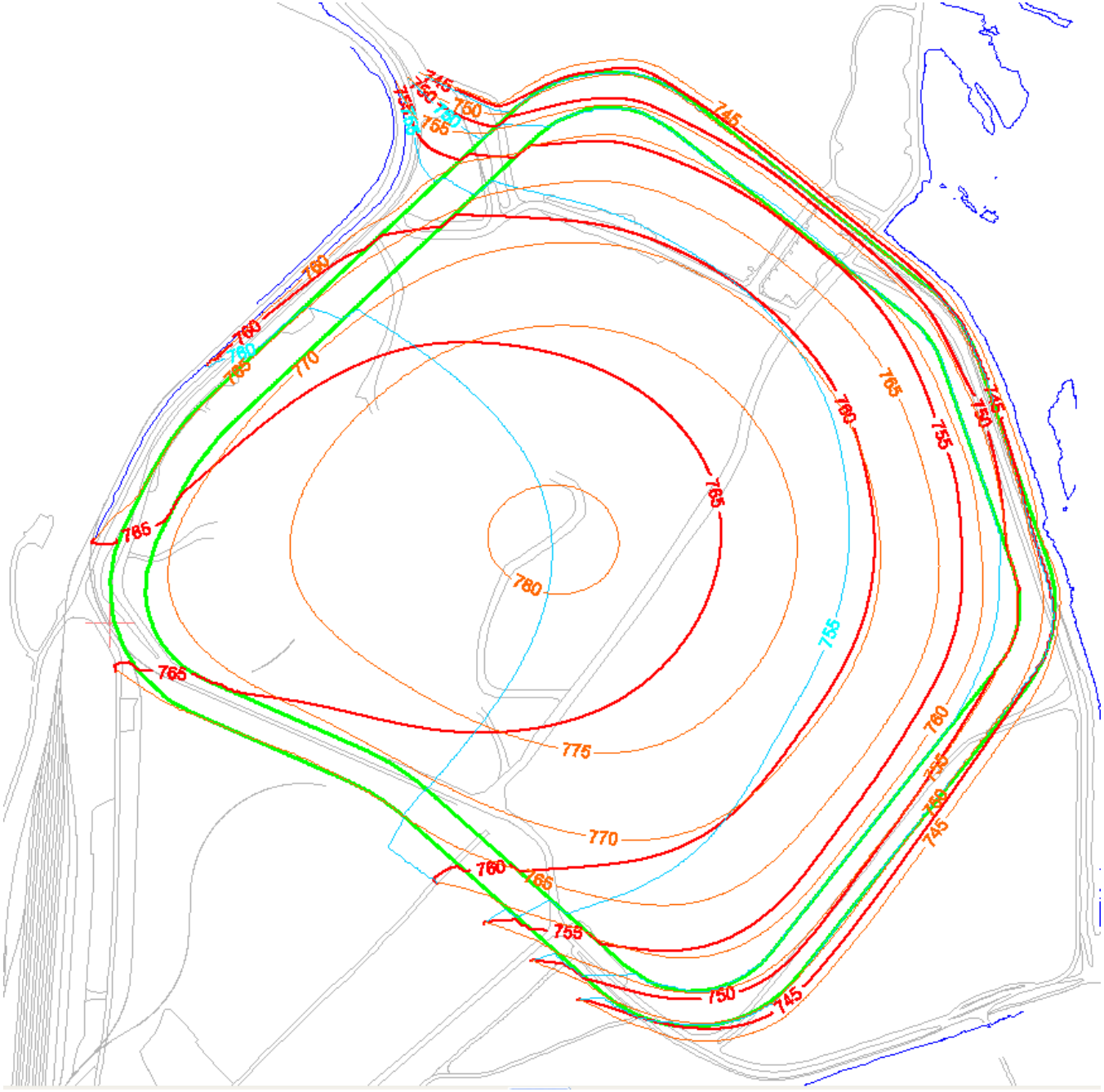

Model Results

Ash
Kh/Kv Ratio
Variation

BE (red)
Max (light blue)
Min (orange)

Conclusion:

For a given Kv, lower Kh/Kv will result in higher water levels within the landfill.

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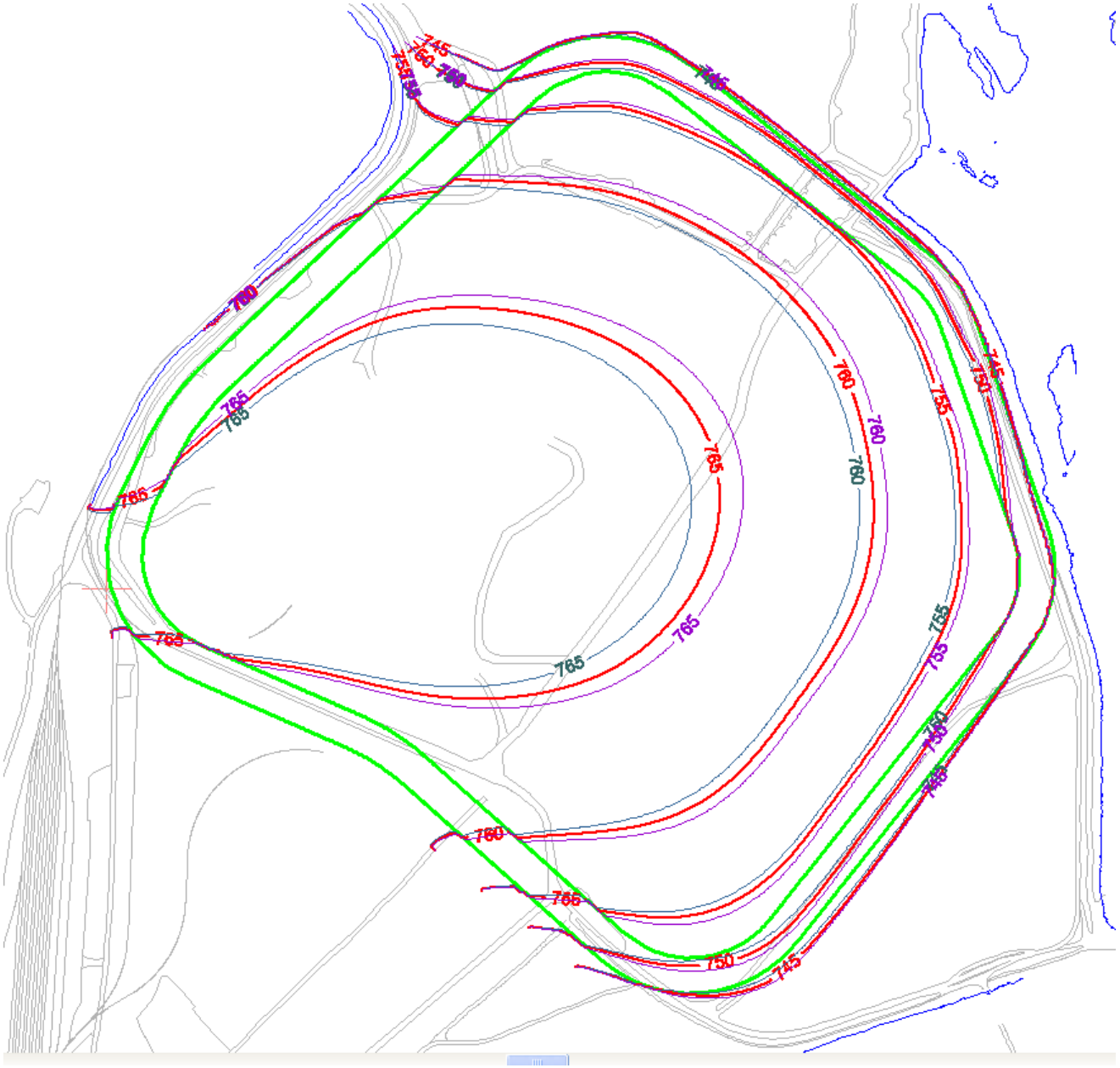

