Groundwater Flow Direction Evaluations in the Spokane River, Mission Reach

Prepared for:
Spokane River Regional Toxics Task Force

20 June 2023
TTWG REDLINE -REVIEW DRAFT

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Executive Summary

Sections of the Spokane River and Lake Spokane have been placed on the State of Washington's 303(d) list of impaired waters due to elevated concentrations of polychlorinated biphenyls (PCBs) that exceed water quality standards. To address these impairments, the Department of Ecology (Ecology) has pursued a toxics reduction strategy that included the establishment of a Spokane River Regional Toxics Task Force (Task Force). The purpose of the Task Force is to identify and remove sources of PCBs to the Spokane River, including potential sources of PCB-impacted groundwater. Sampling of PCBs in Spokane River biofilm by Ecology identified several areas of elevated PCBs in the river section located between the Mission Avenue Bridge and the Spokane Falls Boulevard Bridge (a section commonly referred to as Mission Reach), but the source of this contamination is unknown. Recent work supported by the Task Force has identified several known or suspected upland sources of PCBs near Mission Reach. However, uncertainty exists about the potential for transport between Mission Reach and these known or suspected upland sources. Most of Mission Reach is characterized as a losing reach (meaning that there is a net loss of water from the river to groundwater), and a smaller portion on the western end is characterized as having minimal to no interaction with groundwater. If groundwater in this section primarily moves uniformly away from the river, then that would eliminate upland subsurface contamination as a source of the observed Mission Reach contamination because there would be no mechanisms for transporting groundwater contamination to the river.

Although Mission Reach historically has been mainly characterized as losing, that characterization applies to average conditions over time and space. If portions of Mission Reach are gaining during certain times, then that would provide a potential transport mechanism for delivering contaminated groundwater to the river. The available data are insufficient to define a hydraulic linkage between contamination from identified upland sites and groundwater delivery to Mission Reach. A better understanding of this linkage would identify which (if any) of the upland PCB sources are contributing contaminated groundwater to the observed Mission Reach PCB concentration.

The purpose of this project is to support development of an initial working conceptual site model (CSM) of groundwater flow direction in and near Mission Reach. This model leverages groundwater elevation data from existing monitoring wells to define (to the extent possible) the direction of groundwater flow in upland areas near the Mission Reach and provide a better understanding of the hydraulic linkage between identified historical PCB sites and observed contamination in the Spokane River. Key findings from this initial working CSM are:

- The Hamilton Bridge area continuous monitoring data show that river levels and groundwater levels generally rise and fall closely in sync with each other, and that there are periods when the Hamilton Street Bridge area of the reach has groundwater elevations above surface water levels for consecutive days, indicating gaining episodes. These data are the most robust for

evaluating groundwater exchange with the Spokane River within Mission Reach and are considered to be reliable based on their consistency with river flow and stage data from upstream and downstream USGS monitoring stations. The continuous monitoring data suggest that during more pronounced gaining periods (March and April), there is approximately a 50% chance or less of observing a flow reversal/gaining event when relying on monthly or quarterly depth to groundwater data that are collected manually rather than continuously.

- Other data sources consist of historical manually collected depth to groundwater data for monitoring wells located at five sites within Mission Reach, including the Hamilton Street Bridge site. At most of these sites the wells are known or suspected to be abandoned. The available groundwater elevation data show that groundwater flow within Mission Reach is predominantly away from the river (i.e., losing) with a few documented gaining events. However, as noted above, the historical manual groundwater monitoring was generally conducted too infrequently to be of use in determining groundwater-surface water interactions within Mission Reach.
- Available geologic maps show a shallow basalt ridge is located on the western edge of Mission Reach, and that it crosses the Spokane River where the river is classified as having little to no interaction with groundwater. The basalt ridge drops off steeply to the east at the Hamilton Street Bridge property, where the basalt layer is approximately 90 feet deep at the MW8-90 location. Geologic data obtained from available well logs in this area are consistent with the geologic map depiction of the extent of the basalt ridge where it crops out at the surface. The initial working CSM indicates that the basalt ridge that forms the western edge of the Mission Reach area likely serves as a barrier to shallow groundwater flow, but this needs to be confirmed. At this time there are no known deep wells installed in the basalt ridge within Mission Reach. This boundary/interface may serve as an area of recharge into the river given the transition from transmissive SVRP aquifer system to basalt, and warrants further investigation.
- The origin of the artesian point source/well is unknown but initial evaluations suggest that it could have a connection with one or more local features, including the interface between the basalt ridge and historical riverbank fill material, ~~the City sewer system~~ a possible drainage path associated with a 60-inch sewer line where it cuts through the basalt, and Trent Tunnel. . However, the depth of the sewer line may rule out a possible connection with the artesian point source and should be investigated further.

Recommendations for future activities to address data gaps include:

- Routine monitoring and maintenance of the Hamilton Street Bridge continuous water level monitoring equipment to ensure proper equipment performance.
- Extending the Hamilton Street Bridge continuous water level study through at least December 2023.
- Verifying the surveyed refence elevations for the continuous monitoring equipment.

Commented [DJ1]: The artesian well sits 190 ft away from the sewer line referenced in the report. I couldn't find any other sewer infrastructure in the vicinity of the "artesian well" when I looked through older sewer maps. As discussed below, it also sits above the elevation of the sewer line.

I'd propose either taking out the sewer system reference or clarify that it's not the sewer itself but rather the drainage/path cut through the basalt that is hypothesized to be a possible conduit.

Commented [JD2R1]: Added clarifying text as recommended.

- Further investigations of the role of the interface of the basalt ridge with the SVRP aquifer and historical riverbank fill material, and its role as a possible hydrogeology boundary and an area of recharge into the river on the western end of Mission Reach.
- Further investigations into the origin of the artesian point source/well and its possible association with one or nearby features (basalt ridge, City infrastructure and the Trent Tunnel, of which little currently is known).

1 Introduction

Sections of the Spokane River and Lake Spokane have been placed on the State of Washington's 303(d) list of impaired waters due to elevated concentrations of polychlorinated biphenyls (PCBs). To address these impairments, the Department of Ecology (Ecology) has pursued a toxics reduction strategy that included the establishment of a Spokane River Regional Toxics Task Force (Task Force). The purpose of the Task Force is to identify and remove sources of PCBs to the Spokane River, including potential sources of PCB-impacted groundwater. Sampling of PCBs in Spokane River biofilm by Ecology (Era-Miller, B. and S. Wong, 2022) identified several areas of elevated PCBs in the river section located between the Mission Avenue Bridge and the Spokane Falls Boulevard Bridge (a section commonly referred to as Mission Reach, refer to **Figure 1**), but the source of this contamination is unknown. Recent work supported by the Task Force has identified several known or suspected upland sources of PCBs near Mission Reach (LimnoTech, November 30, 2022). However, uncertainty exists about the potential for transport between Mission reach and these known or suspected upland sources.

Historically, most of Mission Reach has been characterized as a losing reach (SAJB, 2023), meaning that there is a net loss of water from the river to groundwater, and a smaller section on the western end is characterized as having minimal to no interaction with groundwater (refer to **Figure 2**). If groundwater in this section primarily moves uniformly away from the river, then that would eliminate upland subsurface contamination as a source of the observed Mission Reach contamination because there would be no mechanisms for transporting groundwater contamination to the river.

Although Mission Reach is mainly characterized as losing, that characterization applies to average conditions over time and space. If portions of Mission Reach are gaining during certain times, then that would provide a potential transport mechanism for delivering contaminated groundwater to the river (LimnoTech, 2020). The available data are insufficient to define a hydraulic linkage between contamination from identified upland sites and groundwater delivery to Mission Reach. A better understanding of this linkage would identify which (if any) of the upland PCB sources are contributing contaminated groundwater to the observed Mission Reach PCB concentration.

The purpose of this project is to support development of an initial working conceptual site model (CSM) of groundwater flow direction in and near Mission Reach. This model leverages groundwater elevation data from existing monitoring wells to define (to the extent possible) the direction of groundwater flow in upland areas near the Mission Reach and provide a better understanding of the hydraulic linkage between identified historical PCB sites and observed contamination in the Spokane River. Project activities included:

- Identifying potentially existing monitoring well locations and available associated reports;
- Constructing an inventory and interactive ArcGIS online map of available boring log and well construction information, survey data, and groundwater monitoring data for the wells identified above; and,
- Constructing an initial working Conceptual Site Model (CSM) for Mission Reach, including identification of data gaps.

This report documents the results of the above evaluations and is divided into the following sections:

- Chapter One: Introduction
- Chapter Two: Data Sources and Evaluation Approach
- Chapter Three: Results of Data Evaluations
- Chapter Four: Initial Working Conceptual Site Model (CSM)
- Chapter Five: Conclusions and Recommendations

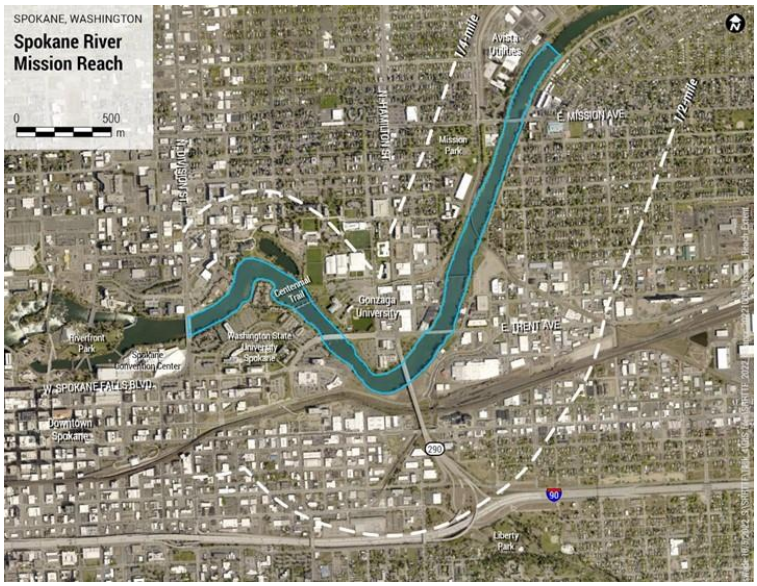


Figure 1. Spatial domain of Mission Reach study area.

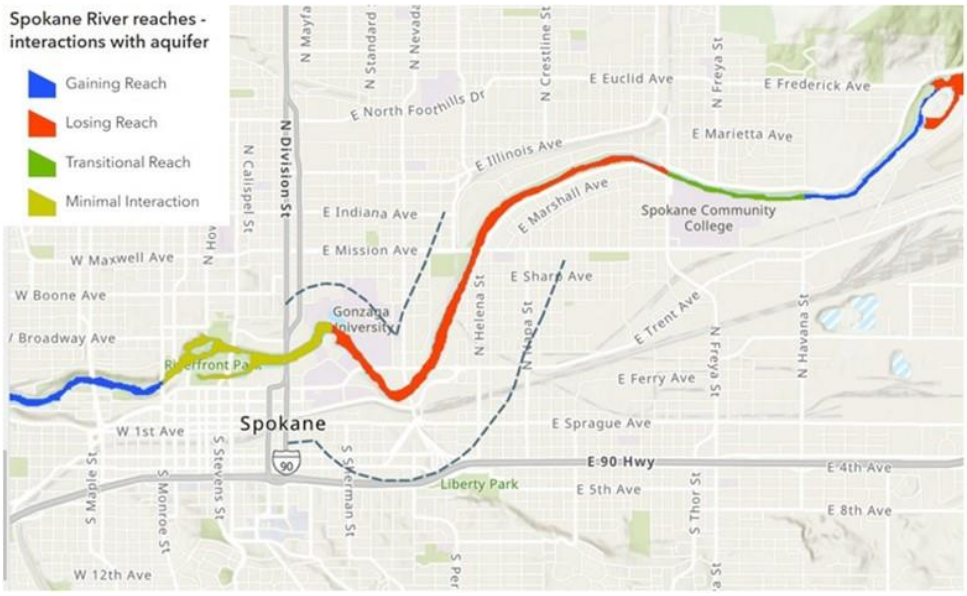


Figure 2. Map of Spokane River surface water/groundwater interactions (modified from SAJB, 2023).

2 Data Sources and Evaluation Approach

This evaluation used available data from online sources and Spokane County investigations within and near Mission Reach to identify potentially existing monitoring well locations and available reports with historical groundwater elevation and flow direction information. The spatial domain of the well search within Mission Reach includes a longitudinal extent from approximately ¼ mile upstream of E. Mission Avenue bridge downstream to the Division St. bridge and a lateral extent of ¼ mile north of the river and ½ mile south of the river (refer to **Figure 1**).

As these data were obtained and evaluated, a working spreadsheet inventory was constructed concurrently with an interactive ArcGIS online map to document the data sources, locations and associated relevant information (e.g., Facility Site ID (FSID), Cleanup Site ID (CSID), site status as soil and/or groundwater investigation areas, well logs, available well survey and construction data, monitoring well abandonment status, listing as a PCB cleanup site). Information was obtained from the data sources listed below, as described more fully in the following subsections of this chapter:

- Hamilton Street Bridge continuous surface water and groundwater level monitoring investigation initiated in late November 2021 by Spokane County personnel (Spokane County Water Resources, 2021), and associated relevant information obtained from:
    - USGS river data for two active gages located upstream and downstream of Mission Reach
    - Avista dam operation information (Lunney, May 3, 2023)
- State of Washington Department of Ecology (Ecology) *What's In My Neighborhood: Toxic Cleanup Sites* map-based search tool
- State of Washington Department of Ecology (Ecology) *Environmental Information Management (EIM) Databas*
- State of Washington Department of Ecology (Ecology) *Well Construction and& Licensing* map-based (or text-based) search tool
- Washington State Department of Natural Resources (DNR) *Geologic Information Portal*
- Washington State Department of Health (DoH) *Wellhead Protection Areas (10 Year)*
- Spokane Aquifer Joint Board (SAJB) *Spokane Valley-Rathdrum Prairie Aquifer Atlas (5th Edition, 2023)*
- City of Spokane Interactive map

2.1 Hamilton Street Bridge Continuous Water Level Monitoring Study

LimnoTech was asked by the Task Force to evaluate recently collected continuous water level data from the Hamilton St. Bridge site. Data collection is ongoing, but at the time of this report LimnoTech has evaluated continuous (i.e., hourly) monitoring data for parts or all of the period November 23, 2021 through April 27, 2023 at the Hamilton Street Bridge staff gage and at five nearby monitoring wells (MW2-20, MW4-20, MW8-20, MW8-90 and MW9-20, refer to **Figure 3**). Initial evaluations conducted for data collected through March 3, 2022 suggested that groundwater flow direction is into the Mission Reach for certain periods of time (i.e., the reach is gaining) and that some data patterns indicated questionable data accuracy. The outcome of this subtask is to provide a determination of the extent to which these data can be relied upon to support groundwater flow assessment.

LimnoTech investigated the methods used to collect these data, and also compared reported river elevation data to other available sources of river data, including (refer to **Figure 4**):

- Spokane River flow data from an active upstream USGS gage located at Green Street Station 12422000 (USGS, Green Street).
- Spokane River flow data from an active downstream USGS gage located approximately 1.75 miles west of Division Street at Spokane Station 12422500 (USGS, Spokane).
- Dam operation data provided by Avista for the period of record (Avista, personal communication, May 3, 2023).

Additional data evaluations included:

- Identifying the timing and frequency of events when shallow groundwater elevations at monitoring wells MW2-20, MW4-20 and MW8-20 were higher than the associated measured surface water elevations at the Hamilton Street Bridge gage. These events indicate when groundwater flow was towards the river (i.e., the reach was gaining).
- Calculating the vertical direction of groundwater flow for clustered well pair MW8-20/MW8-90, which have well screens installed 20 ft and 90 ft below grade, respectively. Upward vertical groundwater gradients generally would indicate groundwater discharge to the river, whereas downward vertical groundwater gradients generally would indicate the river is recharging the aquifer. An upward groundwater gradient is present when the groundwater elevation at the deeper well location is higher than the groundwater elevation in its shallow companion well. A downward vertical groundwater gradient is present when the groundwater elevation at the shallow well location is higher than the groundwater elevation in its deep companion well. Horizontal groundwater flow is indicated by groundwater elevations that are equivalent in the clustered well pair.

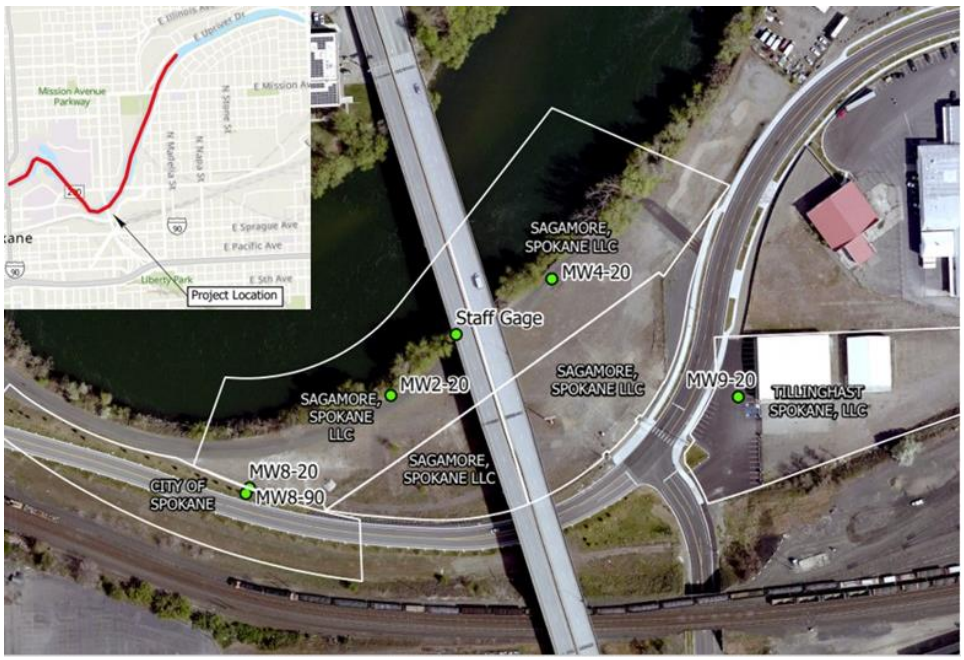


Figure 3. Map of Hamilton Street Bridge continuous surface water and groundwater level monitoring locations (modified from Spokane County Water Resources, September 2021 QAPP).

Figure 4. Map of Spokane River gage stations 12422000 (Green St) and 12422500 (Spokane)

2.2 Ecology What's In My Neighborhood: Toxic Cleanup Sites

This application is available for Users to find contaminated sites in Washington State, including sites that have been cleaned up. A broad map search was conducted to identify sites in and near Mission Reach (refer to **Figure 5**). Each site was entered into the database inventory and the website was used to include relevant information, such: available reports, documented soil and/or groundwater impacts, documented PCB impacts, presence of shallow basalt, and potential monitoring well data). Sites that were identified as having known or suspected groundwater impacts were prioritized as these sites would be more likely to have monitoring well information. Available reports were downloaded and reviewed for information regarding site geology and hydrogeology, well locations, depth to groundwater and/or groundwater flow direction information. Available historical groundwater elevation data that were not found from other sources were compiled and evaluated to determine groundwater flow direction and potential seasonal variability. Sites that were identified in the database as having only soil impacts were given less priority, but available reports for these sites were reviewed to note where shallow basalt and/or perched groundwater were observed.

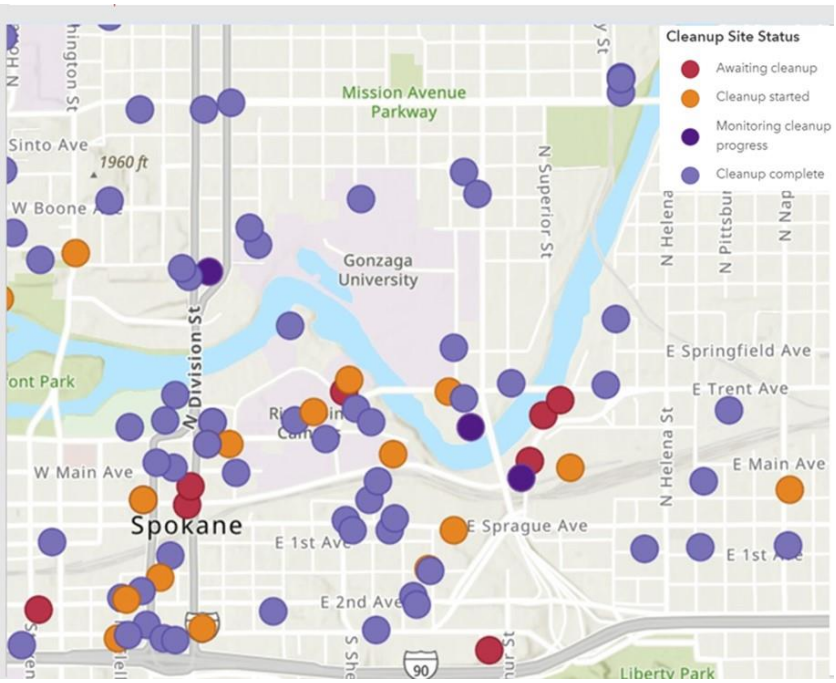


Figure 5. Map of *What's In My Neighborhood Toxic Cleanup Sites* in Mission Reach area (modified from Ecology - https://apps.ecology.wa.gov/neighborhood/) and EIM sites with groundwater monitoring data.

2.3 Ecology *Environmental Information Management (EIM) Database*

The EIM database was accessed to obtain available groundwater monitoring data within the Mission Reach area. Four studies were located within the Mission Reach area with well location information and depth to groundwater data. All four sites are also listed as toxic cleanup sites in the Ecology *What's In My Neighborhood* database, and include (refer to **Figure 6**):

- Avista Corp Spokane Service Center, 1411 E Mission Ave (CSID = 15180, EIM Study = ID VCEA0343)
- Banner 24 Hour Fuel Stop, 126 N Madelia Street (CSID = 13291, EIM Study ID = Banner_FS5559533)
- Front Avenue Properties (a/k/a Brown Building Supply), 112 N Erie Street (CSID = 15185, EIM Study ID = VCEA0351)
- Spokane Hamilton St Bridge Performance Monitoring, 111 N Erie St (CSID = 3509, EIM Study ID = FS84461527)

Available historical groundwater elevation data were compiled and evaluated to determine groundwater flow direction and potential seasonal variability.

Figure 6. Map of EIM sites in Mission Reach area with groundwater monitoring data.

2.4 Ecology *Well Construction & Licensing* Data

This resource was access to obtain available monitoring well construction information and logs for soil borings and monitoring wells that were not available in the Ecology *What's In My Neighborhood* document files. This site includes monitoring well abandonment logs.

2.5 WA DNR *Geologic Information Portal*

This resource was accessed to obtain surface geology information for the Mission reach area. This information also was available in Shape-file format that could be imported into the Arc-GIS ERSI interactive map developed by LimnoTech.

2.6 WA DoH *Wellhead Protection Areas (10-Year)*

This source provides approximate locations of public water supply wellhead protection areas in Washington state. The 10-year time of travel map for the Spokane Mission Reach area was accessed for a general understanding of groundwater flow direction based on active public drinking water supply withdrawals.

2.7 SAJB *Spokane Valley-Rathdrum Prairie Aquifer Atlas (5th Edition, 2023)*

This resource was accessed to obtain general regional information about the geology and hydrogeology of the Spokane Valley-Rathdrum Prairie Aquifer and Columbia River Group basalt formation in the City of Spokane area, including regional aquifer recharge information.

2.8 City of Spokane Interactive Map

The resource was accessed to obtain stormwater and sanitary sewer line information to assist evaluations of an artesian point source (a/k/a "artesian well") that was observed to be discharging into the downstream section of Mission Reach (refer to **Figure 7**). The exact origin and history of the point source is unknown, but previous investigation data show that the discharge has total PCB concentrations above 2,000 ug/l[1].

[1] LimnoTech, March 9, 2022. Monitoring to Assist in Defining the Sources of PCB Contamination in the Spokane River Mission Reach. "*The artesian well discharge had a total PCB concentration of 2150 ug/l, roughly ten times greater than the average river concentration. This indicates that groundwater loading could be an important contributor to the Mission Reach contamination, to the extent that: 1) this concentration is representative of the local groundwater, and 2) an appreciable amount of groundwater flow enters the river in the Mission Reach. The Spokane Aquifer Joint Board's Spokane Valley-Rathdrum Prairie Aquifer Atlas (MacInnis et al., 2004) indicates that net water flow is from the Mission Reach to the aquifer (i.e., a losing reach), but this does not preclude groundwater flow entering the Mission Reach at select times and locations.*

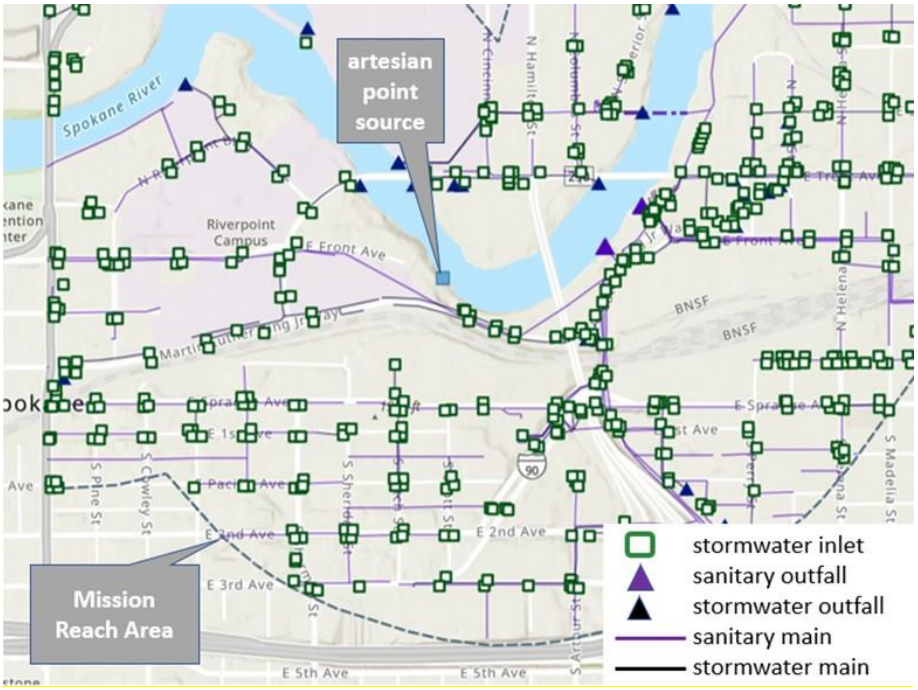


Figure 7. Location map of artesian point source discharge and City of Spokane sanitary and stormwater sewer system within Mission Reach area.

3 Results of Data Evaluations

This chapter provides the results of evaluations of the late November 2021 through April 2023 Hamilton Street Bridge continuous surface water and groundwater level monitoring data, the historical hydrogeological data within and near Mission Reach that was obtained from Ecology online databases, and the possible origins of the artesian point source/pipe located on the south bank of the river that has high PCB concentrations detected in its discharge.

