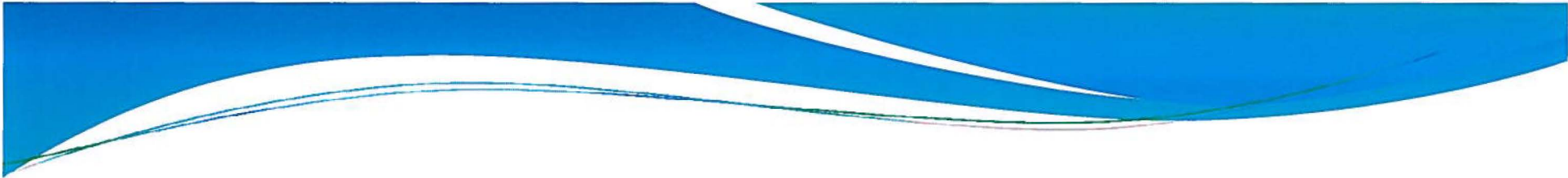


**EVALUATION OF ALTERNATIVE GROUND-
WATER PUMPING SCHEMES AS AN APPROACH
TO MITIGATING PROBLEMS OF CRITICAL LOW
FLOW IN THE SPOKANE RIVER AT SPOKANE,
WASHINGTON**

Dale R. Ralston PhD PE PG
Gary S. Johnson PhD PE

Ralston Hydrologic Services
Moscow, Idaho

February, 2015



Project Description

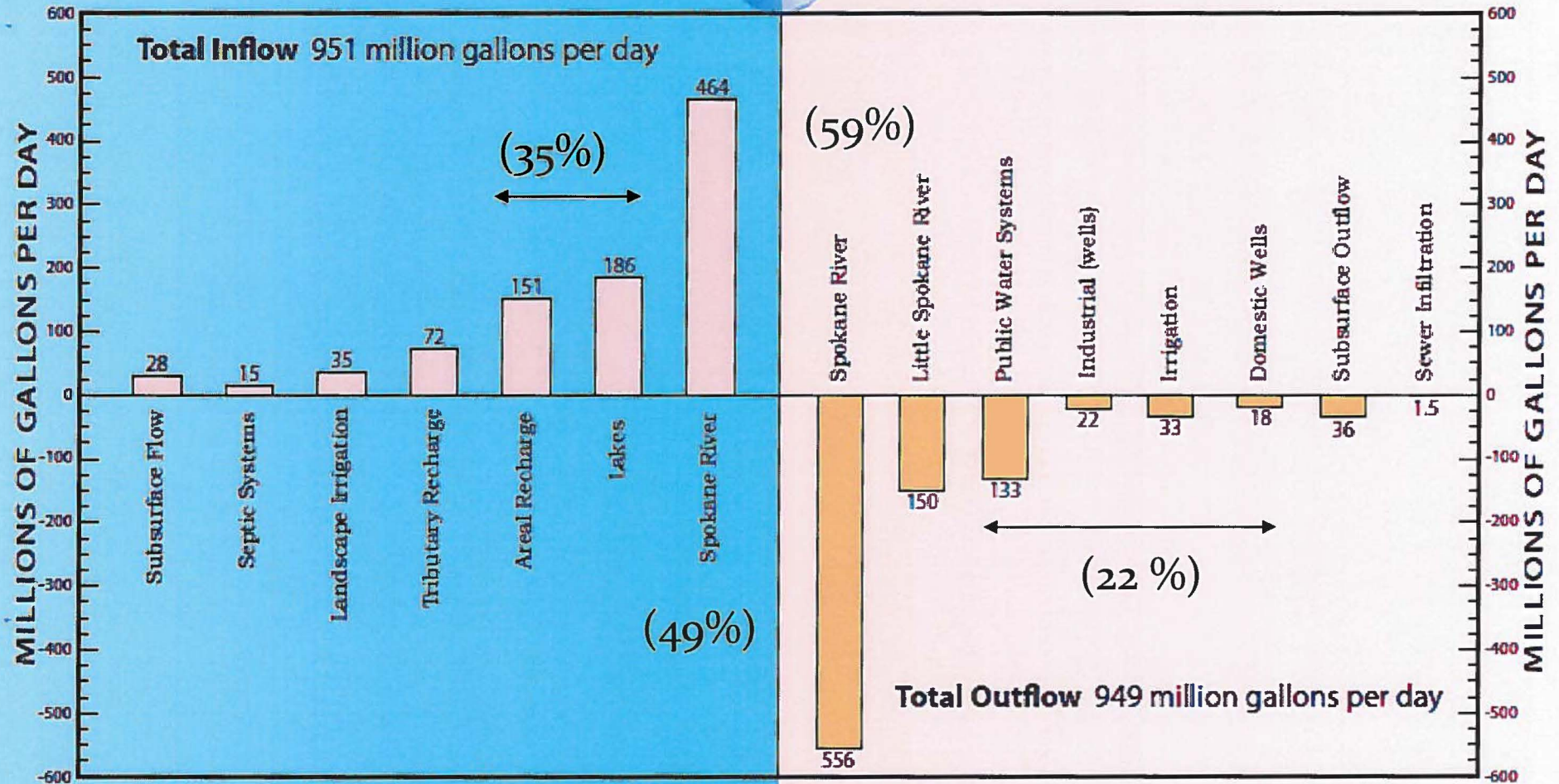
- The problem addressed by the project is low flow in the Spokane River as measured at the Spokane gage during the late summer of some years.
- The project focus is to develop a water management program that includes staged operation and possible relocation of production wells based on the amount and timing of impacts on the Spokane River at the Spokane gage.
- Project was conducted using transient response functions in conjunction with the existing Bi-State MODFLOW aquifer model.

(From 2009 update of aquifer atlas)

IN



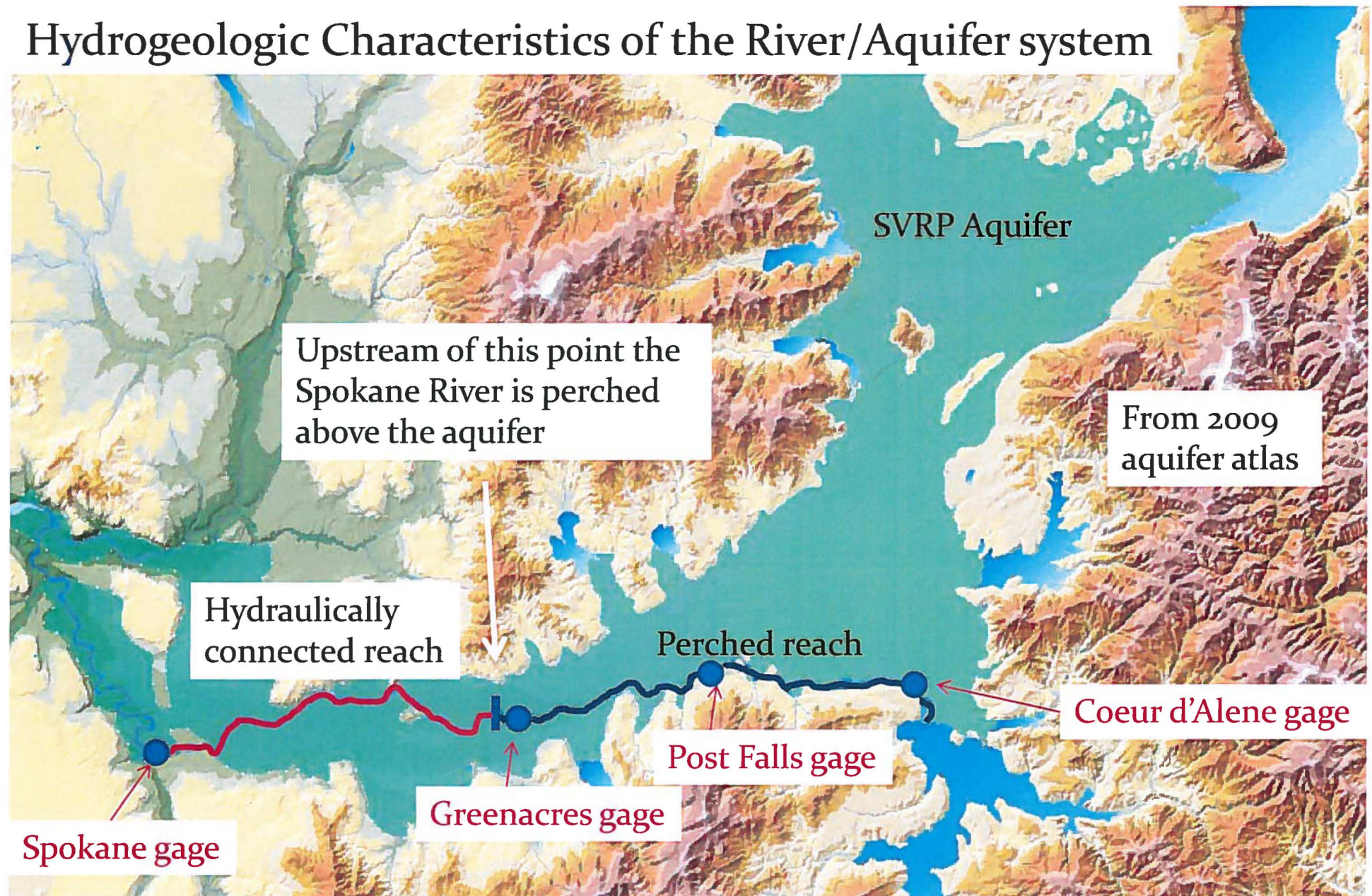
OUT



The groundwater budget component values shown in this graph represent average conditions, 1990-2005.

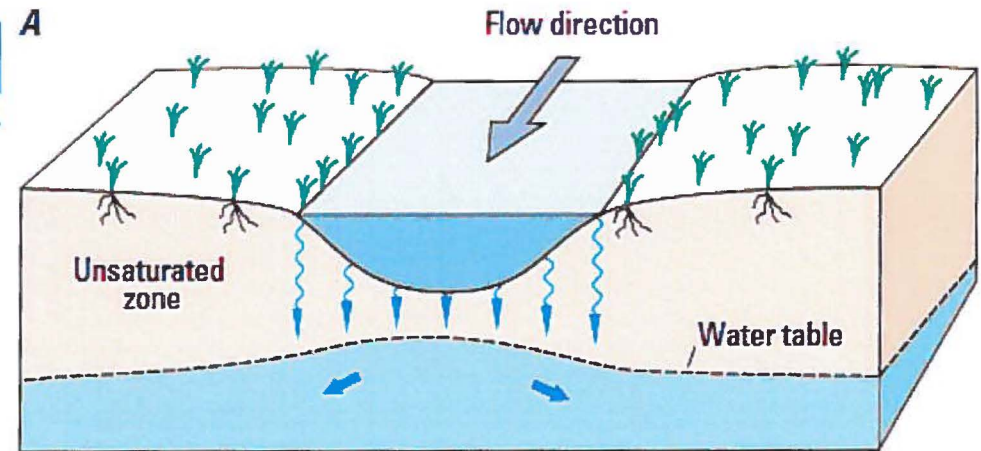
Spokane River is the dominant recharge source and discharge area for the aquifer

Hydrogeologic Characteristics of the River/Aquifer system

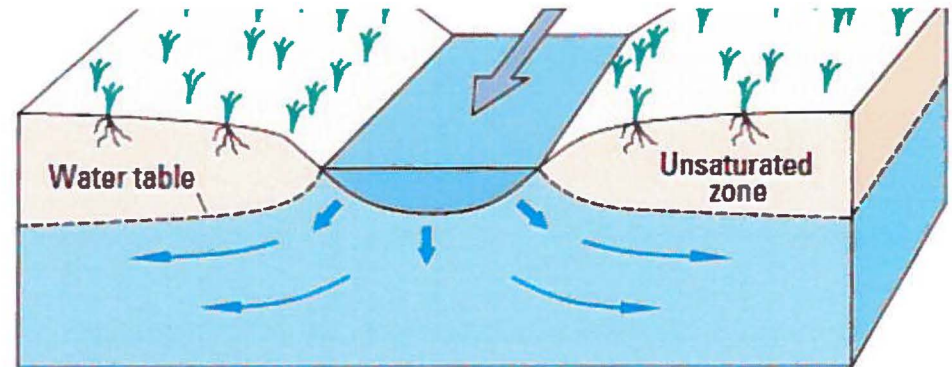


SVRP Aquifer and the Spokane River form a single resource

Perched River – water table is below the bottom of the river channel – amount of aquifer recharge is controlled by the height of water in the river; it is independent of ground-water levels.

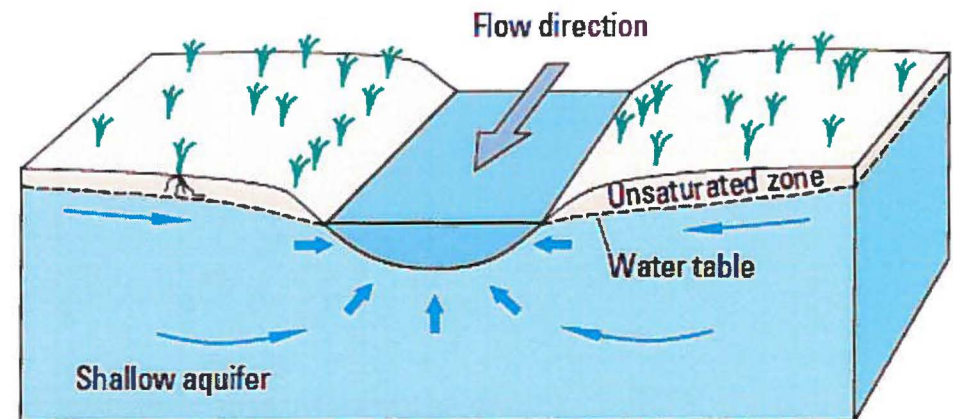


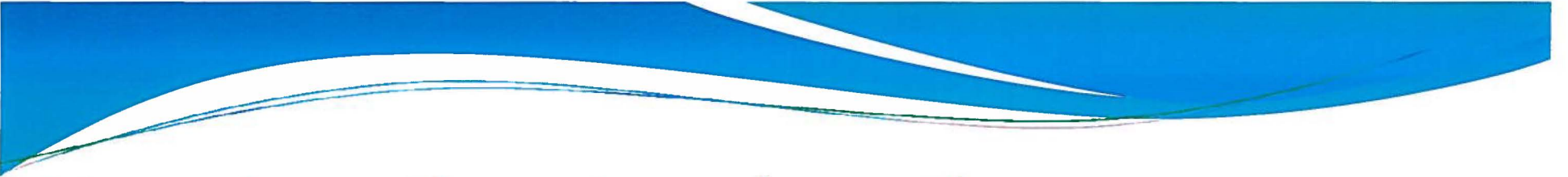
Losing River -- river is in hydraulic connection with the aquifer – amount of aquifer recharge from the river is controlled by the difference between the river water level and the ground-water level.



