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

Proposal Prepared by

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INTRODUCTION

The purpose of this proposal is to evaluate the feasibility of one of several approaches that could be implemented to reduce the severity of extreme low flow in the Spokane River at the Spokane gage during the late summer, fall and early winter. Along with discharge from the Post Falls dam, the Spokane Valley – Rathdrum Prairie (SVRP) aquifer is a primary source of water in the river at the Spokane gage during the critical low-flow period.

Conjunctive management of this ground water/surface water resource is complex because of two major factors.

1. About two-thirds of the aquifer occurs in Idaho while the remaining one-third is in Washington. There is no inter-state compact or agreement relative to administration of this water resource system. While both states manage water based on the Appropriation Doctrine, there are significant differences in management style as well as management laws and rules.
2. Conjunctive management of surface water and ground water is not an issue in the Idaho portion of the SVRP aquifer while it is the dominant issue within Washington. The most significant surface water systems overlying the aquifer are perched within Idaho making them recharge sources that are independent of ground water levels. In contrast, ground water discharge is the primary supply source for the Spokane and Little Spokane Rivers in Washington during the low flow portion of the year. Maintaining target minimum streamflow is a primary driver for water management within the State of Washington.

DESCRIPTION OF THE HYDROLOGIC SYSTEM

The SVRP aquifer underlies a broad valley that extends from northern Idaho into eastern Washington (Figure 1). Recharge occurs in both Idaho and Washington and almost all natural aquifer discharge is to the Spokane and Little Spokane Rivers within Washington.

The aquifer is composed of glacial outwash and flood sediments deposited in a valley eroded into basalt and metamorphic rocks. Kahle and Bartolino (2007, page 12-13) describe the aquifer as follows.

> "The SVRP aquifer consists of unconsolidated, coarse-grained gravel, cobbles, boulders, and some sand primarily deposited by a series of catastrophic glacial outburst floods. The material deposited in this high-energy depositional environment is coarser grained than is typical for most basin-fill deposits and forms one of the most productive aquifers in the United States…The aquifer extends from Lake Pend Oreille through the Rathdrum Prairie and Spokane Valley to near Spokane where it is divided by Five Mile Prairie… On the west side of Five Mile Prairie, the Western Arm of the aquifer follows the course of the present-day Spokane River from near downtown Spokane to the community of Seven Mile. On the east side of Five Mile Prairie, the main body of the aquifer extends through the Hillyard Trough and then west through the Little Spokane River Valley to Long Lake…"

Natural recharge to the aquifer occurs via three primary mechanisms (Kahle and Bartolino 2007, page 21). First, recharge occurs from precipitation and direct infiltration on the glacial sediments (about 16 percent). Second, recharge to the aquifer occurs as underflow from the surrounding tributary valleys and as leakage from the lakes that are present in many of these valleys (about 30 percent). Third, aquifer recharge occurs as leakage from the Spokane River in the reach from Coeur d'Alene Lake to approximately Barker Road in Eastern Washington (about 49 percent). The river is perched above the aquifer throughout this entire reach. The remaining 5 percent is from landscape irrigation and septic systems.

Discharge from the aquifer occurs predominantly to the Spokane and Little Spokane Rivers and ground-water pumping. Kahle and Bartolino (2007, page 21) indicated that these percentages are approximately 59 percent, 16 percent and 22 percent respectively. The remaining discharge is subsurface outflow and infiltration of ground water into sewers. All of the natural discharge from the aquifer occurs within Washington. The total estimated discharge from the aquifer is 1,468 cubic feet per second (ft^3/s).

IMPACTS ON THE HYDROLOGIC SYSTEM

Other than ground-water pumping and the operation of the dam on the Spokane River at Post Falls, human development has done relatively little to change the natural hydrologic system in the area. Surface water was diverted for irrigation from the Spokane River and some of the adjacent lakes starting in the early 1900's but has largely been eliminated in recent decades because of urban development. Ground water based irrigation occurs in dominantly in Idaho but is gradually decreasing with time because of urban pressure.

The largest impact on the hydrologic system stems from the withdrawal of ground water in both Idaho and Washington mostly for municipal and private water supply. Figure 2, taken from Hsieh and others (2007 page 23), shows the combined monthly withdrawal rate from all wells (water purveyor, irrigation, domestic and industrial) in the SVRP aquifer from 1990 to 2005. The figure also shows the relative amounts of withdrawal by the various types of wells. The total ground-water withdrawal is composed mostly of pumpage by water purveyors' wells followed by irrigation wells. The average combined withdrawal rate is 317 cfs (Hsieh and others, 2007, page 23). The summer peaks of the combined withdrawal generally range from 600 to 800 cfs. Figure 3 shows the locations of water purveyor wells and service areas based on 2000 to 2002 data (Hsieh and others, 2007, page 21). Most of the water purveyors' wells are located in Washington. Figure 4 shows the locations of lands irrigated using ground and the irrigation densities (percentage of land irrigated in each area) (Hsieh and others, 2007, page 25). Almost all of the irrigated areas are in Idaho.

Ground-water pumping impacts surface water systems via declining ground-water levels. Lower ground-water levels cause greater losses in hydraulically connected losing stream reaches and reduced gains in gaining reaches. It is important to remember that ground-water level changes only impact flow in streams where there is saturated hydraulic connection between ground water and the stream.

The locations of three wells that have long-term water-level records (two wells in Idaho and one in Washington) are shown on Figure 5. The wells located near Post Falls, Idaho (51N 5W 33bba1/33cba1) and Liberty Lake, Washington (25N 45E 16C01) have the longest records, dating back into the 1920's. Well 53N 4W 28cab1 located near Spirit Lake, Idaho has records starting in the 1970's. Hydrographs for these three wells are presented in Figures 6, 7 and 8. Data were taken from the USGS websites for water resource data from Idaho and Washington with a limited number of additional data points obtained from the Idaho Department of Water Resources (Ken Neely, personal communication, 2013). The lowest levels on record for the wells near Post Falls and Liberty Lake occurred in the early 1930's with the highest records in the mid 1990's. The hydrograph for the well near Spirit Lake is similar in that the highest water level occurred in the 1990's. There is no evidence of long-term water-level decline in any of the three wells.

Flow data taken at the USGS gaging station on the Spokane River at Spokane as analyzed by Barber and others (2011) show that the maximum and average flow of the river have not been impacted by development but that the minimum flow of the river has been impacted. Barber and others (2011, page 6) describe the low-flow characteristics of the river as follows (see Figure 9).

> “As illustrated… summer low flows at the USGS gage near downtown Spokane …. are often less than 1,000 ft^3/s, particularly in the last 40 years. It is this disturbing trend in low flows that raises concerns among water resource agencies. A regression analysis of the minimum annual daily flow data indicates a statistically significant … decrease in low flow between 1900 and 2007. While the rate of decline was steepest from 1900 through 1950…..the downward trends has still continued since that time…..The combined effects of changes in reservoir operations associated with the Post Falls Dam, changes in water use patterns from irrigation of orchards and row crops to suburban residential uses, increases in municipal pumping as the regions’ populations has grown and changes in runoff patterns due to climate change… are creating severe low flow conditions that threaten water users and the environment.”

Hortness and Covert (2005) show that the annual 7-day low flow of the Spokane River near Post Falls (the discharge from the Post Falls Dam) and at Spokane both have a downward trend for the period of 1968 – 2002 (Figure 10). They state the following based on a comparison of the streamflow data from the Post Falls gage and the Spokane gage (page 14).

> “Differences in monthly mean streamflow between the Post Falls and Spokane gaging stations for the months of July through December during 1968 – 2002 were analyzed for trends. Although the upper parts of this reach generally lose streamflow to the aquifer, the overall reach historically has gained streamflow. Trends detected for the months of September, October, and November were statistically significant. The analyses showed that the streamflow gains within this reach decreased over time during the period 1968-2002.”

IDENTIFICATION OF MITIGATION ALTERNATIVES

Three approaches can be identified to reduce the problems of extreme low flow in the Spokane River at the Spokane gage in the late summer and fall.

- The first approach is to reduce and/or relocate ground-water pumpage from the SVRP aquifer at strategic locations in Washington and Idaho and at specific times to allow greater flow in the river in the reaches in question during the critical low flow period.
- The second approach is to increase the discharge from the Post Falls Dam at specific times to allow greater flow in the river in the reaches in question during the critical low flow period.
- The third approach is to construct the facilities necessary to artificially recharge the SVRP aquifer at selected areas such that the positive impacts from recharge would result in greater discharge from the aquifer to the river in the reaches in question during the critical low flow period.

The first approach presented above is the subject of this proposal. The second and third approaches are briefly described below.

There are a number of constraints relative to using the storage behind Post Falls Dam within Lake Coeur d’Alene to mitigate low flow problems within the Spokane River at the Spokane gage. Two physical constraints are important: 1) the outlet channel immediately north of Coeur d’Alene Lake is the hydraulic control for water discharging from the lake to the river during both extreme low flow and extreme high flow and 2) a significant portion of the discharge from the Post Falls Dam infiltrates into the aquifer in the river reach from the dam to approximately Barker Road. Other constraints include maintaining a designated lake level during the summer recreational period and satisfying existing streamflow rights in the river. The alternative of using water from Coeur d’Alene Lake to aid in meeting minimum streamflow targets in the Spokane River is a subject that needs additional research.

The alternative of using the SVRP aquifer for water storage with later recovery via the discharge to the Spokane River was the subject of an extensive study by Barber and others (2011). The following quotes provide an overview that their study.

