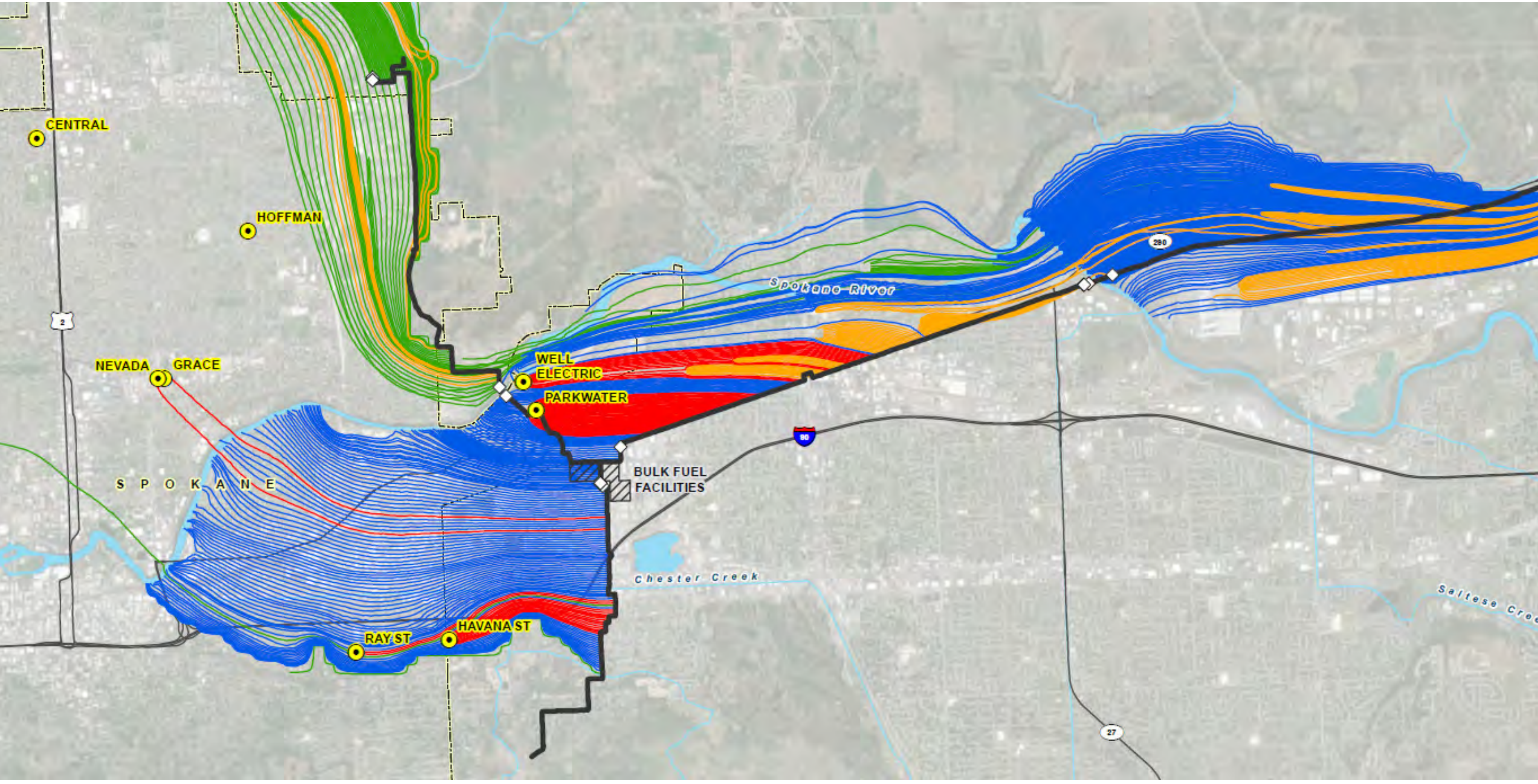
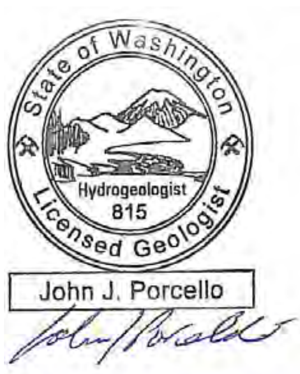
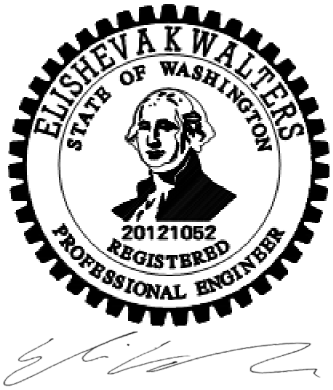


City of Spokane

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

December 2024





Expires 7-12-2025

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Abbreviations and Acronyms

µg/L	micrograms per liter
ADD	average day demand
BAP	benzo(a)pyrene
BTEX	benzene, ethylbenzene, toluene, and xylenes
City	City of Spokane
COC	constituent of concern
Consor	Consor North America, Inc. (formerly known as Murraysmith)
DSCRP	Distribution System Contamination Response Procedure
Ecology	Washington State Department of Ecology
EPS	extended period simulation
ERAP	Emergency Response Action Plan (Phillips 66/Yellowstone Pipe Line Company)
ERP	Emergency Response Plan (City of Spokane)
FF	fire flow
GHG	greenhouse gas
GSI	GSI Water Solutions, Inc.
ICP	Integrated Contingency Plan (Phillips 66/Yellowstone Pipe Line Company)
MDD	maximum day demand
mgd	millions of gallons per day
MTCA	Model Toxics Control Act
P66	Phillips 66
PHD	peak hour demand
PHMSA	Pipeline and Hazardous Materials Safety Administration
PRV	pressure-reducing valve
RCP	Representative Concentration Pathway (for future global greenhouse gas emissions)
SVOC	semi-volatile organic compound
SVRP	Spokane Valley-Rathdrum Prairie
USGS	U.S. Geological Survey
VOC	volatile organic compound
WAC	Washington Administrative Code
YPL	Yellowstone Pipe Line Company

Executive Summary

This report describes an assessment of the vulnerability of groundwater supply facilities owned and operated by the City of Spokane (City) to potential future chemical releases from the Yellowstone petroleum pipeline, which is owned by the Yellowstone Pipe Line Company (YPL) and operated by Phillips 66 (P66). The assessment consisted of first evaluating current water distribution system operations and groundwater flowpaths and travel times to City well stations, then identifying operational responses to a water supply emergency in which a chemical release from the pipeline threatens, or is detected at, one or more City well stations. This vulnerability study was conducted because of the recognition that the City would need to respond quickly to a contamination event or an immediate threat of contamination to continue providing clean drinking water to City residents and to neighboring communities with which it has intertie agreements. Accordingly, with assistance from YPL, the City has conducted this vulnerability assessment to provide technical information on groundwater flow, pumping operations, and chemical risk. This information will be incorporated into the City's existing Emergency Response Plan (ERP), along with recommendations for proactively implementing specific capital improvements to the water transmission system and developing specific plans for how to alter groundwater pumping operations in the event of a future release at different locations along the pipeline.

The primary outcomes for the vulnerability assessment identified by the City during project scoping are (1) a set of one or more feasible scenarios for redistributing groundwater production between the City's multiple well stations (including accounting for the capacities and limitations in the City's water distribution system) and (2) the other elements of an ERP that would need to be implemented in the event that a petroleum release from the pipeline is detected in the future.

Approach

The study began with an in-depth evaluation of current and future operating conditions of the City's eight well stations and its water distribution system in the absence of a contaminant release from the Yellowstone petroleum pipeline; see Section 2 for this evaluation, which provided a baseline set of conditions for subsequently evaluating a series of emergency operating scenarios (see Section 3). These evaluations were conducted using the City's water distribution system model and its groundwater flow model. Using these same tools, four separate emergency operating scenarios were evaluated for conditions under which one or more of the well stations in closest proximity to the pipeline (the Parkwater, Well Electric, Ray Street, and Havana Street well stations) is taken offline because of a contamination event or immediate threat of contamination. Using the results from the baseline (non-emergency) scenario and the four emergency scenarios, the study (in Section 4) then evaluated contaminant risks to drinking water quality and the elements of—and considerations for—implementing various advanced-warning monitoring systems. Section 5 of the report then discusses emergency response measures that could increase water supply reliability during an emergency, and mitigation measures that can be implemented to reduce the overall risks that would arise in the event that an emergency evaluated by this study were to occur. Section 5 concludes with a list of recommended operational response procedures, mitigation measures, and ERP updates for YPL and the City to consider implementing.

Primary Findings

The study has identified numerous findings regarding future operating constraints at certain City well stations, current and potential future operating constraints in the City's water transmission system, the travel times in groundwater from the pipeline to the City's well stations, and the chemical-specific contaminant risks posed by the products conveyed in the Yellowstone petroleum pipeline. These findings in turn have been used in this study to assess options for monitoring potential releases to the subsurface and to City well stations; identify capital improvement measures and operational response measures that the City can take to decrease the vulnerability of its well stations and the distribution system to an aquifer contamination event; and develop a response procedure document for YPL and the City that serves as a coordinating document between YPL and the City and supplements their existing individual ERPs.

The primary findings from the study are as follows:

1. Under non-emergency conditions:

    a. For current levels of demand all but three storage tanks in the City's distribution system are unable to utilize their full volume capacity under non-emergency conditions on a high-use day, such as the day with the highest daily demand during a given year. This occurs even though system supply is adequate to meet the maximum day demand (MDD). This makes the system vulnerable to a loss of supply to City customers, because a portion of the City's storage is not usable for emergency fire flow or peak-use equalization on high-use days due to system losses during tank-filling cycles. See Section 2.1 for details.

    b. The City's Ray Street well station and its four well stations north of the Spokane River (Nevada, Grace, Hoffman, and Central) obtain groundwater from deep zones in the aquifer beneath the Yellowstone petroleum pipeline, while the three other well stations (Havana Street, Parkwater, and Well Electric) capture shallow groundwater beneath the pipeline. This is the case for all three future levels of demand that were evaluated with the groundwater flow model. The capture areas for each well station generally vary only in width, as a function of the amount of groundwater pumping that is required to meet each level of demand. The analysis also shows that the shapes of the capture zones for well stations other than Well Electric and Parkwater are generally insensitive to whether pumping at Well Electric occurs from its existing shallow caisson wells versus future hypothetical deep production wells. See Section 2.2 for details.

2. Under emergency conditions:

    a. For current levels of demand, supply deficits arise in the Intermediate primary supply zone in several situations, and the Low primary supply zone also experiences supply deficits in the most severe scenario (in which both the Parkwater and Well Electric well stations are offline). See Section 3.1.1 for details.

    b. For future levels of demand:

        i. Well Electric would need to operate during all four emergency scenarios, including the two scenarios in which Well Electric would be intended to be offline because of contaminant detection or the threat of contamination. In particular, Well Electric would need to produce significant quantities of water (between 90 and 125 millions of gallons per day) to meet the MDD for the 50-year high level of demand if Parkwater were to be taken offline. This would require that Well Electric pump from a future-constructed group of deep wells not the existing caisson wells, in order to minimize the potential for contaminants to appear in the pumped groundwater.

        ii. The four northernmost well stations (Nevada, Grace, Hoffman, and Central well stations), which are the furthest from the Yellowstone petroleum pipeline, would all be critical for providing sufficient water supply to all three primary supply zones under all four of the emergency scenarios.

iii. The Ray Street and Havana Street well stations are critical for providing sufficient water supply under all of the emergency scenarios involving Parkwater and/or Well Electric being offline.

iv. When Parkwater and/or Well Electric are offline, under a given level of demand the alignments of the groundwater capture areas for the City's other well stations do not change considerably from their capture zones under non-emergency conditions. However, the widths of these capture zones can vary, particularly at a well station where pumping increases under emergency conditions (which widens the capture zone for that well station).

3. Groundwater modeling analyses indicate that groundwater travel times from the Yellowstone petroleum pipeline to City well stations are on the order of a few months for most wells, and potentially up to 12 or even 18 months for the well stations furthest north in the City (Nevada, Grace, Central, and Hoffman). However, for the Parkwater well station, the travel times range from as little as 1 to 2 days from the nearest portions of the pipeline to 2.5 to 3 months from more distant segments of the pipeline that lie due east of Parkwater.

4. The chemical constituents in the Yellowstone petroleum pipeline that pose the greatest risk to the City's groundwater supply are benzene for a gasoline release, and naphthalene and benzo(a)pyrene (BAP) in a diesel or heavy fuel release. The predominant product types conveyed in the Yellowstone petroleum pipeline are gasoline (approximately 40 percent of product), #2 diesel fuel (approximately 40 percent of product), and jet fuel (approximately 20 percent of product). Oxygenates and other petroleum additives have not been added to these fuel blends.

5. Large-magnitude releases of petroleum products from the pipeline would be detected within one day by YPL/P66 personnel using inventory control methods. Smaller releases could go undetected for significantly long periods of time. A subsurface monitoring program could provide an early warning of contamination presence in the subsurface before contamination arrives at a City well station. Early warning monitoring would provide advanced notice of the need for operational changes to the City's water system in the event that contaminants arrive at a City well station after first being detected in an upgradient monitoring system. Traditional groundwater monitoring systems that involve wells installed along the pipeline or between the pipeline and a downgradient well station may require many wells and sampling at a frequency ranging from 1 to 4 months, which will vary for each well station's monitoring network. (Groundwater monitoring upgradient of the pipeline would also allow for evaluation of whether a detection occurring downgradient of the pipeline is attributable to the pipeline or to a different contaminant source.) For Parkwater, the nearby location of the pipeline would warrant much more frequent monitoring as well as higher-priority laboratory analyses of groundwater samples, resulting in costs that would likely be double the laboratory analysis costs for typical priority turnaround times. Vapor monitoring systems could quickly detect releases of volatile organic compounds (VOCs), which would be beneficial at times when gasoline is the primary fuel being transported in the pipeline. But vapor monitoring systems would not detect releases of semi-volatile organic compounds (SVOCs), which are the primary chemical constituents in diesel and jet fuels. Additionally, the origin of an elevated VOC concentration in a vapor sample may not be readily known because vapors can move along preferential pathways such as utility corridors and could originate from other releases such as gas station locations. Frequent (e.g., weekly) monitoring of water quality at the City's well stations may be the best monitoring option, but only as long as samples are analyzed on an accelerated turnaround time (24 to 48 hours) and by a local laboratory that can receive the samples immediately upon their collection. The primary disadvantage of this alternative is that it would not provide any early warning, and it is possible that the first indication of

a release would be a water quality exceedance. Regardless of how monitoring is conducted in the future, the pipeline's close proximity to Parkwater requires particularly rapid communication and coordination between YPL and the City in the event that a release from the nearby pipeline segment is suspected by YPL to have occurred, or in the event that contamination is detected at Parkwater by the City.

6. Distribution system modeling indicates that two emergency responses are feasible for the worst-case emergency scenario, in which both the Parkwater and Well Electric well stations are offline. These emergency responses consist of (1) using pressure-reducing valves (PRVs) at two booster stations (Bishop Court and 9th & Pine) to sustain pressures in a manner that provides backflow (excess supply) from the Intermediate primary supply zone to the Low primary supply zone; and (2) curtailing water demands in the Low primary supply zone by 12 percent or more on the peak-use day to address the location with the most critical supply shortfall (the Northwest Terrace pressure zone, which is fed via PRV). The modeling analyses of the water distribution system and the demand needs in each of the primary supply zones under future levels of demand together have resulted in the identification of several mitigation measures that the City could implement before an emergency occurs (see Sections 5.3.1 and 5.3.2 for details). In the case of Parkwater, which faces the greatest potential threat because of the very short groundwater travel time from the nearest segment of the pipeline, an additional option for protecting groundwater quality could involve batching (i.e., storing) and or blending its pumped groundwater with water from other well stations before releasing it into the distribution system. However, batching or blending is not feasible with the City's current infrastructure due to the interconnectivity of the transmission and distribution systems; retrofits would be required to make batching or blending a feasible mitigation measure for providing sufficient water supply during an emergency.

Distribution System Contamination Response Procedure

A Distribution System Contamination Response Procedure (DSCRP) document was developed as part of this study. The DSCRP, which was developed using U.S. Environmental Protection Agency guidance (EPA, 2018), describes YPL's and the City's ERPs and procedures and is intended to be a reference document to supplement the City's ERP. The DSCRP is contained in Appendix F of this report and was developed specifically to provide City of Spokane staff with procedures for responding to a potential contamination threat to its well stations. The DSCRP was designed to be scalable so that the City can elect to include a broader range of potential contamination incidents across the water distribution system in future iterations. The DSCRP goes beyond the immediate response framework by also outlining potential future mitigation actions that the City may choose to implement to reduce the overall risk of emergency incidents. Future mitigation actions could include infrastructure improvements (listed in Section 5.3.1), planning for changes to water system operations in response to a future release from the pipeline (listed in Section 5.3.2), and planning-level and communication updates and improvements (listed in Section 5.3.3). The DSCRP is intended to be a living document and should be updated as new information is identified, policies and response procedures are updated, and/or infrastructure improvements are completed.

Limitations

The study described in this report used a detailed process for identifying and evaluating how a range of aquifer conditions, water demand scenarios, and operational and infrastructure aspects of the water distribution system affect the City's ability to prepare for and respond to a hypothetical future release of contaminants from the Yellowstone petroleum pipeline. The study also relied on information provided by YPL about the petroleum products and pipeline infrastructure, which informed the evaluation of contaminant risks to drinking water quality, considerations for implementing various advanced-warning monitoring systems, and the design of the DSCRP document.

The supporting data and analyses provide simplifications of complex natural systems and built infrastructure. Accordingly, this study relies on certain assumptions pertaining to natural systems, the nature of future water demands, the ability of built infrastructure to allow certain emergency response procedures to be implemented, and the nature and location(s) of contaminant releases from the pipeline that could hypothetically occur in the future. The interpretations and conclusions presented in this study should not be viewed as absolute results and could change in the future as new information becomes available. Reliance on this document for any uses other than emergency response planning by the City and YPL (including infrastructure planning, operational planning, and advanced-warning monitoring) is at the sole risk of the user.

1 Introduction

This report describes an assessment of the vulnerability of groundwater supply facilities owned and operated by the City of Spokane (City) to potential future chemical releases from the Yellowstone petroleum pipeline, which is owned by the Yellowstone Pipe Line Company (YPL) and operated by Phillips 66 (P66). The assessment consisted of first evaluating current water distribution system operations and groundwater flowpaths and travel times to City well stations, then identifying operational responses to a water supply emergency in which a chemical release from the pipeline threatens, or is detected at, one or more City well stations. The assessment was conducted by GSI Water Solutions, Inc. (GSI), and Consor North America, Inc. (Consor) (formerly known as Murraysmith).

1.1 Background and Reasons for the Assessment

The Yellowstone petroleum pipeline is a 10-inch diameter buried steel pipeline that conveys petroleum products into Washington from Montana. The pipeline alignment passes through the Spokane Valley and lies above the Spokane Valley-Rathdrum Prairie (SVRP) Aquifer, which is the sole source of water supply for the City of Spokane and nearby communities in the Spokane Valley. As shown in Figure 1-1, the pipeline route lies immediately next to the City's Parkwater well station and passes near the Well Electric well station, which are the City's two highest-capacity potable water supply sources. The pipeline also lies upgradient of other City well stations, passing through areas where the well stations capture groundwater (i.e., the "groundwater capture zones" for the well stations). East and north of the City, the pipeline also passes by municipal groundwater supply wells owned by neighboring water purveyors, some of whom also obtain supplemental and/or emergency drinking water supply from the City.

The pipeline operates under the terms of a franchise agreement between the City and the pipeline owner (YPL) that became effective on February 10, 2022, and is codified by the City as Ordinance No. C-35924. The franchise agreement has a 25-year life and can be extended for as long as 10 years. The agreement recognizes the presence of the regional aquifer system and its designation as a sole-source aquifer providing the City's sole source of drinking water. The agreement also identifies the aquifer as a "high consequence area" and an "unusually sensitive area" and defines an emergency incident as a release of petroleum products from the pipeline that "requires immediate response to protect persons or property from substantial injury or damage to the public health and safety, including damage to the environment or the Aquifer." A remote system for monitoring pressures and flows in the pipeline is in place "to accurately detect pipeline leaks, spills, or ruptures, as required by Environmental Laws and the applicable regulations of Jurisdictional Agencies" and as required under this franchise agreement.

Although the City has long had a groundwater quality monitoring program in place for its well stations under its wellhead protection program, this monitoring program is not specifically designed to provide early-warning detection of a release of petroleum products from the Yellowstone petroleum pipeline. If a release were to occur, changes to the operation of the City's well stations would need to quickly occur in order for the City to be able to continue providing clean drinking water to City residents and to neighboring communities with which it has intertie agreements. Accordingly, with assistance from YPL, the City has conducted this vulnerability assessment to provide technical information on groundwater flow, pumping operations, and chemical risk that can be incorporated into the City's existing Emergency Response Plan (ERP), including specific plans for how groundwater pumping operations could be altered in the event of a future release at different locations along the pipeline. YPL's and the City's mutual goal for this study and for emergency response planning is to avoid disruptions to the City's ability to provide drinking water supplies and to avoid disruptions in YPL's ability to deliver its petroleum products.

1.2 Description of Yellowstone Petroleum Pipeline

This section summarizes information about the location and pertinent features of the Yellowstone petroleum pipeline transmitted to the project team by YPL/P66 personnel in multiple meetings and written communications. In the City of Spokane and adjoining portions of the Spokane Valley, the Yellowstone petroleum pipeline consists of three segments of buried steel pipe. Two segments of the pipeline (YP-02 and YP-04) were constructed during the 1950s, and the third segment (YP-03) was constructed during the 1980s. Segment YP-02 branches into segment YP-03 running to the north and segment YP-04 running to the south. Figure 1-1 shows the locations of (1) the three segments, (2) control valves on each segment, (3) three bulk fuel storage facilities owned by YPL/P66 and others at the west end of segment YP-02, and (4) nearby City well stations. Segment YP-03 is the segment passing near the City's Parkwater and Well Electric well stations.

The pipeline is buried between 3 to 8 feet below ground surface within the study area and lies approximately 12 to 7 feet above the average depth of the water table, depending on location. Pipeline infrastructure includes mainline pumps, transfer pumps, and the bulk fuel storage facilities that are present at the western end of segment YP-02 and the northern end of segment YP-03.[1] No booster stations are present in the local study area shown in Figure 1-1. The predominant product types conveyed in the pipeline are gasoline (approximately 40 percent of the time), #2 diesel fuel (approximately 40 percent of the time), and jet fuel (approximately 20 percent of the time). Oxygenates and additives have not yet been added to these petroleum products.

The pipeline has cathodic protection with protective coating on the internal and external surfaces of all pipeline segments. Leak detection activities consist of the following:

- Aerial patrols of aboveground segments of the pipeline outside of the local study area are conducted every 2 weeks. No aerial patrols are conducted within the study area shown in Figure 1-1.
- Valve inspections are conducted twice each year.
- Hydrostatic testing is conducted every 5 years on most pipeline segments (including segments YP-02 and YP-04), but every 10 years for newer lines (including YP-03).
- Continuous (24/7) monitoring of metered inflows and outflows is conducted on individual pipeline segments to detect possible releases using metering as an inventory-control technique. Monitoring is conducted if the pipeline is operating or shut down.

YPL/P66 personnel report that the leak detection monitoring system does not include groundwater monitoring wells or vadose zone monitoring wells stationed along the pipeline.

Table 1-1 summarizes the minimum leakage rates in the three different pipeline segments necessary to be able to detect a release using the inventory control method. Larger leaks can be detected in 1 hour. Smaller leaks may take up to 24 hours to detect. Leaks less than these thresholds would not be detected using the inventory control method. YPL/P66 personnel report that no known releases have occurred from these three segments of the pipeline or at the bulk fuel storage facility located at the terminus of segment YP-02.

[1] Three bulk fuel storage facilities are present at the western end of segment YP-02: The P66 facility, and two others, including the Conoco Phillips Spokane Terminal and the Exxon Mobil Spokane Terminal.

Table 1-1 Yellowstone Petroleum Pipeline Segment Data and Minimum Leakage Rates

Pipeline Segment	Period of Construction	Average Product Flow Rates	Average Pressure	1-Hour Minimum Detection Volume	24-Hour Minimum Detection Volume
YP-02 (operated full-time)	1950s	850–1,800 bbl/hr	850 psi	≥38 bbl/hr (1,596 gal/hr) leak rate	≥9 bbl/hour (378 gal/hr or 9,072 gal/day)
YP-03 (operated ~25% of the time)	Late 1980s	500–1,800 bbl/hr	180 psi	≥28 bbl/hr (1,176 gal/hr) leak rate	≥9 bbl/hour (378 gal/hr or 9,072 gal/day)
YP-04 (operated ~50% of the time)	1950s	350–500 bbl/hr	780 psi	≥12.5 bbl/hr (525 gal/hr) leak rate	≥2.5 bbl/hour (105 gal/hr or 2,520 gal/day)

Notes

bbl/hr = barrels per hour
gal/hr = gallons per hour
gal/day = gallons per day
psi = pounds per square inch

1.3 Project Objectives

The specific objectives that were identified during scoping of this vulnerability assessment consisted of (1) evaluating the nature of the risks posed by the Yellowstone petroleum pipeline to groundwater operations and specific wells in the event of a release; (2) identifying how operations at the two nearest well stations (Parkwater and Well Electric) and other City well stations should be modified in response to a release to protect the quality of potable water delivered to ratepayers, and (3) evaluating the relative differences in chemical-specific risks to the aquifer and source wells arising from the different mobility, persistence, and toxicological characteristics of the multiple chemical constituents that are present in the different types of petroleum products that are conveyed in the pipeline, including jet fuel, diesel fuel, and gasoline.

Two primary outcomes for the vulnerability assessment were identified by the City during project scoping to be (1) a set of one or more feasible scenarios for redistributing groundwater production between the City's multiple well stations (which will need to include consideration of the capacities and limitations in the City's water distribution system) and (2) the other elements of an ERP that will need to be implemented in the event that a petroleum release from the pipeline is detected in the future. GSI and Consor also identified an additional outcome as being an evaluation of the need for, and design of, a subsurface monitoring program.

1.4 Methodology

The methodology for the vulnerability assessment consisted of six basic work steps:

- **Step 1: Establishing and evaluating baseline operating conditions for the City's well stations under non-emergency conditions.** This consisted of developing groundwater capture zones under seasonally varying conditions and using the most up-to-date estimates of future City water demands. This work was conducted using an updated version of the City's three-dimensional numerical groundwater flow model.

- **Step 2: Identifying locations associated with the highest potential risk from petroleum release.** This consisted of identifying locations and types of future potential small-scale and/or large-scale releases from the pipeline and comparing these locations with well station capture zone alignments.
- **Step 3: Developing and evaluating multiple scenarios for City well station operations in response to a release.** This consisted of identifying emergency scenarios of interest to the City, conducting groundwater (aquifer flow) modeling to evaluate capture zones, and conducting water distribution system modeling to evaluate limitations in the water transmission system.
- **Step 4: Evaluating the relative risk posed by different petroleum products.** This consisted of evaluating the relative differences in contamination risks of the different petroleum products that are thought to be conveyed in the pipeline (considering aquifer-specific and chemical-specific behavioral indicators).
- **Step 5: Developing a concept plan for focused subsurface monitoring.** This consisted of evaluating how a subsurface monitoring program might be designed, constructed, and operated to provide timely detection of a release that threatens vulnerable locations near and upgradient of the City's well stations.
- **Step 6: Incorporating study findings into a project report and the City's existing ERP.** This documentation step included helping City personnel develop specific operating procedures for responding to a release and a suspected or confirmed detection of contaminants at a City well station, including pumping operations during and after an emergency.