From USGS Circular 1376

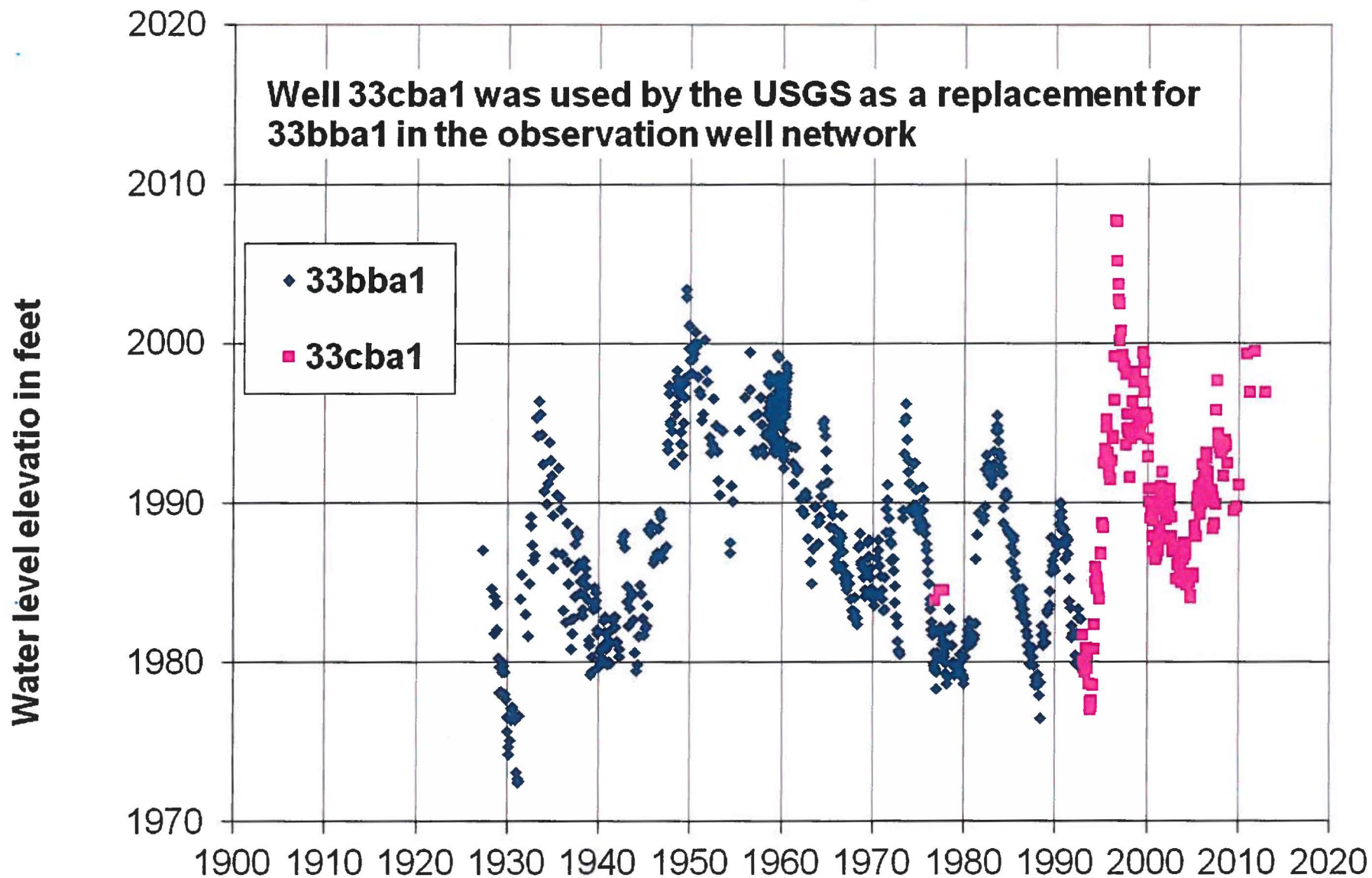
Gaining River – river is in hydraulic connection with the aquifer – amount of ground-water discharge to the river is controlled by the difference between the river water level and the ground-water level.



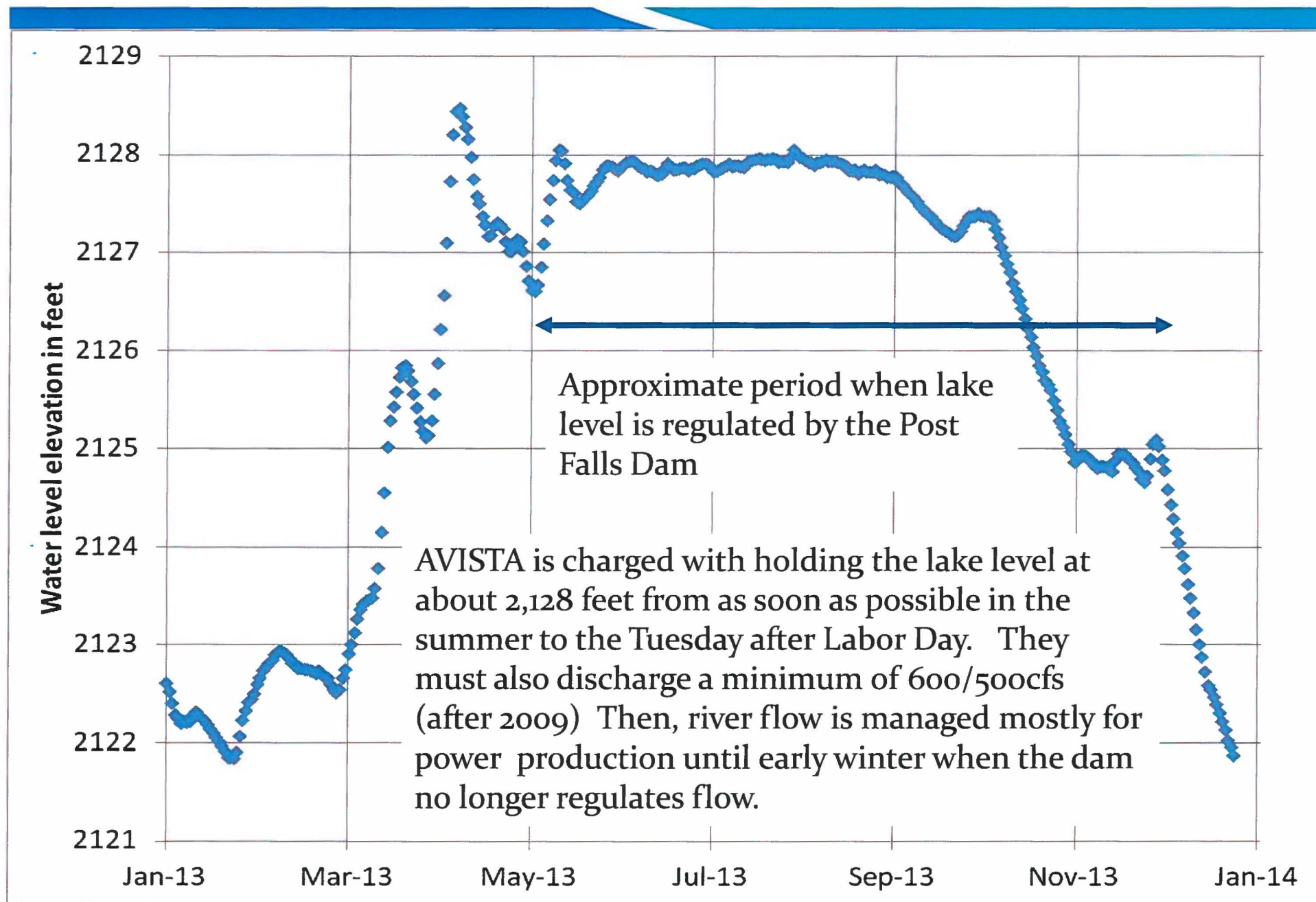


How has the river/aquifer system changed with development?

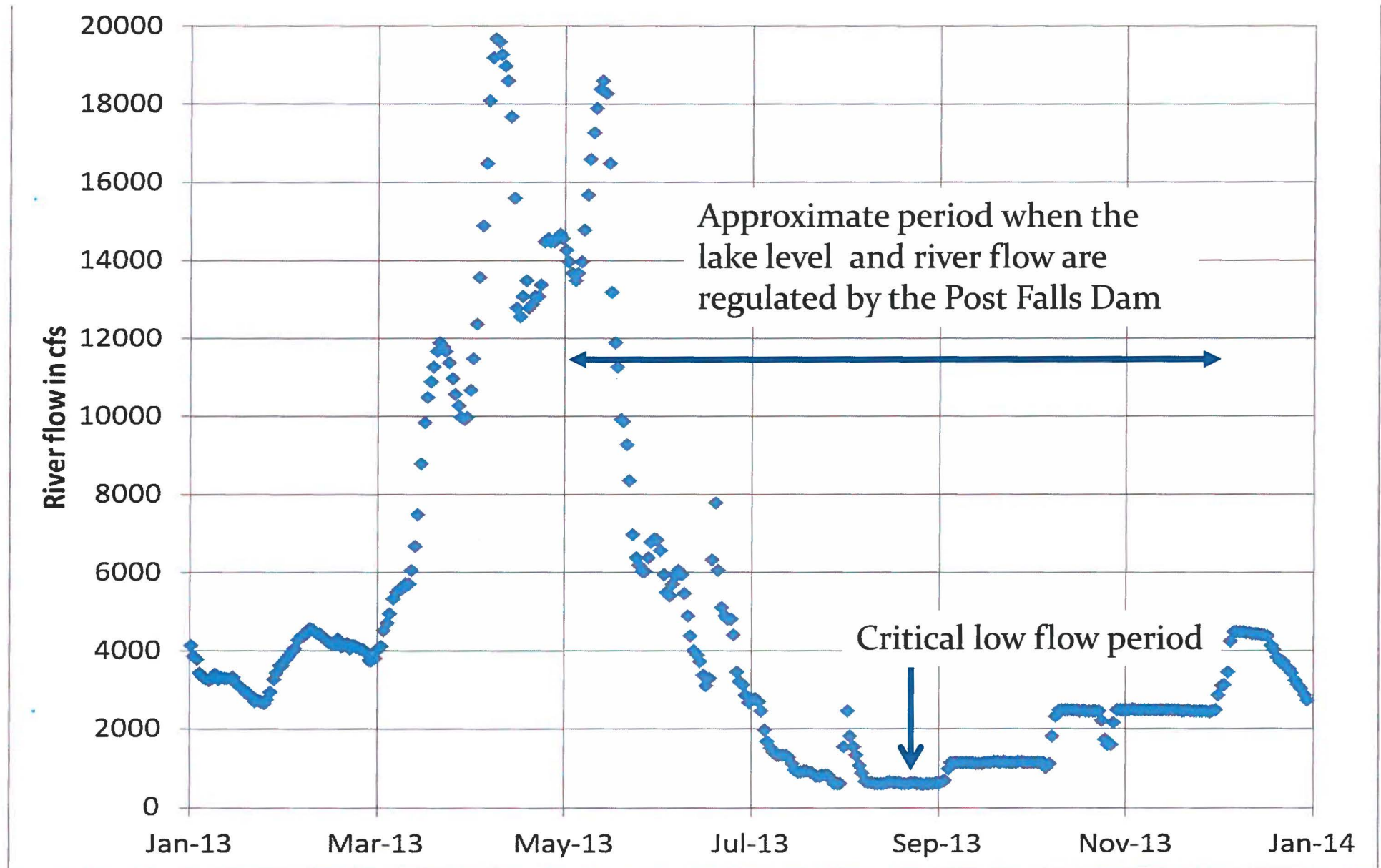
- No pattern of long-term water-level decline in the aquifer
- No significant change within the Coeur d'Alene Lake drainage; no reservoirs on St. Joe or CdA Rivers
- Dam at Post Falls on the Spokane River controls lake level and flow only during the summer and fall.
- No change to high and average annual flow in the river.
- Seven-day low flow in the river has decreased with time.
- Ground-water development is the most significant change to the water resource.



**Hydrograph for Wells 51N 5W 33bba1 and 33cba1
Located Near Post Falls, Idaho**



Hydrograph for Coeur d'Alene Lake for 2013



Hydrograph for the Spokane River near Post Falls, Idaho for 2013

Aquifer recharge from river loss during August 20-31, 2010 in the perched reach of the river from the Coeur d'Alene gage to the Greenacres gage

Post Falls to Greenacres:
Average river loss (aquifer recharge) was 388 cfs or 61% of the flow

Coeur d'Alene to Post Falls:
Average river loss (aquifer recharge) was 360 cfs or 36% of the flow

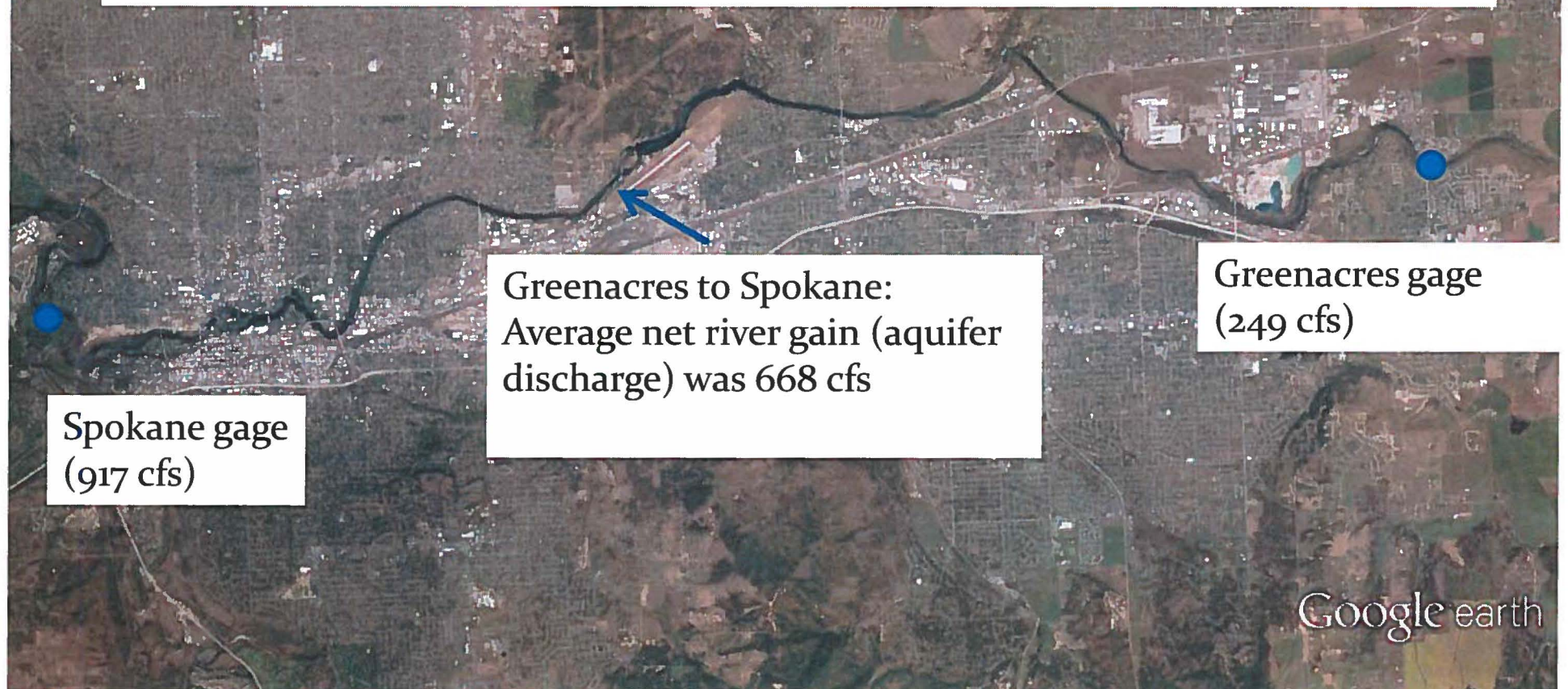
Post Falls gage (637 cfs)