Model Results

Alluvial Clay K Variation

BE (red)
Max (dark blue)
Min (purple)

Conclusion:

Lower K (hydraulic conductivity) will result in <u>slightly</u> higher water levels within the landfill. (Mainly due to very low Ks of the clay for all the scenarios)

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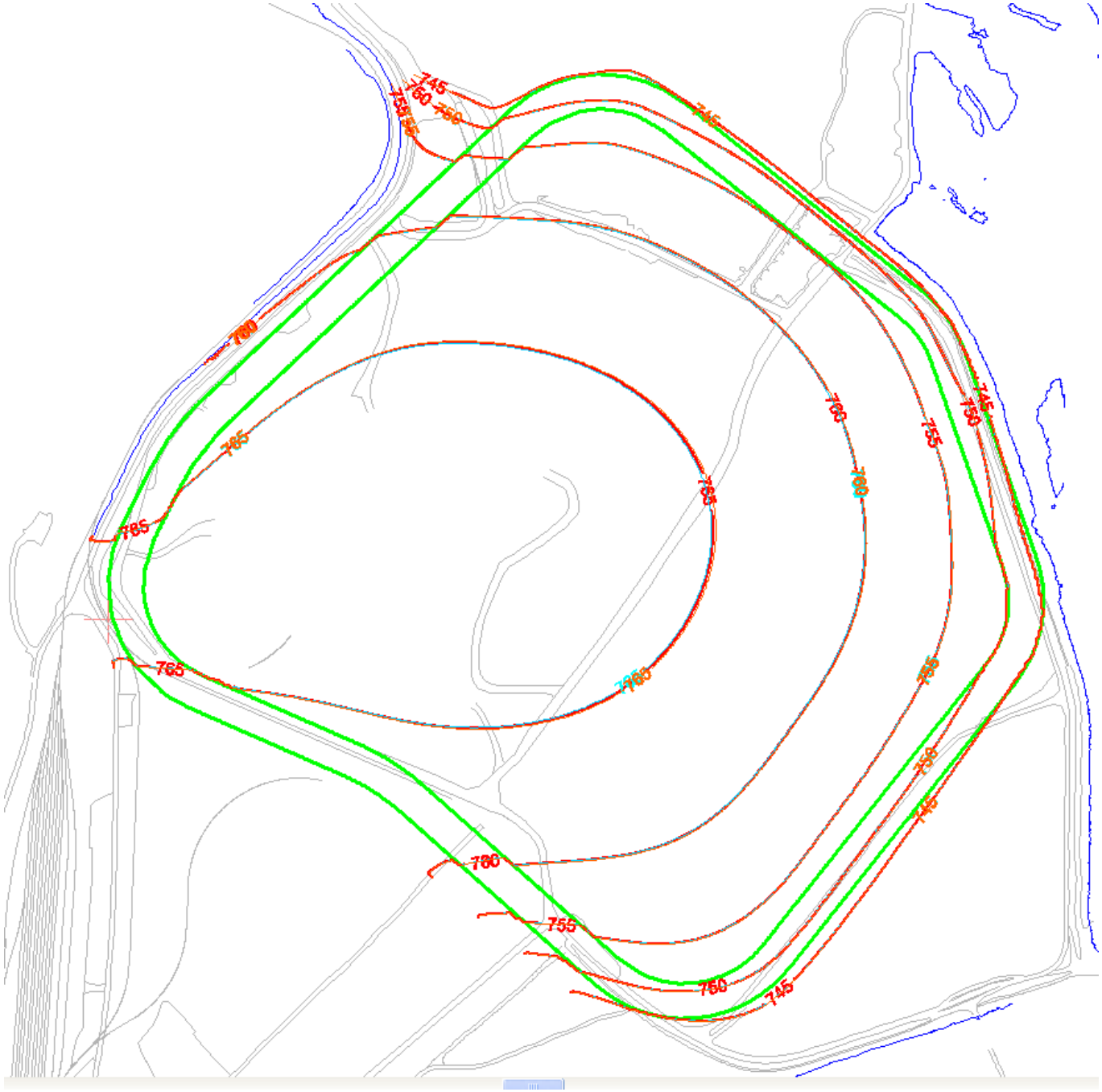

Model Results

Clay
Kh/Kv Ratio
Variation

BE (red)
Max (light blue)
Min (orange)

Conclusion:

Very little impact, (Mainly due to very low Ks of the clay for all the scenarios K < E-06 cm/s)

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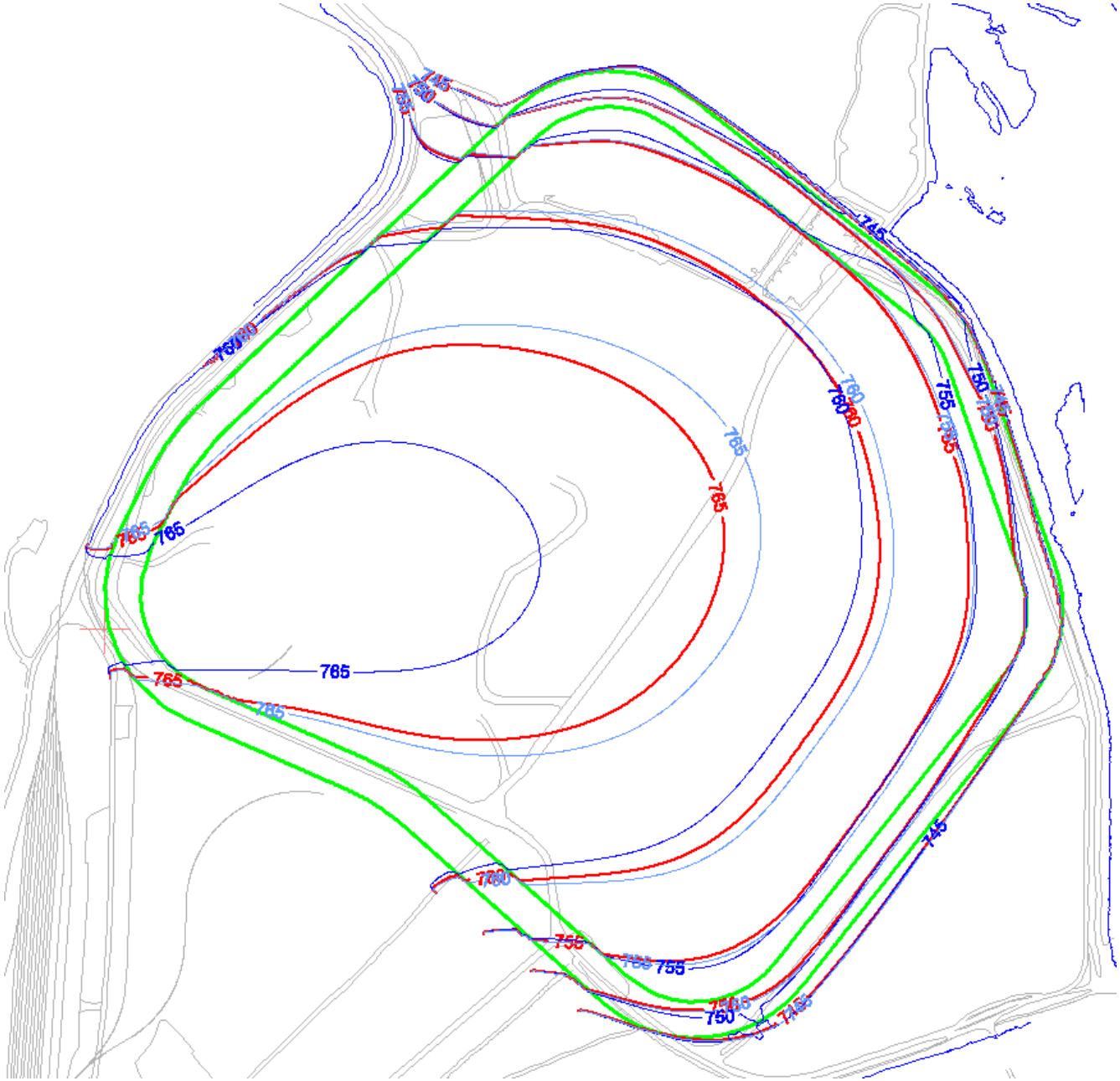