1.5 Primary Tools and Data Sources

The primary tools and sources of data used in the study were the following:

- **Data provided by YPL for the Yellowstone petroleum pipeline.** Data included the pipeline's alignment, the locations of primary valves controlling the flow of products, the types of products conveyed in the pipeline, methods used to search for and detect possible leaks in the pipeline, and the Integrated Contingency Plan developed by P66 as operator of the YPL.
- **The City's projections of future conditions in its service area and in the aquifer system.** These consisted of:
  - **Water demand projections 20 years and 50 years into the future, as developed by HDR (2022 and 2023) and as further refined by GSI to account for climate change influences on demand (GSI, 2024).** The HDR-published demand scenarios were provided for the entire City water service area. City personnel provided details regarding the distribution of average day demand (ADD) and maximum day demand (MDD) needs amongst the City's three primary supply zones that receive and distribute groundwater that is pumped from the City's well stations. See Appendix A for a discussion of these system-wide demand scenarios and how they were used to develop monthly pumping profiles for each City well station under non-emergency operating conditions.
  - **Climate change influences on the SVRP Aquifer and the Spokane River, as described by GSI (2024).** Climate-change scenarios were obtained from an online data portal called The Climate Toolbox (accessible at https://climatetoolbox.org/) and programmed into the City's numerical groundwater flow model as described by GSI (2024). See Appendix B for a discussion of the development of these climate change factors for the SVRP Aquifer and the Spokane River.
- **Prior groundwater modeling and hydrogeologic studies.** Numerous studies have been used to develop the City's most current version of its groundwater flow model of the SVRP Aquifer. This model is a three-dimensional numerical groundwater flow model of the SVRP Aquifer and is used by the City to support its ongoing long-range groundwater supply source planning efforts, which are focused on capital improvements planning. The City's groundwater flow model builds upon prior groundwater models developed by the City (CH2M HILL, 1998; GSI, 2012) and by the U.S. Geological Survey (USGS) (Hsieh et

al., 2007) and incorporates hydrogeologic data collected by the City in more recent years. The model uses the USGS software MODFLOW-USG (Panday et al., 2013; Panday, 2023) to calculate groundwater elevations and water budgets[2] and the modPATH3D software (Muffels et al., 2021) to calculate (trace) three-dimensional groundwater flowpaths in the aquifer system. A description of the development of the City's groundwater flow model and key data sources supporting the model is contained in Appendix C.

- **The City's existing water distribution system model.** The City's water distribution system model uses the Autodesk InfoWater Pro® hydraulic model and includes the City's well stations, water transmission pipes, booster pump stations, and storage facilities. The model is used to estimate service pressures, flow availability, storage reservoir cycling, and the operation of the entire water transmission and distribution system under various scenarios using extended period simulation (EPS) methods.

1.6 Report Organization

The remainder of this report is organized as follows:

- **Section 2** presents the analysis of baseline (non-emergency) operating conditions for the City's water system under current and projected future levels of demand.
- **Section 3** describes and analyzes four emergency operating conditions involving shutdown of one or more City well stations. This section first discusses water system operations, including demand needs in each of the three primary supply zones in the distribution system, and operation of well stations and the distribution system. Groundwater modeling analyses are then presented to show capture zones for each City well station under the emergency conditions and groundwater flow directions away from the pipeline when the City alters its well station operations.
- **Section 4** discusses the contaminant risks to drinking water quality and alternatives for monitoring for and detecting releases from the pipeline. This section first presents a risk evaluation that describes the chemical constituents of concern (COCs) for the pipeline's petroleum products and estimates groundwater and contaminant travel times to City well stations. This is followed by a discussion of the ability to monitor for releases.
- **Section 5** provides a description of emergency response actions and the City's ERP for responding to a future release threat from the pipeline or an actual detection of pipeline petroleum products in one or more City well stations. This section of the report concludes with a list of recommended operational response procedures, mitigation measures, and plan updates for YPL and the City to consider incorporating into their ERPs.
- **Section 6** presents a list of references cited in this report.
- **Tables** are embedded within the text of this report.
- **Exhibits** are embedded in the text of this report.
- **Figures** are presented at the end of the report (following the text).
- **Appendix A** describes the development of monthly distributions for groundwater pumping at City well stations under a 20-year projection and two 50-year projections for future water demands in the City's water service area, under normal non-emergency operations (i.e., in the absence of contaminant releases from the Yellowstone petroleum pipeline or other potential contaminant sources).
- **Appendix B** describes the development of climate-change factors affecting future water demands, the SVRP Aquifer, and the Spokane River.

[2] The water budget calculations include the rates of water exchange between groundwater and the Spokane and Little Spokane Rivers.

- **Appendix C** describes the development and calibration quality of the most current version of the City's numerical groundwater flow model.
- **Appendix D** describes the redistribution of pumping between the City's well stations under emergency operating scenarios
- **Appendix E** presents the baseline and emergency water system operations results obtained from the use of the City's water distribution system model.
- **Appendix F** contains the Distribution System Contamination Response Procedure (DSCRP) document developed as part of this study, which is intended to be a reference document to supplement the City's ERP.

2 Baseline (Non-Emergency) Conditions for Water System Operations

The study began with an in-depth evaluation of future operating conditions for the City's eight well stations in the absence of a contaminant release from the Yellowstone petroleum pipeline. This evaluation of non-emergency conditions served as a baseline condition against which subsequent analyses of emergency scenarios (as described in Section 3 of this report) could be compared. Section 2.1 provides an overview of current water system operations and performance conditions, including the evaluation criteria used to evaluate the distribution system. Section 2.2 then describes groundwater flow patterns in the aquifer, which are focused on identifying groundwater capture locations and depths for City well stations and identifying where groundwater passing beneath the pipeline moves both geographically and vertically in the aquifer system under typical operating conditions for the City's well stations.

2.1 Current Water System Operations

To establish baseline operational and level-of-service conditions in the distribution system, the City's hydraulic distribution system model, hosted by Autodesk's InfoWater Pro® platform, was used to estimate typical system tank cycling behavior and transmission capacity. Baseline modeling is a key component of emergency analysis because changes in system performance during emergency conditions can be highlighted. Without baseline modeling, it would be unclear which analysis results are caused by the emergency and which are normal system outcomes.

The distribution system model is configured both for steady-state hydraulic analysis and EPS hydraulic scenarios. A "steady-state" distribution modeling scenario is an instantaneous calculation of the system's conditions such as pressures, velocities, tank levels and cycles, pump operations, demand, and supply. An EPS scenario is a calculation of system conditions on a timestep basis as they change over time. EPS simulations were modeled for 96 hours (4 days) and in some cases 168 hours (1 week). The typical criteria evaluated for the baseline scenarios and for the emergency distribution system scenarios are summarized in Table 2-1 and provide reliable water service to meet system performance standards.

Table 2-1 Distribution System Operational Criteria

Condition	Criteria for Non-Emergency Operations	Criteria for Emergency Operations
Fire-flow availability	Industrial hydrant: 6,000 gpm during MDD Commercial hydrant: 4,000 gpm during MDD	Same as non-emergency criteria
Minimum pressure during FF	20 psi	Same as non-emergency criteria
Minimum pressure during peak hour demand	40 psi	30 psi[1]
Supply	Average daily supply must meet MDD. FF intended to be supplied by storage, not supply.	Average daily supply must meet MDD. Fire flow should be supplied by storage but can be supplemented by excess supply.
Transmission main maximum head loss	3.5 feet per 1,000 feet of pipeline	Same as non-emergency criteria
Tank minimum volume level	Tanks should not drop below minimum levels needed to provide minimum pressure to the highest elevation customer served.	Same as non-emergency criteria
Tank recovery minimum volume level	Tanks should recover to their maximum operating level (typically 90 to 100%) during non-peak timeframes.	Tanks should cycle in a stable manner and use as much storage volume as possible.

Notes

[1] The City's Water System Plan notes 40 psi as their performance goal, but the Washington State Department of Health (DOH) requirement of 30 psi was chosen for the emergency level of service.

FF = fire flow gpm = gallons per minute MDD = maximum day demand psi = pounds per square inch

The model's EPS capabilities were used to review typical summer tank and booster pump station operations. Steady-state simulations were also performed for the MDD + fire flow (FF) and peak hour demand (PHD) conditions to review typical pressures and FF availability. However, because the system's response to a loss of supply during a contamination event takes time to play out, the EPS baseline scenario served as the primary comparison point for emergency pressures and transmission main head loss after the system behavior had stabilized in the simulation. The steady-state baseline scenarios functioned as a validation basis for the EPS results. More detail on the baseline analysis is provided in Appendix E.

During baseline conditions, the model predicts that 0.20 percent of customers experience pressures below 30 psi spread across the system when the tanks are at their lowest levels on a high use summer day. The model predicts maximum head losses greater than 3.5 feet per 1,000 feet of pipeline in the Northwest Terrace pressure zone, near the Browne Park and Glennaire tanks, near the Nevada Well Station, and crossing the Spokane River at Upriver Dam from Well Electric.

The baseline EPS simulation also demonstrates that due to head loss in the system's transmission system, tanks located farther away from the City's supply sources in the three primary supply zones do not typically utilize their full volume capacity because the inlet pressure is too low to completely fill the tanks. Exhibit 2-1 shows that all but three of the system's supply/primary supply zone tanks are underutilized by more than 5 percent of their volumes on a high-use summer day even though system supply is more than adequate to meet MDD. Only the North Hill, Shadle Park, and Five Mile supply/primary supply zone tanks are underutilized by 5 percent or less. Further details on the baseline system modeling are included in the Task 2 and Task 8 technical memorandum contained in Appendix E.

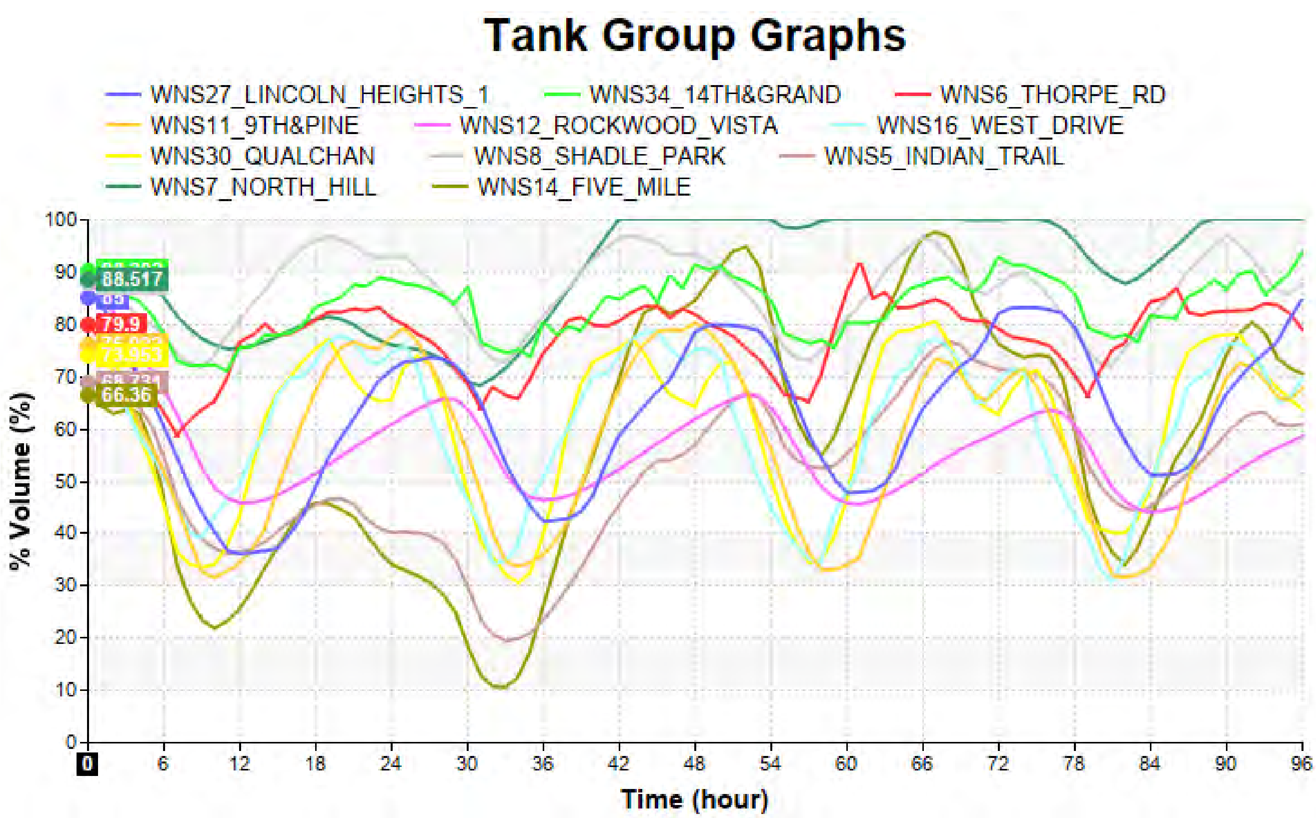

Exhibit 2-1 Baseline Operations Tank Volumes (Primary Supply Zones)

The City's baseline transmission system limitations make the system vulnerable to a loss of supply because a portion of the City's storage is not usable in the summertime due to system losses during tank fill cycles. Sections 3 and 4 continue the distribution system analysis for scenarios in which groundwater supply is lost at one or more City well stations because of a contamination threat or occurrence from the Yellowstone petroleum pipeline or other potential contaminant sources, creating an emergency loss of supply. Sections 3 and 4 also discuss proposed emergency response measures under these hypothetical scenarios.

2.2 Groundwater Capture by City Well Stations and Groundwater Flowpaths Away from the Pipeline

The study used a numerical three-dimensional groundwater flow model of the SVRP Aquifer and overlying and adjacent surface water bodies to simulate projected conditions in the aquifer and then delineate groundwater flowpaths under those conditions. See Appendix C for more details about the model's design and calibration. The groundwater flowpaths that were delineated using the model were examined for two characteristics of flow pertaining to the City's groundwater pumping and the location of the Yellowstone petroleum pipeline: (1) the locations and depths from which groundwater is drawn towards (i.e., captured by) each well station, and (2) the locations to which groundwater passing beneath the pipeline moves.

Three separate model simulations were conducted—one for each of three future levels of water demand (groundwater supply need) that are described below in Section 2.2.1. Each of the three simulations was designed to account for (1) future climate-change-driven impacts on the natural hydrology of the aquifer, and (2) future demands for groundwater from each of the City's eight well stations. For each of the three levels of future demand, the model assumed that pumping operations from all eight well stations would be "normal," meaning that pumping would occur under non-emergency conditions in which water supply needs are met by all eight well stations rather than being curtailed at one or more well stations because of groundwater quality impacts arising from the Yellowstone petroleum pipeline or other potential contaminant sources.

For this non-emergency future condition, following are discussions of the methodology (Section 2.2.1), modeled water demand scenarios (Section 2.2.2), capture zones of each City well station (Section 2.2.3), groundwater flowpaths away from the pipeline (Section 2.2.4), and a summary of the groundwater modeling results (Section 2.2.5).

2.2.1 Methodology

Each model run simulated a 5-year period of time, with pumping and hydrologic conditions varied on a monthly basis. Values for a given month were the same during each of the 5 years, to reflect long-term average conditions for pumping and for background hydrologic conditions. Background hydrologic conditions consisted of conditions in the latter third of this century as described by an average of climate projections for the period 2070–2099 obtained from an online data portal called The Climate Toolbox, which is accessible at https://climatetoolbox.org/. This data portal contains projections of future streamflows for the Spokane River and future climate variables (precipitation, temperature, evapotranspiration, growing-season length, and first and last frost dates) that affect water demands and recharge to the SVRP Aquifer. In a separate study, GSI (2024) evaluated six climate scenarios that are based on (1) two different scenarios for greenhouse gas (GHG) emissions (named Representative Concentration Pathway [RCP] 4.5 and RCP 8.5)[3] and (2) low, median, and high degrees of climate change under each of these two future emissions scenarios during the last three decades of the 21st century. For the pipeline vulnerability study, GSI simulated just one of these six climate-change scenarios (the median degree of climate change under the RCP 8.5 emissions scenario), which formed the basis for defining (1) streamflows in the Spokane River at Post Falls, Idaho (where the river first crosses over the SVRP Aquifer), (2) inflows to the SVRP Aquifer from tributary valleys that drain towards the aquifer from upstream watershed areas, and (3) future projections of how customer water demands (and hence required groundwater pumping volumes) might change in the future as temperatures change and the growing season lengthens (which affects outdoor watering needs). See Appendix B for details regarding the climate-change factors that are used in the model to simulate Spokane River streamflows and recharge to the aquifer from tributary valley inflows.

The groundwater flowpath analyses consisted of three steps:

1. Running the groundwater flow model using the MODFLOW-USG software (Panday, 2023; Panday et al., 2013) to compute groundwater elevations and groundwater budgets for each month throughout the 5-year simulation period.

[3] RCP 4.5 and RCP 8.5 each describe a specific "Representative Concentration Pathway" for future global GHG emissions. Under RCP 4.5, GHG emissions stabilize by the year 2050 and then decline steadily; this can be thought of as a somewhat optimistic scenario for future GHG emissions. Under RCP 8.5, GHG emissions do not decline and continue at their historical rates, resulting in continued accumulation of GHGs in the atmosphere; this can be thought of as a "business as usual" scenario for future GHG emissions.

2. Conducting reverse particle-tracking simulations using the modPATH3DU software (Muffels et al., 2021) to identify the capture zones for each City well station during the 5-year simulation period.
3. Conducting forward particle-tracking simulations with modPATH3DU in which particles were initiated along the length of the pipeline in Spokane County and traced forward in time to understand (1) where a release to the water table might migrate spatially in the SVRP Aquifer, and (2) whether releases would likely stay in the shallow portion of the aquifer versus migrating into deep portions of the aquifer.

2.2.2 Modeled Water Demand Scenarios

Future pumping by the City was derived from published projections of water demands in 20 years (HDR, 2022) and 50 years (HDR, 2023), with additional adjustments to those demands to account for the effects of changing temperatures on the length of the growing season and changes in water needs on agricultural and urban landscapes requiring irrigation water supplies. Three future pumping scenarios were evaluated: a single scenario for the projected 20-year demand, and two 50-year demand projections that differ in their assumptions regarding growth and water conservation. The ADD and MDD for each of these three demand scenarios are summarized in Table 2-2 and are higher than the HDR-published projections because of different interpretations about future irrigation needs under a changing climate.

For this study, GSI developed monthly estimates of the City's system-wide demands using the HDR projections, the City's current seasonal variation in demands, and future projections of how demands might change in the future as temperatures change and the growing season lengthens (which affects outdoor watering needs). Figure 2-1 provides a visual comparison of the resulting monthly distributions of system-wide demand. Details regarding the technical methodology for developing the water demand scenarios and simulating them in the groundwater model at each City well station each month are provided in Appendix A.

Table 2-2 Water Demand Values for Recent Historical Usage and Future Demand Scenarios

Water Demand Scenario	ADD	MDD
Recent Historical Usage (Average for 2015 through 2020)	63.60	141.30
20-Year Projection with 2070–2099 Climate Change	91.47	186.42
50-Year Projection (Modest Level of Demand) ▪ Demographics: Baseline ▪ Conservation: Standard ▪ Climate Change: Aggressive (RCP 8.5, 2070–2099)	95.32	217.40
50-Year Projection (High Level of Demand) ▪ Demographics: High Growth/High Commercial ▪ Conservation: No Change from Current Conditions ▪ Climate Change: Aggressive (RCP 8.5, 2070–2099)	127.06	259.75

Notes

All values are in units of millions of gallons per day (mgd).
ADD = average day demand MDD = maximum day demand
RCP = Representative Concentration Pathway for future global greenhouse gas emissions

2.2.3 Capture Zones of City Well Stations

For the 20-year and two 50-year demand scenarios, Figures 2-2, 2-3, and 2-4, respectively, show capture zones that extend to and beyond the path of the Yellowstone petroleum pipeline under non-emergency operating conditions for the City's existing well stations (i.e., unaltered by a potential future release from the pipeline). The capture zones are shown as path lines radiating backwards from each well, with the different colors representing the following depth zones in the aquifer:

- Red = the upper 75 feet of the aquifer below the average water table position (simulated with model layer 1)
- Orange = depth interval 75 to 150 feet below the average water table position (simulated with model layer 2)
- Blue = depth intervals in the aquifer that are more than 150 feet below the average water table position (simulated with model layers 3 through 8)

Figures 2-2 through 2-4 together indicate that the three well stations closest to the Yellowstone petroleum pipeline (Parkwater and Well Electric) capture groundwater from the upper portion of the aquifer that intersect the pipeline east of the City's well stations. The next closest well station to the pipeline (Ray Street) captures groundwater from slightly deeper in the system, as indicated by the lack of red lines near the pipeline and the predominance of orange and blue lines. In contrast, the well stations that lie north of the river (Central, Hoffman, Grace, and Nevada) only capture groundwater from the upper portion of the aquifer (red and orange lines) at and north of the river, while nearly all flowlines south of the river lie more than 150 feet below the water table (blue lines), including where these capture zones pass beneath the pipeline.

Figures 2-5 through 2-7 together show these capture zones in the case where a hypothetical set of deep vertical production wells are pumped in the future at the Well Electric well station, instead of the existing caisson wells. The capture zone alignments generated by the groundwater model for all City well stations when pumping the hypothetical deep wells at Well Electric are estimated to be similar to the capture zones when pumping the existing caisson wells at Well Electric (see Figures 2-2 through 2-4), with the primary difference being the greater depth zones pumped by the hypothetical deep wells at Well Electric (blue flowlines in Figures 2-5 through 2-7) versus the existing caisson wells at Well Electric (red flowlines in Figures 2-2 through 2-4).

The capture zones were developed by initiating imaginary particles at each City well station during the highest-pumping month of the last year in the 5-year simulation and tracing the particles backwards in time in the upgradient direction (i.e., from the west and northwest to the east and southeast). Initiation of particles in other months of the year revealed that the shapes and alignments of the capture zones were generally insensitive to the time of year in which the flowline analysis was initiated in the model.

2.2.4 Groundwater Flow Directions Away from the Yellowstone Petroleum Pipeline

Figures 2-8 through 2-10 show the travel paths of flowlines that are initiated in the model along the length of the Yellowstone petroleum pipeline. These three figures show groundwater migration for the case where City groundwater pumping is occurring from all eight existing City well stations, including the existing caisson wells at Well Electric. Figures 2-11 through 2-13 show these same flowlines for a case where pumping at the Well Electric well station is conducted from deep vertical wells instead of the existing shallow caisson wells. In each of these six map figures, the groundwater flowpaths are color-coded as follows:

- Red = shallow groundwater is captured by a City well station
- Orange = shallow groundwater captured by one or more other groundwater supply wells (not owned and operated by the City)
- Blue = shallow groundwater flows into the Spokane River
- Green = shallow groundwater remains in the aquifer system (i.e., is not captured by wells and does not flow into the Spokane River)

Key observations are:

- Shallow groundwater beneath the portions of segment YP-02 lying directly east of Well Electric and Parkwater are captured by those two well stations. However, when pumping from Well Electric occurs from future deep wells, the groundwater that moves from east to west across the Well Electric facility migrates to the Spokane River rather than being captured in the Well Electric groundwater supply.
- Elsewhere along segment YP-02, much of the groundwater passing beneath the pipeline eventually is captured by other groundwater wells north and east of the City or flow into the Spokane River. The northernmost of the groundwater flowpaths located north of segment YP-02 pass to the north of Well Electric and then migrate northwards to areas east of the City's northernmost well stations.
- Groundwater that is along the portion of segment YP-03 south of the Spokane River migrates to the Parkwater well station and to the Spokane River. North of the river, groundwater beneath segment YP-03 migrates northwards to areas east of the City's northernmost well stations.
- The majority of the shallow groundwater that is present beneath segment YP-04 migrates to the Spokane River, with small quantities passing beneath the river and migrating further to the north and west in the aquifer. Groundwater from beneath segment YP-04 is also captured by the City's Ray Street and Havana Street well stations.

2.2.5 Summary of Groundwater Modeling Results for Non-Emergency Conditions

The modeling analysis of non-emergency conditions shows that the City's well stations capture groundwater from beneath a long reach of pipeline segment YP-02, a short reach of segment YP-03 near the Parkwater well station, and from some portions of segment YP-04. The City's four well stations north of the Spokane River (the Central, Hoffman, Grace, and Nevada well stations) are pulling groundwater from deep zones in the aquifer beneath the Yellowstone petroleum pipeline, while the two largest well stations (Parkwater and Well Electric, which lie further east along the northern margin of the aquifer) are capturing shallow groundwater beneath the pipeline. Along the southern margin of the aquifer, the City's Havana Street and Ray Street well stations capture a mixture of shallow and deep groundwater. While some of the shallow groundwater beneath the pipeline is captured by City well stations, flowlines traced forward from the pipeline show that notable amounts of shallow groundwater also are migrating to and north of the Spokane River and to wells owned by other water purveyors outside the Spokane city limits.

The modeling analyses also show that for each of the three levels of demand, the capture zones for a given City well station are similar in their upgradient extent and primarily differ only in their width. The analysis also shows that the shapes of the capture zones for well stations other than Well Electric and Parkwater are generally insensitive to whether pumping at Well Electric occurs from its existing shallow caisson wells versus future hypothetical deep production wells. For these reasons, groundwater modeling analyses of emergency conditions (discussed in Section 3) were able to be conducted for just one level of demand, which was chosen to be the 50-year high level of demand.

3 Emergency Scenarios for Water System Operations

Four emergency scenarios involving impacts to specific City well stations from future releases from the Yellowstone petroleum pipeline were evaluated:

1. Parkwater is offline
2. Well Electric is offline
3. Both Parkwater and Well Electric are offline
4. Both Ray Street and Havana Street are offline

Potential contamination impacts to these four well stations were the focus of the assessment because of the close proximity of these well stations to the Yellowstone petroleum pipeline. The results of the non-emergency modeling analyses described in Section 2 showed that (1) these well stations lie directly downgradient of the pipeline and could experience contamination within a few days to a few months after a release begins from the pipeline, and (2) the City's four other well stations (Central, Hoffman, Grace, and Nevada) are at lower risk of contamination because of their greater distances from the pipeline and the predominantly deep (not shallow) groundwater that they obtain from areas near the pipeline.

The groundwater modeling analyses of emergency operations focused on the 50-year high level of demand. Additional analyses of groundwater flowpaths under the 20-year level of demand and the lower of the two 50-year levels of demand were deemed unnecessary because of the similarity of the groundwater modeling results for all three levels of demand that were evaluated under non-emergency conditions, as discussed in Section 2. Nonetheless, Section 3.1 below discusses the adjustments to water system operations that warrant consideration under current levels of demand and all three future demand projections, to provide a complete understanding of conditions to inform demand management and other operational responses under each of the four emergency scenarios listed above. Section 3.2 then presents the groundwater flowpath analyses for the four emergency scenarios under the 50-year high level of demand.