3.1 Hamilton Street Bridge Continuous Monitoring Data Evaluations

Continuous (i.e., hourly) groundwater level monitoring data were evaluated for the periods of record outlined below and depicted on **Figure 8**:

- Shallow wells MW2-20 and MW4-20 have continuous monitoring data starting at noon on November 23, 2021 through 9:00 am on April 27, 2023.
- Shallow well MW8-20 has continuous monitoring data starting at noon on November 23, 2021 through 10:00 am on April 27, 2023.
- Shallow well MW9-20 has continuous monitoring data starting at 1:00 pm on November 23, 2021 through 2:00 pm on March 2, 2022. After this, the pressure transducer ceased to work properly, and no additional data was recorded.
- Deep well MW8-90 has continuous monitoring data starting at 10:00 am on November 24, 2021 through 2:00 pm on March 2, 2022. After this, the pressure transducer ceased to work properly, and no additional data was recorded.
- The Hamilton Street Bridge surface water gage location has continuous monitoring data starting at noon on November 23, 2021 through 8:00 am on August 24, 2022, and again from 2:00 pm on October 11, 2022 through 8:00 am February 2, 2023, after which the pressure transducer stopped working.

Table 1 provides a summary by month and year of the range and number of time-synchronous surface water to groundwater elevation changes between the river and the four shallow monitoring wells (MW2-20, MW4-20, MW8-20 and MW9-20). ~~**(FIX WHEN MW9-20 REF ELEVATION IS CONFIRMED)**~~ The positive range of values designates surface water level readings above groundwater level readings (I.e., generally losing events), whereas the negative range of values designates surface water level readings below groundwater level readings (i.e., generally gaining events). For this evaluation, elevation differences <0.005 ft (0.06 inches) are considered negligible. There are occasions when there is no apparent difference between surface and groundwater levels, which may be an indication of parallel flow relative to the riverbank with minimal groundwater/surface water exchange.

As summarized in **Table 1**, the maximum water level differences between the Hamilton Street Bridge gage and shallow groundwater in nearby monitoring wells MW2-20, MW4-20 and MW8-20 range up to 2.464 ft, 2.031 ft and 2.499 ft, respectively, during “losing” events and up to 0.604 ft, 0.871 ft and 0.552

ft, respectively, during "gaining" events. The most extreme losing event was recorded in June 2022 at all three locations, and the most extreme gaining event was recorded in March 2022 at MW2-20 and MW8-20 and in April at MW4-20. During March 2022, groundwater levels were observed to be above surface water levels for approximately 46%, 56% and 37% of the month at the MW2-20, MW2-40 and MW8-20 locations, respectively. During April 2022, groundwater levels were observed to be above surface water levels for approximately 49% of the month at the MW2-40 location. This suggests that during more pronounced gaining periods (March and April), there is approximately a 50% chance or less of observing a flow reversal/gaining event when relying on monthly or quarterly depth to groundwater data that are collected manually rather than continuously. There were no readings where the river level was below the groundwater elevation in shallow monitoring well MW9-20 for the period November 23, 2021 through March 2, 2022. The maximum water level differences between the Hamilton Street Bridge gage and shallow groundwater in MW9-20 ranged from 0.064 ft to 1.508 ft during this "losing" period. MW9-20 is located further from the river than the other three shallow wells.

The September 2021 QAPP states that the pressure transducers were calibrated in the factory prior to shipment and notes that pressure transducers are subject to some sensor drift. The September 2021 QAPP also states that the pressure transducer water level readings have an accuracy of +/- 0.05%, with a minimum value of 0.01 ft. The pressure transducers may have been subject to drift, in addition to periodic malfunctions, and have not been factory recalibrated since they were installed in late November 2021. Consequently, the calculated water level differences are subject to more error as the differences decrease.

Figure 8. Continuous surface water and groundwater level monitoring data for the Hamilton Street Bridge study area.

Commented [JD3]: NEED TO CONFIRM REFERENCE ELEVATION FOR MW9-20

Commented [JD4R3]: Confirmed that this figure is OK as-is.

Table 1~~1~~. Monthly range of water level elevation differences between the Hamilton Street Bridge surface water gage data and shallow well monitoring data for hourly readings collected between late November 2021 and late April 2023.

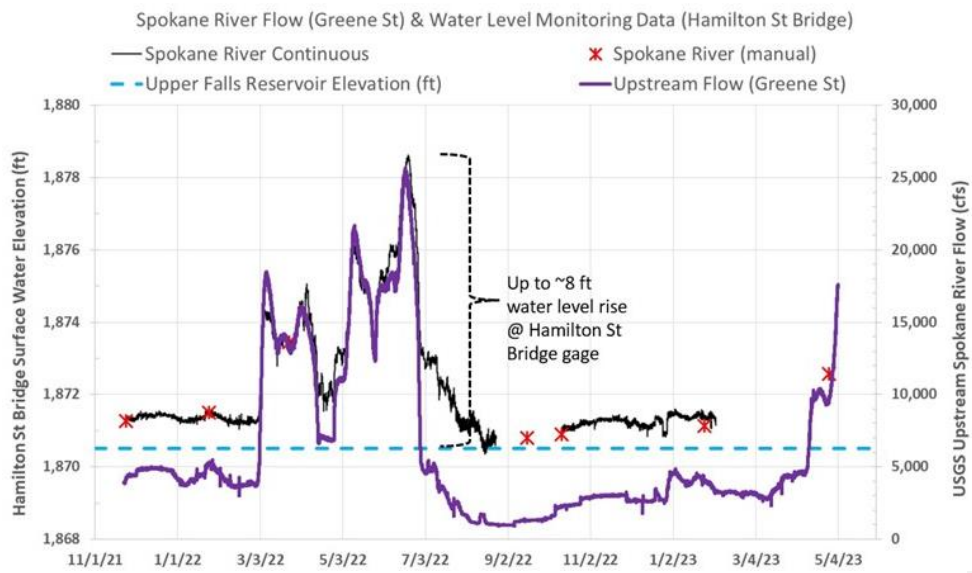
Commented [JD5]: This table was updated with data for MW9-20 after the reference survey was confirmed. No other changes were made to the table.

	2021		2022												2023			
MW2-20	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
River level above GW level (ft):	>0.005 to 0.090	>0.005 to 0.137	>0.005 to 0.098	>0.005 to 0.094	>0.005 to 0.534	0.006 to 1.279	0.006 to 1.039	0.507 to 2.464	0.278 to 1.814	0.006 to 0.892	n/a^	0.10 to 0.34	0.09 to 0.40	0.11 to 0.40	0.05 to 0.41	0.12 to 0.23	n/a^	n/a^
Measurement count:	109	667	548	481	379	697	743	720	744	487		490	720	743	744	32		
River level below GW level (ft):	<-0.005 to -0.042	<-0.005 to 0.039	<-0.005 to 0.050	<-0.005 to 0.043	<-0.005 to 0.604	-0.008 to -0.176	-0.011	- - -	- - -	<-0.005 to 0.174	n/a^	- - -	- - -	-0.08	- - -	-0.02	n/a^	n/a^
Measurement count:	**36**	**38**	**107**	**98**	**343**	**23**	**1**	0	0	**67**		0	0	**1**	0	**1**		
River Level ~ GW level (ft):	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	n/a^	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	n/a^	n/a^
Measurement count:	35	39	89	93	21	0	0	0	0	6		0	0	0	0	0		
MW4-20																		
River level above GW level (ft):	0.924 - 1.226	0.604 - 1.029	0.578 - 0.911	0.582 - 1.084	0.006 - 2.428	0.008 - 0.868	0.006 - 1.045	0.128 - 2.031	0.613 - 1.513	0.887 - 1.841	n/a^	1.179 - 1.483	0.939 - 1.394	0.797 - 1.512	0.542 - 1.207	0.647 - 1.877	n/a^	n/a^
Measurement count:	180	744	744	672	326	351	504	720	744	560		490	720	744	744	33		
River level below GW level (ft):	- - -	- - -	- - -	- - -	-0.016 to -0.712	-0.006 to -0.871	-0.006 to -0.605	- - -	- - -	- - -	n/a^	- - -	- - -	- - -	- - -	- - -	n/a^	n/a^
Measurement count:	0	0	0	0	**414**	**350**	**228**	0	0	0		0	0	0	0	0		
River Level ~ GW level (ft):	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	n/a^	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	n/a^	n/a^
Measurement count:	0	0	0	0	4	19	12	0	0	0		0	0	0	0	0		
MW8-20																		
River level above GW level (ft):	0.006 - 0.871	0.007 - 0.174	0.006 - 0.170	0.006 - 0.143	0.006 - 0.574	0.014 - 1.332	0.011 - 1.062	0.536 - 2.499	0.258 - 1.833	0.008 - 0.859	n/a^	0.043 - 0.282	0.031 - 0.224	0.029 - 0.311	0.013 - 0.417	0.135 - 0.237	n/a^	n/a^
Measurement count:	156	741	742	671	458	701	741	720	744	460		490	720	743	744	32		
River level below GW level (ft):	-0.007 to -0.062	- - -	- - -	- - -	-0.006 to -0.552	-0.016 to -0.176	-0.008 to -0.031	- - -	- - -	-0.006 to -0.210	n/a^	- - -	- - -	-0.162	- - -	-0.018	n/a^	n/a^
Measurement count:	**20**	0	0	0	**277**	**17**	**2**	0	0	**87**		0	0	**1**	0	**1**		
River Level ~ GW level (ft):	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	n/a^	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	n/a^	n/a^
Measurement count:	4	3	2	1	9	2	1	0	0	13		0	0	0	0	0		
MW9-20																		
River level above GW level (ft):	1.044 - 1.391	0.705 - 1.180	0.640 - 1.027	0.649 - 1.214	1.044 - 1.508	n/a*	n/a*	n/a*	n/a*	n/a*	n/a^*	n/a*	n/a*	n/a*	n/a*	n/a*	n/a^*	n/a^*
Measurement count:	179	744	744	672	39													
River level below GW level (ft):	- - -	- - -	- - -	- - -	- - -	n/a*	n/a*	n/a*	n/a*	n/a*	n/a^*	n/a*	n/a*	n/a*	n/a*	n/a*	n/a^*	n/a^*
Measurement count:	0	0	0	0	0													
River Level ~ GW level (ft):	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	-0.005 to 0.005	n/a*	n/a*	n/a*	n/a*	n/a*	n/a^*	n/a*	n/a*	n/a*	n/a*	n/a*	n/a^*	n/a^*
Measurement count:	0	0	0	0	0													

n/a^ There are no river elevation data between 8:00 am August 24, 2022 & 2:00 pm October 11, 2022, & after 8:00 am February 2, 2023 due to pressure transducer malfunctions.
n/a* The MW9-20 pressure transducer failed after 2pm March 2, 2022, no data are available since this failure

3.1.1 USGS Gage Data and Hamilton Street Bridge Continuous Monitoring Data

The Spokane River continuous elevation data also compare very well with the USGS flow and gage data obtained from the upriver Green Street gage (**Figure 9**) and the downriver Spokane gage (**Figure 10**). Historical manual river elevation data are included in these figures for reference, as is the pool elevation for the Upper Falls Reservoir (1870.5 ft), which has remained relatively stable since November 2021. These figures show that river levels and flows rose and fell very rapidly upstream and downstream of the Upper Falls and Monroe Street dam systems during the period from early March through early July. During the low flow interval, surface water levels at the Hamilton Street Bridge location were generally 1 foot or less above the downstream Upper Falls Reservoir pool elevation. However, during the 2022 high flow period, the Hamilton Street Bridge water level increased by approximately 7 to 8 ft. This is a significant increase above the Upper Falls controlled pool elevation, but the 2023 SVRP Aquifer Atlas indicates that the river elevation trends shown in the late 2021 through early 2023 Hamilton Street Bridge continuous monitoring data are consistent with historical Spokane River monitoring information (refer to **Figure 11**). The rapid surface water and groundwater level increases in spring coincide with snow melts, and the SVRP Aquifer can manage large recharge volumes because groundwater flow velocities are very rapid in the SVRP Aquifer (up to 50 ft/day) because of the very permeable nature of the aquifer.



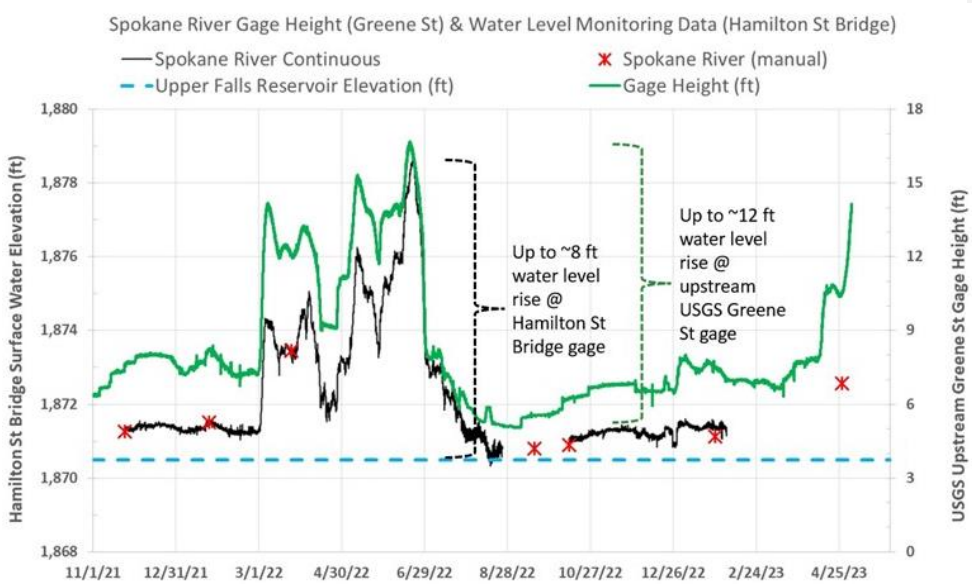


Figure 9. Continuous and manual surface water level monitoring data for the Hamilton Street Bridge study area and USGS Green Street flow and gage data.

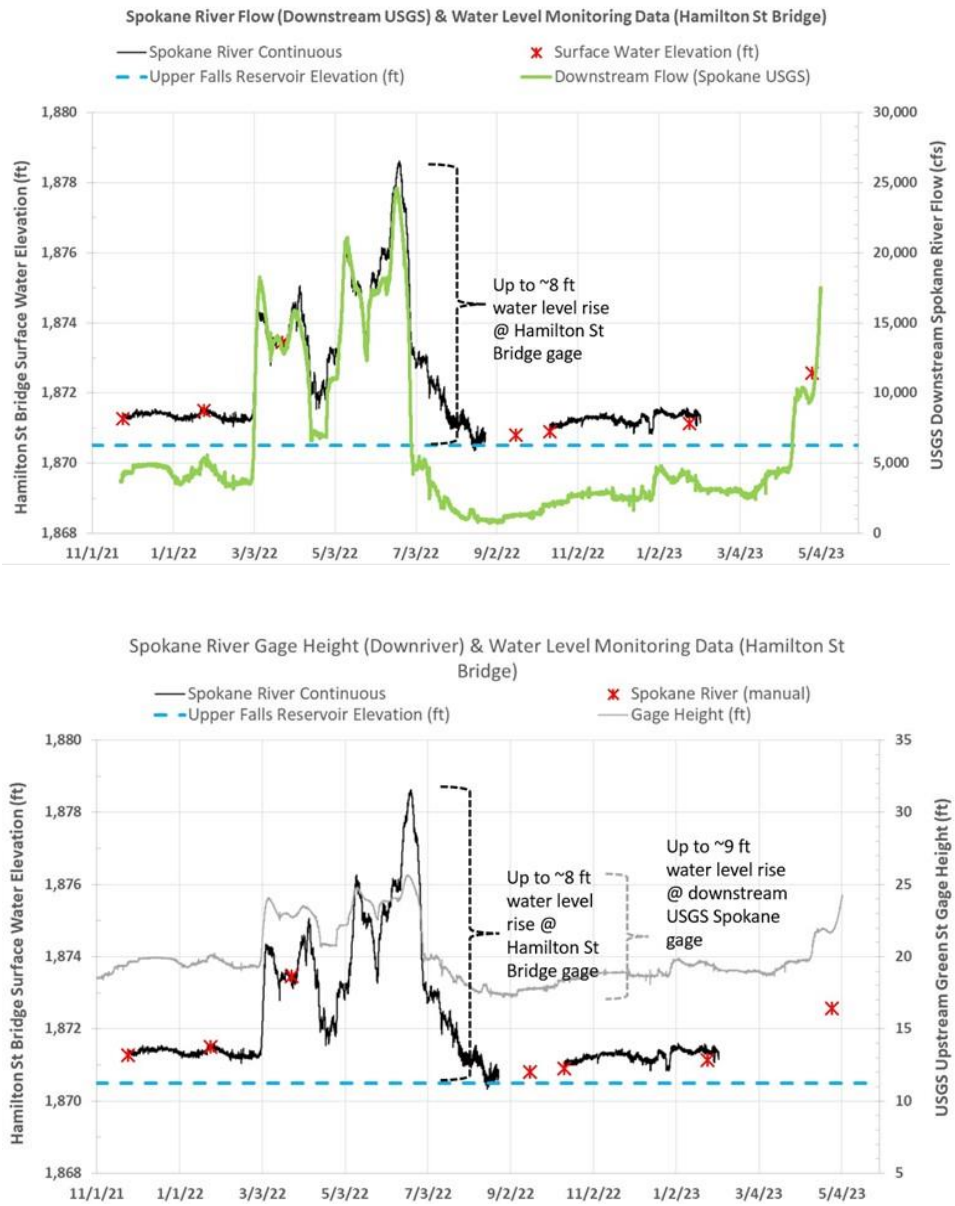
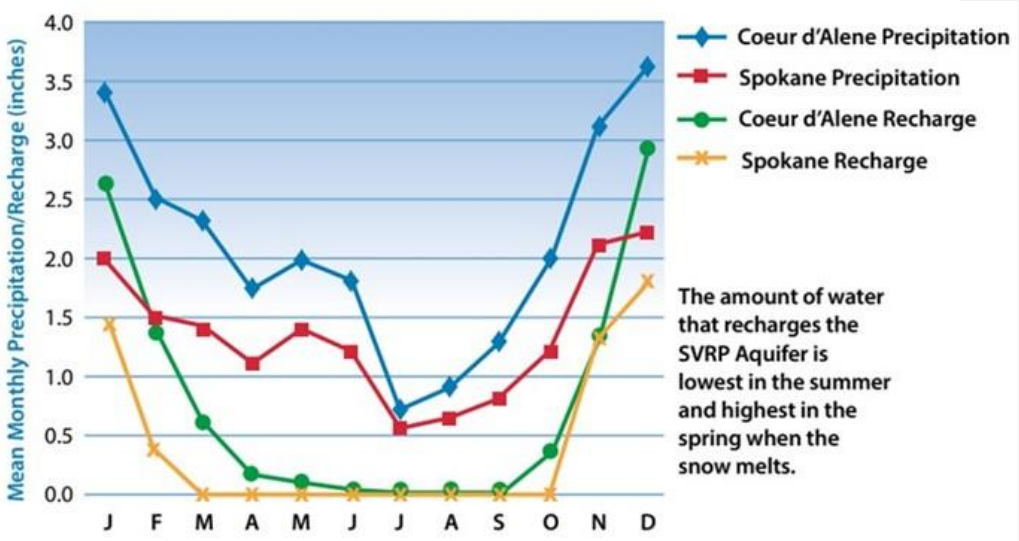


Figure 10. Continuous and manual surface water level monitoring data for the Hamilton Street Bridge study area and USGS Spokane flow and gage data.



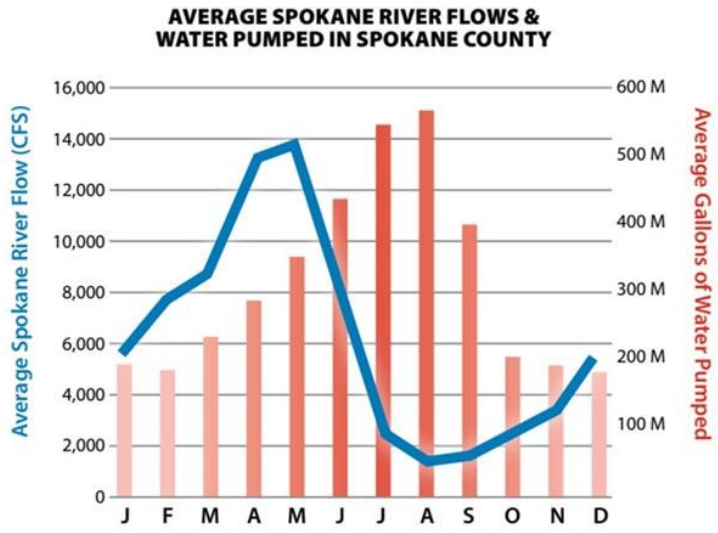


Figure 11. Recharge to the Spokane Valley Rathdrum Prairie Aquifer and average monthly Spokane River flows relative to groundwater withdrawals (Source: 2023 SVRP Aquifer Atlas).

3.1.2 Timing and Frequency of Groundwater Flow Reversals Observed In Continuous Monitoring Data

The continuously monitored (hourly) groundwater elevation data from the shallow monitoring wells located closest to the river (MW2-20, MW4-20 and MW8-20) were individually compared to time-synchronous continuous surface water elevation data for the Hamilton Street Bridge staff gage. Groundwater elevations that were above surface water levels would indicate groundwater flow towards the river; consequently, these events were evaluated for frequency (by day per month), magnitude range by month, and duration (what percentage of the hourly groundwater readings were above surface water levels during a given day). The results of this evaluation are summarized in **Tables 2**, **3** and **4** and depicted in **Figures 12**, **13** and **14** for monitoring well locations MW2-20, MW4-20 and MW8-20, respectively. These results show the following:

- Groundwater elevations were higher on occasion than surface water levels in all three shallow monitoring wells, but this occurred more frequently and for longer periods in the two wells located closest to the riverbank (i.e., MW2-20 and MW4-20).
- Groundwater levels exceeded surface water levels most frequently and for longer durations at all three locations during the spring months of 2022:
    - At all three monitoring well locations during the month of March 2022, groundwater levels were above surface water levels most frequently and for longer durations, including every hour for up to 5 consecutive days at the MW2-20 location and every hour or up to 16 consecutive days at the MW4-20 location.
    - During the months of April and May 2022 at the MW4-20 location, groundwater levels were above surface water levels every hour for at least 3 consecutive days at a time.
    - There are no water level comparison data for February through April 2023 due to a malfunction of the Hamilton Street Bridge surface water gage on February 2, 2023.
- During the summer months June through early August 2022, hourly surface water level readings were above groundwater levels relative to all three locations. This time interval likely coincides with the 2022 snow melt period when the highest surface water-to-groundwater level differences were observed. During mid-August 2022, groundwater levels are above surface water levels at the MW2-20 and MW8-20 locations for up to approximately 17% and 54% of the day, respectively, for up to nine consecutive days. There are no river elevation data between 8:00 am August 24, 2022 and 2:00 pm October 11, 2022 due to a pressure transducer malfunction at the Hamilton Street Bridge gage location.
- At the MW2-20 location, the data also show that groundwater levels are above surface water levels for intermittent periods during the late fall and early winter months of November and December 2021 and January and February 2022.
    - These events were recorded in approximately 4% to 33% of the hourly readings each day for 8 consecutive days in late November 2021 and 7 consecutive days in early December 2021.

- During the months of January and February 2022, the daily duration of these events increased to approximately 58% and 75%, respectively and lasted for up to 7 and 8 consecutive days, respectively.

- During the late November 2021 through February 2022 monitoring period at the MW4-20 location, the hourly data show that groundwater levels were below surface water levels.
- During the late November 2021 through February 2022 monitoring period at the MW8-20 location, there were three days in December 2021 when hourly groundwater levels were above surface water levels, for approximately 1% to 10% of each day.

Table 2~~2~~. Daily frequency, magnitude and duration of events where MW2-20 hourly groundwater elevations were above Hamilton Street Bridge river gage elevations.

MW2-20	2021		2022												2023			
Day of Month	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	0.0%	12.5%	0%	0%	37.5%	0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	0%	n/a^	n/a^
2	0.0%	8.3%	8.3%	0.0%	0%	0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	4.2%	n/a^	n/a^
3	0.0%	0.0%	12.5%	4.2%	0%	0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
4	0.0%	8.3%	25.0%	0%	0%	12.5%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
5	0.0%	25.0%	4.2%	0%	20.8%	0.0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
6	0.0%	29.2%	8.3%	0.0%	100%	0.0%	4.2%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
7	0.0%	33.3%	58.3%	8.3%	100%	0.0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
8	0.0%	8.3%	8.3%	0%	100%	0.0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
9	0.0%	4.2%	0.0%	0.0%	100%	0.0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
10	0.0%	4.2%	0.0%	62.5%	100%	0.0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
11	0.0%	0%	12.5%	4.2%	87.5%	0.0%	0%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
12	0.0%	8.3%	41.7%	0%	100%	0.0%	0%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
13	0.0%	4.2%	54.2%	0.0%	87.5%	0.0%	0%	0%	0%	16.7%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
14	0.0%	4.2%	0%	12.5%	37.5%	0.0%	0%	0%	0%	37.5%	n/a^	0%	0%	4.2%	0%	n/a^	n/a^	n/a^
15	0.0%	0%	16.7%	16.7%	100.0%	0.0%	0%	0%	0%	41.7%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
16	0.0%	0%	4.2%	29.2%	8.3%	0.0%	0%	0%	0%	54.2%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
17	0.0%	0%	41.7%	16.7%	45.8%	0.0%	0%	0%	0%	25.0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
18	0.0%	0%	16.7%	8.3%	79.2%	29.2%	0%	0%	0%	25.0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
19	0.0%	4.2%	0.0%	25.0%	100.0%	12.5%	0%	0%	0%	25.0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
20	0.0%	0%	45.8%	75.0%	25.0%	25.0%	0%	0%	0%	25.0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
21	0.0%	0%	12.5%	20.8%	4.2%	16.7%	0%	0%	0%	8.3%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
22	0.0%	0%	0.0%	0%	0%	0%	0%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
23	25.0%	0%	20.8%	0%	0%	0%	0%	0%	0%	20.8%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
24	33.3%	0%	29.2%	4.2%	25.0%	0%	0%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
25	12.5%	0%	0.0%	0%	58.3%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
26	20.8%	4.2%	4.2%	16.7%	25.0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
27	4.2%	0%	0.0%	50.0%	79.2%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
28	25.0%	0%	0.0%	54.2%	8.3%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
29	20.8%	0%	4.2%		0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	0%		n/a^	n/a^
30	8.3%	0%	8.3%		0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	0%		n/a^	n/a^
31		0%	8.3%		0%		0%		0%	n/a^		0%		0%	0%		n/a^	
Water Level Difference (ft):	>0.005 - 0.042	>0.005 - 0.039	>0.005 - 0.050	>0.005 - 0.043	>0.005 - 0.604	>0.008 - 0.176	0.011	---	---	>0.005 - 0.174	n/a^	---	---	0.080	---	0.020	n/a^	n/a^

n/a^	There are no river elevation data between 8:00 am August 24, 2022 & 2:00 pm October 11, 2022, & after 8:00 am February 2, 2023 due to pressure transducer malfunctions.
Green highlight/font	Indicates percent of day when groundwater level exceeded surface water level by more than 0.005 ft

Table 3~~3~~. Daily frequency, magnitude and duration of events where MW4-20 hourly groundwater elevations were above Hamilton Street Bridge river gage elevations.