Model Results

Alluvial Silt/Sand
K Variation

BE (red)
Max (bright blue)
Min (dark blue)

Conclusion:

Lower K (hydraulic conductivity) will result in higher water levels within the landfill (less water flow out the sandy layer to River)

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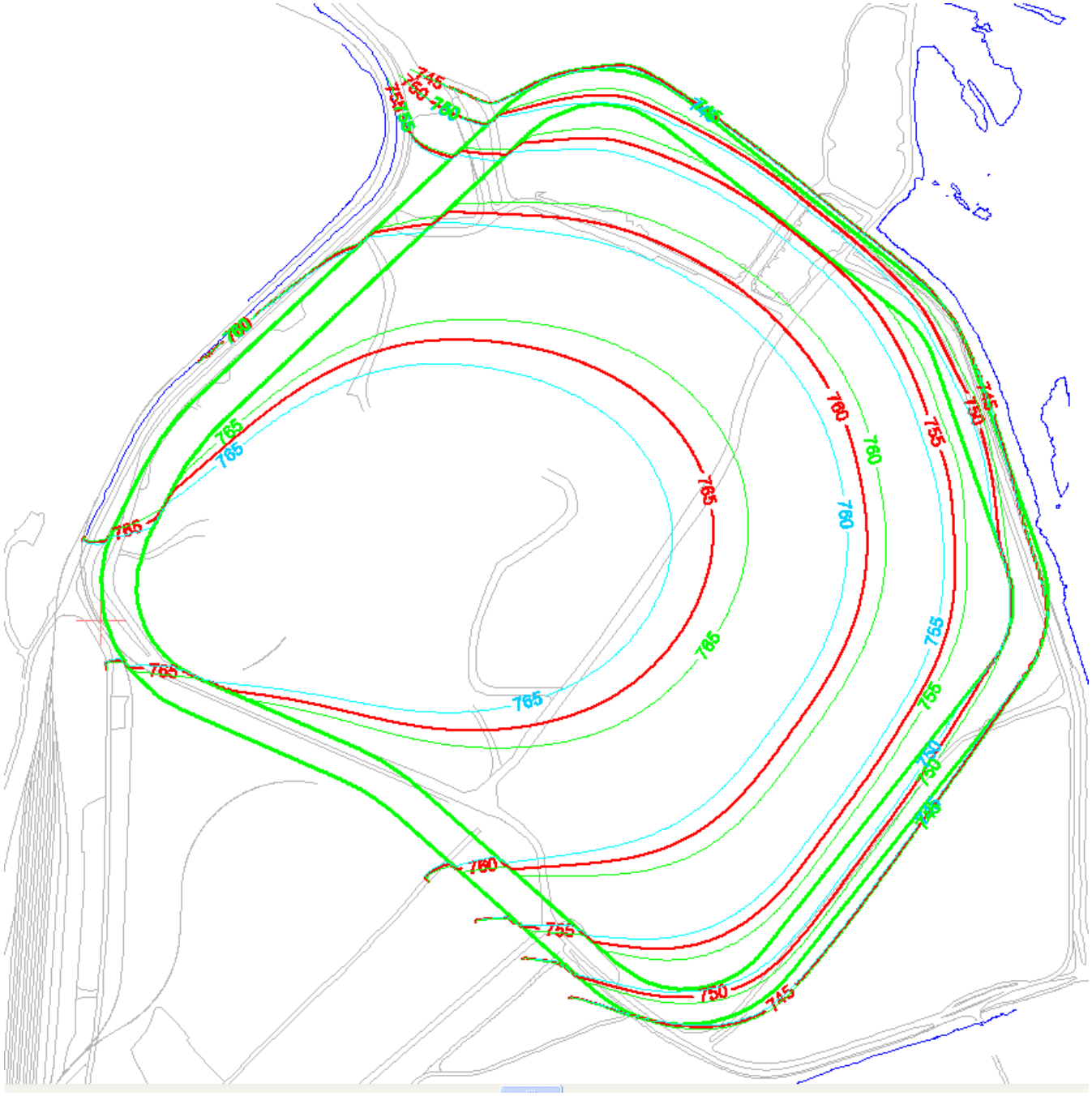
745
760
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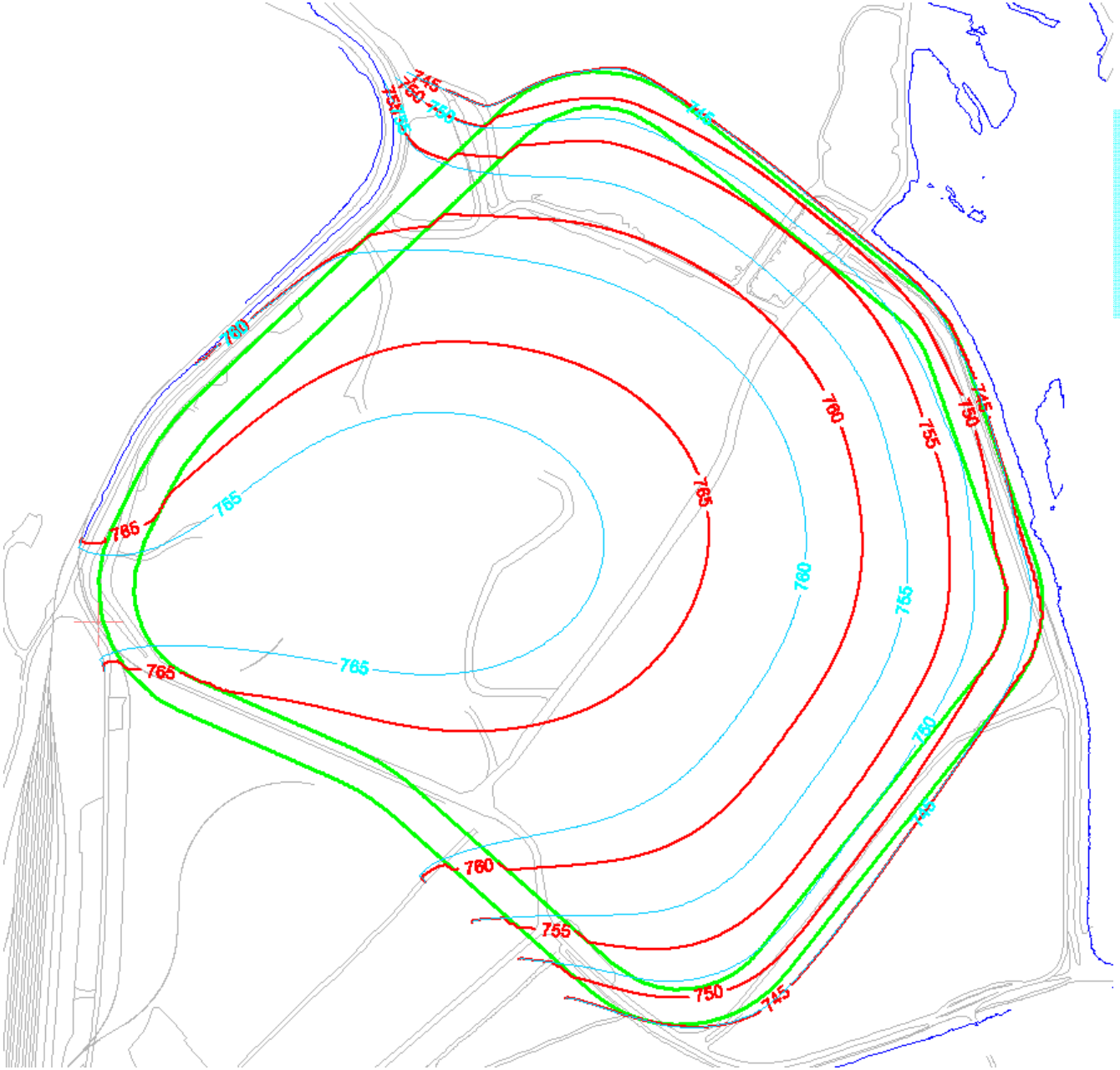
745