3.1 Water System Operations under Emergency Conditions

Water system operations under the four emergency scenarios are discussed in Section 3.1.1 for the current level of demand and in Section 3.1.2 for future levels of demand.

3.1.1 Distribution System and Well Station Operations Under Current Levels of Demand

As discussed in Section 2.1, the distribution system modeling analysis revealed that the model EPS simulation was more valuable than any steady state scenario for evaluating the loss of supply impacts to the system. The EPS distribution system modeling conducted for the emergency scenarios listed above focuses around a supply-demand mass balance for each scenario, the behavior of the system tanks after a loss of supply, and the associated impacts to system pressures and losses. Appendix E includes more detail on which well stations were turned on in the model to supplement loss of supply from one or more hypothetically contaminated wells. These assumptions are intended to be used by the City to develop complete emergency operational response procedures for a contamination event.

3.1.1.1 Mass Balance Summary

Available supply was compared to MDD for each emergency scenario in each of the City's three primary supply zones: the North Hill System, the Intermediate System, and the Low System. Exhibits 3-1 and 3-2 show that in the worst-case loss-of-supply scenario (Parkwater and Well Electric offline), the North Hill and Intermediate primary supply zones have enough supply to meet demand (with surpluses of 9,484 gpm and 2,236 gpm, respectively). However, Exhibit 3-3 shows that the Low primary supply zone experiences a 2,718 gpm deficit of supply under this same emergency scenario. Most storage systems are designed with enough extra volume to provide required FF for a certain fire duration even after the tanks have drained to their low operational levels on a hot day. The Washington State Department of Health does not require water systems to have enough supply to provide FF on top of MDD because FF can come from storage. However, FF was included in the mass balance analysis to show system redundancy if FF storage is not available.

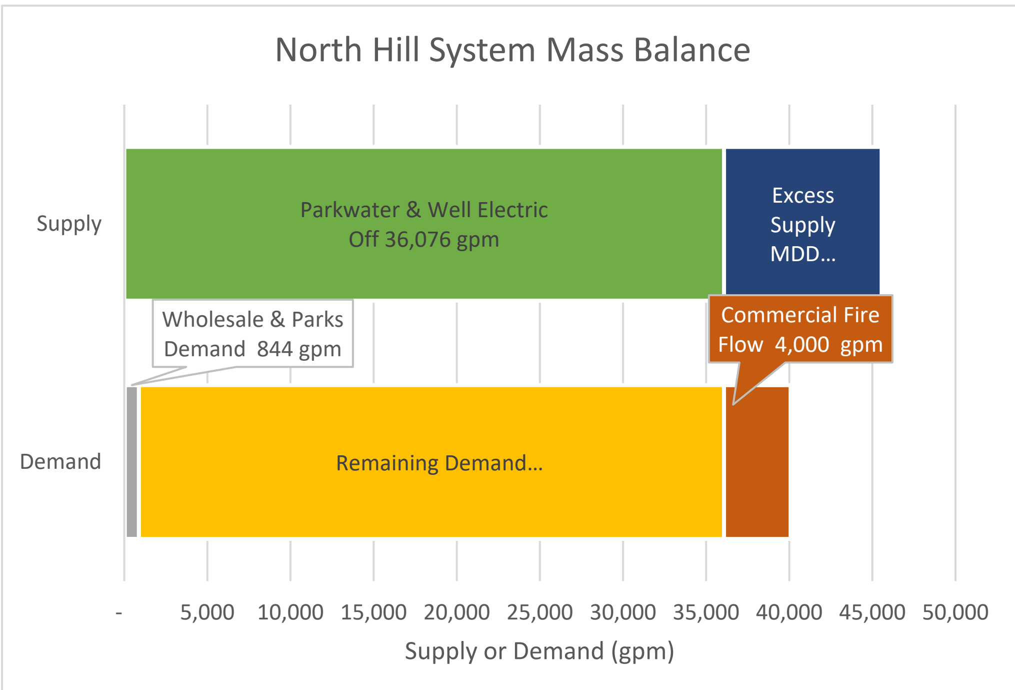

Exhibit 3-1 North Hill System Mass Balance for Parkwater and Well Electric Offline Scenario: MDD and FF

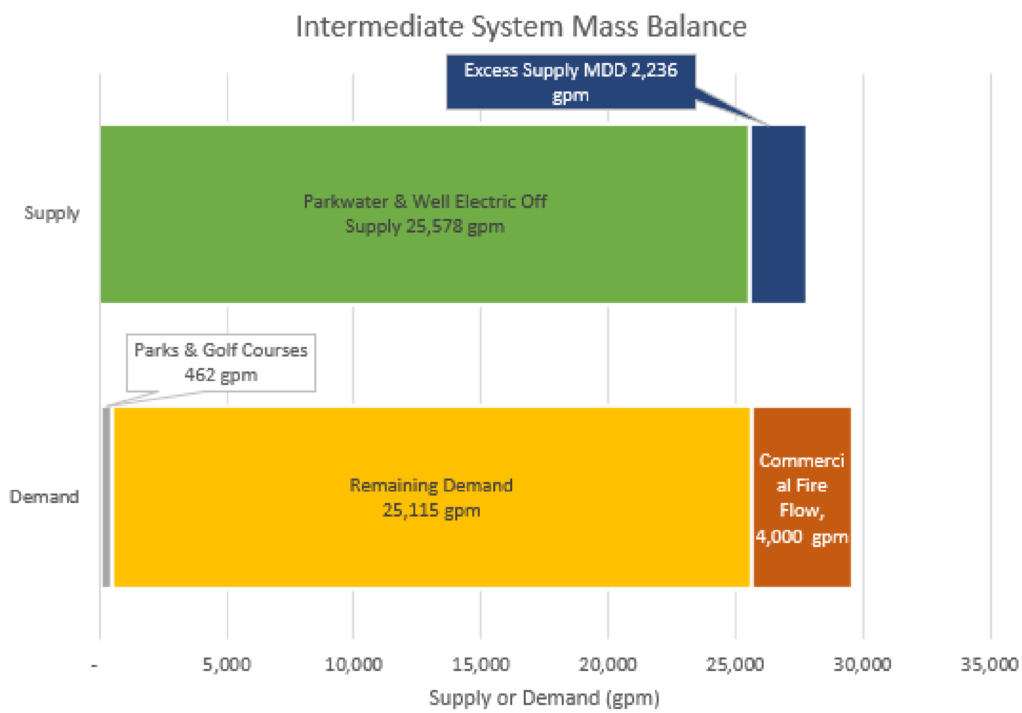

Exhibit 3-2 Intermediate System Mass Balance for Parkwater and Well Electric Offline Scenario: MDD and FF

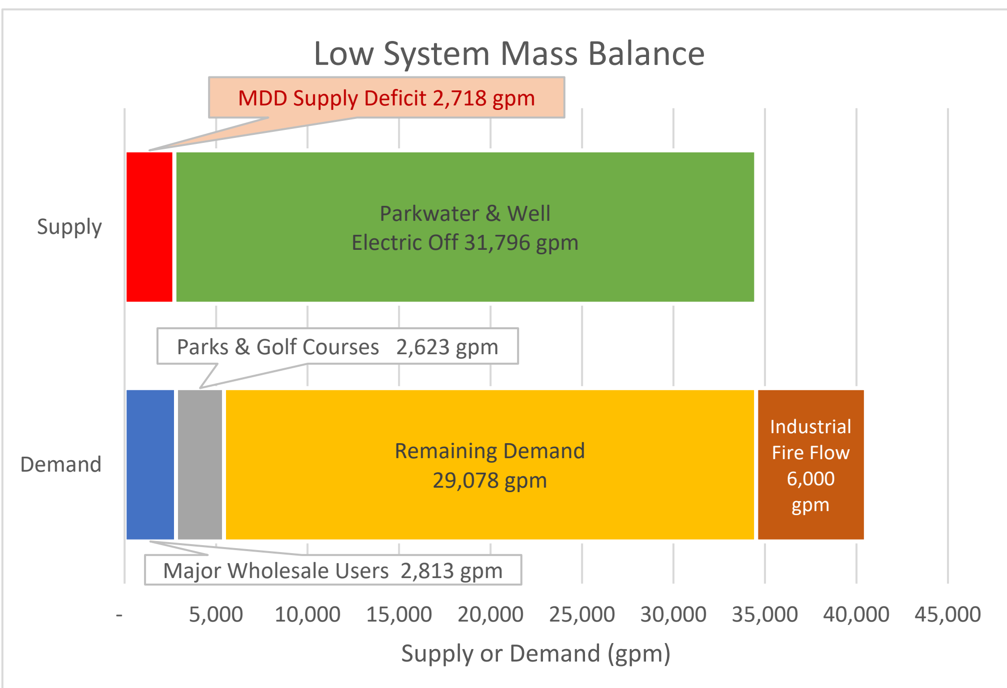

Exhibit 3-3 Low System Mass Balance for Parkwater and Well Electric Offline Scenario: MDD and FF

Table 3-1 summarizes the mass balance analysis for each emergency scenario. As shown in the table, mass balances that consider MDD and FF together produce supply deficits in the Intermediate primary supply zone under three of the four emergency scenarios. The Intermediate primary supply zone also experiences a deficit in MDD alone under the emergency scenario in which the Havana Street and Ray Street well stations are taken offline. The Low primary supply zone experiences a deficit in only one case (MDD plus FF for the scenario in which the Parkwater and Well Electric well stations are taken offline). The North Hill primary supply zone does not experience a supply deficit for any of the cases displayed in Table 3-1.

The mass balance analysis assumes that the Northwest Terrace pressure zone, which is served via PRV by both the Low and North Hill primary supply zones, is fully served by the North Hill supplies. However, the EPS analysis showed that this is not feasible operationally due to system losses; see Section 5.1 and Appendix E for more discussion. The mass balance analysis also ignored flow to the Intermediate primary supply zone from the Low primary supply zone via the Bishop Court and 9th & Pine booster stations.

Table 3-1 Summary of Supply Surpluses and Deficits Under Current Levels of Demand

Scenario	Primary Supply Zone ("System")	Supply Capacity (gpm)[1]	MDD (gpm)[2]	FF (gpm)	MDD Mass Balance (gpm)	MDD + FF Mass Balance (gpm)
Non-Emergency (Baseline) Conditions	Intermediate	33,306	25,578	4,000	7,728	3,728
	Low	54,919	34,514	6,000	20,405	14,405
	North Hill	47,252	36,076	6,000	11,176	5,176
Parkwater Well Station Offline	Intermediate	28,542	25,578	4,000	2,964	(1,036)[3]
	Low	46,282	34,514	6,000	11,768	5,768
	North Hill	44,241	36,076	6,000	11,176	5,176
Well Electric Well Station Offline	Intermediate	31,694	25,578	4,000	6,116	2,116
	Low	42,882	34,514	6,000	8,368	2,368
	North Hill	45,560	36,076	6,000	9,484	3,484
Havana Street and Ray Street Well Stations Offline	Intermediate	19,618	25,578	4,000	(5,960)[3]	(9,960)[3]
	Low	47,346	34,514	6,000	12,832	6,832
	North Hill	47,252	36,076	6,000	11,176	5,176
Parkwater and Well Electric Well Stations Offline	Intermediate	27,814	25,578	4,000	2,236	(1,764)[3]
	Low	31,796	34,514	6,000	(2,718)	(8,718)
	North Hill	45,560	36,076	6,000	9,484	3,484

Notes

[1] Supply capacity based on City flow test data. Pump flows will vary based on system conditions.

[2] For simplicity, the mass balance analysis assumed all Northwest Terrace pressure zone demand is to be served by the North Hill primary supply zone. However, the model EPS simulations do split flow to the Northwest Terrace pressure zone (unless otherwise noted) and account for the correct supply scheme to this pressure zone.

[3] Mass balances in the Intermediate primary supply zone do not include flow from the 9th & Pine booster station or the Bishop Court booster station, but the model EPS scenarios do include flow through these two pump stations unless otherwise noted.

EPS = extended period simulation

FF = fire flow

gpm = gallons per minute

MDD = maximum day demand

3.1.1.2 Emergency Extended Period Simulation Results

Full graphical and by-criteria EPS results are summarized in the Task 2 and Task 8 technical memorandum in Appendix E. Table 3-2 summarizes key findings.

Exhibit 3-4 is an example EPS result from the worst-case scenario (Parkwater and Well Electric Well Stations Offline), where the tanks in the Low primary supply zone begin to crash due to the loss of supply from these two well stations.

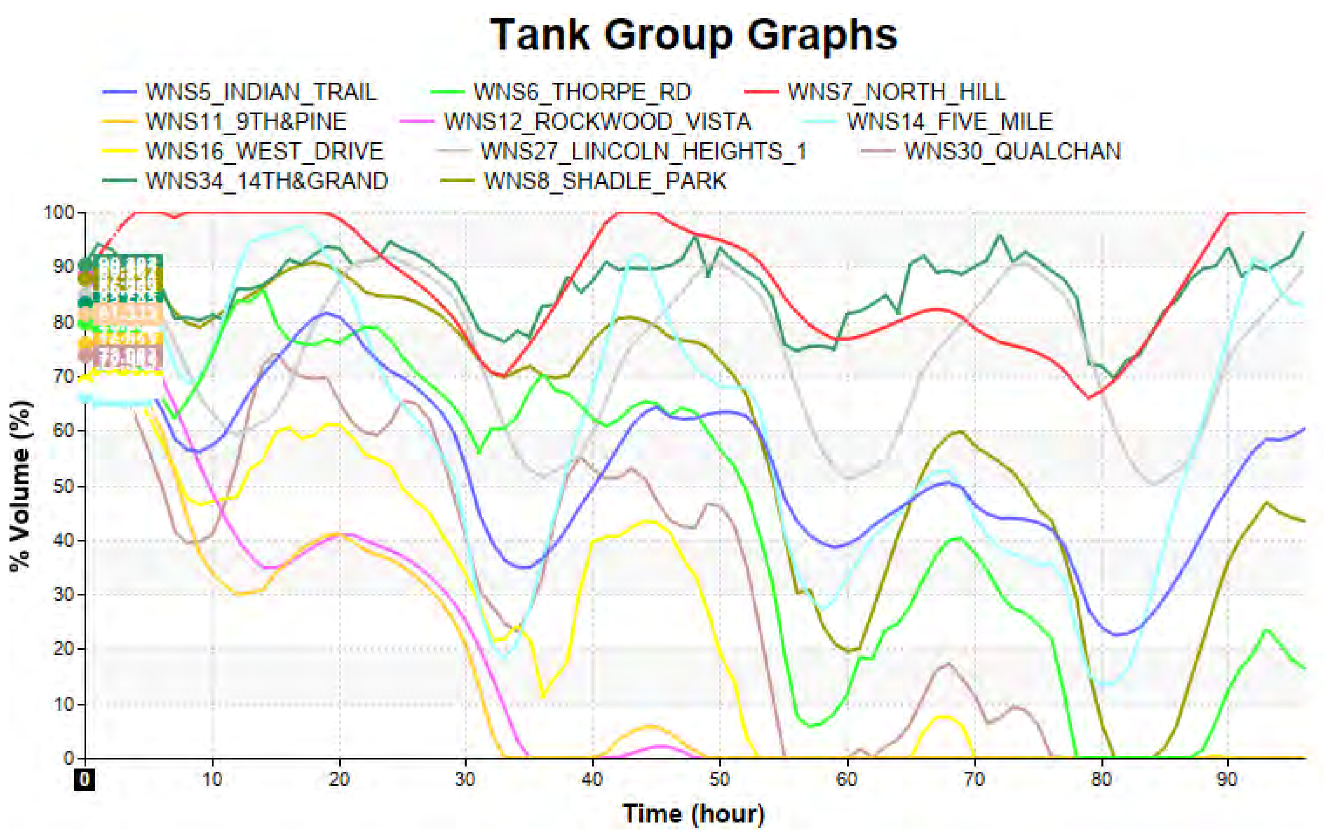

Exhibit 3-4 **Extended Period Simulation Tank Graphs: Parkwater and Well Electric Wells Offline**

Table 3-2 Operating Results Under Each Scenario for an Emergency Loss of Supply

<table>
<tr><th>Criteria</th><th>Non-Emergency (Baseline) Conditions</th><th>Parkwater Well Station Offline</th><th>Well Electric Well Station Offline</th><th>Havana St. and Ray St. Well Stations Offline</th><th>Parkwater and Well Electric Well Stations Offline</th></tr>
<tr><td>Primary zones with failed MDD mass balance</td><td>None</td><td>None</td><td>None</td><td>Intermediate (supplemented from Low Zone)</td><td>Low</td></tr>
<tr><td>% customers with pressures < 30 psi</td><td>0.2%</td><td>Negligible change</td><td>Negligible change</td><td>Negligible change</td><td>100%</td></tr>
<tr><td>Primary supply zone tanks[1] that fail to reach 95% tank volume</td><td>Indian Trail
Qualchan
9th & Pine
Rockwood Vista
Shadle Park
Thorpe Rd
West Drive</td><td colspan="2">Tank max fill levels impact is limited (see below)</td><td>Baseline Tanks
14th & Grand</td><td rowspan="4">Low primary supply zone tanks begin draining completely starting at 32 hours.</td></tr>
<tr><td>Approx % tank recovery volume lost</td><td>NA, compare to baseline</td><td>Qualchan: 6%</td><td>Five Mile: 5%
Indian Trail: 7%
9th&Pine: 9%
Thorpe Rd: 11%
Qualchan: 9%</td><td>9th & Pine: 39%
14th&Grand: 39%
Rockwood Vista: 4%
Lincoln Heights: 31%
Shadle Park: 6%
Qualchan: 9%
West Drive: 19%</td></tr>
<tr><td>Tanks where minimum level decreases by >5%</td><td>NA, compare to baseline</td><td>None</td><td>Qualchan
Thorpe Rd</td><td>9th&Pine
14th&Grand
Thorpe Rd
Rockwood Vista
Lincoln Heights
Qualchan</td></tr>
<tr><td>Tanks that drain to empty</td><td>None</td><td>None</td><td>None</td><td>None</td></tr>
<tr><td>Primary zones affected</td><td>NA</td><td>Low</td><td>Low
North Hill</td><td>Intermediate
Low</td><td>Intermediate
Low
North Hill</td></tr>
<tr><td>Transmission Impacts</td><td>NA</td><td>Limited</td><td>Losses in North Hill</td><td>Excessive loss across Spokane River at Parkwater</td><td>Losses in North Hill</td></tr>
</table>

Notes

[1] This number represents the model's attempt to solve for system flows and mass balance once tanks begin draining to zero volume. Eventually, all customers would experience no water pressure.

NA = not applicable

psi = pounds per square inch

3.1.2 Distribution System and Well Station Operations Under Future Levels of Demand

The water distribution system modeling results developed by Consor were used by GSI to develop operating scenarios for all four emergency conditions that would meet the projected 20-year and 50-year demands in each of the City's three primary supply zones. The analysis focused on extrapolating the MDD values system-wide and in each primary supply zone while considered the operating limitations of each pump under current conditions or (at certain well stations) under future improvements that have been developed and used by the City for capital improvements planning. For a given emergency scenario, these calculations produced (1) the volume of pumping from each well station for the MDD, and (2) the percentage of system-wide MDD pumping being produced by each well station. The percentage numbers for each well station were then assumed to be applicable to each month of the year, given that emergency operations would likely require continuous operations of all non-impacted well stations. Under this assumption, the MDD values were scaled to the system-wide demand needs to calculate pumping volumes from each well station on a month-by-month basis. Details regarding these calculations are presented in Appendix D.

Key conclusions from the pumping redistribution analysis under emergency operations are as follows:

1. Under the 50-year high-demand projection, to meet the system-wide MDD, Well Electric would need to operate during all four emergency scenarios, including the two scenarios in which Well Electric would be intended to be offline because of contaminant detection or the threat of contamination. As shown in Table 3-3, Well Electric would need to produce significant quantities of water to meet the MDD for the 50-year high level of demand if Parkwater were to be taken offline under an emergency. For this reason, the City would need to pump from a future wellfield constructed deep in the aquifer system at Well Electric, to minimize the risk that contaminants at the water table (in the shallow aquifer) would show up in groundwater that is pumped from this well station.

Table 3-3 MDD Water Supply Need from Well Electric (for the 50-Year High Level of Demand)

Primary Supply Zone	Non-Emergency (Baseline) Conditions	Parkwater Well Station Offline	Well Electric Well Station Offline	Parkwater and Well Electric Well Stations Offline	Ray St. and Havana St. Well Stations Offline
Intermediate	9.16	13.01	0	0	39.59
Low	5.96	81.51	5.96	81.51	5.96
North Hill	26.64	30.88	8.39	8.39	28.89
Total	**41.76**	**125.40**	**14.35**	**89.90**	**74.44**

Notes

All values are in units of millions of gallons per day (mgd).

MDD = maximum day demand

2. To meet the system-wide MDD under the 50-year modest-demand projection and the 20-year demand projection, Well Electric would need to pump from deep wells that are operated during three of the four emergency scenarios, including one of the two scenarios in which Well Electric would be intended to be offline because of contaminant detection or the threat of contamination. See Tables 3-4 and 3-5 for details.

Table 3-4 MDD Water Supply Need from Well Electric (for the 50-Year Modest Level of Demand)

Primary Supply Zone	Non-Emergency (Baseline) Conditions	Parkwater Well Station Offline	Well Electric Well Station Offline	Parkwater and Well Electric Well Stations Offline	Ray St. and Havana St. Well Stations Offline
Intermediate	9.16	10.89	0	0	30.03
Low	0	60.75	0	60.75	0
North Hill	24.20	25.85	0	0	24.17
Total	**33.36**	**97.49**	**0**	**60.75**	**54.20**

Notes

All values are in units of millions of gallons per day (mgd).

MDD = maximum day demand

Table 3-5 MDD Water Supply Need from Well Electric (for the 20-Year Level of Demand)

Primary Supply Zone	Non-Emergency (Baseline) Conditions	Parkwater Well Station Offline	Well Electric Well Station Offline	Parkwater and Well Electric Well Stations Offline	Ray St. and Havana St. Well Stations Offline
Intermediate	8.07	9.34	0	0	23.02
Low	0	45.48	0	45.58	0
North Hill	20.75	22.02	0	0	20.73
Total	**28.82**	**76.94**	**0**	**435.58**	**43.75**

Notes

All values are in units of millions of gallons per day (mgd).

MDD = maximum day demand

3. The four northernmost well stations (Nevada, Grace, Hoffman, and Central well stations), which are the furthest from the Yellowstone petroleum pipeline, are all critical for providing sufficient water supply to all three primary supply zones under all four of the emergency scenarios. Details are presented in Table 3-6, which shows the range of MDD values for the collective group of three future water demand scenarios.

Table 3-6 MDD Water Supply Need from Northern Well Stations

Primary Supply Zone	Non-Emergency (Baseline) Conditions	Parkwater Well Station Offline	Well Electric Well Station Offline	Parkwater and Well Electric Well Stations Offline	Ray St. and Havana St. Well Stations Offline
Nevada	34.10 to 45.79	45.79	45.79	45.79	45.79
Grace	10.73 to 15.71	10.31 to 14.30	18.61 to 24.20	18.61 to 24.20	10.74 to 14.96
Hoffman	10.73 to 15.71	10.31 to 14.30	15.72	15.72	10.74 to 14.96
Central	10.73 to 15.71	10.31 to 14.30	18.61 to 25.46	18.61 to 25.46	10.74 to 14.96
Total	**66.29 to 92.92**	**76.71 to 88.68**	**98.73 to 111.17**	**98.73 to 111.17**	**78.00 to 90.67**

Notes

All values are in units of millions of gallons per day (mgd).

MDD = maximum day demand

4. The Ray Street and Havana Street well stations are critical for providing sufficient water supply under all of the emergency scenarios involving Parkwater and/or Well Electric. The Ray Street and Havana Street well stations feed two of the City's three primary supply zones (the Low and Intermediate primary supply zones) and would need to produce a higher combined capacity under each emergency scenario than is needed under non-emergency conditions. Details are presented in Table 3-7, which shows the range of MDD values for the collective group of three future water demand scenarios.

Table 3-7 MDD Water Supply Need from the Ray Street and Havana Street Well Stations

Primary Supply Zone	Non-Emergency (Baseline) Conditions	Parkwater Well Station Offline	Well Electric Well Station Offline	Parkwater and Well Electric Well Stations Offline	Ray St. and Havana St. Well Stations Offline
Ray Street	12.03 to 16.77	16.15 to 22.51	14.57 to 22.99	25.05 to 33.72	0
Havana Street	14.25 to 19.85	16.62 to 23.16	9.97 to 16.60	17.06 to 24.96	0
Total	**26.28 to 36.62**	**32.77 to 45.67**	**24.54 to 39.59**	**42.11 to 58.68**	**0**

Notes

All values are in units of millions of gallons per day (mgd).

MDD = maximum day demand

3.2 Groundwater Capture by City Well Stations and Groundwater Flow Away from the Yellowstone Petroleum Pipeline

Groundwater modeling analyses similar to those conducted for non-emergency operations (see Section 2.2) were conducted for each of the four emergency scenarios. These analyses were conducted for the 50-year high level of demand and assumed that pumping from the Well Electric well station would occur from future hypothetical wells developed on the existing Well Electric property and on a City-owned land parcel located immediately across the river from (to the north of) the Well Electric property. Pumping at these future hypothetical wells was assumed to occur from deep portions of the aquifer, given that pumping would need to occur from deep zones to minimize the potential that a future contaminant release to the water table (i.e., the shallow portion of the aquifer) from the pipeline would be captured by pumping operations at Well Electric.

3.2.1 Capture Zones of City Well Stations

The capture zones for the City's well stations have similar alignments for each emergency scenario but differ in their width from one scenario to the next. Key features of the capture zones are the following:

- When Parkwater is offline (Figures 3-1 and 3-3), Well Electric has a wide capture zone that draws water primarily from deep aquifer zones near the north and south wellfields. For all four emergency scenarios, flowlines traced upgradient from the north wellfield at Well Electric move upwards into the shallow portion of the aquifer (orange and red) to the north of the wellfield and to the east where the pipeline crosses the Spokane River on the far right-hand side of these maps.
- The capture zone for Well Electric is much wider (in the north-south direction) when Parkwater and Well Electric are both offline (Figure 3-3) than when just Well Electric is offline (Figure 3-2). In both cases,

pumping needs to occur from deep wells at Well Electric to provide sufficient supply to each of the City's three primary supply zones for the 50-year high level of demand. However, the amount of pumping that is needed when only Well Electric is affected by a release from the pipeline (14.35 millions of gallons per day [mgd] for the MDD) is much less than the amount required from Well Electric when Parkwater and Well Electric are both affected by a pipeline release (89.90 mgd for the MDD); as shown in the attachments to Appendix D, this difference arises because of the importance of Parkwater for providing water supply to the Low primary supply zone, and the subsequent reliance on Well Electric to make up the lost Parkwater supply for this primary supply zone.