MW4-20	2021		2022												2023			
Day of Month	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	0.0%	0%	0%	0%	0.0%	0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	0%	n/a^	n/a^
2	0.0%	0%	0%	0%	0%	0%	38%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	0%	n/a^	n/a^
3	0.0%	0%	0%	0%	0%	42%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
4	0.0%	0%	0%	0%	0%	95.8%	13%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
5	0.0%	0%	0%	0%	0.0%	0.0%	58%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
6	0.0%	0%	0%	0%	0%	0.0%	4.2%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
7	0.0%	0%	0%	0%	0%	0.0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
8	0.0%	0%	0%	0%	0%	16.7%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
9	0.0%	0%	0%	0%	0%	29.2%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
10	0.0%	0%	0%	0%	0%	54.2%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
11	0.0%	0%	0%	0%	0.0%	100.0%	0%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
12	0.0%	0%	0%	0%	96%	91.7%	0%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
13	0.0%	0%	0%	0%	100.0%	100.0%	0%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
14	0.0%	0%	0%	0%	100.0%	100.0%	0%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
15	0.0%	0%	0%	0%	100.0%	100.0%	46%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
16	0.0%	0%	0%	0%	100.0%	100.0%	100%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
17	0.0%	0%	0%	0%	100.0%	29.2%	29%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
18	0.0%	0%	0%	0%	100.0%	83.3%	67%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
19	0.0%	0%	0%	0%	100.0%	100.0%	71%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
20	0.0%	0%	0%	0%	100.0%	100.0%	4%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
21	0.0%	0%	0%	0%	100.0%	100.0%	0%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
22	0.0%	0%	0%	0%	100%	92%	42%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
23	0.0%	0%	0%	0%	100%	4%	96%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
24	0.0%	0%	0%	0%	100.0%	17%	100%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
25	0.0%	0%	0%	0%	100.0%	50%	100%	0%	0%	n/a^	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
26	0.0%	0%	0%	0%	100.0%	54%	100%	0%	0%	n/a^	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
27	0.0%	0%	0%	0%	100.0%	0%	75%	0%	0%	n/a^	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
28	0.0%	0%	0%	0%	100.0%	0%	4%	0%	0%	n/a^	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
29	0.0%	0%	0%	0%	29%	0%	4%	0%	0%	n/a^	n/a^	0%	0%	0%	0%		n/a^	n/a^
30	0.0%	0%	0%	0%	0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	0%		n/a^	n/a^
31	0.0%	0%	0%	0%	0%		0%		0%	n/a^		0%		0%	0%		n/a^	
Water Level Difference (ft):	---	---	---	---	>0.005 - 0.712	>0.005 - 0.871	>0.005 - 0.605	---	---	---	n/a^	---	---	---	---	n/a^	n/a^	n/a^

n/a^ There are no river elevation data between 8:00 am August 24, 2022 & 2:00 pm October 11, 2022, & after 8:00 am February 2, 2023 due to pressure transducer malfunctions.
Green highlight/font Indicates percent of day when groundwater level exceeded surface water level by more than 0.005 ft

Table 44. Daily frequency, magnitude and duration of events where MW8-20 hourly groundwater elevations were above Hamilton Street Bridge river gage elevations.

MW8-20	2021		2022												2023			
Day of Month	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	0%	0%	0%	0%	0.0%	0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	0%	n/a^	n/a^
2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	1.0%	n/a^	n/a^
3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
4	0%	0%	0%	0%	0%	1.0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
5	0%	0%	0%	0%	3.0%	0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
6	0%	0%	0%	0%	24%	0%	2.0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
7	0%	0%	0%	0%	24%	0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
8	0%	0%	0%	0%	24%	0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
9	0%	0%	0%	0%	24%	0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
10	0%	0%	0%	0%	24%	0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	n/a^	n/a^	n/a^
11	0%	0%	0%	0%	16.0%	0%	0%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
12	0%	0%	0%	0%	24%	0%	0%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
13	0%	0%	0%	0%	9.0%	0%	0%	0%	0%	5%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
14	0%	0%	0%	0%	5.0%	0%	0%	0%	0%	11%	n/a^	0%	0%	1.0%	0%	n/a^	n/a^	n/a^
15	0%	0%	0%	0%	17.0%	0%	0%	0%	0%	12%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
16	0%	0%	0%	0%	0%	0%	0%	0%	0%	17%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
17	0%	0%	0%	0%	9.0%	0%	0%	0%	0%	6%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
18	0%	0%	0%	0%	10.0%	5.0%	0%	0%	0%	8%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
19	0%	0%	0%	0%	24.0%	2.0%	0%	0%	0%	9%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
20	0%	0%	0%	0%	1.0%	5.0%	0%	0%	0%	8%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
21	0%	0%	0%	0%	0%	4.0%	0%	0%	0%	4%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
22	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
23	10.0%	0%	0%	0%	0%	0%	0%	0%	0%	7%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
24	9.0%	0%	0%	0%	6.0%	0%	0%	0%	0%	0%	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
25	0%	0%	0%	0%	12.0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
26	0%	0%	0%	0%	5.0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
27	0.0%	0%	0%	0%	16.0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
28	1.0%	0%	0%	0%	0.0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	0%	n/a^	n/a^	n/a^
29	0%	0%	0%		0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	0%		n/a^	n/a^
30	0%	0%	0%		0%	0%	0%	0%	0%	n/a^	n/a^	0%	0%	0%	0%		n/a^	n/a^
31		0%	0%		0%		0%		0%	n/a^		0%		0%	0%		n/a^	
Water Level Difference (ft):	>0.005 - 0.062	- - -	- - -	- - -	>0.005 - 0.552	0.016 - 0.176	>0.005 - 0.031	- - -	- - -	>0.005 - 0.210	n/a^	- - -	- - -	0.162	- - -	0.018	n/a^	n/a^

n/a^ There are no river elevation data between 8:00 am August 24, 2022 & 2:00 pm October 11, 2022, & after 8:00 am February 2, 2023 due to pressure transducer malfunctions.
Green highlight/font Indicates percent of day when groundwater level exceeded surface water level by more than 0.005 ft

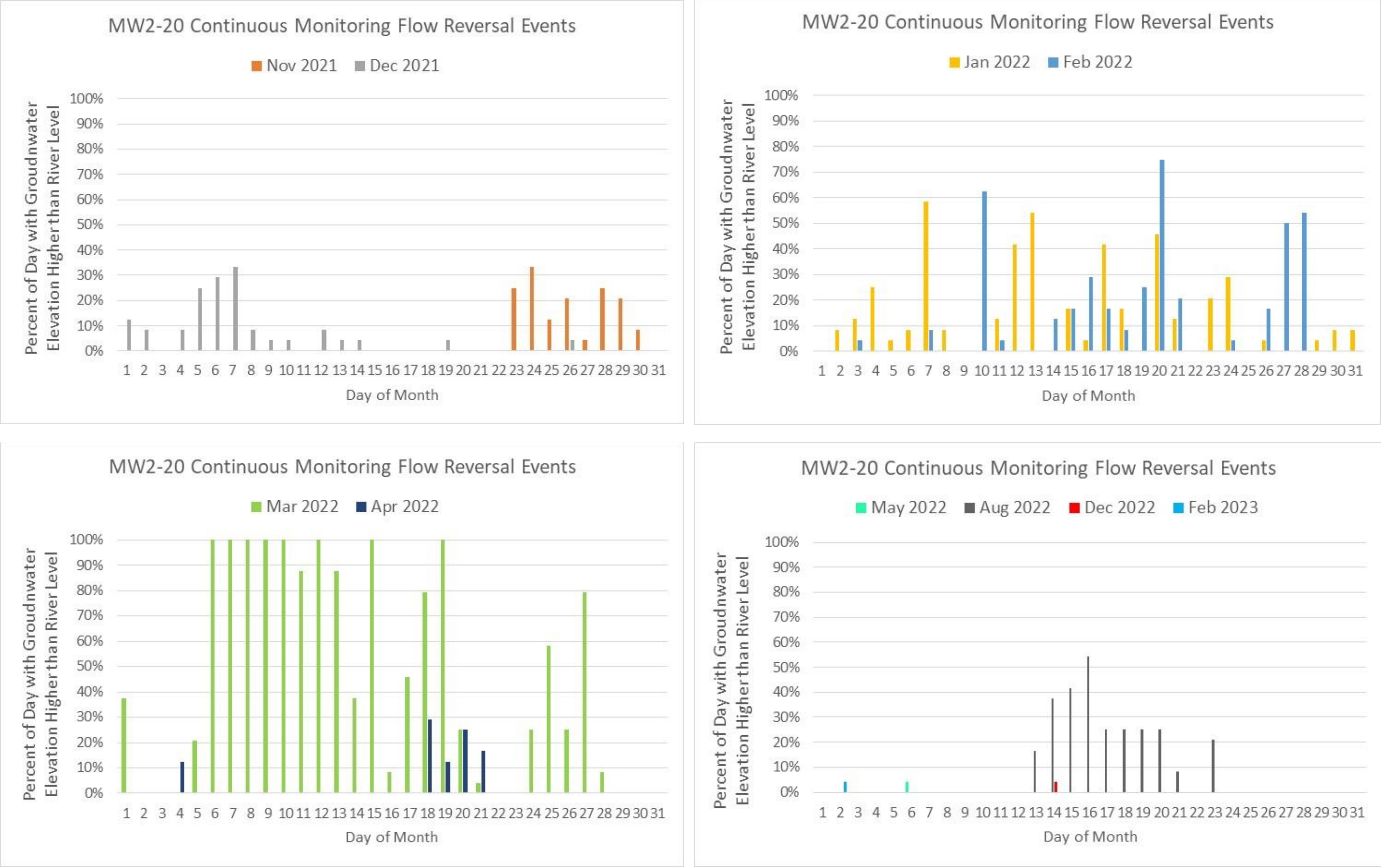
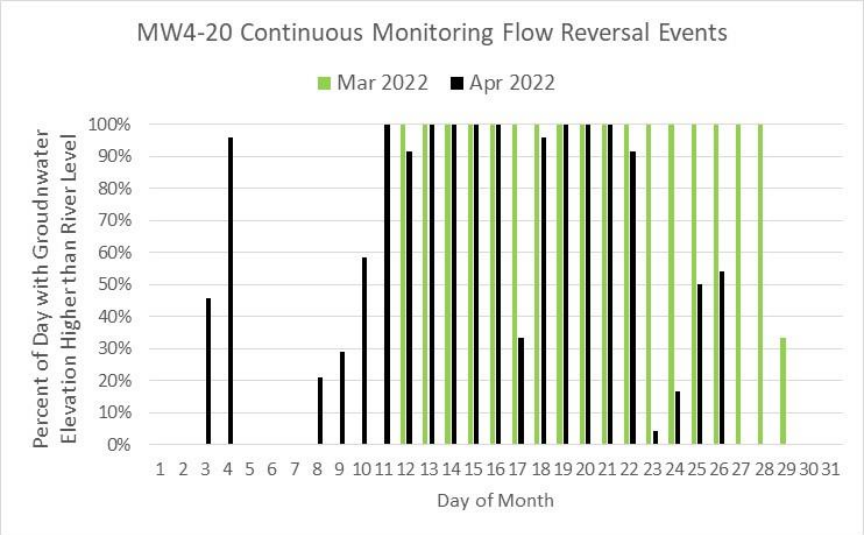


Figure 12. Graphs of daily frequency and duration of events for months where MW2-20 hourly groundwater elevations were above Hamilton Street Bridge river gage elevations.



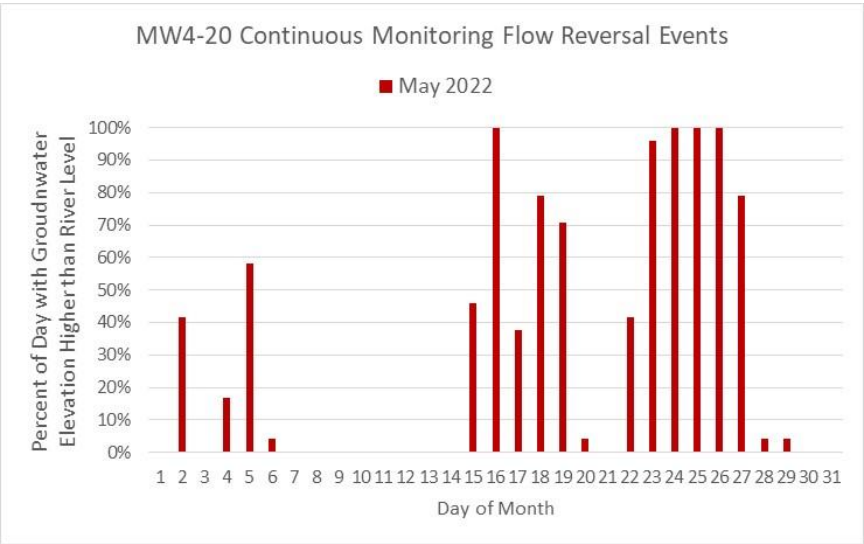


Figure 13. Graphs of daily frequency and duration of events for months where MW4-20 hourly groundwater elevations were above Hamilton Street Bridge river gage elevations.

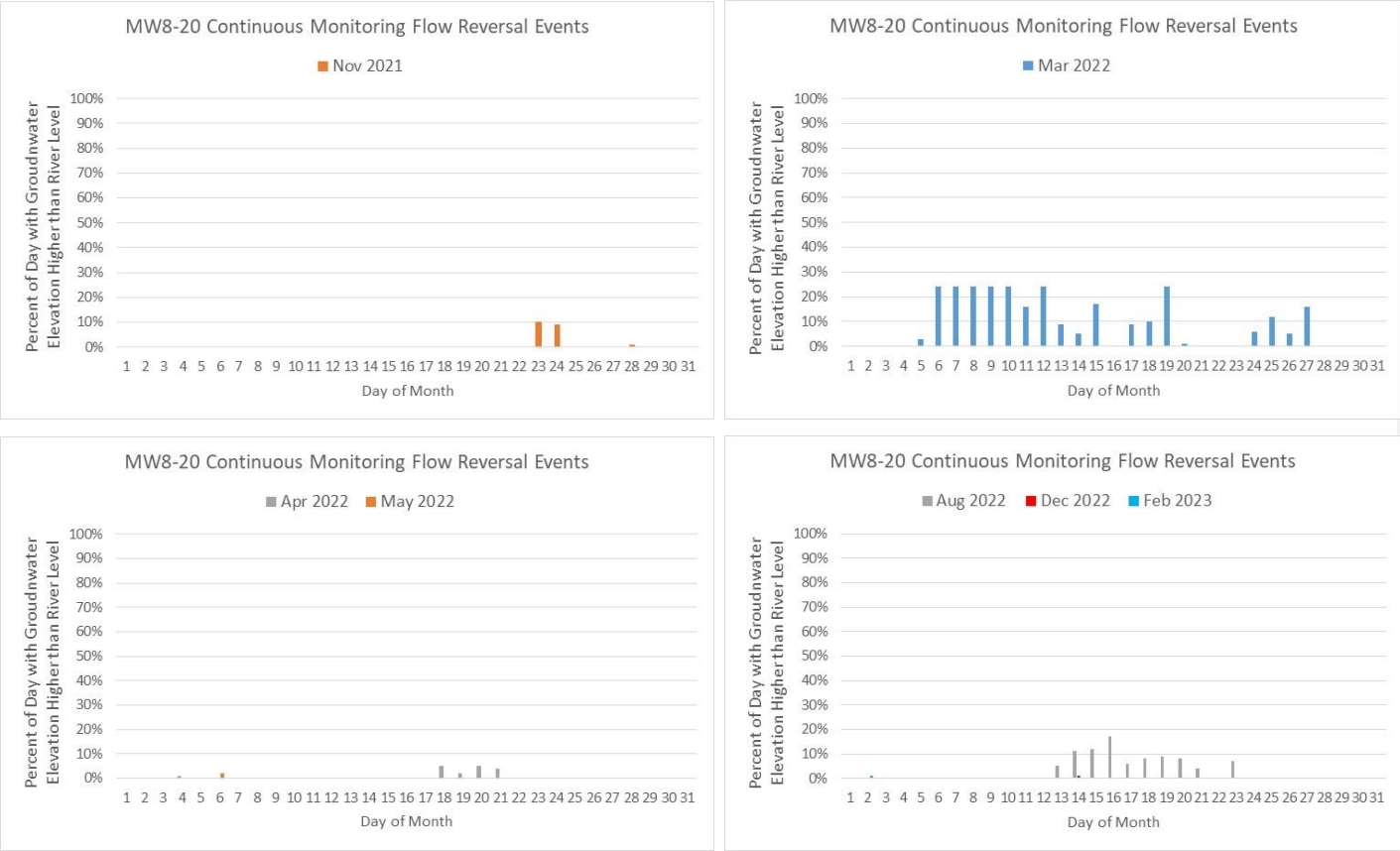


Figure 14. Graphs of daily frequency and duration of events for months where MW8-20 hourly groundwater elevations were above Hamilton Street Bridge river gage elevations.

3.1.3 Vertical Groundwater Gradients Observed in Continuous Monitoring Data

Continuously monitored vertical groundwater gradients data are available for clustered monitoring wells MW8-20/MW8-90 for the period 10:00 am on November 24, 2021 through 2:00 pm on March 2, 2022. The results are depicted in **Figure 15**, which shows that groundwater elevations at the shallower MW8-20 well location consistently were above groundwater elevations at the deeper MW8-90 well location (i.e., a consistent downward vertical gradient), which indicates that the river generally was losing to the aquifer for this period. The groundwater level difference between the two wells ranged from 0.45 ft to 1.53 ft, with an average difference of 0.71 ft. Downward vertical gradients were calculated relative to the differences between the screen center elevations for the two clustered wells (approximately 70 ft), and ranged from 0.0064 ft/ft to 0.0218 ft/ft, with an average downward gradient of 0.0102 ft/ft.

These results are generally consistent with the evaluations described in Section 3.1.2 above because, except for three days in November 2021, hourly surface water levels were higher than groundwater levels at the MW8-20 location. For the three days in November when MW8-20 groundwater levels were higher than surface water levels, there is only one reading for MW8-90 that coincides with these events (06:00 on November 28). At that time, the MW8 cluster well downward vertical gradient was 0.0139 ft/ft (suggesting the river was losing) and the difference between the surface water level and MW8-20 shallow groundwater level was -0.011 ft (suggesting the river was gaining). No definitive conclusions can be drawn from this single datapoint, and there are no clustered monitoring well data after 14:00 March 2, 2022 for evaluating vertical groundwater gradients relative to higher flow periods or other low flow periods. Repairs to the MW8-90 pressure transducer would help to fill this data gap.

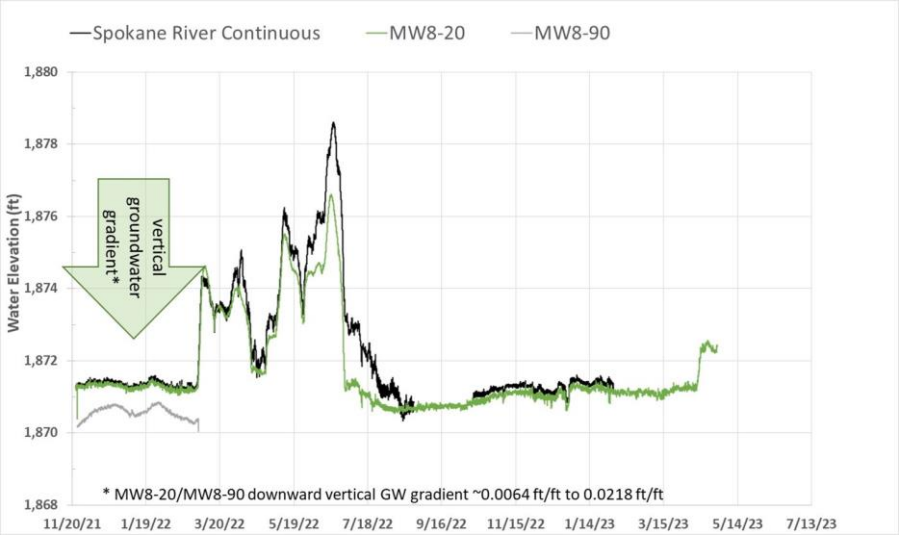


Figure 15. Graph of continuous groundwater level monitoring data for clustered wells MW8-20 and MW8-90, showing a consistent downward vertical gradient for the period late November 2021 through March 2, 2022.

3.2 Results From Ecology Online Database Searches and Evaluations

The tabulated inventory of Ecology *Whats' In My Neighborhood* sites that fall within the Mission Reach study area is provided in **Appendix A**. At a minimum, the Ecology online database includes a 1-page Cleanup Site Details document with general site information; this information source was used to document the current site cleanup status (refer to **Figure 5**) as well as other relevant facility information. If additional site-specific documents are available, this is noted on the Cleanup Site Details page and can be downloaded from the website using the site name, FSID or CSID information that is summarized in **Appendix A**. A total of 69 sites are included in the inventory. As shown in **Figure 16**:

- 22 sites had known or suspected groundwater impacts
- 4 sites have documented historical PCB impacts, including Sterling Property (230 N Division St), 24-28 E Spokane Falls Blvd, Schade Brewery (528 E Trent Ave) and Inland Metals (534 E Trent Ave)
- 11 sites with hydrogeological information reported shallow basalt where groundwater was either not present or was perched in shallow weathered basalt zones

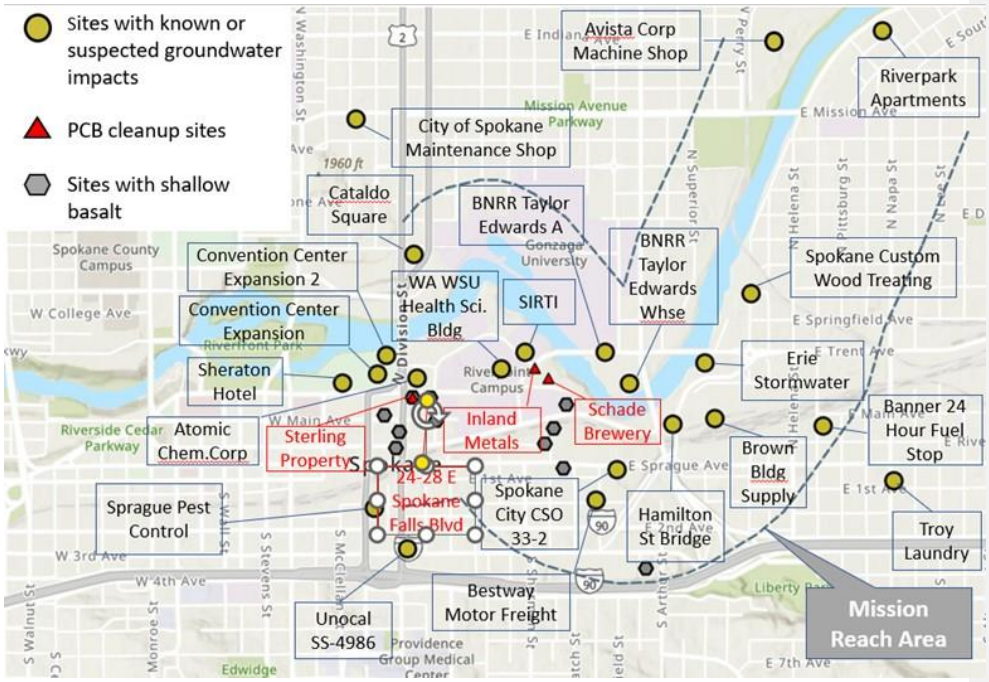


Figure 16. What's In My Neighborhood cleanup sites within and near Mission Reach with known or suspected groundwater impacts, documented PCB impacts and shallow basalt.

Of the twenty-two sites located within and near Mission Reach with known or suspected groundwater impacts, only seven sites had historical depth to groundwater data (refer to **Figure 17**):

- Avista Corp Machine Shop (1411 E Mission Ave)
- Banner 24 Hour Fuel Stop (126 N Madelia Street)
- Brown Building Supply/Front Ave Property (112 N Erie Street)
- City of Spokane Maintenance Shop (127 W Mission Ave)
- Hamilton Street Bridge Street (111 N Erie Street)
- Riverpark Apartments (1842 E South Riverton Ave)
- Spokane Convention Center Expansion (200 W Spokane Falls Blvd)

Available well construction, location, survey and historical depth to groundwater data were compiled from the downloaded reports and from the EIM database and are provided in **Appendix B**. Historical depth to groundwater data were converted to groundwater elevations if surveyed reference data were available for their associated monitoring wells, so that site-specific groundwater flow direction maps could be developed. The two sites that are not included in this evaluation are:

- Riverpark Apartments because survey data were not available to convert the depth to groundwater data to elevations, and
- City of Spokane Maintenance Shop because it is located too far north of the Mission Reach study area to likely be affected by groundwater-surface water interactions.

The results of this evaluation include historical groundwater elevation data and horizontal groundwater flow direction maps for the five sites described in the following subsections.

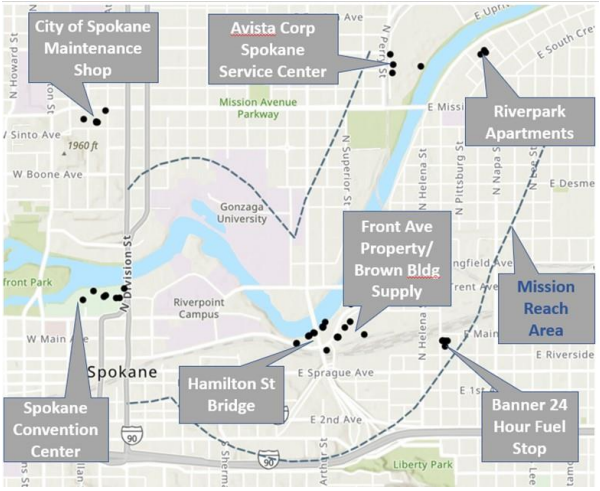


Figure 17. Sites within and near Mission Reach with historical depth to groundwater data.

Commented [JD6]: This appendix will need to be revised in data for Hamilton St Bridge site wells MW9-20 and MW9-100 cannot be verified.

Commented [JD7R6]: Appendix B has been updated with the correct 2001 survey data for converting the MW9 cluster well groundwater monitoring data - only the historical depth to groundwater measurements from the 2019 Landua report were used, not their groundwater elevations.

3.2.1 Avista Corp Machine Shop Historical Groundwater Data Evaluations

The Avista Corp Machine Shop site is located in the extreme northeastern end of the Mission Reach study area, on the north bank of the Spokane River. Seven sets of historical depth to groundwater data are available for this site from August 17, 2018 through October 14, 2020 for up to seven monitoring well locations. The groundwater elevation data are shown graphically in **Figure 18** and are plotted on maps in **Appendix C** to show horizontal groundwater flow direction variability through time. The sources of this information are the EIM online database and the July 2020 Quarterly Groundwater Monitoring Report (SES, August 12, 2020). The information obtained for this site shows the following:

- Horizontal groundwater flow direction is consistently towards the west to northwest and away from the river, indicating a losing river reach at this location.
- Monitoring wells MW-1, MW-1A, MW-5A and MW-5B are either abandoned or likely abandoned.
- Well construction information is not available for MW-1; consequently, the data are not included in the **Appendix C** flow direction maps. MW-1A appears to be a replacement well for MW-1 because depth to groundwater data for MW-1 are not available after November 20, 2018, and depth to groundwater data for MW-1A begin on July 31, 2019.
- Well construction information is not available for MW-5A; consequently, the data are not included in the **Appendix C** flow direction maps. MW-5B appears to be a replacement well for MW-5A because depth to groundwater data for MW-5A are not available after October 10, 2018, and depth to groundwater data for MW-5B begin on July 31, 2019.