Model Results



Wall Impact

BE (red)
No Wall (light Blue)

Conclusion:

For the given K value for the ash (low K), wall has relatively small hydraulic impact (localized impact near the walls). < 2 ft.

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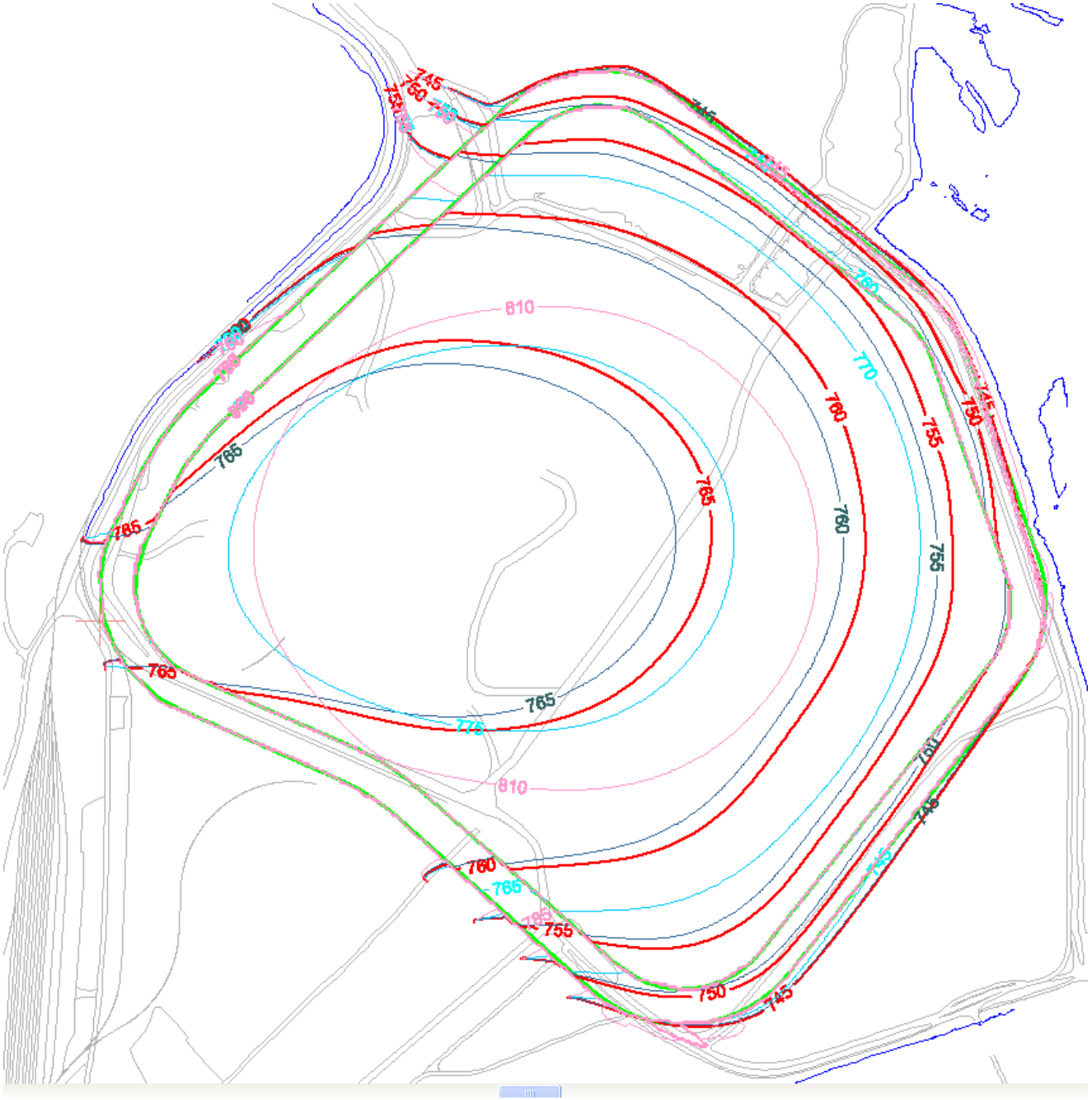

Model Results

Wall K Variation

BE (red)

All Ash Mix (dark blue)
All Clay Mix (pink)
All Silt/Sand Mix (light blue)

Conclusion:

Large impact.

Used clay mix value, the walls are almost impervious (K < E-08).