CdA gage (997 cfs)

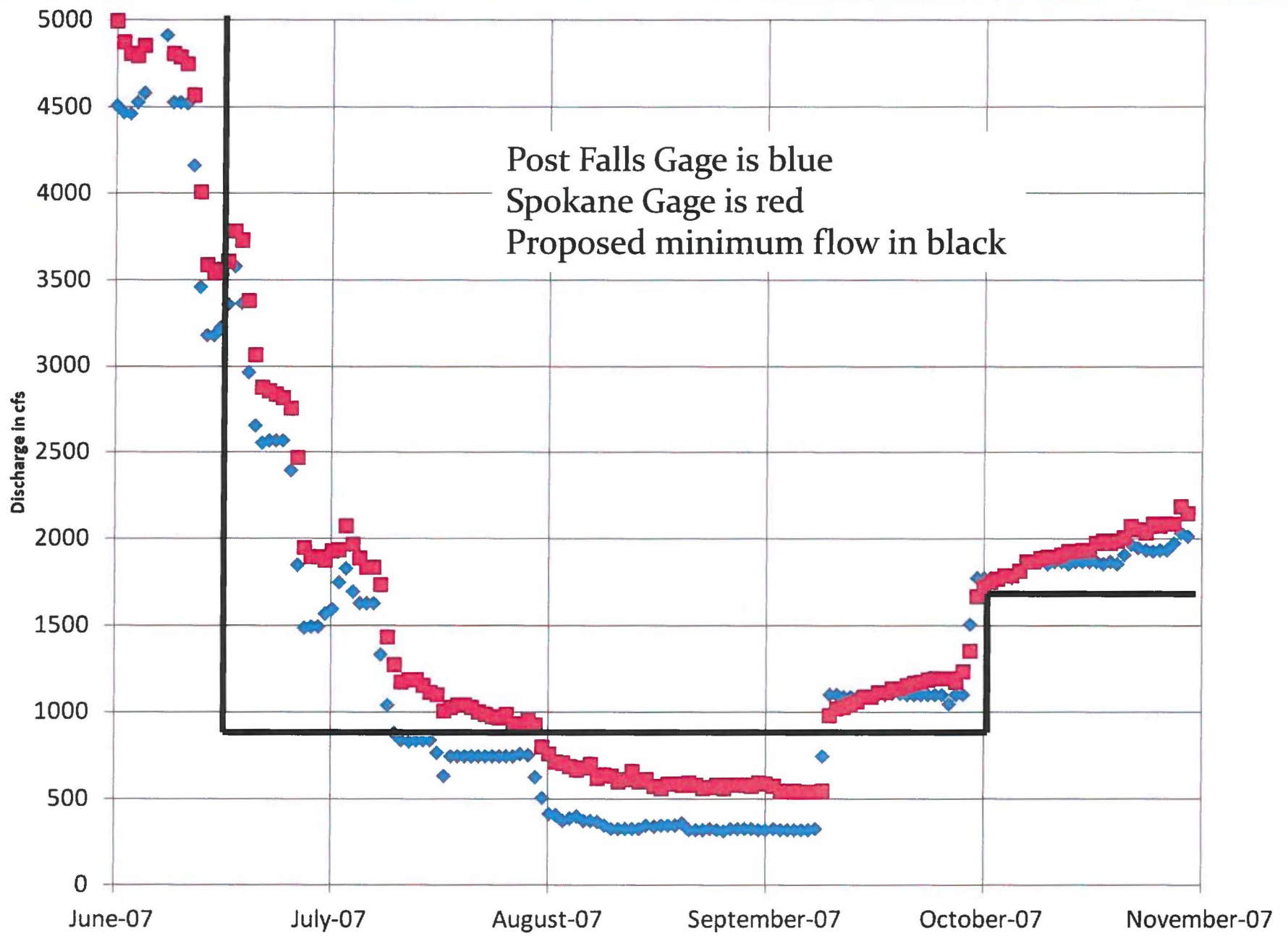
Greenacres gage (249 cfs)

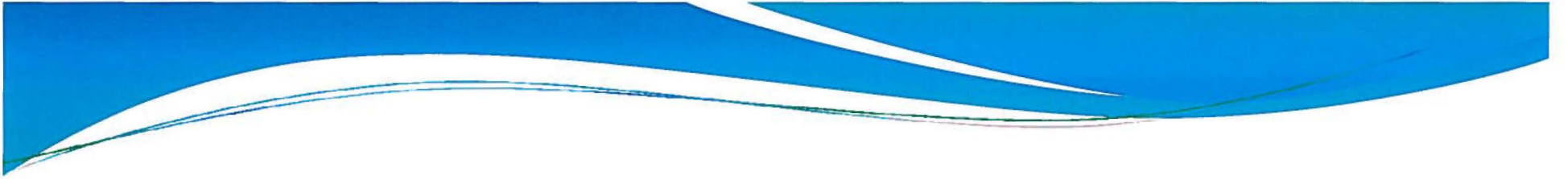
Google earth

Net river gain during August 20-31, 2010 in the hydraulically connected reach of the river from the Greenacres gage to the Spokane gage



The Spokane River is perched above the aquifer for a short distance below the Greenacres gage. From there downstream, the river is hydraulically connected to the aquifer with both gaining and losing reaches.

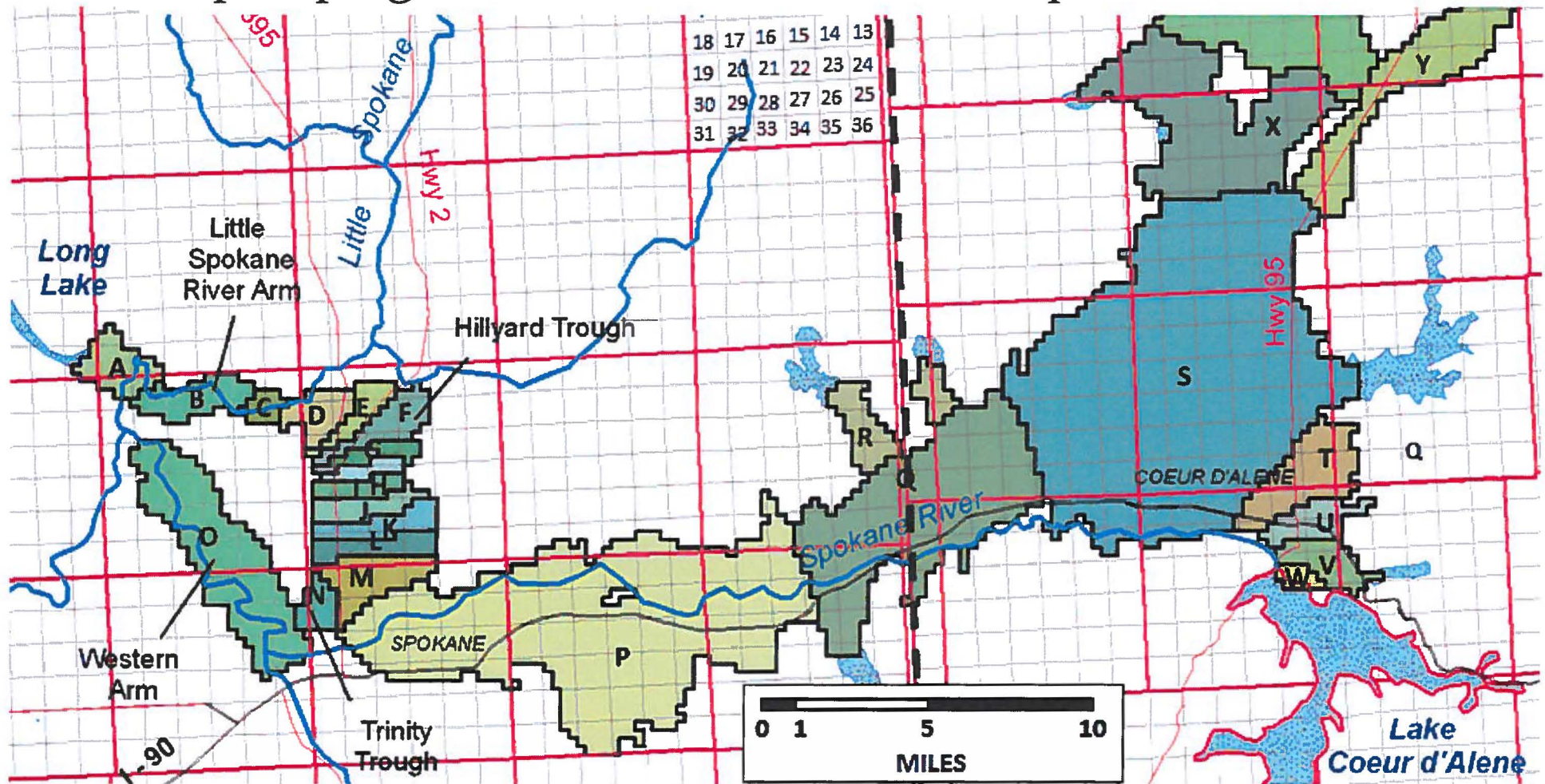




Low Flow in the Spokane River

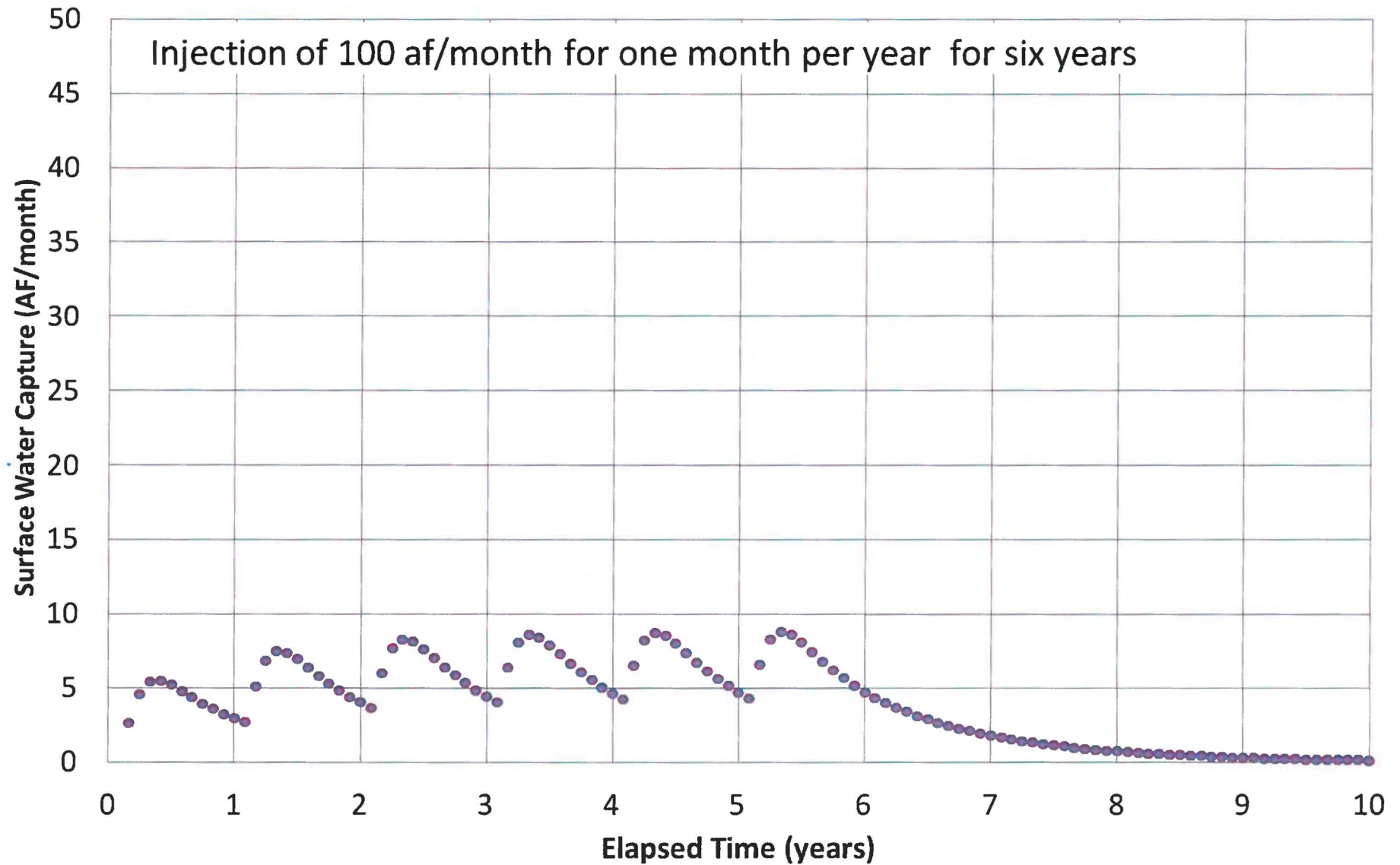
- Results from a combination of three factors:
 - Discharge rate from the Post Falls Dam
 - Time-lag impacts from ground-water recharge events
 - Time-lag impacts effects from ground-water pumping

Spreadsheet created by Taylor, Contor and Johnson (2008) allow analysis of multi-year effects on the flow of the Spokane River at the Spokane gage from recharge or pumping events within zones of the aquifer



Based on the Bi-State model

Uses monthly time steps



This is an example of the impacts on the Spokane River from recharge in area “S” (i.e. overflow from Hayden Lake)



Objective: Build a Spreadsheet Tool That Water Interests Can Use to Evaluate Effects of Changes in Aquifer Pumping on the Spokane River

- Accessible to water providers, regulators, other water interests
- Easy to use
- Best existing science
- Flexible enough to address multiple needs
- Daily time steps



Bi-State MODFLOW Model (2007)

Prepared in cooperation with the
IDAHO DEPARTMENT OF WATER RESOURCES
WASHINGTON STATE DEPARTMENT OF ECOLOGY
UNIVERSITY OF IDAHO
WASHINGTON STATE UNIVERSITY