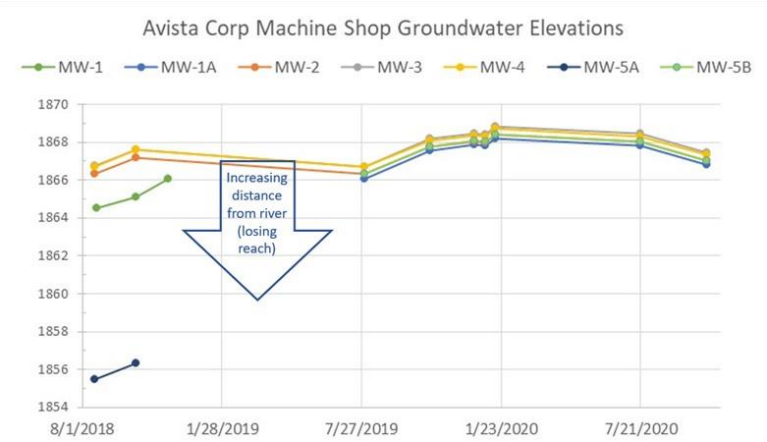


Figure 18. Historical groundwater elevation data for Avista Corp Machine Shop site, August 2018 through October 2020.

3.2.2 Banner 24 Hour Fuel Stop Historical Groundwater Data Evaluations

The Banner 24 Hour Fuel Stop site is located on the southeastern end of the Mission Reach study area. Ten sets of historical depth to groundwater data are available for this site from May 8, 2018 through December 24, 2021 for four monitoring well locations. The groundwater elevation data are shown graphically in **Figure 19** and are plotted on maps in **Appendix D** to show groundwater flow direction variability through time. The sources of this information are the EIM online database and the site Environmental Covenant (Environmental Covenant for the Banner 24 Houre Fuel Stop, April 20, 2019). The information obtained for this site shows the following:

- The available data suggest that the four site monitoring wells may still exist, but this needs to be confirmed. However, these wells are located at the outer edge of the Mission Reach study area and are not as helpful as wells located closer to the riverbank.
- The horizontal groundwater gradient is extremely flat across the site, varying by less ≤0.07 ft over a distance of 120 ft. This is illustrated in **Figure 19** by the lack of obvious separation between the well groundwater elevation graphs.
- The horizontal groundwater flow direction is predominantly to the east-southeast, with one exception observed on May 8, 2018, when the horizontal direction of flow was to the north.
- For four vintages of data the horizontal groundwater flow direction could not be determined because data for MW-1 were not available (13 July 2021, 11 December 2019, 30 September 2019 and 19 March 2019).

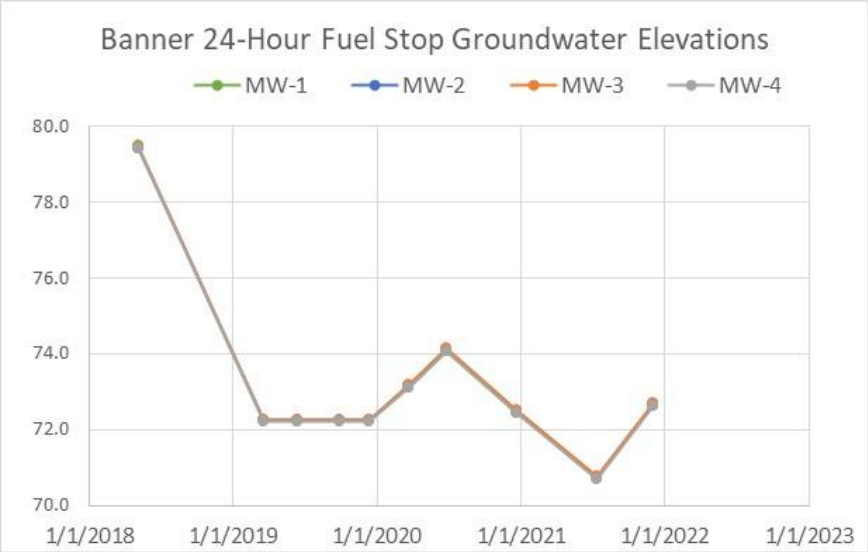


Figure 19. Historical groundwater elevation data for Banner 24 Hour Fuel Stop site, May 2018 through December 2021.

3.2.3 Brown Building Supply/Front Ave Property Historical Groundwater Data Evaluations

The Brown Building Supply site is located just east of (and adjacent to) the Hamilton Street Bridge site. Two sets of historical depth to groundwater data are available for this site (January 21 and July 20, 2020) for six monitoring well locations, including the MW9-20/MW9-40/MW9-100 clustered well set located on the southeastern end of the Hamilton Street Bridge site. The groundwater elevation data are shown graphically in **Figure 20** and are plotted on maps in **Appendix E** to show groundwater flow direction variability through time. The sources of this information are the EIM online database and the August 2020 Remedial Investigation Feasibility Study and Cleanup Action Plan (Aspect Consulting, August 13, 2020). The limited information obtained for this site shows the following:

- Groundwater flow was generally towards the river for both monitoring events; however, the horizontal groundwater gradients are very low (approximately 0.00011 ft/ft to 0.00023 ft/ft).
- The January 2020 data for the MW9 clustered wells shows a downward vertical groundwater gradient.

Commented [JD8]: Need to verify the GW elev data for these wells

Commented [JD9R8]: Data are OK to use as-is - verified.

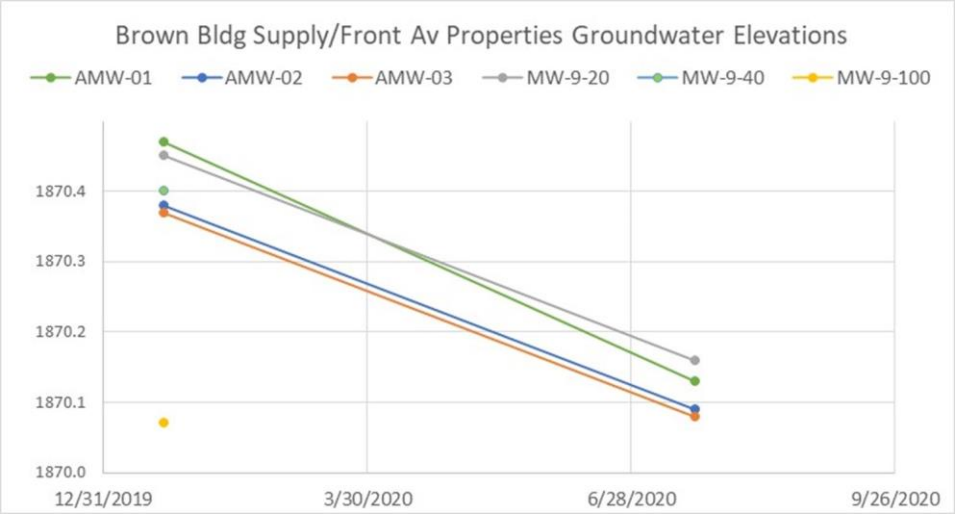


Figure 20. Historical groundwater elevation data for Brown Building Supply/Front Street Property site, January and July 2020

Commented [JD10]: Delete MW9 data if can't confirm

Commented [JD11R10]: MW9 data are confirmed - ok to use as-is

3.2.4 Hamilton Street Bridge Historical Groundwater Data Evaluations (Manual Data)

The results from the November 2021 through April 2023 continuous depth to groundwater monitoring data for the Hamilton Street Bridge site were presented in Section 3.1 above; however, in addition, there is over 16 years of manually collected groundwater monitoring data for this site. The historical manually collected groundwater elevation data are summarized in **Table 5**, shown graphically in **Figure 21** and are plotted on maps for shallow and deep monitoring wells in **Appendix F** to show horizontal and vertical groundwater flow direction variability through time since early 2006. The historical data includes two sets of clustered monitoring wells at the site to support evaluations of vertical groundwater flow direction over time (MW8-20/MW8-90 and MW9-20/~~MW9-40/~~MW9-100). The proximity of deep monitoring well MW7-90 to the bridge staff gage also provides data for determining vertical groundwater flow direction relative to the river. The sources of this information are the EIM online database and the December 2019 Semiannual Monitoring Report (Landau Associates, December 10, 2019) for historical depth to groundwater monitoring data, and the 2001 survey data for the MW9 cluster wells (Wyatt Engineering, June 2001) for converting the depth to groundwater data to groundwater elevations. The historical manual groundwater elevation data for this site show the following ~~(**COMPLETE WHEN MW9 DATA ARE VERIFIED OR NOT USED**)~~:

- ~~Groundwater flow was~~ There are 31 to 38 paired readings between the river gage and the three shallow monitoring wells located closest to the river (MW2-20, MW4-20 and MW8-20). For the majority of these observations, surface water levels are above groundwater levels, indicating that the reach is generally "losing". But as noted in Section 3.1 above, there is approximately a 50% chance or less of observing a flow reversal/gaining event when relying on monthly or quarterly depth to groundwater data that are collected manually rather than continuously.
- The maximum water level differences between the Hamilton Street Bridge gage and shallow groundwater in nearby monitoring wells MW2-20, MW4-20 and MW8-20 range up to 0.54 ft, 3.53 ft and 0.52 ft, respectively, during "losing" events and up to 0.13 ft, 0.72 ft and 1.02 ft, respectively, during "gaining" events.
- Groundwater levels were above surface water levels (i.e., the reach was "gaining") on three occasions at the MW8-20 location (23 March 2017, 24 January 2022 and 25 January 2023), on five occasions at the MW4-30 location (31 January 2006, 3 February 2011, 2 March 2015, 3 March 2016 and 12 March 2018), and on four occasions at the MW8-20 location (8 August 2006, 23 March 2017, 24 January 2022 and 27April 2023). With the exception of the August 8, 2006 reading at the MW8-20 location, all "gaining" events occurred in the late winter to spring timeframe, which is generally consistent with the results of the continuous monitoring study.
- There were no readings where the difference between the river elevation and groundwater elevations at the MW2-20, MW4-20 and MW8-20 locations were between -0.005 ft and 0.005 ft, the arbitrary range used to determine horizontal flow for this evaluation.
- Vertical groundwater gradients at the MW8-20/MW8-90 and MW9-20/MW9-100 clustered well locations ranged from -0.013 ft/ft to 0.036 ft/ft and from -0.018 ft/ft to 0.0005 ft/ft, respectively. Upwards gradients (i.e., negative values) occurred during the January through

Commented [JD12]: This table is new.

Commented [JD13]: Only a portion of the flow maps were posted - the remainder will be added when PW9 well data are verified

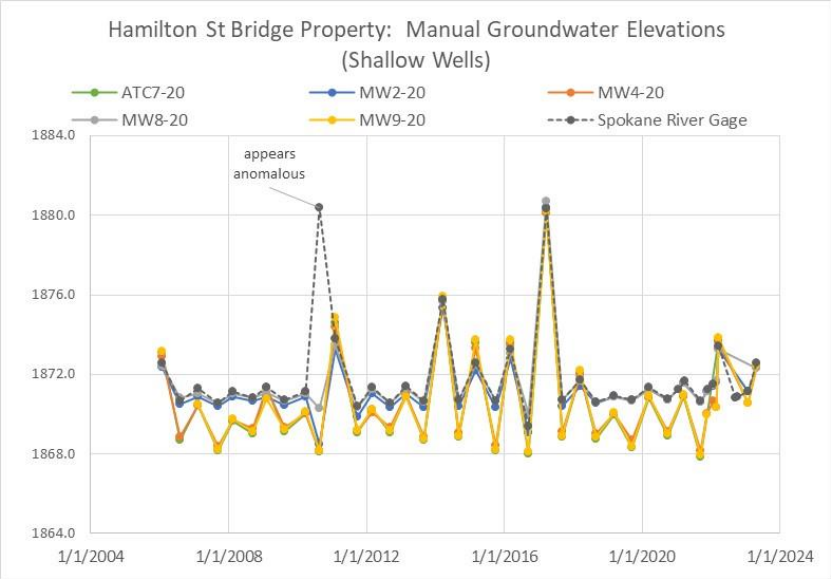
Commented [JD14R13]: Appendix F flow maps were updated with the corrected MW9 groundwater elevation data

April months at the MW8 cluster location, and during the February, March, August and September months at the MW9 cluster location. However, the vertical gradients are predominantly very small at the MW9 cluster location and can be considered negligible for most of the monitoring events. There are no continuously monitored vertical gradients data at the MW9 cluster location to compare to the historical manual data. As noted in Section 3.1.3 above, only downward vertical gradients were observed in the MW8-20/MW8-90 continuous monitoring data collected from late November 2021 through early March 2022 (0.0064 ft/ft to 0.0218 ft/ft, with an average downward gradient of 0.0102 ft/ft).

Table 5. Historical manual water elevation data for Spokane River gage and nearby shallow monitoring wells. ~~**Table 5. Historical manual water elevation data for Spokane River gage and nearby shallow monitoring wells.**~~

Date	Spokane Gage	MW2-20	River to Groundwater Difference	MW4-20	River to Groundwater Difference	MW8-20	River to Groundwater Difference
1/31/2006	1872.55	1872.34	0.21	1872.87	-0.32	1872.42	0.13
8/8/2006	1870.65	1870.50	0.15	1868.83	1.82	1870.84	-0.19
2/12/2007	1871.29	1870.86	0.43	1870.43	0.86	1871.01	0.28
9/6/2007	1870.57	1870.39	0.18	1868.36	2.21	1870.55	0.02
2/13/2008	1871.12	1870.86	0.26	1869.72	1.40	1871.03	0.09
9/10/2008	1870.82	1870.66	0.16	1869.28	1.54	1870.80	0.02
2/5/2009	1871.37	1870.87	0.50	1871.30	0.07	1871.10	0.27
8/19/2009	1870.70	1870.46	0.24	1869.34	1.36	1870.66	0.04
3/25/2010	1871.15	1870.87	0.28	1870.02	1.13	1871.03	0.12
8/17/2010	1880.39*	1868.50		1868.19		1870.31	
2/3/2011	1873.78	1873.28	0.50	1874.39	-0.61	1873.50	0.28
9/22/2011	1870.42	1869.88	0.54	1869.18	1.24	1870.33	0.09
2/28/2012	1871.37	1871.03	0.34	1870.06	1.31	1871.26	0.11
9/5/2012	1870.57	1870.33	0.24	1869.31	1.26	1870.56	0.01
2/20/2013	1871.38	1871.04	0.34	1870.96	0.42	1871.32	0.06
9/5/2013	1870.65	1870.35	0.30	1868.85	1.80	1870.63	0.02
3/20/2014	1875.77	1875.34	0.43	1875.72	0.05	1875.63	0.14
9/10/2014	1870.72	1870.42	0.30	1869.09	1.63	1870.71	0.01
3/2/2015	1872.59	1872.19	0.40	1873.31	-0.72	1872.48	0.11
9/28/2015	1870.67	1870.34	0.33	1868.42	2.25	1870.64	0.03
3/3/2016	1873.25	1872.79	0.46	1873.48	-0.23	1873.05	0.20
9/13/2016	1869.39	1869.08	0.31			1870.01	
3/23/2017	1880.33	1880.39	-0.06	1880.14	0.19	1880.72	-0.39
9/6/2017	1870.74	1870.41	0.33	1869.14	1.60	1870.72	0.02
3/12/2018	1871.73	1871.40	0.33	1871.96	-0.23	1871.68	0.05
8/28/2018	1870.63	1870.58	0.05	1869.03	1.60	1870.62	0.01
3/7/2019	1870.94	1870.86	0.08	1870.05	0.89	1870.90	0.04
9/17/2019	1870.74	1870.70	0.04	1868.69	2.05	1870.68	0.06
3/9/2020	1871.33	1871.24	0.09	1870.88	0.45	1871.26	0.07
9/28/2020	1870.76	1870.69	0.07	1869.14	1.62	1870.72	0.04
1/24/2021	1871.27						
3/22/2021	1871.67	1871.56	0.11	1870.94		1871.56	
9/7/2021	1870.65	1870.61	0.04	1868.14	3.53	1870.61	
11/23/2021		1871.15		1870.02	0.63	1871.15	0.52
11/24/2021	1871.27	1871.40	-0.13	1870.65		1871.44	-0.79
1/24/2022	1871.51						
3/2/2022		1871.62		1870.33	0.94	1871.65	
3/24/2022	1873.45	1873.28	0.17	1873.61		1873.26	
9/16/2022	1870.80						
10/11/2022	1870.90						
1/25/2023	1871.13	1871.16	-0.03	1870.54			
4/27/2023	1872.57	1872.38	0.19	1872.34	1.11	1872.29	-1.02
3/24/2022	1872.35						

* Gage reading appears erroneous - did not use in this evaluation



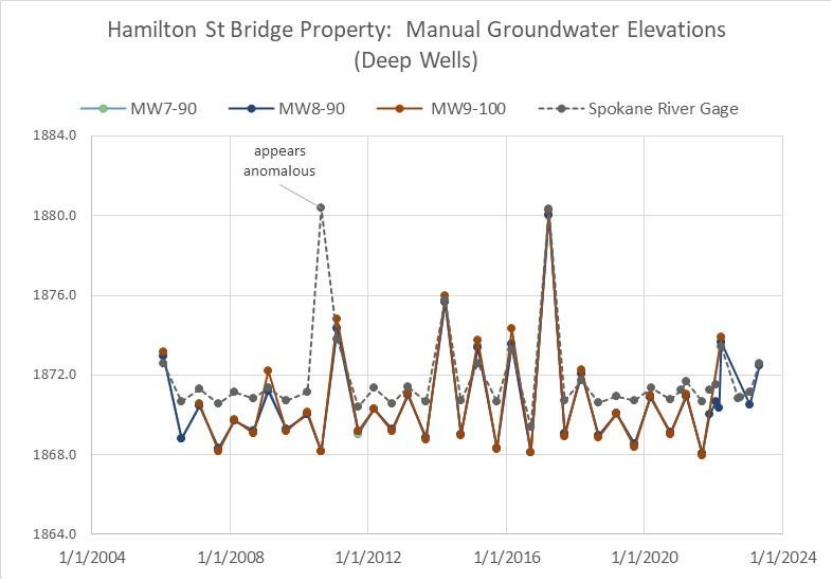


Figure 21. Historical manual groundwater elevation data for Hamilton Street Bridge site shallow and deep monitoring wells, January 2006 through March 2022.

Commented [JD15]: Remove PW-9 data if necessary

Commented [JD16R15]: Updated versions of former Fig 21 were inserted - the data were also split between shallow and deep wells for visual clarity.

3.2.5 Spokane Convention Center Expansion Historical Groundwater Data Evaluations

The Spokane Convention Center Expansion site is located just west of the western end of the Mission Reach study area, on the southern riverbank. Historical depth to groundwater data is available for this site from May 1993 through February 2005 for up to six monitoring well locations. The groundwater elevation data are shown graphically in **Figure 22** and are plotted on maps in **Appendix G** to show groundwater flow direction variability through time. The source of this information is the Ecology June 2013 Periodic Review (State of Washington Department of Ecology, June 2013). The information obtained for this site shows the following:

- This site is situated on a shallow basalt ridge.
- Monitoring wells appears to be installed in a shallow weathered basalt interval.
- Although shallow groundwater flow appears to be primarily away from the river (losing reach), groundwater likely is perched within the weather basalt zone; consequently, groundwater may be stagnant.

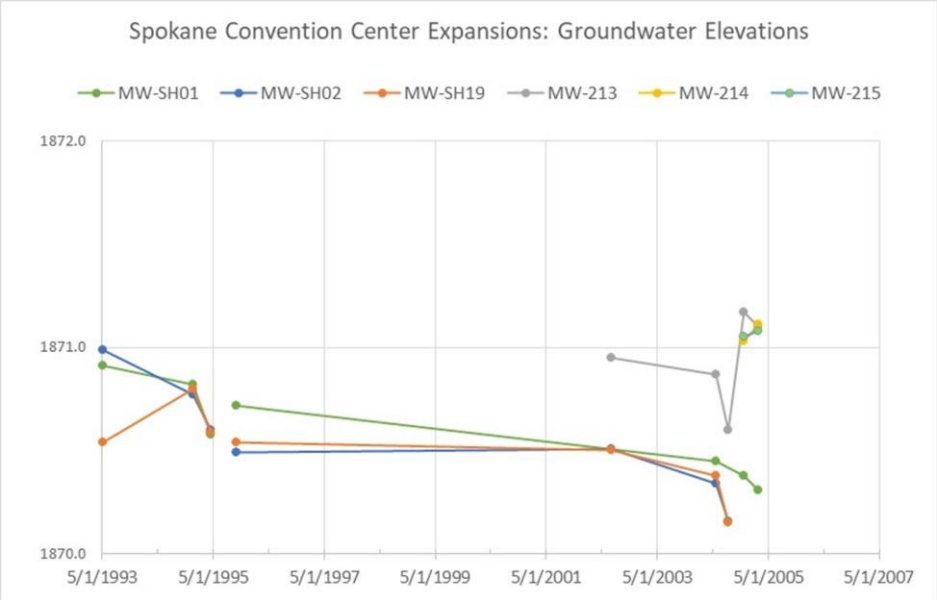


Figure 22. Historical manual groundwater elevation data for Spokane Convention Expansion site, May 1993 through February 2005.

3.3 Initial Artesian Point Source/Well Investigation Results

As noted in Section 2.8, the artesian point source/well discharge is located on the southern bank of the Spokane River (refer to **Figure 7**) and had a measured total PCB concentration of 2,100 ug/l in 2021 and 1300 to 1500 pg/l in 2022, roughly ten times greater than the average river concentration. Although unconfirmed, initial investigations into the origins of this point source suggest that this discharge may ~~serve as a part of a drainage line/system for~~be associated with one or more of the following local features (refer to **Figures 23** through **25**):

- **Historical fill zone adjacent to shallow basalt ridge.** The western end of the Mission Reach Study area includes a large shallow basalt ridge of the Columbia River Group that trends roughly southeast to northwest and crosses the Spokane River in a reach that historically has been designated as having minimal interaction with groundwater. The artesian point source/well is located near the eastern edge of this basalt ridge and on the western perimeter of a fill zone that is bounded by the former riverbank fill zone (based on a 1910 topographic map). The eastern flank of the basalt ridge drops off steeply to the east (where it was encountered 90 ft below grade at the Hamilton Street Bridge MW8-90 well location), so the fill zone may be bounded by the basalt in the subsurface. Both the basalt ridge and the fill zone likely have significant influence on subsurface flow, especially if the basalt ridge is a relatively impermeable feature, as suggested by the arcing pattern of the Well Head Protection groundwater flow paths on the east side of the ridge (refer to **Figures 24**). No water wells were found within the basalt zone in the Mission Reach area, and no information was found regarding the permeability of the basalt or its hydraulic communication with the SVRP aquifer within Mission Reach. If the basalt ridge is relatively impermeable, then the interface of the basalt ridge and the fill zone may have required dewatering during historical development of this area.
- **City of Spokane sewer infrastructure**. A west-to-east trending 60-inch diameter sanitary sewer line runs through the Hamilton Street Bridge property, south of the artesian point source, and near PCB cleanup sites Schade Brewery and Inland Metals (refer to **Figure 25**). The bedding material surrounding sewer infrastructure can function as a preferential pathway for subsurface flow, especially if embedded within a relatively finer-grained material such as a basalt or weathered basalt. The artesian point source may have a connection to the sewer line bedding if the point source serves as an area drainage feature for sections of the line that are carved within the basalt ridge. However, the depth of the sewer line may rule out a possible connection with the artesian point source and should be investigated further.
- **Trent Tunnel**. This structure is located due west of the artesian point source and is constructed within the basalt ridge. Drainage management for the tunnel currently is unknown, but the tunnels proximity to the artesian point source/well suggests that there could be a connection that warrants additional investigation.

Commented [DJ17]: Not completely ruling this out but the sewer line in question is showing that it sits ~30 ft below the surface at the 1895 ft elevation level. That puts it at about the same elevation as the river. Water level would have to be pretty high along the line for enough pressure to bring it up to where it would theoretically be discharging out the "artesian well".

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Commented [JD19]: Haven't been able to find much about this structure.

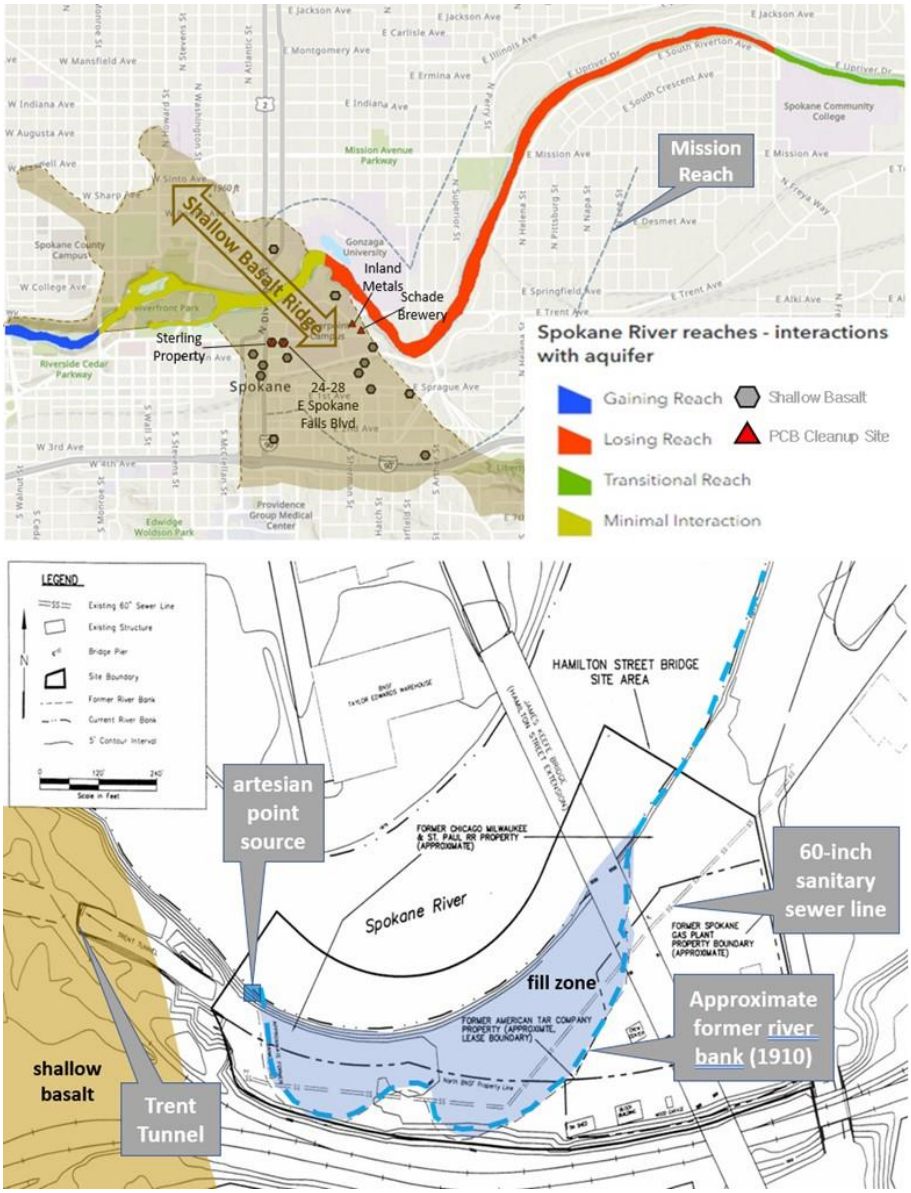

Figure 23. Location of artesian point source/well relative to shallow basalt ridge, former river bank (vintage 1910)/fill zone, 60-inch sanitary sewer line and Trent Tunnel (lower figure is modified from State of Washington Department of Ecology, July 2004).

