GSI Water Solutions, Inc.

January 16, 2015

Mr. Ty Wick
Chair, Spokane Aquifer Joint Board
General Manager, Spokane County Water District #3
1225 N. Yardley Street
Spokane, WA 99212

Subject: Technical Approach, Scope of Work, and Cost Estimate for Conducting a Phased Analysis of the Causes of Historical Changes to Seasonal Low Flows in the Spokane River

Dear Ty,

This letter presents a technical approach and scope of work for conducting a three-phase historical hydrologic evaluation study of the causes of historical (and sustained) declines in the amount of seasonal low flow that is present in the Spokane River, as measured at the Spokane Gage in downtown Spokane, Washington. GSI Water Solutions, Inc. (GSI), has prepared this technical approach and scope of work under Task 4 of its existing contract (Resolution No. 2013-06) with the Spokane Aquifer Joint Board (SAJB). The remainder of this letter presents the following information:

- Problem statement
- Key questions and study objectives
- Overview of information sources
- Technical approach and Phase 1 scope of work
- Estimated budget for Phase 1
- General work scope and planning-level costs for Phases 2 and 3
- Contracting
- Project team

## Problem Statement

In 2014, GSI completed groundwater modeling analyses of various hypothetical scenarios for relocating small amounts of municipal groundwater pumping in the Spokane Valley on a seasonal basis. This work was conducted for the SAJB to understand the degree to which reapportioning summer-time pumping between certain existing wells in the Spokane Valley (the area located between the City of Spokane and the Washington/Idaho state line) might benefit the Spokane River by increasing the amount of groundwater recharge back into the river in its gaining reaches during the late summer months, when river flows are at their seasonal lows. For the collective group of relocation scenarios that were examined, the modeling effort concluded that the benefit to river flows at and downstream of the Spokane Gage would be only a small percentage of the amount of pumping that was relocated.

GSI's modeling work for the SAJB (which was conducted using the City/SAJB groundwater model) has led to significant doubts regarding the effectiveness of strategies that would involve changing the rates and locations of spring/summer pumping to increase summer low flows in the Spokane River. During GSI's modeling study, a research team from Ralston Hydrologic Services (RHS), working for the Idaho Department of Water Resources (IDWR), conducted similar, but independent, modeling using a different groundwater model (created by the U.S. Geological Survey [USGS]) of the local aquifer system. RHS reached conclusions that were very similar to those made by GSI and the SAJB. RHS and GSI presented these findings jointly at a well-attended session at the Spokane River Forum this past November, and to the Idaho Washington Aquifer Collaborative (IWAC) during its January 2015 meeting. In these sessions, participants expressed a desire to find ways for local water purveyors and other local stakeholders to work together collaboratively to find strategies that are practical and effective for increasing the river's seasonal low flows, given (1) the region's reliance on the Spokane Valley – Rathdrum Prairie (SVRP) aquifer for its sole water supply and (2) the need to rigorously manage river flows to meet hydropower, recreation, and other needs in the Spokane River / Coeur d'Alene Lake system.

Other studies of the SVRP have found that minimum daily flows and 7-day low flows in the Spokane River declined at a much steeper rate during the first half of the 20$^{th}$ century (which were years of predominantly agricultural surface water use east of the Spokane city limits) than in later years (which were characterized by the gradual retirement of agricultural lands, gradual urbanization, and conversion of surface water supplies to groundwater). Those studies, which were conducted by the USGS and the Washington Department of Ecology (Ecology), also provide certain insights to river flow conditions during specific historical time periods. However a comprehensive evaluation currently does not exist of how the historical changes in river flows at both the Post Falls and Spokane stream gages since the late 1800s (the earliest years of settlement and river stream gaging) compare with historical changes in population, land use, water use, ambient hydrology and climate, and the historical management of water levels in Coeur d'Alene Lake (at the headwaters of the Spokane River). Such a study is warranted to not only understand past causes of declines in the seasonal-low river flows, but to provide further insights on the potential effectiveness of changing groundwater pumping programs or implementing other strategies that are intended to prevent further declines in seasonal-low river flows or potentially increase those flows.