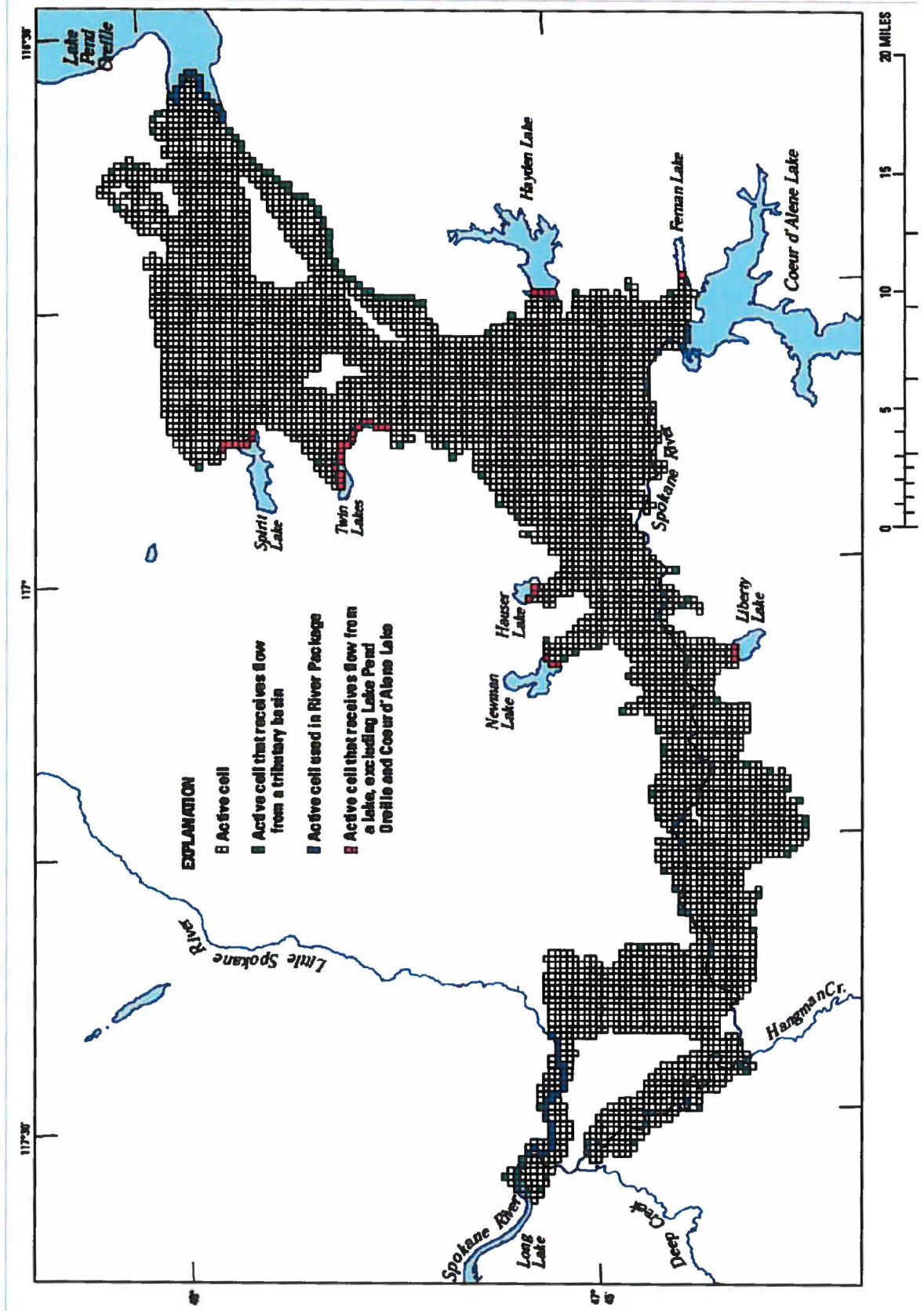


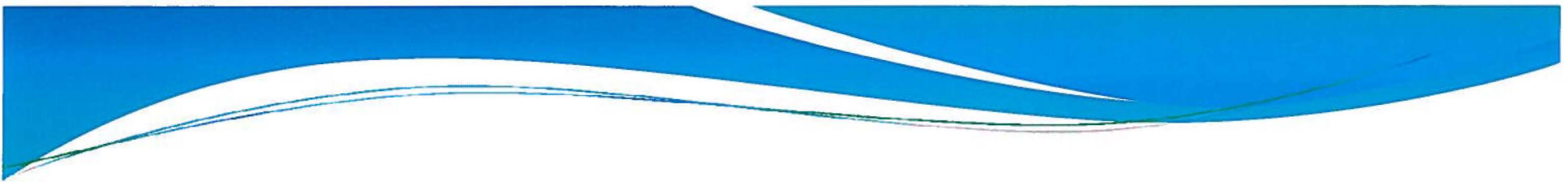
Ground-Water Flow Model for the Spokane Valley-Rathdrum Prairie Aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho

- Grid Spacing: $\frac{1}{4}$ Mile (>5,000 Grid Cells)
- Mostly a single layer model
- One-month stress periods
- Calibrated to ground-water level and streamflow data from 1990 - 2005

Extent: Entire Aquifer

Grid Spacing: ¼ Mile (>5,000 Grid Cells)

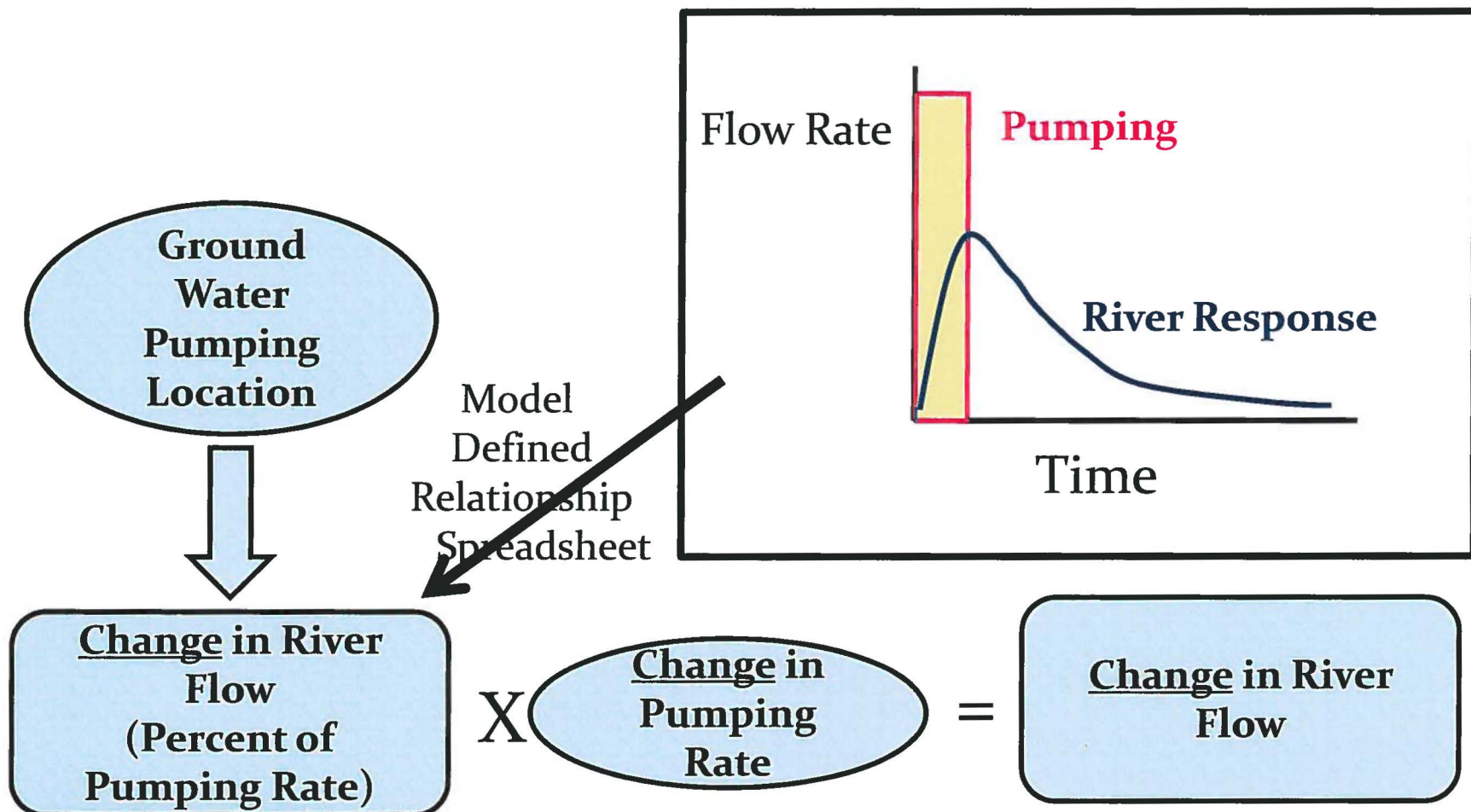




What Does the Model Do?

- Calculates aquifer water levels and flow between surface water bodies and the aquifer.
- Can be used to ask “what if” questions.
- Question posed in our project is “what happens to flow in the Spokane River if more or less water is pumped at an existing well location?”
 - Answer is a “response function”

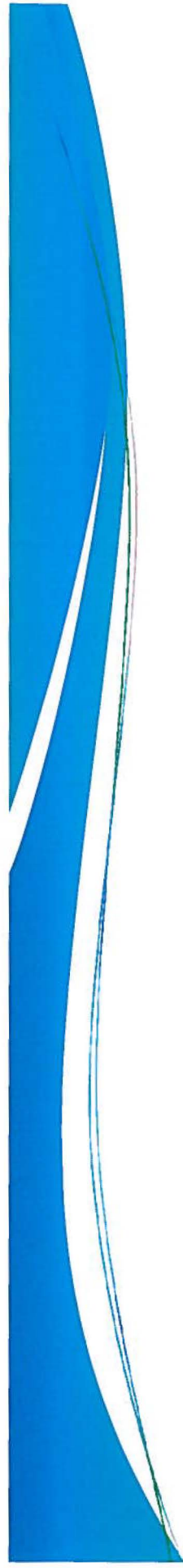
The Tool: Spreadsheet Using Response Functions Determined from The MODFLOW Model





Primary question relative to use of Bi-State model for pumping analysis

- **Can the Bi-State model that was calibrated with one month stress periods and has a grid spacing of 1,320 feet be used for the analysis of daily impacts on the river from an individual well or from groups of wells?**
- Used data from WDOE “6-minute” test to determine how well the model represented short-term aquifer responses.
- Compared results to a finite element model that was created for capture zone analysis of entities of the Spokane Aquifer Joint Board (Washington water purveyors) to assess the node spacing issue.



Spreadsheet Interface to Bi-State MODFLOW model



Summary of GW Pumping Impacts on the Spokane River

- Wells near the hydraulically connected reach of the river have the fastest response with the greatest percentage impact on the river.
- Wells more distant from the hydraulically connected reach of the river have a more delayed response with a smaller percentage impact on the river.
- Problem of low flow in the river is short duration, from a few days to as long as a month.
- Our focus was to develop short-term solutions to the short-term problem.



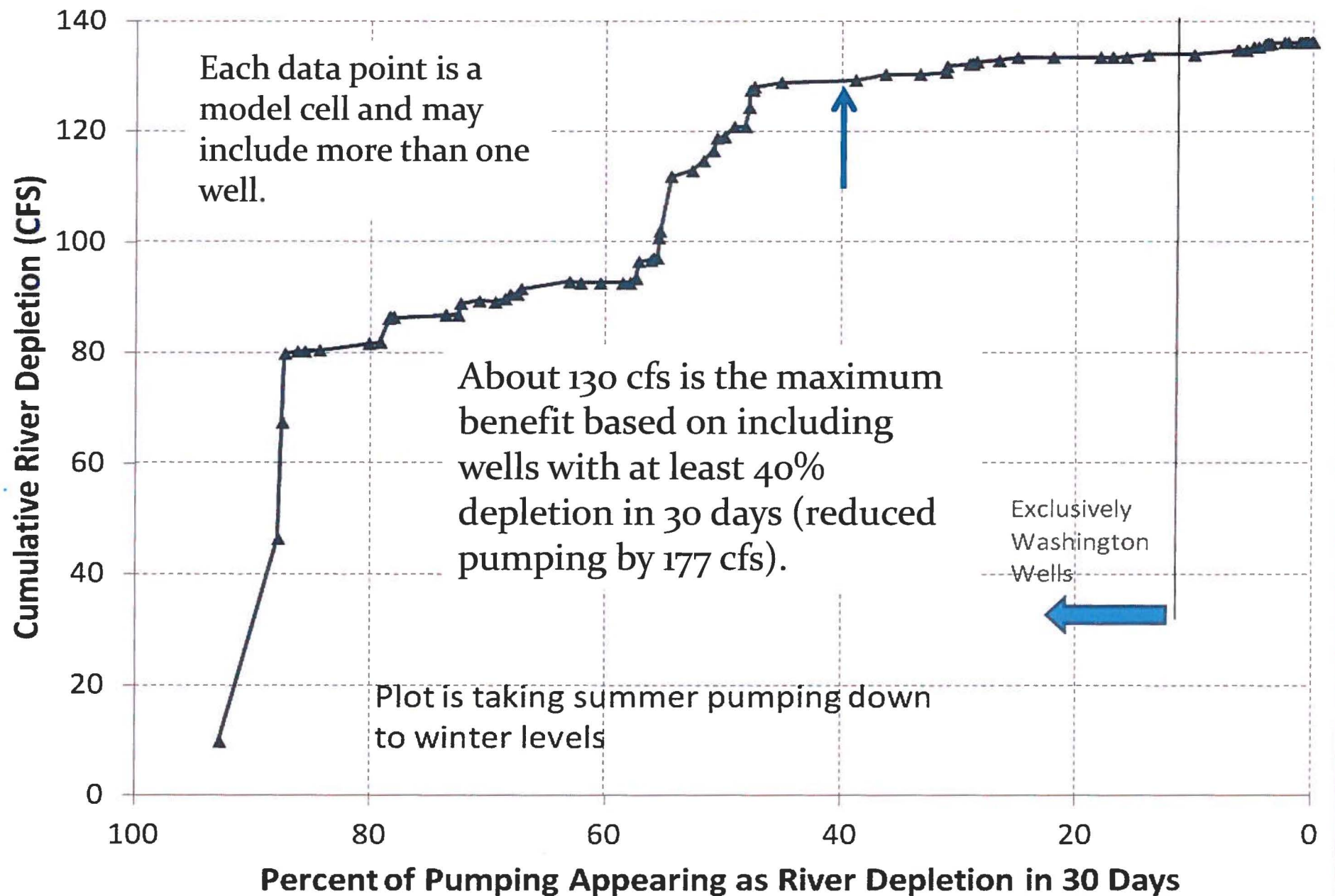
Two alternative approaches for mitigating short periods of low flow in the river

- Alternative #1 -- Reduce the pumping rate from selected wells that have large percentage impact on the river.
- Alternative #2 -- Transfer pumping from selected wells near the river to wells more distant from the river.