> "Using Visual MODFLOW with the regionally-approved 1990-2005 MODFLOW-2000 model data, a comprehensive aquifer recharge and natural recovery feasibility study involving two water sources, multiple injection sites, and timing considerations was conducted with withdrawals occurring during periods of excess river flows in the Spokane and Pend Oreille watersheds. One of the primary project constraints involved the influence of injection on flows in the Spokane River. The optimized artificial recharge was designed to improve low flows in the months of August, September, and October ….
>
> MODFLOW modeling results showed increases in head by artificial recharge produce increased flows into gaining reaches and decreased flow out of losing reaches…. Surface water diversions from the Spokane River proved to be problematic due to excessive treatment costs and groundwater extraction from the Washington side of the aquifer to the injection sites created large depressions that had to fill prior to any river benefit. Therefore, the optimum solution was to take water from the Lake Pend Oreille area during high flow periods. This increases the net recharge already occurring from that area….
>
> The two best alternatives involve 300 $ft^{3/}$s of extraction/injection via a 72-inch pipeline for four months (April – July) originating from near Lake Pend Oreille and terminate near the intersection of N. Ramsey and E. Diagonal Road…. or at Rathdrum" (pages x-xii).

DESCRIPTION OF THE PROPOSED PROJECT

<u>Introduction</u>

The proposed project addresses whether changing the amount, timing and location of ground-water pumping within the SVRP aquifer in Washington and Idaho can be used as a management approach to mitigate the problems associated with critical low flow in the Spokane River at the Spokane gage during late summer and fall months. We know that ground-water pumping in both states impacts the flow of the river. We also know that the time lag between operation of a given well and the associated impacts on the river is controlled by the distance to the river and the hydraulic properties of the aquifer. A well located very near a reach of the river where there is saturated hydraulic connection of ground water and surface water obviously has a greater and more immediate impact on the flow of the river than a well located at a greater distance from the river.

The focus of the proposed project is the analysis and development of 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. At least four major questions need to be addressed relative to this water management program.

- First, what criteria would be used to select wells to be part of the management program?
- Second, how would the program of staged operation of production wells operate in order to meet target discharge rates within the river?
- Third, how would impacts from decreased water supply for users of the wells included in the program be mitigated?
- Fourth, how would the proposed management program be administered within the constraints of the water-right systems of both Washington and Idaho?

The proposed project is designed to address technical issues associated with the first three questions posed above.

Problems associated with conjunctive management of water resources in the SVRP aquifer/Spokane River system are similar to those currently being addressed in the Eastern Snake Plain Aquifer/Snake River system in Idaho. Both aquifers have high transmissivity and both aquifers act as unconfined ground-water systems. The primary water management issues in both areas are impacts of ground-water pumping on surface water systems. The primary issue in the Snake Plain aquifer is decreased discharge rates from springs, many of which are located topographically above the Snake River. The primary issue in the SVRP aquifer is the decreased discharge of ground water into the Spokane River.

Conjunctive management of surface water and ground water in the Snake Plain aquifer has been based in part on using steady state and transient response functions in conjunction with the existing aquifer numerical model to predict impacts of wells in different areas on groups of springs. Cosgrove and Johnson (2004, page 1470) describe the response function approach as follows.

> "Response functions are mathematical descriptions of the relationship between a unit stress to an aquifer at a specified location and an impact elsewhere in the aquifer system. The impact could be stream depletion at a hydraulically connected river reach or change in aquifer water level at a location other than the pumping location. The response function, for example, could be a curve describing stream depletion over time, resulting from a unit stress. Each response function models the response of a specific river reach or aquifer water level to a unit stress at a specified location….
>
> Response functions can be generated using either analytical techniques or a numerical model….. Generating response functions using a numerical ground water model enables the representation of complex system heterogeneities and anisotropies."

The response function approach has been applied to a limited extent in the SVRP aquifer/Spokane River system. Taylor, Contor and Johnson (2007) used the model of Hsieh and others (2007) to develop a series of contour maps illustrating the effect of pumping or recharge in the SVRP aquifer on different reaches of the Spokane and Little Spokane rivers and on Pend Oreille and Coeur d'Alene lakes. They also developed a spreadsheet that was capable of estimating river depletion for a series of SVRP zones with user entered pumping rates. Both of these efforts on the SVRP involved transient capture response functions determined on a monthly basis. Johnson, Contor and Taylor (2009) determined that non-linearity did not create significant error with SVRP response functions provided the functions were determined using an unconfined version of the SVRP aquifer model.

This proposal includes expansion of the Taylor, Contor and Johnson (2007) work by development of transient response functions on a daily basis. We propose to use the response function approach to analyze the timing and amounts of impacts of individual wells and groups of wells within the SVRP aquifer on the flow of the Spokane River as measured at the Spokane gage. We will be using MODFLOW with the regionally-approved 1990-2005 MODFLOW-2000 model developed by Hsieh and others (2007).

<u>Purpose, Objectives and Scope of Work</u>

The purpose of the project is to assess whether a program of reduced or relocated pumping from specific wells at specific times within the SVRP aquifer can be an important component in mitigating critical low-flow conditions in the Spokane River as measured at the Spokane gage. The general objective of the project is to use transient response functions in conjunction with investigations of the surface water – ground water system to assess changes in the flow of the Spokane River at the Spokane gage resulting from a program of reductions or relocations in pumping from selected wells during selected periods.

The following are a list of specific objectives along with a description of the proposed work and the proposed product. Products A and B constitute Phase I of the project and products C and D constituted Phase II of the project.

- ***Product A. Gain an improved understanding of low-flow conditions in the Spokane River from the Post Falls gage to the Spokane gage in order to better understand the surface water/ground water system and provide a basis to evaluate the results of the transient the response function analysis.*** The river reach from the Post Falls gage to the Spokane gage includes both losing and gaining segments. Hortness and Covert (2005) provide a temporal analysis of the net changes in flow between these stream gaging stations for the July through December period through 2002. Two previously operated gaging sites below Post Falls were reinitiated in 1999. These stations are the Spokane River above Liberty Bridge near Otis Orchards (USGS 12419500) and the Spokane River at Greenacres (USGS 12420500). Only about three years of record for these sites were included in the analysis by Hortness and Covert (2005). We believe that analysis of an additional 10 years of record (through 2012) for all four of the gaging stations will provide very useful results in support of the response function analysis.
    - Project work would involve compilation and analysis of U.S. Geological Survey streamflow data in the period of approximately 1999 through 2012 for gaging stations at Post Falls (USGS 12419000), Otis Orchards, Greenacres and Spokane (USGS 12422000). The focus would be on describing flow rates during the months of July through December for each year. These results would be compared to the analysis presented in Hortness and Covert (2005).
    - The analysis will also summarize calculated daily Spokane River gains and losses (water budget determinations) for river reaches between the gages identified.
    - As pumping decreases during September and October due to decreased lawn watering and irrigation, river depletion may be noticeably diminished. Gain and loss estimates for the August through December period will be compared to pumping volumes and pumping effects as presented in Hsieh and others (2007) to identify possible correlation. Significant correlation would support the hypothesis that aquifer pumping is a substantial contributor to river depletion.
    - The product of this work would be: 1) a memo report that describes the stream loss and/or gain between these stations, the range of river discharges during the critical low-flow periods from 1999 through 2012 period and the possible temporal correlation to changes in pumping amounts and 2) a presentation/discussion meeting if desired.
- ***Product B: Conduct a Reconnaissance Transient Response-Function Analysis of Pumping Effects on the flow of the Spokane River at the Spokane Gage.*** The purpose of is effort is to do a reconnaissance-level analysis of the magnitude and timing of ground water pumping effects on depletion of the Spokane River.
    - A transient response function analysis on a daily time increment will be conducted to create a series of graphs that illustrate river depletion from a one day pumping event at 10 to 15 selected locations at varying distances from the Spokane River. The graphs, similar to that shown on Figure 11, will illustrate river depletion (as a percent of pumped volume) over a period of one month resulting from the one day pumping event. These graphs will be created using the SVRP aquifer model by Hsieh and others (2007).
    - The graphs will provide the basis for developing the detailed procedure to

accomplish Product C below. The degree to which pumping location affects the timing and magnitude of Spokane River depletion will influence the selection and number of locations included in the spreadsheet of Product C. For example, if depletion lags pumping effects by less than one day at all locations within two miles of the river, then the spreadsheet may aggregate these areas together in a zone of near immediate response. Conversely, evidence of significant lag times between pumping and river depletion will require representation of unique pumping locations throughout the area of concern.
    - Application of the graphs will be demonstrated by several hypothetical scenarios of reducing pumping rates or altering the areal distribution of pumping to achieve the objective of having additional flow within the river. These examples will illustrate how Products C and D will be developed and applied.
    - The product of this work would be: 1) a memo report that describes the preliminary transient response function analysis and the associated graphs and 2) a presentation/discussion meeting if desired.
- ***Product C: Create a River Depletion Spreadsheet.*** The purpose of the River Depletion spreadsheet is two-fold. First, the spreadsheet will provide the computational capability to efficiently complete Product D below. Second, the spreadsheet will allow any water interest to perform independent estimates of pumping impacts of Spokane River depletion and evaluate alternate pumping scenarios.
    - The spreadsheet will contain a large matrix of response function coefficients determined via numerous simulations using the SVRP aquifer model by Hsieh and others (2007). Users will be able to enter actual or hypothetical daily pumping volumes at any of a series of locations representing either: a) identified locations of wells with significant pumping rates, or b) non-pumping sites with potential to delay effects of river depletion. It is expected that a maximum of 50 sites will be included. The location of these sites will be identified in collaboration with IDWR using Product B above.
    - The spreadsheet will multiply the model determined response function coefficients times the user entered pumping volumes and superimpose in time the effects (convolution) of pumping at a given location on depletion of the Spokane River. The effects will be determined for the collective reach of the Spokane River from Post Falls to the Spokane gage. A hypothetical example output of the spreadsheet, resulting from a user evaluating the depletion effects of a five-day shut down of a well pumping at a rate of 10 ft^3/s, is shown in Figure 12. Complex scenarios of changing pumping rates at multiple locations will be possible by storing results in the worksheet and summing results for the multiple locations.
    - The product of this work would be: 1) a memo report that describes the spreadsheet is to be used and includes the spreadsheet and 2) a presentation/discussion meeting if desired. .
    - ***Product D: Assessment of Alternative Pumping Scenarios***. The purpose of this portion of the project is to describe the potential effects (in ft^3/s) of alternative ground water pumping schemes on Spokane River flows. Alternative schemes may involve hypothetical alterations in either pumping rates, locations, or both.
    - The assessment will be made by first evaluating impacts of reported or estimated pumping rates for each significant production well or groups of wells using the spreadsheet described in Product C above. The pumping rates will be typical for the months of July through December. Individual and cumulative effects on the Spokane River will be graphically illustrated. The appearance of the cumulative graph of existing pumping may be similar to that shown by the blue line in