## Key Questions and Study Objectives

The objectives for the proposed study arise from the primary questions that GSI has identified as being at the core of developing an understanding of the causes of historical trends in the seasonal low flows of the river. The key questions to evaluate are as follows:

1. **To what extent did the declines in Spokane River seasonal low-flows from 1900 through 1950 arise from groundwater pumping (which occurred primarily in the City of Spokane), versus other factors?** This question arises because it is known that:
    - Prior to the mid-1960s, groundwater pumping occurred primarily in the City of Spokane, with only limited pumping in certain parts of the Spokane Valley and the Idaho portion of the aquifer.
    - Significant surface water diversions for agricultural irrigation began in the early 1900s and continued until the 1960s. These diversions not only removed water from the river, but introduced three new hydrologic processes -- evaporation from canals and furrows, consumptive use by crops, and return flow leakage to the aquifer (from unlined canals).

- Although Coeur d'Alene Lake is a natural feature, the construction of Post Falls Dam in 1906 – and possibly even the construction of the first crib dam on the river in the mid-1890s – might have altered the lake levels slightly. The first significant change in the level of Coeur d'Alene Lake appears to have been a 1.5-foot rise in lake level that began in 1941, to increase electricity production and allow logs to be floated to sawmills near the dam (all in support of activities associated with the region's response to the onset of World War II).

2. **Why did the rate of decline in the river's 7-day low flows become less severe beginning in the 1950s? What changes in the hydrologic regime caused this flattening in the rate of decline?** These questions arise because little to no groundwater pumping had yet begun in the Spokane Valley portion of the aquifer (between the City of Spokane and the state line) until the mid-1960s. The only potential groundwater-related influences on the river during the 1950s and early to mid-1960s would have been any substantial increases in pumping by the City of Spokane and/or cities and agriculture in Idaho (if such increases even occurred during this period). Groundwater use in the Spokane Valley did not occur until about 1967, when the U.S. Bureau of Reclamation completed construction of wells and storage facilities for several of the local irrigation districts.
3. **Was the onset of large-scale groundwater pumping in the Spokane Valley (in about 1967) the primary reason for the subsequent lack of rebound in the river's 7-day low flows and the apparent continued decline in those flows? Or were other factors contributing to this trend (and perhaps more influential than groundwater pumping)?** These questions are important to evaluate because the modeling work by GSI and RHS indicates that modest future changes in groundwater pumping locations and rates might have only a small (or very modest) beneficial effect on future seasonal low-flows in the river. If past changes (increases) in regional pumping also had a marginal effect on the river, then this would suggest changes to groundwater pumping programs may not, by themselves, improve river flows to a noticeable degree.

When considering the three key questions listed above, several related questions arise that also comprise the key elements of the technical approach that will best address the key questions. GSI has identified the following six related questions that are of most pertinence in evaluating the key questions:

1. How significant were the losses in river flows arising from the direct diversions of water from the river and the subsequent use of those diversions for agricultural irrigation? (Losses of water were in the form of uptake by crops, evaporation in canals and furrows, and leakage from canals.)
2. What was the likely predevelopment condition in the river-aquifer system (without Post Falls Dam, and with no surface water or groundwater diversions and uses)? Specifically, with no human development, how much river loss might have once occurred in the losing reach in Spokane Valley, and how much return flow of groundwater might have occurred in the gaining reaches between Spokane Valley and the Spokane Gage?
3. What has been the effect on river flows of urbanization and the shift to groundwater pumping? Specifically, how does the lower water use associated with retiring agricultural lands compare with increases in urban water use? Did this conversion result in an overall increase or decrease in water use, and how do any such changes compare with the trends in river flows?
4. How much did wastewater returns (direct and via septic systems) change river flows historically?

5. If groundwater usage from 1900 to 1950 had continued (i.e., groundwater usage mainly by the City, and not by others), would the river flows be higher than occurs under the current pumping regime?
6. Have summer water temperatures (max-month) in Coeur d'Alene Lake and the Spokane River changed over the past many years (as measured at or near Post Falls Dam or at the stream gages located in the Spokane Valley, east of the City limits)? If summer water temperatures have increased in recent years, how much has the leakage rate increased out of the riverbed in the losing reach (between the state line and roughly Sullivan Road)? Do any such changes in the losing reach explain the ongoing declines in seasonal low-flows that have been observed at the Spokane Gage in recent years/decades?

Three other related questions also will be considered, though these question will receive less scrutiny during the initial (first phase) of this study than the prior six questions:

7. Did construction of Post Falls Dam (the coffer dam in the late 1890s and the existing dams in 1906) alter the runoff curve in the river? Did this cause a change (particularly an increase) in seasonal low-flows at the Post Falls Gage compared with pre-dam conditions? If so, did the Spokane Gage show any changes in flow?
8. Did the earliest diversions of water for agricultural irrigation (in the late 1890s/early 1900s) actually offset an earlier increase in summer river flows at the Post Falls Gage that might have occurred after the 1890s-era construction of the initial coffer dam at Post Falls? Did these diversions actually create a condition in the river below Post Falls that was comparable to pre-dam conditions?
9. How significant was the 1941 change in the stage of Coeur d'Alene Lake (to maintain 1.5-foot higher lake levels)? Did this new operation of the lake and the Post Falls Dam cause observable changes in daily, 7-day, or monthly flows during the summer during the next few years?