- For the Ray Street and Havana Street well stations, their capture zones are similar for the emergency scenarios involving Parkwater and/or Well Electric being offline (Figures 3-1 through 3-3). Figure 3-4 shows narrower capture zones for Ray Street and Havana Street when these well stations are offline.
- The Hoffman, Grace, and Nevada well stations show similar capture zones for each emergency scenario because of the similarities in their pumping rates for each scenario. In each emergency scenario, the Nevada well station pumps at its full capacity, while Grace and Hoffman pump at or near their full capacity.
- The Central well station shows a wider capture zone in the two cases where Well Electric is offline (see Figures 3-2 and 3-3) than under the other two emergency scenarios (Figures 3-1 and 3-4). This occurs because the Central well station (in addition to Grace and Hoffman) is critical for providing makeup water to the North Hill primary supply zone when Well Electric is offline.

3.2.2 Groundwater Flow Directions Away from the Yellowstone Petroleum Pipeline

Figures 3-5 through 3-8 show the travel paths of flowlines that are initiated in the model along the length of the Yellowstone petroleum pipeline for the four emergency scenarios. Figures 3-9 through 3-13 show close-in views at Well Electric and Parkwater for the non-emergency condition and the four emergency scenarios. Key observations from these modeling analyses are as follows:

- Groundwater that is moving east-to-west towards the Well Electric property (south of the river) generally migrates to the river because pumping is from the deep aquifer zones, rather than from the shallow depths that are pumped today by the existing caisson wells. This is shown by the prevalence of red on the groundwater flowlines throughout this area on each figure.
- Groundwater that is moving towards the City-owned land parcel north of the river (across from the Well Electric property) has some potential to migrate from the shallow depths (red) to intermediate (orange) and potentially deep zones (blue). However, these groundwater flowlines originate from distant portions of the pipeline located in the Spokane Valley, well east of the City limits and extending towards the Washington/Idaho state line. Accordingly, a contaminant release from these distant segments of the pipeline would potentially be more diluted than releases occurring from pipeline segments located near Parkwater and the existing Well Electric property south of the river.
- In the case of a contaminant release along the section of pipeline located immediately east of the City-owned parcel where future deep wells might be someday constructed north of the river, the groundwater model indicates that these contaminants would be more likely to move westward in shallow groundwater than moving east towards the future deep wells (see Figures 3-9 through 3-13).
- In the cases where Parkwater is operating (see Figures 3-9, 3-11, and 3-13), groundwater that is along the portion of segment YP-03 south of the Spokane River migrates to the Parkwater well station. When Parkwater is off, this groundwater shows a greater tendency to move to the Spokane River (see Figures 3-10 and 3-12); however, the close proximity of the pipeline to Parkwater means that contaminants could potentially still appear at Parkwater even when this well station is not operating.

- As was simulated under non-emergency conditions, the majority of the shallow groundwater that is present beneath segment YP-04 migrates to the Spokane River under each of the four emergency scenarios, with small quantities passing beneath the river and migrating further to the north and west in the aquifer. Groundwater from beneath segment YP-04 is also captured by the City's Ray Street and Havana Street well stations, even in the case when these well stations are not operating.

3.2.3 Summary of Groundwater Modeling Results for Emergency Conditions

The groundwater capture zones for the City's well stations under the four emergency operating conditions are similar in a general sense to those from the non-emergency conditions. For a given well station, the primary differences are in the widths of the various capture zones, which are governed by increases or decreases in pumping of the well station under a given emergency scenario compared with non-emergency conditions. Changes to pumping operations under a given emergency condition do not appreciably change groundwater flowpaths at a broad scale, nor the degree to which groundwater beneath the pipeline moves towards production wells versus the Spokane River versus areas north of the City. Changes are very localized, with the lack of broad-scale differences in the capture zones and flowlines occurring because of the very high permeability of the SVRP Aquifer.

In addition to understanding migration and potential capture of groundwater from beneath the pipeline, the groundwater flow model was used to estimate groundwater travel times to each well station from the portions of the pipeline that could be captured by a given well station. Using the time-varying simulations of groundwater elevations and flow directions along with assumed effective porosity values ranging from 0.15 to 0.20, the travel times are on the order of a few months for most wells, and potentially up to 12 or even 18 months for the well stations furthest north in the City (Nevada, Grace, Central, and Hoffman). See Table 3-8 for a summary of these travel times. However, for the Parkwater well station, the travel time will depend greatly on exactly where a contaminant release occurs along the pipeline. If a release were to occur where segment YP-03 passes closest to Parkwater, then the travel time to this well station could be as short as 1 to 2 days. If a release were to occur further south along segment YP-03, then the travel time would likely be a few days to a week or more. A release along segment YP-02 due east of Parkwater is estimated to travel to Parkwater over a period of 2.5 to 3 months.

Table 3-8 Estimated Groundwater Travel Times to City Well Stations from Nearest Sections of the Yellowstone Petroleum Pipeline

Well Station	Estimated Travel Time	Comments
Well Electric	6 to 7 months	This estimate pertains to pumping from the existing shallow caisson wells. Travel times are likely to be longer for future hypothetical wells constructed in deep aquifer zones.
Parkwater	1 to 2 days 2.5 to 3 months	The 1- to 2-day travel time is for a release from the portion of pipeline segment YP-03 passing near this well station. The 2.5 to 3-month travel time is for a release that occurs east of this well station from pipeline segment YP-02.
Havana Street	3 to 4 months	This well obtains groundwater from shallow and intermediate depths in the aquifer system.
Ray Street	6 to 7 months	This well obtains groundwater from shallow, intermediate and deeper depth zones in the aquifer system.
Nevada	12 months	This well obtains groundwater from deep aquifer zones in the vicinity of the Yellowstone petroleum pipeline.
Grace	12 months	This well obtains groundwater from deep aquifer zones in the vicinity of the Yellowstone petroleum pipeline.
Hoffman	9 to 18 months	This well obtains groundwater from deep aquifer zones in the vicinity of the Yellowstone petroleum pipeline.
Central	9 to 18 months	This well obtains groundwater from deep aquifer zones in the vicinity of the Yellowstone petroleum pipeline.

The risks that would be posed by chemical contaminants released from the pipeline are discussed in Section 4 of this report, along with an evaluation of potential monitoring programs and a discussion of emergency responses to a release event.

4 Risks to Drinking Water Quality and Monitoring Alternatives

This section of the report summarizes an evaluation of the contaminant exposure risk to drinking water quality via a pipeline leak to groundwater, and the types and efficacy of monitoring alternatives that could be implemented to attempt to detect a release before it affects drinking water quality in the City's supply sources. Section 4.1 presents the evaluation of contaminant exposure risk via a pipeline leak to groundwater. Section 4.2 describes the types of monitoring systems typically used to provide early detection of a release before it affects a groundwater source of supply, and the potential efficacy in this context.

4.1 Chemical Risk Evaluation

The chemical risk evaluation for this well station vulnerability assessment focuses on potential risks to human health via the groundwater pathway. In the event of a release from the pipeline, risks to human health via other pathways (e.g., vapor intrusion) or to ecological receptors would be assessed as part of characterization and cleanup response actions carried out by YPL under Washington State Department of Ecology (Ecology) oversight.

Table 1-1 illustrates that a release of product may not be detected unless it reached minimum threshold rates of approximately 500 to 1,600 gallons in 1 hour or 2,500 to 9,100 gallons in 24 hours, depending on the pipeline segment. A release at lower than threshold rates, even over a longer period of time, may not be detected until the petroleum product either appears on the ground surface, is observed on surface water, or is detected in City water supplies. For example, if a leak occurred at a rate less than 105 to 378 gallons per hour, nearly 2,500 to 9,000 gallons of petroleum (depending upon the pipeline segment) could be discharged per day without being immediately detected. A leak of this size may not be detected under current circumstances until the petroleum product either appears on the ground surface, is observed on surface water, or is detected in City water supplies.

Because of the relatively shallow depth to groundwater and highly permeable soils, transport within the vadose zone is assumed to be a relatively insignificant consideration in evaluating the risk of potential groundwater impacts. Consequently, this chemical risk evaluation focuses solely on groundwater transport of the COCs to the City's water supply facilities.

4.1.1 Constituents of Concern and their Physical Properties

As described in Section 1.2, the predominant product types conveyed in the Yellowstone petroleum pipeline are gasoline (approximately 40 percent of product), #2 diesel fuel (approximately 40 percent of product), and jet fuel (approximately 20 percent of product). Oxygenates and other petroleum additives are added at the points of distribution and are not present in the fuel blends during transport in the pipeline. Gasoline, diesel fuel, and jet fuel consist of hundreds of individual compounds. The State of Washington's Model Toxics Control Act (MTCA), which is administered by Ecology, identifies key constituents and cleanup standards for select compounds in each of these fuel types. GSI used the MTCA COC list for this evaluation (see Table 4-1).

The most significant COCs likely consist of benzene for a gasoline release, and naphthalene and benzo(a)pyrene (BAP) in a diesel or heavy fuel release.[4] These compounds have relatively low drinking water quality standards in the Washington Administrative Code (WAC) (see WAC 173-200) that are established at 1 microgram per liter (µg/L), 160 µg/L, and 0.008 µg/L for benzene, naphthalene, and BAP, respectively. Chemical characteristics of the MTCA COCs in each fuel type are outlined in Table 4-1.

[4] Under Ecology's MTCA program, jet fuel is generally considered to be a heavy fuel.

Table 4-1 Petroleum Constituents and Screening Values

Common Name	Use	Human Health (Drinking Water)	Transport in Groundwater	Health Risk	Volatility	Other Properties			
		WAC 173-200 Regulatory Levels[1, 2] (µg/L)	Retardation Factor[3]	Oral Reference Dose (mg/kg-day)	Henry's Constant (Kh') (unitless)	Organic Carbon Partition Coefficient (Koc) (L/kg)	Molecular Weight (g/mol)	Aqueous Solubility (mg/L)	Liquid Density (mg/L)
Benzene	Gasoline	1	1	4.00E-03	1.34E-01	62	78	1,750	8.77E+05
Ethylbenzene	Gasoline	700	1	1.00E-01	1.64E-01	204	106	169	8.67E+05
Toluene	Gasoline	1,000	1	8.00E-02	1.49E-01	140	92	526	8.67E+05
Xylenes (total)	Gasoline	10,000	1	2.00E-01	1.41E-01	233	106	171	8.75E+05
Benz(a)anthracene	Heavy fuel/Diesel	TEF	507	—	9.60E-05	3.58.E+05	228.3	9.40E-03	1.27E+06
Benzo(a)pyrene	Heavy fuel/Diesel	0.008	1,371	3.00E-04	3.61E-06	9.69.E+05	252.32	1.62E-03	1.35E+06
Benzo(b)fluoanthene	Heavy fuel/Diesel	TEF	848	—	6.04E-06	5.99.E+05	252.32	1.50E-03	1.30E+06
Benzo(k)fluoranthene	Heavy fuel/Diesel	TEF	831	—	4.28E-06	5.87.E+05	252.32	8.00E-04	1.30E+06
Chrysene	Heavy fuel/Diesel	TEF	257	—	3.87E-05	1.81.E+05	228.3	2.00E-03	1.27E+06
dibenz(a,h)anthracene	Heavy fuel/Diesel	TEF	2,688	—	7.45E-07	1.90.E+06	278.36	2.49E-03	1.28E+06
Indeno(1,2,3-c,d)pyrene	Heavy fuel/Diesel	TEF	2,759	—	8.32E-03	1.95.E+06	276.34	1.90E-04	1.40E+06
Napthalene	Gasoline/Diesel	160	3	2.00E-02	8.32E-03	1,190	128	31	1.16E+06
n-hexane	Gasoline	NE	6	6.00E-02	4.47E+01	3,410	86	9.5	6.59E+05
1-methylnaphthalene	Gasoline/Diesel	160	5	7.00E-02	8.16E-03	2,530	142.2	25.8	1.02E+06
2-methylnaphthalene	Gasoline/Diesel	160	5	4.00E-03	7.00E-03	2,480	142.2	24.6	1.01E+06

Notes

[1] WAC 173-200 regulatory levels for drinking water are from https://apps.ecology.wa.gov/publications/documents/9602.pdf

[2] Values of TEF for the drinking water regulatory levels are calculated using a TEF based on the relative potency of benzo(a)pyrene.

[3] The retardation factor is calculated using effective porosity = 35%, fraction organic carbon (foc) = 0.0001, and soil bulk density =1,650 kg/m^3.

— = not applicable

µg/L = micrograms per liter

g/mol = grams per mole

kg/m^3 = kilograms per cubic meter

Koc = organic carbon partition coefficient

mg/kg-day = milligrams per kilograms per day

mg/L = milligrams per liter

NE = not established

TEF = toxicity equivalence factor

WAC = Washington Administrative Code

4.1.2 Travel Times from Yellowstone Petroleum Pipeline to City Well Stations

In general, the COCs present in gasoline (primarily consisting of benzene, ethylbenzene, toluene, and xylenes [BTEX]) consist of smaller carbon chains and have lower retardation factors than those for compounds found in diesel and jet fuel. The retardation factor reflects the average velocity of the COC in the mid-portion of a plume. A retardation factor of 1 indicates that the COC would travel at the same relative velocity as the groundwater and would not be retarded significantly by organic carbon and other materials in the aquifer matrix. A COC with a low retardation factor can be present at the leading edge of a plume at concentrations that may exceed its associated drinking water standard if that standard is relatively low. Based on aquifer conditions, BTEX compounds would be expected to have retardation factors of approximately 1, meaning these compounds would move at a rate nearly equivalent to the overall groundwater seepage velocity and would be retarded only slightly by adsorption to the soil matrix of the aquifer. This is especially of concern for benzene, which has a drinking water standard of 1 μg/L.

Diesel fuel and jet fuel consist of longer chain hydrocarbons which generally have higher retardation factors than the BTEX compounds associated with gasoline. The compounds found in the heavier diesel and jet fuels would be expected to travel slower (be retarded more) than the lighter fractions present in gasoline. However, as shown on Table 4-1, although the retardation factor for BAP is approximately three orders of magnitude higher than that of benzene, its drinking water standard is also three orders of magnitude lower. Therefore, the BAP present in a diesel and/or jet fuel release would pose a similar risk to that of the benzene in a gasoline release.

Based on groundwater flow modeling results summarized in Section 3, travel times between a potential release and a City well station can span from several days to several months, depending on the location of the leak and type of product (and associated COCs) released. With a travel time of only a few days, there would be very little retardation of the COCs, and there would be a higher probability that the leading edge of a plume would contain COCs at concentrations near or exceeding applicable drinking water standards as a function of the type of product released, the size of the release, and the travel time in the subsurface.

4.2 Monitoring Alternatives

Releases from the pipeline that exceed minimum threshold rates would be detected within one day by YPL/P66 personnel using inventory control methods. In contrast, leakage rates that are less than the detection thresholds identified in Section 1.2 could go undetected for a long period of time, and alternative methods of detecting a release would be needed to provide early detection of threats to the City's groundwater sources. This section evaluates potential alternatives for using a subsurface monitoring program to detect petroleum hydrocarbons between a release at the pipeline and the well stations and includes discussion of the potential efficacy of the alternatives.

The primary purpose of a subsurface monitoring program would be to provide an early warning of contamination presence in the subsurface before contamination arrives at a City well station. Early warning monitoring would provide advanced notice of the need for operational changes to the City's water system in the event that contaminants arrive at a City well station after first being detected in an upgradient monitoring system. An effective detection monitoring system has the following attributes:

- Technically feasible and implementable within reasonable capital and operational resource requirements
- High likelihood of detecting a release, ideally sufficiently in advance of reaching a well station

Highly permeable soils, the length of pipeline upgradient of the City's well stations, and short travel times present challenges in developing and implementing a monitoring program that can provide high confidence that a release can be detected before water quality at a given well station is impaired. Possible monitoring alternatives include:

- Groundwater monitoring well network and sampling program to detect and quantify contaminated groundwater that may reach a well station
- Vapor monitoring to detect petroleum vapors overlying the pipeline and/or in the vadose zone downgradient of the pipeline
- Increased frequency of sampling of source water at the well stations

Each of these is discussed in further detail in the following sections.

4.2.1 Groundwater Monitoring Network

A groundwater monitoring system would involve installation of monitoring wells at locations where well station capture zones intersect the pipeline alignment, and a regular sampling and laboratory analysis regimen to provide early warning of the presence of contaminants within the capture zone of a well station. Although field screening methods are available, the detection limits would be elevated relative to drinking water standards and therefore may not capture the leading edge of a contaminant plume. The elements and considerations for a groundwater monitoring system are summarized as follows:

- **Monitoring Network:** Monitoring wells would be installed within a well station's capture zone at locations lying both upgradient and downgradient of the segments of the pipeline that intersect a well station's capture zone. Several dozen wells may be needed to provide sufficient spatial density within the City's well station capture zones to ensure detection of a release. The spacing of monitoring wells and their distances upgradient and downgradient from the pipeline would be determined from modeled plume geometry and travel times to the downgradient well station, with placement nearer to the pipeline and tighter spacing where the time of travel is short. In the case of Parkwater, where the travel time between the YP-03 segment of the pipeline and the well station is on a scale of a few days, wells would need to be placed adjacent to the pipeline and tightly spaced to provide high confidence in early detection of a release. Monitoring wells would be drilled and constructed to be screened across the water table.
- **Sampling:** Monitoring wells would be sampled on a regular frequency. For most well stations, the frequency of conducting sampling at an upgradient monitoring well or monitoring well network would need to be on the order of 1 to 4 months at a minimum. However, for the Parkwater well station, the frequency of sampling of the upgradient monitoring wells next to the pipeline segment that is closest to the well station would need to be on the order of 1 to 2 days, with samples analyzed on a rush (24-hour analysis) basis to provide a high level of confidence that a release would be detected before it affected water quality at this well station.
- **Considerations and Limitations:**
    - Establishing an effective network of wells for each well station would require significant capital expenditures for siting, property access (purchase/easement) and drilling wells. Interpretation of groundwater monitoring data could require that groundwater sampling be performed upgradient of the pipeline either as part of routine monitoring or in the event that contamination is detected in a monitoring well located downgradient of the pipeline. Data upgradient of the pipeline would allow for interpretations of whether a detection occurring downgradient of the pipeline is attributable to the pipeline or to a different contaminant source.

- While groundwater monitoring provides positive confirmation of the presence and actual concentrations of contaminants present in groundwater for comparison with drinking water standards, implementation of sampling at the frequencies needed for timely identification of threats to each well station would require one or more trained City personnel or a contractor for as long as the pipeline operates and/or a spill from the pipeline can affect the well stations.
- Another consideration is laboratory analysis of the samples. Standard analysis timeframes to process and analyze samples may be sufficient for the groundwater monitoring networks for most well stations, but overnight (“rush”) analyses would be required for some of the Parkwater monitoring wells to ensure early detection of a spill from the pipeline segment that lies nearest the well station. This “rush” analysis would cost roughly twice the cost of a standard analysis timeframe.

4.2.2 Vapor Monitoring System

A vapor monitoring system could be installed in the vicinity of pipeline segments that are intersected by well station capture zones to detect the volatile fraction of hydrocarbon vapors emanating from a release.

- **Monitoring Network:** Vapor monitoring would utilize a system of relatively closely spaced shallow wells completed in the unsaturated zone above or a short distance downgradient of pipeline segments. Each well would be installed to a depth of approximately 5 feet below grade, with a short screen section open to the unsaturated zone.
- **Sampling:** Instrumentation is available that is capable of immediately detecting elevated volatile organic compound (VOC) concentrations in the field, eliminating time lags for laboratory analyses and it is possible to sample many points quickly.
- **Considerations and Limitations:**
  - Vapors can readily move along preferential pathways such as utility corridors and could originate from other releases such as gas station locations. Therefore, the origin of an elevated VOC concentration may not necessarily be readily known; this limitation can be somewhat mitigated by increasing the density of the well network.
  - The unit cost for drilling and installing vapor monitoring wells would be significantly less than a groundwater monitoring network; however, the costs for siting and property access would be similar or perhaps more than in the case of a groundwater monitoring network, depending on the required density to mitigate for potential false positives caused by preferential pathways in the vadose zone (such as utility corridors).
  - The major drawback to a vapor monitoring system is that it has limited effectiveness in detecting releases of semi-volatile organic compounds (SVOCs). Diesel and jet fuel consist almost predominantly of SVOCs. Because 60 percent of the product transported through the pipeline consists of heavier fuel consisting of SVOCs, there may be limited utility in installing a vapor monitoring system because it may not be effective in detecting releases of product other than gasoline (which comprises 40 percent of the product transported through the pipeline).
  - Vapor monitoring also would not quantify the concentration of COCs in groundwater alone, which means that groundwater monitoring wells and/or a groundwater investigation would be necessary to quantify and further understand the nature and extent of contaminants in the subsurface.

4.2.3 Supply Source (Wellhead) Monitoring

High frequency point-of-source sampling is another alternative in lieu of establishing monitoring wells/observation wells located upgradient of a given well station—particularly in the case of the Parkwater well station. For Parkwater, this alternative would involve sampling raw water produced at Parkwater and analyzing the samples for VOCs and SVOCs on an accelerated (24- to 48-hour basis). The advantage of this alternative is that samples could be obtained from a single point with existing infrastructure, and sampling could be conducted using existing staff and protocols, thereby saving the cost of installing wells, training additional staff, and sampling multiple points. The primary disadvantage of this alternative is that it would not provide any early warning, and it is possible that the first indication of a release would be a water quality exceedance.

4.2.4 Conclusions

Each alternative described in this section of the report for early detection of a release would be resource-intensive and costly. Costs would include capital costs for (1) equipment installation and maintenance (i.e., installing and maintaining vapor monitoring wells, groundwater monitoring wells, and sampling equipment), (2) laboratory analytical costs, and (3) labor costs (for sample collection, data management and review, data interpretation, and communication of results to stakeholders). The efficacy of any of the monitoring alternatives would depend on long-term commitment of City resources to varying degrees. For most of the well stations, a groundwater monitoring system may be the most effective way to provide significant lead time to respond operationally to a release that is not detected by YPL's inventory control methods. In the case of the Parkwater well station, with travel times from one segment of the pipeline that are on the order of a few days, the required density and frequency of sampling monitoring wells to provide any advance warning of a release may be cost prohibitive; an increased frequency of point-of-source sampling may be the most feasible of the monitoring alternatives. Regardless of how monitoring is conducted in the future, the pipeline's close proximity to Parkwater requires particularly rapid communication and coordination between YPL and the City in the event that a release from the nearby pipeline segment is suspected by YPL to have occurred, or in the event that contamination is detected at Parkwater by the City.

5 Emergency Operational Responses, Mitigation Measures, and Emergency Response Plan Updates

This section provides a summary of the types of emergency response measures and procedures for the City to take with its well stations and distribution system operations for incorporation into the City's existing ERP. The emergency response actions summarized in this report focus on operational responses, mitigation measures, and ERP updates the City could take to protect the quality of drinking water served to the public and to address supply shortfalls caused by the shutdown of affected sources. It is assumed that YPL would be responsible for cleanup responses, including source control and delineation and remediation of contaminated media, including groundwater.

Section 5.1 presents the distribution system modeling of two emergency response scenarios and the operational responses and mitigation measures that have been identified from the modeling results. Section 5.2 briefly describes the DSCRP document, which is contained in Appendix F of this report. Section 5.3 summarizes the recommended operational response procedures, mitigation measures, and plan updates for YPL and the City to consider implementing and incorporating into the ERPs.

5.1 Emergency Response Modeling

The distribution system model was used to evaluate two emergency response scenarios. Section 5.1.1 describes the scenarios and presents the model simulation results for each scenario. Section 5.1.2 discusses operational response procedures and mitigation measures for the water system that the City can undertake to decrease the vulnerability of the distribution system to an aquifer contamination event.

5.1.1 Scenarios and Results

After reviewing distribution system behavior during an emergency loss of supply due to a contamination event, Consor and the City identified two feasible emergency responses for the worst-case supply scenario (Parkwater and Well Electric Well Stations Offline):

- **Emergency Response 1:** Backflow from Intermediate primary supply zone to Low primary supply zone. PRVs with pressure-sustaining features were added in the model to the Bishop Court and 9th & Pine booster stations. This allows excess supply from the Intermediate primary supply zone to be used in the Low primary supply zone.
- **Emergency Response 2:** Demand Curtailment. Based on the mass balance analysis and the estimated minimum amount of supply needed through the Northwest Terrace Dalke PRV, a 12 percent demand reduction was applied to the Low primary supply zone in the model.

Table 5-1 summarizes the results with and without these two emergency response scenarios.

Table 5-1 Emergency Response Results Summary for the Worst-Case Supply Scenario (Parkwater and Well Electric Well Stations Offline)

<table>
<tr><th>Result</th><th>Before Applying Emergency Responses</th><th>Emergency Response 1: Backflow from Intermediate to Low</th><th>Emergency Response 2: Demand Curtailment</th></tr>
<tr><td>Primary zones with failed MDD mass balance</td><td>Low</td><td>None</td><td>None</td></tr>
<tr><td>% customers with pressures < 30 psi</td><td>100%</td><td>+0.2% from baseline</td><td>0.1% from baseline</td></tr>
<tr><td>Primary supply zone tanks[1] that fail to reach 95% tank volume</td><td rowspan="4">Low primary supply zone tanks begin draining completely starting at 32 hours</td><td>Baseline Tanks
14th & Grand</td><td>Thorpe Rd</td></tr>
<tr><td>Approx % tank recovery volume lost</td><td>Indian Trail: 18%
West Drive: 19%
9th&Pine: 50%
14th&Grand: 21%
Rockwood Vista: 33%
Lincoln Heights: 8%
Shadle Park: 8%
Five Mile: 6%
Qualchan: 8%</td><td>Indian Trail: 18%
West Drive: 16%
9th&Pine: 51%
Thorpe Rd: 19%
Rockwood Vista: 34%
Shadle Park: 7%
Five Mile: 6%
Qualchan: 14%</td></tr>
<tr><td>Tanks where minimum level decreases by >5%</td><td>9th&Pine
14th&Grand
Thorpe Rd
Rockwood Vista
Lincoln Heights
Qualchan</td><td>9th&Pine
14th&Grand
Thorpe Rd
Rockwood Vista
Qualchan</td></tr>
<tr><td>Tanks that drain to empty</td><td>None</td><td>None</td></tr>
<tr><td>Primary zones affected</td><td>Intermediate
Low
North Hill</td><td>Intermediate
Low
North Hill</td><td>Intermediate
Low
North Hill</td></tr>
<tr><td>Transmission Impacts</td><td>Losses in North Hill</td><td colspan="2">Losses near 9th&Pine and 14th&Grand</td></tr>
</table>

Notes

psi = pounds per square inch

PRV = pressure-reducing valve

Exhibits 5-1 and 5-2 show the primary supply zone tank cycles in percent volume over the course of a week under the two emergency response scenarios.

