Description of the City/SAJB Groundwater Flow Model

Spokane Valley – Rathdrum Prairie Aquifer

Prepared by

John Porcello, LHG - GSI Water Solutions

Walt Burt, LHG - GSI Water Solutions

August 13, 2013

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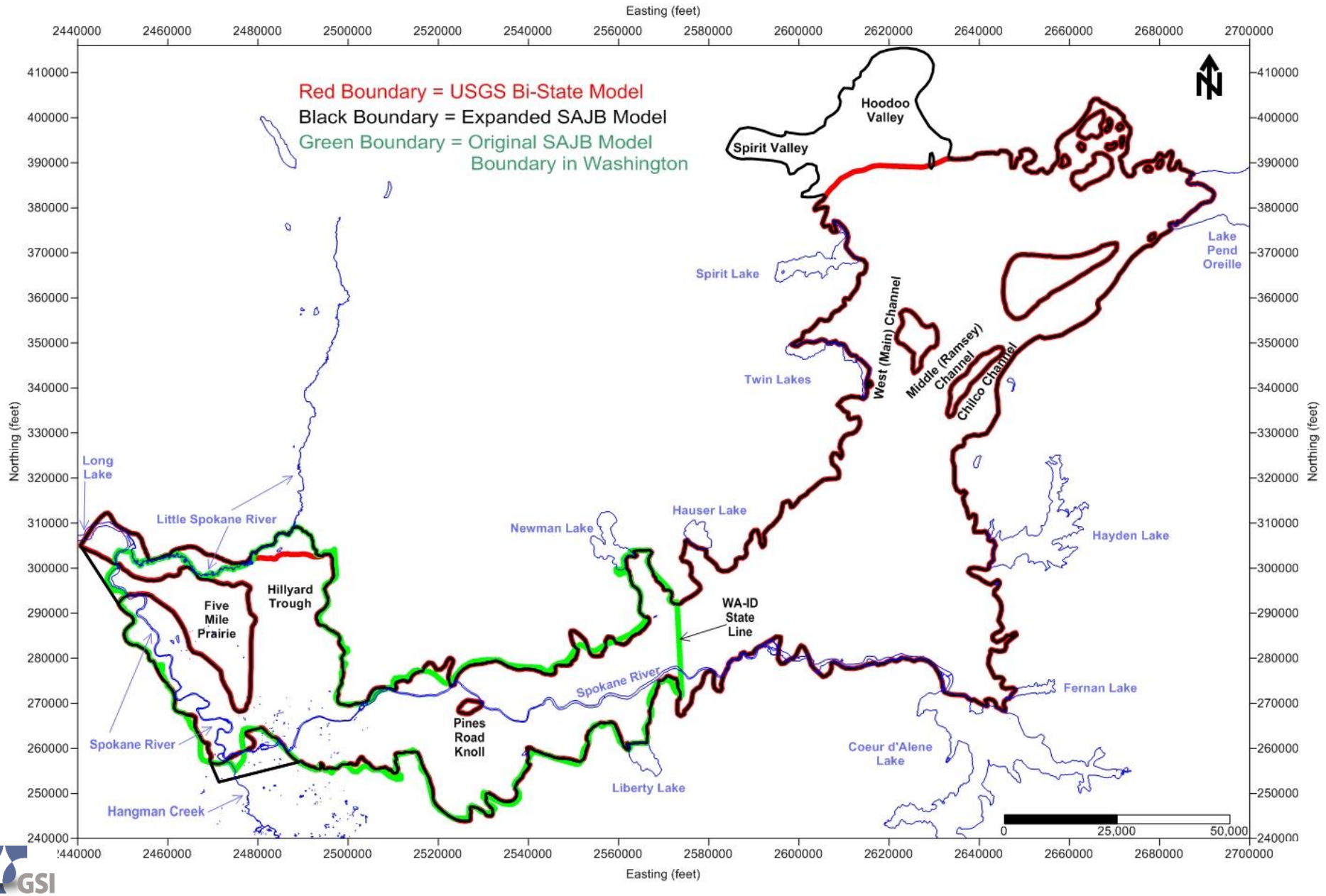
City/SAJB Model and Bi-State Model Areas



Groundwater Modeling History

1981: USGS

- Simple 1-layer model
- Groundwater levels 100+ feet too low in Hillyard Trough
- Reflected lack of bedrock data
  - Five Mile Prairie, Trinity Trough, Western Arm versus Hillyard Trough

1994-2000: City, SAJB, CH2M HILL

- New 3-layer model in Washington, using flexible mesh
- Data collection program provided bedrock data
- Model calibration subsequently “fell into place”
- Calibrated to two seasons: Fall 94 and Spring 95
- Model was used to delineate wellhead protection areas

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Groundwater Modeling History

2000: EWU Bi-State Model

- MODFLOW: Rectangular cells, rather than flexible mesh
- Scale was rather coarse (1/2-mile cells, computing limitations)
  - Fine for basin-scale and subregional-scale analysis
  - Not as adaptable to analyses in wellfields and along rivers

Mid-2000s: USGS Bi-State Model

- More detailed resolution (MODFLOW, 1/4-mile cells)
- Focus was on basin and sub-regional scale
- Detailed transient calibration (monthly, 1990-2005)
- Only 1 layer (except 3 layers in Hillyard Trough)
- Appears to not use the correct aquifer thickness

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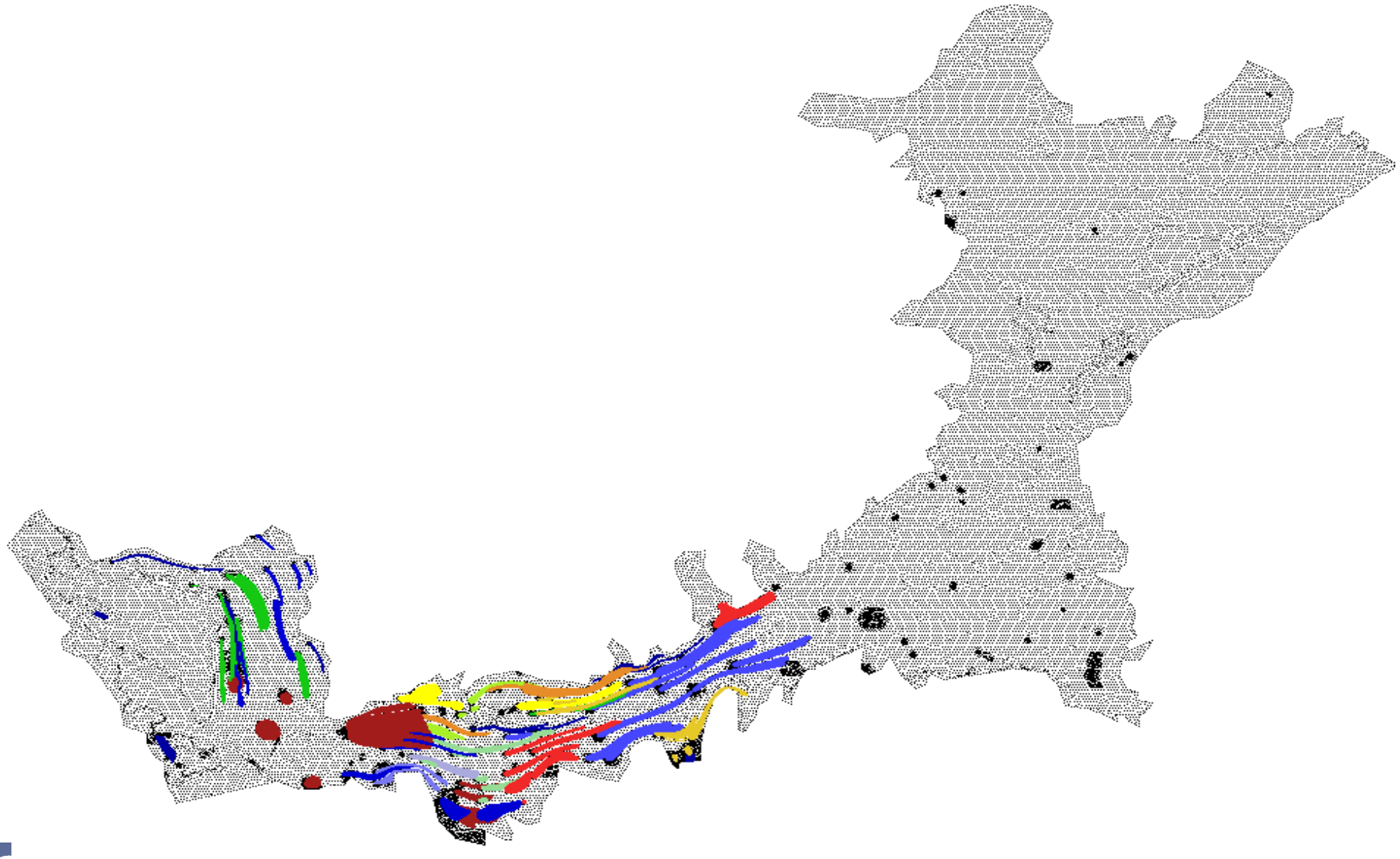
Groundwater Modeling History

2012: City/SAJB Model Expansion

- Objective: Create a high-resolution aquifer-wide model
  - Idaho: Incorporate Bi-State model as much as possible
  - Washington: From both the City/SAJB model and the Bi-State model
- Study effects of stormwater recharge facilities on source water protection areas (SWPAs)
- Verify the method for delineating SWPAs

2013: Finalize SWPAs (City & SAJB)

Special Wellhead Protection Areas (Model View)



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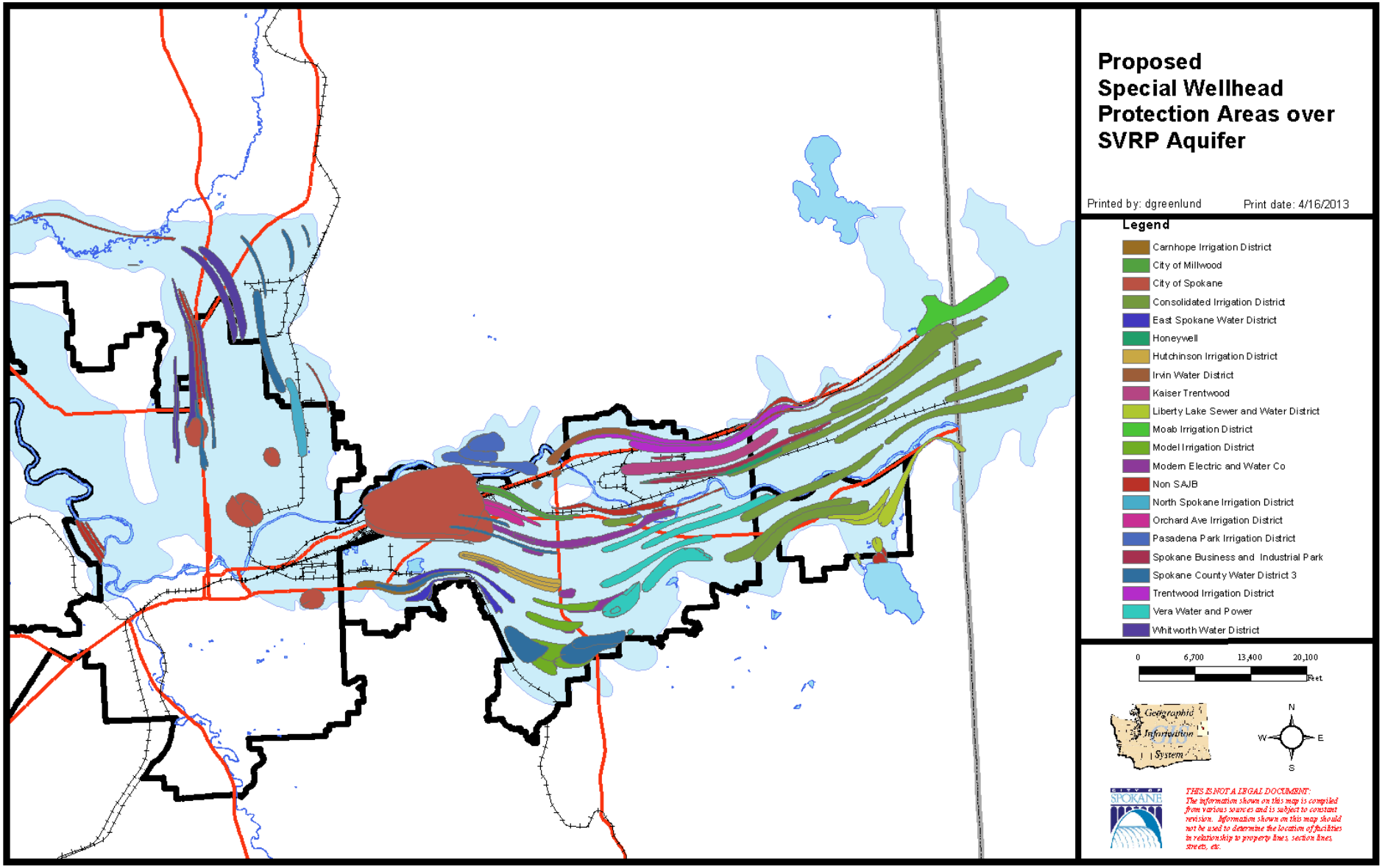
Special Wellhead Protection Areas (ArcGIS)



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2012 City/SAJB Model Project

Objectives for the Expansion Process and for Use of the Updated Model

1. Support wellhead protection planning
   → Avoid truncation of capture zones at state line
2. Provide a high-resolution, up-to-date tool for
   → Wellfield-scale analyses
   → Groundwater resource management at other scales