Based on the three key questions, the nine related questions, and discussions with SAJB and various attendees at the recent Spokane River Forum conference, GSI has identified five primary objectives for the historical study:

1. **Focus on understanding trends in river flows and the components of the local hydrology and water budget that directly influence river flows.** To keep the study focused and cost-effective, the technical approach and scope of work will not include creating a comprehensive reconstruction and review of the entire history of all water uses in the valley. Additionally, at this time, GSI does not plan to evaluate flows into Coeur d'Alene Lake because prior studies have reported finding no discernible long-term historical changes in lake inflows[1].
2. **Understand pre-development conditions.** Specifically, evaluate why river flows were high in 1900 (which was approximately 5 years after the first coffer dam was constructed at Post Falls).
3. **Compare the historical trends in river flows at the Spokane Gage to changes in water use.** Specifically, understand how the timing of historical trends compares with the construction of the first coffer dam at Post Falls; the subsequent construction of the first hydropower dam at Post Falls; the onset of, and growth in, diversions for agricultural irrigation; the onset of, and

[1] Flows into Coeur d'Alene Lake are measured at two gages, which are the Coeur d'Alene River at Cataldo (gage 12413500) and the St. Joe River at Cataldo (gage 12414500). Citing a study by Woods and Beckwith (1977), Hortness and Covert (2005) state that these gages account for about 92 percent of the total inflows to Coeur d'Alene Lake.

growth in, agricultural groundwater usage in the Idaho portion of the SVRP; the conversion of agricultural irrigation from surface water to groundwater in the Spokane Valley portion of the aquifer; the later conversion from agricultural to urban land uses in the Spokane Valley (which was accompanied by decreased water demands experienced by some, if not all, of the irrigation districts and other water utilities in that area); the growth in municipal groundwater pumping inside the City of Spokane, along with the associated increase in treated water discharges into the river downstream of the Spokane Gage; and the gradual construction of sanitary sewers and an associated wastewater treatment plant that now discharges into the river upstream of the Spokane Gage (replacing former septic systems in the urbanized portions of the Spokane Valley).

4. **Conduct a first look at these questions, compile the basic findings, and discuss them with key stakeholders (Phase 1).** Rather than conduct an exhaustive analysis and final documentation from the onset, GSI recommends first conducting a focused technical evaluation (Phase 1 of the study), then launching a discussion with local water experts as a means of using this study to continue collaboration on water management in the SVRP. This would include giving presentations to SAJB and the Idaho Washington Aquifer Collaborative (IWAC), and using those meetings to obtain perspectives and additional information and knowledge from key personnel at Spokane County, Ecology, and the Idaho Department of Environmental Quality who have contributed to past studies of the river-aquifer system. Further analysis and subsequent reporting and local educational outreach activities would be determined after obtaining this input (and as part of a separate project / scope of work). Additionally, if desired by the SAJB, information sharing with Dr. Dale Ralston (of Ralston Hydrologic Services) could occur during the course of the initial analysis, given his familiarity with some of the available data sets in recent time periods and his past work (concurrent with GSI) to evaluate pumping influences on river flows.

5. **Refine the initial technical analysis (Phase 2) and prepare final documentation that can support a variety of future uses (Phase 3).** The scope and level of effort for these activities will be defined by the SAJB after reviewing the initial analysis and obtaining input on the analysis from local stakeholders. In Phase 2 of the project, activities could potentially include detailed reviews of historical maps and air photos; searches for archived written records of groundwater development and use; and more in-depth (but focused) groundwater modeling and/or statistical analysis. Phase 3 activities would include preparation of formal documentation and final presentation of the study to the SAJB. The final report and presentation will be developed in a manner to support educational outreach activities, aquifer resource planning, and the future preparation of technical materials to support groundwater adjudication activities (if adjudication occurs in the future).