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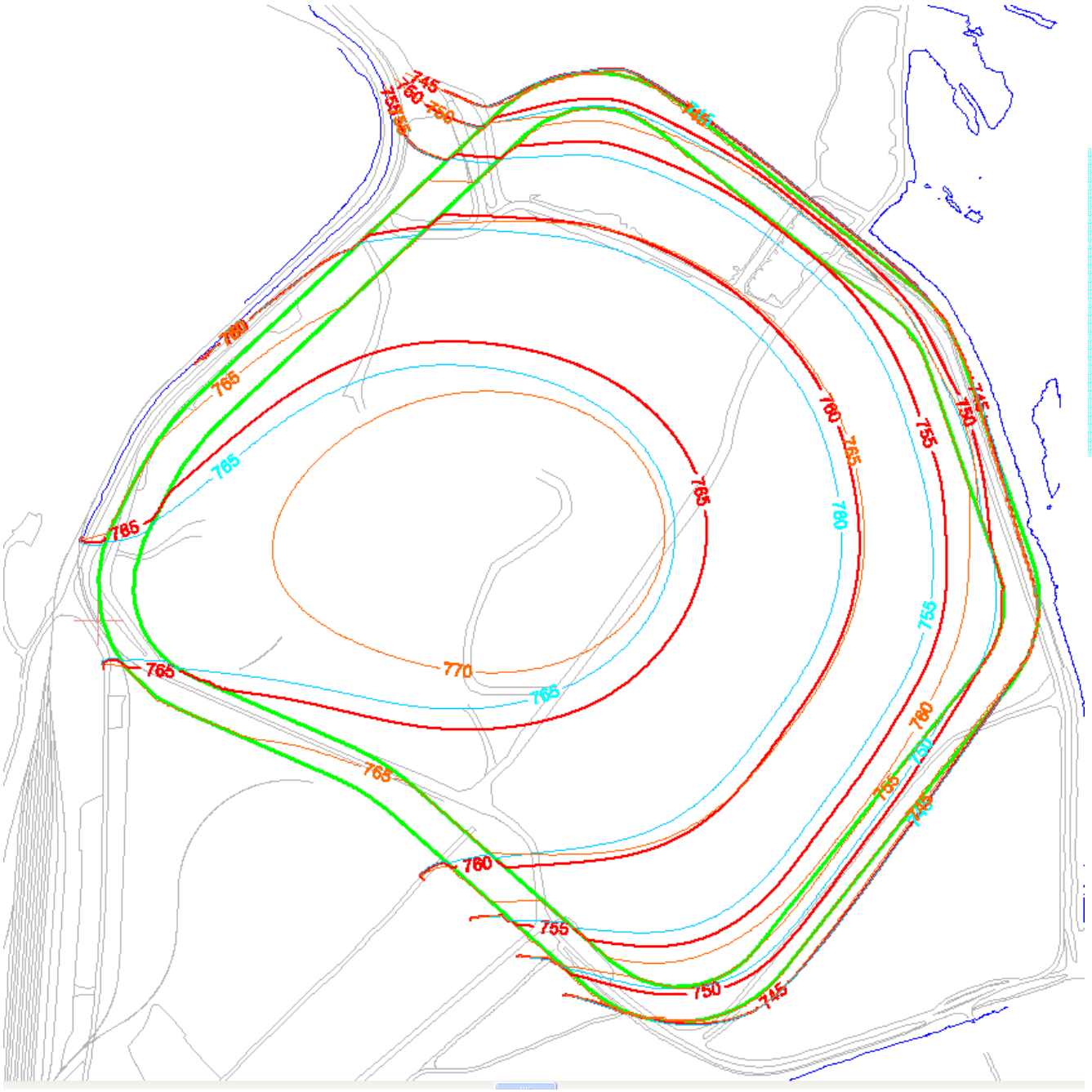

Model Results

Wall K Variation

BE (red)

Ash Mix max (light blue)
Ash Mix min (orange)

Ash layer variable only.

Conclusion:

Lower K walls for the ash layer will likely cause slightly higher water level.

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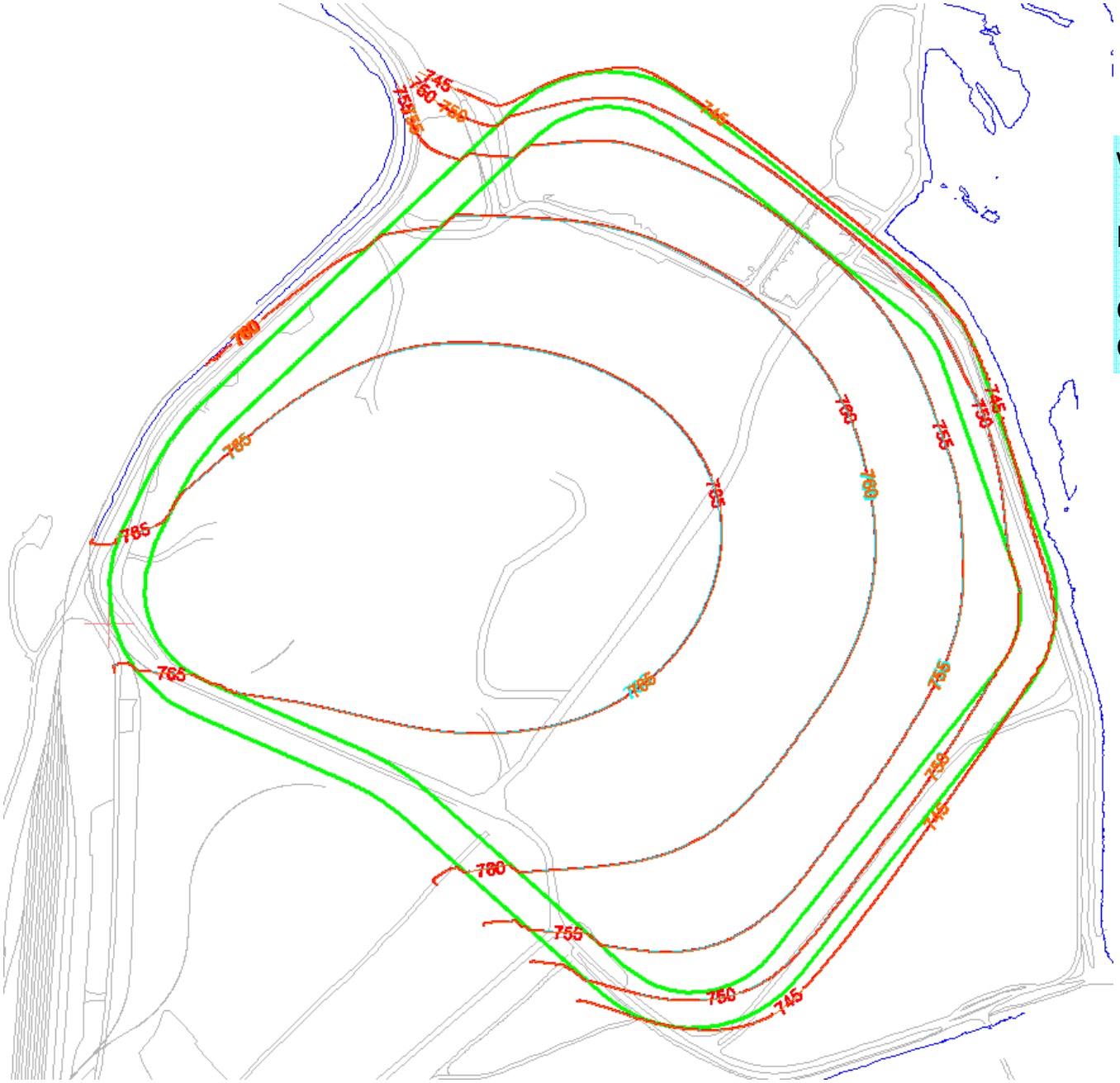

Model Results

Wall K Variation

BE (red)

Clay Mix max (light blue)
Clay Mix min (orange)

Conclusion:

Minimal impact.