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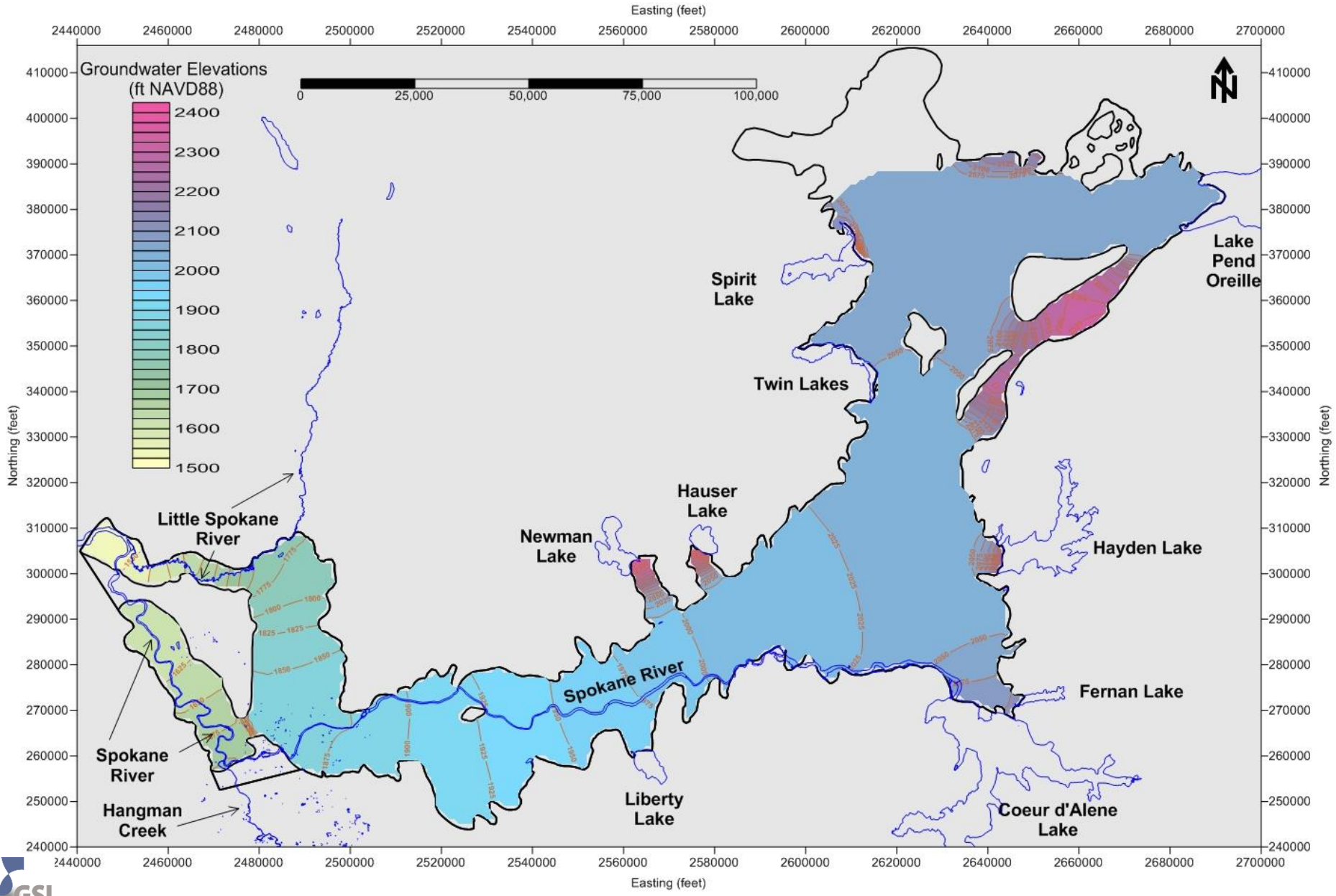
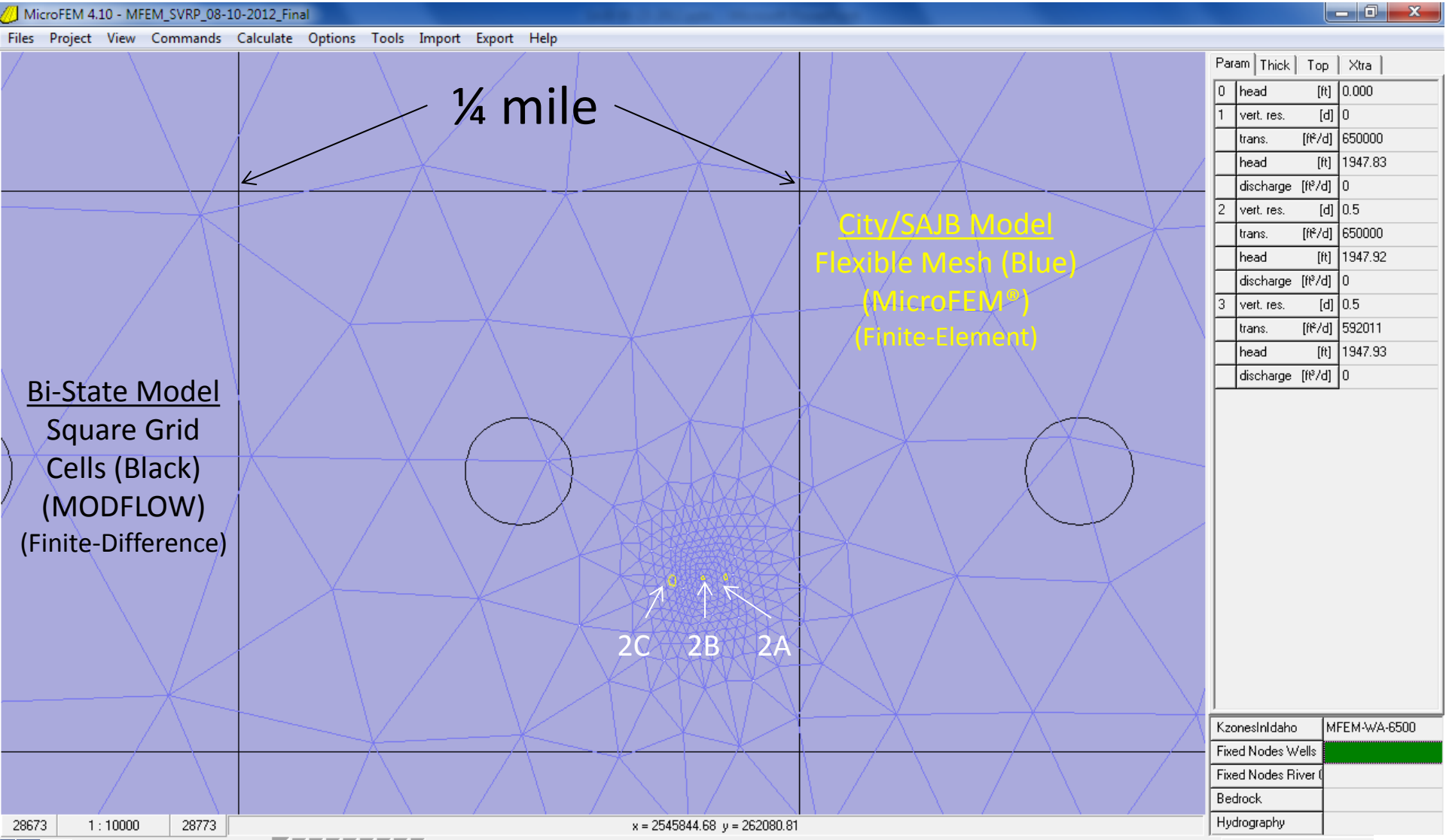
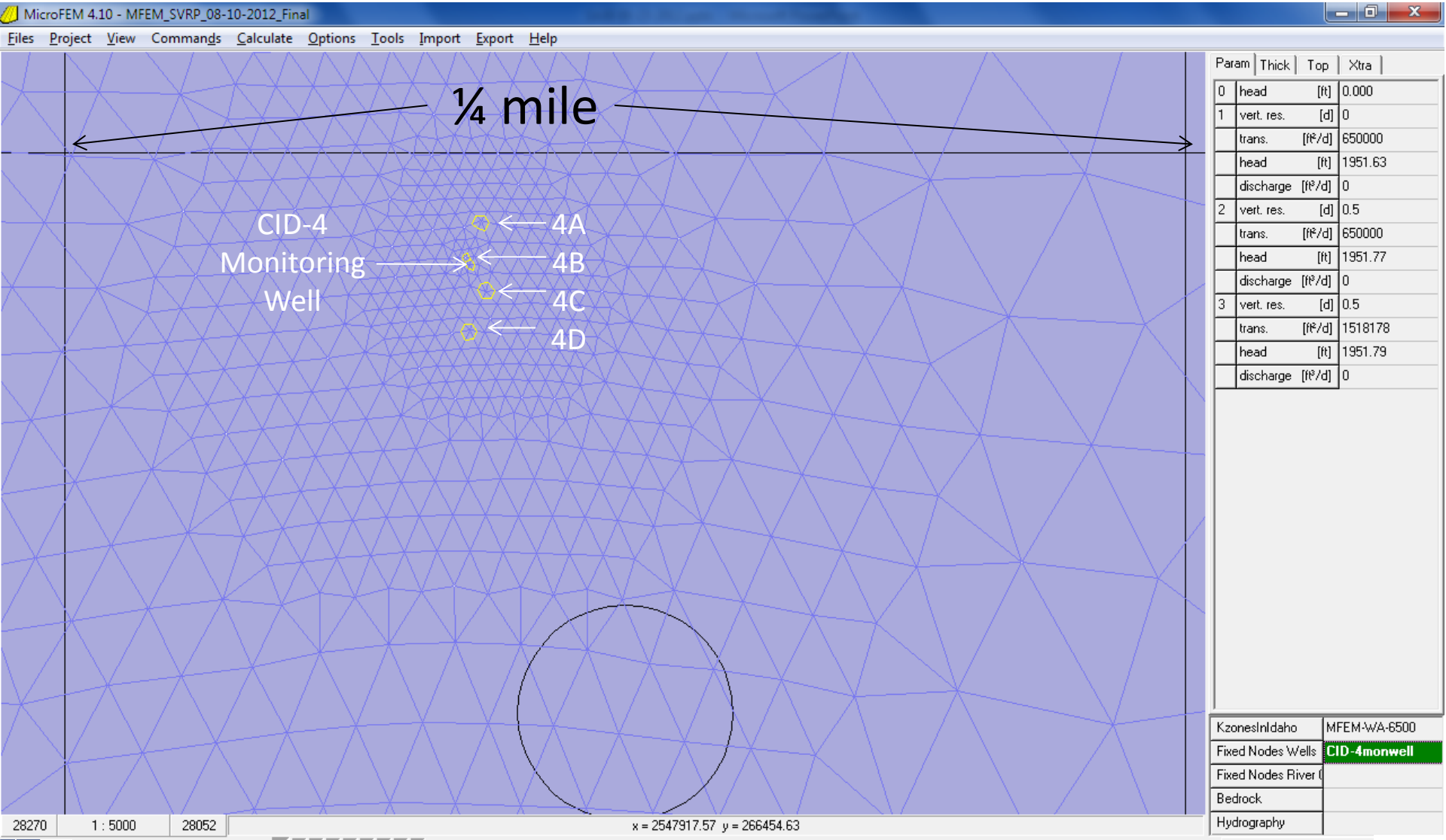
City/SAJB Model - Groundwater Elevations



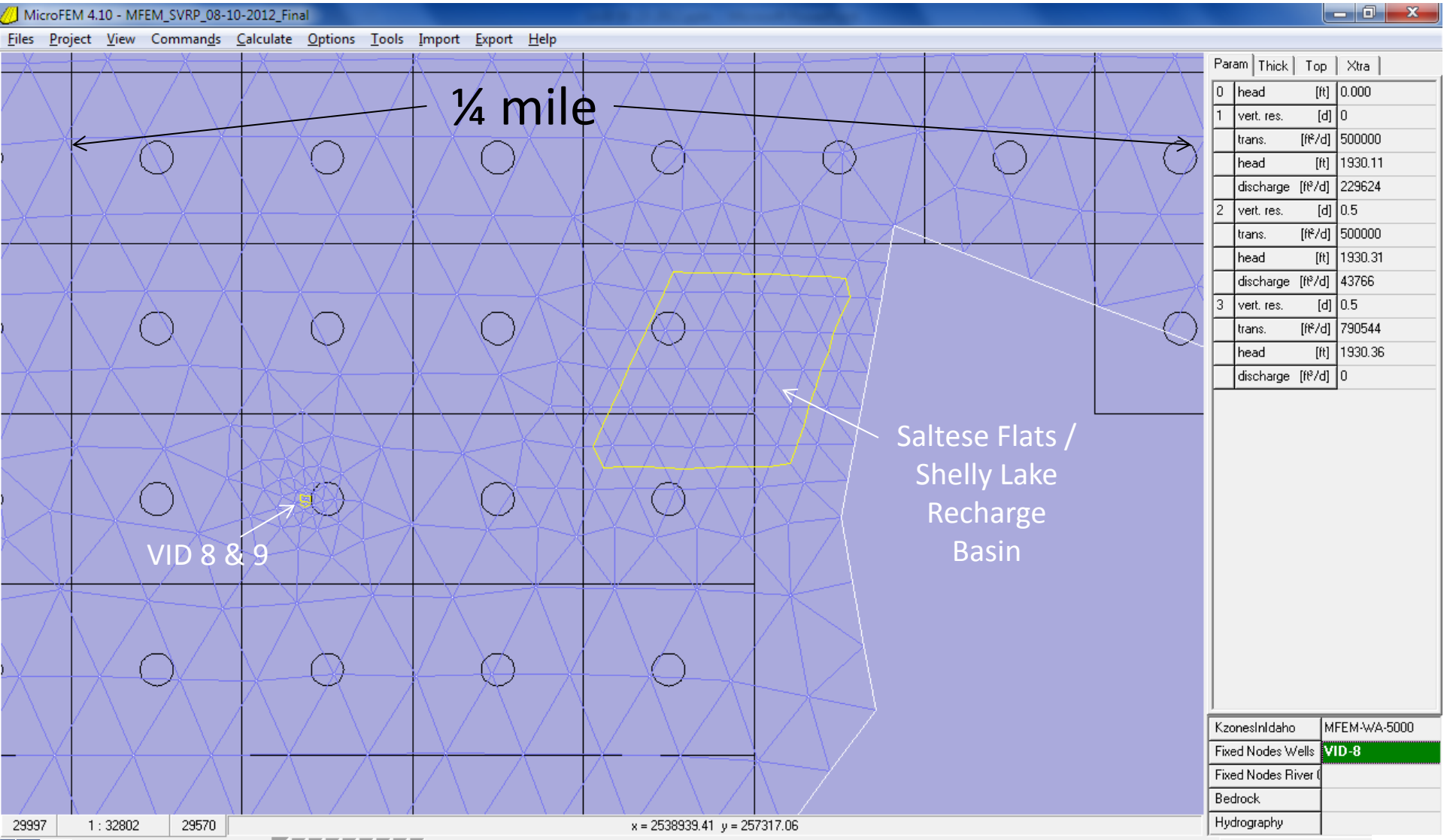
City/SAJB and Bi-State Model Grids at CID-2



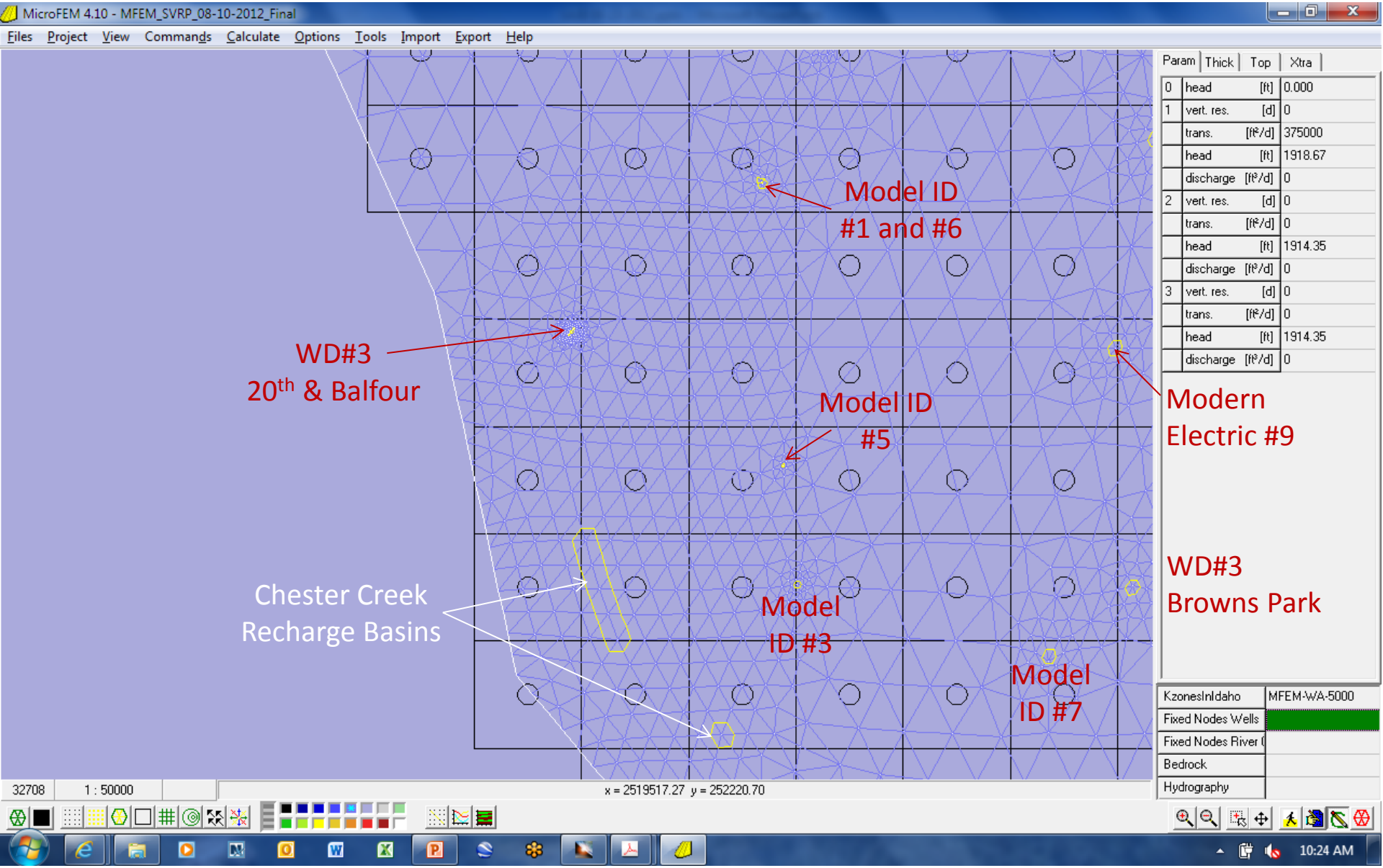
City/SAJB and Bi-State Model Grids at CID-4