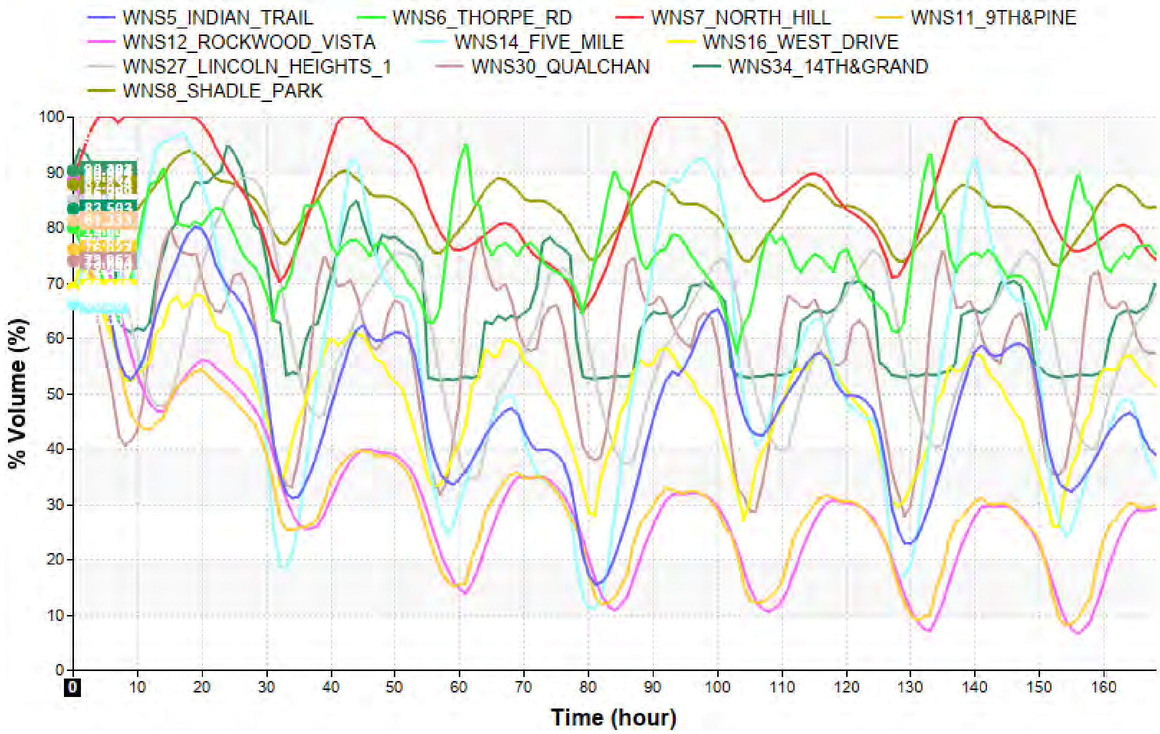

Exhibit 5-1 Tank Cycles for Backflow Emergency Response Scenario

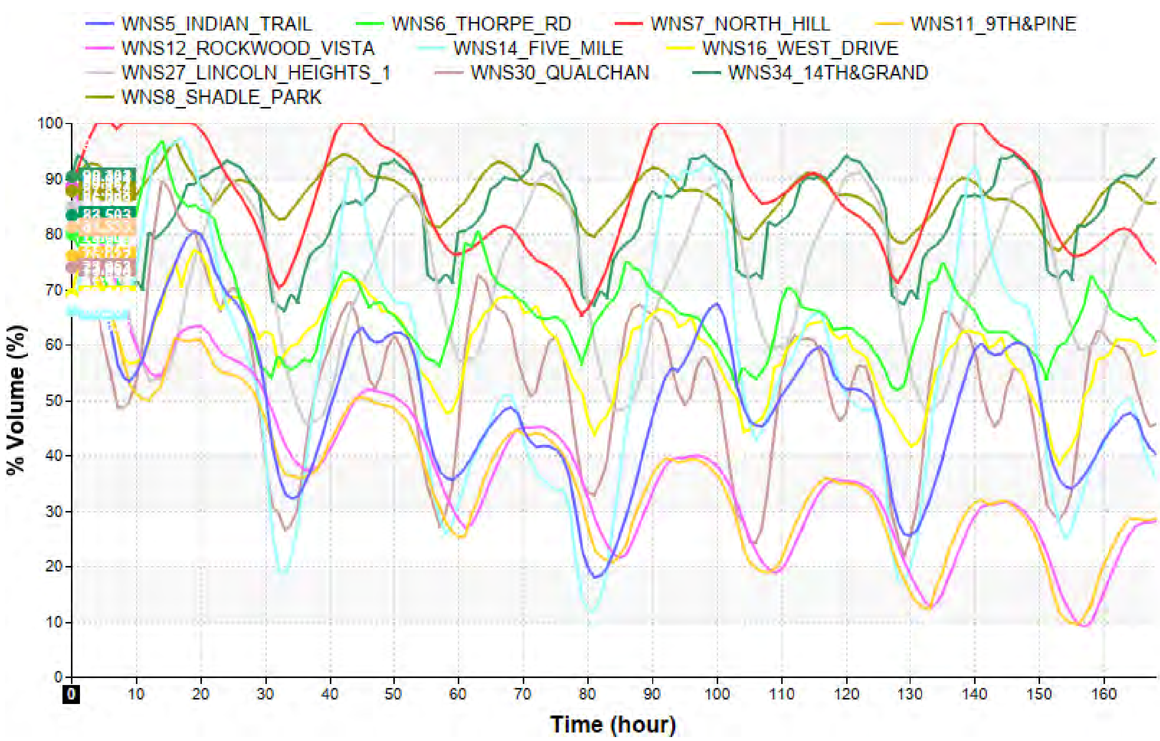

Exhibit 5-2 Tank Cycles for Demand Curtailment Emergency Response Scenario

5.1.2 Operational Response Procedures and Mitigation Measures

The City can take several steps to decrease the vulnerability of the distribution system to an aquifer contamination event. Table 5-2 lists emergency response procedures and mitigation measures that the modeling analysis showed to be effective in meeting the performance criteria defined in Table 2-1 for an emergency supply configuration. Note that the modeling analysis focused on the distribution system behavior during a high-use summer day with an MDD level of demand; fewer extreme measures would be required during a cooler part of the year.

Table 5-2 Potential Operational Response Procedures and Mitigation Measures for the Four Emergency Scenarios Evaluated

Operational Response Procedure or Mitigation Measure	Proactive or Reactive?	Addresses Which of the Evaluated Scenarios?	Notes
Demand curtailment: Temporarily stop Parks irrigation	Reactive Operational Response	All Four Scenarios	Request that the City Parks Department temporarily stop irrigation until a city-wide demand curtailment campaign is complete.
Demand curtailment: 12% Minimum in the Low primary supply zone	Reactive Operational Response	All Four Scenarios	Implement an irrigation reduction campaign to all customers, but focus on customers served by the Low primary supply zone.
Install/operate backflow pressure-reducing valves between Low and Intermediate primary supply zones	Proactive (Installation) and Reactive (Operational Response)	Parkwater and Well Electric Well Stations Offline Parkwater Well Station Offline	PRVs may require a sustaining feature to prevent excessive flow from the Intermediate primary supply zone.
Install/operate secondary reducing pilot system at the new Northwest Terrace PRV station	Proactive Reactive Operational Response	Parkwater and Well Electric Well Stations Offline Parkwater Well Station Offline	Design should allow for lower emergency PRV setting on new PRVs serving the Northwest Terrace pressure zone.
Utilize the Kempe-Shawnee intertie	Reactive Operational Response	Well Electric Offline	Operators should be ready to supplement recovery of the Shawnee tank during peak use times from the Kempe tank during emergency supply scenarios.
Transmission System Improvements: Parkwater Intermediate 24-inch discharge	Proactive	Havana St. and Ray St. Well Stations Offline	This emergency scenario requires the use of both Intermediate Parkwater Pumps 1 and 2.
Transmission System Improvements: Northwest Terrace pressure zone and Indian Trails area	Proactive	Parkwater and Well Electric Well Stations Offline Parkwater Well Station Offline	With transmission upgrades here, the Sundance North Hill PRV to Northwest Terrace could take over from the Low PRV is Low supply is lost. Some transmission upgrades in this area are already in design/construction.
Transmission System Improvements: Low primary supply zone	Proactive	Parkwater and Well Electric Well Stations Offline Parkwater Well Station Offline	Increased transmission capacity in the Low primary supply zone would allow the system more flexibility to leverage the Nevada well station. The ongoing Marshall Road transmission improvements will contribute to this mitigation measure.
Review summertime usable storage	Proactive	All Four Scenarios	Ensure adequate emergency storage available after summer operational/equalizing storage is depleted.

In addition to the operational response procedures and mitigation measures shown in Table 5-2, another long-term potential option could involve batching and or blending the groundwater pumped by a given well station, particularly in a case where the Parkwater well station is impacted by a release from the pipeline. Currently, water generated at this well station is distributed through the water system almost immediately. Storing the water for a period and/or blending it with other well water before distribution could dilute COC concentrations in the event of a release. However, batching or blending is not feasible with the City's current infrastructure due to the interconnectivity of the transmission and distribution systems; retrofits would be required to make batching or blending a feasible mitigation measure for providing sufficient water supply during an emergency.

5.2 Distribution System Contamination Response Procedure

A DSCRP document was developed during this study, using the U.S. Environmental Protection Agency's *Guidance for Responding to Drinking Water Contamination Incidents* (EPA, 2018). The DSCRP describes YPL's and the City's ERPs and procedures and is intended to be a reference document included as an appendix to the City's ERP. The DSCRP can be found in Appendix F.

The DSCRP was developed during this study specifically for City of Spokane staff to respond to a potential leak or break from the Yellowstone petroleum pipeline, as well as resulting contamination incidents impacting the SVRP Aquifer. The DSCRP is intended to be a living document and should be updated as new information is identified, policies and response procedures are updated, or infrastructure improvements are completed. The DSCRP is designed to be scalable such that, for future iterations, the City can elect to include a broader range of potential contamination incidents across the water distribution system.

The purpose of the DSCRP is to clearly outline the roles and responsibilities of City personnel and the operational responses of the distribution system in the event of a potential contamination incident involving the Yellowstone petroleum pipeline, considering the current infrastructure and demands. However, the DSCRP goes beyond the immediate response framework by also outlining potential future mitigation actions that the City may choose to implement to reduce the overall risk of such incidents. As previously mentioned, the DSCRP is intended to be iterative as new mitigation measures are introduced. It should be considered a living document, continuously updated to reflect ongoing improvements and changes. The project scope did not include full development of specific operational response procedures for a contamination event, but this study—particularly the groundwater and distribution system modeling results—form the building blocks for the City to add concise and usable response procedures to the DSCRP.

5.3 Recommended Operational Response Procedures, Mitigation Measures, and Plan Updates

This section of the report concludes with a list of recommended operational response procedures and mitigation measures for YPL and the City to incorporate into their ERPs. The list falls under three categories: infrastructure improvements (Section 5.3.1), water system operations (Section 5.3.2), and planning-level and communication improvements (Section 5.3.3). This section is intended to support the City's decision-making in capital improvement planning and to support the creation of specific operational procedures that would be added to the DSCRP and used by City operators during a contamination event.

5.3.1 Infrastructure Improvements

- Implement the 6 proactive infrastructure improvements identified in Table 5-2 for the water distribution system:
  - Confirm the feasibility of operating backflow PRVs between the Low and Intermediate primary supply zones.
  - Consider adding a secondary reducing pilot system at the new Northwest Terrace PRV station to reduce flow during emergencies.
  - Implement transmission system improvements at the Parkwater well station (24-inch discharge piping for the Intermediate primary supply zone).
  - Implement transmission system improvements in the Northwest Terrace Pressure Zone and Indian Trails area.
  - Implement transmission system improvements in the Low primary supply zone, to better leverage production from the Nevada well station.
  - Ensure adequate emergency storage is available after summer operational/equalizing storage is depleted.
- Implement improvements at City well stations, including:
  - Construct a new deep wellfield at the Well Electric well station, which would pump from deep zones in the SVRP Aquifer to minimize the potential for contaminants in shallow groundwater to appear in the pumped groundwater supply.
  - Implement improvements where needed at the four northernmost well stations (Nevada, Grace, Hoffman, and Central), which are the furthest from the Yellowstone petroleum pipeline, but would all be critical for providing sufficient water supply to all three primary supply zones under each of the emergency scenarios evaluated in this study.
  - Implement improvements at the Ray Street and Havana Street well stations, which are critical for providing sufficient water supply under all of the emergency scenarios involving Parkwater and/or Well Electric being offline. Water supply to the Low primary supply zone from the Havana Street well station should be prioritized because of the Low primary supply zone’s vulnerability to an emergency, and the ability of the Havana Street well station to augment supplies feeding the Low primary supply zone.
  - Consider other locations to develop one or more new well stations.

5.3.2 Water System Operations

- Evaluate the feasibility and value of implementing changes to the transmission system that would allow batching and or blending to occur when groundwater pumped from a well station is impacted by a release from the pipeline.
- To meet current and/or future levels of demand:
  - Be prepared to immediately conduct a demand curtailment campaign, including coordination with the City Parks Department on stopping irrigation at City parks until other irrigators begin curtailment.
  - Be prepared to operate backflow PRVs and/or a secondary pilot system at the proposed Northwest Terrace PRV to limit flow out of the Low primary zone.
  - Be prepared to operate the Kempe-Shawnee intertie during a loss of supply to the North Hill primary supply zone.

- To meet the future 50-year projected level of demand:
  - Be prepared to operate deep wells at the Well Electric well station under any of the four emergency scenarios evaluated in this study. Operation of a deep wellfield may not be necessary from a supply standpoint for the projected 20-year level of demand, but may be desirable to provide increased supply resiliency and minimize the potential for contaminants to enter any groundwater that is pumped from this well station.
  - Be prepared to operate the Parkwater well station at its maximum production capacity to meet the MDD if Well Electric is offline.
  - Be prepared to operate the Nevada, Grace, Hoffman, and Central well stations at or near their maximum production capacity to meet the MDD under each emergency scenario.

5.3.3 Planning-Level and Communication Updates and Improvements

Planning-level and communication-related updates and improvements are warranted to existing response plans developed by YPL and the City. These updates and improvements are as follows:

- YPL
  - Update Sections 2.8 and 2.9.4 of the Yellowstone Pipe Line Company's Integrated Contingency Plan (ICP) to include timely notification to the City Water Department's emergency contacts. Emergency phone number contacts for the City Water Department are:
    - Station A: 509-625-7800
    - Upriver Control: 509-742-8141
  - Update the Emergency Response Action Plan (ERAP) (Appendix 8b of the ICP) to highlight the following:
    - If a release is suspected along pipeline segment YP-02 or YP-03 (both of which lie close to the Parkwater well station), provide timely notification to the City Water Department's emergency contacts in concurrence with YPL's initial condition assessment and as part of P66's execution of federal requirements (under Pipeline and Hazardous Materials Safety Administration [PHMSA] regulations) for notifications on pipeline releases.
  - In Appendix 3b (Section 3.2.31) of the ICP, highlight that the SVRP Aquifer is a sole source aquifer.
  - Continue to include the City in emergency operation response training exercises in accordance with the 2022 franchise agreement (City Ordinance C-35924) and Section 3.1 of the ICP.
  - Continue to meet annually with City of Spokane Water Department personnel to review YPL's Emergency Incident Response Plan and Incident Response Procedures and allow access to the plan through the third-party site Paradigm.
- City of Spokane
  - Develop an Operational Response Planning Decision Tree demonstrating the City's operational response to a pipeline leak.
    - Model the decision tree after the City's existing Wellhead Protection Emergency Response Flow Chart.
    - Include a long-term remediation and recovery phase.
    - Include an Emergency Contaminant Response Plan that is specific to the Parkwater well station. List concise pre-planned step-by-step operational procedures that can be quickly evaluated and implemented during an incident. This study, especially the distribution system analysis, is intended to provide a basis for developing such a procedure.

- Update the following City documents to incorporate current distribution system impacts, operational response and recovery measures, and YPL's Notification and Emergency Response Action Plan Field Document:
  - City Water Department's Emergency Notification Flow Chart.
  - City Water Department standard operating procedures.
  - Risk and Resiliency Assessment.
  - Wellhead Protection Plan.
  - Water Emergency Communications Plan (which is used to communicate with the public). This could be updated to reflect possible water restrictions, or a demand curtailment campaign based on which wells are impacted.
- Evaluate existing groundwater testing locations and capabilities for possible expansion improvements necessary to meet demands if a contamination incident were to occur.
- Review existing water testing laboratory contracts and capabilities to confirm they can test for petroleum products and confirm their capacity to respond to increased sampling needs, including turnaround time.
- Continue to meet annually with YPL/P66 to review the ICP and Incident Response Procedures. Use these meetings to review and discuss with YPL/P66 any updates on technologies that can be (or are being) implemented to quantify the lowest leakage rate (or range of rates) that can be detected in the pipeline, with appropriate qualifiers as needed to address measurement limitations/ uncertainties and to acknowledge the variability in product mixes and operating conditions for the pipeline. P66 personnel encourage annual response training exercises to be the venue for annual review and discussion of the ICP and response procedures.

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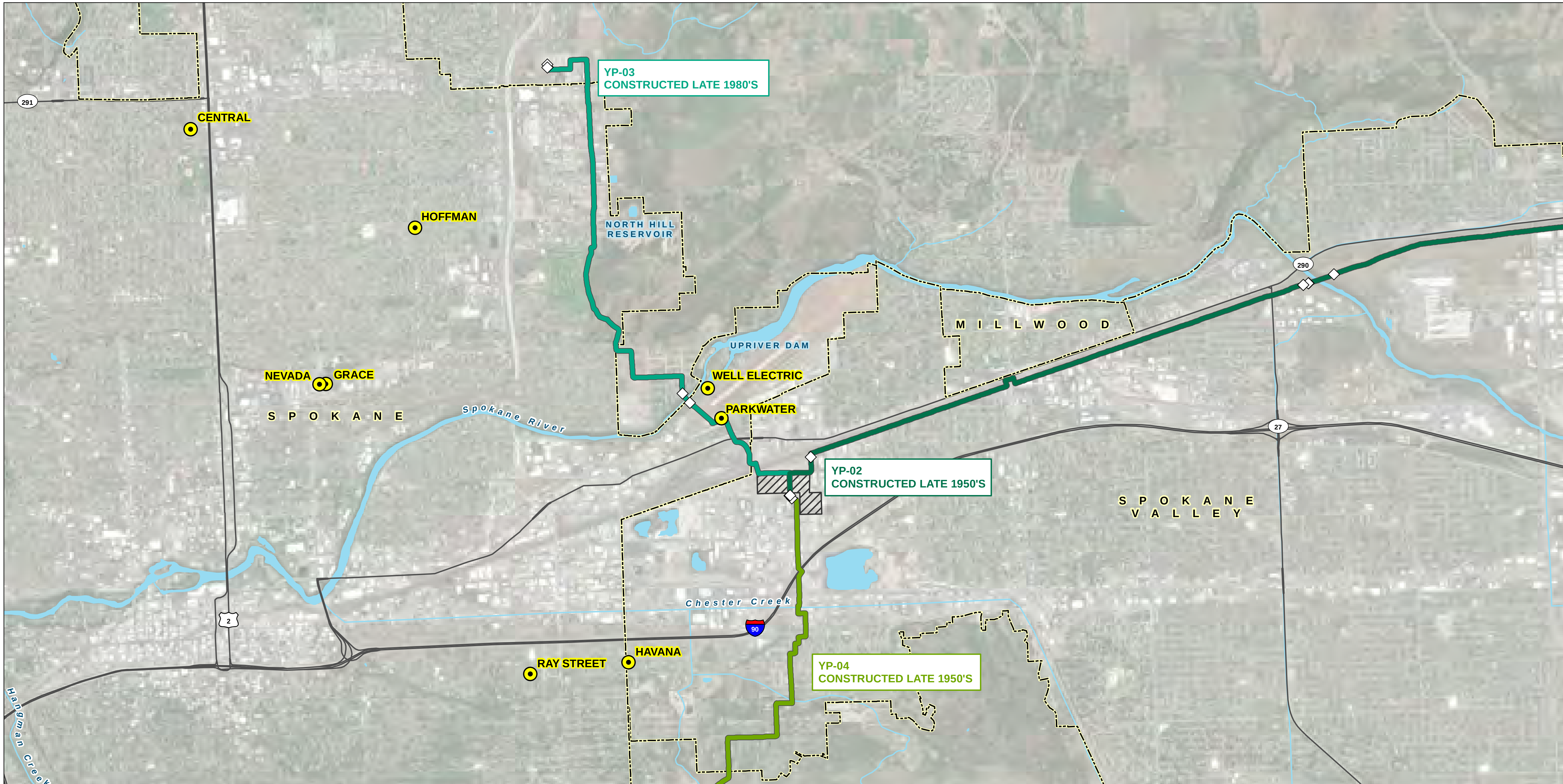
Figures



LEGEND

- Control Valves
- Well Station
- Bulk Fuel Facilities

Pipeline

- YP-02
- YP-03
- YP-04

All Other Features

- City Boundary
- Major Road
- Watercourse
- Waterbody

FIGURE 1-1

Location Map for City Well Stations

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

N

0 2,000 4,000 6,000

feet

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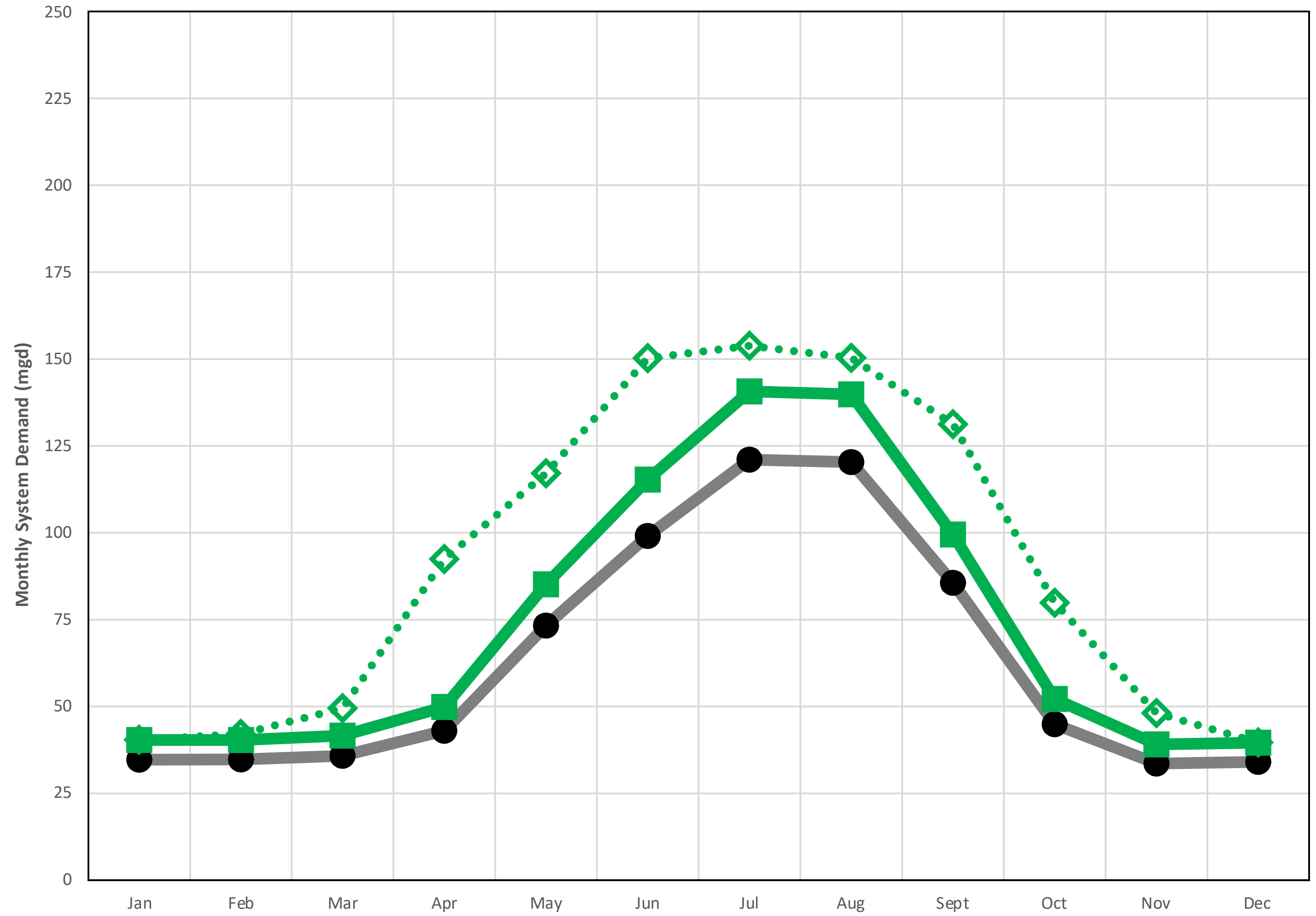
20-Year Demand Projection

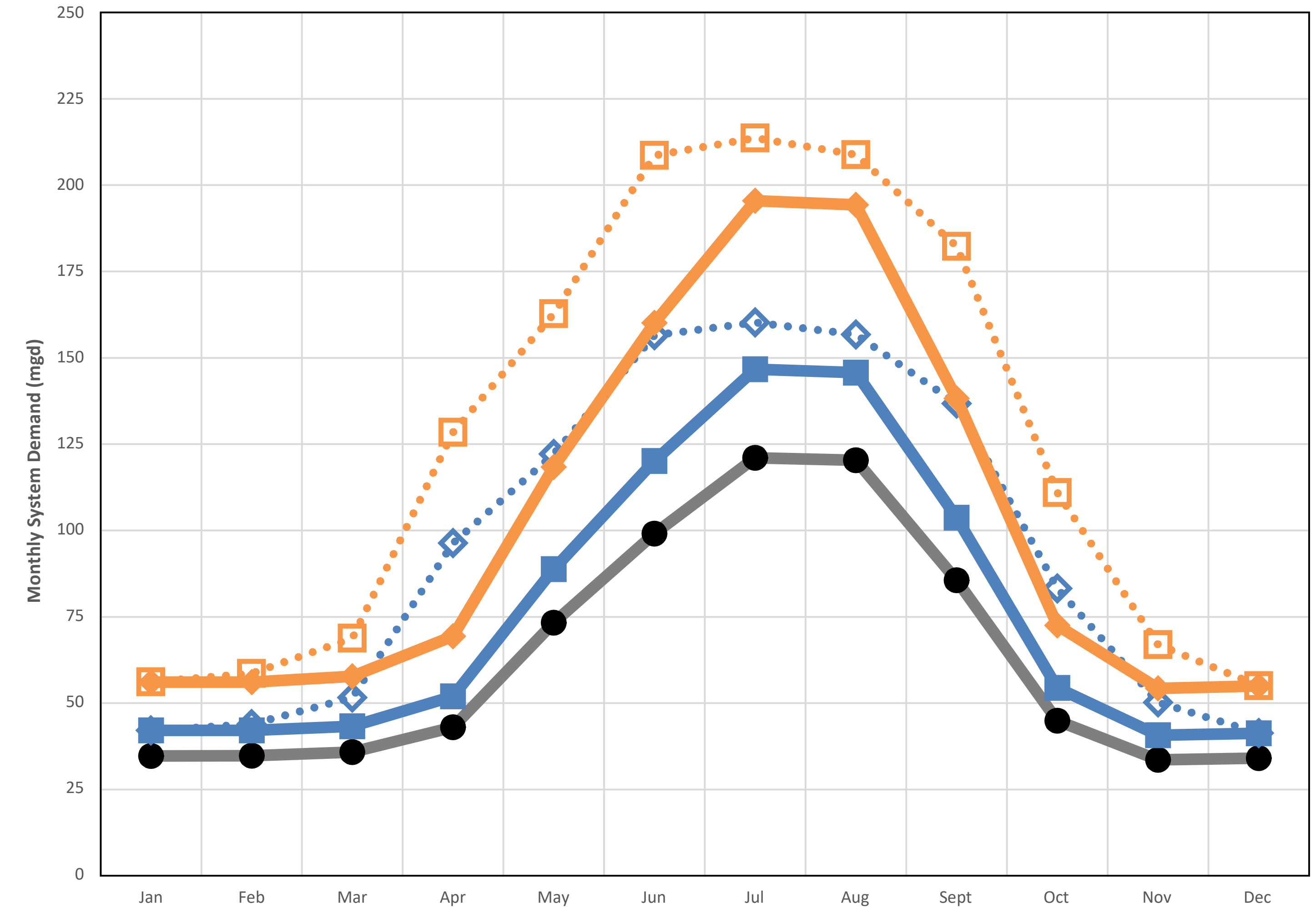


Average-Day Demands (ADD) and
Maximum Day Demands (MDD)

2015–2020:
ADD = 63.60 mgd, MDD = 141.30 mgd

2042:
ADD = 91.47 mgd, MDD = 186.42 mgd

50-Year Demand Projection



Average-Day Demands (ADD) and
Maximum-Day Demands (MDD)

2015–2020:
ADD = 63.60 mgd, MDD = 141.30 mgd

2072 Modest Level of Demand:
ADD = 95.32 mgd, MDD = 217.40 mgd

2072 High Level of Demand:
ADD = 127.06 mgd, MDD = 259.75 mgd

LEGEND

- 2015–2020 Avg. Demands
- 2042 Demands, No Climate Change
- 2042 Demands, RCP 4.5 Avg. Emissions Scenario
- 2072 Modest Level of Demand, No Climate Change
- 2072 Modest Level of Demand, RCP 8.5 Avg. Emissions Scenario
- 2072 High Level of Demand, No Climate Change
- 2072 High Level of Demand, RCP 8.5 Avg. Emissions Scenario

NOTES

RCP: Representative Concentration Pathway for future global greenhouse gas emissions.