(Mainly due to very low Ks of the clay-mixed wall for all the scenarios)
K < E-07 cm/s)

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Comments and Questions ?

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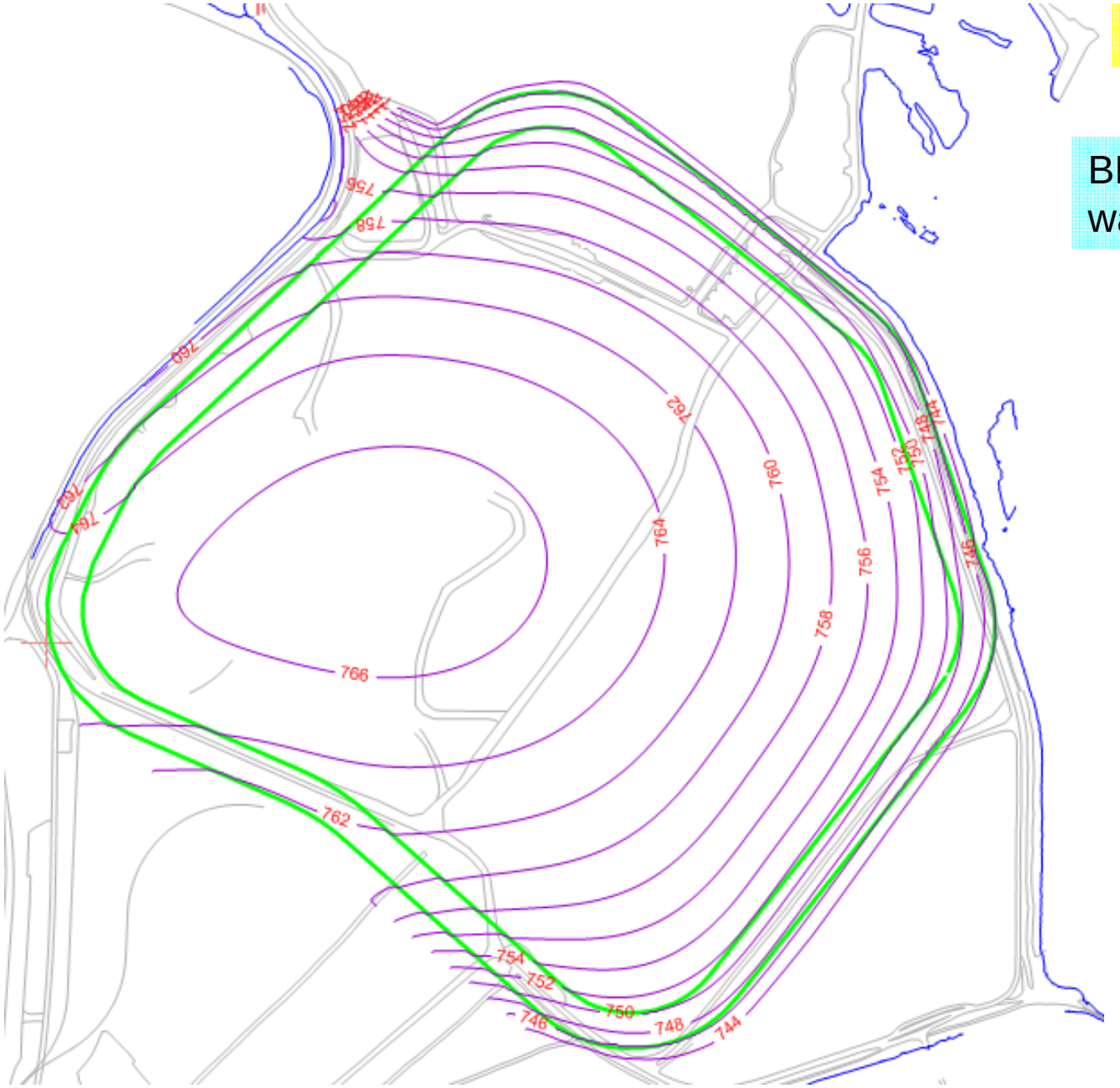
Model Results

BE with 3-ft thick walls



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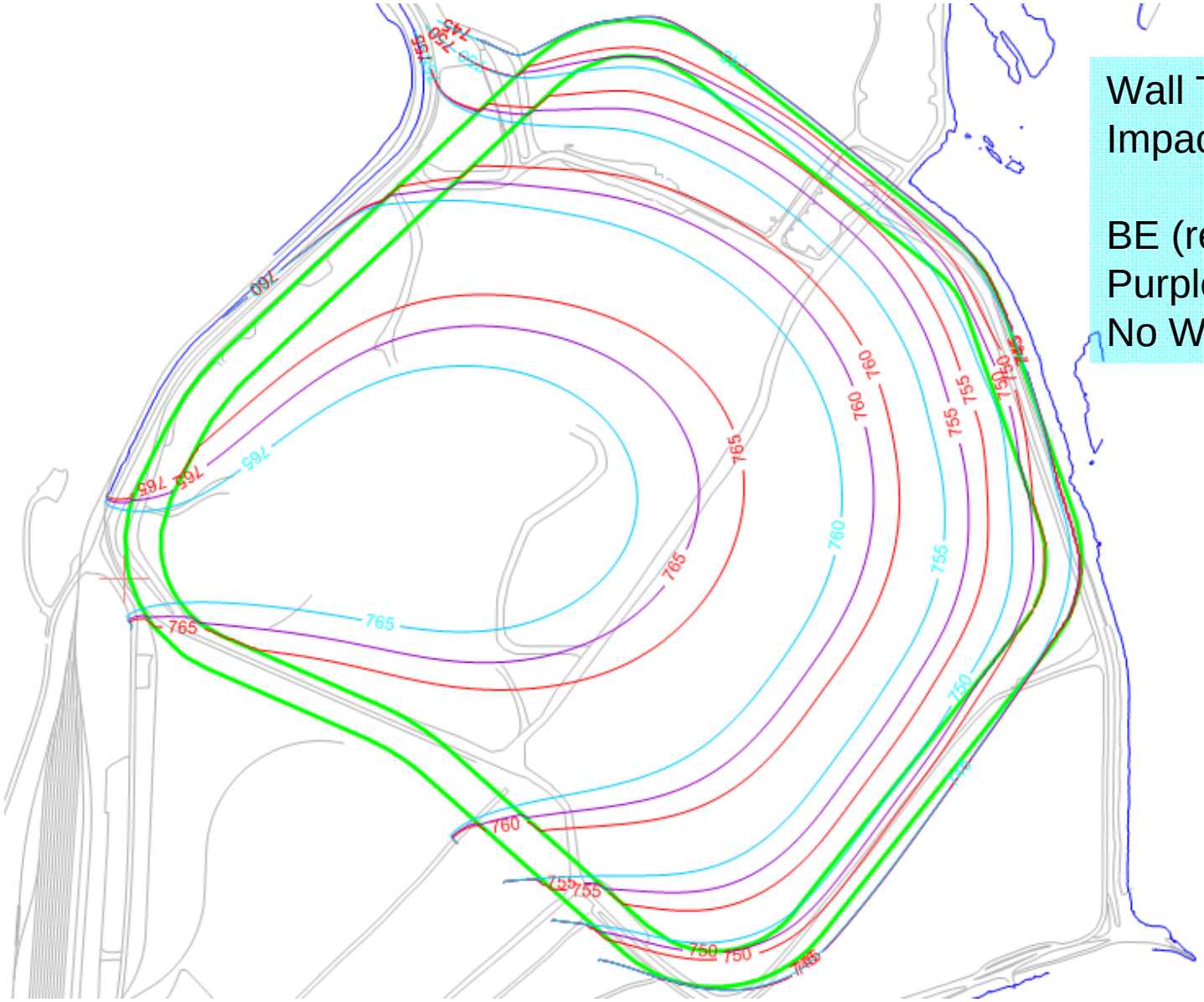
Model Results



Wall Thickness Impact

BE (red) – 7 ft walls
Purple – 3 ft walls
No Wall (light Blue)

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Groundwater Modeling Analyses on the Potential Impact of the Stilling Pond Trench Design On the Water Level and Flux Associated with the KIF Dredge Cell

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Objectives

Several proposed surface trench designs along the foot of the dredging cell at the Stilling Pond were analyzed.