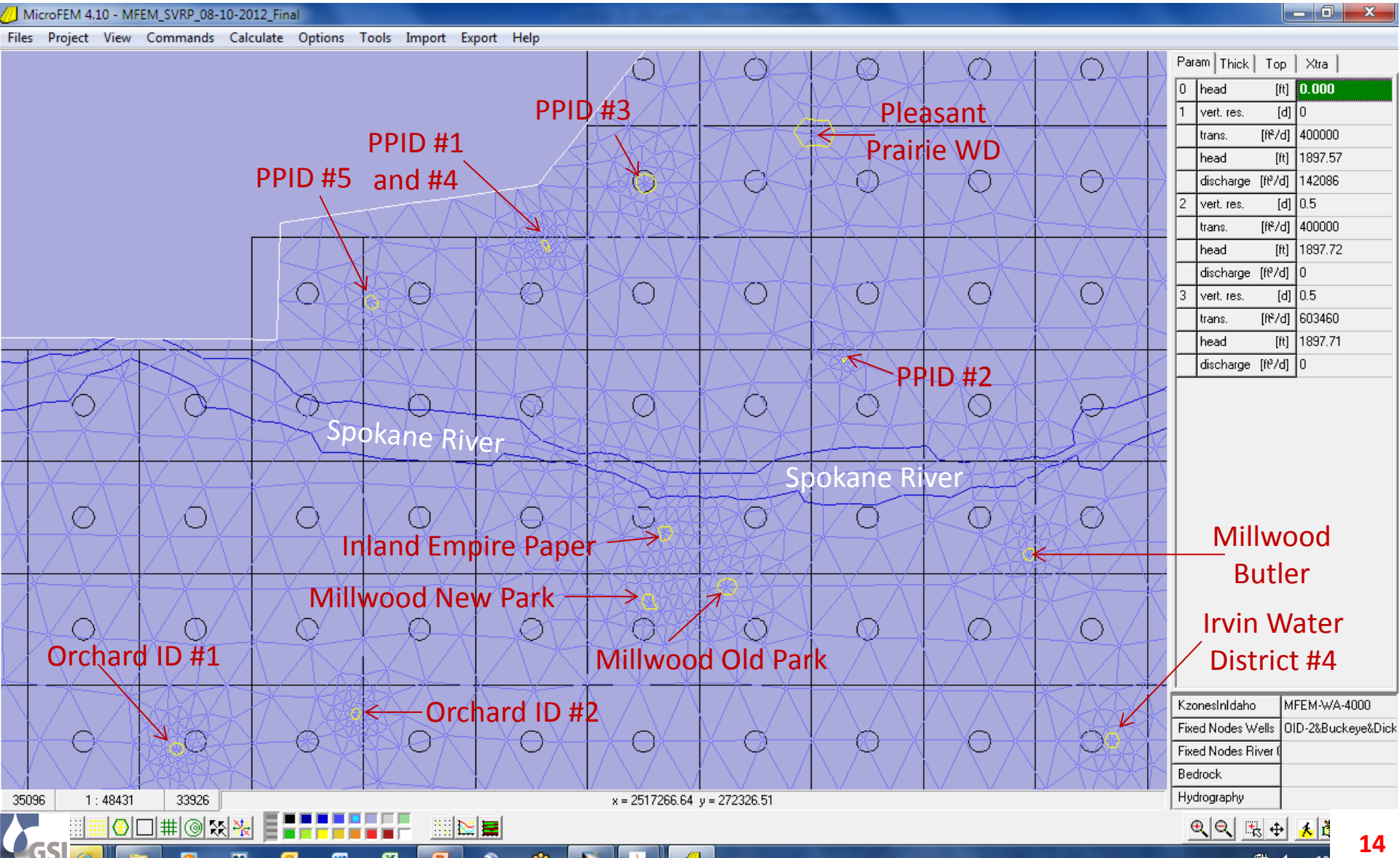
City/SAJB and Bi-State Model Grids at Saltese Flats / Shelley Lake Recharge Basin



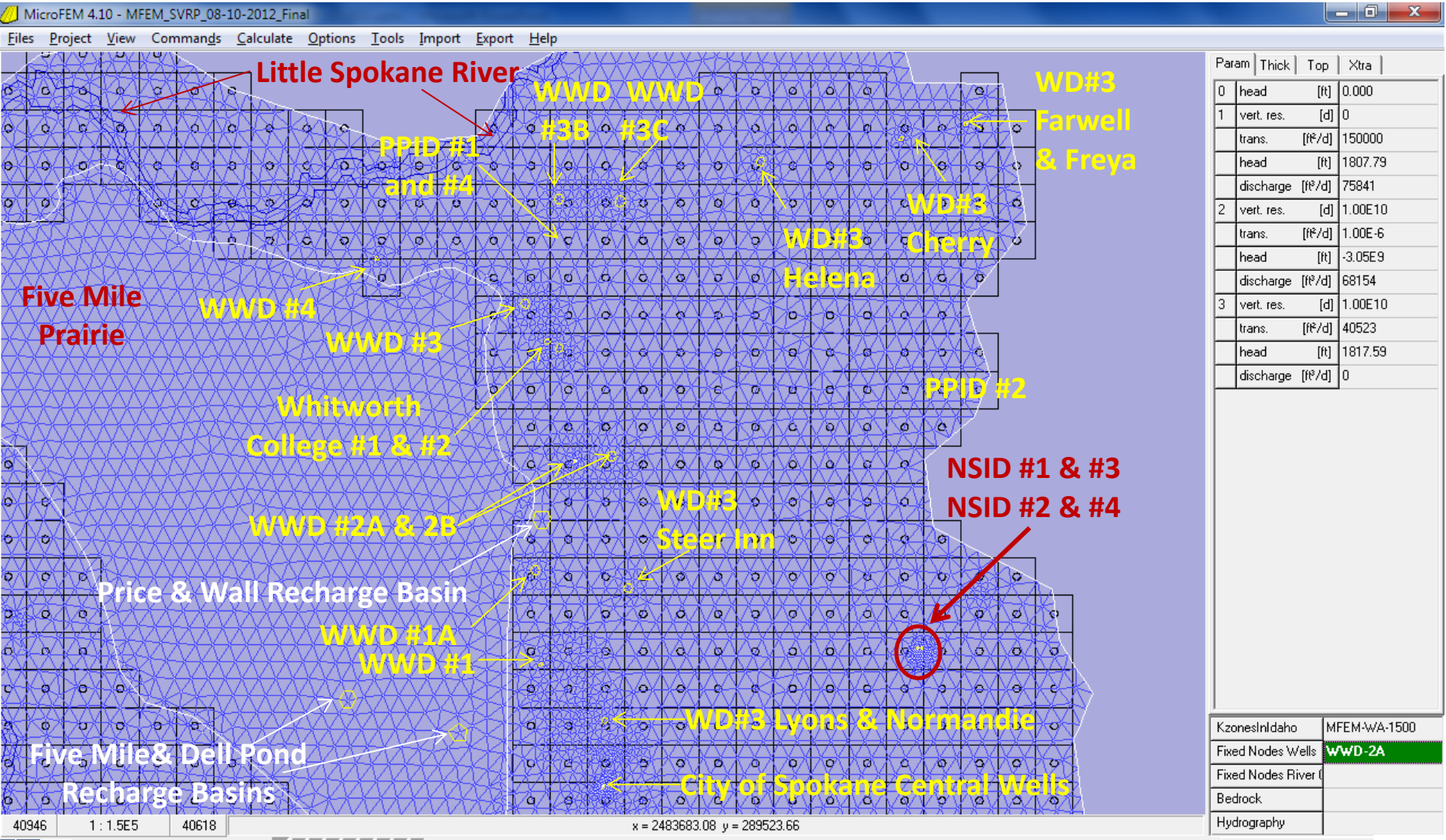
City/SAJB and Bi-State Model Grids at Chester Creek



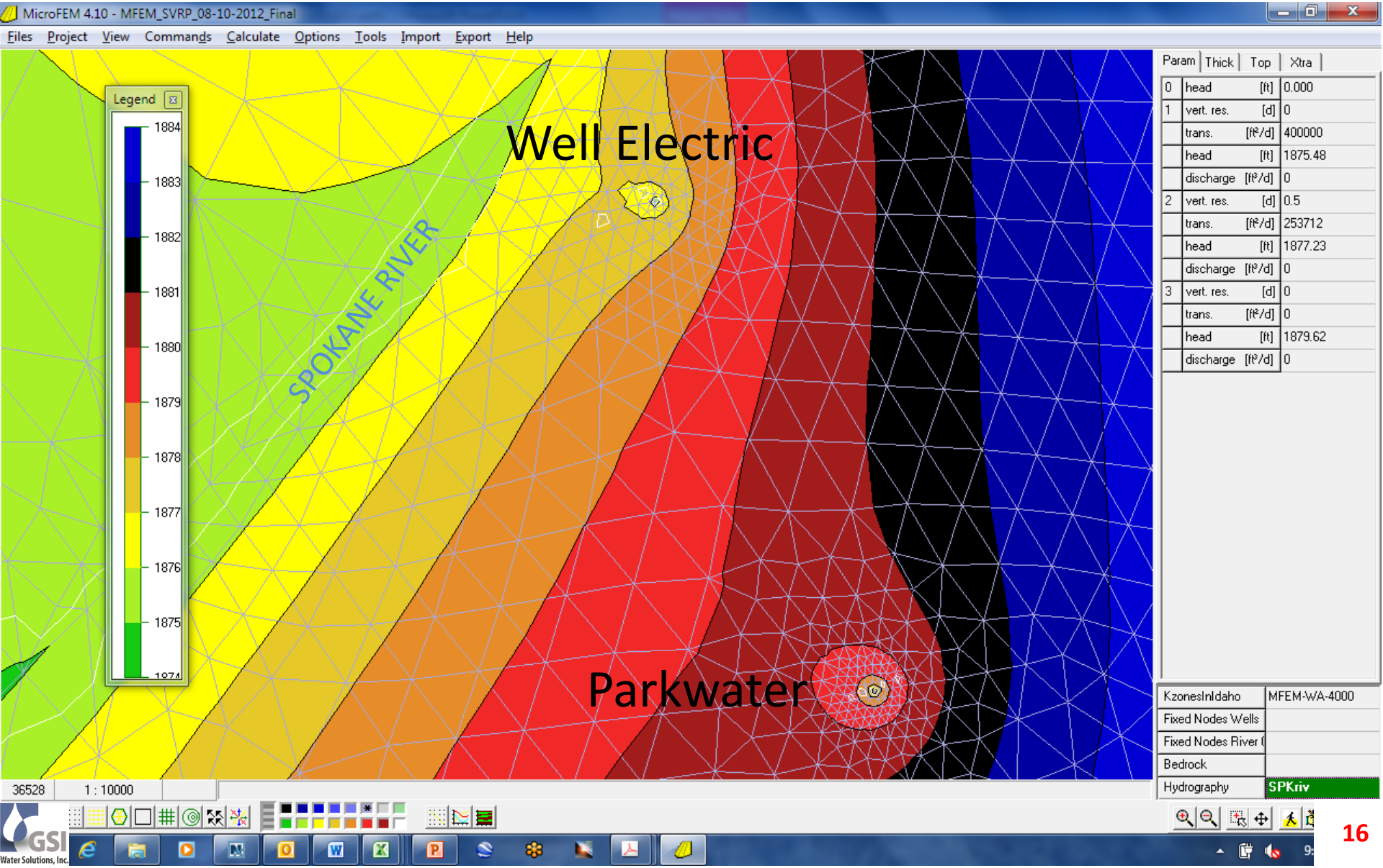
City/SAJB and Bi-State Model Grids at PPID, OID, Millwood



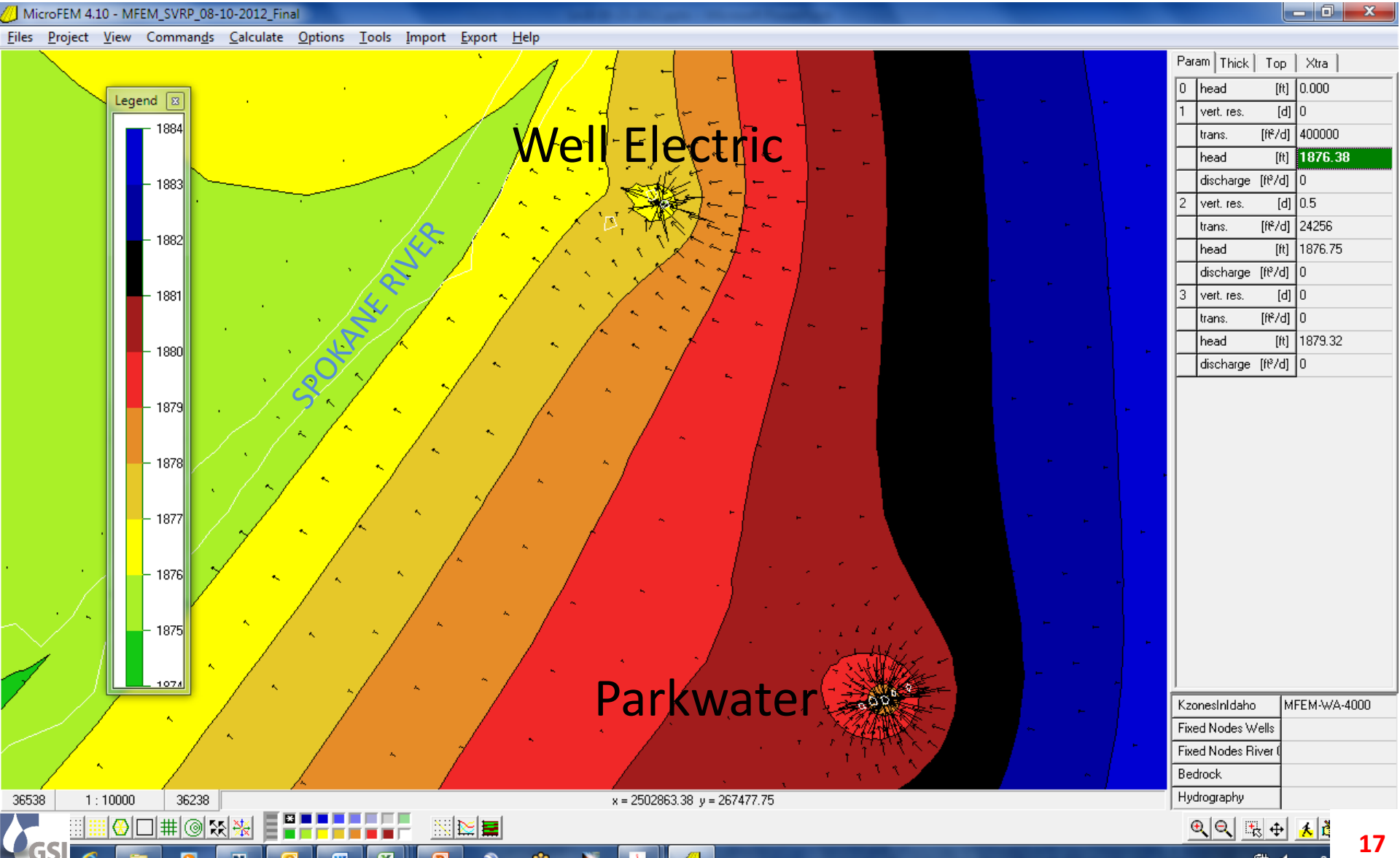
City/SAJB and Bi-State Model Grids in Hillyard Trough



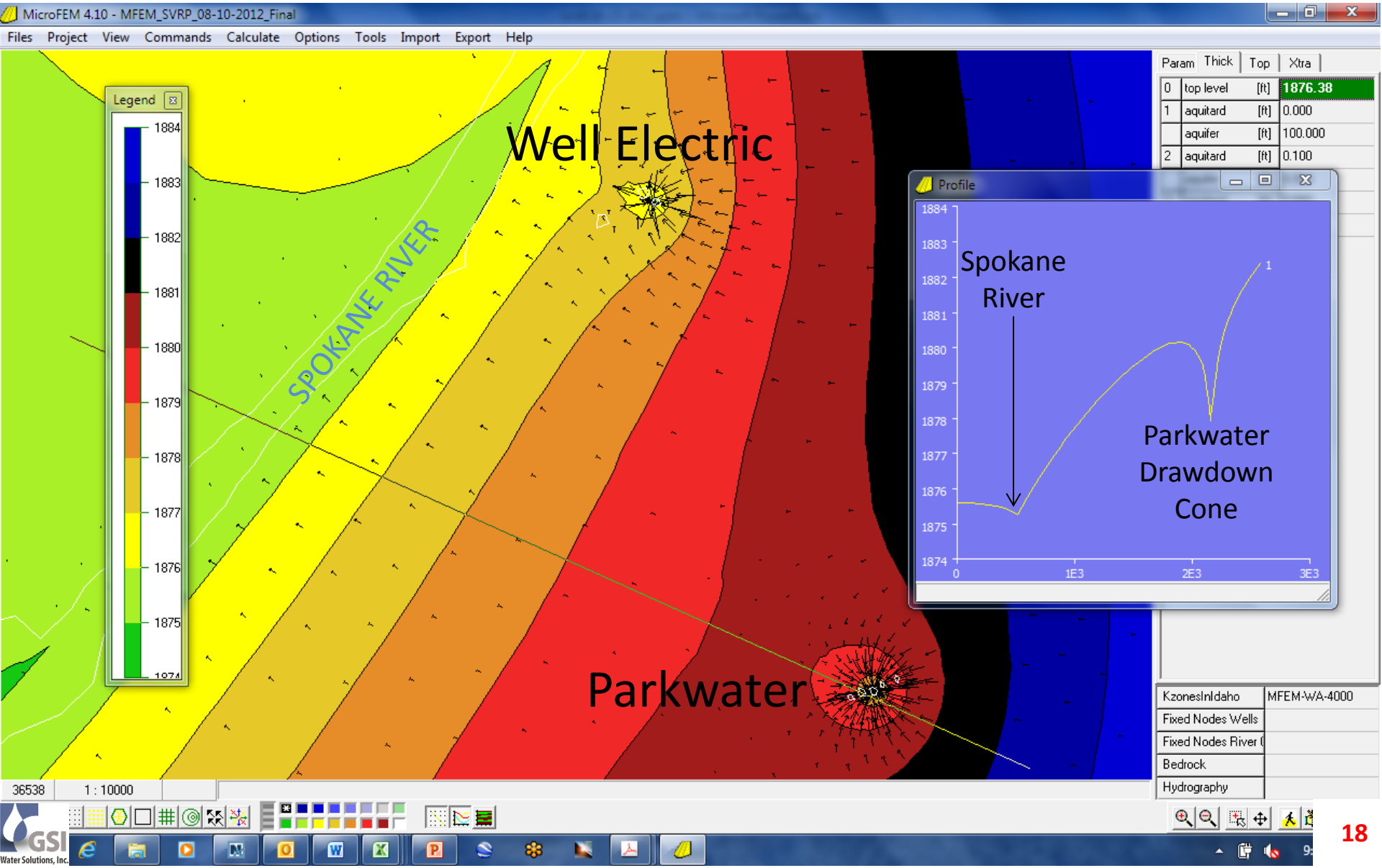
Drawdown Cones at Parkwater and Well Electric