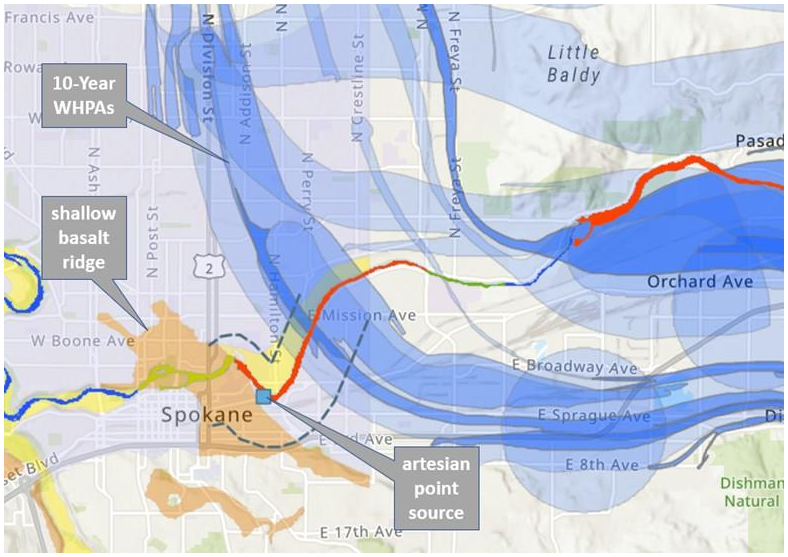

Figure 24. Location of City of Spokane 10-Year Well Head Protection Areas (WHPAs) relative to the artesian point source/well and shallow basalt ridge.

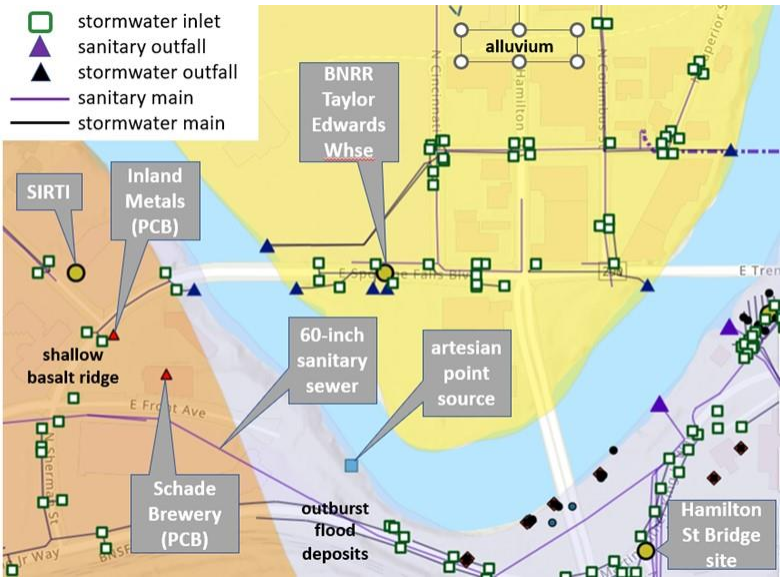

Figure 25. Location of artesian point source/well relative to shallow basalt ridge, 60-inch sanitary sewer line and nearby PCB cleanup sites (Schade Brewery and Inland Metals).

4 Initial Working Conceptual Site Model (CSM)

As described in the following subsections, an initial working CSM has been developed from the evaluations summarized in the previous sections of this report. The initial CSM includes identification of data gaps that might serve to support future investigation efforts regarding groundwater flow interactions with the Spokane River along Mission Reach.

4.1 Mission Reach Has Documented Gaining Periods

The ongoing Hamilton Street Bridge continuous water level monitoring study currently shows that the Mission Reach area includes periods when groundwater flow is directed towards the river, which means that Mission Reach has periods when it is gaining. The gaining periods have been documented to extend all day, for days to weeks, during the early spring, primarily March and April, and likely are related to snow melt events. The continuous monitoring data also show that that the gaining periods coincide with high flow events as recorded by upstream and downstream USGS river gaging stations. They occur rapidly, as manifested by river level and groundwater level rises of 5 ft to 6 ft within an hour. The highly permeable, coarse-grained nature of the SVRP aquifer can accommodate these rapid changes. Gaining periods also are documented during the months of August, November, and December, but they are less frequent and don't last all day.

Additionally, the relative change in surface water to groundwater levels is not extreme during gaining periods (less than 1 foot), and there are periods when the relative differences are negligible. The latter events are more difficult to characterize but may suggest horizontal groundwater flow that could be parallel to the riverbank.

The continuous water level monitoring data are the most robust for evaluating groundwater exchange with the Spokane River within Mission Reach and are considered to be reliable based on their consistency with river flow and stage data from upstream and downstream USGS monitoring stations. The continuous monitoring data suggest that during more pronounced gaining periods (March and April), there is approximately a 50% chance or less of observing a flow reversal/gaining event when relying on monthly or quarterly depth to groundwater data that are collected manually rather than continuously.

However, the continuous monitoring data have gaps because of instrument malfunctions, in particular the pressure transducers stopped performing for extended intervals at the Hamilton Street Bridge surface water gage station and at deep monitoring well MW8-90. These malfunctions resulted in a lack of information regarding vertical groundwater flow direction at the MW8 clustered monitoring well location during high flow periods. Groundwater is generally presumed to have an upward component of flow during river gaining periods and a downward component of flow during losing periods, but the continuous study data are not sufficiently robust to confirm these suspected trends because of the instrument malfunctions.

4.2 Shallow Basalt Ridge Likely Influences Groundwater Flow Direction

The presence of the shallow basalt ridge on the western end of Mission Reach and adjacent to the Hamilton Street Bridge continuous monitoring area is suspected to play a significant role in groundwater flow patterns. Geologic data obtained from available well logs in this area are consistent with the geologic map depiction of the extent of the basalt ridge where it crops out at the surface. The basalt ridge currently is assumed to be relatively impermeable, functioning as a barrier to groundwater flow west of the Hamilton Street Bridge Study area, but this has not been confirmed. This boundary/interface may serve as an area of recharge into the river given the transition from transmissive SVRP aquifer system to basalt. In addition, the interface between the basalt ridge and riverbank fill material may have a connection to the discharge observed at the nearby artesian point source.

5 Conclusions and Recommendations

The Hamilton Bridge area continuous monitoring data show that river levels and groundwater levels generally rise and fall closely in sync with each other, and that there are periods when the Hamilton Street Bridge area of the reach has groundwater elevations above surface water levels for consecutive days, indicating gaining episodes. These events are much more likely to be observed using continuous monitoring of water levels rather than less frequent manual monitoring methods. Consequently, the Hamilton Street Bridge continuous water level monitoring project has been valuable in documenting groundwater flow reversals for extended periods of time during rapidly changing flow events. A continuation of this project through at least December 2023 is recommended, along with routine (monthly) monitoring and maintenance of the pressure transducer equipment, to fill data gaps that occurred for extended periods due to equipment malfunctions. In addition, the surveyed reference elevation data for the monitoring equipment should be confirmed because of the relatively frequent subtle variations in water level differences between the river and shallow groundwater.

Other data sources consist of historical manually collected depth to groundwater data for monitoring wells located at five sites within Mission Reach, including the Hamilton Street Bridge site. At most of these sites the wells are known or suspected to be abandoned. The available groundwater elevation data show that groundwater flow within Mission Reach is predominantly away from the river (i.e., losing), with a few documented gaining events. Historical manual groundwater monitoring was generally conducted too infrequently to be of use in determining groundwater-surface water interactions within Mission Reach.

A shallow basalt ridge is located on the western edge of Mission Reach and crosses the Spokane River where the river is classified as having little to no interaction with groundwater. The basalt ridge drops off steeply to the east at the Hamilton Street Bridge property, where the basalt layer is approximately 90 feet deep at the MW8-90 location. Geologic data obtained from available well logs in this area are consistent with the geologic map depiction of the extent of the basalt ridge where it crops out at the surface. The initial working CSM indicates that the basalt ridge that forms the western edge of the Mission Reach area likely serves as a barrier to shallow groundwater flow, but this needs to be confirmed. At this time there are no known deep wells installed in the basalt ridge within Mission Reach. This boundary/interface may serve as an area of recharge into the river given the transition from transmissive SVRP aquifer system to basalt, and warrants further investigation.

The origin of the artesian point source/well is unknown but initial evaluations suggest that it could have a connection with one or more local features, including the interface between the basalt ridge and historical riverbank fill material, ~~the City sewer system~~ a possible drainage path associated with a 60-inch sewer line where it cuts through the basalt and -Trent Tunnel.

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Recommendations for future activities to address data gaps include:

- Routine monitoring and maintenance of the Hamilton Street Bridge continuous water level monitoring equipment to ensure proper equipment performance.

- Extending the Hamilton Street Bridge continuous water level study through at least December 2023.
- Verifying the surveyed refence elevations for the continuous monitoring equipment.
- Further investigations of the role of the interface of the basalt ridge with the SVRP aquifer and historical riverbank fill material, and its role as a possible hydrogeology boundary and an area of recharge into the river on the western end of Mission Reach.
- Further investigations into the origin of the artesian point source/well and its possible association with one or nearby features (basalt ridge, City infrastructure and the Trent Tunnel, of which little currently is known).

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Appendix A:
Ecology *What's In My Neighborhood* Cleanup Sites Within and Near Mission Reach

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INSERT APPENDIX A TABLE FROM EXCEL FILE (4 pages, tabloid, landscape)

Appendix B:
Historical Depth to Groundwater Data Within and Near Mission Reach

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INSERT APPENDIX B TABLE

Appendix C:
Historical Groundwater Flow Direction Maps:
Avista Corp Machine Shop (1411 E Mission Ave)

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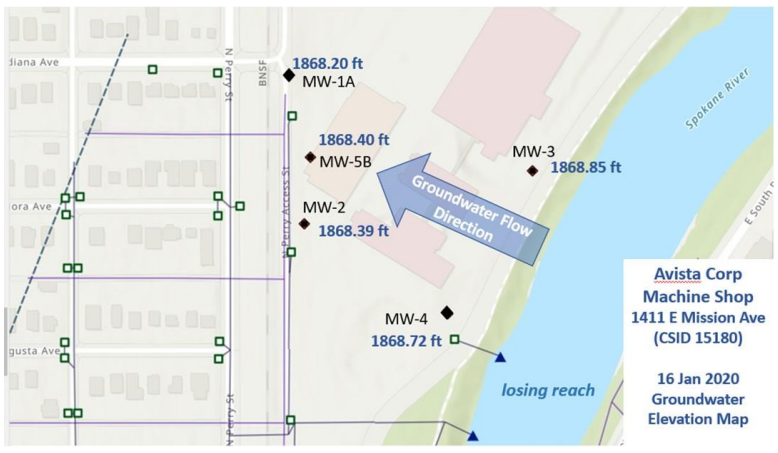
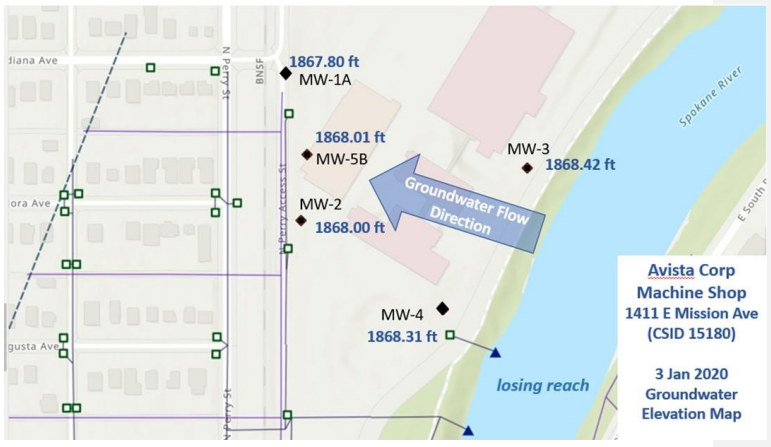
1866.83 ft
MW-1A
1867.01 ft
MW-5B
MW-3
1867.44 ft
MW-2
1867.01 ft
MW-4
1867.32 ft
Groundwater Flow Direction
losing reach
Spokane River
Avista Corp
Machine Shop
1411 E Mission Ave
(CSID 15180)
14 Oct 2020
Groundwater
Elevation Map

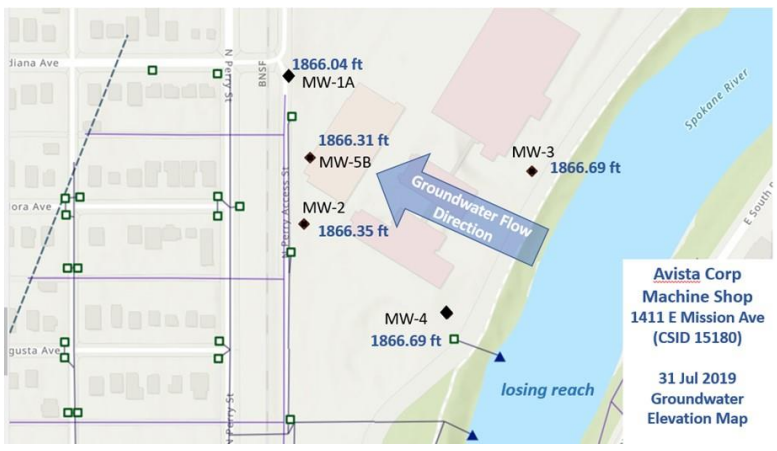

1867.83 ft
MW-1A
1868.04 ft
MW-5B
MW-3
1868.44 ft
MW-2
1868.03 ft
MW-4
1868.31 ft
Groundwater Flow Direction
losing reach
Spokane River
Avista Corp
Machine Shop
1411 E Mission Ave
(CSID 15180)
21 Jul 2020
Groundwater
Elevation Map


1868.20 ft
MW-1A
1868.40 ft
MW-5B
MW-3
1868.85 ft
MW-2
1868.39 ft
MW-4
1868.72 ft
Groundwater Flow Direction
losing reach
Spokane River
Avista Corp
Machine Shop
1411 E Mission Ave
(CSID 15180)
16 Jan 2020
Groundwater
Elevation Map


1867.80 ft
MW-1A
1868.01 ft
MW-5B
MW-3
1868.42 ft
MW-2
1868.00 ft
MW-4
1868.31 ft
Groundwater Flow Direction
losing reach
Spokane River
Avista Corp
Machine Shop
1411 E Mission Ave
(CSID 15180)
3 Jan 2020
Groundwater
Elevation Map


1867.87 ft
MW-1A
1868.07 ft
MW-5B
MW-3
1868.47 ft
MW-2
1868.05 ft
MW-4
1868.36 ft
Groundwater Flow Direction
losing reach
Spokane River
Avista Corp
Machine Shop
1411 E Mission Ave
(CSID 15180)
20 Dec 2019
Groundwater
Elevation Map


1867.57 ft
MW-1A
1867.78 ft
MW-5B
MW-3
1868.21 ft
MW-2
1867.76 ft
MW-4
1868.09 ft
Groundwater Flow Direction
losing reach
Spokane River
Avista Corp
Machine Shop
1411 E Mission Ave
(CSID 15180)
23 Oct 2019
Groundwater
Elevation Map


1866.04 ft
MW-1A
1866.31 ft
MW-5B
MW-3
1866.69 ft
MW-2
1866.35 ft
MW-4
1866.69 ft
Groundwater Flow Direction
losing reach
Spokane River
Avista Corp
Machine Shop
1411 E Mission Ave
(CSID 15180)
31 Jul 2019
Groundwater
Elevation Map

Appendix D:
Historical Groundwater Flow Direction Maps:
Banner 24 Hour Fuel Stop (126 N Madelia Street)

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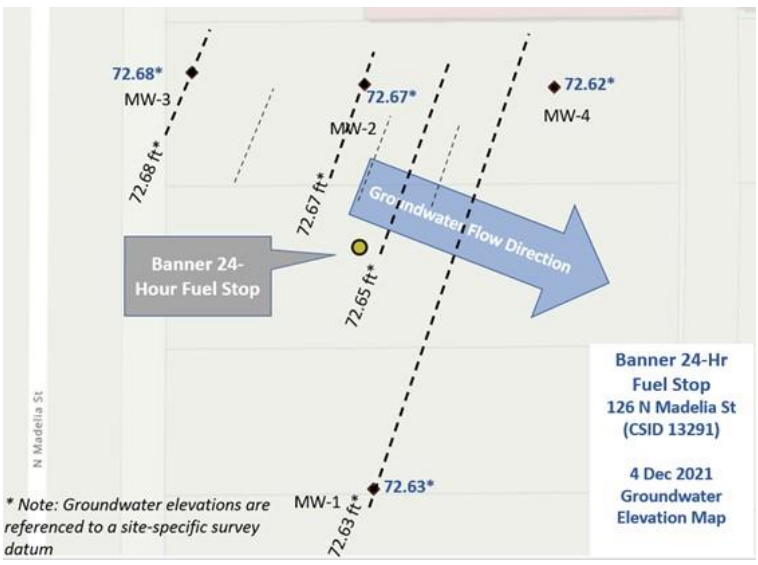
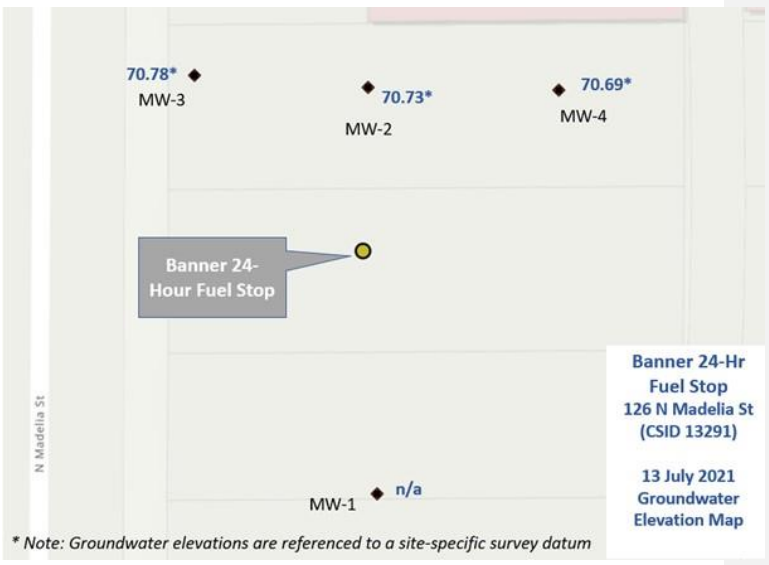
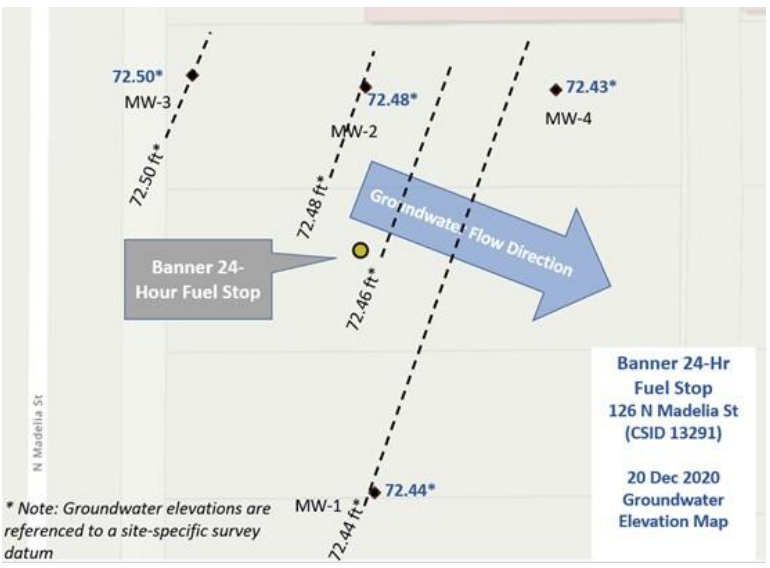
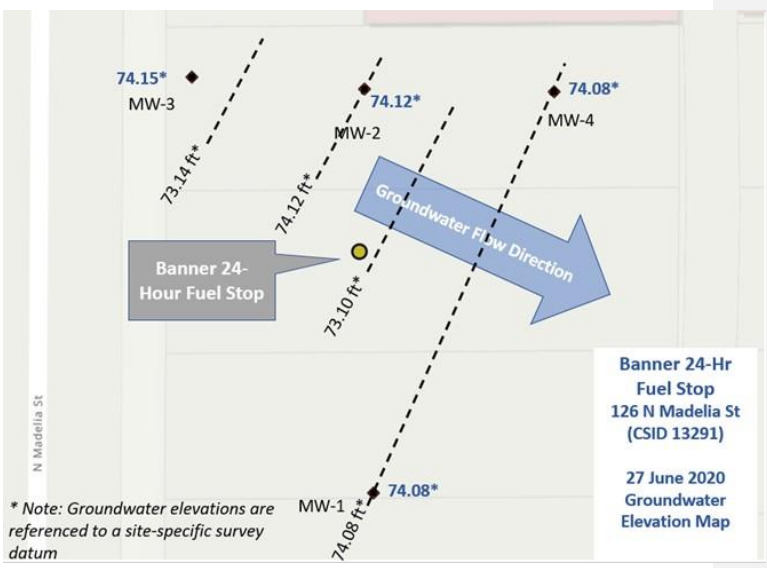
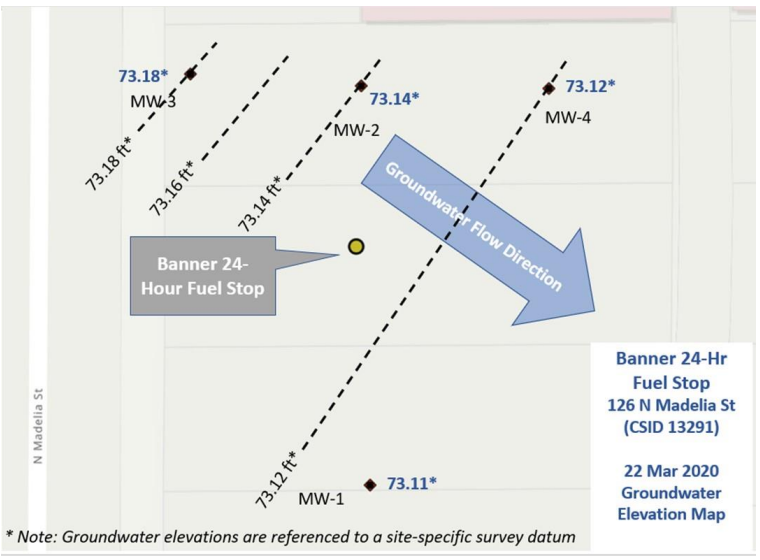
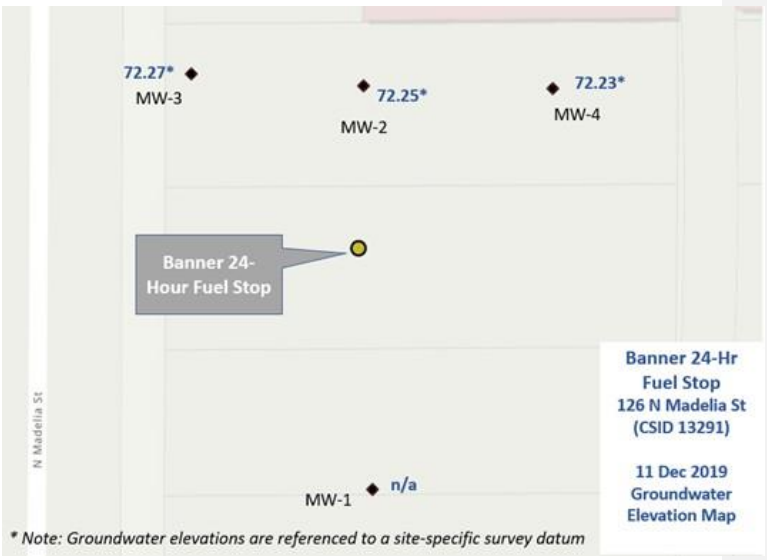

72.68*
MW-3
72.67*
MW-2
72.62*
MW-4
72.68 ft*
72.67 ft*
72.65 ft*
Groundwater Flow Direction
Banner 24-Hour Fuel Stop
N Madelia St
MW-1
72.63*
72.63 ft*
* Note: Groundwater elevations are referenced to a site-specific survey datum
Banner 24-Hr Fuel Stop
126 N Madelia St
(CSID 13291)
4 Dec 2021
Groundwater Elevation Map

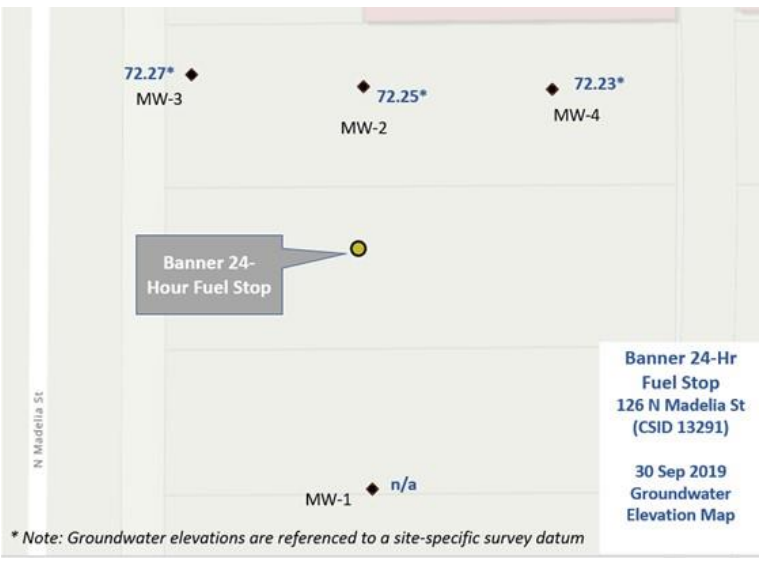

70.78*
MW-3
70.73*
MW-2
70.69*
MW-4
Banner 24-Hour Fuel Stop
N Madelia St
MW-1
n/a
* Note: Groundwater elevations are referenced to a site-specific survey datum
Banner 24-Hr Fuel Stop
126 N Madelia St
(CSID 13291)
13 July 2021
Groundwater Elevation Map

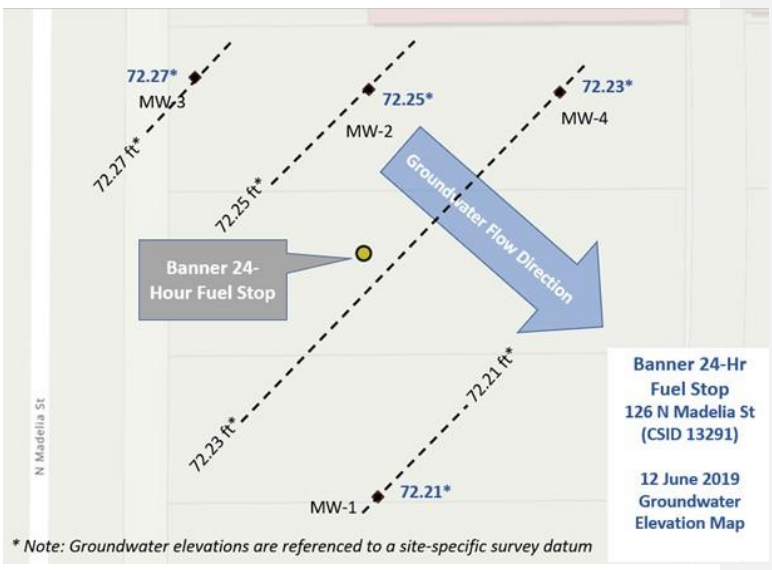

72.50*
MW-3
72.48*
MW-2
72.43*
MW-4
72.50 ft*
72.48 ft*
72.46 ft*
Groundwater Flow Direction
Banner 24-Hour Fuel Stop
N Madelia St
MW-1
72.44*
72.44 ft*
* Note: Groundwater elevations are referenced to a site-specific survey datum
Banner 24-Hr Fuel Stop
126 N Madelia St
(CSID 13291)
20 Dec 2020
Groundwater Elevation Map