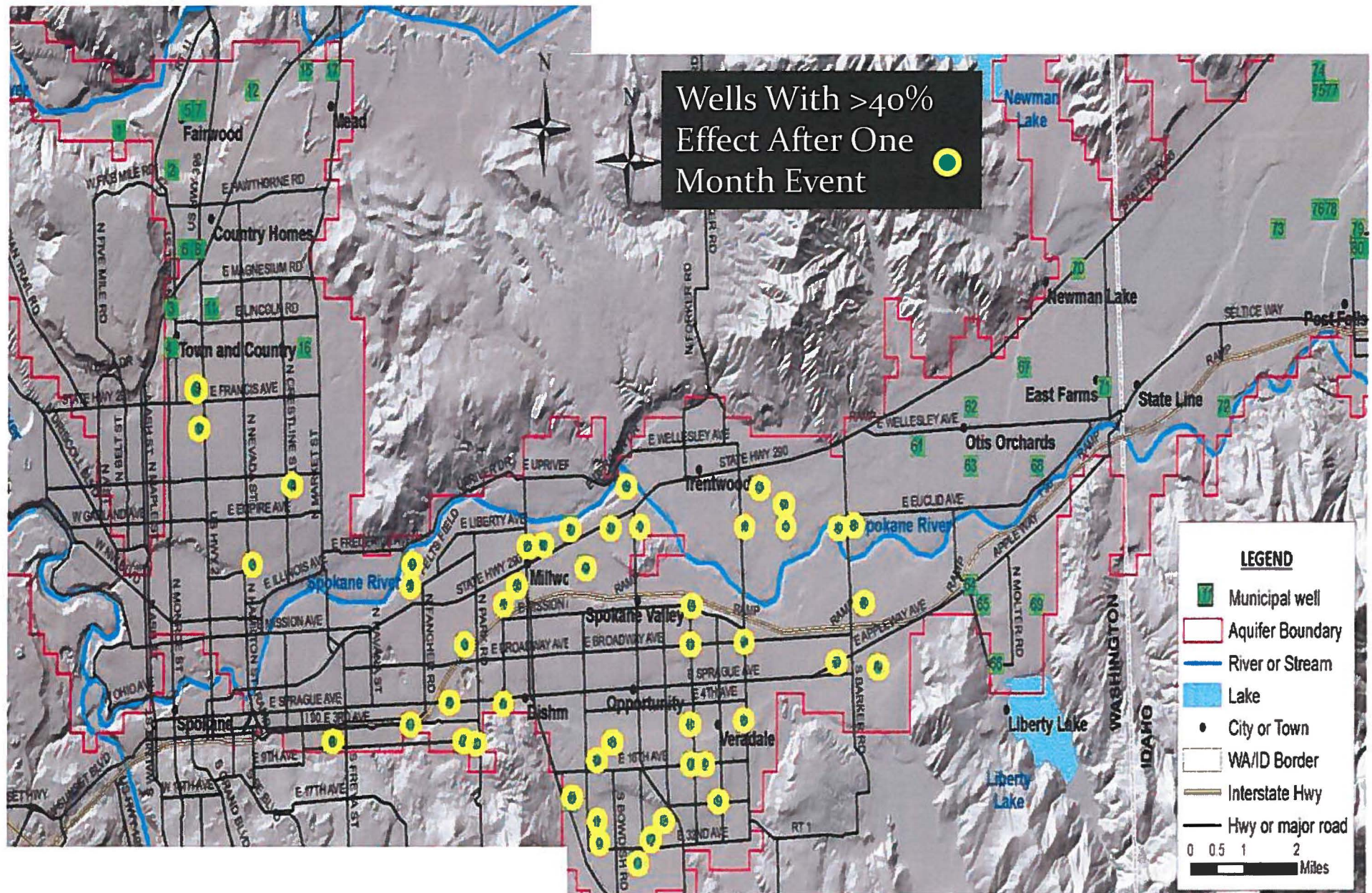


Scenario #1 Reduce the pumping rate from selected wells that have large percentage impact on the river.

- Use the alternative of reducing the pumping rate from summer to winter pumping rates. The pumping rate data were taken from the Bi-State model report.
- Selection of wells to be included in the program is based on the percentage impact on the river after one month of pumping.



Scenario #1 Reduce pumping in wells selected based on percentage impact on the river

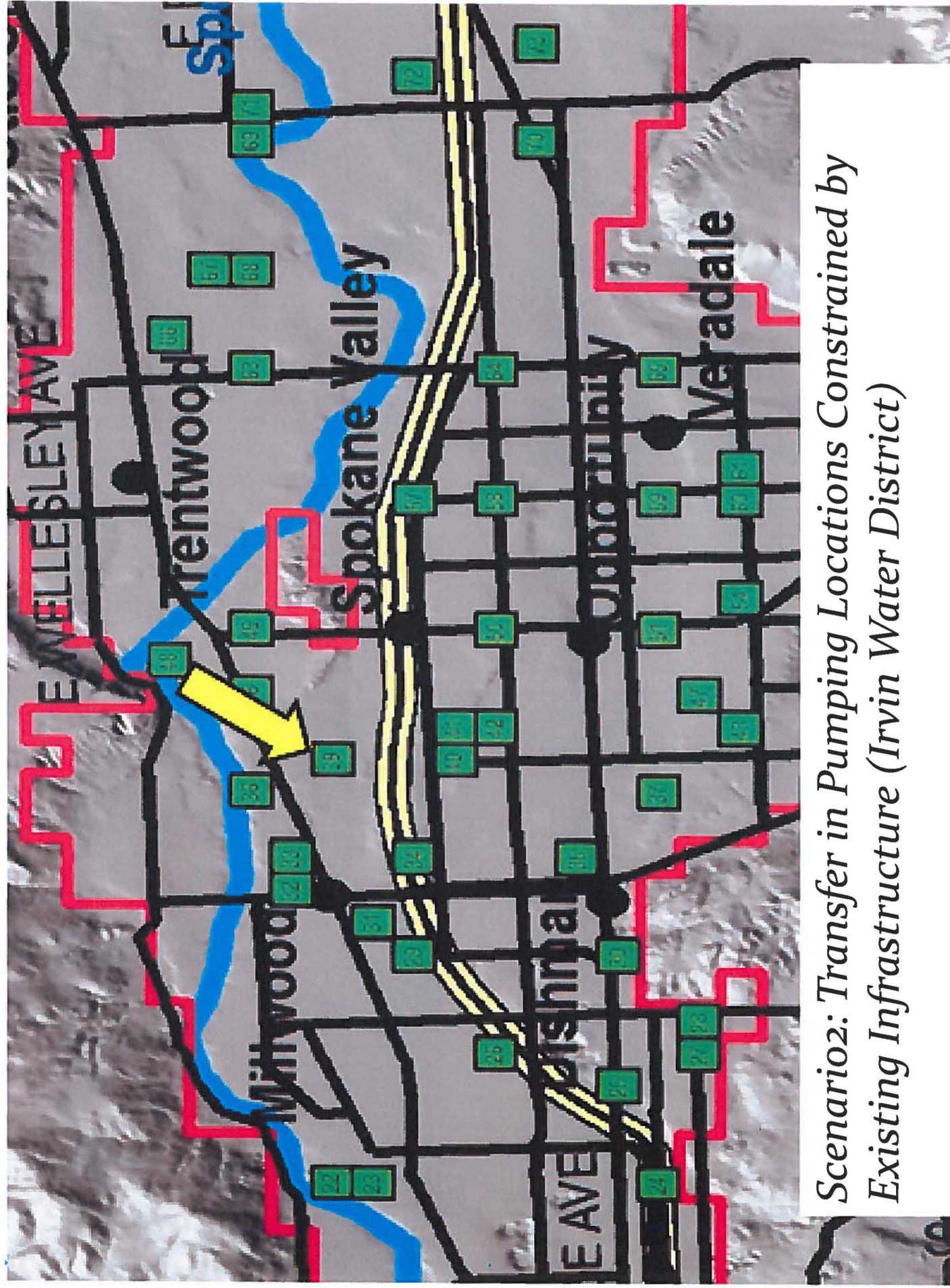


All of the wells would be in the western portion of the SVRP aquifer

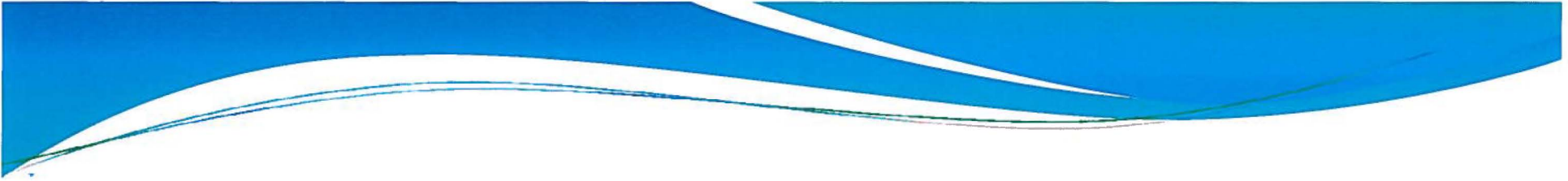


Alternative #2 --Transfer pumping from a well with greater impact to a well with less impact on the river.

1. The wells are within the same water district and connected to an existing water distribution system.
2. The wells are within the same state but not within the same water district; connecting pipes would need to be constructed.
3. Wells are within different states; connecting pipes would need to be constructed.

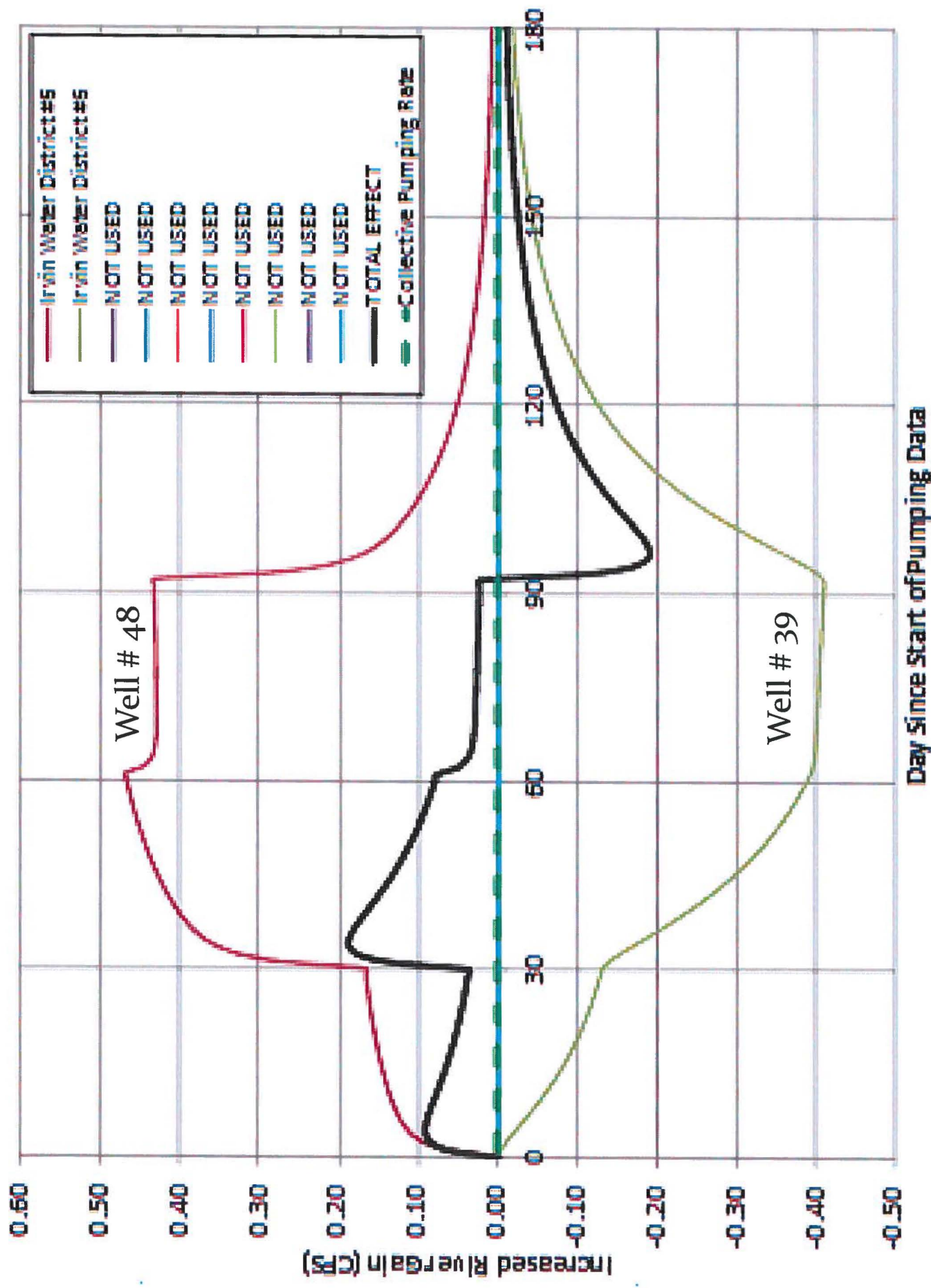


Scenario2: Transfer in Pumping Locations Constrained by Existing Infrastructure (Irvin Water District)