The City's water rights are for an instantaneous pumping rate of 241,100 gallons per minute (gpm), which is equivalent to 347.184 million gallons per day (mgd).
The annual pumping allowed under the City's water rights is 147,570 acre-feet per year.

FIGURE 2-1

Historical and Projected Water Demands

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

GSI Water Solutions, Inc.

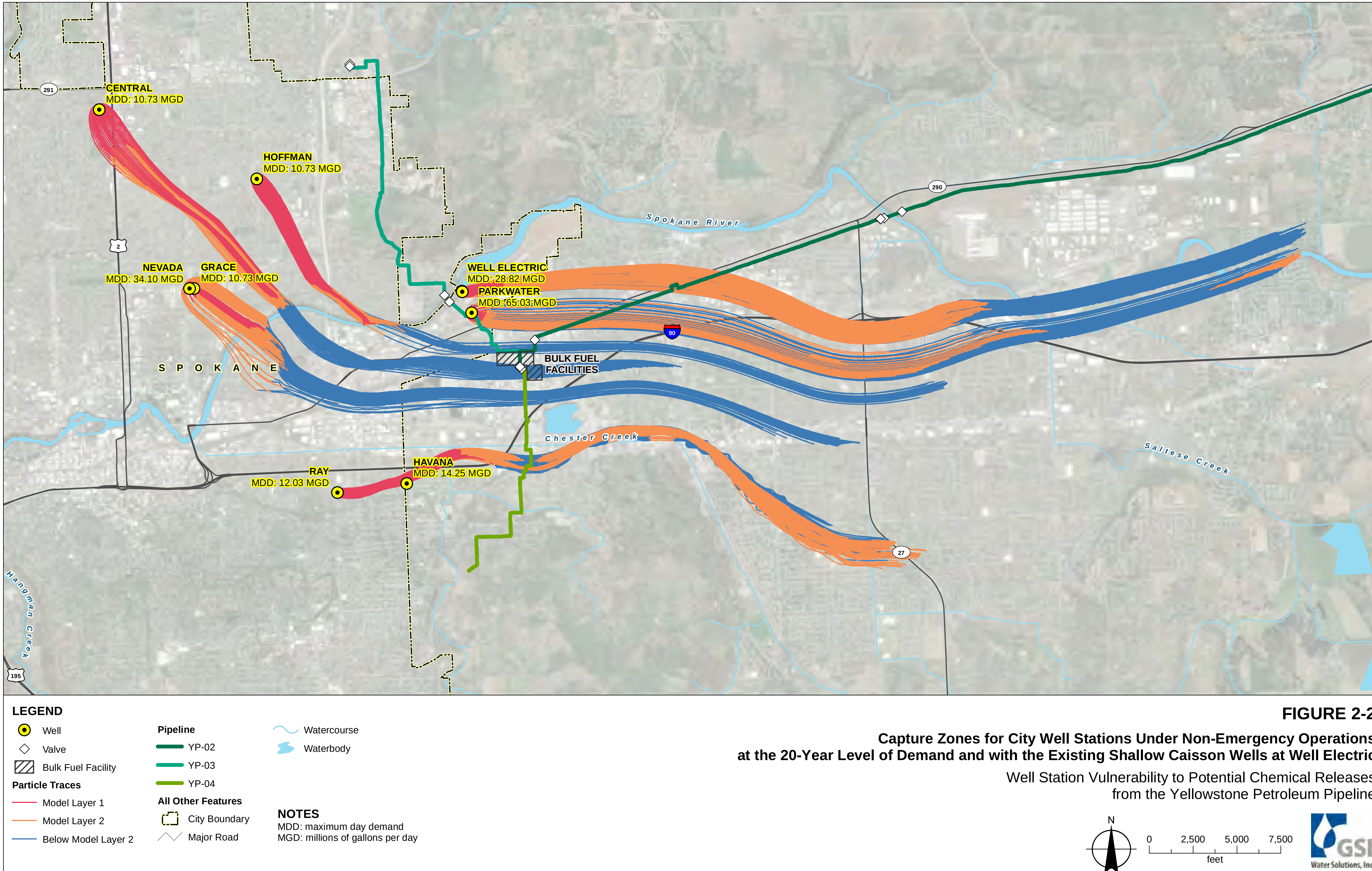


FIGURE 2-2

Capture Zones for City Well Stations Under Non-Emergency Operations at the 20-Year Level of Demand and with the Existing Shallow Caisson Wells at Well Electric

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

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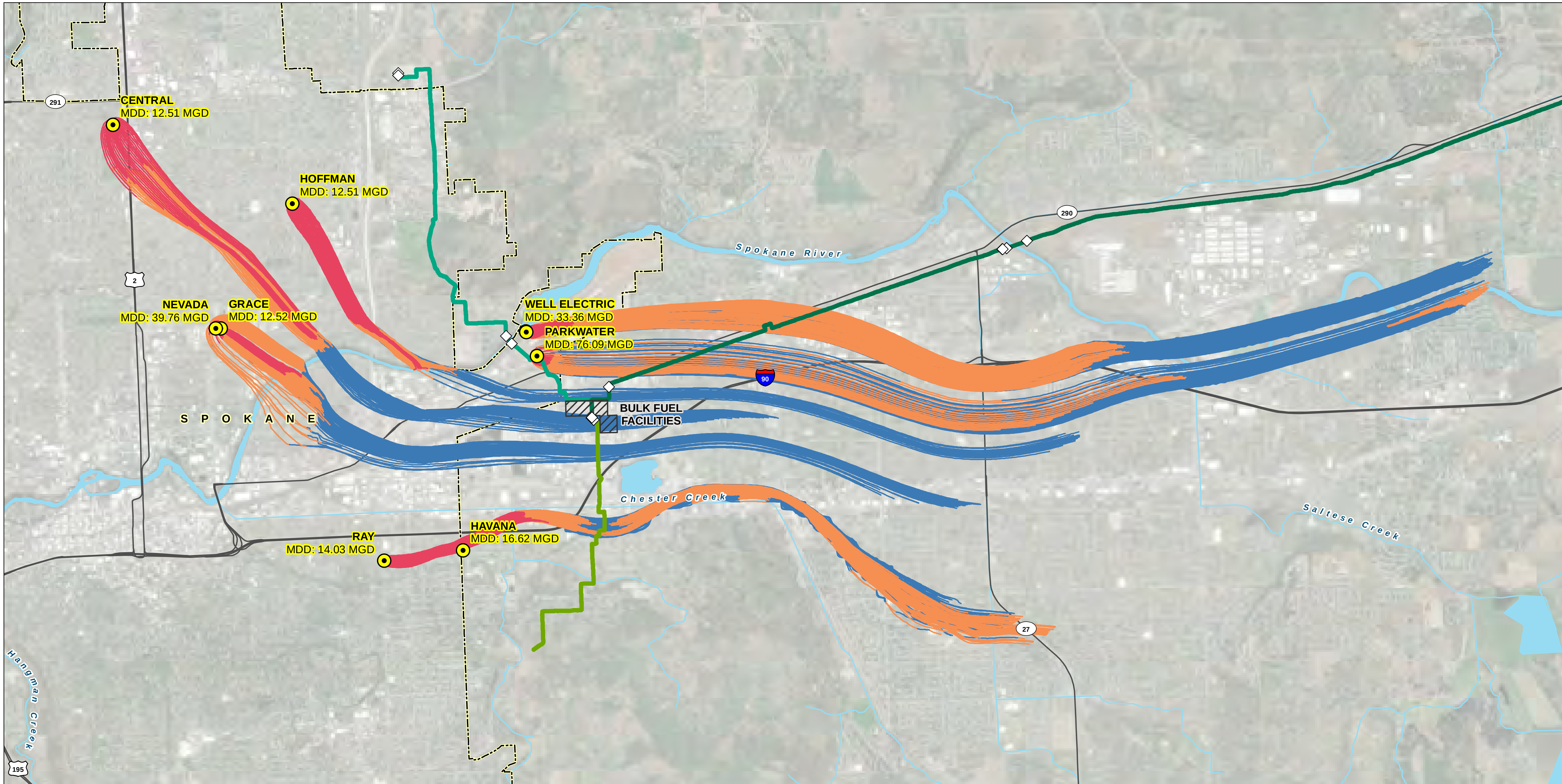

LEGEND

Well
Valve
Bulk Fuel Facility

Particle Traces
Model Layer 1
Model Layer 2
Below Model Layer 2

Pipeline
YP-02
YP-03
YP-04

All Other Features
City Boundary
Major Road

Watercourse
Waterbody

NOTES
MDD: maximum day demand
MGD: millions of gallons per day

N
0 2,500 5,000 7,500
feet

GSI Water Solutions, Inc.

FIGURE 2-3

Capture Zones for City Well Stations Under Non-Emergency Operations at the 50-Year Modest Level of Demand and with the Existing Shallow Caisson Wells at Well Electric

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

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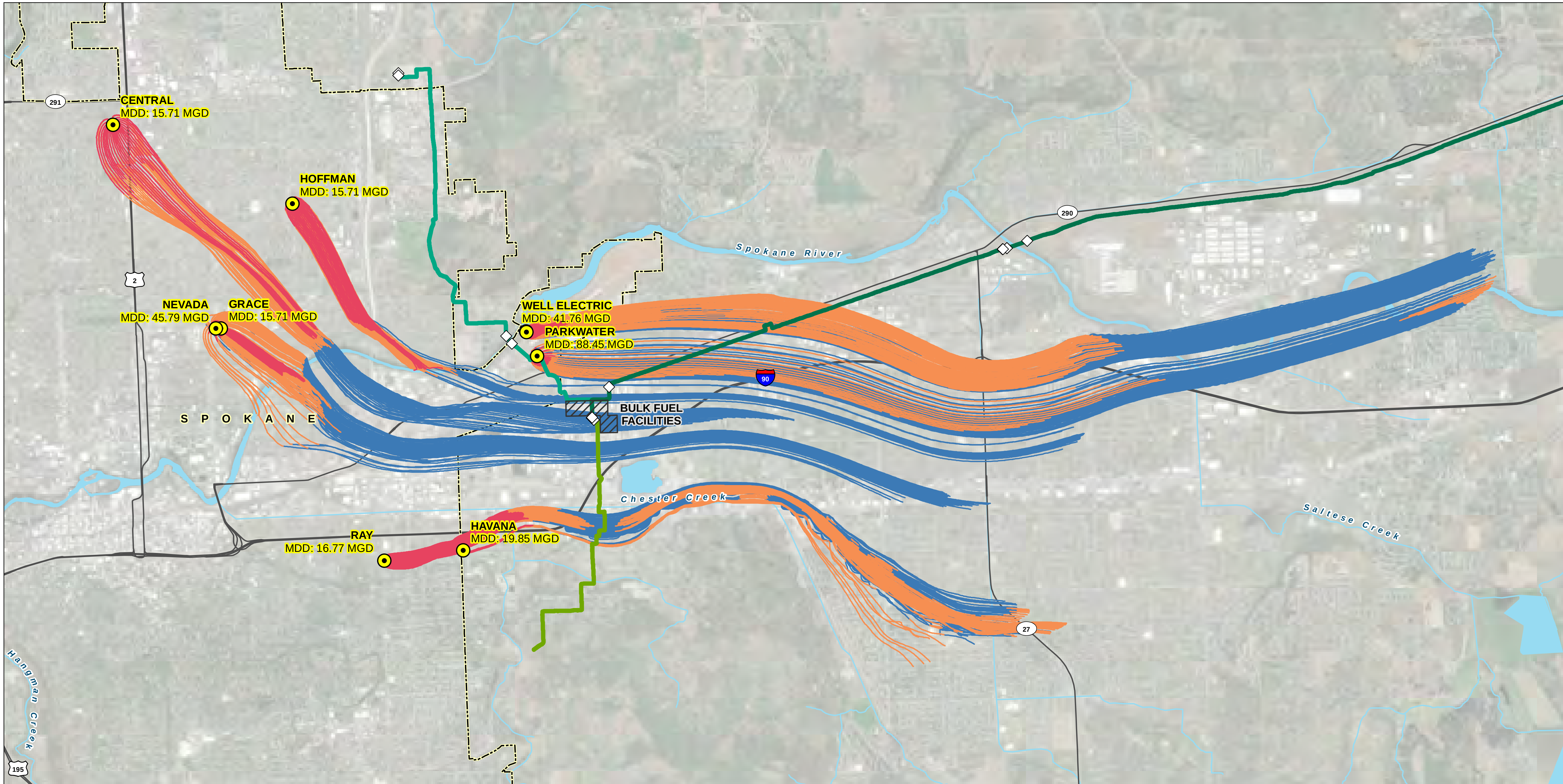


LEGEND

- Well
- Valve
- Bulk Fuel Facility

Particle Traces

- Model Layer 1
- Model Layer 2
- Below Model Layer 2

Pipeline

- YP-02
- YP-03
- YP-04

All Other Features

- City Boundary
- Major Road
- Watercourse
- Waterbody

NOTES

MDD: maximum day demand
MGD: millions of gallons per day

FIGURE 2-4

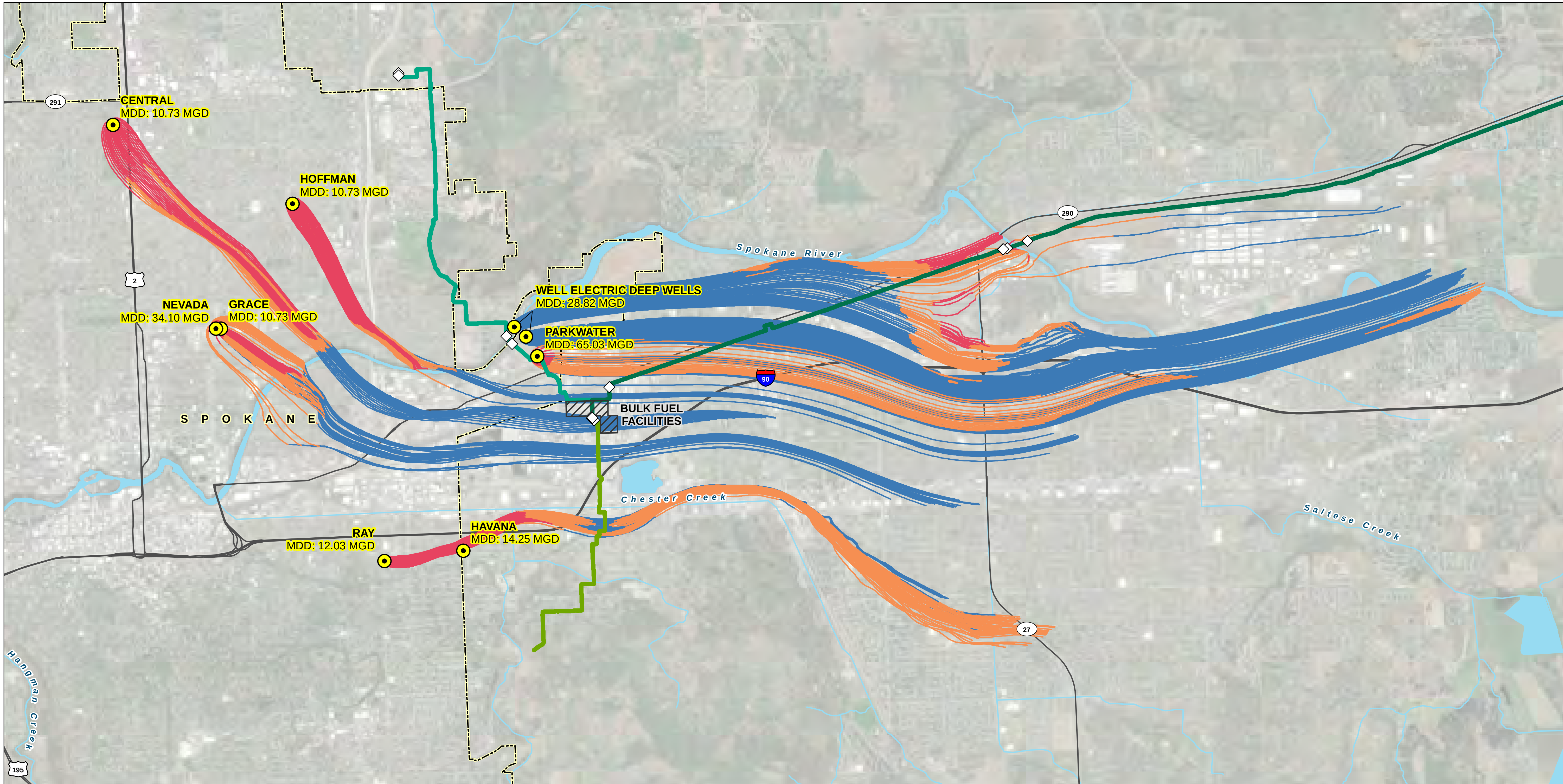
Capture Zones for City Well Stations Under Non-Emergency Operations at the 50-Year High Level of Demand and with the Existing Shallow Caisson Wells at Well Electric

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

N

0 2,500 5,000 7,500
feet

GSI Water Solutions, Inc.



LEGEND

Well

Valve

Bulk Fuel Facility

Particle Traces

Model Layer 1

Model Layer 2

Below Model Layer 2

Pipeline

YP-02

YP-03

YP-04

All Other Features

City Boundary

Major Road

Watercourse

Waterbody

NOTES

MDD: maximum day demand
MGD: millions of gallons per day

FIGURE 2-5

Capture Zones for City Well Stations Under Non-Emergency Operations at the 20-Year Level of Demand and with Future Hypothetical Deep Wells at Well Electric

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

N

0 2,500 5,000 7,500
feet

GSI Water Solutions, Inc.

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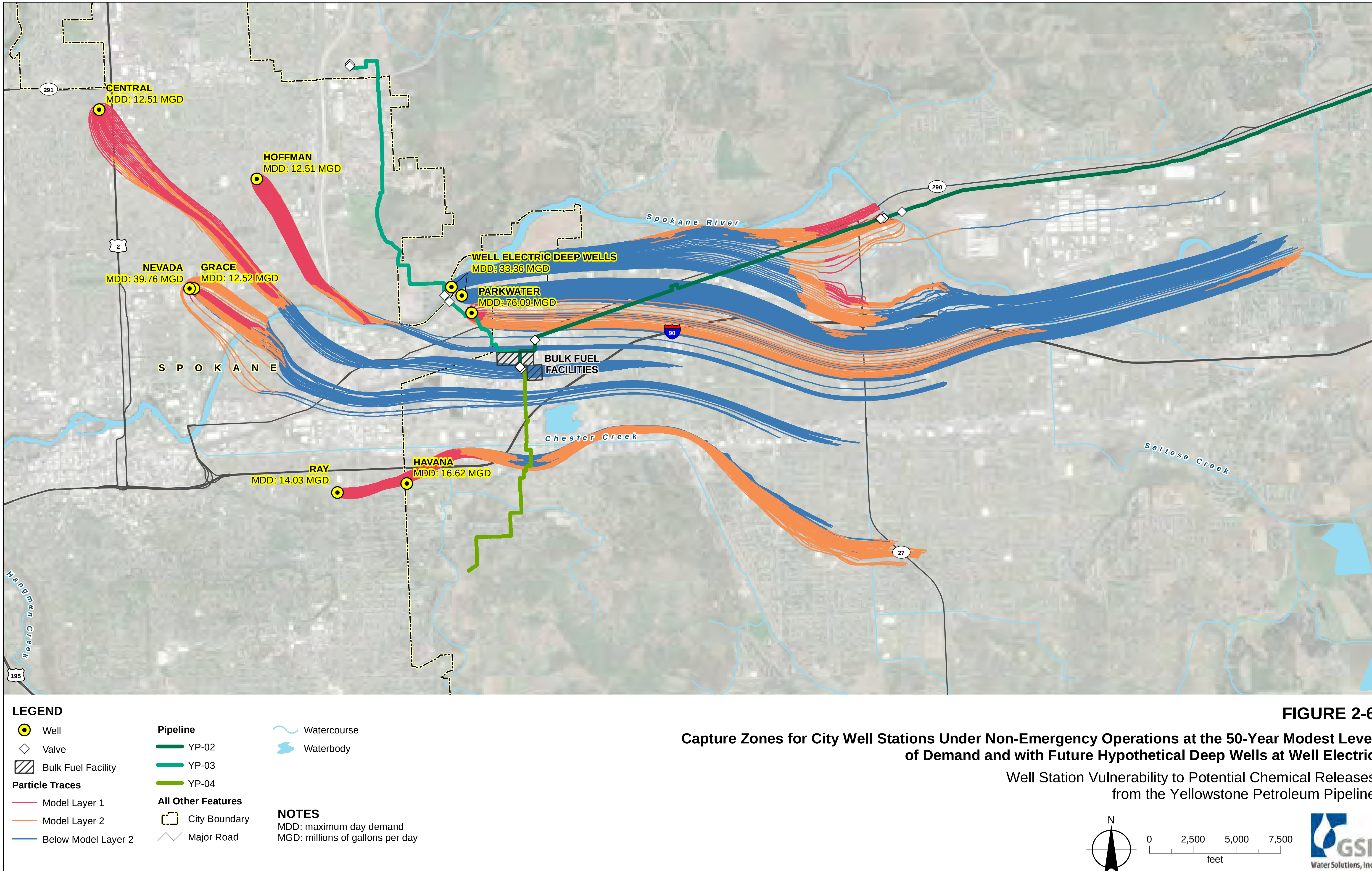

FIGURE 2-6

Capture Zones for City Well Stations Under Non-Emergency Operations at the 50-Year Modest Level of Demand and with Future Hypothetical Deep Wells at Well Electric

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

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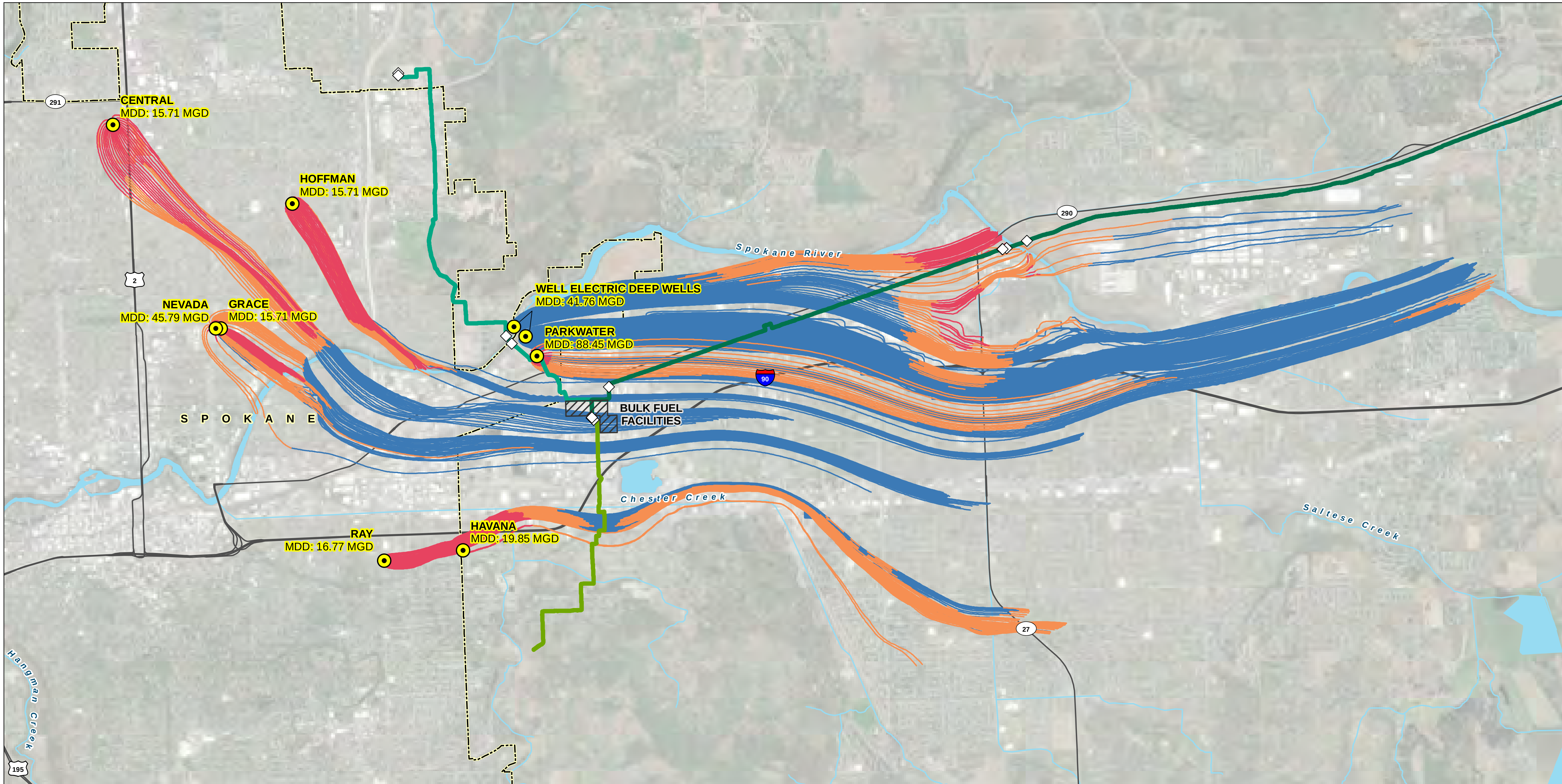

LEGEND

- Well
- Valve
- Bulk Fuel Facility

Particle Traces

- Model Layer 1
- Model Layer 2
- Below Model Layer 2

Pipeline

- YP-02
- YP-03
- YP-04

All Other Features

- City Boundary
- Major Road
- Watercourse
- Waterbody

NOTES

MDD: maximum day demand
MGD: millions of gallons per day

FIGURE 2-7

Capture Zones for City Well Stations Under Non-Emergency Operations at the 50-Year High Level of Demand and with Future Hypothetical Deep Wells at Well Electric

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

N

0 2,500 5,000 7,500
feet

GSI Water Solutions, Inc.