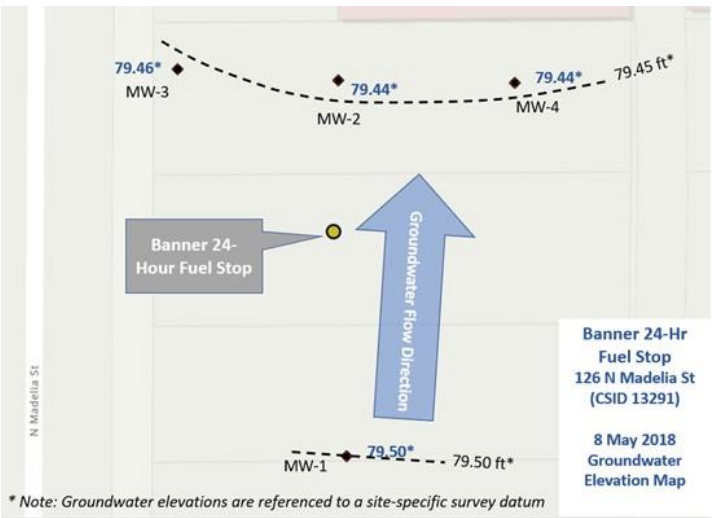

74.15*
MW-3
74.12*
MW-2
74.08*
MW-4
73.14 ft*
74.12 ft*
73.10 ft*
Groundwater Flow Direction
Banner 24-Hour Fuel Stop
N Madelia St
MW-1
74.08*
74.08 ft*
* Note: Groundwater elevations are referenced to a site-specific survey datum
Banner 24-Hr Fuel Stop
126 N Madelia St
(CSID 13291)
27 June 2020
Groundwater Elevation Map

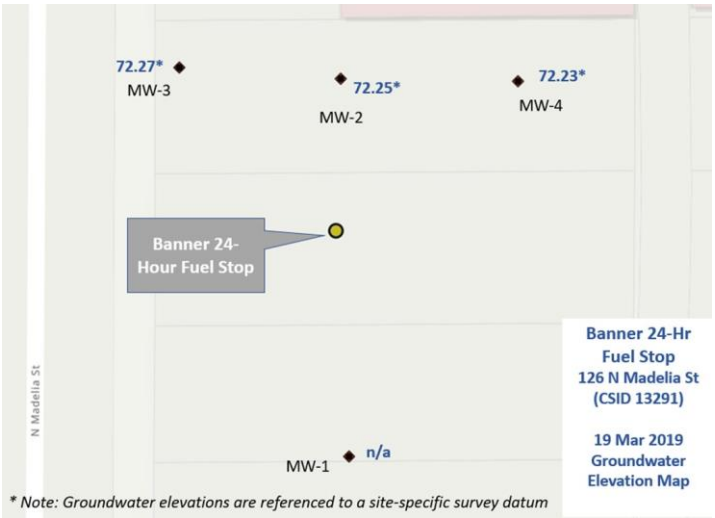

73.18*
MW-3
73.14*
MW-2
73.12*
MW-4
73.18 ft*
73.16 ft*
73.14 ft*
Groundwater Flow Direction
Banner 24-Hour Fuel Stop
N Madelia St
73.12 ft*
MW-1
73.11*
* Note: Groundwater elevations are referenced to a site-specific survey datum
Banner 24-Hr Fuel Stop
126 N Madelia St
(CSID 13291)
22 Mar 2020
Groundwater Elevation Map


72.27*
MW-3
72.25*
MW-2
72.23*
MW-4
Banner 24-Hour Fuel Stop
N Madelia St
MW-1
n/a
* Note: Groundwater elevations are referenced to a site-specific survey datum
Banner 24-Hr Fuel Stop
126 N Madelia St
(CSID 13291)
11 Dec 2019
Groundwater Elevation Map


72.27*
MW-3
72.25*
MW-2
72.23*
MW-4
Banner 24-Hour Fuel Stop
N Madelia St
MW-1
n/a
* Note: Groundwater elevations are referenced to a site-specific survey datum
Banner 24-Hr Fuel Stop
126 N Madelia St
(CSID 13291)
30 Sep 2019
Groundwater Elevation Map


72.27*
MW-3
72.25*
MW-2
72.23*
MW-4
72.27 ft*
72.25 ft*
Groundwater Flow Direction
Banner 24-Hour Fuel Stop
N Madelia St
72.23 ft*
72.21 ft*
MW-1
72.21*
* Note: Groundwater elevations are referenced to a site-specific survey datum
Banner 24-Hr Fuel Stop
126 N Madelia St
(CSID 13291)
12 June 2019
Groundwater Elevation Map


79.46*
MW-3
79.44*
MW-2
79.44*
MW-4
79.45 ft*
Banner 24-Hour Fuel Stop
Groundwater Flow Direction
N Madelia St
MW-1
79.50*
79.50 ft*
Banner 24-Hr Fuel Stop 126 N Madelia St (CSID 13291)
8 May 2018 Groundwater Elevation Map
* Note: Groundwater elevations are referenced to a site-specific survey datum


72.27*
MW-3
72.25*
MW-2
72.23*
MW-4
Banner 24-Hour Fuel Stop
N Madelia St
MW-1
n/a
Banner 24-Hr Fuel Stop 126 N Madelia St (CSID 13291)
19 Mar 2019 Groundwater Elevation Map
* Note: Groundwater elevations are referenced to a site-specific survey datum

Appendix E:
Historical Groundwater Flow Direction Maps: Brown Building Supply/Front Ave Property (112 N Erie Street)

Commented [JD22]: MW9 data will need to be removed from figures if cant confirm GW elevations

Commented [JD23R22]: The survey data used for the MW-9 cluster wells in this study are not exact matches with the 2001 survey data but close enough that I didn't change the maps. Appears that the consultant had the wells resurveyed in the 2109/202 timeframe.

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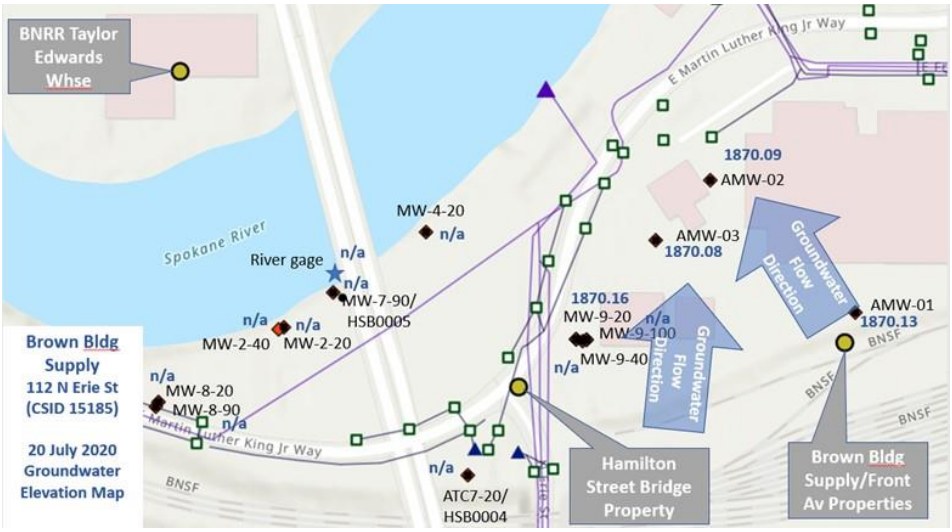
BNRR Taylor Edwards Whse
E Martin Luther King Jr Way
1870.09
AMW-02
MW-4-20
n/a
Spokane River
River gage
n/a
n/a
MW-7-90/
HSB0005
AMW-03
1870.08
Groundwater Flow Direction
1870.16
MW-9-20
n/a
MW-9-100
MW-9-40
n/a
AMW-01
1870.13
n/a
n/a
MW-2-40
MW-2-20
Brown Bldg Supply
112 N Erie St
(CSID 15185)
20 July 2020 Groundwater Elevation Map
n/a
MW-8-20
MW-8-90
n/a
Martin Luther King Jr Way
BNSF
n/a
ATC7-20/
HSB0004
Hamilton Street Bridge Property
Brown Bldg Supply/Front Av Properties


BNRR Taylor Edwards Whse
E Martin Luther King Jr Way
1870.38
AMW-02
MW-4-20
n/a
Spokane River
River gage
n/a
n/a
MW-7-90/
HSB0005
AMW-03
1870.37
Groundwater Flow Direction
1870.45
MW-9-20
1870.07
MW-9-100
MW-9-40
1870.40
AMW-01
1870.47
n/a
n/a
MW-2-40
MW-2-20
Brown Bldg Supply
112 N Erie St
(CSID 15185)
21 Jan 2020 Groundwater Elevation Map
n/a
MW-8-20
MW-8-90
n/a
Martin Luther King Jr Way
BNSF
n/a
ATC7-20/
HSB0004
Hamilton Street Bridge Property
Brown Bldg Supply/Front Av Properties

Appendix F:
Historical Groundwater Flow Direction Maps: Hamilton Street Bridge Area (111 N Erie Street)

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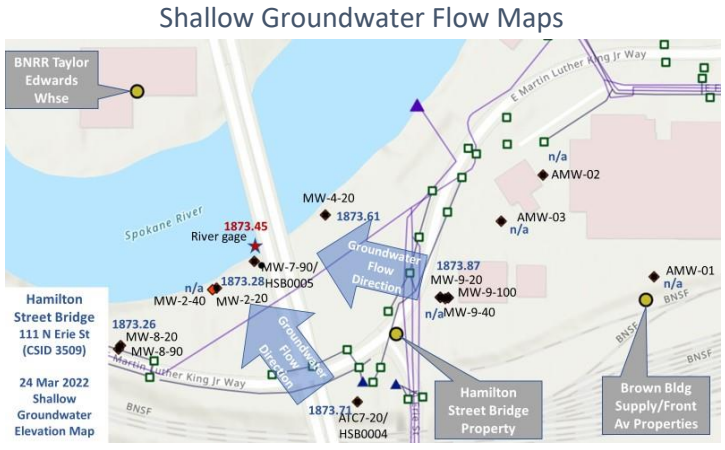
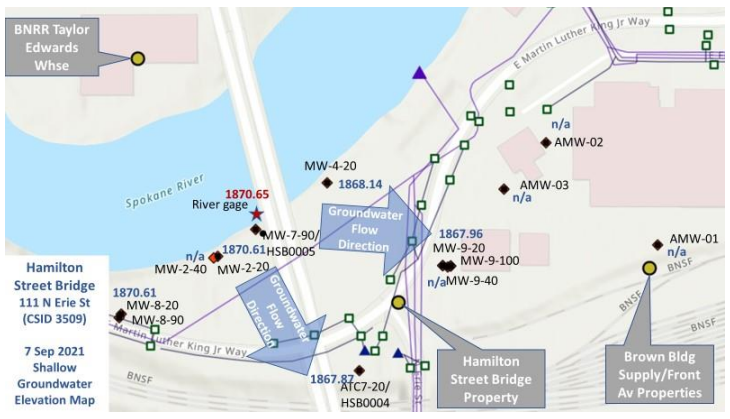
Shallow Groundwater Flow Maps

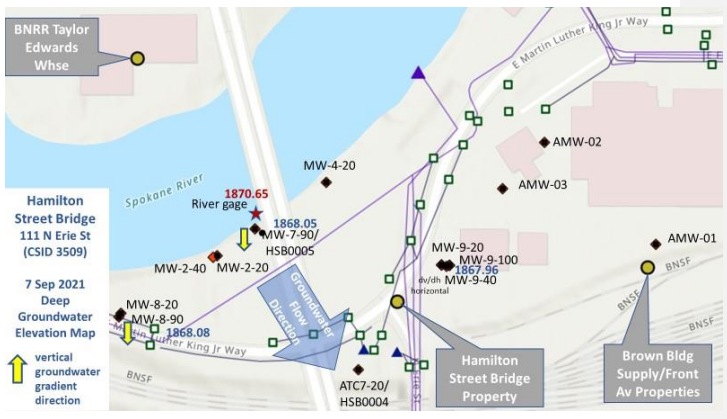
Deep Groundwater Flow Maps

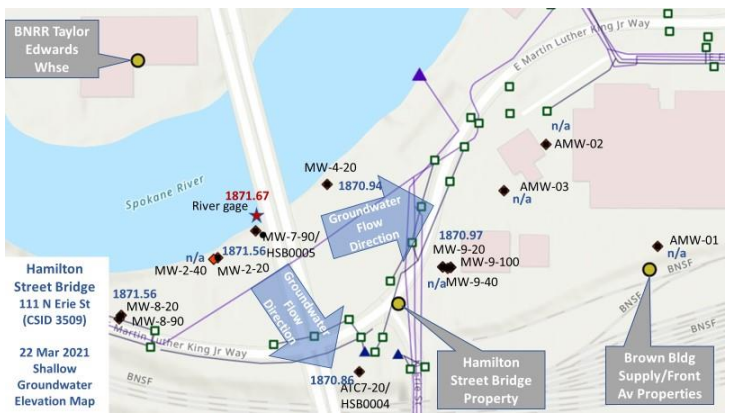
Commented [JD24]: MW9 cluster well data will need to be removed or updated pending confirmation with Landua on TOC survey elevation data

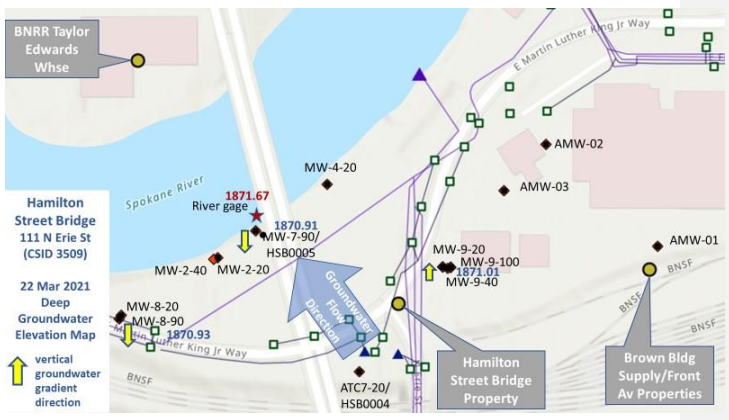
Commented [JD25R24]: All maps have been updated/corrected