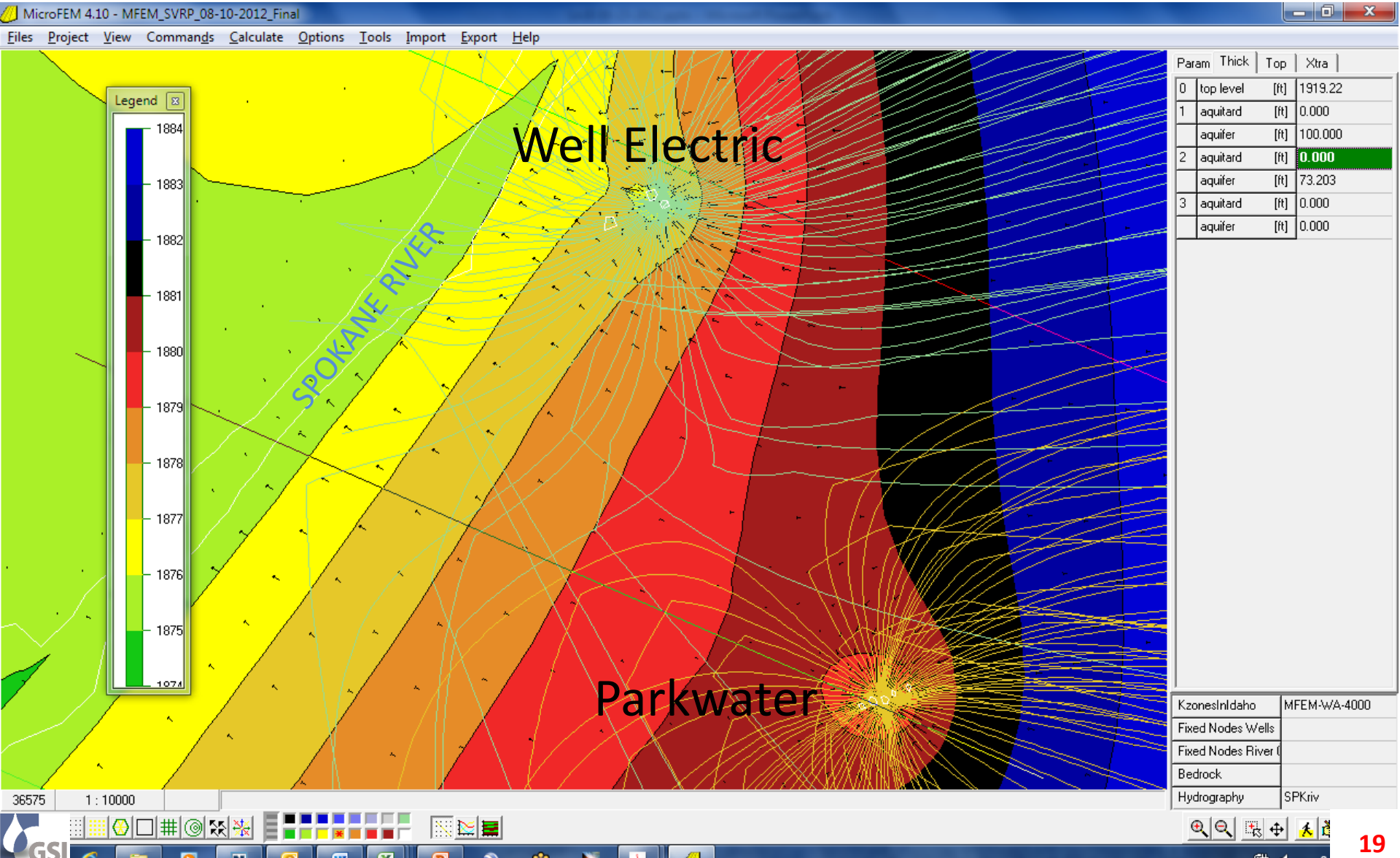
Flow Patterns at Parkwater and Well Electric



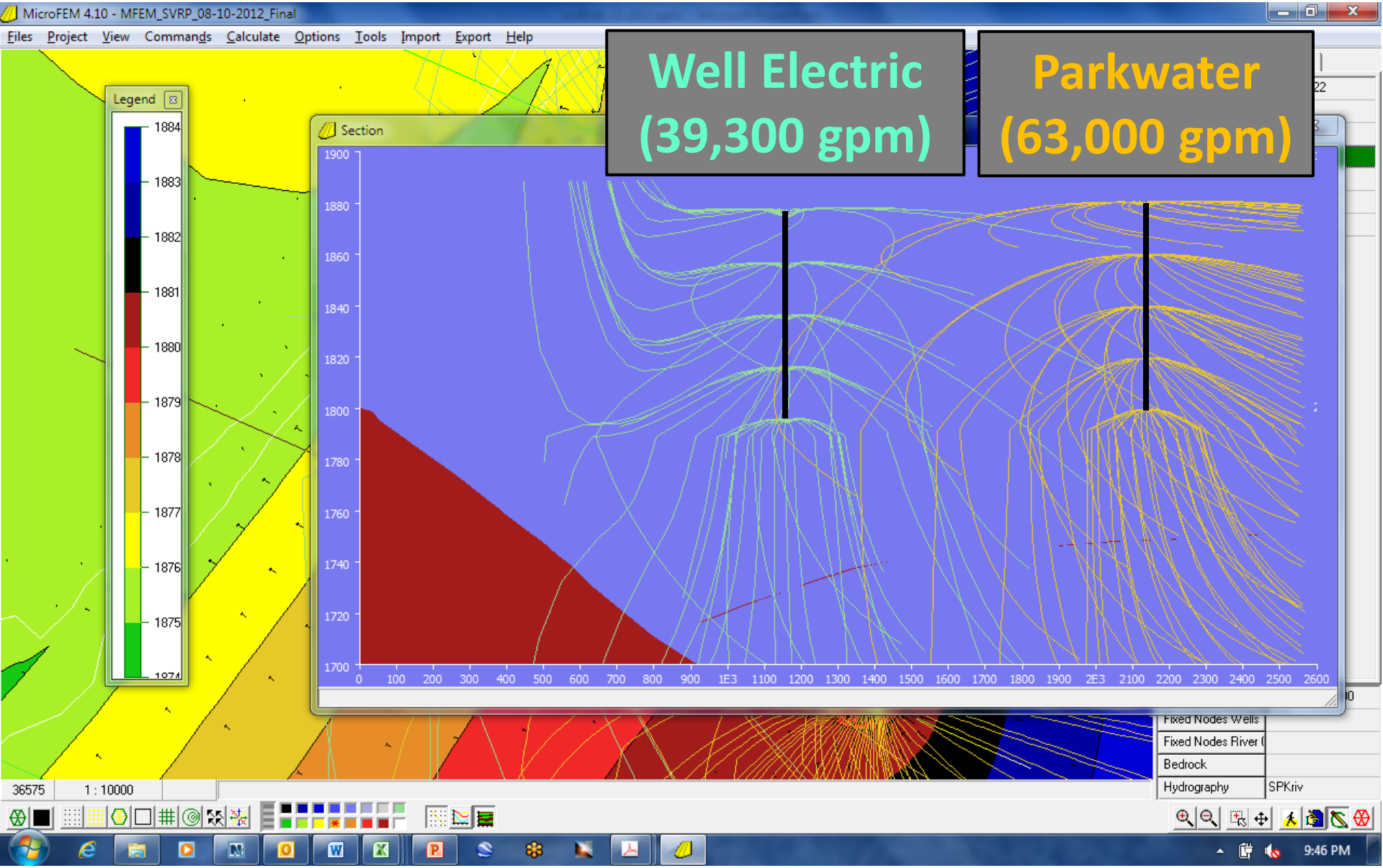
Water Table Profile in Cross-Sectional View



Three-Dimensional Groundwater Flow Paths (Projected onto Plan View)



Capture In Cross-Sectional View



Simulated Aquifer-Wide Water Budget (Average Annual Conditions)

Water Budget Term	Rate (cfs)		
	GW Recharge	GW Discharge	Net Recharge
MODEL LAYER 1			
Precipitation	406	---	406
Rivers	607	851	-244
Lateral Subsurface Flow	294	67	227
Pumping	---	365	-365
Vertical Leakage (Layer 2)	1,055	1,071	-16
Total Flow	2,362	2,355	
Error in Flow			7
Error (%)			0.29%
MODEL LAYER 2			
Vertical leakage (Layer 1)	1,071	1,055	16
Lateral Subsurface Flow	6	6	0
Pumping	---	9	-9
Vertical leakage (Layer 3)	924	932	-8
Total Flow	2,001	2,001	
Error in Flow			-1
Error (%)			-0.03%
MODEL LAYER 3			
Vertical leakage (Layer 2)	932	924	8
Lateral Subsurface Flow	10	18	-8
Pumping	---	0	0
Total Flow	941	941	
Error in Flow			0
Error (%)			-0.000007%
TOTAL			
Precipitation	406	---	406
Rivers	607	851	-244
Lateral Subsurface Flow	309	90	219
Pumping	---	374	-374
Total Flow	1,322	1,315	
Error in Flow			6
Error (%)			0.48%

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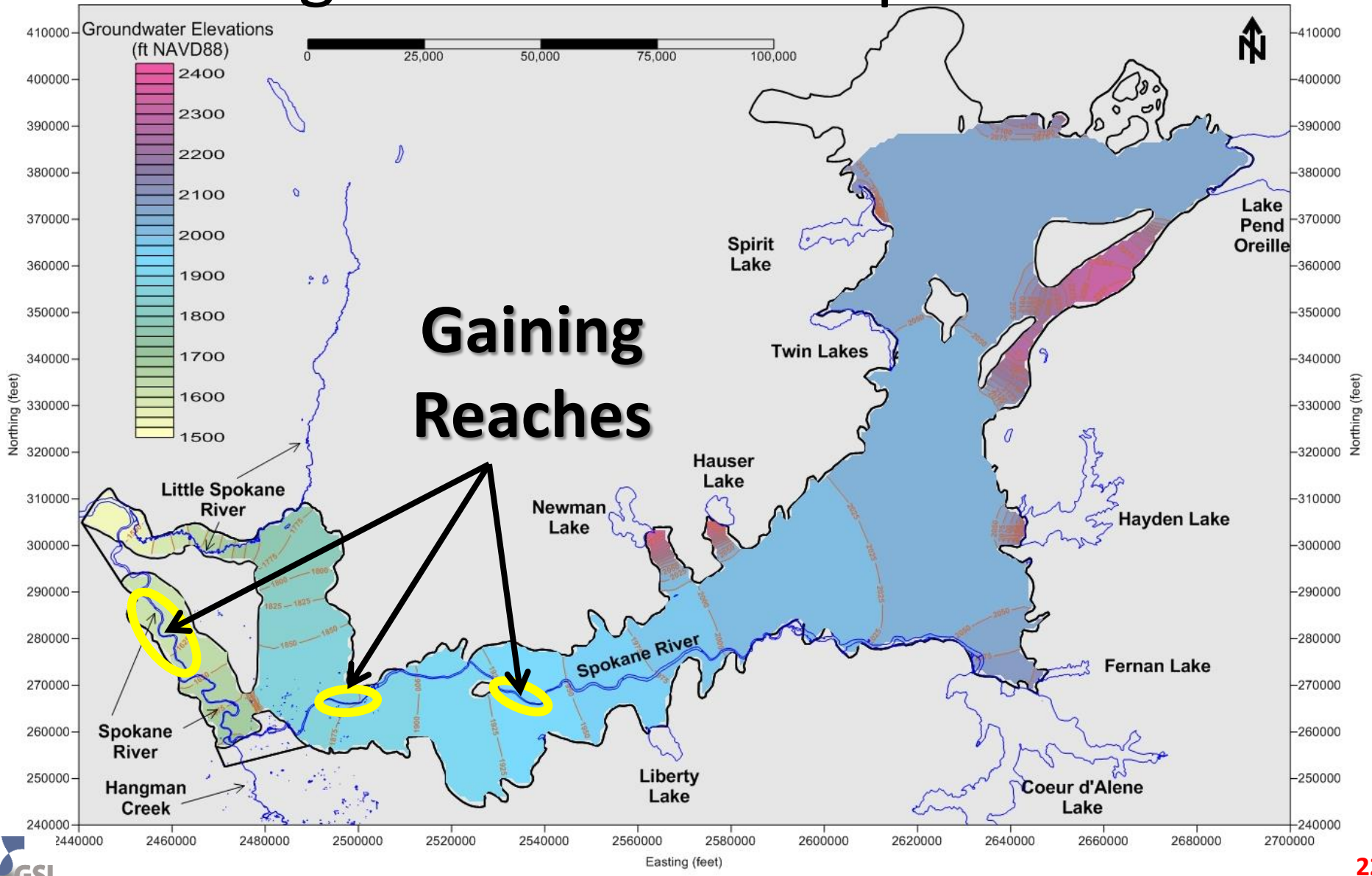
Groundwater Elevations and Gaining Reaches of the Spokane River



Simulated Spokane River / Aquifer Exchanges
(Average Annual Conditions)

Simulated Annual Average Groundwater Exchanges (cfs) with the Spokane River in the City/SAJB 2012 Regional Model		Gaging Station		Exchange (cfs)
		Upstream	Downstream	
Coeur d'Alene Lake to Sullivan Road	-307	Lake CDA Bed Seepage		-41
		Lake CDA	Stateline	-128
		Stateline	BAR	-63
		BAR	SUL	-75
Sullivan Road to Plantes Ferry	**198**	**SUL**	**KAI**	**130**
		KAI	ETR	57
		ETR	PLF	11
Plantes Ferry to Upriver Dam Forebay	-13	PLF	ARG	-6
		ARG	UDF	-7
Upriver Dam Tailway to Greene Street Bridge	**241**	**UDT**	**GRE**	**241**
Greene Street Bridge to Monroe Street Bridge	16	GRE	MIS	-1
		MIS	SIR	15
		SIR	MST	2
Western Arm of Aquifer (Below Monroe Street Bridge)	24	MST	USGS Gage	-28
		USGS Gage	TJM	-93
		TJM	BAP	-10
		BAP	**7ML**	**140**
		7ML	9DF	15

Negative values indicate losing river reach.

Positive values indicate gaining river reach.