Figure 13.

- The second part of the assessment results from evaluating approximately 10 different schemes (identified in collaboration with IDWR) that alter both pumping rates and locations. The individual well and net effects will be graphically illustrated for each scenario and compared to the effects from the existing pumping scheme. Results of an example scenario may appear similar to that shown by the red line in Figure 13. This product will not provide a comprehensive analysis of all alternative schemes, but should serve as a catalyst to initiate discussions and further use of the spreadsheet in Product C by collaborations of water interests to evaluate and consider mitigation alternatives.
- The potential benefit from completion of production wells with screens deeper within the aquifer will also be explored.
- The product of this work would consist of a final report that includes the results of products A, B and C with the results of product D plus presentation of one or more workshops.

Operation, Administration and Budget for the Project

All of the work on the project would be conducted by Dr. Ralston and Dr. Johnson (or under their direct supervision) with input from IDWR and other interested parties. The project would be administered through Ralston Hydrologic Services, Inc. with Dr. Ralston as lead.

A budget for the project will be created based on the final scope of work as determined with input from IDWR. The project can be completed within one year of award.

REFERENCES CITED

Barber, M.E., M.A. Hossain, C.J. Poor, C. Shelton, L. Garcia and M. McDonald, 2011, Spokane Valley – Rathdrum Prairie Aquifer Optimized Recharge for Summer Flow Augmentation of the Columbia River; State of Washington Water Research Center, Washington State University, Prepared for the Washington State Department of Ecology.

Cosgrove, D.S, and G.S. Johnson, 2004, Transient Response Functions for Conjunctive Management of the Snake River Plain, Idaho; Journal of the American Water Resources Association, December, Pages 1469-1482.

Cosgrove, D.M. and G.S. Johnson, 2005, Aquifer management zones based on simulated surface-water response to aquifer stress (response functions). ASCE Journal of Water Resources Planning and Management, Vol. 131, No. 2, pp. 89-100.

Hortness, J.E. and J.J. Covert, 2005, Streamflow Trends in the Spokane River and Tributaries, Spokane Valley/Rathdrum Prairie, Idaho and Washington; U.S. Geological Survey Scientific Investigations Report 2005-5005.

Hsieh, P.A., M.E. Barber, B.A. Contor, M.A. Hossain, G.S. Johnson, J.J. Jones and A.H. Wylie, 2007, Ground-Water Flow Model for the Spokane Valley – Rathdrum Prairie Aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho; U.S. Geological Survey Scientific Investigations Report 2007-5044.

Johnson, G.S., B.A. Contor, and D.M. Cosgrove, 2007, Efficient and practical approaches to ground water right transfers under the prior appropriation doctrine and the Snake River example. Journal of the American Water Resources Association, vol 44, no 1, pp 27-36.

Johnson, G.S., B.A. Contor, and S.L. Taylor, 2009. Evaluation of potential errors resulting from imposing linearity in the development of capture response functions for the Spokane Valley-Rathdrum Prairie aquifer. Idaho Water Resources Research Institute Technical Completion Report 2009-04.

Kahle, S.C. and J.R. Bartolino, 2007, Hydrogeologic Framework and Ground-Water Budget of the Spokane Valley – Rathdrum Prairie Aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho; U.S. Geological Survey Scientific Investigations Report 2007-5041.

Neely, K., 2013, Personal communication, Idaho Department of Water Resources.

Taylor, S.L., B.A. Contor, and G.S. Johnson, 2007, Spokane Valley – Rathdrum Prairie Capture Spreadsheet. An on-line and interactive spreadsheet for evaluation of surface and ground water interaction available at
http://www.if.uidaho.edu/%7Ejohnson/ifiwrri/research_and_education.html

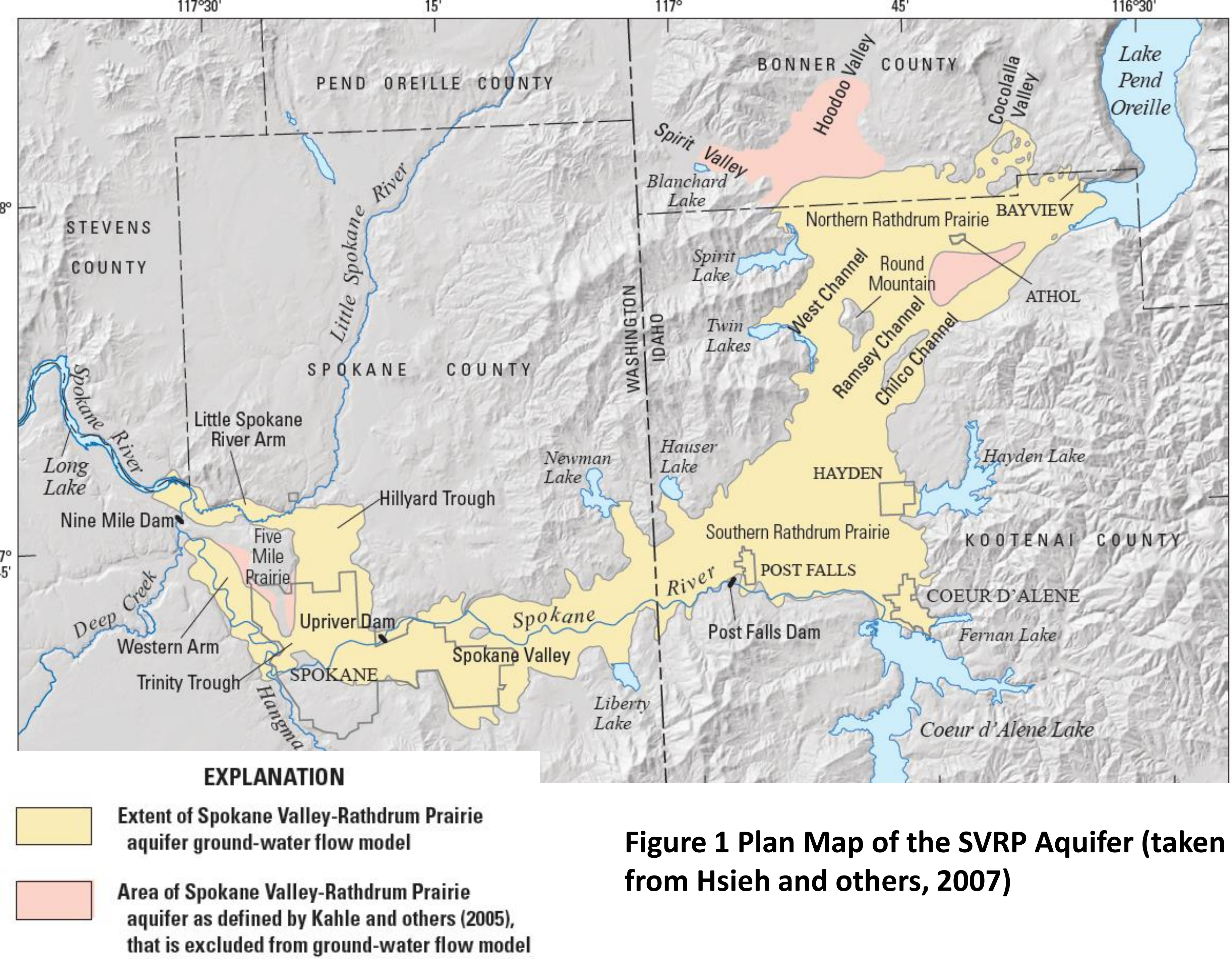


Figure 1 Plan Map of the SVRP Aquifer (taken from Hsieh and others, 2007)