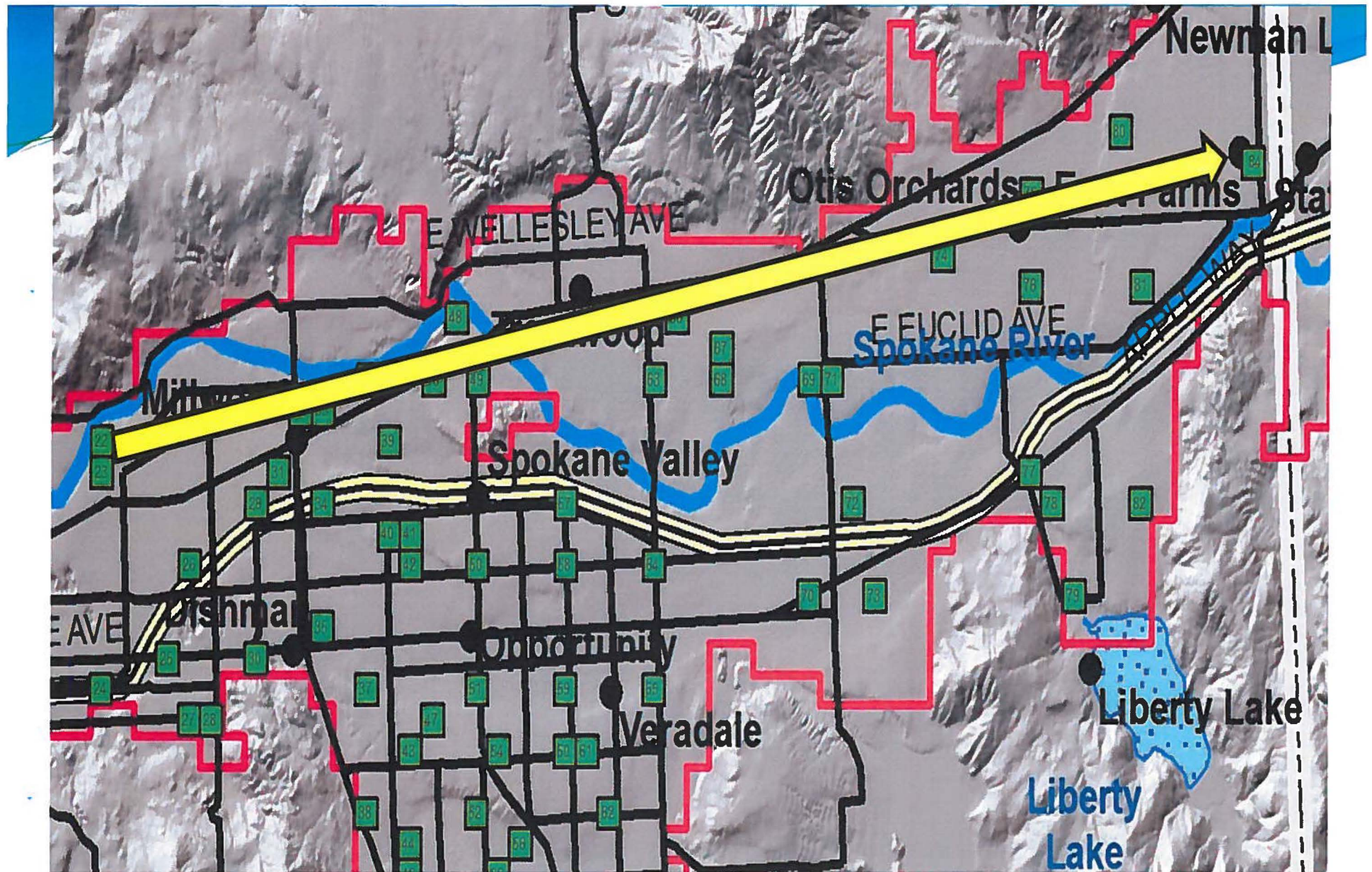


Irvin Water District

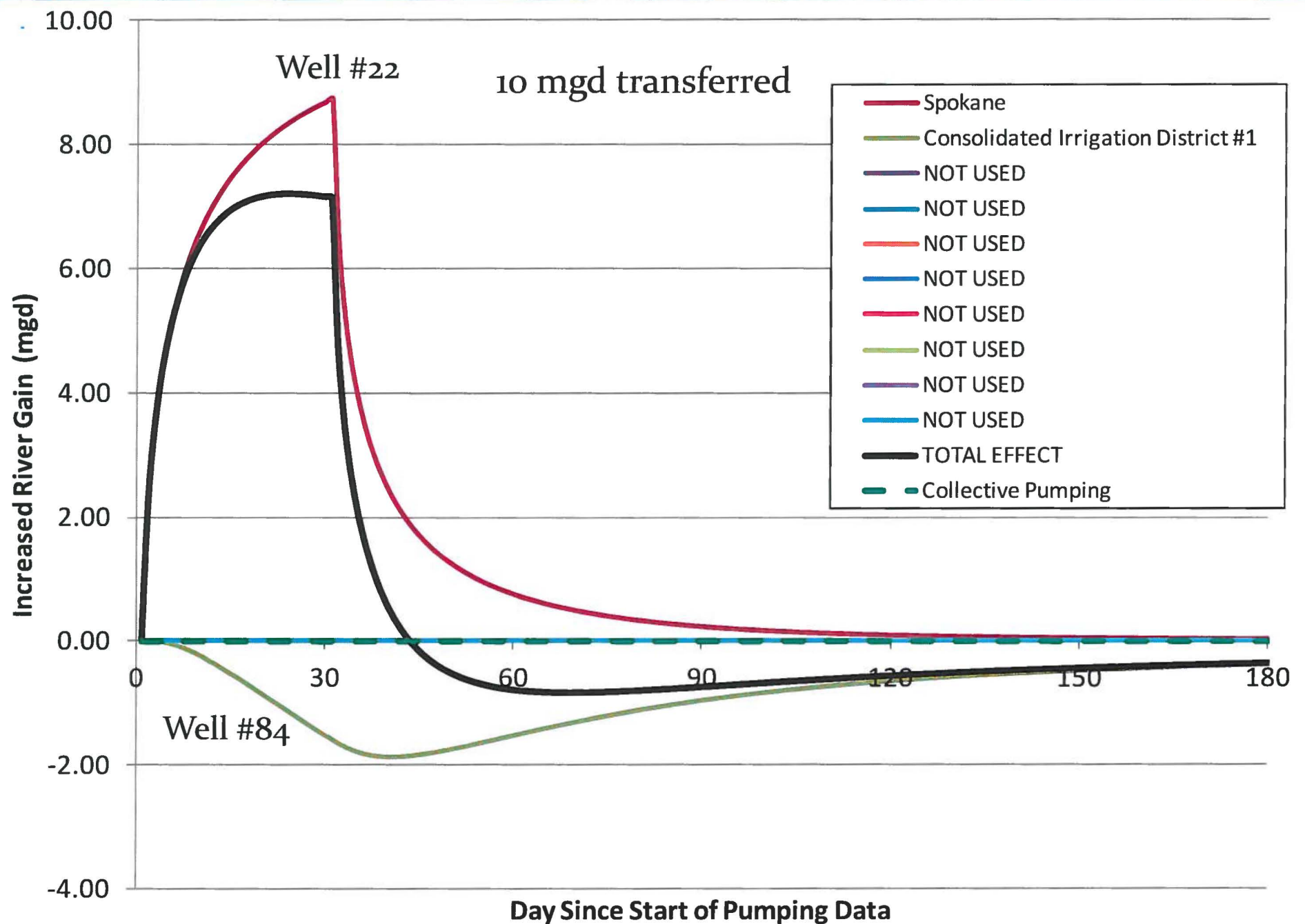
- Example used by John Porcello for the Spokane Aquifer Joint Board (SAJB).
- Wells are 1.25 miles apart.
- The transferred pumping rate was simulated as the following: 0.12 cfs in June, 0.34 cfs in July, and 0.29 cfs in August and zero at all other times.
- Results from the spreadsheet interface to the Bi-State model were similar to the results obtained by John Porcello using the SAJB finite element model.



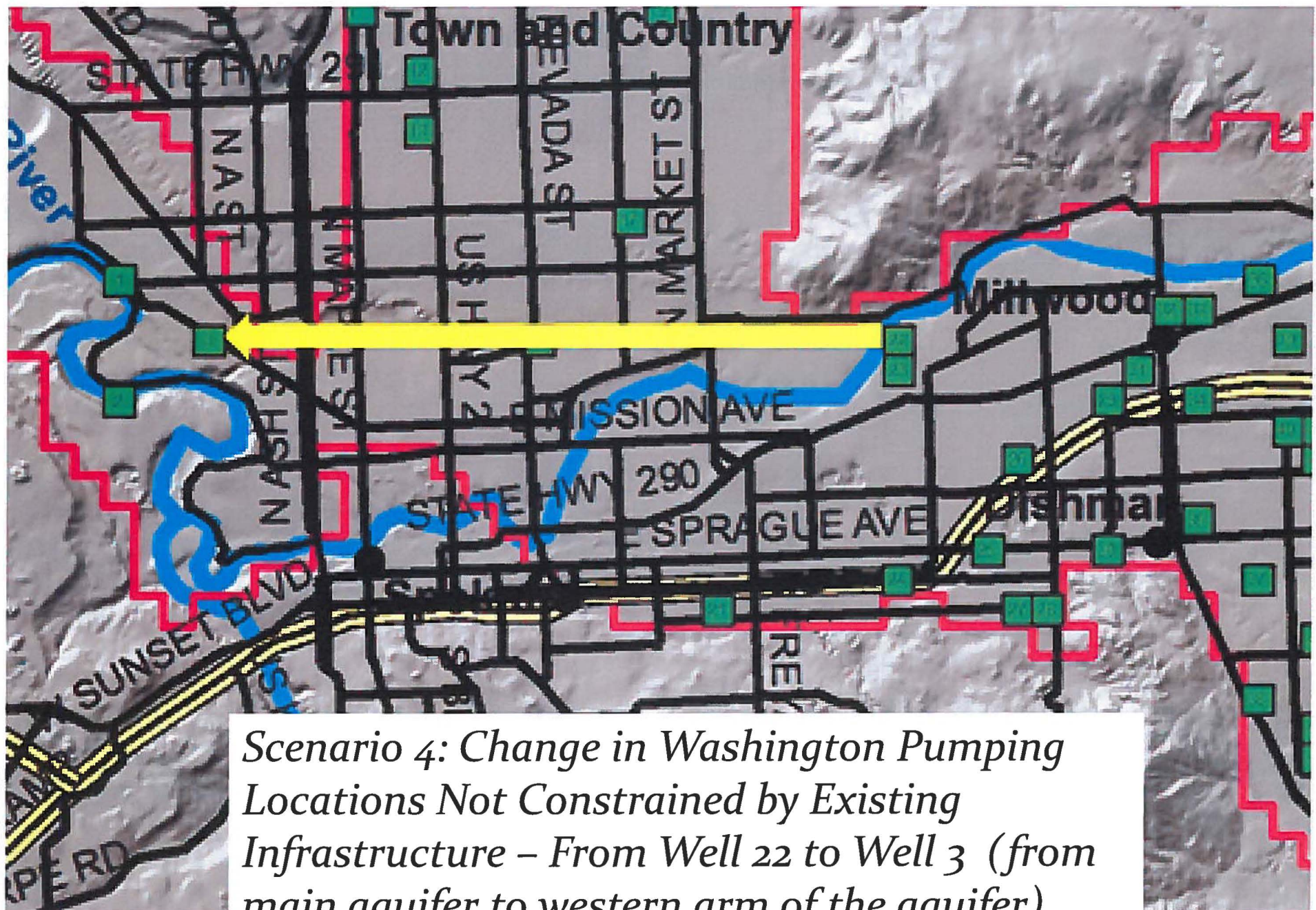
Scenario # 2 -- Irvin Water District



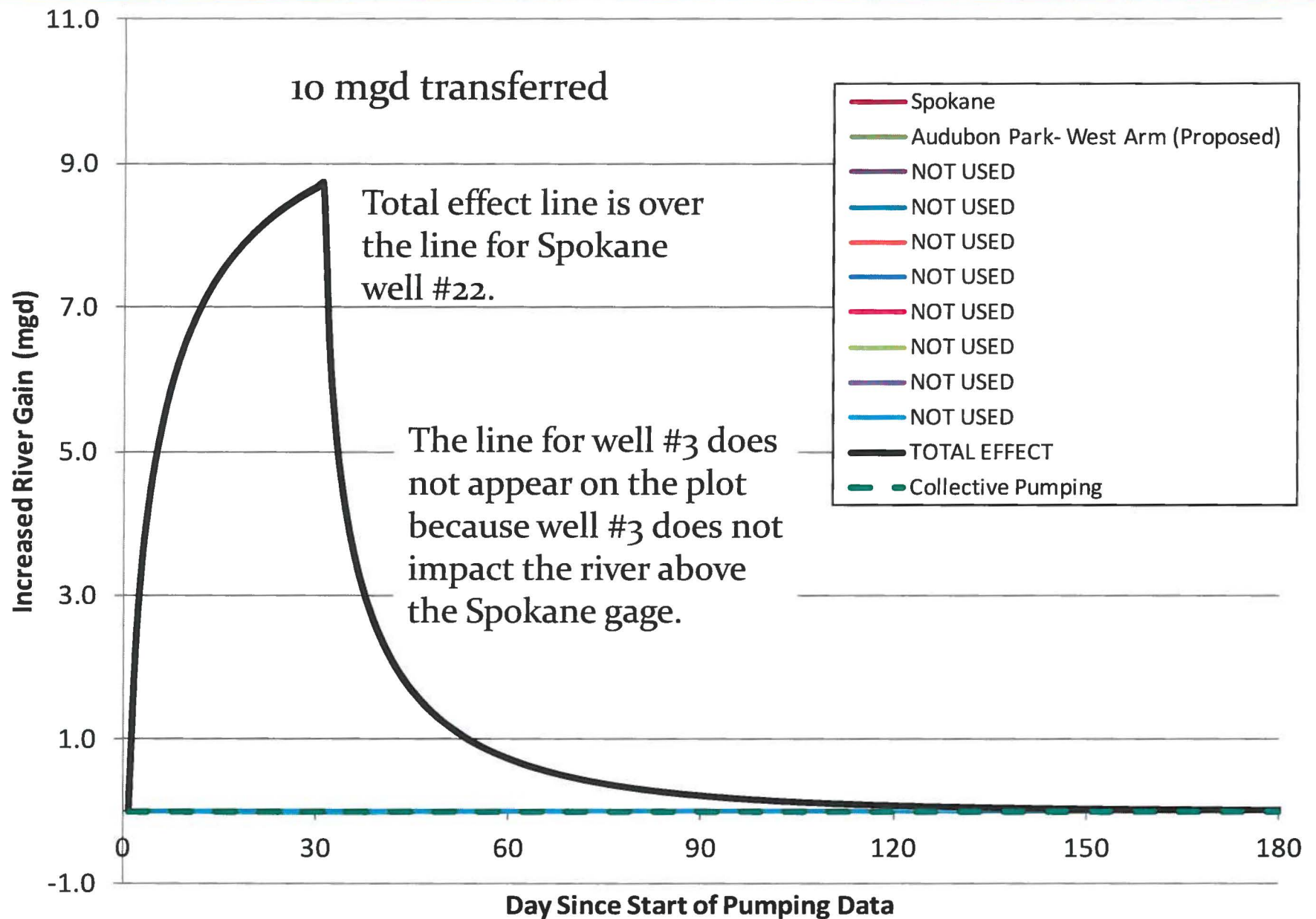
Scenario 3: Transfer in Washington Pumping Locations Not Constrained by Existing Infrastructure – From Well 22 to Well 84