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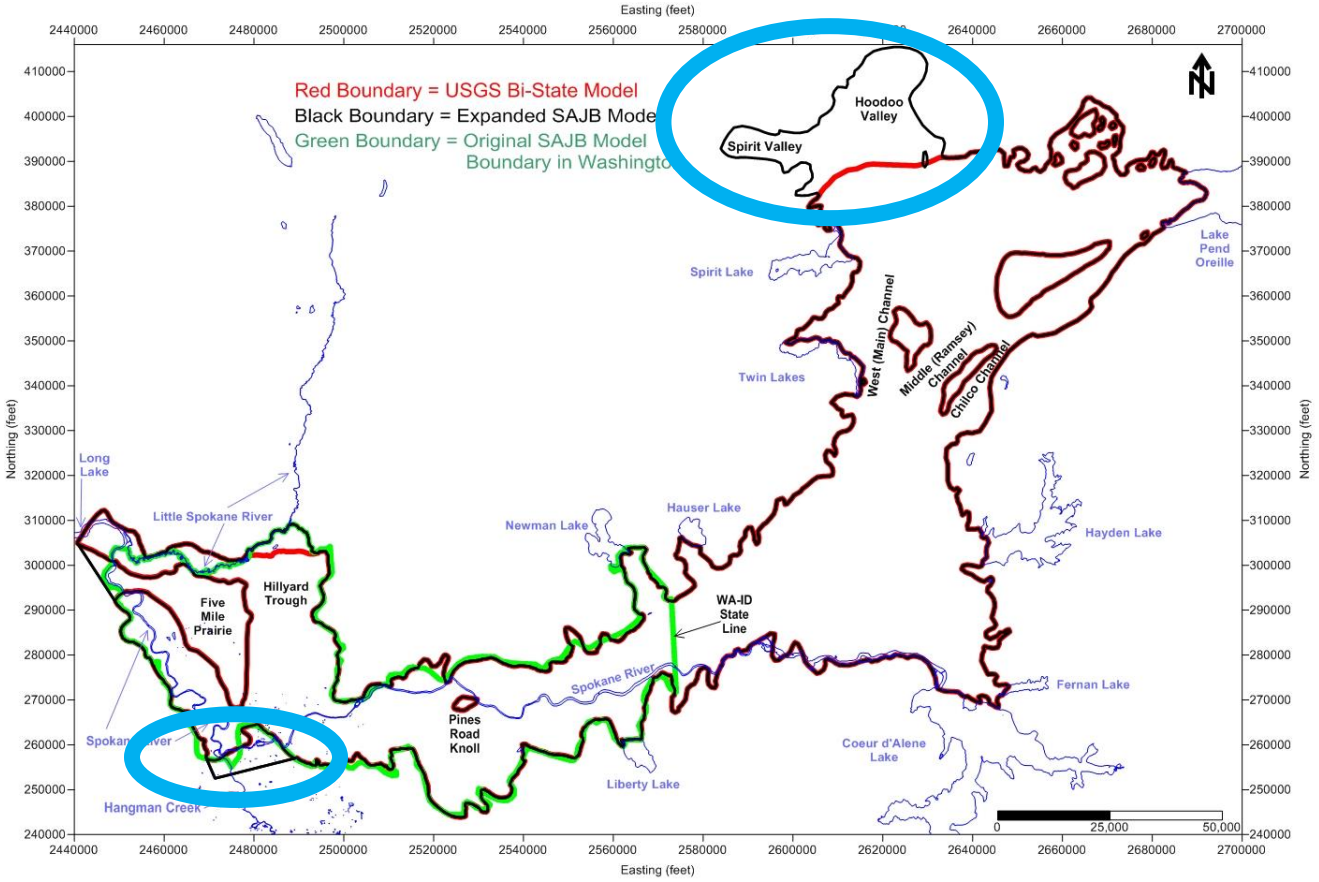
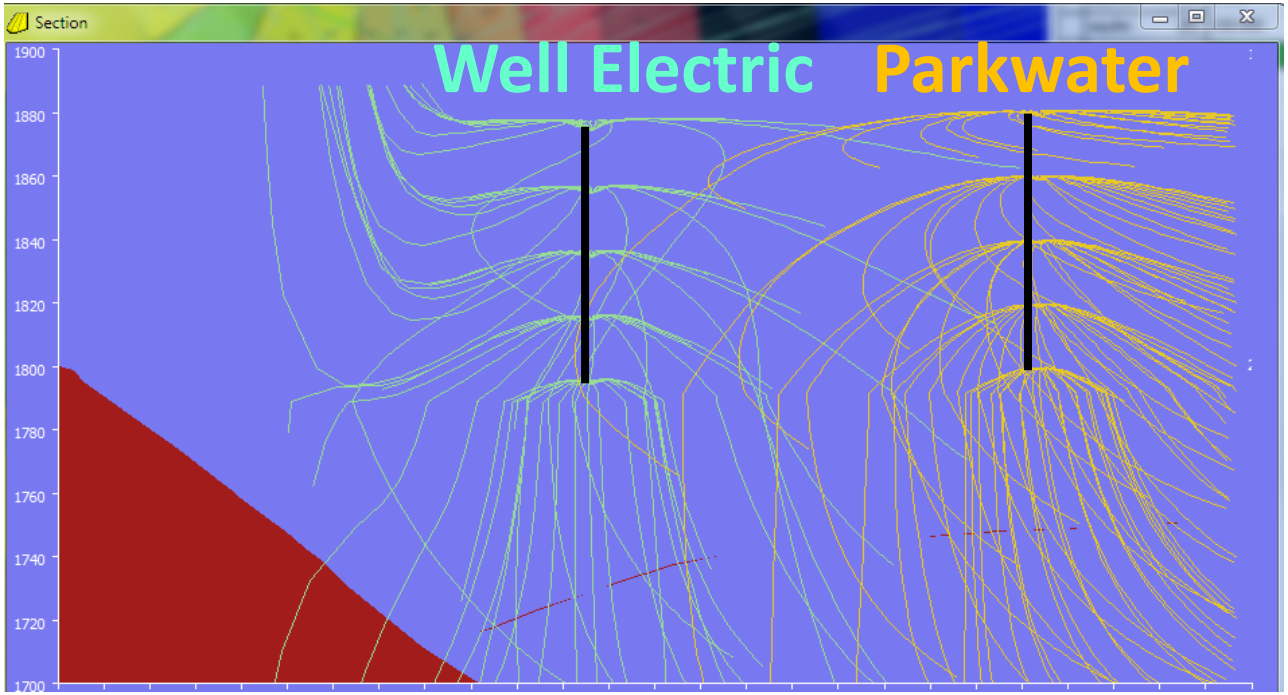
Other Aspects of City/SAJB Model

1. Grid includes some adjoining areas with alluvial deposits that might be of interest in the future
   - Mouth of Hangman Creek; Spirit and Hoodoo valleys in Idaho



Other Aspects of City/SAJB Model

2. Uses three layers to simulate groundwater flow
   - Most wells in upper 100 feet of aquifer (Layer 1)
   - Few wells in Layer 2 (depths of 100-200 ft below water table)
   - No wells in Layer 3 (more than 200 ft below water table)
   - Bi-State model has just one layer, except north of city



Other Aspects of City/SAJB Model

3. Updated interpretation of aquifer thickness

   – Incorporate Ecology information near Greene Street Bridge

   – Reconcile discrepancies in USGS-published mapping

Groundwater Elevation minus Bedrock Elevation

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Aquifer Thickness

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Other Aspects of City/SAJB Model

USGS-Published Water Table Map

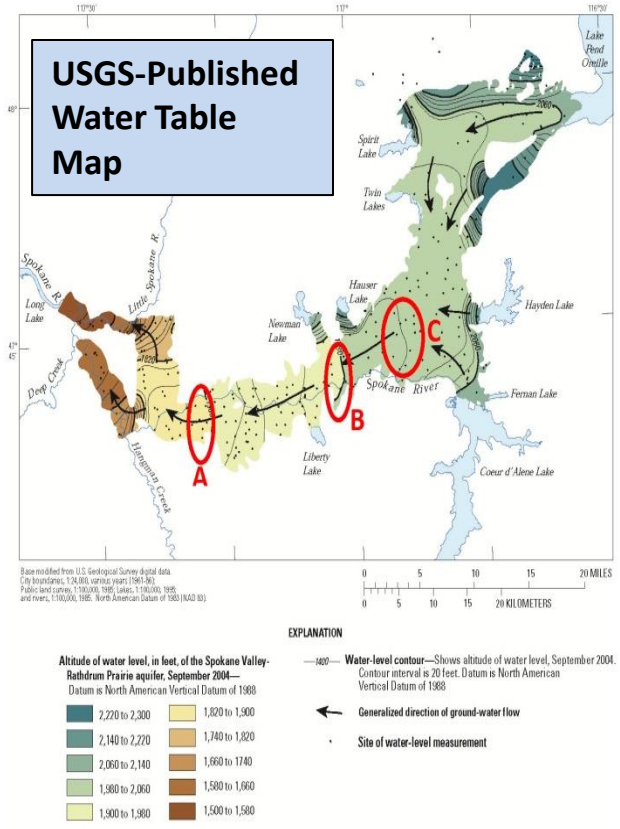

Figure 22. Ground-water levels for the Spokane Valley-Rathdrum Prairie aquifer, Washington and Idaho, September 2004 (revised after Campbell, 2005).

USGS-Published Bedrock Map

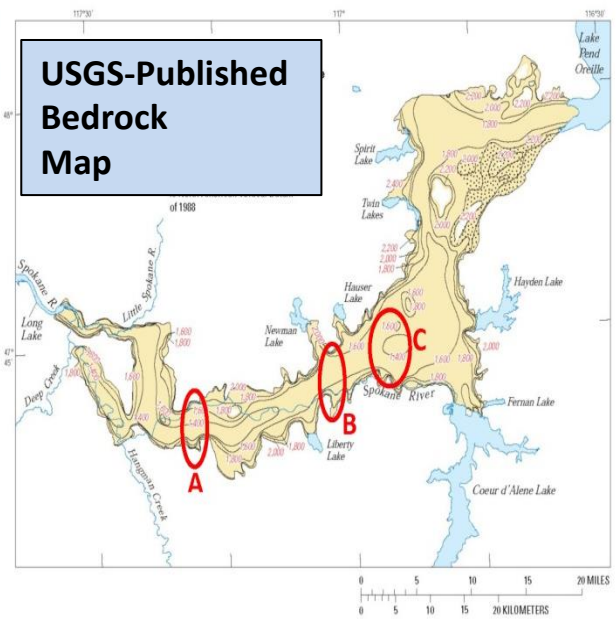

Figure 3. Approximate altitude of the base of the Spokane Valley-Rathdrum Prairie aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.

USGS-Published Aquifer Thickness Map

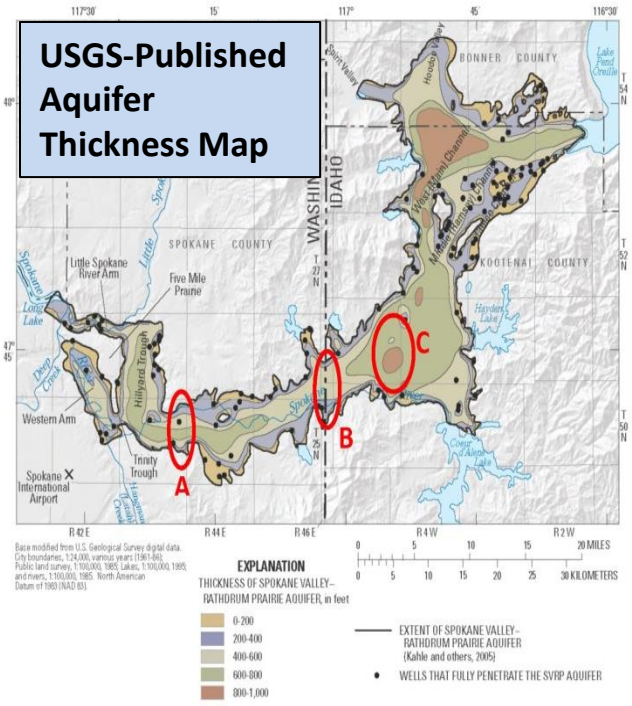

Figure 10. Approximate thickness of the Spokane Valley-Rathdrum Prairie aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho.

Location	Groundwater Elevation (feet) (Figure 22)	Aquifer Base Elevation (feet) (Figure 3)	GSI-Calculated Saturated Thickness (feet)	Published Saturated Thickness (feet) (Figure 10)	Difference (feet) in Saturated Thickness (Published minus GSI-Calculated)	Ratio of Published Values to GSI-Calculated Values
A (Trough Center)	1890	~ 1300 to 1400	~ 500 to 600	600 to 800	0 to 200	1.0 to 1.6
B (Trough Center)	1980	~ 1400 to 1500	~ 500 to 600	400 to 600	-200 to 100	0.7 to 1.2
C (Deepest Area)	2000	~ 1300 to 1400	~ 600 to 700	800 to 1000	100 to 400	1.2 to 1.4

Note: The groundwater elevation contour map (Figure 22) and the aquifer base elevation map (Figure 3) are from Hsieh and others (2007). The saturated thickness contour map (Figure 10) is from Kahle and Bartolino (2007).

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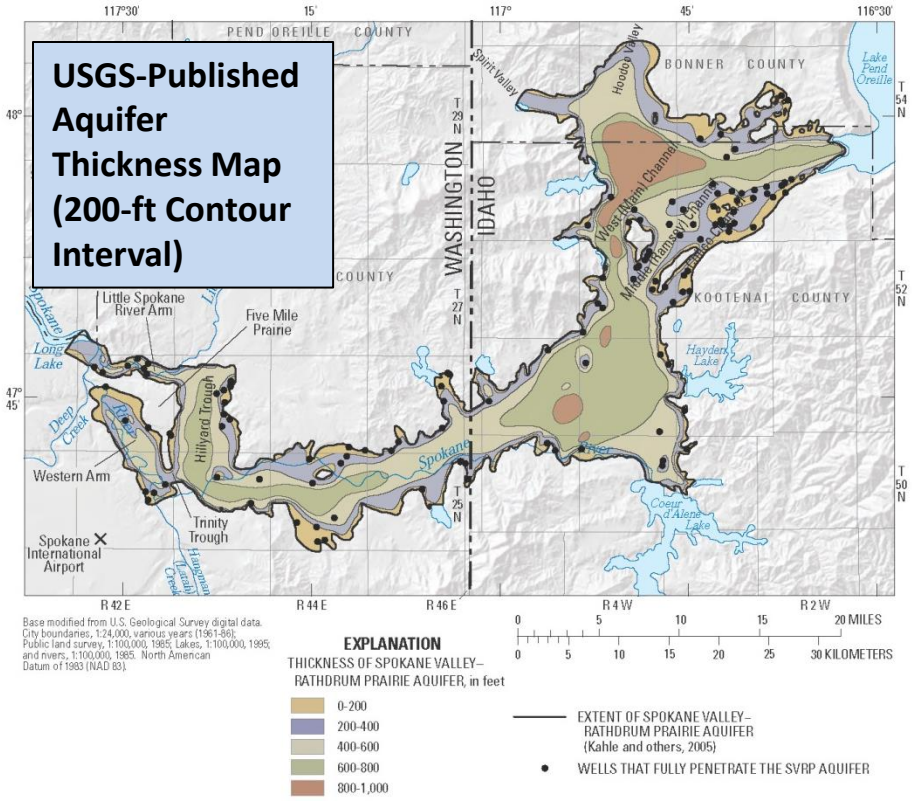
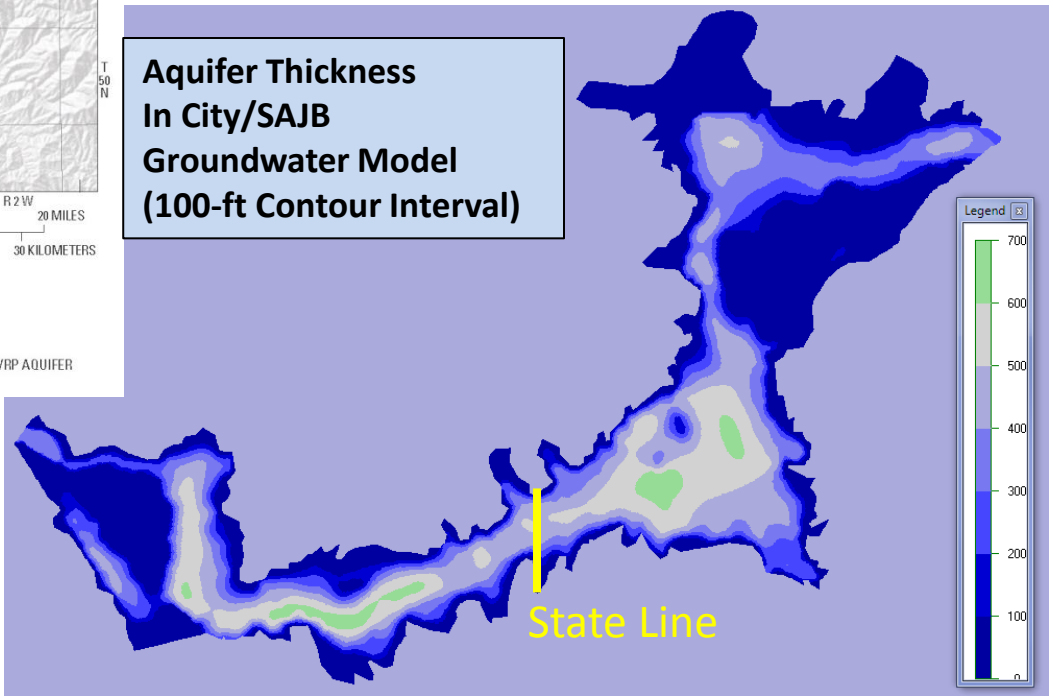
Other Aspects of City/SAJB Model