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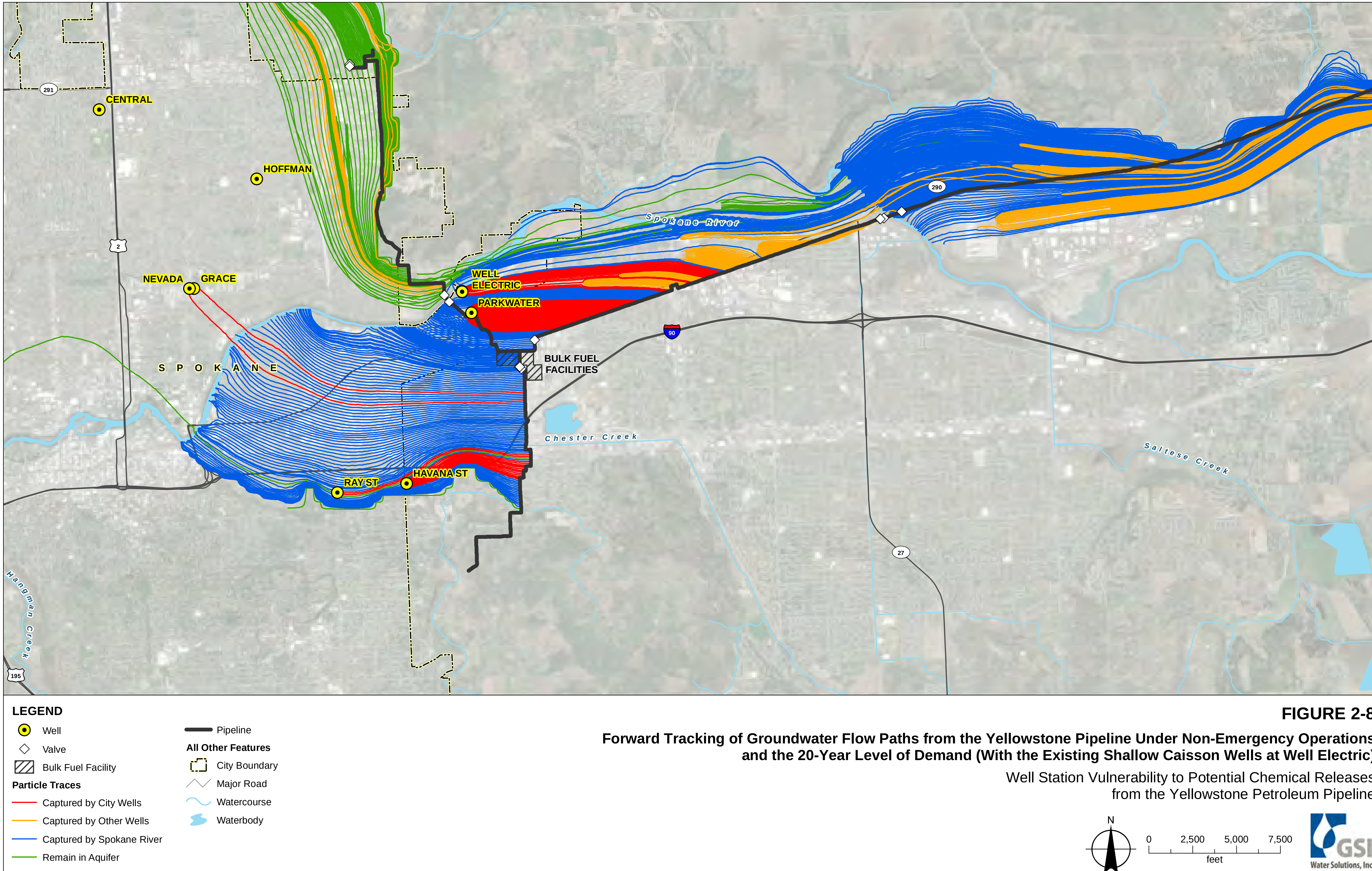
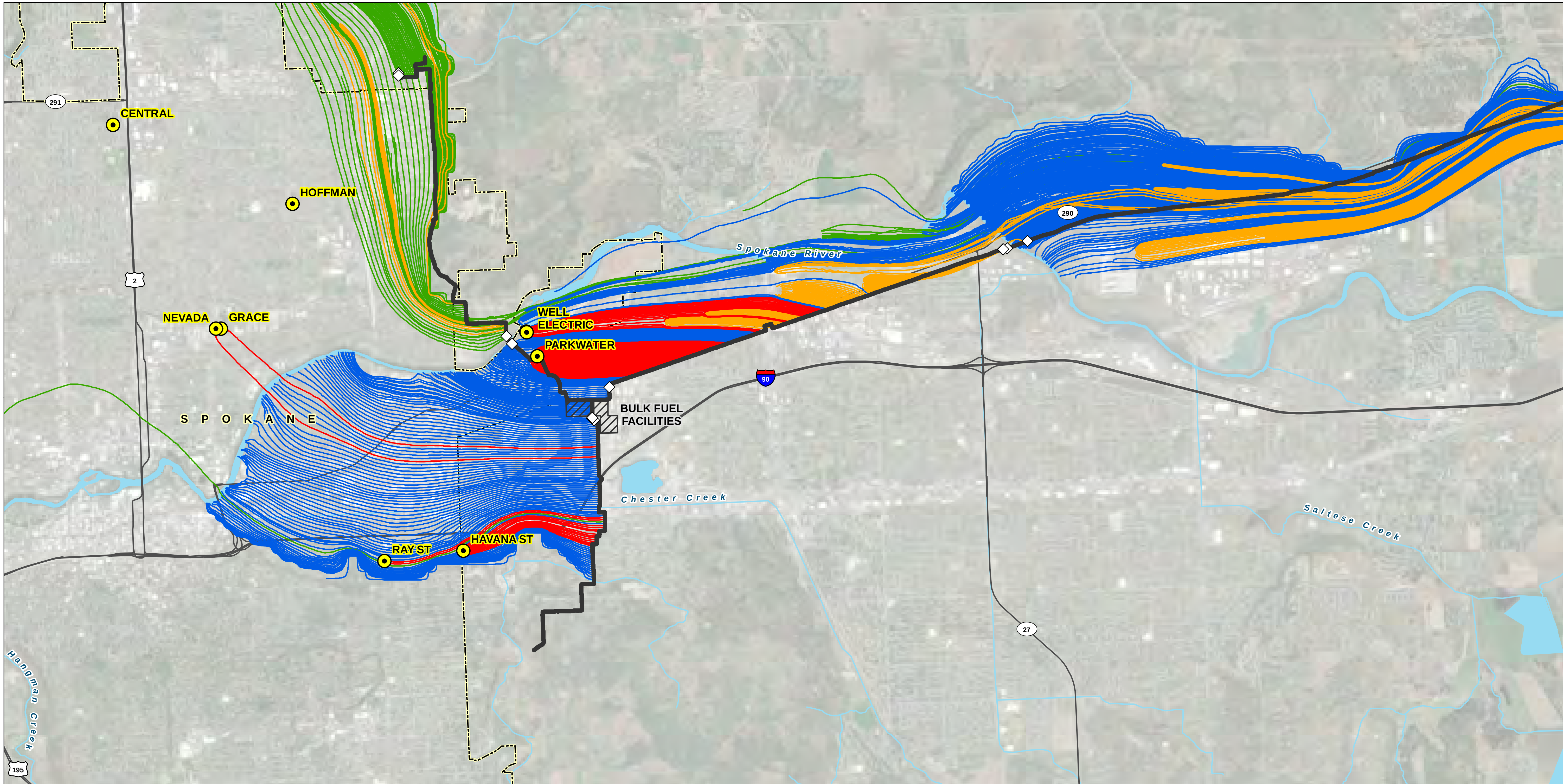


FIGURE 2-8

Forward Tracking of Groundwater Flow Paths from the Yellowstone Pipeline Under Non-Emergency Operations and the 20-Year Level of Demand (With the Existing Shallow Caisson Wells at Well Electric)

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

Document Path: Y:\0436_City_of_Spokane\Source_Figures\010_Yellowstone_Pipeline\Well_Station_Vulnerability\Figure2-8_Forward_Tracking20yr_Well_Electric_Shallow.mxd, npalmer



LEGEND

Well
Valve
Bulk Fuel Facility

Particle Traces

Captured by City Wells
Captured by Other Wells
Captured by Spokane River
Remain in Aquifer

Pipeline

All Other Features

City Boundary
Major Road
Watercourse
Waterbody

N

0 2,500 5,000 7,500
feet

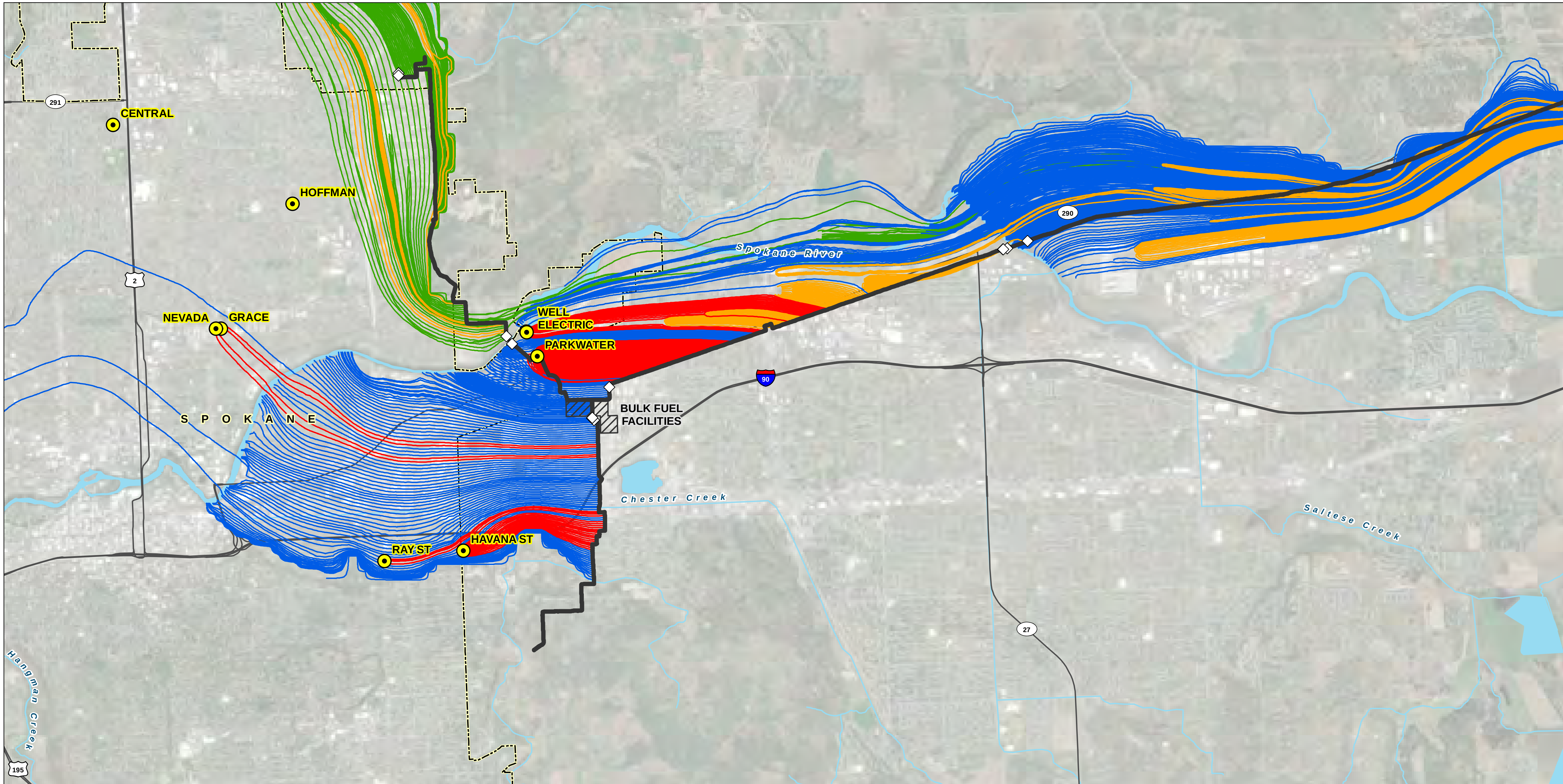
GSI Water Solutions, Inc.

FIGURE 2-9

Forward Tracking of Groundwater Flow Paths from the Yellowstone Pipeline Under Non-Emergency Operations and the 50-Year Modest Level of Demand (With the Existing Shallow Caisson Wells at Well Electric)

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

Document Path: Y:\0436_City_of_Spokane\Source_Figures\010_Yellowstone_Pipeline\Well_Station_Vulnerability\Figure2-9_Forward_Tracking50yr_Well_Electric_Shallow.mxd, npalmer



LEGEND

- Well
- Valve
- Bulk Fuel Facility

Particle Traces

- Captured by City Wells
- Captured by Other Wells
- Captured by Spokane River
- Remain in Aquifer

- Pipeline

All Other Features

- City Boundary
- Major Road
- Watercourse
- Waterbody

N

0 2,500 5,000 7,500
feet

GSI Water Solutions, Inc.

FIGURE 2-10

Forward Tracking of Groundwater Flow Paths from the Yellowstone Pipeline Under Non-Emergency Operations and the 50-Year High Level of Demand (With the Existing Shallow Caisson Wells at Well Electric)

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

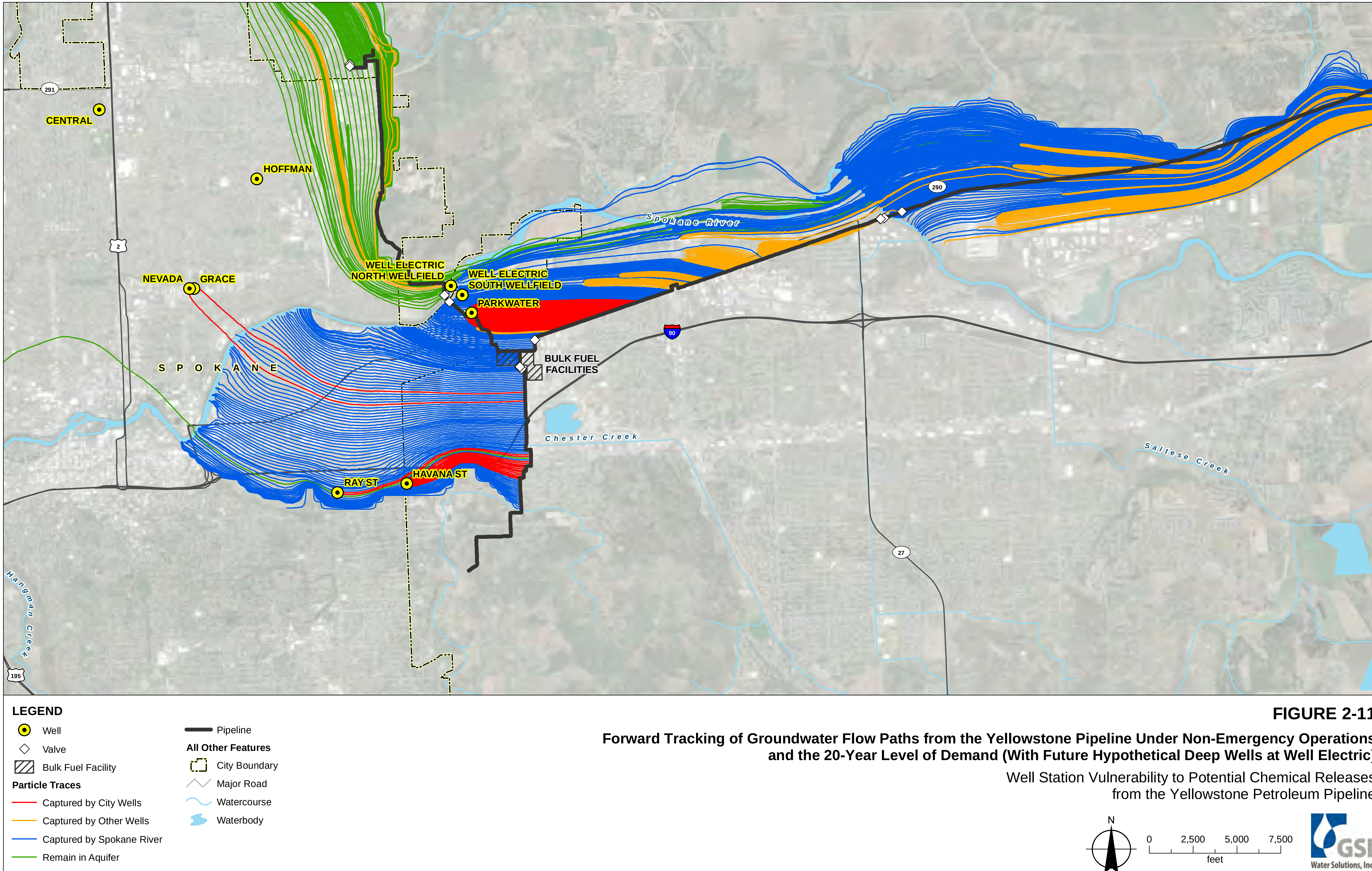


FIGURE 2-11

Forward Tracking of Groundwater Flow Paths from the Yellowstone Pipeline Under Non-Emergency Operations and the 20-Year Level of Demand (With Future Hypothetical Deep Wells at Well Electric)

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

Document Path: Y:\0436_City_of_Spokane\Source_Figures\010_Yellowstone_Pipeline\Well_Station_Vulnerability\Figure2-11_Forward_Tracking20yr_Well_Electric.mxd, npalmer

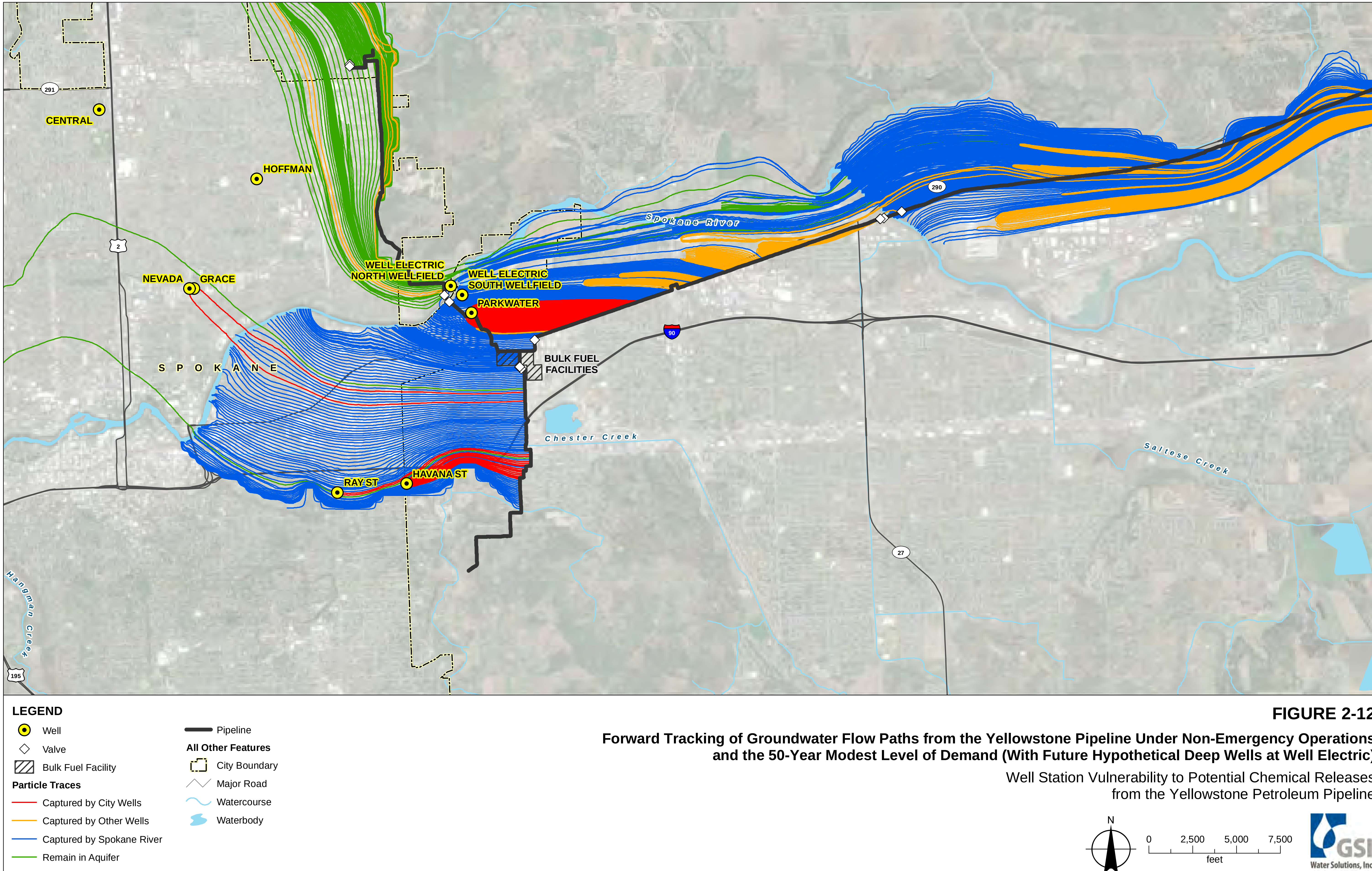


FIGURE 2-12

Forward Tracking of Groundwater Flow Paths from the Yellowstone Pipeline Under Non-Emergency Operations and the 50-Year Modest Level of Demand (With Future Hypothetical Deep Wells at Well Electric)

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

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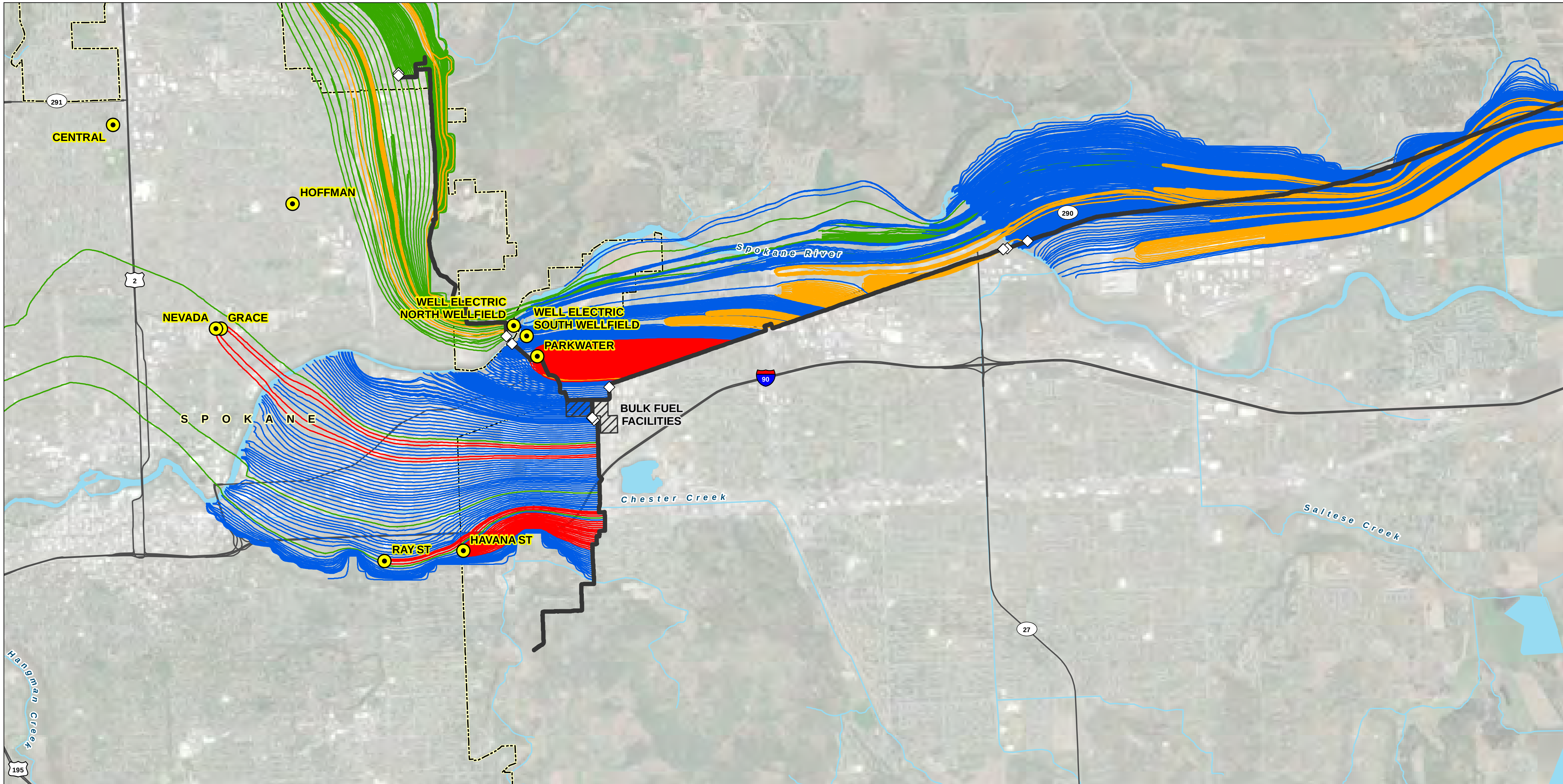


LEGEND

- Well
- Valve
- Bulk Fuel Facility

Particle Traces

- Captured by City Wells
- Captured by Other Wells
- Captured by Spokane River
- Remain in Aquifer

- Pipeline

All Other Features

- City Boundary
- Major Road
- Watercourse
- Waterbody

FIGURE 2-13

Forward Tracking of Groundwater Flow Paths from the Yellowstone Pipeline Under Non-Emergency Operations and the 50-Year High Level of Demand (With Future Hypothetical Deep Wells at Well Electric)

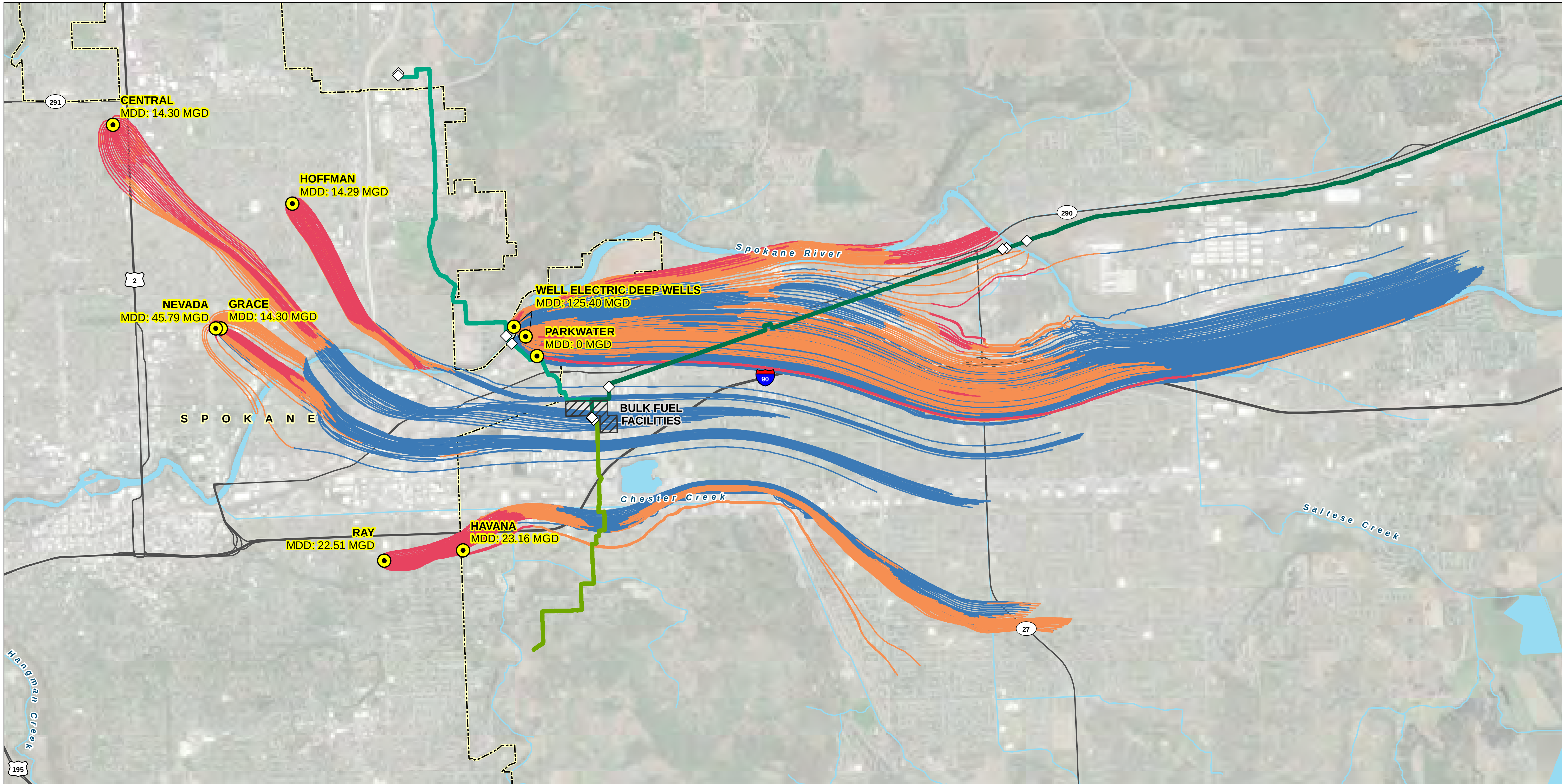
Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

N

0 2,500 5,000 7,500
feet

GSI Water Solutions, Inc.