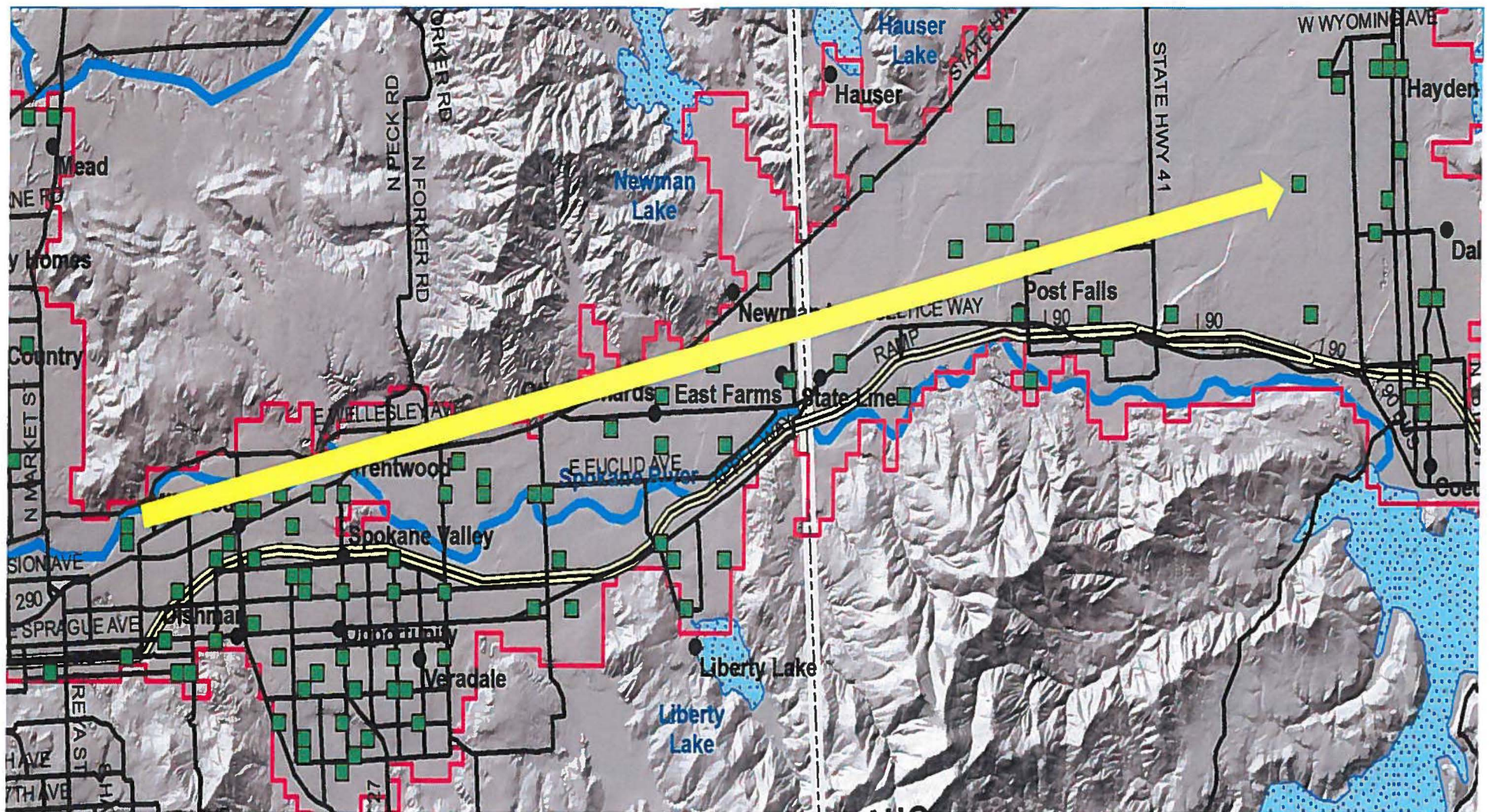
Scenario #3 Transfer pumping from well #22 to well #84



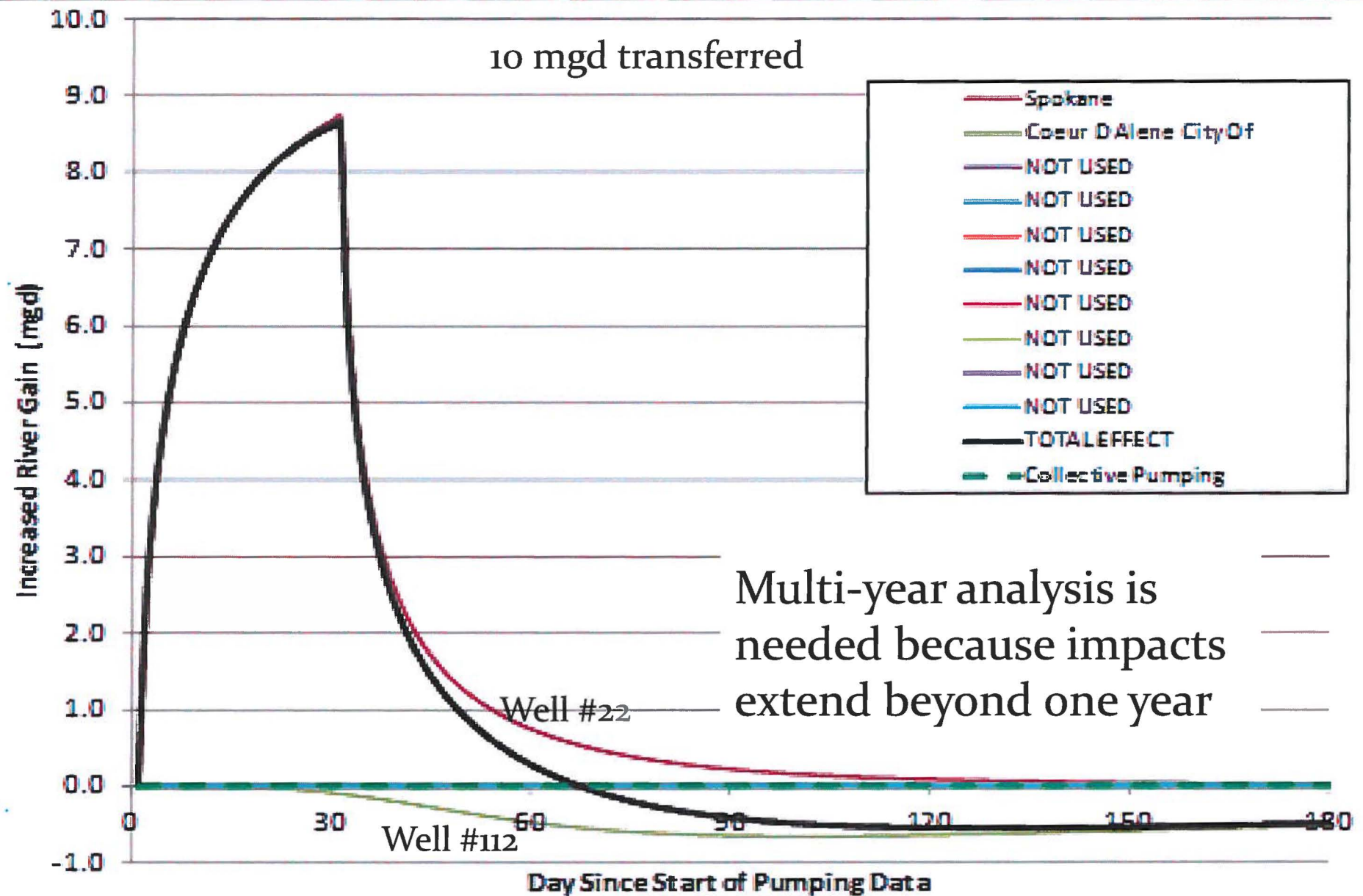
Scenario 4: Change in Washington Pumping Locations Not Constrained by Existing Infrastructure - From Well 22 to Well 3 (from main aquifer to western arm of the aquifer)



Scenario #4 Transfer pumping from well #22 to well #3



Scenario 5: Change in Washington Pumping Location to an Idaho Pumping Location – Not Constrained by Existing Infrastructure; From Spokane Well #22 to Coeur d'Alene Well #112

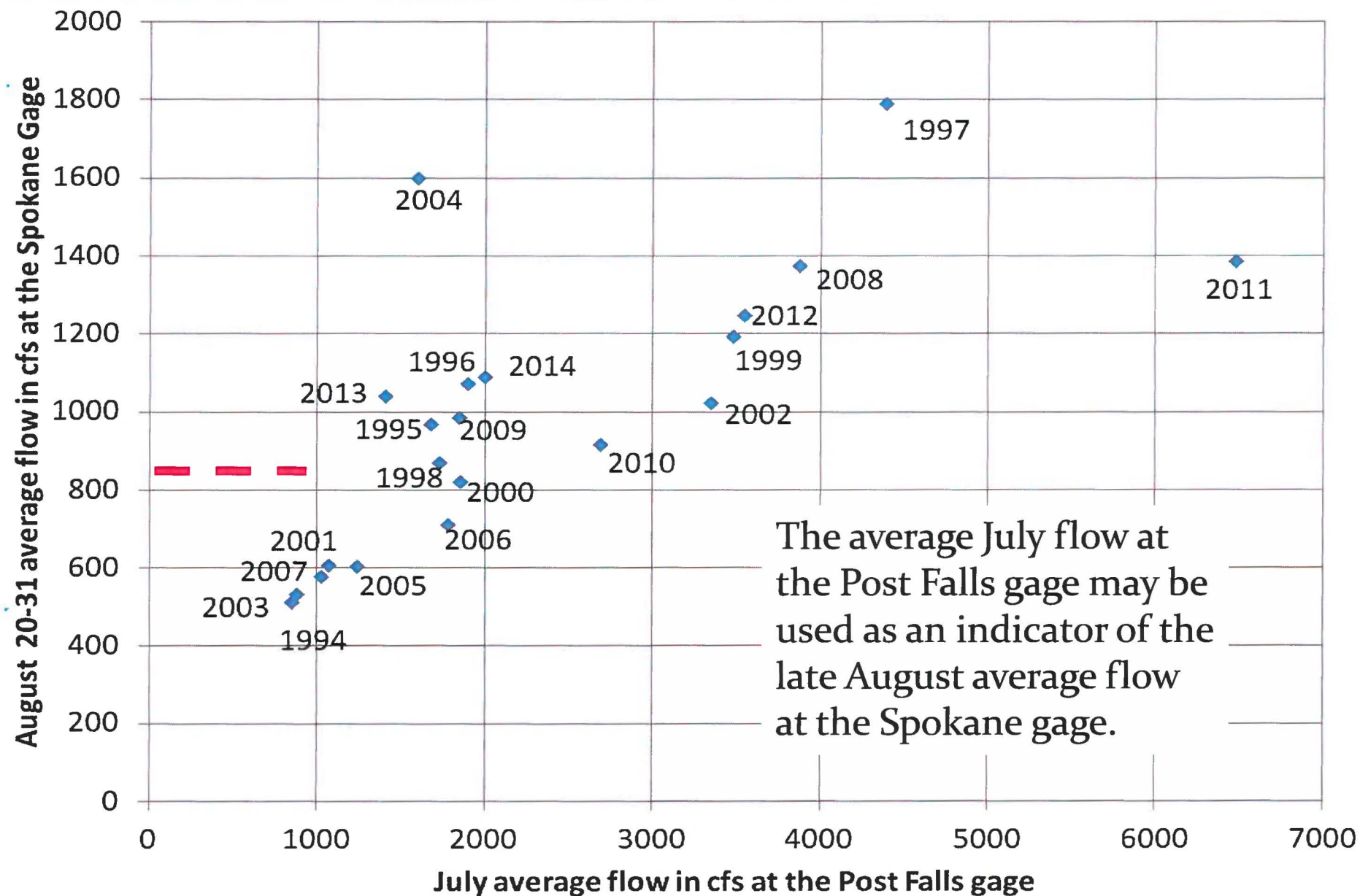


Scenario 5: Transfer pumping From Spokane Well #22 to Coeur d'Alene Well #112



How would any of these programs work?

- An agreement would be needed in order to manipulate pumping based on benefit to the river rather than priority based on the Appropriation Doctrine. The last scenario would also require an agreement between Washington and Idaho.
- A funding source would needed to construct the needed infrastructure.
- An “indicator” would be needed to identify probable low-flow periods at least a few weeks to a month prior to when action would need to be taken.

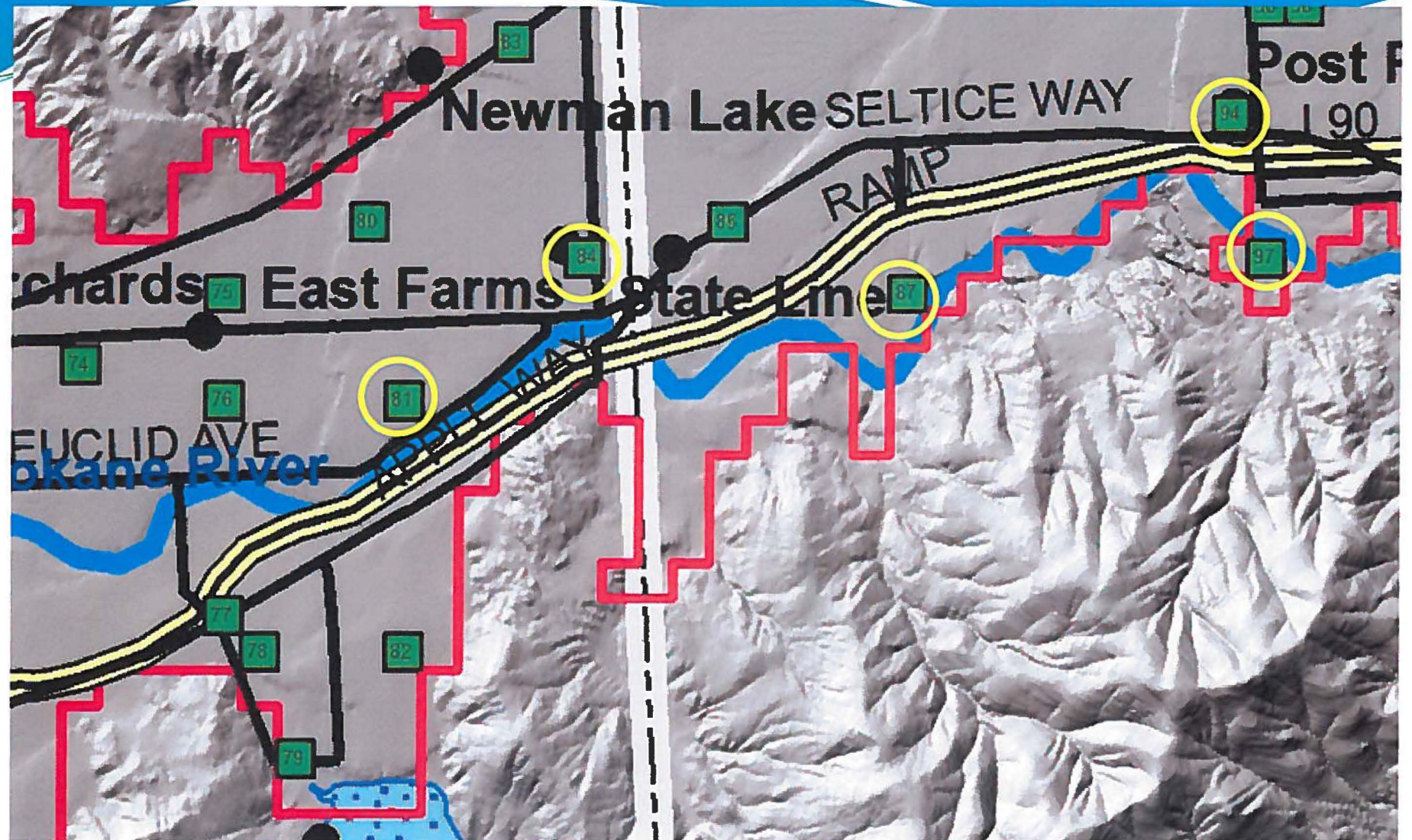


Plot of average July flow at the Post Falls gage versus the late August flow at Spokane gage