USGS-Published Aquifer Thickness Map (200-ft Contour Interval)



Aquifer Thickness In City/SAJB Groundwater Model (100-ft Contour Interval)



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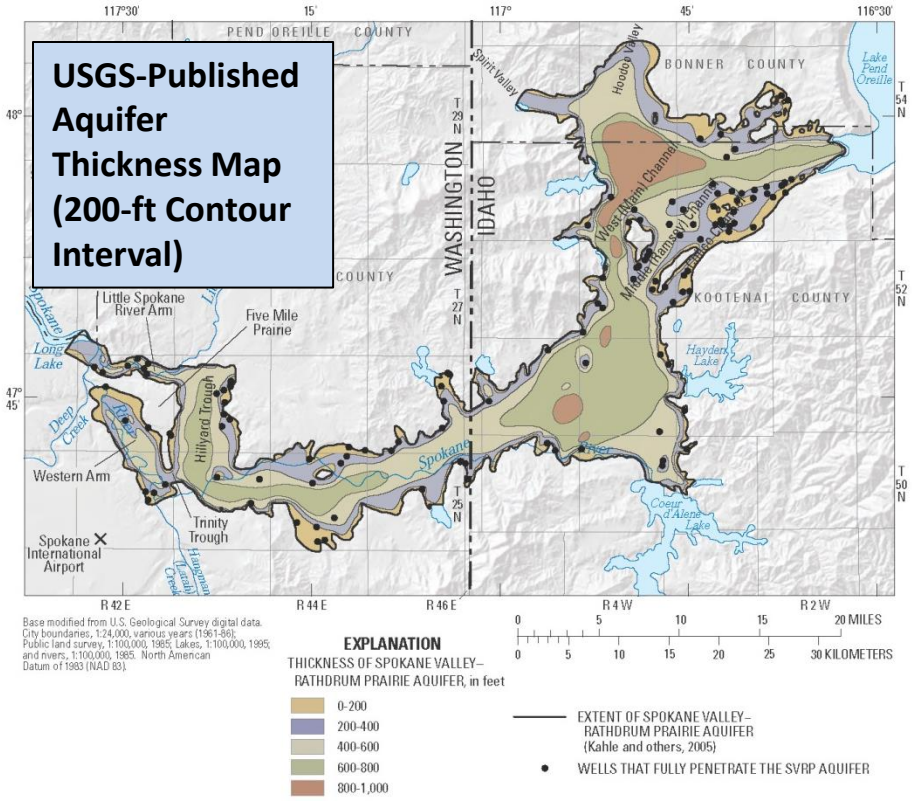
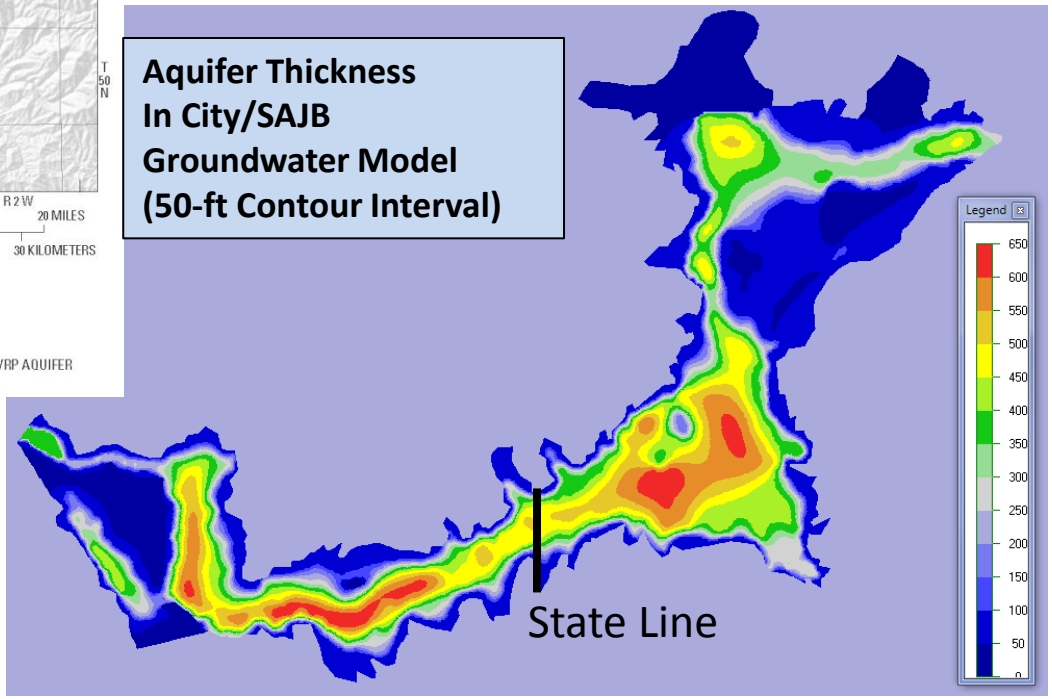
Other Aspects of City/SAJB Model

USGS-Published Aquifer Thickness Map (200-ft Contour Interval)



Aquifer Thickness In City/SAJB Groundwater Model (50-ft Contour Interval)



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Other Aspects of Expanded Model

4. Inflows from tributary drainages and lakes
   - 37 areas in Washington and 38 areas in Idaho
   - Same representation as in USGS Bi-State model
5. Multiple stage profiles for the Spokane River
   - Summer conditions (low-stage / low-flow)
   - Spring conditions (high-stage / high-flow)
   - Annual average conditions

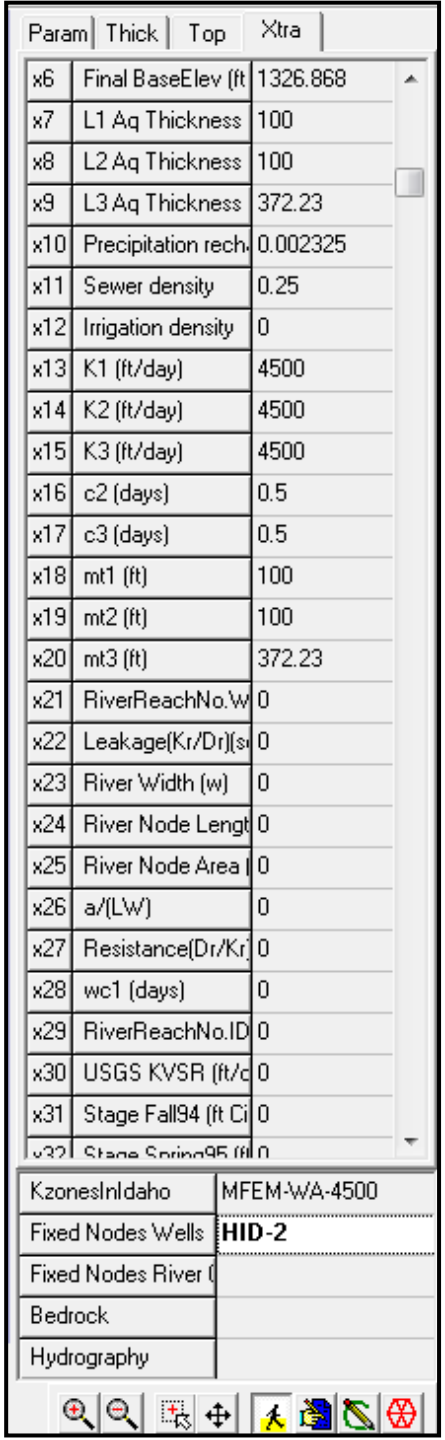
Other Aspects of Expanded Model

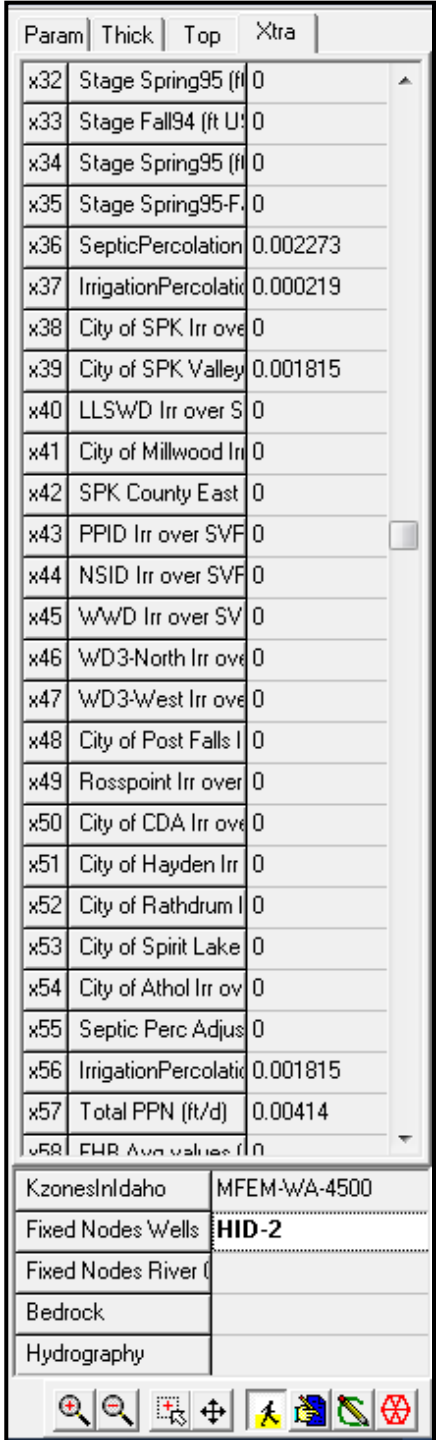
6. Updated well list and pumping rates
   - Annual average rates, as compiled by City of Spokane
7. Areal recharge from Bi-State model
8. Pumping and areal recharge are now separated
   - Lumped together into single term in Bi-State model

     Bi-State model pumping = Net withdrawal =
     (1) Actual pumping minus
     (2) Septic system infiltration minus
     (3) 40% of outdoor-applied water in urban areas minus
     (4) 40% of outdoor-applied water on irrigated fields
   - This makes it difficult to change pumping in Bi-State model: requires decisions on whether (and how) to change recharge
   - These two terms are now separate in the City/SAJB model

Other Aspects of Expanded Model

9. All input data are stored in the model software
   - Facilitates visual display
   - Allows mathematical analysis of input data, facilitates QC
   - Includes labels of key features
   - Facilitates future adjustments to the model grid (i.e., the data values at existing nodes won't get lost)





Comparison: Bi-State and City/SAJB Models

Model Aspect	Bi-State Model	City/SAJB Model
Multi-layered in N. Hillyard Trough	Yes	Yes
Multi-layered elsewhere	No	Yes
Aquifer thickness coverage reproducible	No	Yes
Wells penetrate only upper portion of aquifer	No	Yes
Pumping can be changed separately from recharge	No	Yes
Wellfield-scale analysis (fine detail in the grid)	No	Yes
Higher spatial resolution along river than elsewhere	No	Yes (in places)
Tributaries, lakes, and irrigation recharge	Yes	Yes
Calibration (water levels, exchanges with river) - Summer - Winter - Year Round	 Yes Yes Yes (WY 1990-2005)	 Yes (Sept. 1994) Yes (April 1995) No

Other Work and Findings

- Review of SWPA delineation methodology
  - Can we replicate the 2010 Special Wellhead Protection Areas?
- Regional stormwater recharge facilities
  - Study effects of large-scale recharge on 2010 SWPAs

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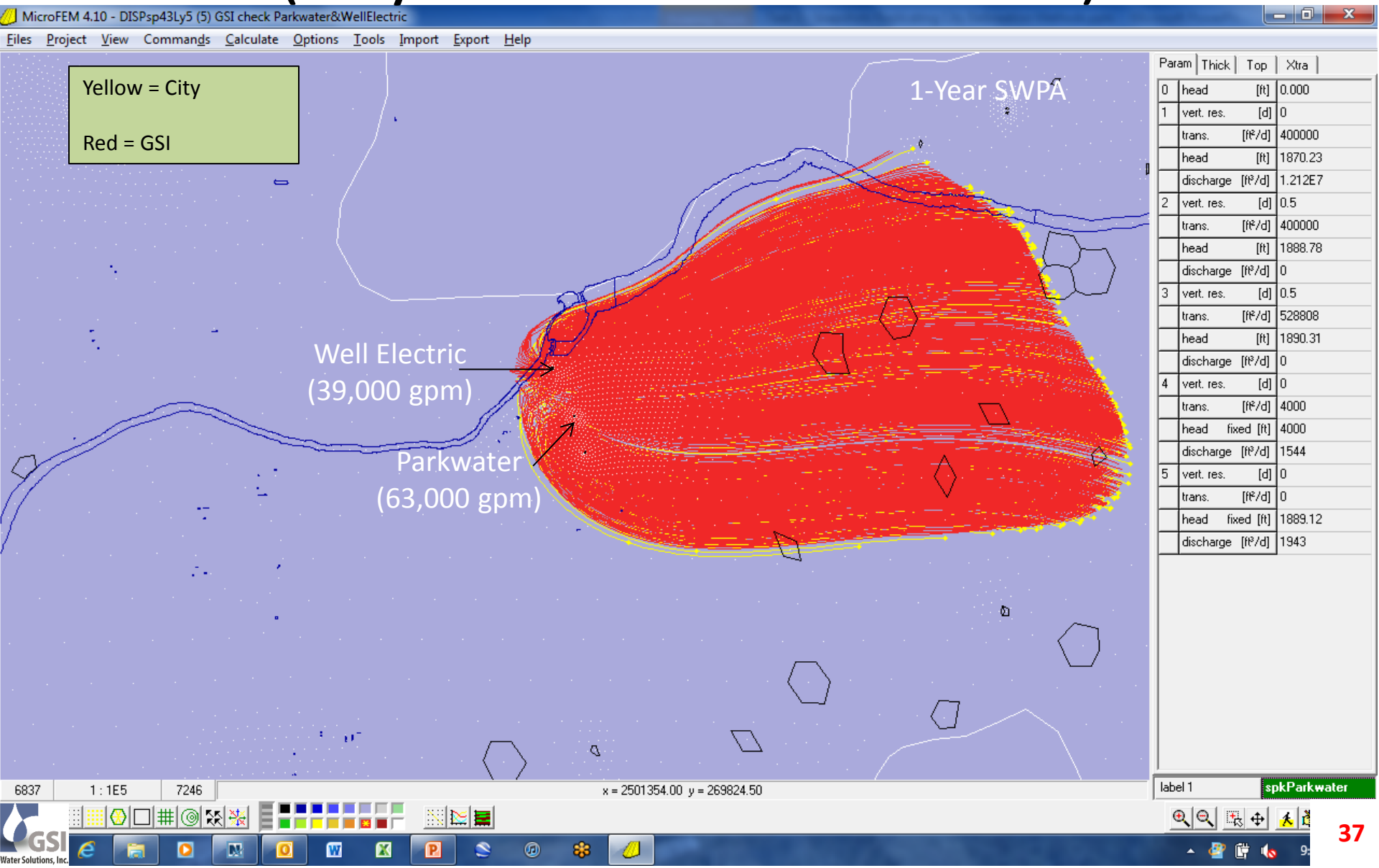
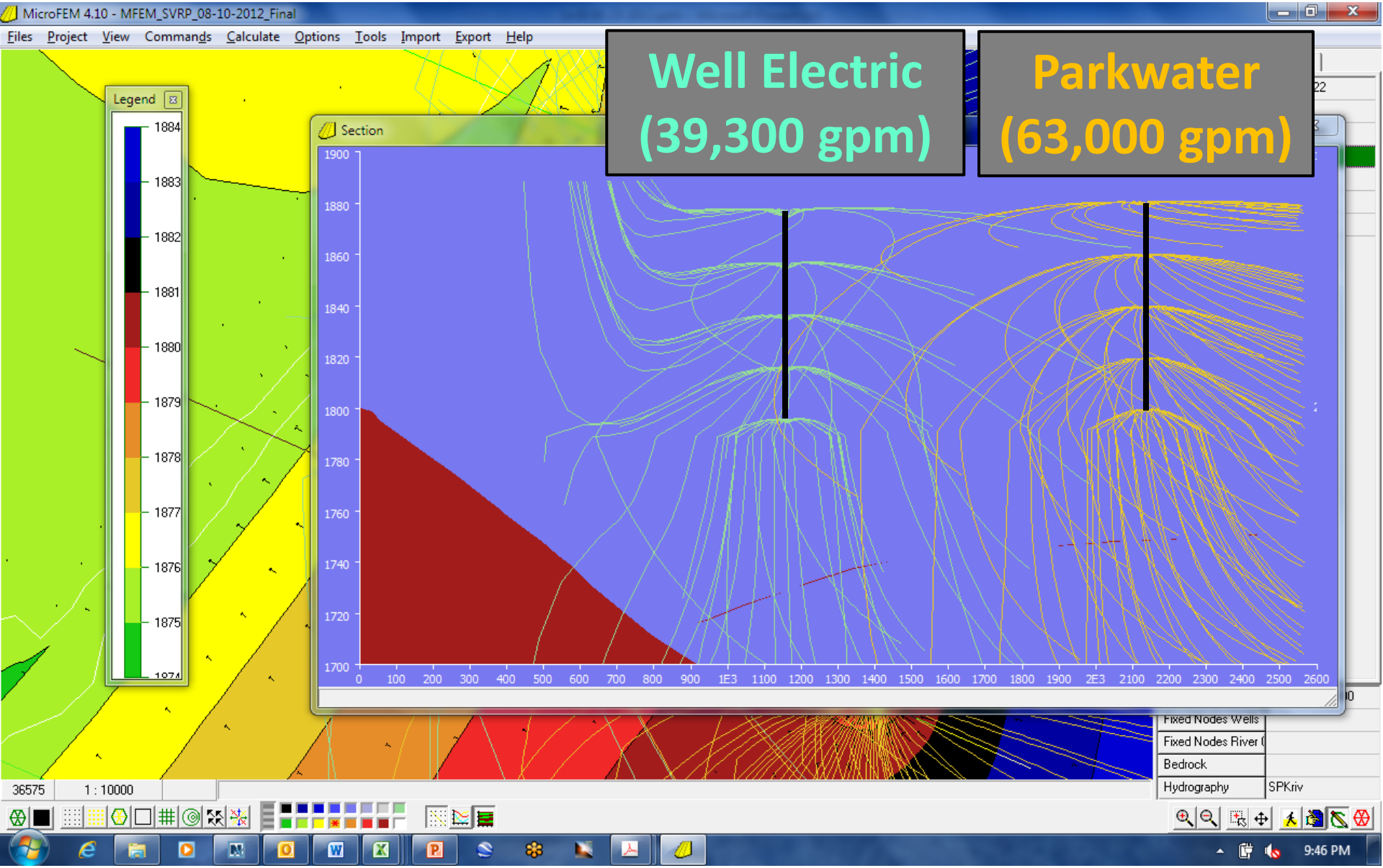
Wells Selected, And Rationale