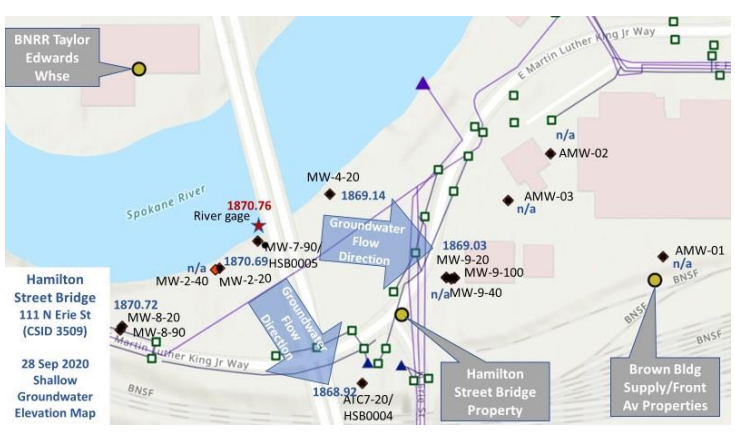


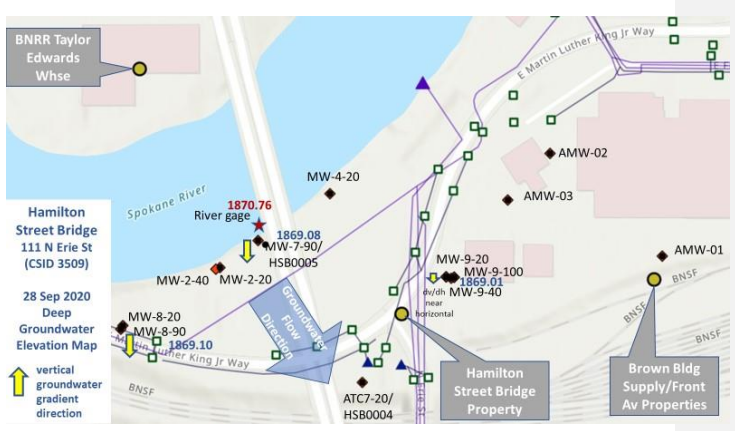


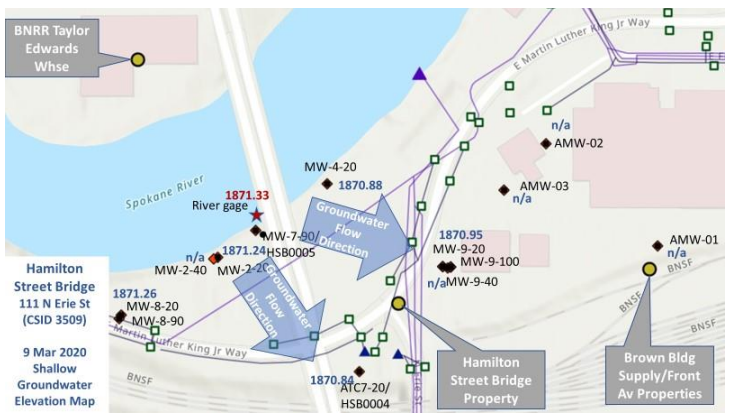


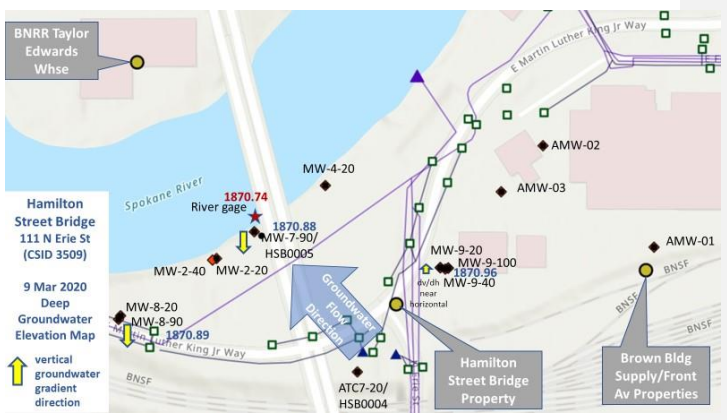






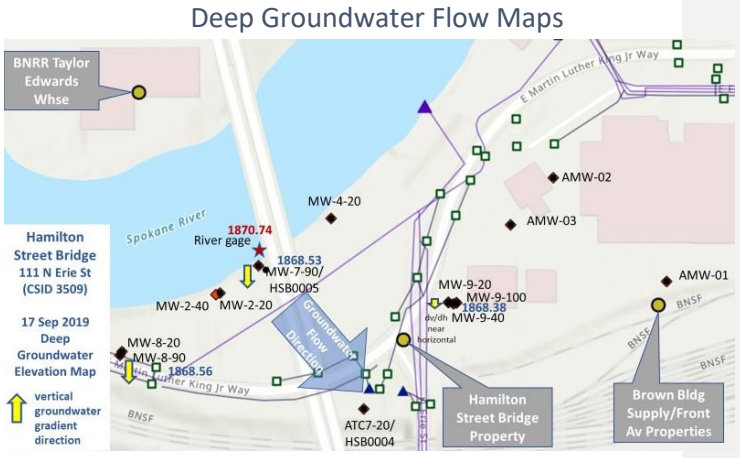


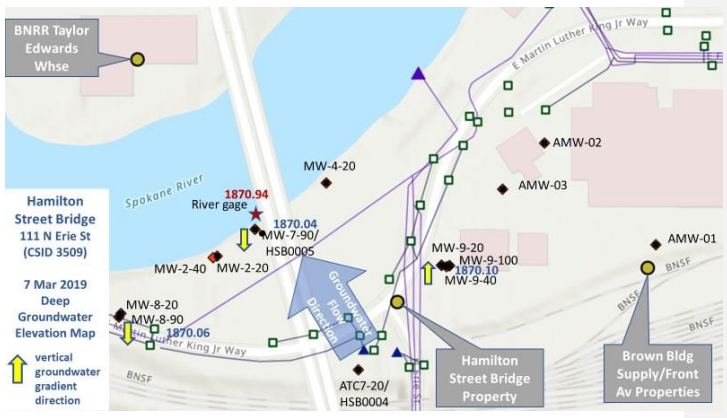


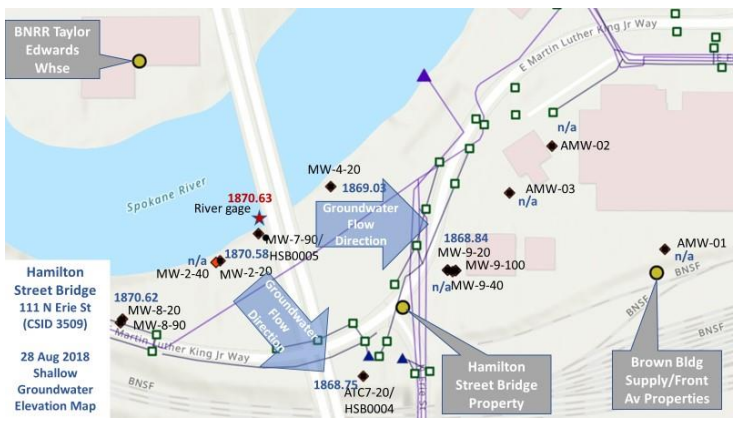


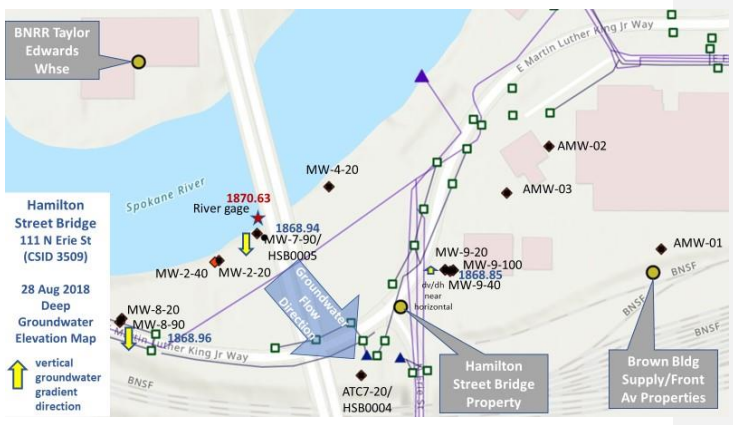
Shallow Groundwater Flow Maps

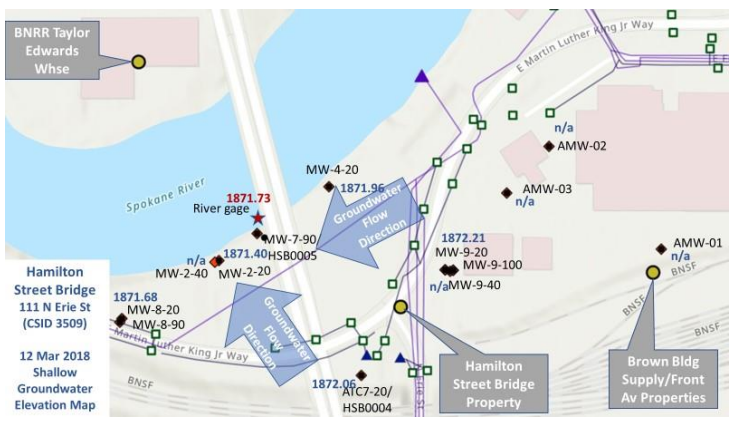
Deep Groundwater Flow Maps

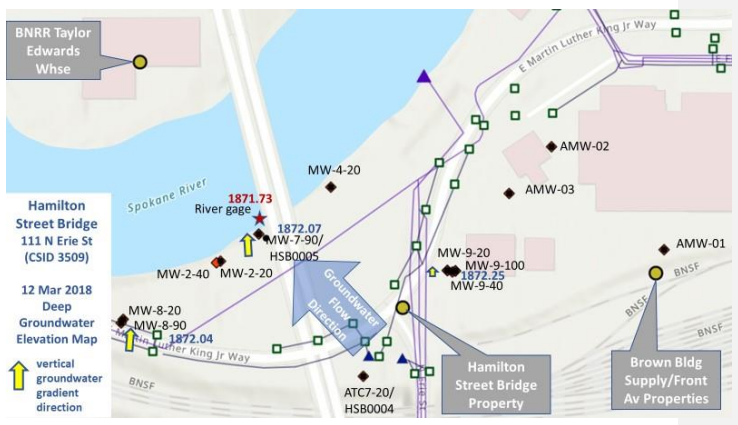


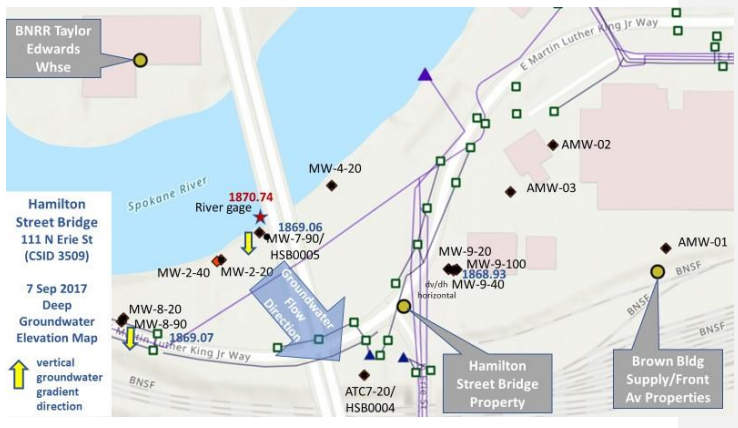




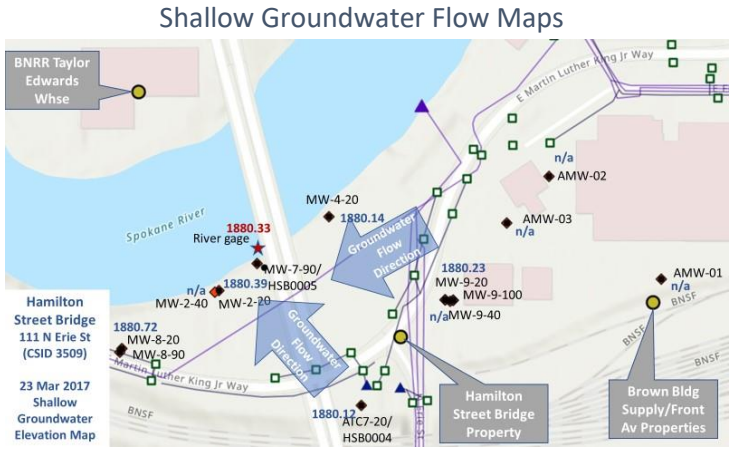




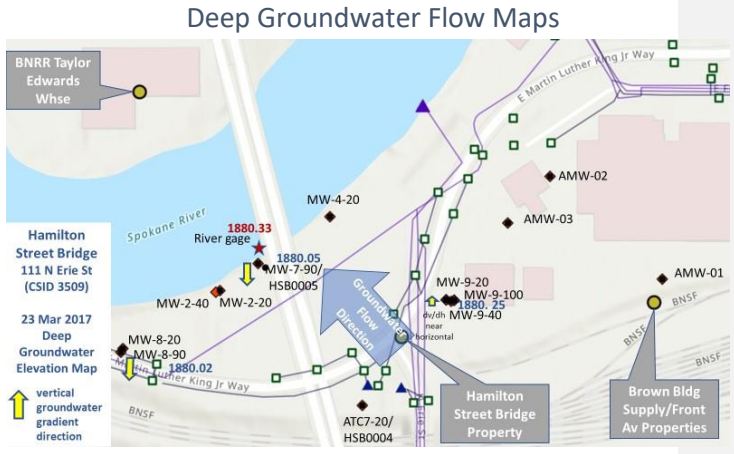


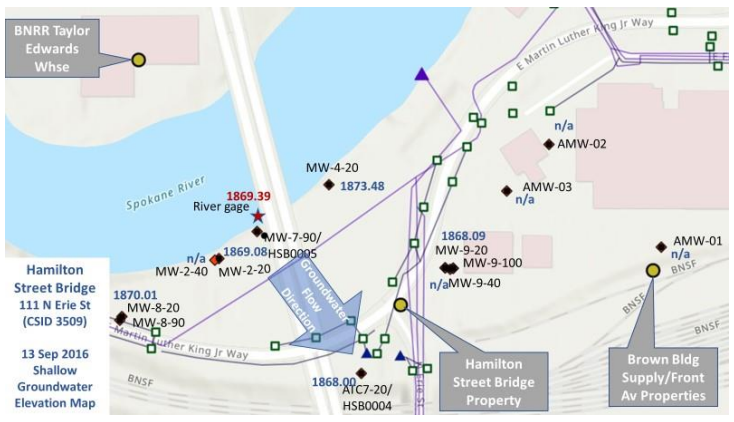


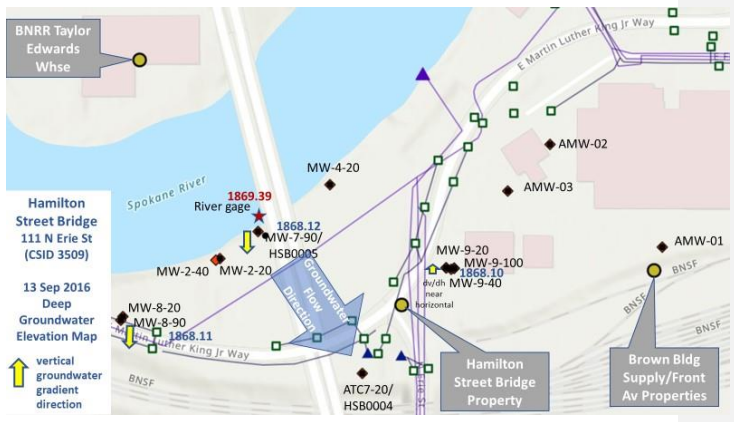
Shallow Groundwater Flow Maps

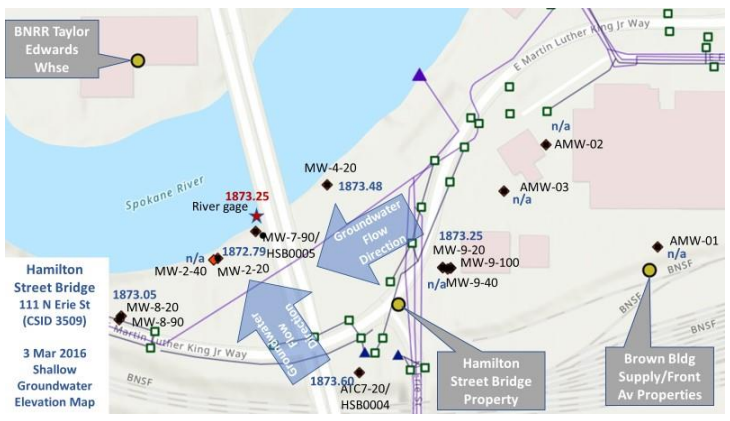


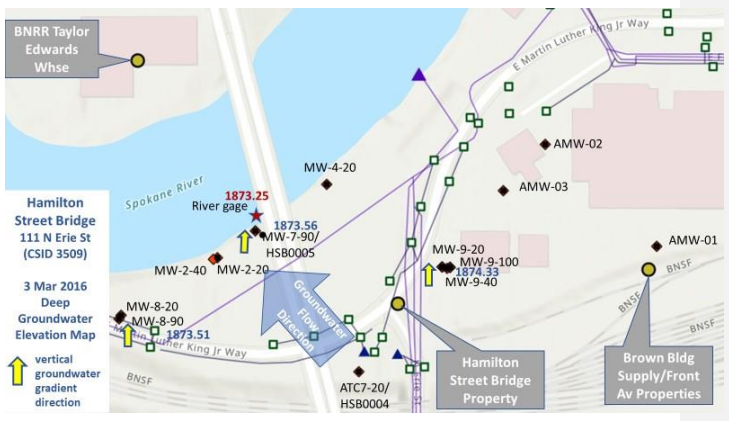
Deep Groundwater Flow Maps

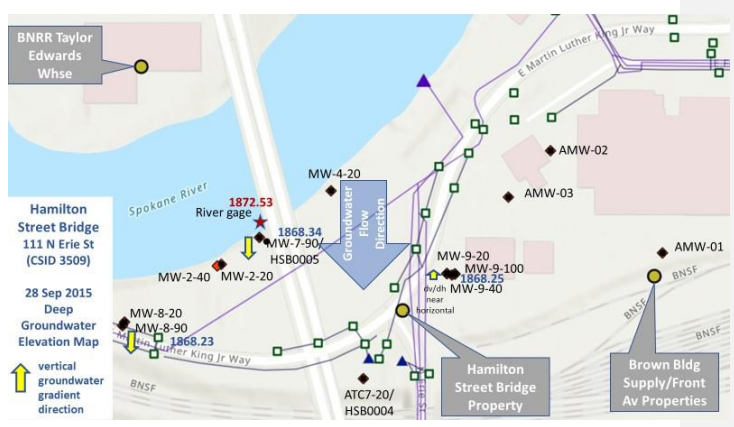


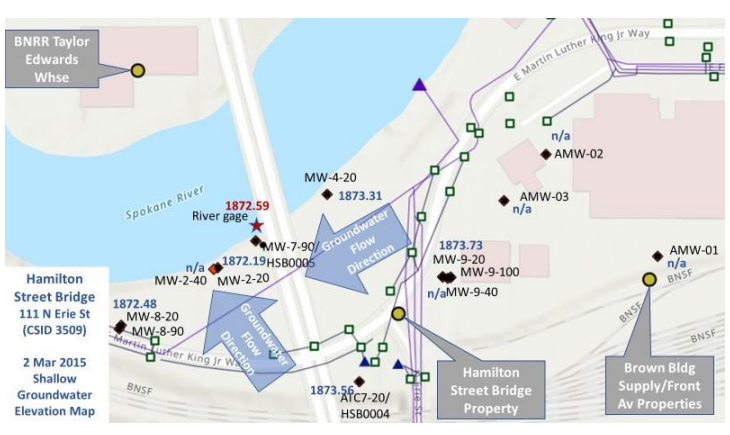


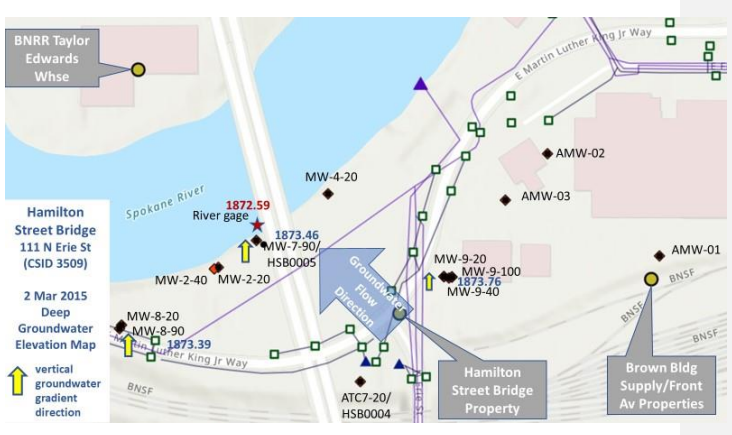






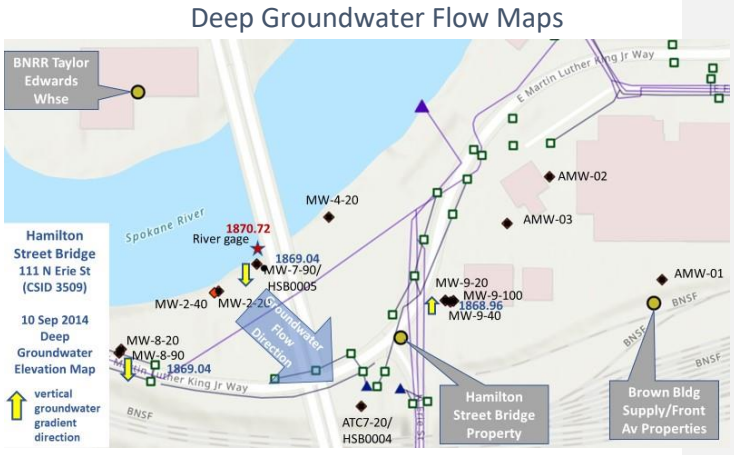


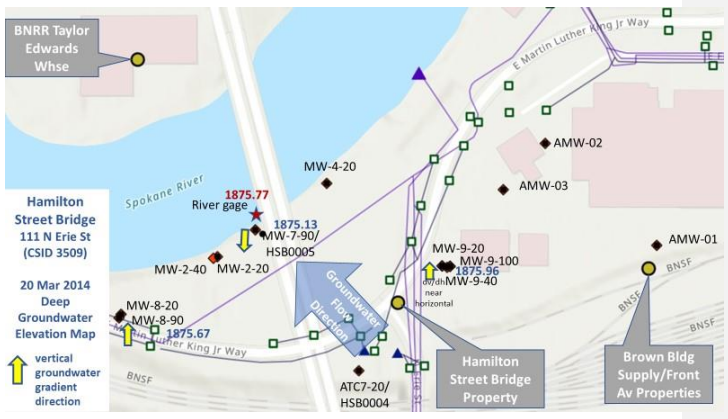


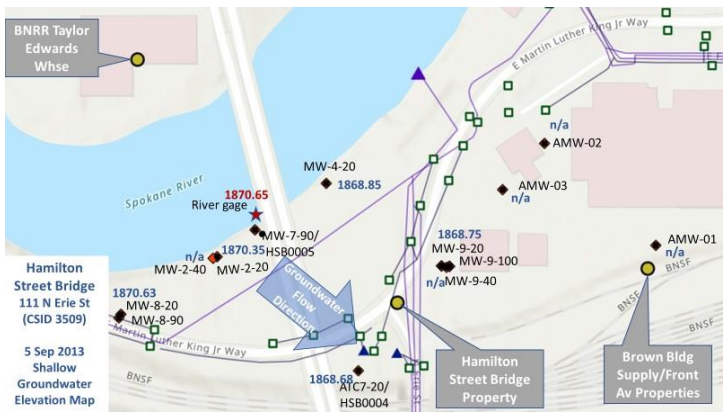


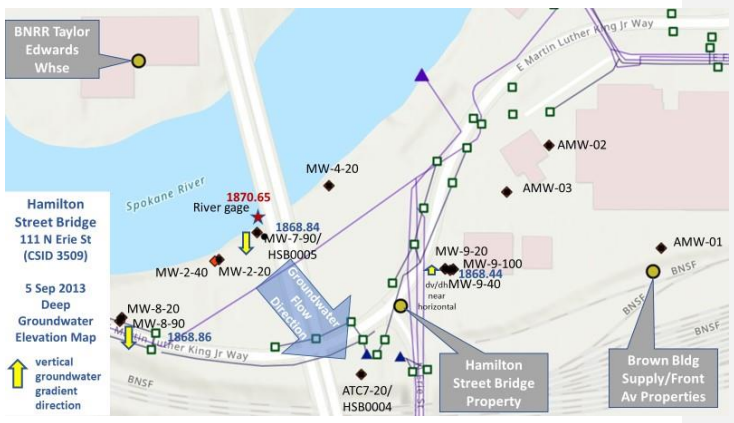
Shallow Groundwater Flow Maps

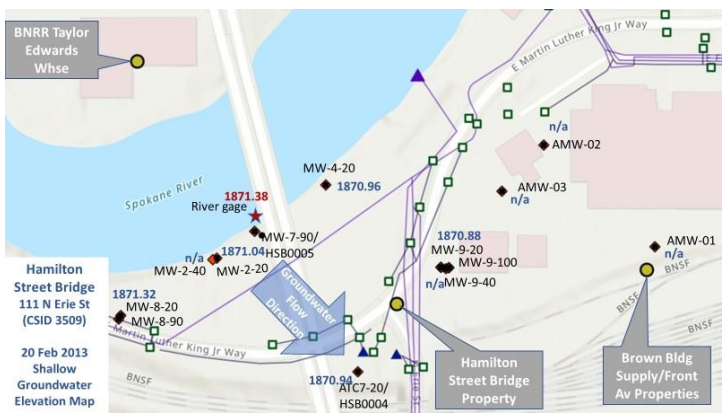
Deep Groundwater Flow Maps

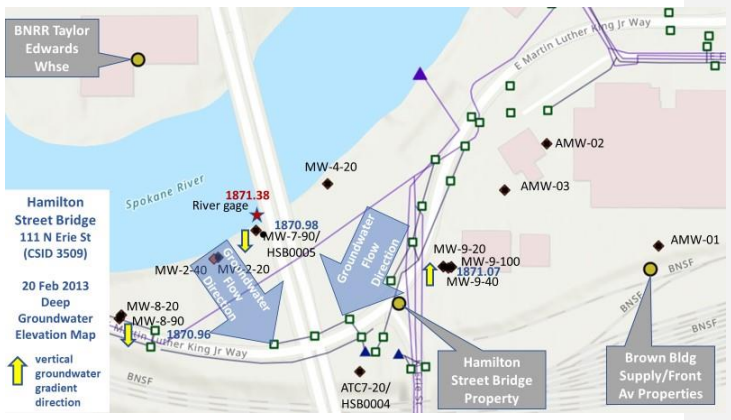


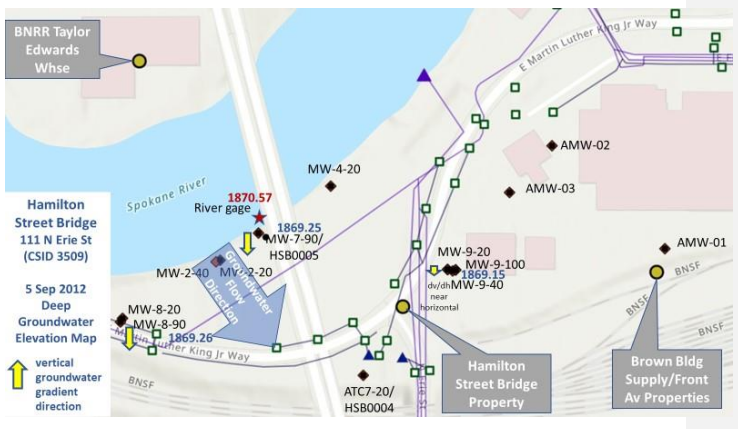




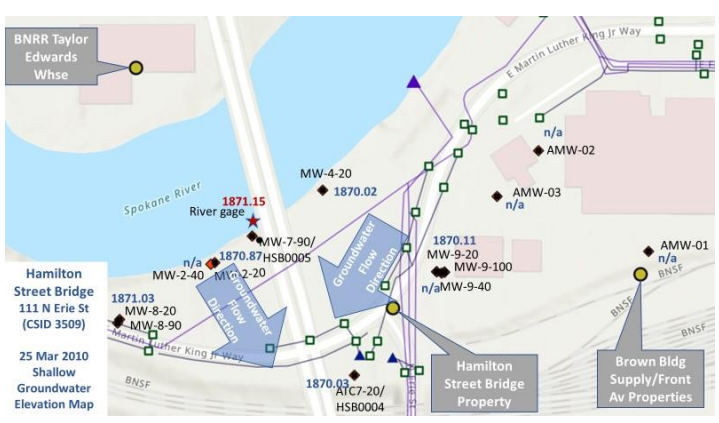




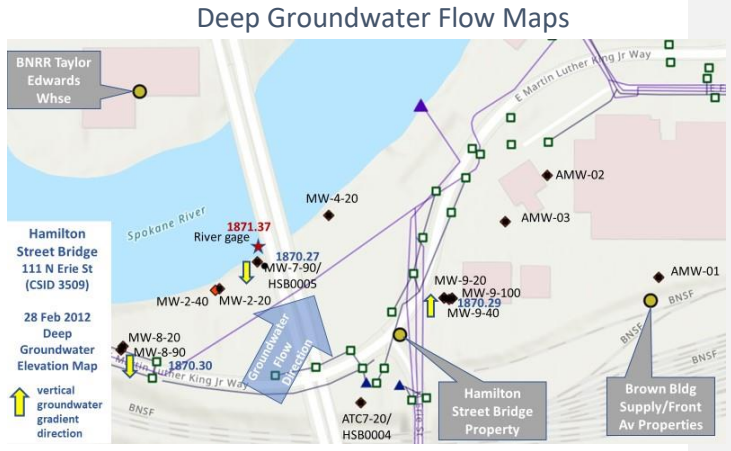


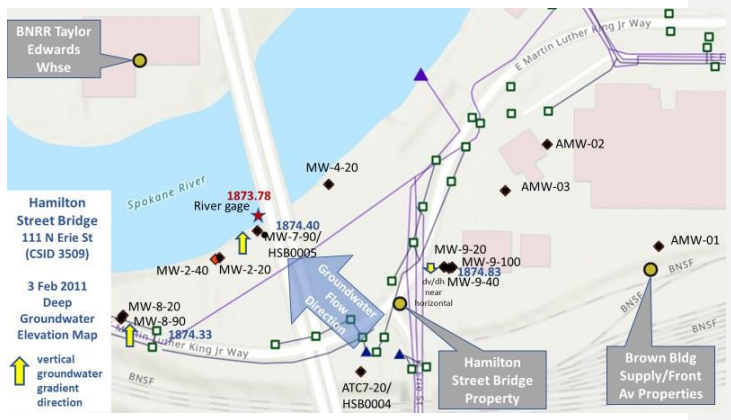


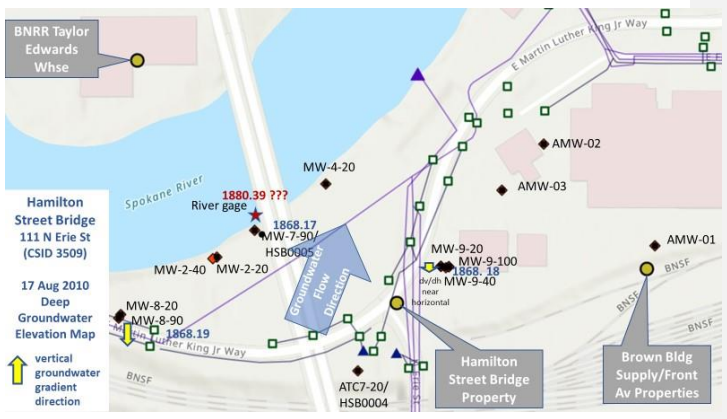
Shallow Groundwater Flow Maps

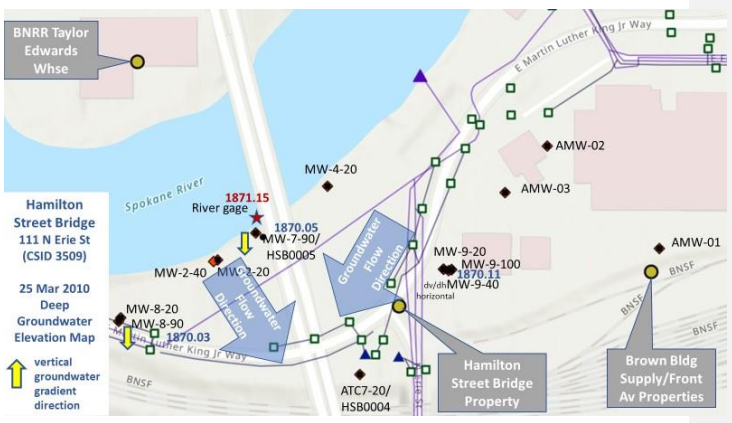


Deep Groundwater Flow Maps

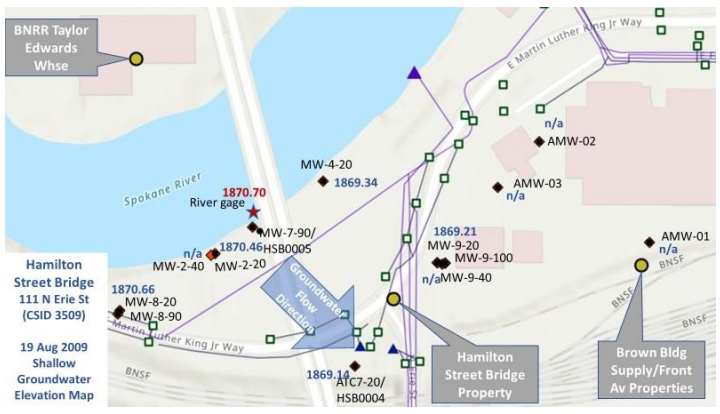




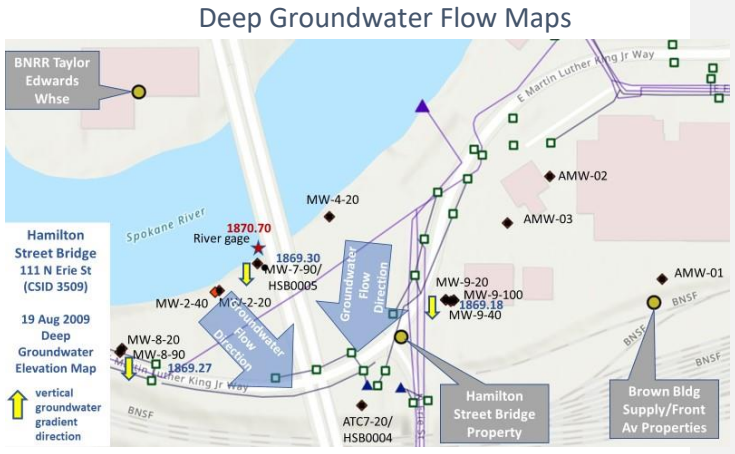


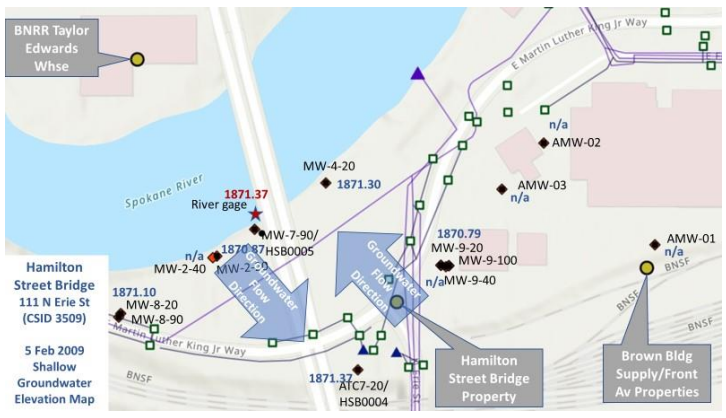


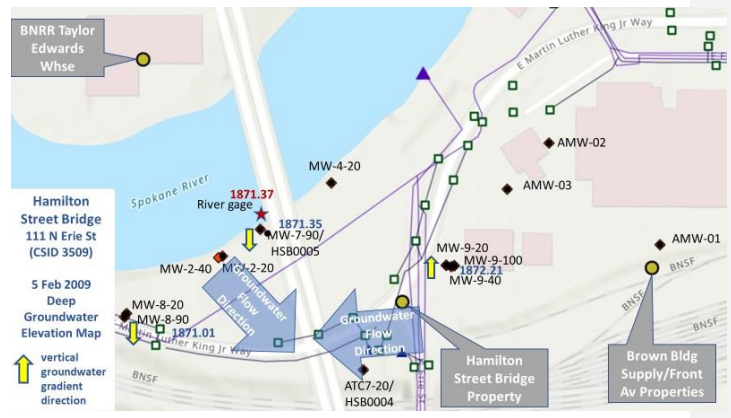
Shallow Groundwater Flow Maps

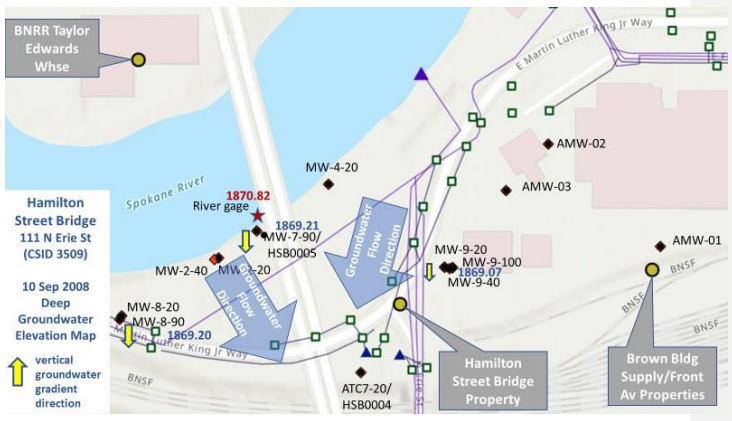


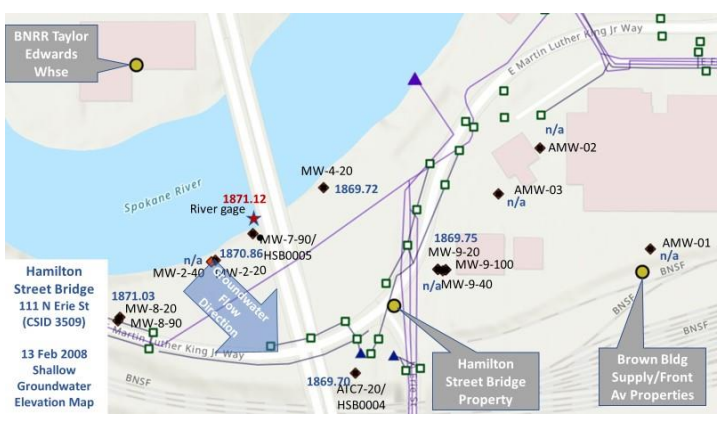
Deep Groundwater Flow Maps

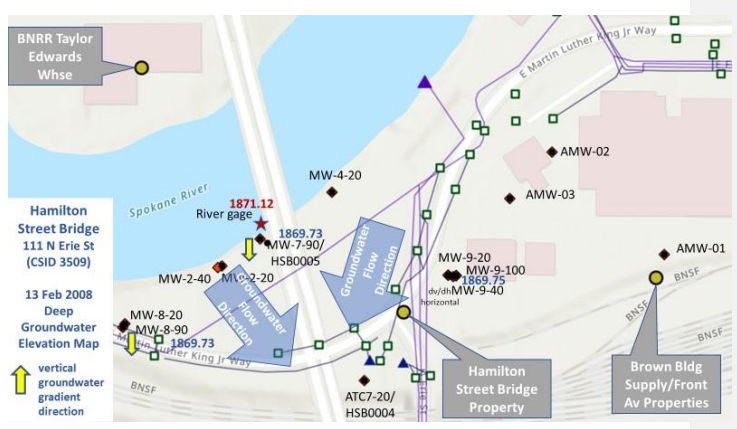


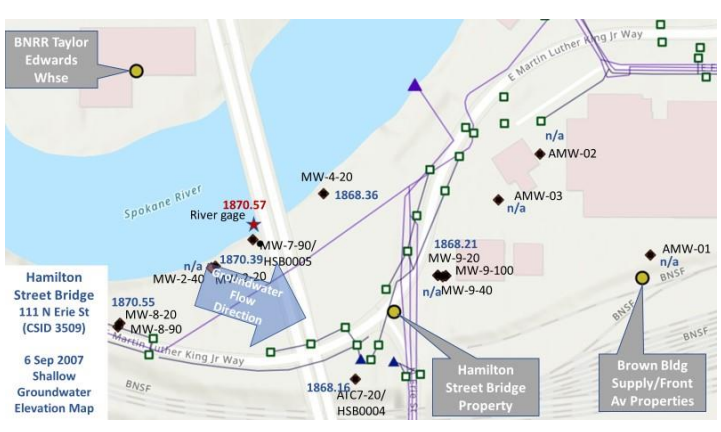


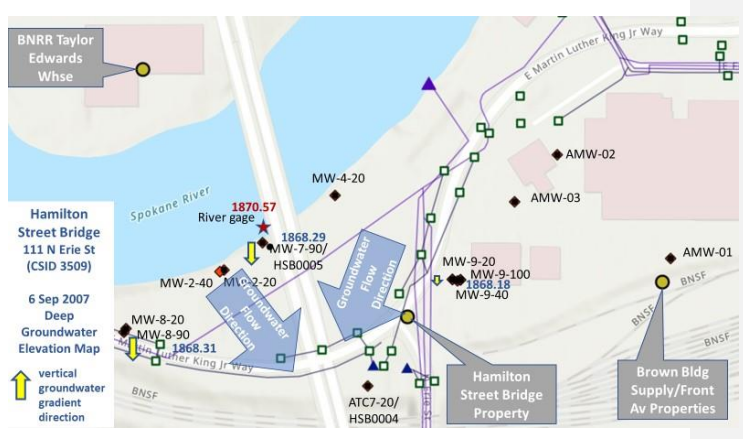




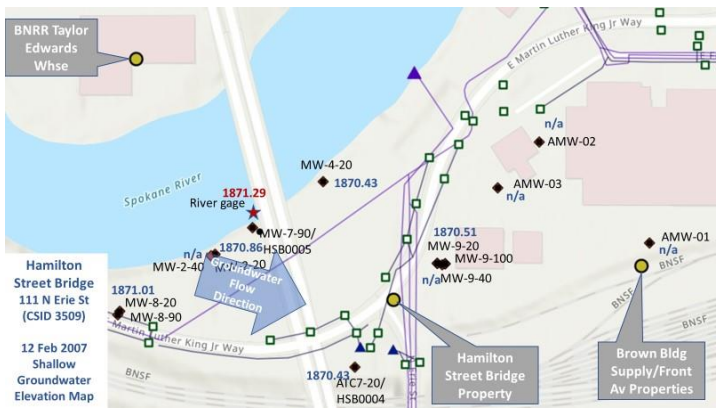




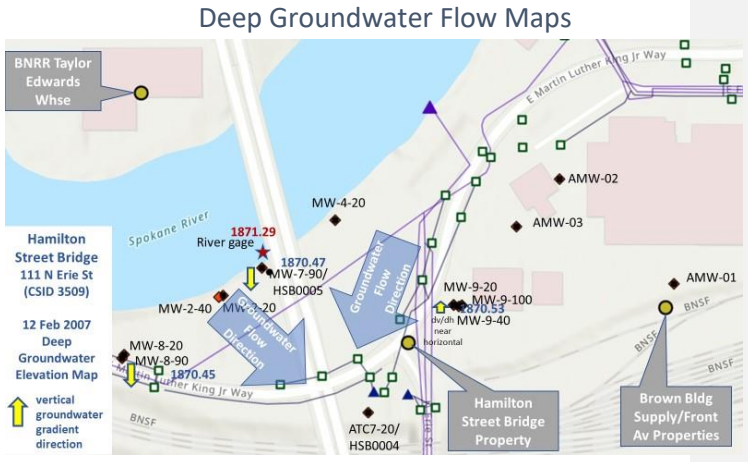


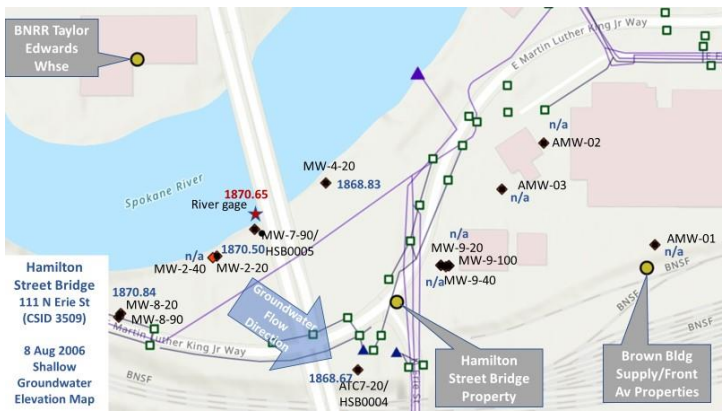


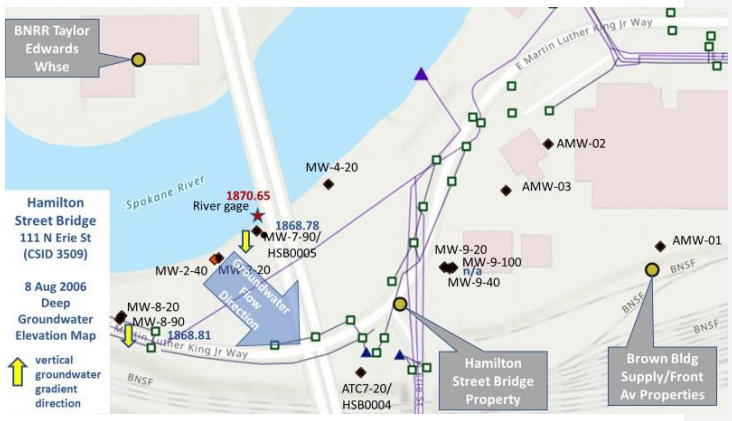
Shallow Groundwater Flow Maps

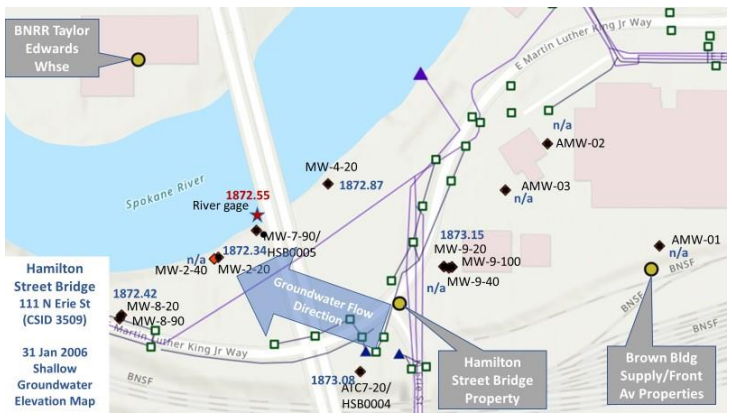


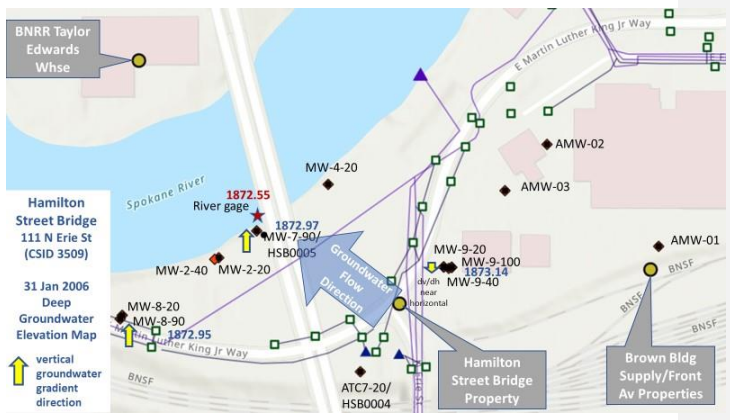
Deep Groundwater Flow Maps











Appendix G:
Historical Groundwater Flow Direction Maps: Spokane Convention Center Expansion Area (200 W Spokane Falls Blvd)

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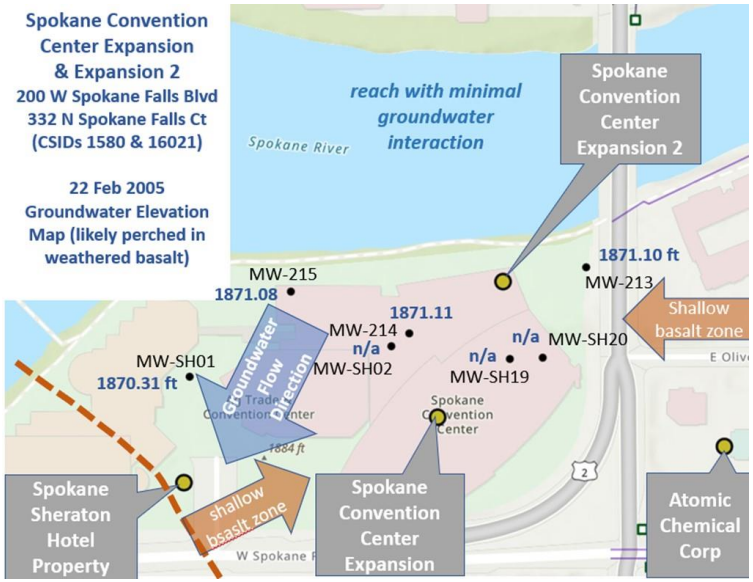
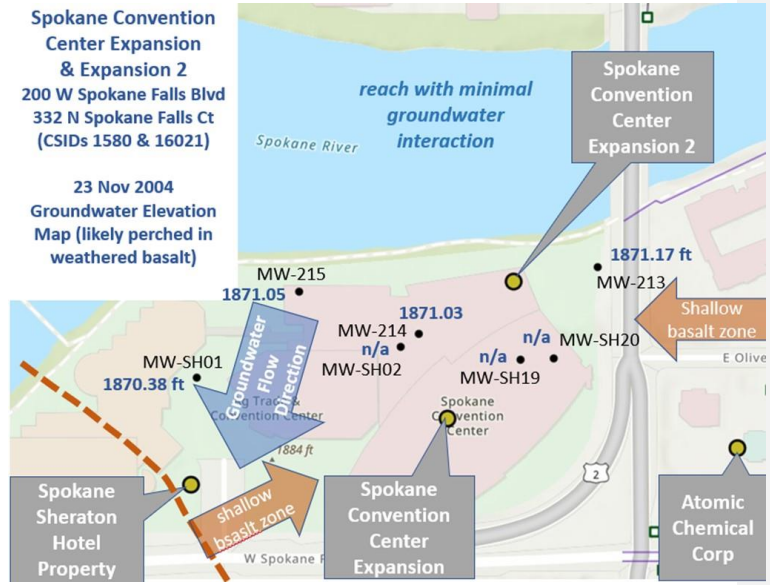
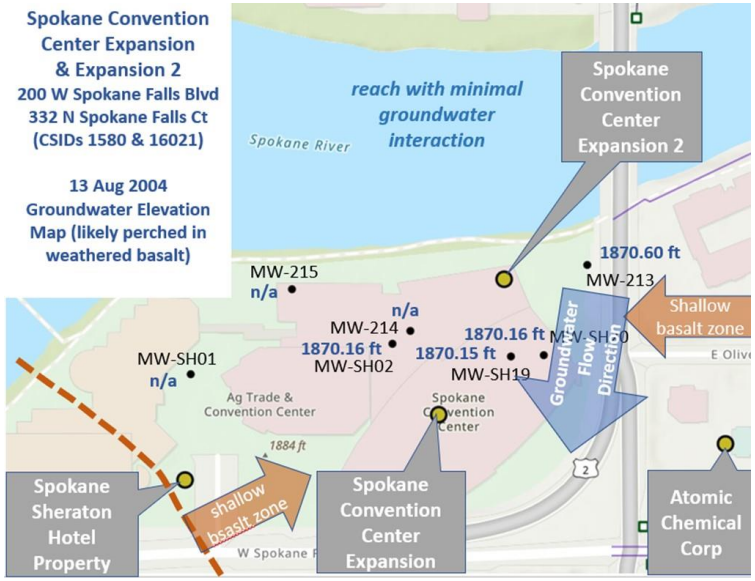
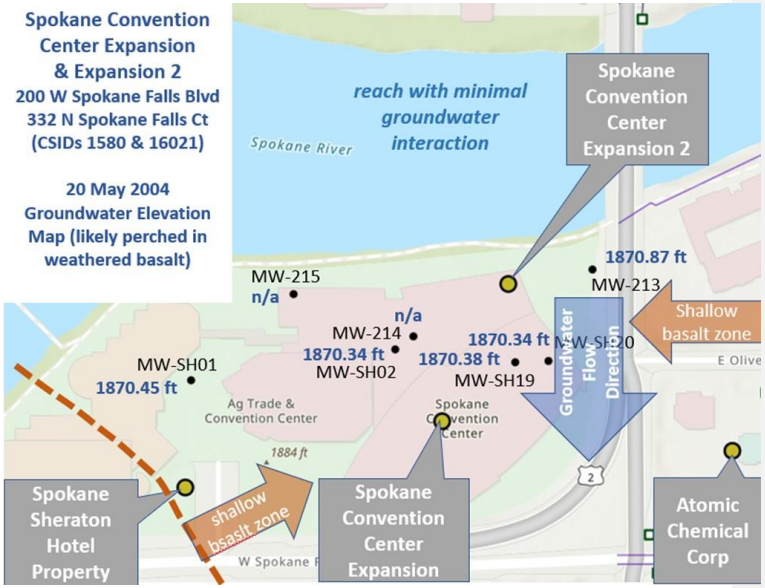
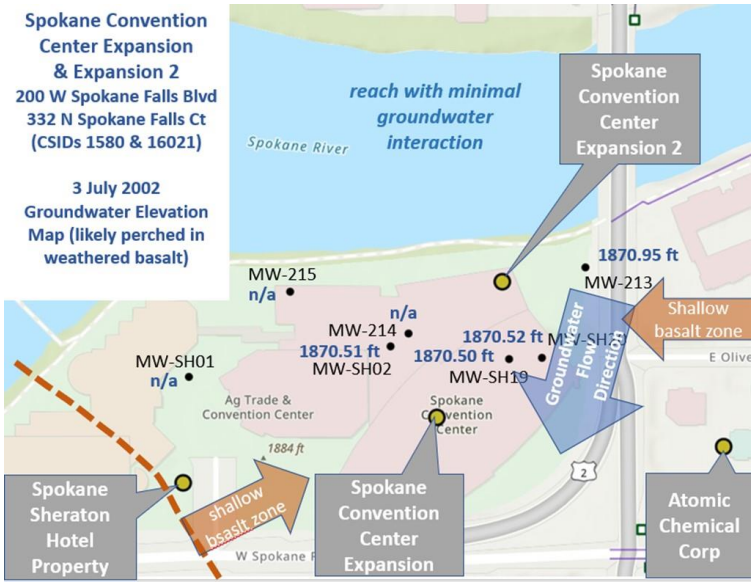
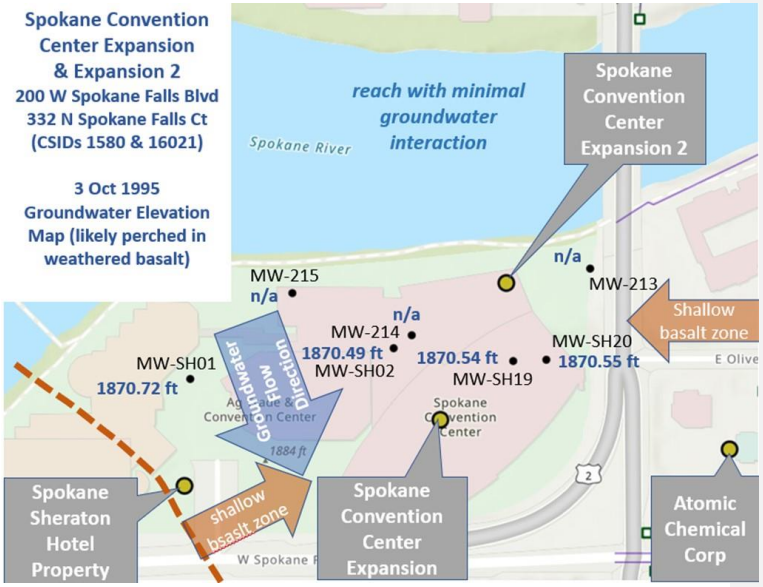

Spokane Convention Center Expansion & Expansion 2
200 W Spokane Falls Blvd
332 N Spokane Falls Ct
(CSIDs 1580 & 16021)
22 Feb 2005
Groundwater Elevation Map (likely perched in weathered basalt)
reach with minimal groundwater interaction
Spokane River
Spokane Convention Center Expansion 2
MW-215
1871.08
1871.11
MW-214
n/a
MW-SH02
n/a
n/a
MW-SH19
MW-SH20
1871.10 ft
MW-213
Shallow basalt zone
MW-SH01
1870.31 ft
Groundwater Flow Direction
Spokane Convention Center
Spokane Sheraton Hotel Property
shallow basalt zone
Spokane Convention Center Expansion
Atomic Chemical Corp

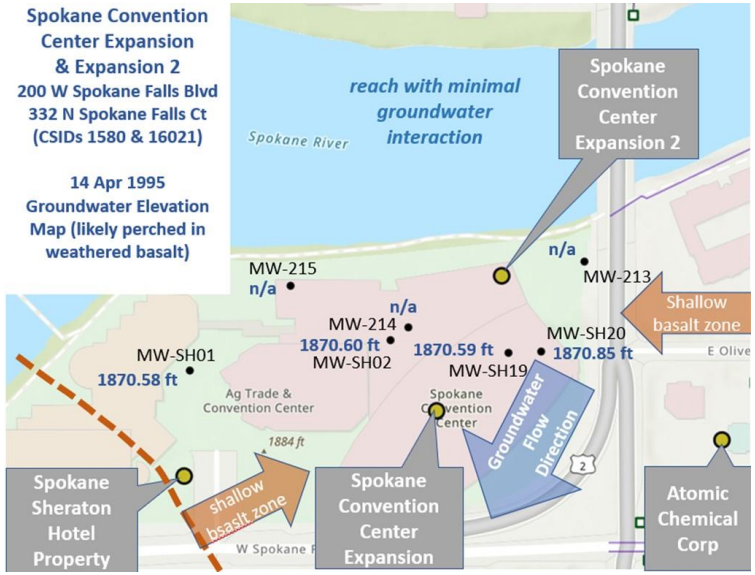

Spokane Convention Center Expansion & Expansion 2
200 W Spokane Falls Blvd
332 N Spokane Falls Ct
(CSIDs 1580 & 16021)
23 Nov 2004
Groundwater Elevation Map (likely perched in weathered basalt)
reach with minimal groundwater interaction
Spokane River
Spokane Convention Center Expansion 2
MW-215
1871.05
1871.03
MW-214
n/a
MW-SH02
n/a
n/a
MW-SH19
MW-SH20
1871.17 ft
MW-213
Shallow basalt zone
MW-SH01
1870.38 ft
Groundwater Flow Direction
Spokane Convention Center
Spokane Sheraton Hotel Property
shallow basalt zone
Spokane Convention Center Expansion
Atomic Chemical Corp

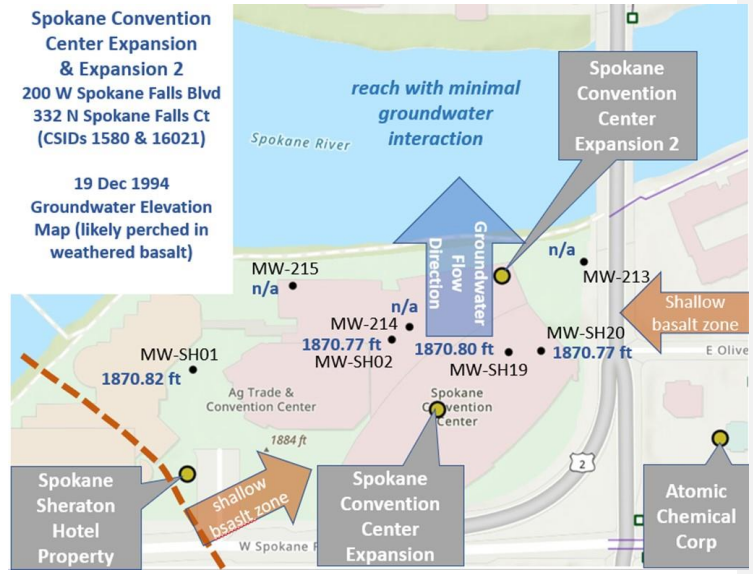

Spokane Convention Center Expansion & Expansion 2
200 W Spokane Falls Blvd
332 N Spokane Falls Ct
(CSIDs 1580 & 16021)
13 Aug 2004