Two basic designs were considered:

1. A uniformly sloped trench toward the Emory River and Intake Channel with crest elevate at the mid section of the Stilling Pond. Crest elevations at 750-msl (highest restored surface elevation) and 748 (assumed 2ft gravel backfilled) were considered.
2. A flat surface trench (or pond) with elevations at 750 and 748 at the Stilling Pond, then sloped (under the Berm) to Emory River and Intake Channel at both ends.

Groundwater flow simulations were conducted to predict the groundwater levels and flux rates to the trench for each of the four scenarios.

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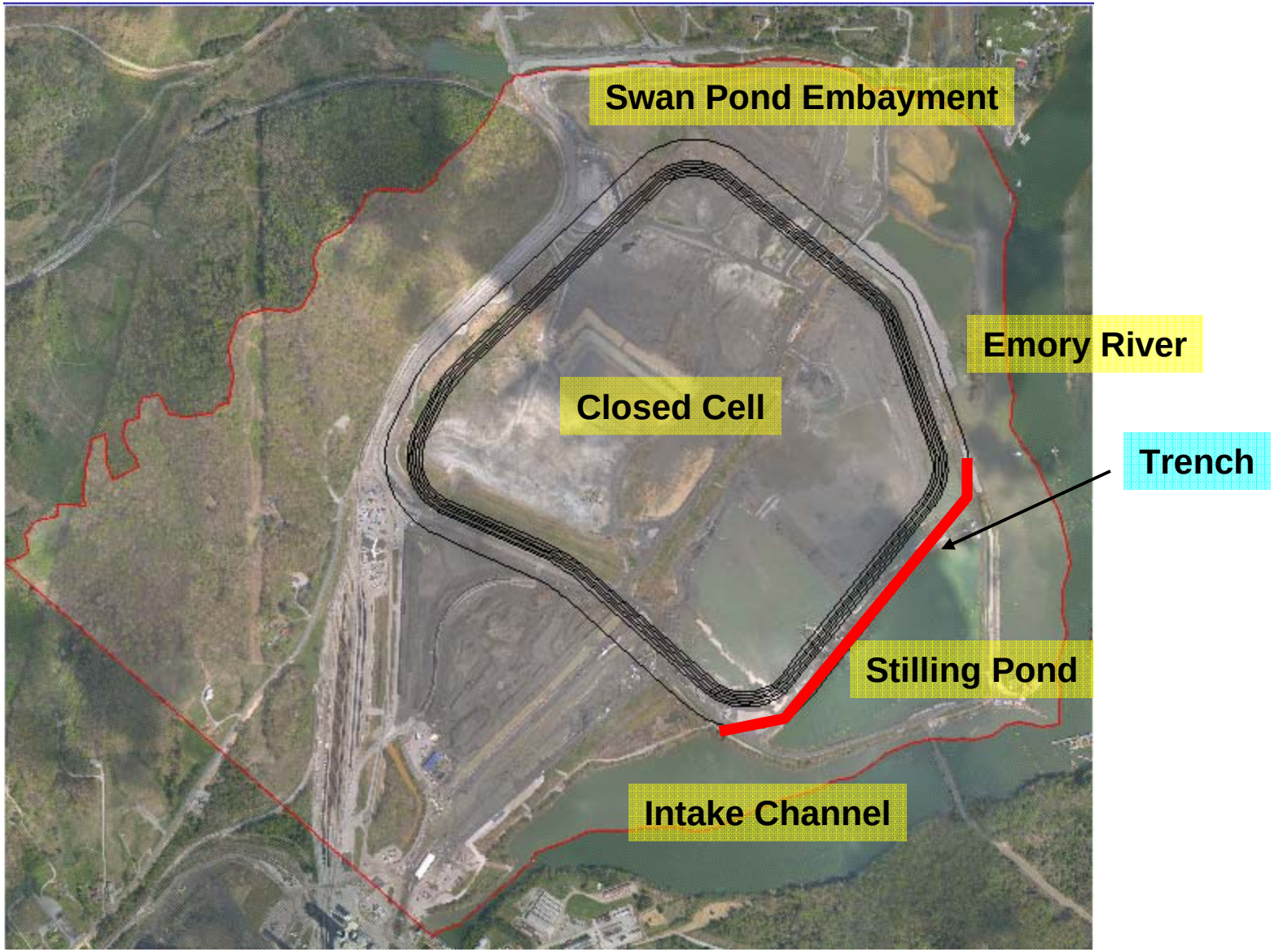
KIF Landfill Site and Stilling Pond Surface Trench