## Overview of Information Sources

The approach to the project will be driven by not only the objectives listed above, but by the amount and types of data that are available. GSI anticipates that much of the readily available data (outside of information in formal publications and books) will be in the form of tabulations and data listings downloaded from a variety of websites. It is likely that historical maps will not be readily available, and will exist primarily in the archives of member utilities, local agencies, and museums and other organizations interested in local culture and history. To keep the project focused and cost-efficient, GSI plans on using data that are readily available on public agency websites (for example, streamflow and temperature data available online from the USGS) and directly from the water providers (records of annual water use). For the initial analysis, GSI personnel will not spend time conducting research in

archival collections. However, the findings from the initial analysis will be used to evaluate whether archival research is warranted in the subsequent refinement phase of the study.

The primary information sources that GSI will seek to obtain for the initial analysis phase of the study are listed below. In each case, GSI will seek to obtain data as far back as the 1890s or 1900, though we recognize that several data sets will start much later in time.

1. Historical groundwater pumping data
    a. City of Spokane (since 1900)
    b. SAJB member water districts and irrigation districts (since the 1960s)
    c. Idaho member irrigation districts
    d. Per-acre and per-capita estimates of water use

2. Historical population
    a. Cities of Spokane, Post Falls, and Coeur d'Alene
    b. Spokane County and Kootenai County

3. Historical irrigation
    a. Acreage estimates in Spokane Valley and Kootenai County
    b. Crop types and water demands

4. Historical hydrology
    a. Spokane River flows at Post Falls Dam, the Spokane Gage, and intermediate gages (such as Otis Orchards or Greenacres)
    b. Diversions at Post Falls Dam (for irrigated agriculture)
    c. Water temperatures, especially from the late spring through early fall
    d. Meteorological data
        i. Rainfall, air temperature, and pan evaporation data
        ii. Spokane, Coeur d'Alene

Several publications also provide descriptive information and interpretations at certain time periods, which will be references that we consult as we conduct our work. A bibliography of the publications that GSI consulted during preparation of this letter appears at the end of this letter.

## Technical Approach and Phase 1 Scope of Work

The approach to the historical evaluation will be to conduct a three-phased examination of system changes from year to year and decade to decade to the extent possible, beginning in the 1890s (when stream gaging first began in downtown Spokane) and continuing to the present (through 2014). The study will examine hydrologic and meteorological data sets to evaluate how daily and monthly conditions vary from year to year and over longer time frames. Those analyses will then be compared with available information on the evolution of – and changes in – population, groundwater use, land use (agricultural and municipal), river diversions (for agricultural irrigation), and river flows at Post Falls.

The study will be conducted in three primary work phases, which are: an initial technical evaluation and subsequent discussion of findings with the SAJB (Phase 1); further archival research and technical analyses to refine and finalize the study findings (Phase 2); and formal documentation of the study (Phase 3). This letter defines the scope of work and requested budget for Phase 1 and provides order-of-magnitude cost estimates for Phases 2 and 3 for the SAJB's consideration and planning. GSI has organized the Phase 1 scope of work into four primary tasks summarized below. The work scope and

budget requests for Phases 2 and 3 will be developed at a later date, in consultation with the SAJB during review of the findings from Phase 1.

The work scope for Phase 1 is organized into four primary tasks:

- **Task 1: Initial Data Review.** GSI will retrieve time-series data that are readily available online, such as stream gaging and climate records and census information. Substantial help may be required from SAJB members to find and gather information that is not readily available online (which is most likely to be in the areas of historical irrigation patterns, agricultural groundwater pumping, and the early years of municipal groundwater pumping). Rather than spending significant amounts of time on data gathering, GSI's efforts on Task 1 instead will focus on organizing and "exploring" the data that we receive, in order to identify what types of analyses can be conducted with confidence. For example, river flow data at the Post Falls Gage and the Spokane Gage may be examined in a number of ways for certain stream gaging sites, such as plotting up the average flows from one year to the next for a certain month (such as June, which is often the first month that follows the spring snowmelt runoff period), then considering whether additional months should be plotted, versus focusing on daily or 7-day-low flow, or perhaps each of those time periods. Similar considerations will go into analyzing other hydrological and meteorological data. We anticipate that groundwater use, population, and irrigation information will be reviewed for changes on a year-by-year and perhaps longer frequency.

- **Task 2: Data Analysis.** A more in-depth analysis will then be conducted to search for relationships between the various data sets. While we will use statistical methods to a limited degree, our analysis will focus primarily on the construction of time-series plots that illustrate the degree to which conditions historically changed in the river and the aquifer. Limited use of the City/SAJB groundwater model will occur as well, primarily to examine (1) differences between present and pre-development groundwater / river water exchanges in gaining and losing reaches of the river and (2) seasonal and longer-term changes in the amounts of river losses to groundwater in the eastern Spokane Valley (particularly during the summer).