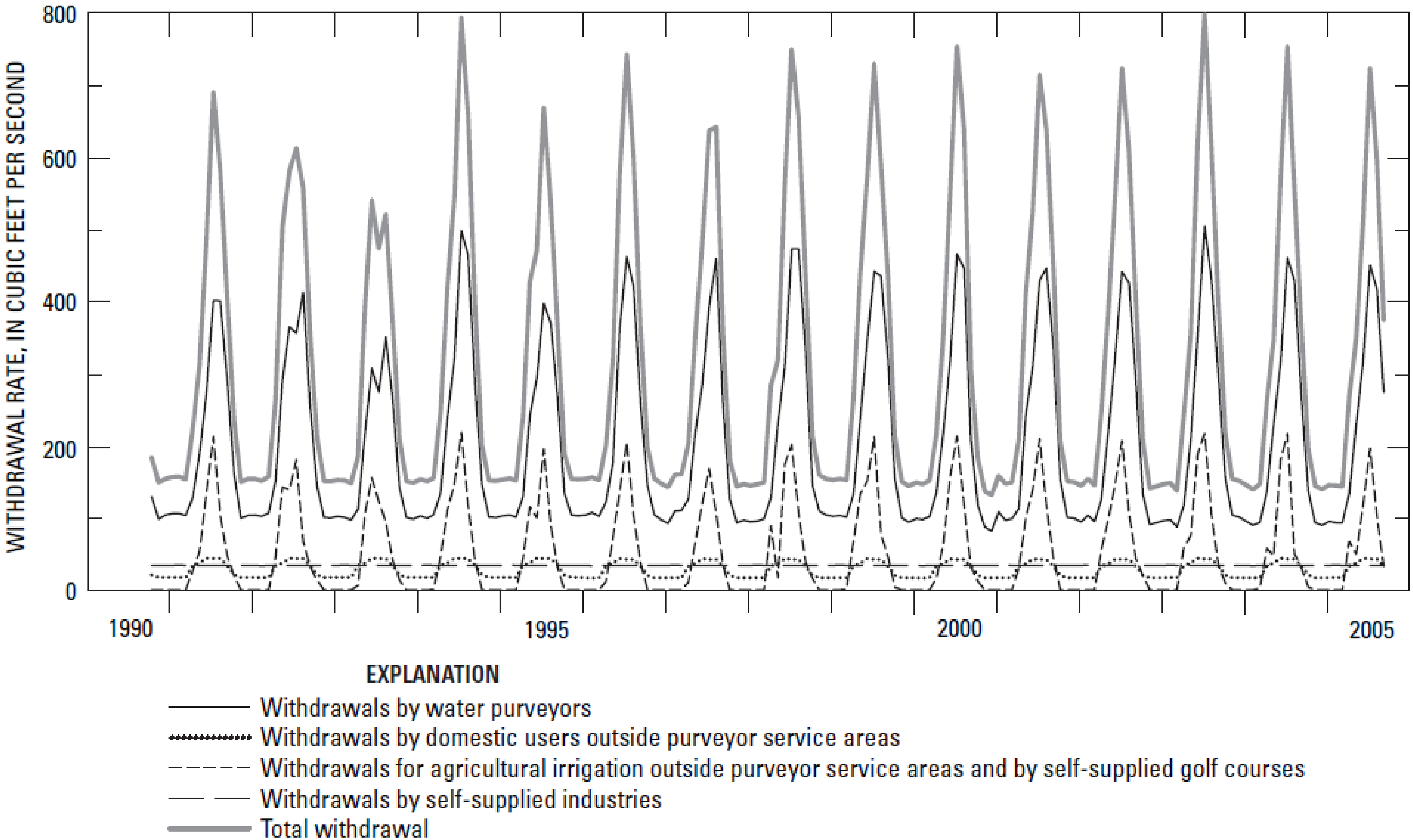


Figure 2 Withdrawal rates from wells (Taken from Hseih and others, 2007)

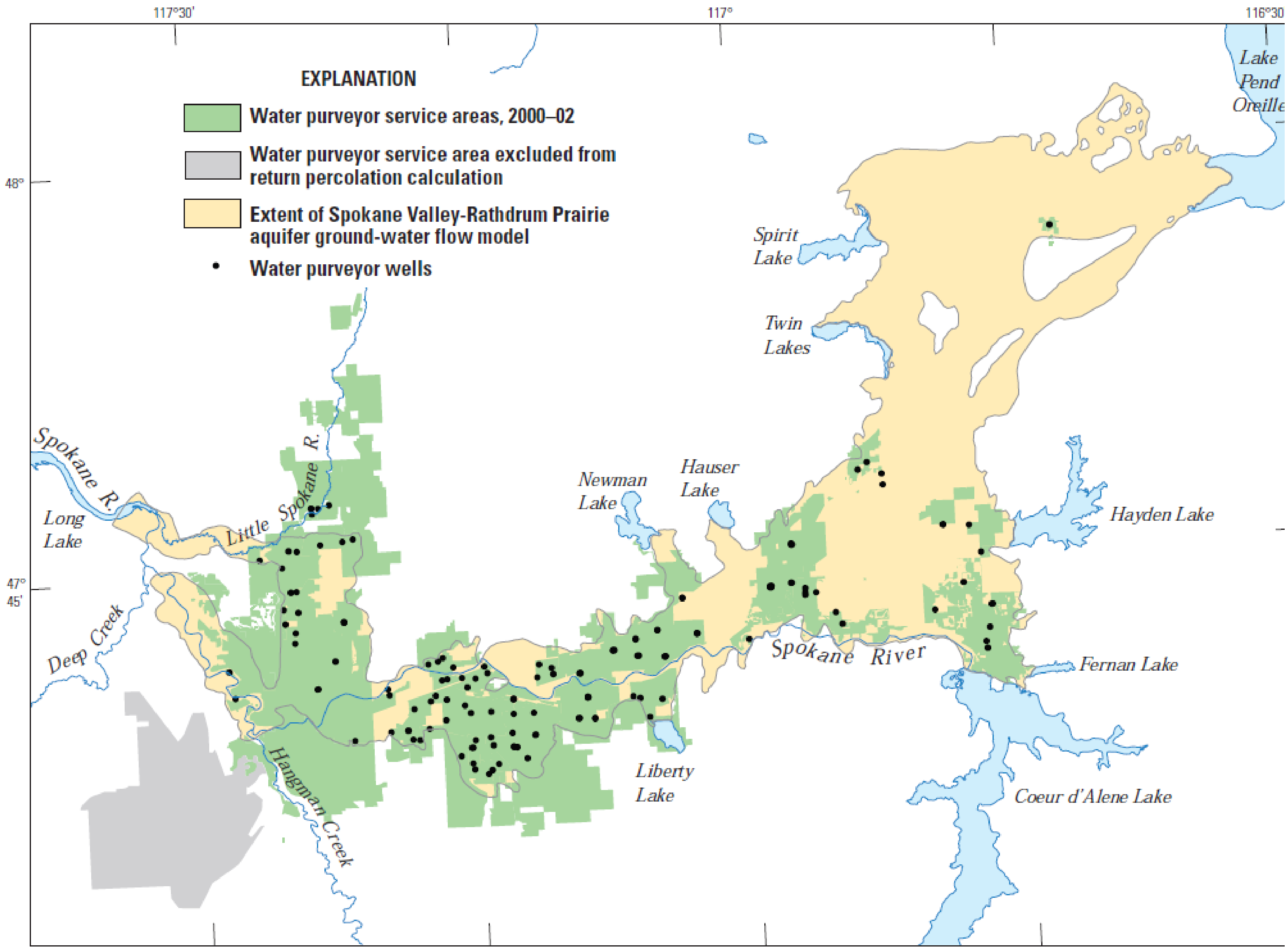


Figure 3 Location of Water Purveyors' Wells (Taken from Hseih and others, 2007)