Groundwater Elevation Map (likely perched in weathered basalt)
reach with minimal groundwater interaction
Spokane River
Spokane Convention Center Expansion 2
1870.60 ft
MW-213
MW-215
n/a
n/a
MW-214
1870.16 ft
MW-SH02
1870.16 ft
1870.15 ft
MW-SH19
MW-SH20
Shallow basalt zone
Groundwater Flow Direction
MW-SH01
n/a
Ag Trade & Convention Center
Spokane Convention Center
1884 ft
Spokane Sheraton Hotel Property
shallow basalt zone
Spokane Convention Center Expansion
Atomic Chemical Corp

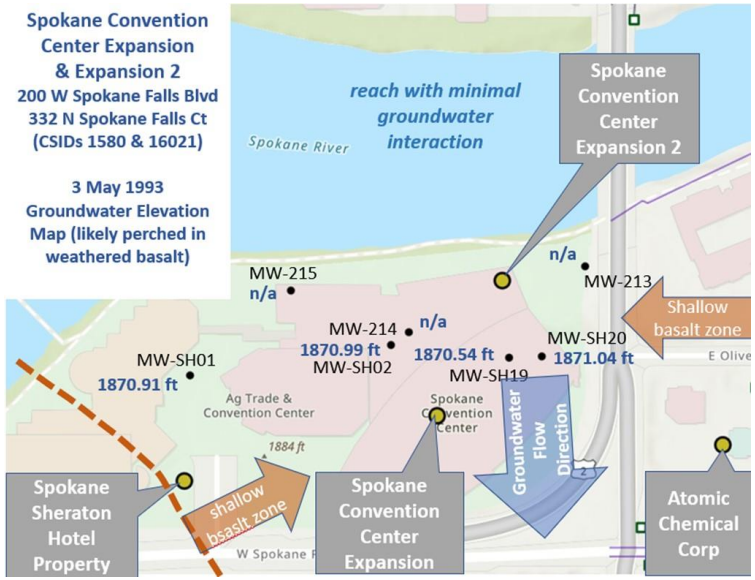

Spokane Convention Center Expansion & Expansion 2
200 W Spokane Falls Blvd
332 N Spokane Falls Ct
(CSIDs 1580 & 16021)
20 May 2004
Groundwater Elevation Map (likely perched in weathered basalt)
reach with minimal groundwater interaction
Spokane River
Spokane Convention Center Expansion 2
1870.87 ft
MW-213
MW-215
n/a
n/a
MW-214
1870.34 ft
MW-SH02
1870.34 ft
1870.38 ft
MW-SH19
MW-SH20
Shallow basalt zone
Groundwater Flow Direction
MW-SH01
1870.45 ft
Ag Trade & Convention Center
Spokane Convention Center
1884 ft
Spokane Sheraton Hotel Property
shallow basalt zone
Spokane Convention Center Expansion
Atomic Chemical Corp


Spokane Convention Center Expansion & Expansion 2
200 W Spokane Falls Blvd
332 N Spokane Falls Ct
(CSIDs 1580 & 16021)
3 July 2002
Groundwater Elevation Map (likely perched in weathered basalt)
reach with minimal groundwater interaction
Spokane River
Spokane Convention Center Expansion 2
1870.95 ft
MW-213
MW-215
n/a
n/a
MW-214
1870.51 ft
MW-SH02
1870.52 ft
1870.50 ft
MW-SH19
Groundwater Flow Direction
Shallow basalt zone
MW-SH01
n/a
Ag Trade & Convention Center
Spokane Convention Center
1884 ft
E Olive
W Spokane
Spokane Sheraton Hotel Property
shallow basalt zone
Spokane Convention Center Expansion
Atomic Chemical Corp


Spokane Convention Center Expansion & Expansion 2
200 W Spokane Falls Blvd
332 N Spokane Falls Ct
(CSIDs 1580 & 16021)
3 Oct 1995
Groundwater Elevation Map (likely perched in weathered basalt)
reach with minimal groundwater interaction
Spokane River
Spokane Convention Center Expansion 2
n/a
MW-213
MW-215
n/a
n/a
MW-214
1870.49 ft
MW-SH02
1870.54 ft
MW-SH19
MW-SH20
1870.55 ft
Groundwater Flow Direction
Shallow basalt zone
MW-SH01
1870.72 ft
1884 ft
E Olive
W Spokane
Spokane Sheraton Hotel Property
shallow basalt zone
Spokane Convention Center Expansion
Atomic Chemical Corp


Spokane Convention Center Expansion & Expansion 2
200 W Spokane Falls Blvd
332 N Spokane Falls Ct
(CSIDs 1580 & 16021)
14 Apr 1995
Groundwater Elevation Map (likely perched in weathered basalt)
reach with minimal groundwater interaction
Spokane River
Spokane Convention Center Expansion 2
MW-215
n/a
n/a
MW-214
1870.60 ft
MW-SH02
1870.59 ft
MW-SH19
n/a
MW-213
MW-SH20
1870.85 ft
Shallow basalt zone
MW-SH01
1870.58 ft
Ag Trade & Convention Center
Spokane Convention Center
Groundwater Flow Direction
1884 ft
Spokane Sheraton Hotel Property
shallow basalt zone
Spokane Convention Center Expansion
Atomic Chemical Corp


Spokane Convention Center Expansion & Expansion 2
200 W Spokane Falls Blvd
332 N Spokane Falls Ct
(CSIDs 1580 & 16021)
19 Dec 1994
Groundwater Elevation Map (likely perched in weathered basalt)
reach with minimal groundwater interaction
Spokane River
Spokane Convention Center Expansion 2
Groundwater Flow Direction
MW-215
n/a
n/a
MW-214
1870.77 ft
MW-SH02
1870.80 ft
MW-SH19
n/a
MW-213
MW-SH20
1870.77 ft
Shallow basalt zone
MW-SH01
1870.82 ft
Ag Trade & Convention Center
Spokane Convention Center
1884 ft
Spokane Sheraton Hotel Property
shallow basalt zone
Spokane Convention Center Expansion
Atomic Chemical Corp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200 W Spokane Falls Blvd
332 N Spokane Falls Ct
(CSIDs 1580 & 16021)
3 May 1993 Groundwater Elevation Map (likely perched in weathered basalt)
reach with minimal groundwater interaction
Spokane River
Spokane Convention Center Expansion 2
n/a
MW-213
MW-215
n/a
MW-214
n/a
1870.99 ft
MW-SH02
1870.54 ft
MW-SH19
MW-SH20
1871.04 ft
Shallow basalt zone
E Olive
MW-SH01
1870.91 ft
Ag Trade & Convention Center
Spokane Convention Center
1884 ft
Groundwater Flow Direction
Spokane Sheraton Hotel Property
shallow basalt zone
Spokane Convention Center Expansion
Atomic Chemical Corp
W Spokane R