- CID #4
  - Crosses underneath losing reach of Spokane River
- Fairchild #5
  - City found SWPA was sensitive to how river is modeled
- Pinecroft
  - In complex area (near bedrock knoll), and crosses river
- City of Spokane's Parkwater and Well Electric wells
  - Huge pumpers, near river

Parkwater and Well Electric (City and GSI Delineations)



Capture In Cross-Sectional View



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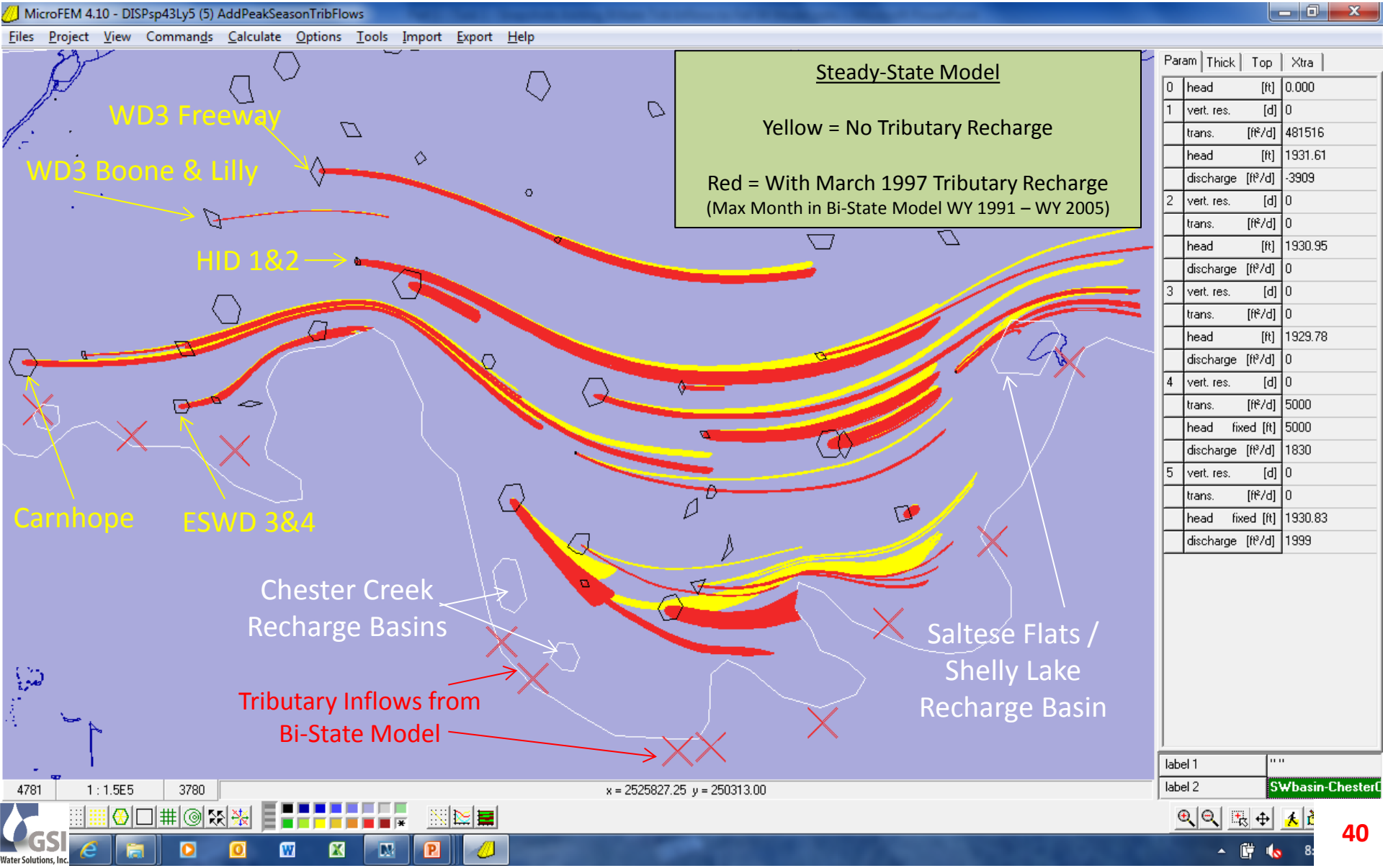
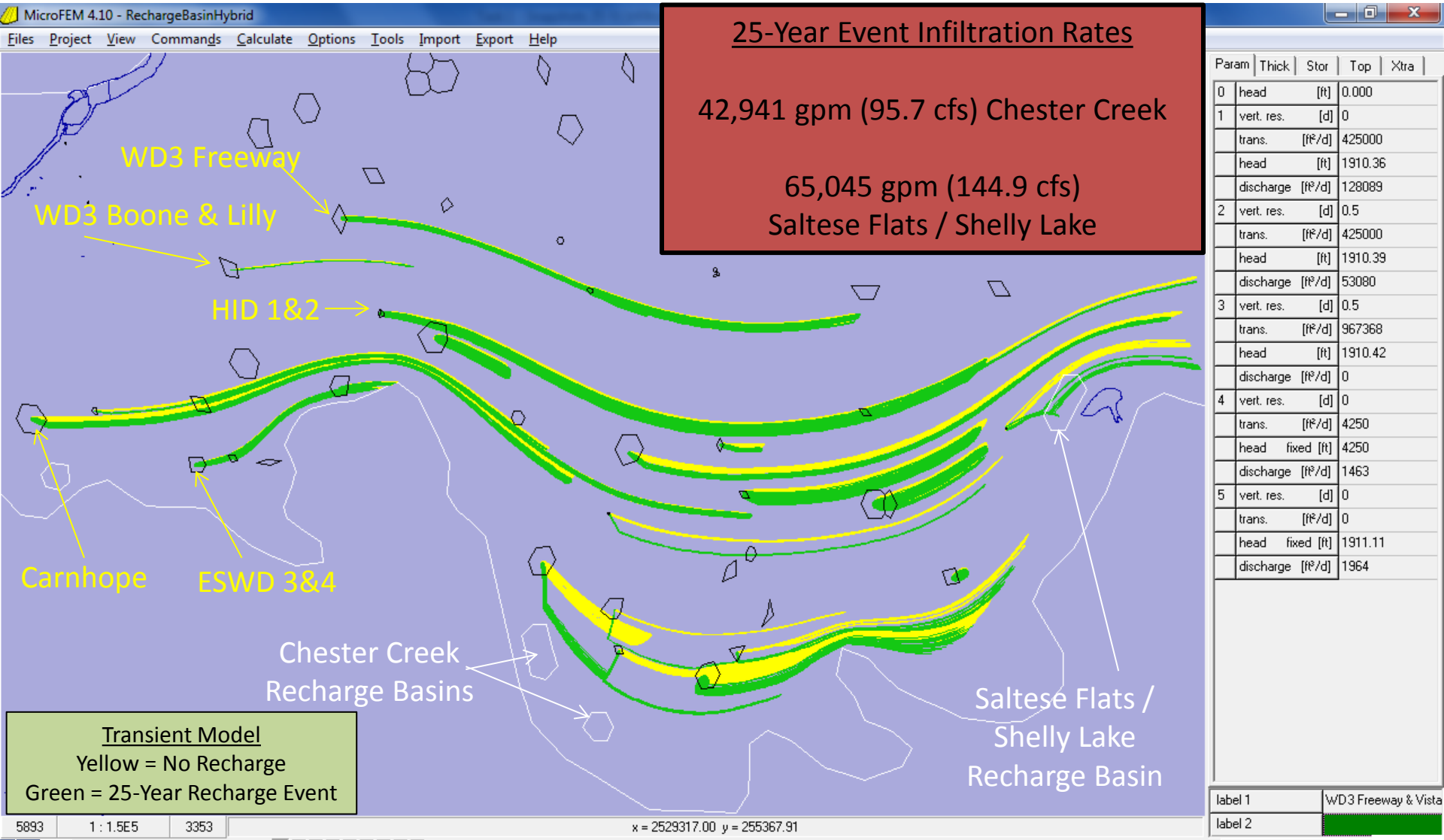
Bi-State Tributary Recharge Effects on Wells Near Chester Cr. And Saltese Recharge Basins



Influence of 25-Year Infiltration Events at the Chester Creek And Saltese Recharge Basins



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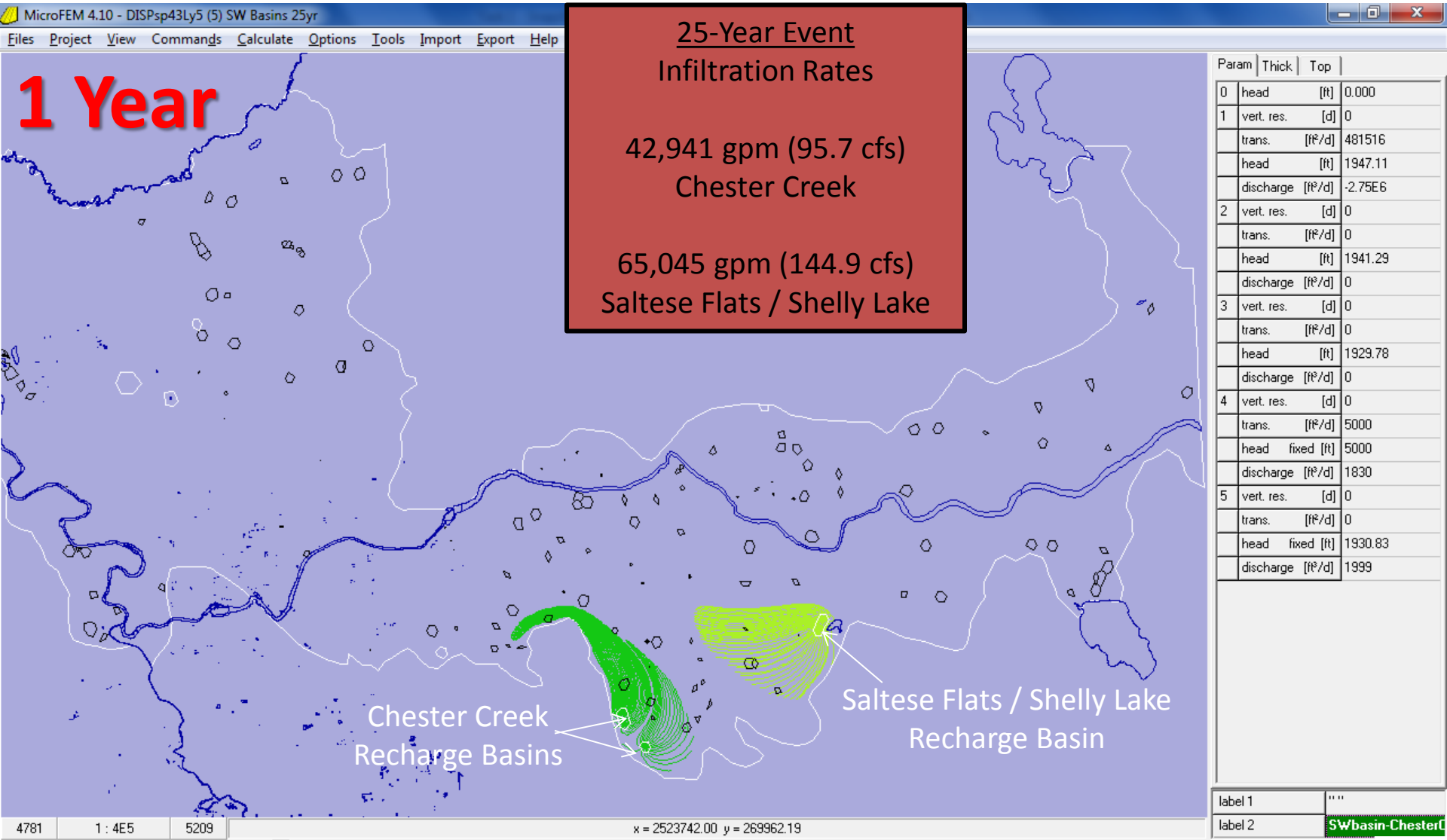

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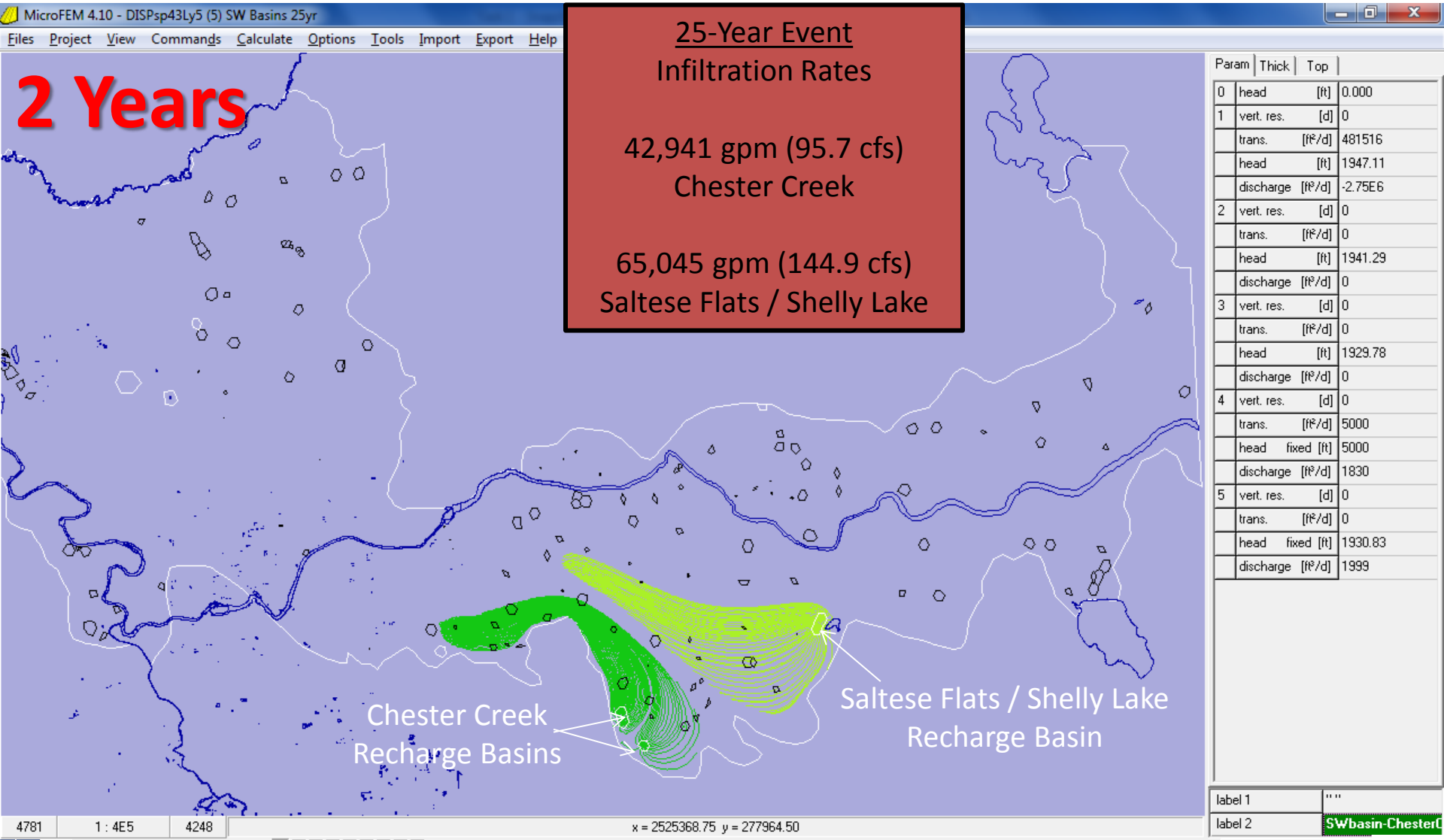