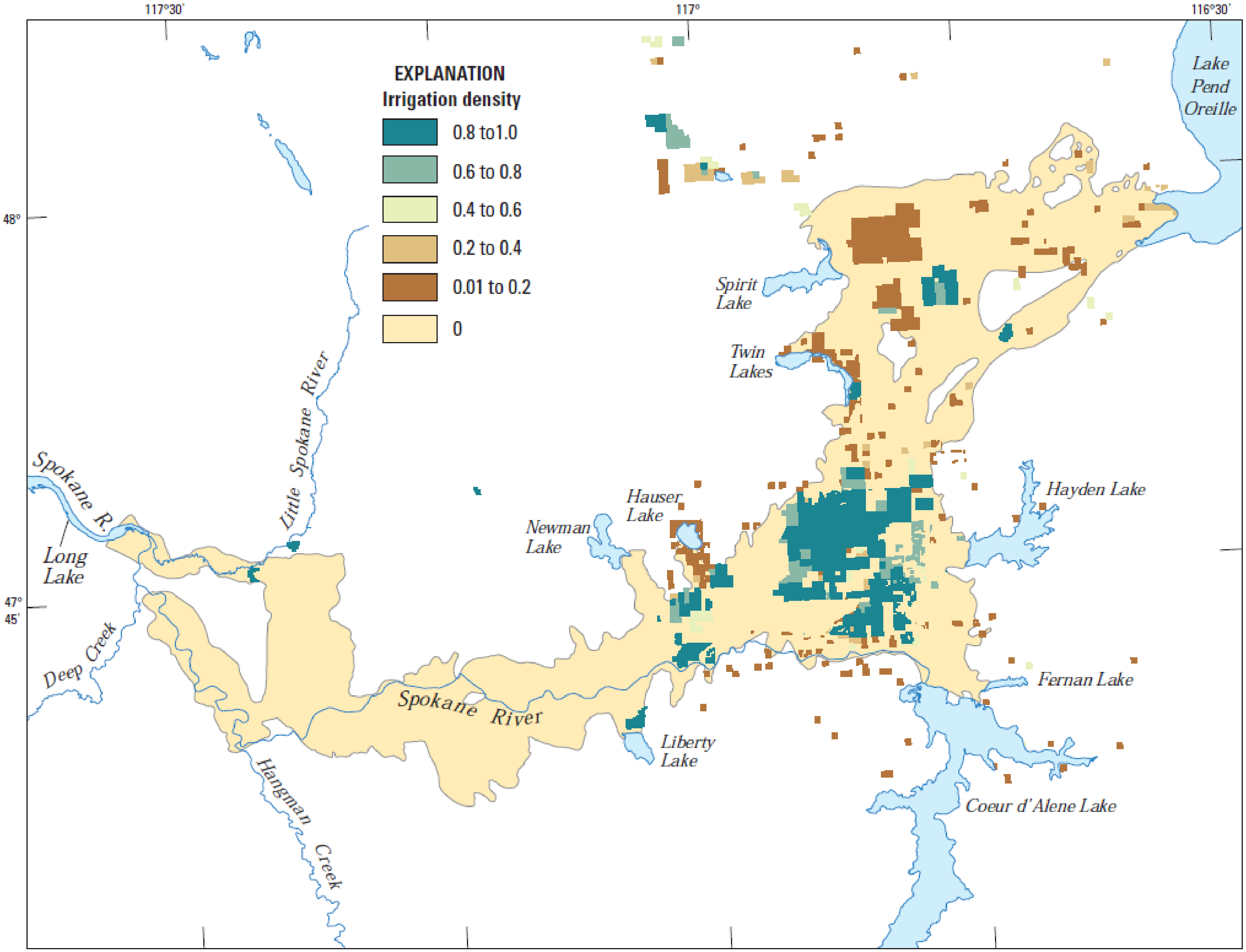


Figure 4 Map of Irrigation Densities (Taken from Hseih and others, 2007)