- **Task 3: Develop Summary-Level Findings.** The technical findings derived during the work in Tasks 1 and 2 will be compiled into a descriptive summary of the nature and causes of changes in the hydrologic system. This summary will be focused on providing initial answers to the key questions and related questions described in this letter, and identifying additional information that could strengthen the analysis.

- **Task 4: Meeting / Presentation.** At the conclusion of Phase 1, GSI will present the findings in a meeting with the SAJB, along with recommendations for further archival data research and technical analysis activities to conduct under Phase 2 of the study. Our work under Task 4 will include developing presentation materials for those meetings.

## Estimated Budget for Phase 1

The estimated budget for Phase 1 of the study is $25,000. The technical evaluation (Tasks 1 through 3) comprises $20,000 of the budget, while the fourth task (one meeting / presentation) comprises $5,000. Budget and labor-hour breakdowns for this work are provided in the table below.

| ***GSI Water Solutions Estimated Budget*** <br> ***Phase 1:*** <br> ***Screening Level Analysis of Causes of Historical Changes to Seasonal Low Flows in the Spokane River*** | | | | |
|---|---|---|---|---|
| **Task** | **Labor (hours)** | **Labor ($)** | **Expenses ($)** | **Total ($)** |
| Task 1: Initial Data Review | 50 | $5,500 | $0 | $5,500 |
| Task 2: Data Analysis | 70 | $8,500 | $0 | $8,500 |
| Task 3: Develop Summary-Level Findings | 47 | $6,000 | $0 | $6,000 |
| **Subtotal** | **167** | **$20,000** | **$0** | **$20,000** |
| Task 4: Meeting / Presentation | 28 | $4,400 | $600 | $5,000 |
| **Total for Phase 1** | **195** | **$24,400** | **$600** | **$25,000** |

## General Work Scope and Planning-Level Costs for Phases 2 and 3

The findings of Phase 1 will provide the SAJB with an informed perspective from which to make decisions on the appropriate level of effort and technical needs for Phases 2 and 3. Because the findings of Phase 1 will greatly influence the subsequent work effort, GSI can only roughly estimate at this time the work scope and associated costs of Phases 2 and 3. We currently envision the following for Phases 2 and 3:

- Phase 2:
    - Potential work activities: collection and review of historical maps and aerial photos; interviews with persons knowledgeable of land use and water use changes during the latter half of the 20$^{th}$ century; information searches in local archived collections (at irrigation districts, the Northwest Museum of Arts and Culture); more detailed modeling using the City/SAJB and/or Bi-State groundwater flow models; refinement of the data analyses conducted in Phase 1; and one or more meetings with the SAJB.
    - Potential cost: $25,000 +/- 40%
- Phase 3:
    - Potential work activities: develop report outline and content in collaboration with SAJB; prepare draft report for SAJB review and comment; address comments and prepare a final report stamped by a GSI hydrogeologist licensed in the State of Washington.
    - Potential cost: $25,000 +/- 40%

The costs listed above are rough estimates that are based on the experiences that GSI personnel have had in other locations developing historical reconstructions and conceptual models of the cause-and-effect relationships between the many hydrologic variables and land use activities that affect the exchanges of water between rivers and aquifers in groundwater basins. GSI will provide more refined estimates of these costs during our review with the SAJB of the findings from Phase 1.

## Contracting

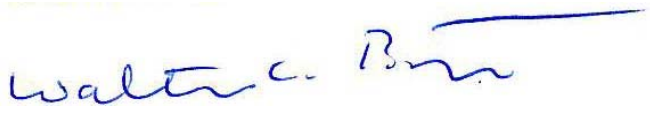
Work will be conducted by GSI on a time-and-materials basis for an amount not to exceed the authorized budget. If it is determined that greater effort or additional activities will be required to complete the work, GSI will notify you upon this determination and will not exceed this budget without first obtaining your approval to proceed with the additional work.

## Project Team

This work will be managed and directed by John Porcello, LHG, a principal hydrologist at GSI who constructed and operates the City/SAJB model. John will be supported by Walt Burt, LHG (principal, internal peer review) who specializes in characterizing groundwater basins and stream/aquifer interactions, evaluating the conditions of groundwater supplies, and preparing groundwater supply master plans. John and Walt will be heavily supported by Jake Gorski, EIT, a staff engineer who specializes in environmental and water resources engineering, hydrologic studies, and data management and analysis.

Please contact either of us at your convenience if you have any questions.

Sincerely,
GSI Water Solutions, Inc.



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