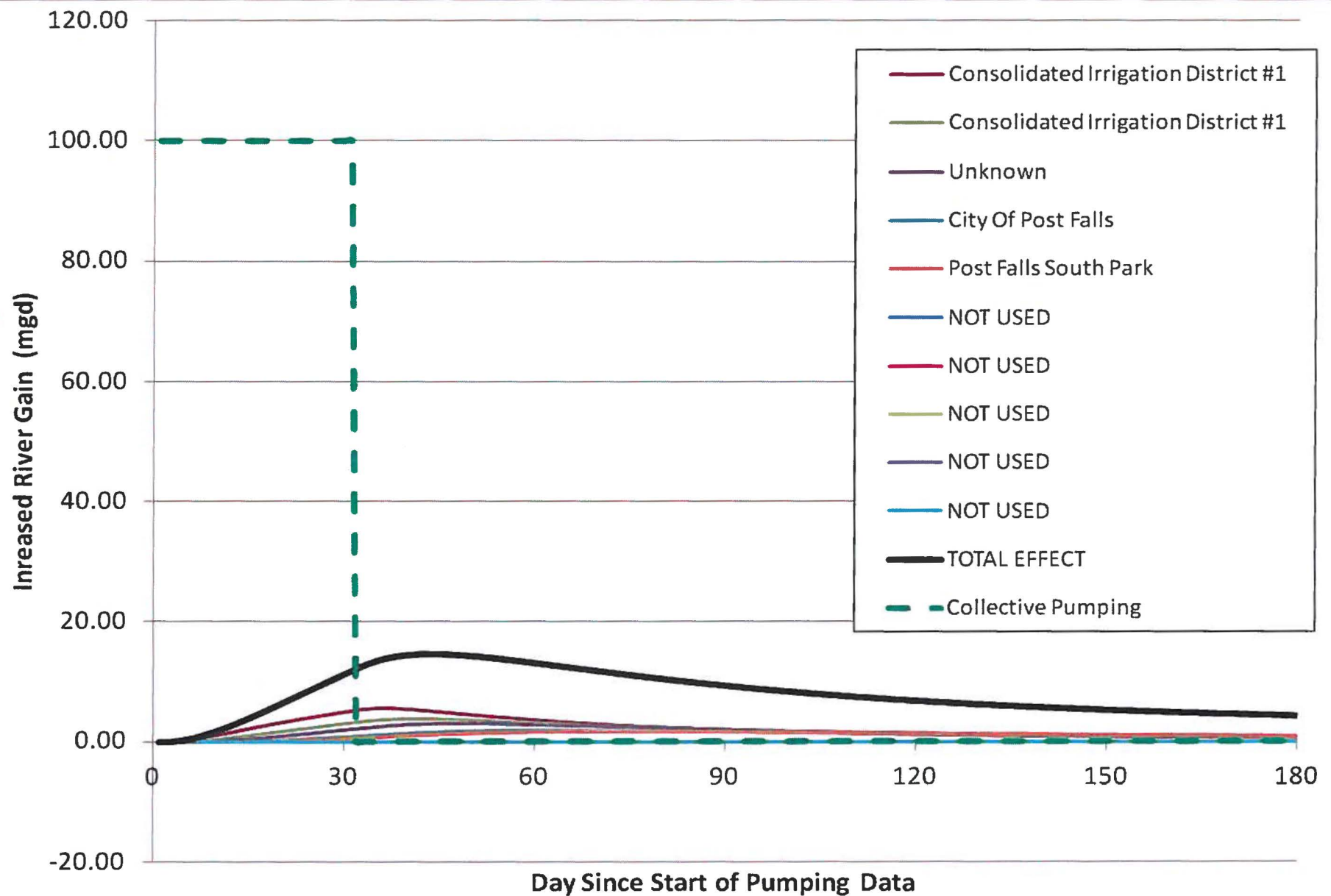


Why would there be a relationship between average July flow at Post Falls and average late August flow at Spokane?

- Leakage from the river is a major component of recharge to the aquifer.
- The locations where river leakage occurs are near enough to the hydraulically connected to reach to make temporal changes significant.
- Can use the spreadsheet to analyze the question.



Wells used in analysis to represent recharge from the river in the perched reach

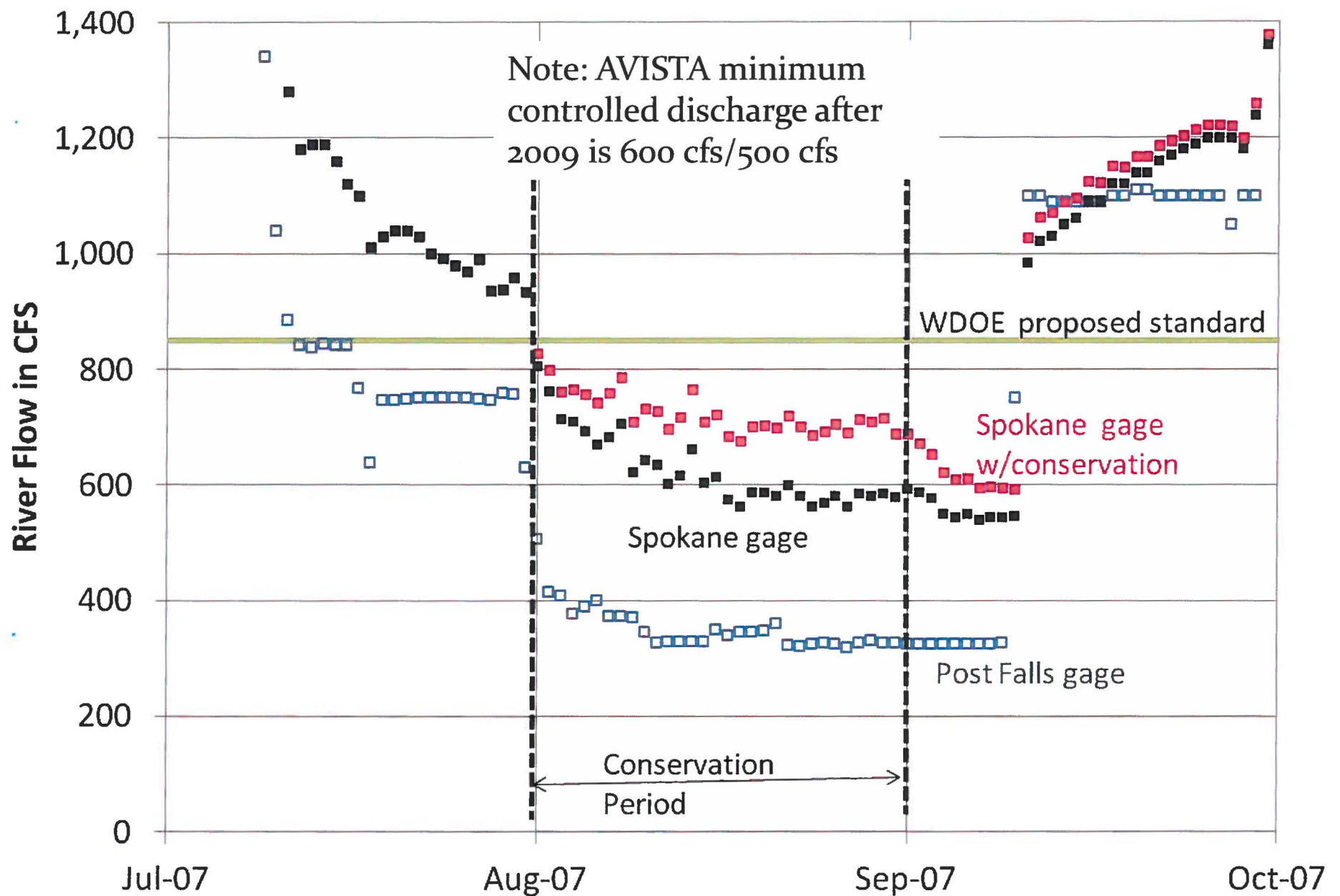


Model predicted river flow effect from river recharge in the perched reach as represented by five wells



Apply Scenario #1 (pumpage reduction) to 2007 flow conditions

- Flow at the Spokane gage was as much as 250 cfs below the proposed standard of 850 cfs.
- Analysis
 - Calculate what the flow of the Spokane River would have been under 2007 conditions if all of the wells with a 40% or greater impact on the river after 30 days had reduced pumping from “summer” to “winter” rates for one month.
 - The river flow was also adjusted to reflect a minimum 600 cfs discharge from the Post Falls Dam.

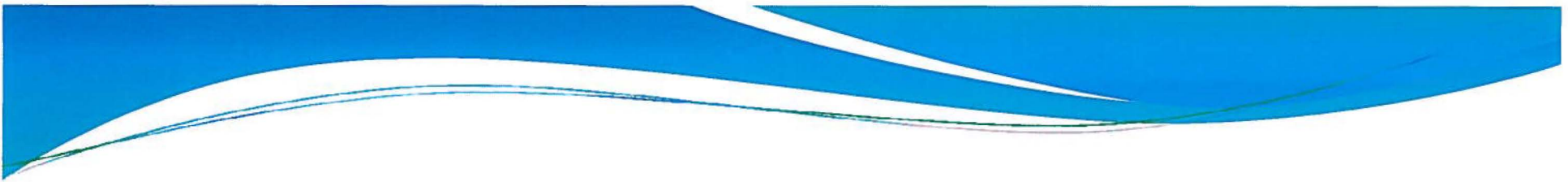


Example application of pumping reduction to 2007 hydrograph (at 40% conservation efficiency)



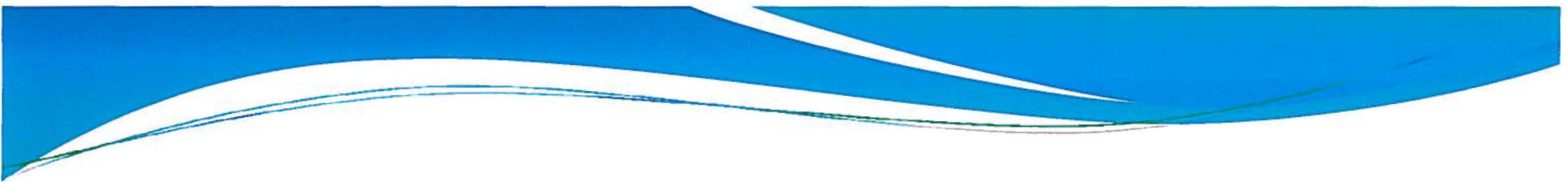
Spokane River near Greenacres on August 1, 2003 (Aquifer Atlas, 2009)

River flow at Greenacres and other locations upstream of where the aquifer is hydraulically connected to the river cannot be impacted by changes in ground-water pumping or aquifer recharge.



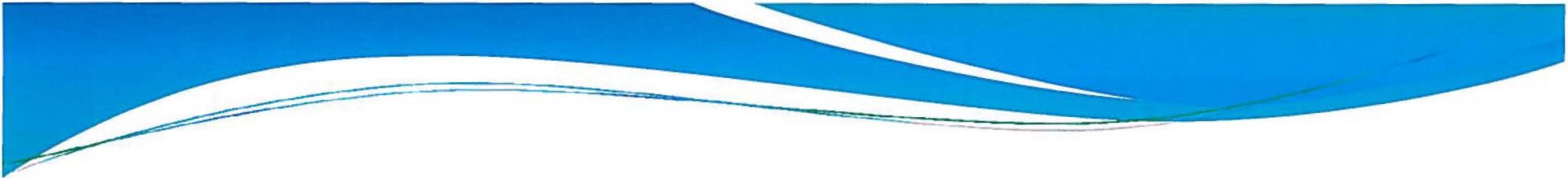
Summary and Conclusions - 1

- Three factors control the low flow in the river as measured at the Spokane gage: 1) the discharge rate from the Post Falls Dam, 2) the time-lag effects from recharge events and 3) the time-lag effects from ground-water pumping events.
- Long-term water-level decline has not occurred in the aquifer.
- The Bi-State numerical model is a useful tool for evaluating the time-lag effects of pumping and recharge events.
- The distance from the well to the hydraulically connected reach of the river is the dominant factor in controlling both the magnitude and timing of pumping and recharge impacts on river flow.



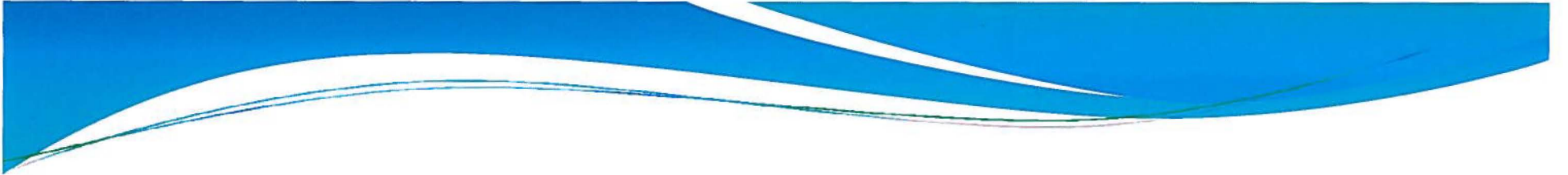
Summary and Conclusions - 2

- For our pumping reduction analysis, we selected reduction of pumping rates from “summer” to “winter” as the basis for our analysis.
- We also decided that short-term solutions are needed since the problem with river flow is short duration (1 to 4 weeks).
- The late August flow of the river at Spokane appears to be correlated with average July flow at Post Falls; This illustrates the time-lag effects of recharge events from the Spokane River and could provide an “indicator” to use to initiate pumping reductions to benefit river flow.



Summary and Conclusions - 3

- Reduction of pumping from “summer” to “winter” in those wells with a minimum of 40% impact on river flow results in an increase in river flow of about 130 cfs.
- This reduction in pumping would help mitigate problems associated with low discharge but would not result in meeting the WDOE proposed minimum flow in about six of the last 21 years.
- Inclusion of wells with an impact on river flow of less than 40% results in little additional increase in river flows.



Summary and Conclusions - 4

- Transfer of pumping from wells near the hydraulically connected portion of the river to more distant wells provides benefit for river flows. The amount of benefit is dependent dominantly on the amount of water transferred and the distance of the replacement pumping well to the hydraulically connected portion of the river.
- In most cases, infrastructure is not in place for transfer of pumping considerable distances.

Thank you!