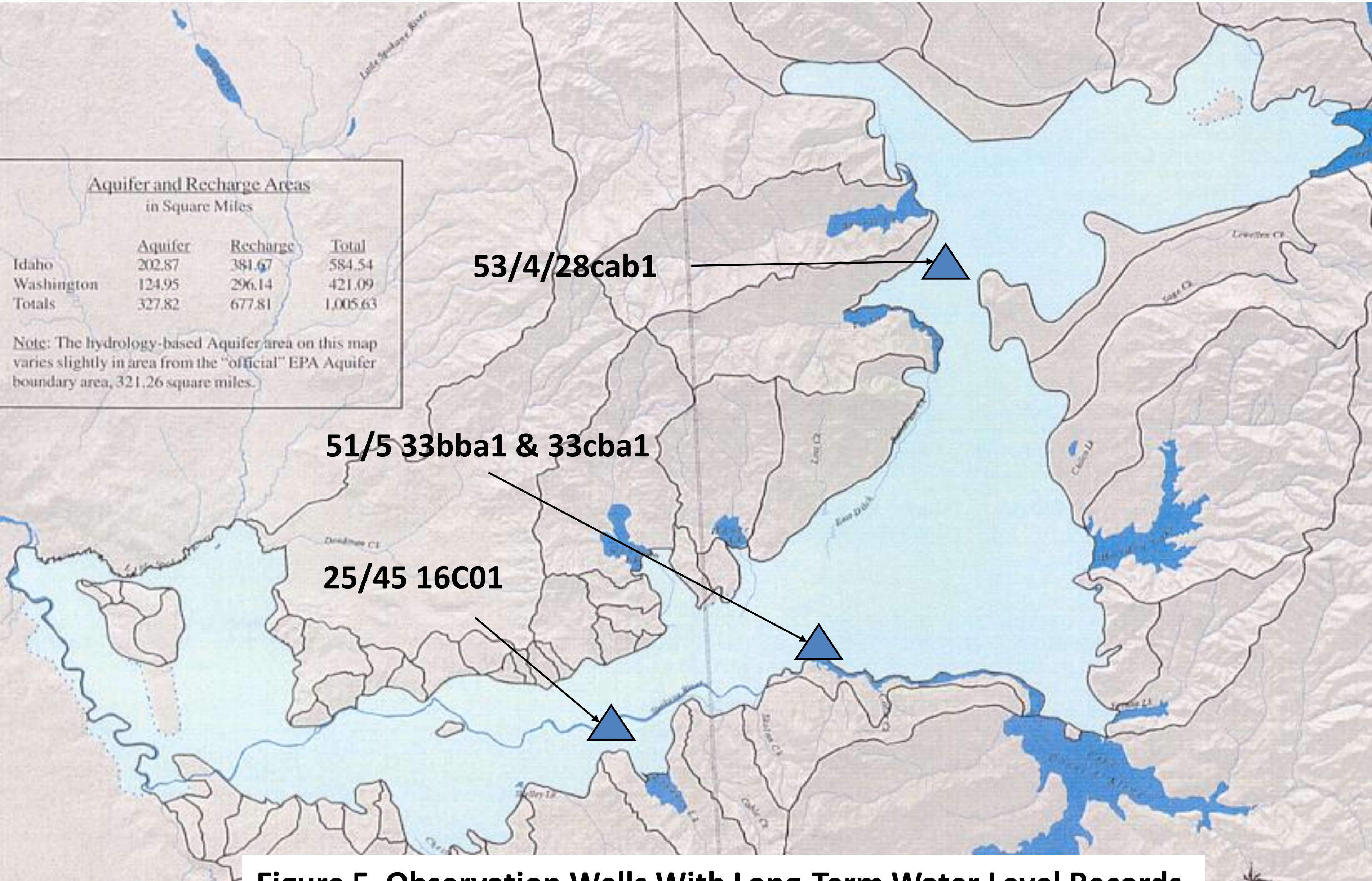


Figure 5 Observation Wells With Long-Term Water Level Records

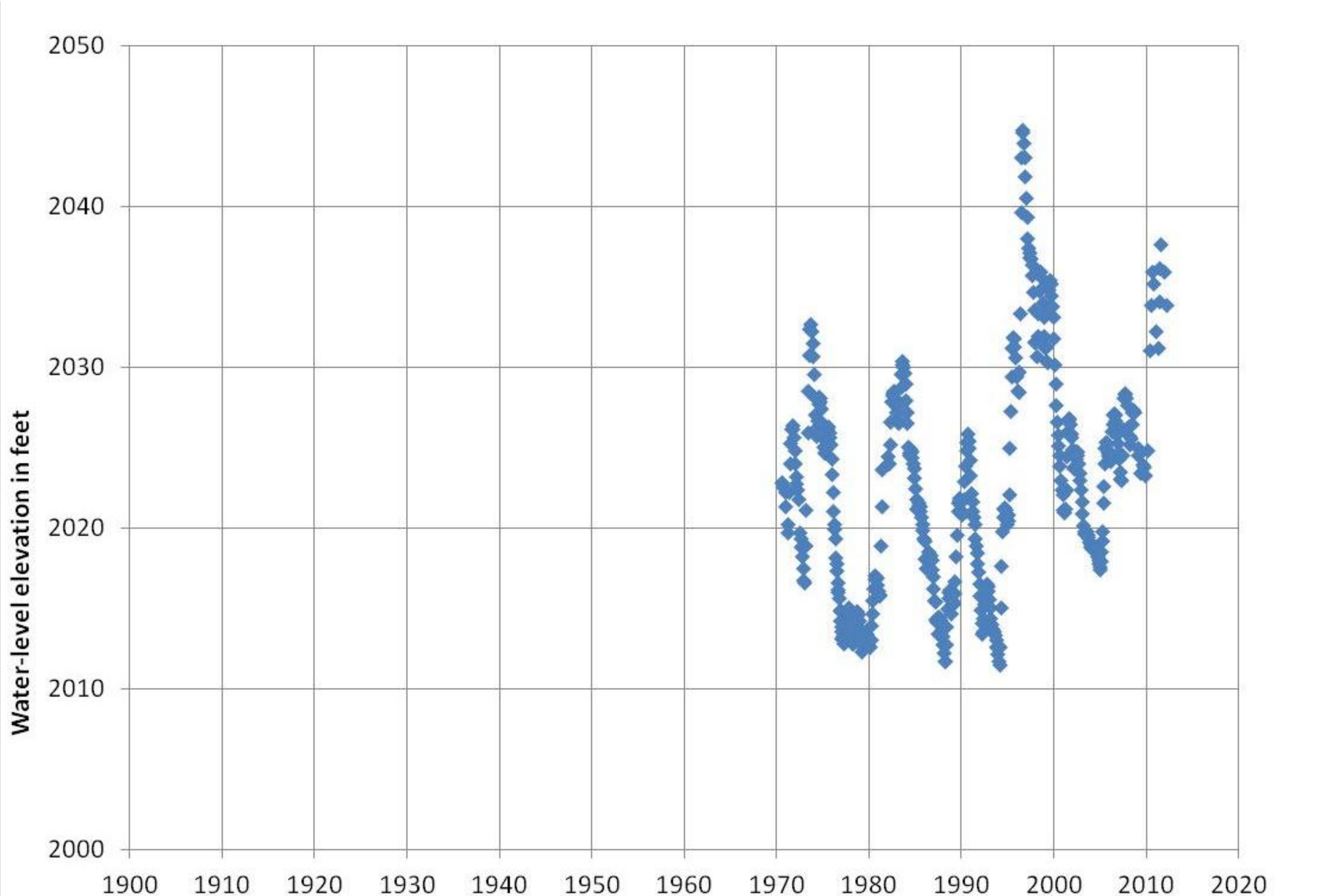


Figure 6 Hydrograph for Well 53/4 28cab1 Located Near Spirit Lake, Idaho

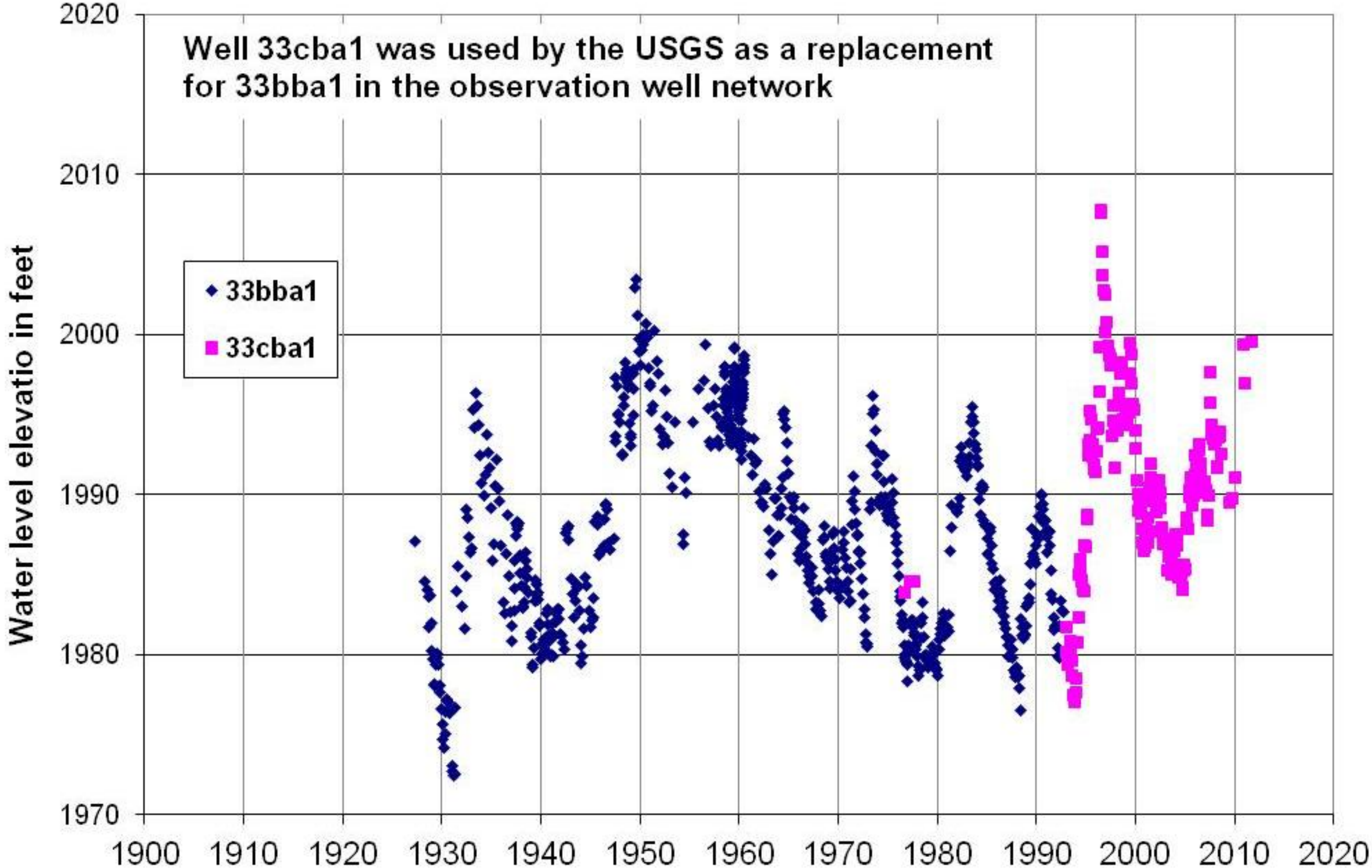


Figure 7 Hydrograph for Wells 51/5 33bba1 and 33cba1 Located Near Post Falls, Idaho