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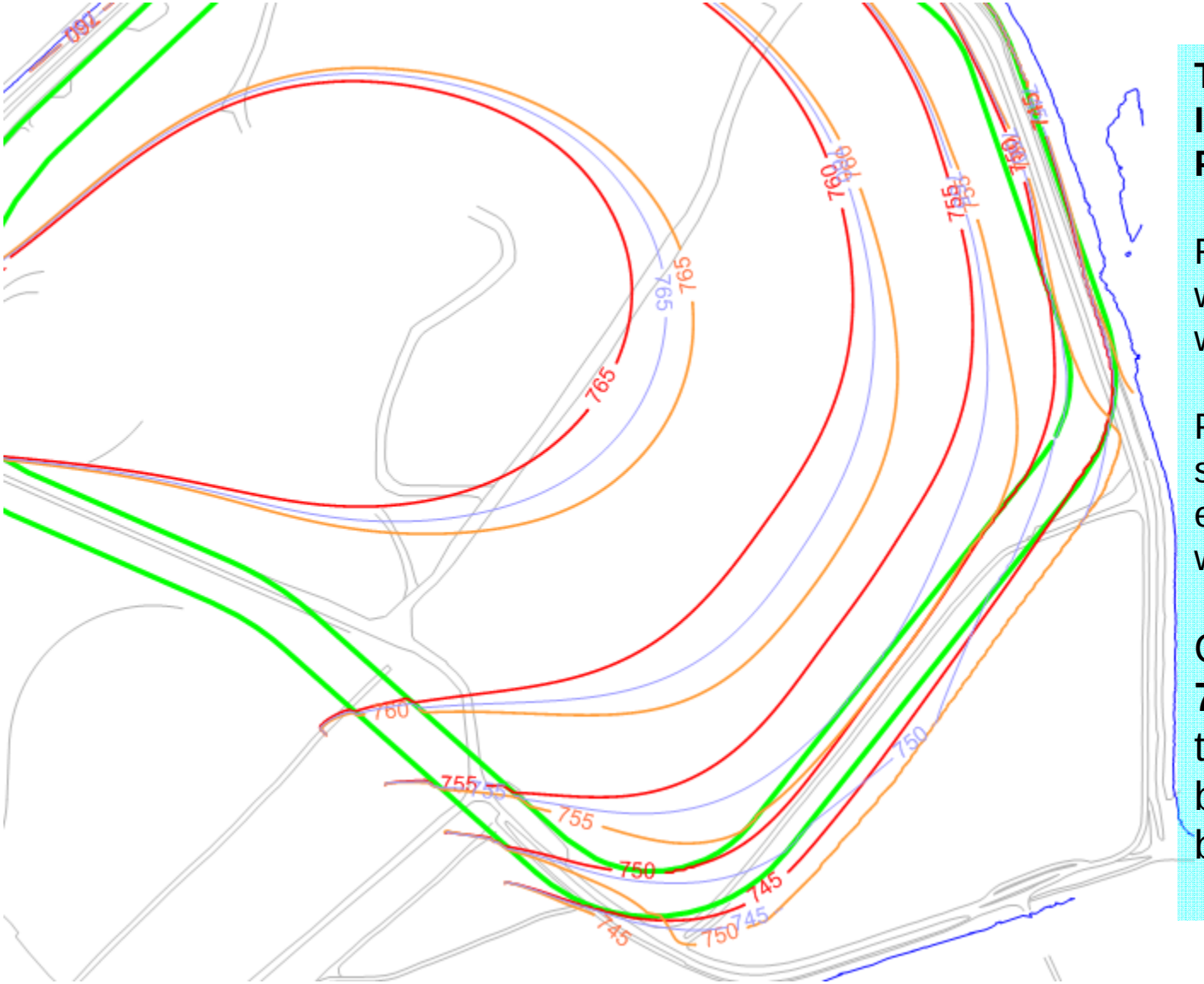
Model Results



Trench design Impact (Stilling Pond)

RED – Base Case with 3 ft walls (open water @ 742)

Purple Blue – uniform sloped trench to either ends (**750** to 742 at water bodies)

Orange – flat @ **750** in Pond and then slope to water body @ 742) at both ends.

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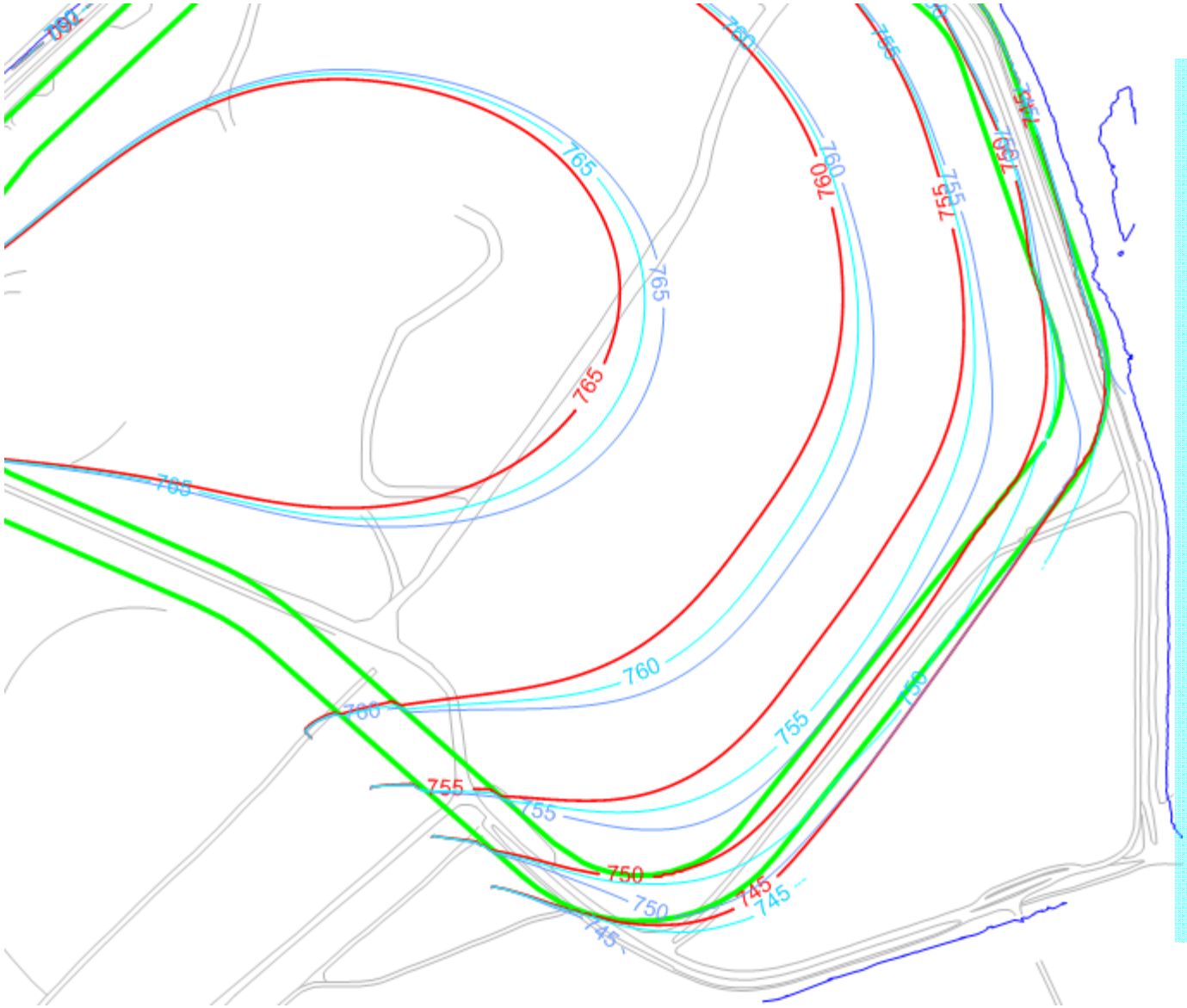
Model Results



Trench design Impact (Stilling Pond)

RED – Base Case with 3 ft walls (open water @ 742)

Purple Blue – uniform sloped trench to either ends (**748** to 742 at water bodies)

Orange – flat @ **748** in Pond and then slope to water body @ 742) at both ends.

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Predicted Flux Rates

Trench Design		Flux to the boundary along Stilling Pond (cf/day) - from Dredgign Cell Side Only	Flux to the boundary along Swan Pond Embayment and Emory River (cf/day)		Flux to the boundary along Stilling Pond (GPM) - from Dredgign Cell Side Only	Flux to the boundary along Swan Pond Embayment and Emory River (GPM)
Original Best Estimate - Constant Head @ 742-msl (Open Water)		188.81	322.32		0.98	1.67
Sloped Trench @ 750-msl		177.77	329.77		0.92	1.71
Sloped Trench @ 748-msl		181.52	327.55		0.94	1.70
Flat Trench @ 750-msl		159.49	345.57		0.83	1.79
Flat Trench @ 748-msl		166.85	336.47		0.87	1.75

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