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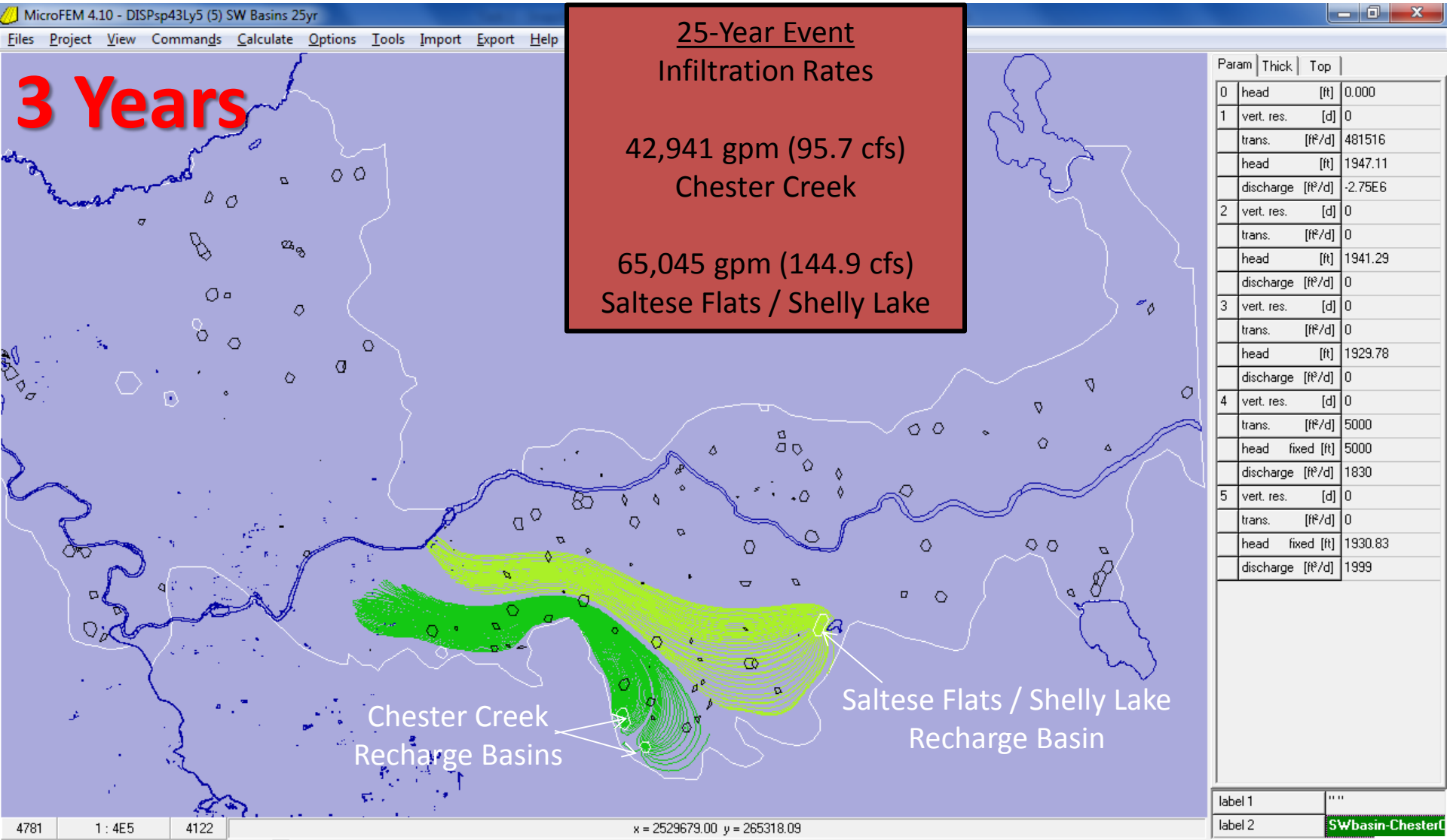

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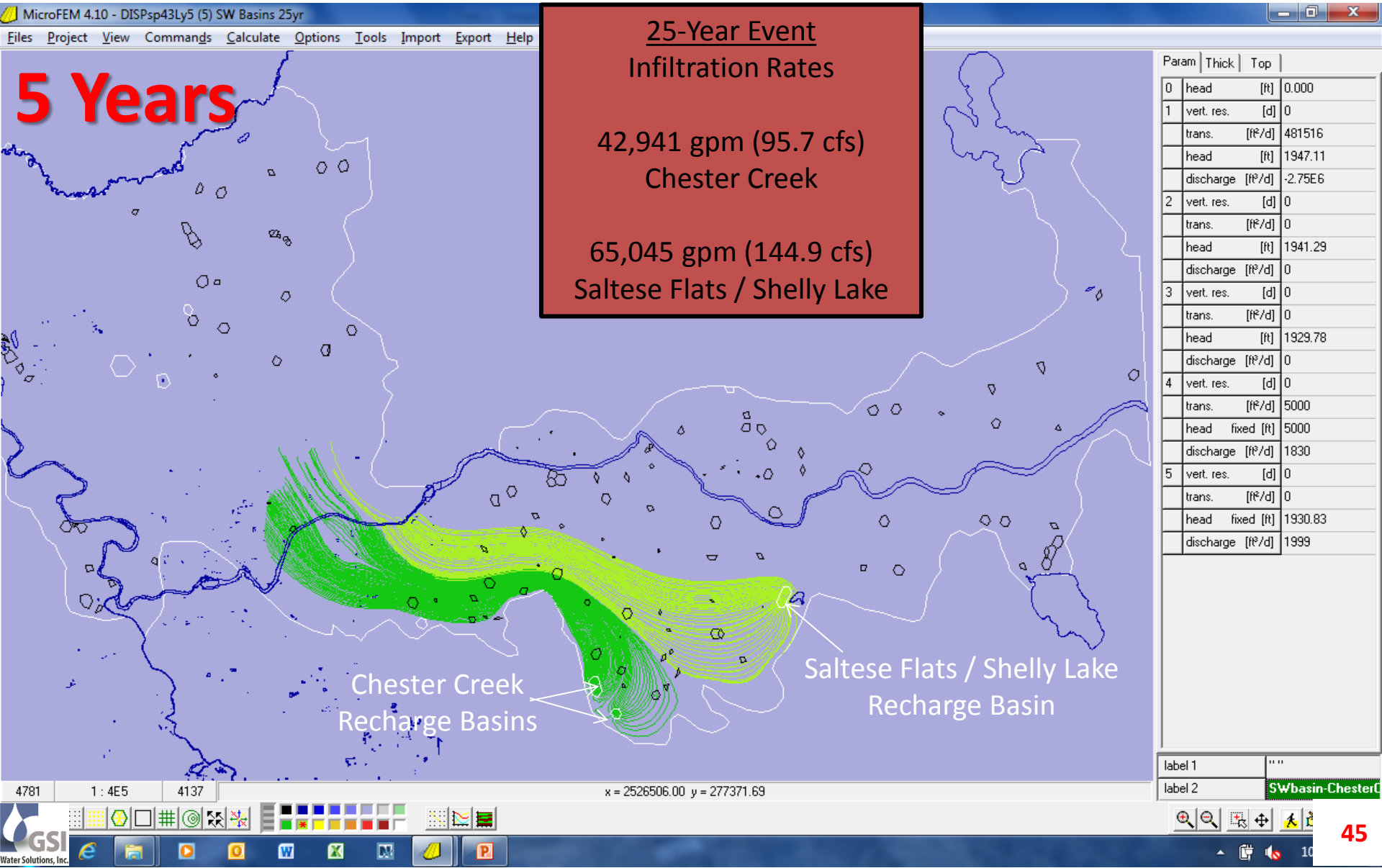

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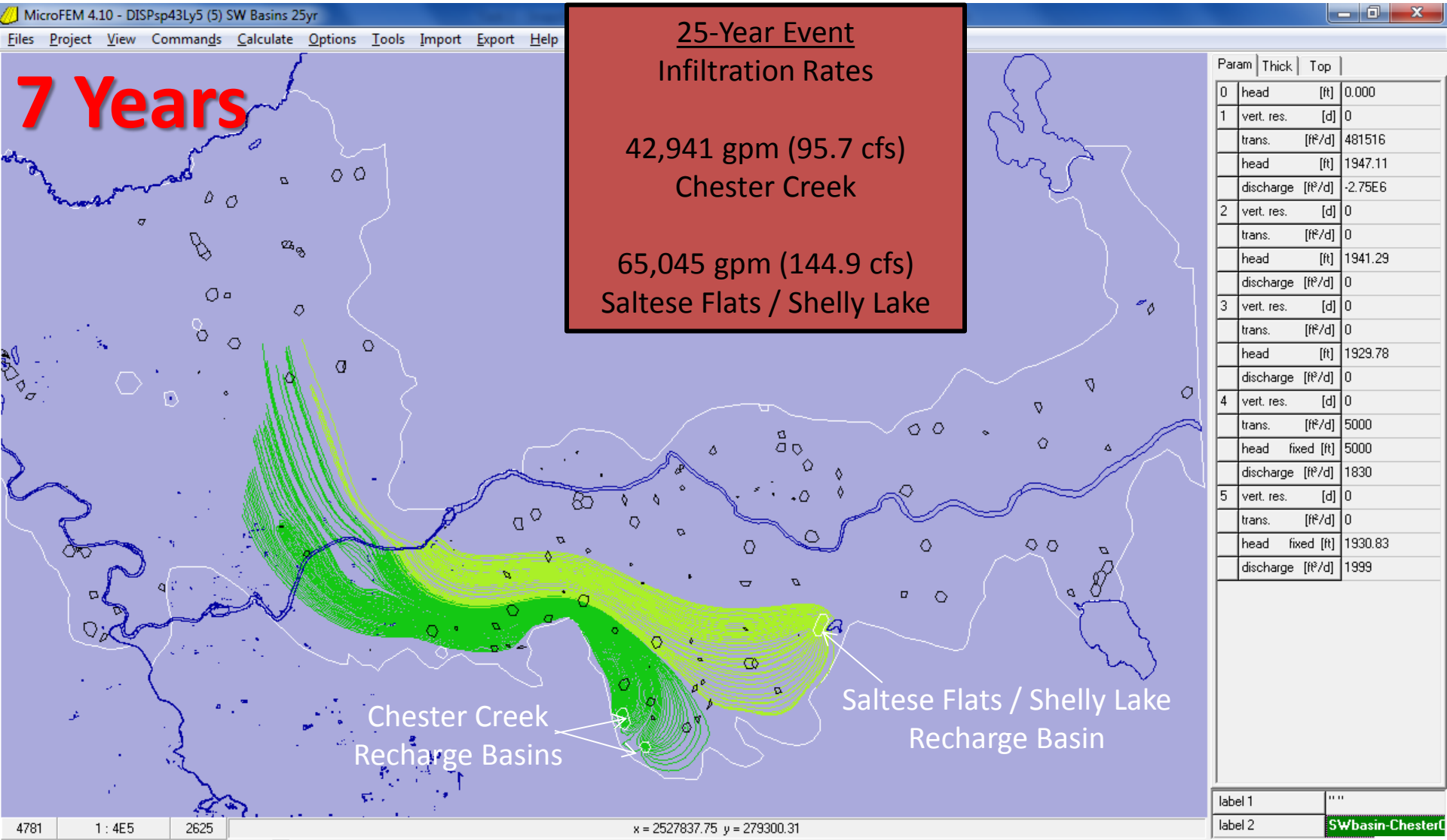
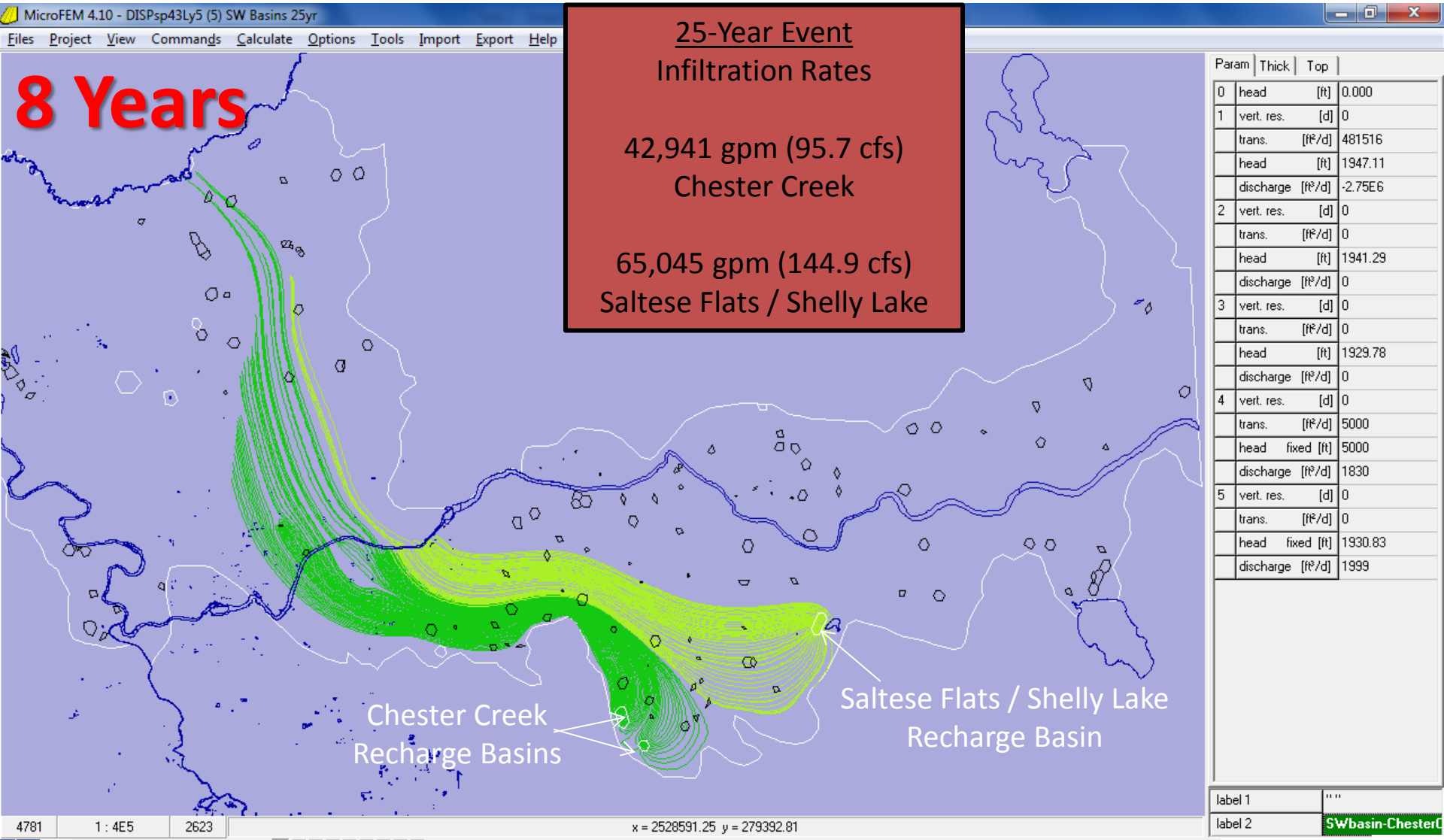


Influence of 25-Year Infiltration Events at the Chester Creek And Saltese Recharge Basins



Influence of 25-Year Infiltration Events at the Chester Creek And Saltese Recharge Basins