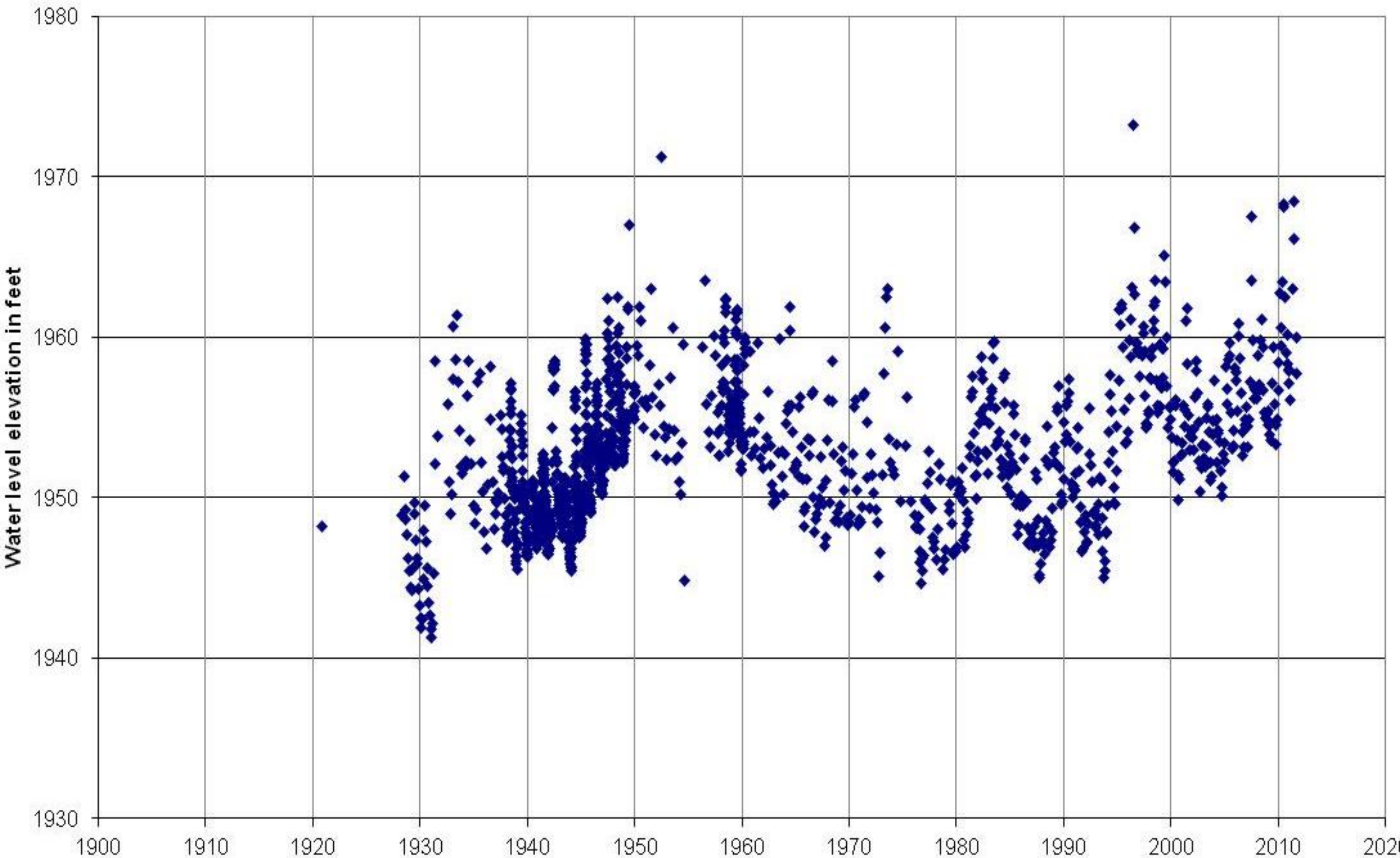


Figure 8 Hydrograph for Well 24N 45E 16C01Located Near Liberty Lake, Washington

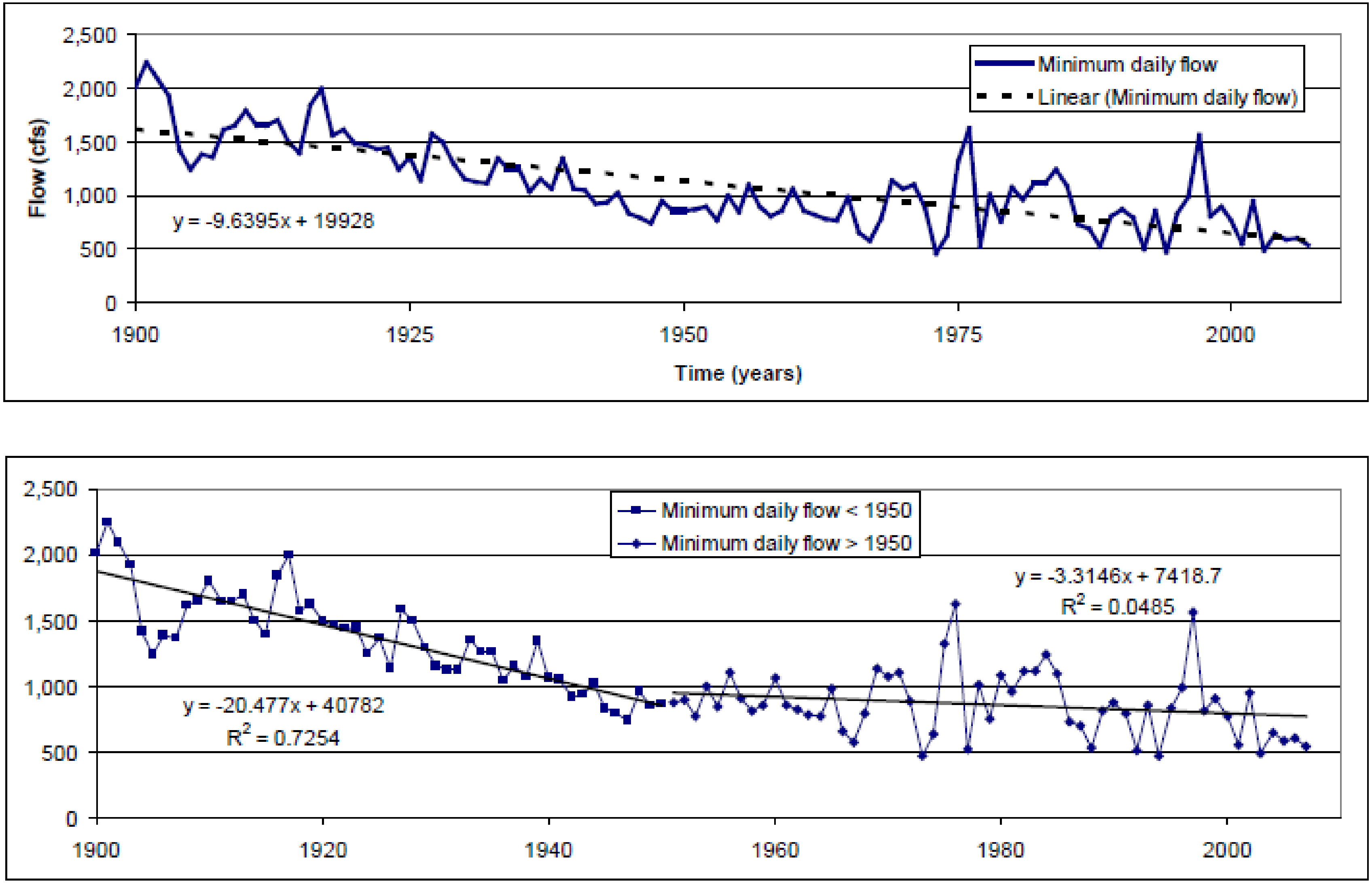
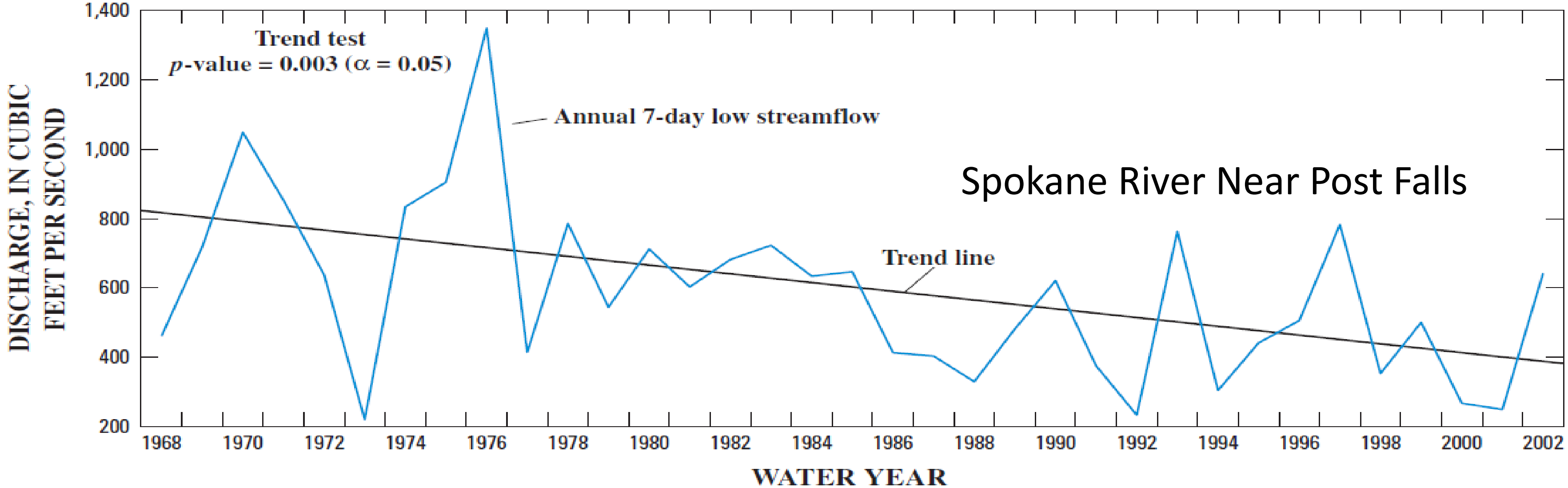


Figure 9 Minimum Daily Flow of the Spokane River at the Spokane Gage (Taken from Barber and others 2011)



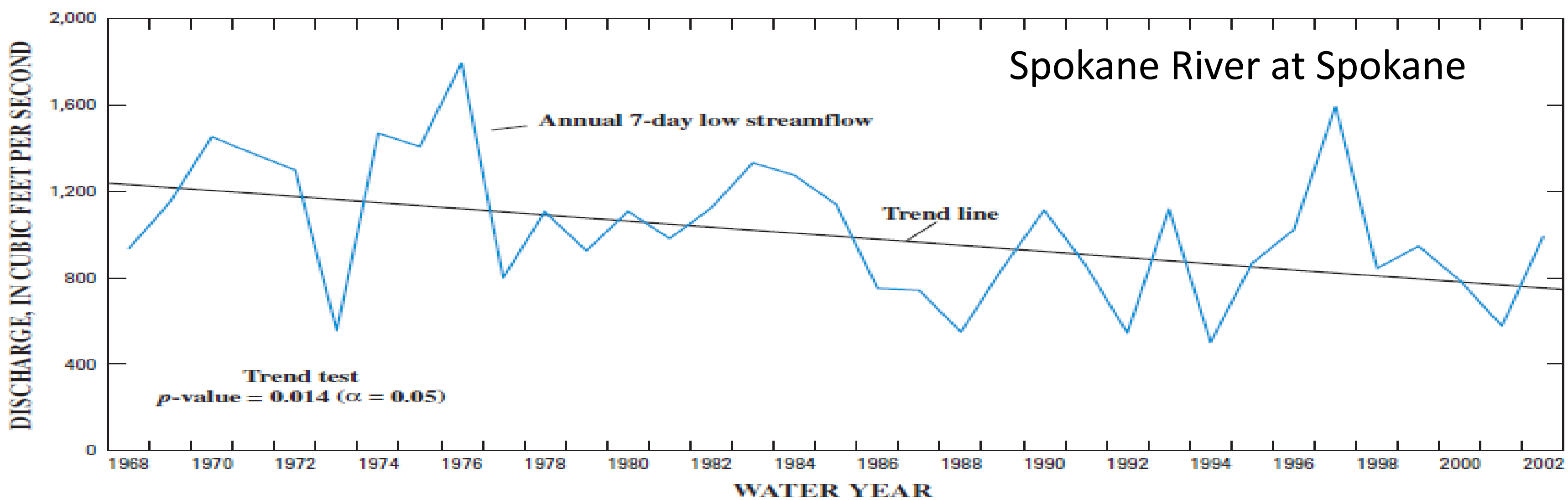


Figure 10 Trend Analysis of 7-Day Low Streamflows for the Spokane River Near Post Falls and at Spokane, 1968-2002 (Taken from Hortness and Covert, 2005)

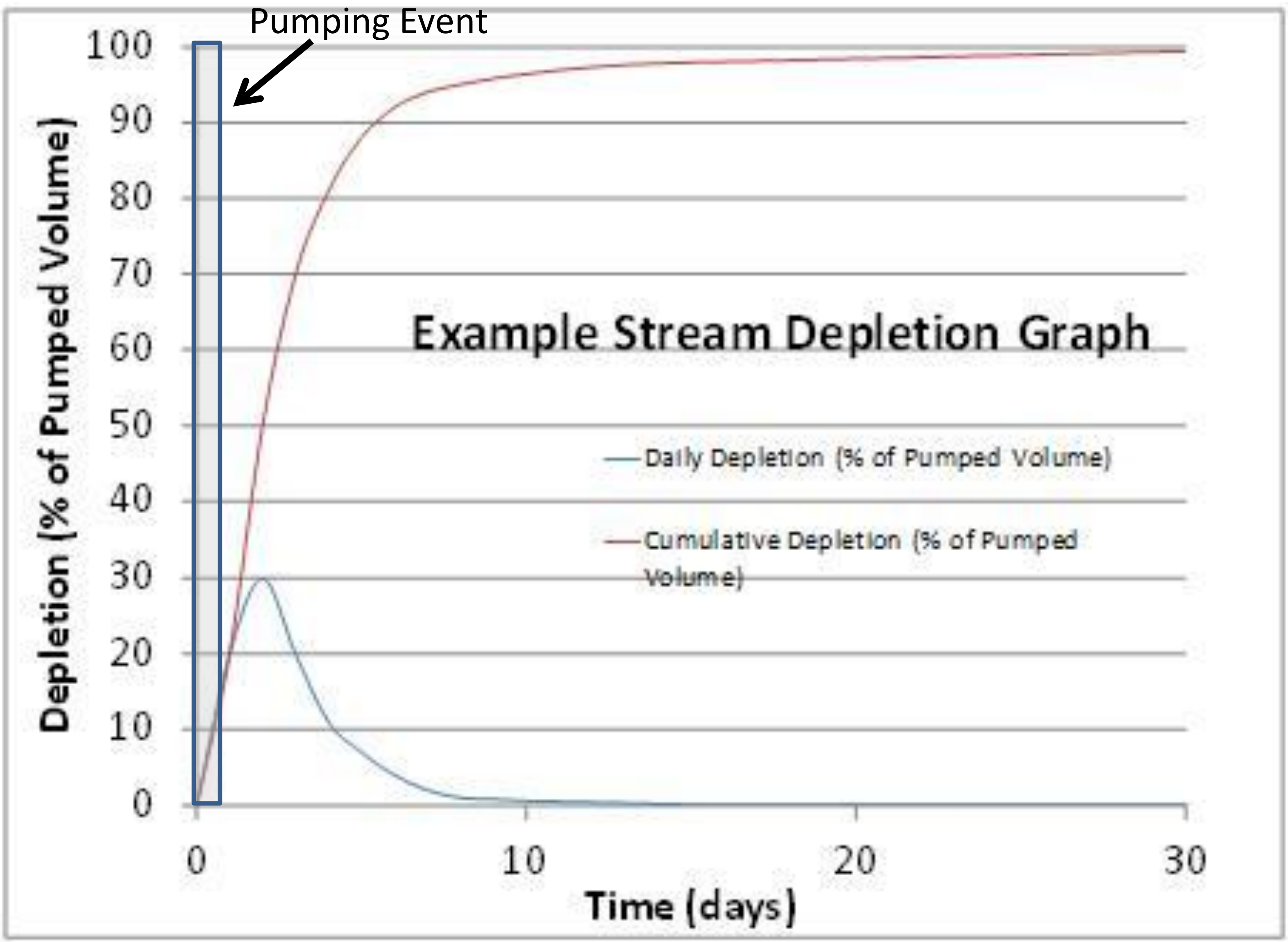


Figure 11 Example Stream Depletion Graph

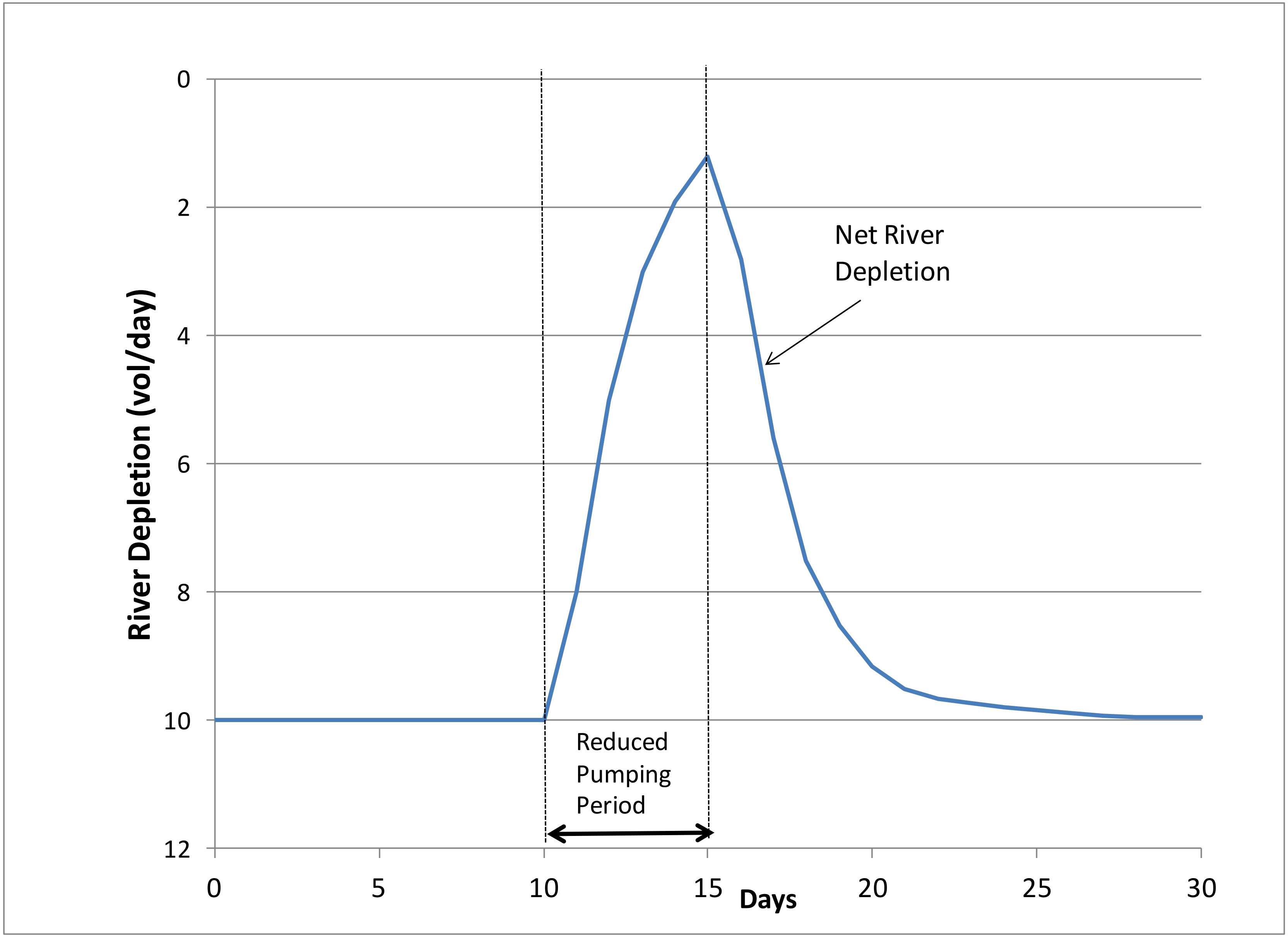


Figure 12. Hypothetical example of change in depletion resulting from a five-day cessation in pumping.

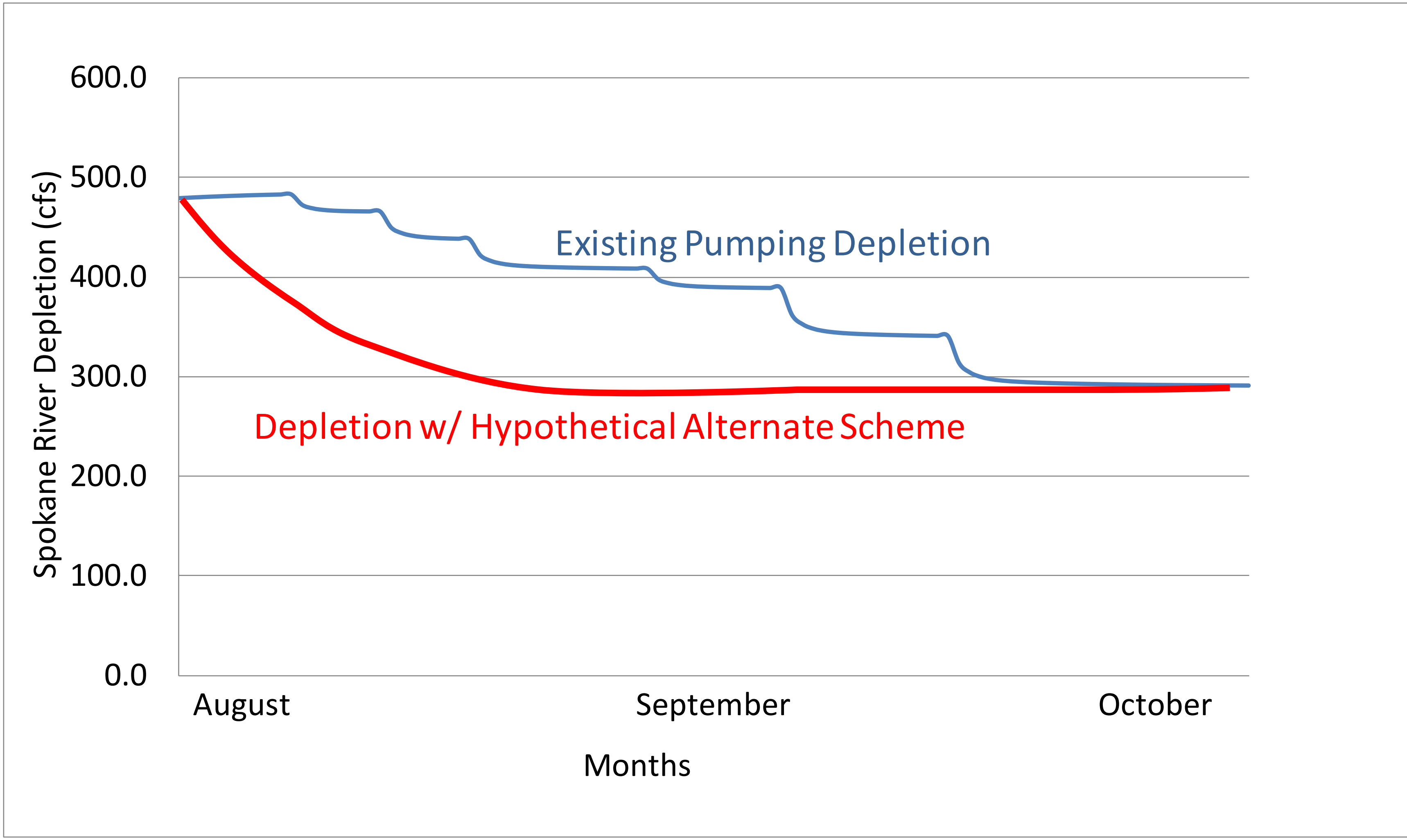


Figure 13. Hypothetical depletion estimates for existing pumping and an alternate scheme.