Document Path: Y:\0436_City_of_Spokane\Source_Figures\010_Yellowstone_Pipeline\Well_Station_Vulnerability\Figure2-13_Forward_Tracking50yrHigh_Well_Electric.mxd, npalmer



LEGEND

- Well
- Valve
- Bulk Fuel Facility

Particle Traces

- Model Layer 1
- Model Layer 2
- Below Model Layer 2

Pipeline

- YP-02
- YP-03
- YP-04

All Other Features

- City Boundary
- Major Road
- Watercourse
- Waterbody

NOTES

MDD: maximum day demand
MGD: millions of gallons per day

N

0 2,500 5,000 7,500
feet

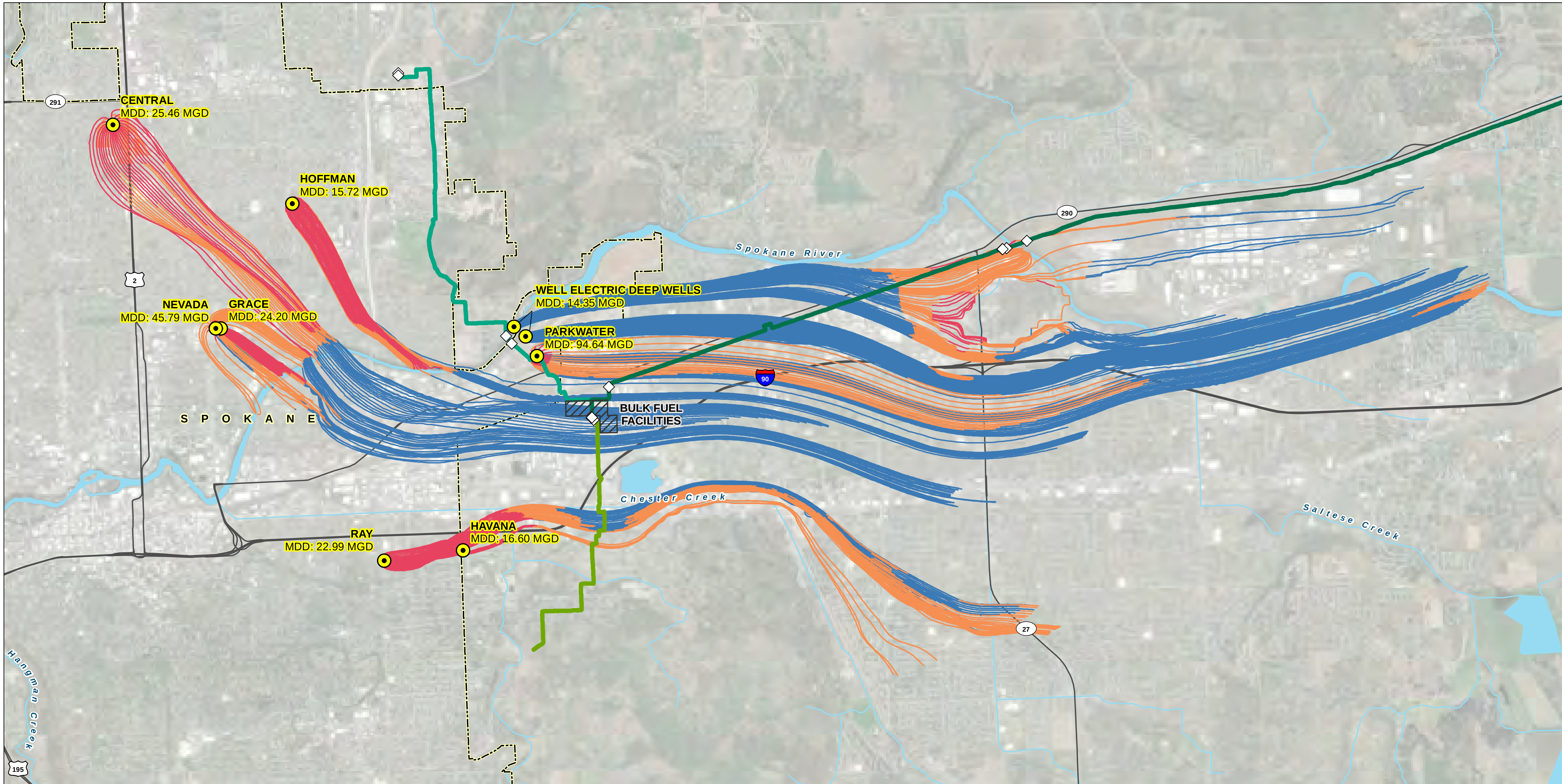
GSI Water Solutions, Inc.

FIGURE 3-1

Capture Zones for City Well Stations with Parkwater Offline (50-Year High Level of Demand with Future Hypothetical Deep Wells at Well Electric)

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

Document Path: Y:\0436_City_of_Spokane\Source_Figures\010_Yellowstone_Pipeline\Well_Station_Vulnerability\Figure3-1_CaptureZones_Parkwater.mxd, npalmer



LEGEND

Well
Valve
Bulk Fuel Facility

Particle Traces

Model Layer 1
Model Layer 2
Below Model Layer 2

Pipeline

YP-02
YP-03
YP-04

All Other Features

City Boundary
Major Road

Watercourse
Waterbody

NOTES

MDD: maximum day demand
MGD: millions of gallons per day

FIGURE 3-2

Capture Zones for City Well Stations with Well Electric Offline (50-Year High Level of Demand with Future Hypothetical Deep Wells at Well Electric)

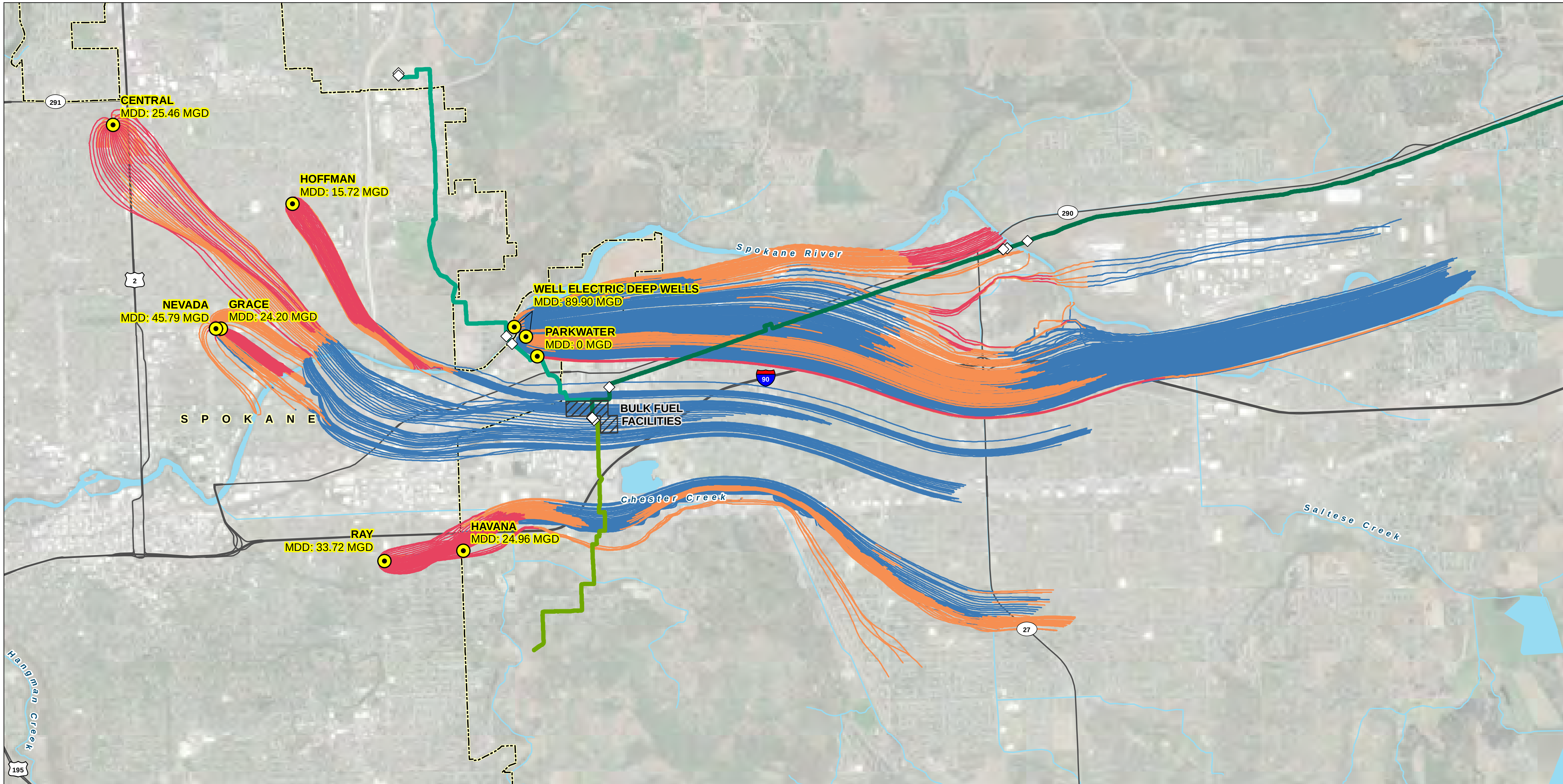
Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

N

0 2,500 5,000 7,500
feet

GSI Water Solutions, Inc.

Document Path: Y:\0436_City_of_Spokane\Source_Figures\010_Yellowstone_Pipeline\Well_Station_Vulnerability\Figure3-2_CaptureZones_Well_Electric.mxd, npalmer



LEGEND

Well

Valve

Bulk Fuel Facility

Particle Traces

Model Layer 1

Model Layer 2

Below Model Layer 2

Pipeline

YP-02

YP-03

YP-04

All Other Features

City Boundary

Major Road

Watercourse

Waterbody

NOTES

MDD: maximum day demand

MGD: millions of gallons per day

FIGURE 3-3

Capture Zones for City Well Stations with Parkwater and Well Electric Offline (50-Year High Level of Demand with Future Hypothetical Deep Wells at Well Electric)

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

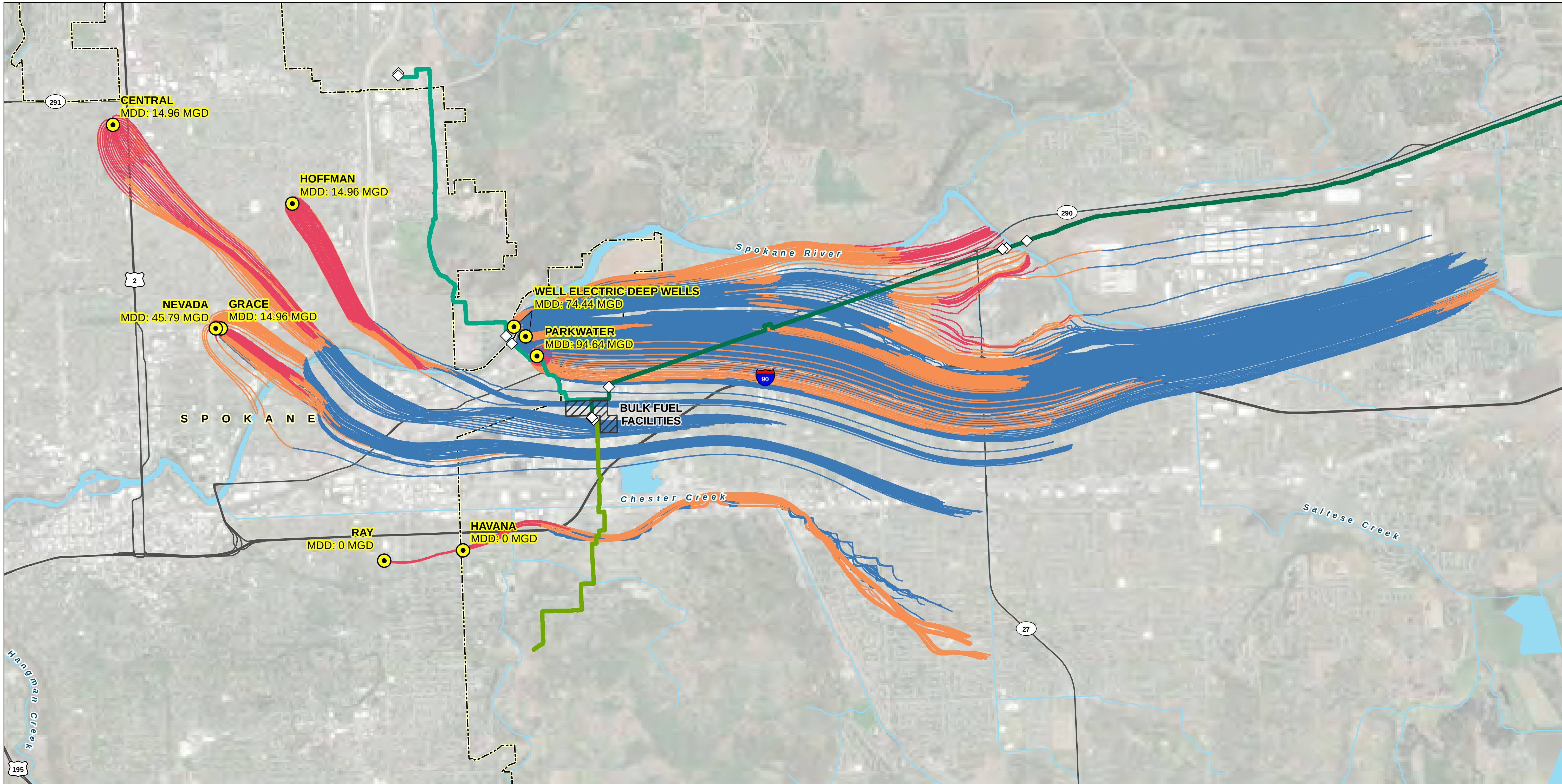
N

0 2,500 5,000 7,500

feet

GSI Water Solutions, Inc.

Document Path: Y:\0436_City_of_Spokane\Source_Figures\010_Yellowstone_Pipeline\Well_Station_Vulnerability\Figure3-3_CaptureZones_Parkwater_Well_Electric.mxd, npalmer



LEGEND

- Well
- Valve
- Bulk Fuel Facility

Particle Traces
- Model Layer 1
- Model Layer 2
- Below Model Layer 2

Pipeline
- YP-02
- YP-03
- YP-04

All Other Features
- City Boundary
- Major Road

- Watercourse
- Waterbody

NOTES
MDD: maximum day demand
MGD: millions of gallons per day

N

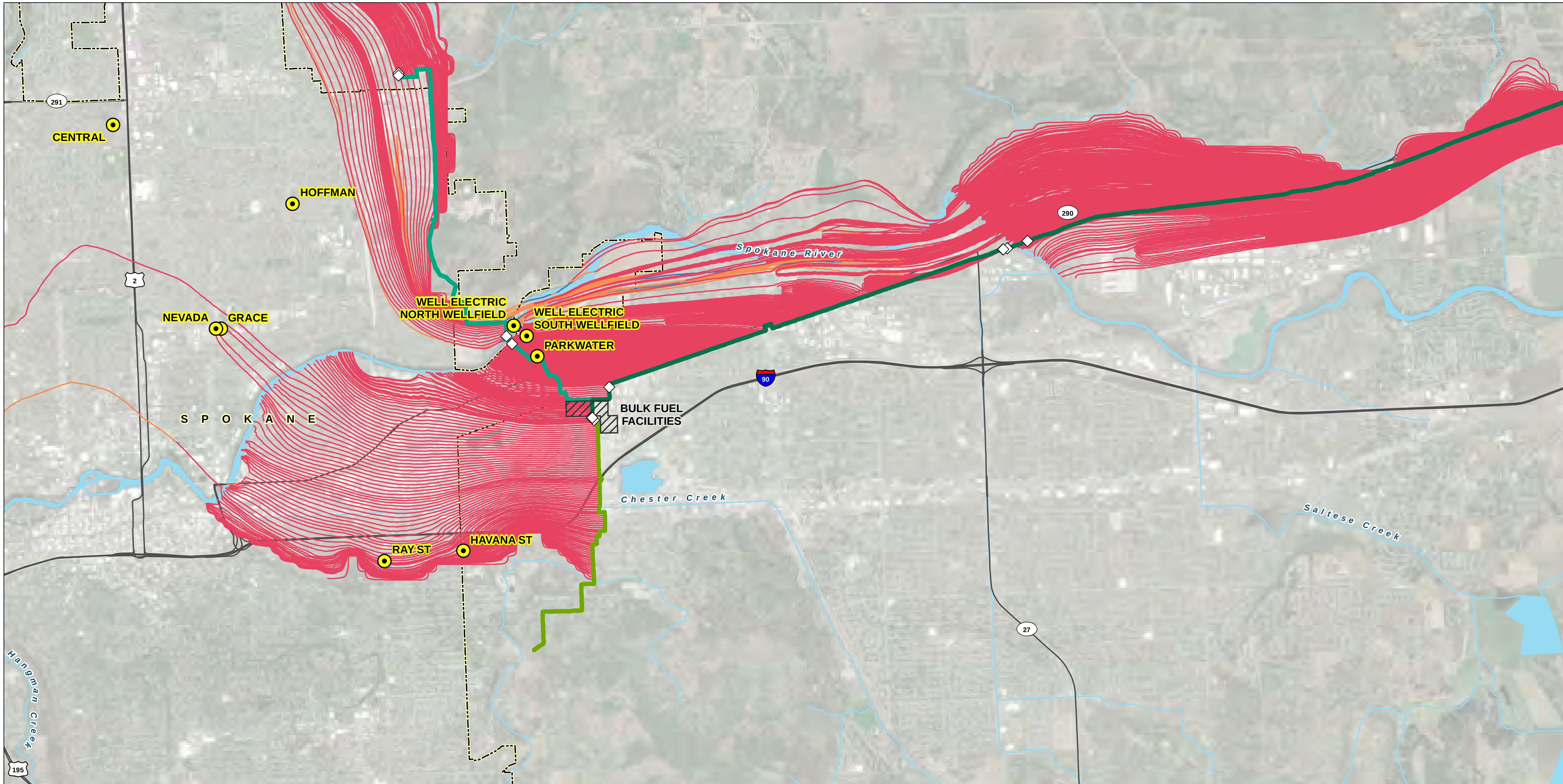
0 2,500 5,000 7,500
feet

GSI Water Solutions, Inc.

FIGURE 3-4

Capture Zones for City Well Stations with Ray Street and Havana Street Offline (50-Year High Level of Demand with Future Hypothetical Deep Wells at Well Electric)

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline



LEGEND

- Well
- Valve
- Bulk Fuel Facility

Particle Traces

- Model Layer 1
- Model Layer 2
- Below Model Layer 2

Pipeline

- YP-02
- YP-03
- YP-04

All Other Features

- City Boundary
- Major Road

- Watercourse
- Waterbody

FIGURE 3-5

Forward Tracking of Groundwater Flow Paths from the Yellowstone Pipeline with Parkwater Offline (50-Year High Level of Demand with Future Hypothetical Deep Wells at Well Electric)

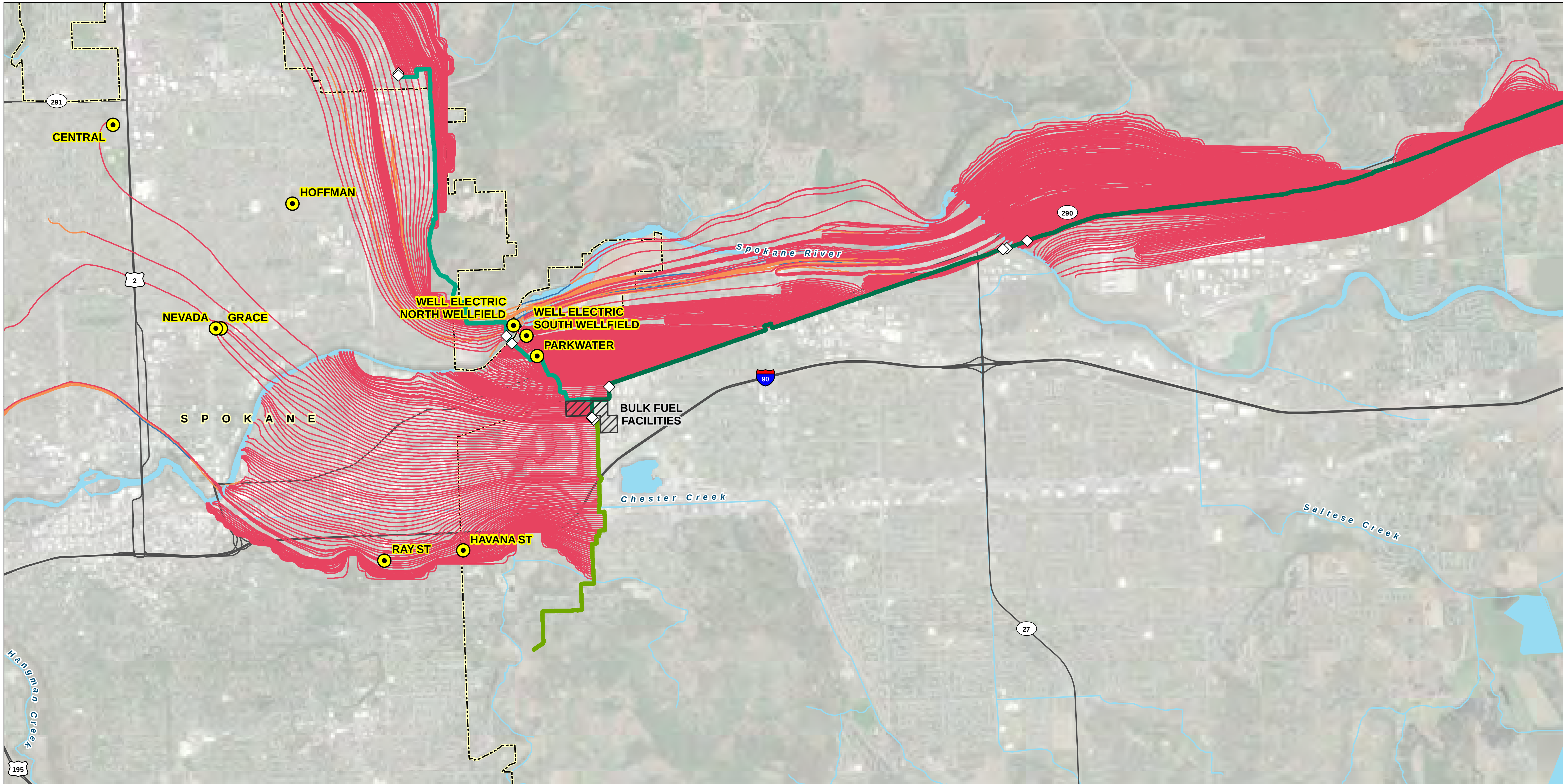
Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

N

0 2,500 5,000 7,500
feet

GSI Water Solutions, Inc.

Document Path: Y:\0436_City_of_Spokane\Source_Figures\010_Yellowstone_Pipeline\Well_Station_Vulnerability\Figure3-5_Forward_Tracking_Parkwell.mxd, npalmer



LEGEND

Well
Valve
Bulk Fuel Facility

Particle Traces
Model Layer 1
Model Layer 2
Below Model Layer 2

Pipeline
YP-02
YP-03
YP-04

All Other Features
City Boundary
Major Road

Watercourse
Waterbody

N

0 2,500 5,000 7,500
feet

GSI Water Solutions, Inc.

FIGURE 3-6

Forward Tracking of Groundwater Flow Paths from the Yellowstone Pipeline with Well Electric Offline (50-Year High Level of Demand with Future Hypothetical Deep Wells at Well Electric)

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

Document Path: Y:\0436_City_of_Spokane\Source_Figures\010_Yellowstone_Pipeline\Well_Station_Vulnerability\Figure3-6_Forward_Tracking_Well_Electric.mxd, npalmer

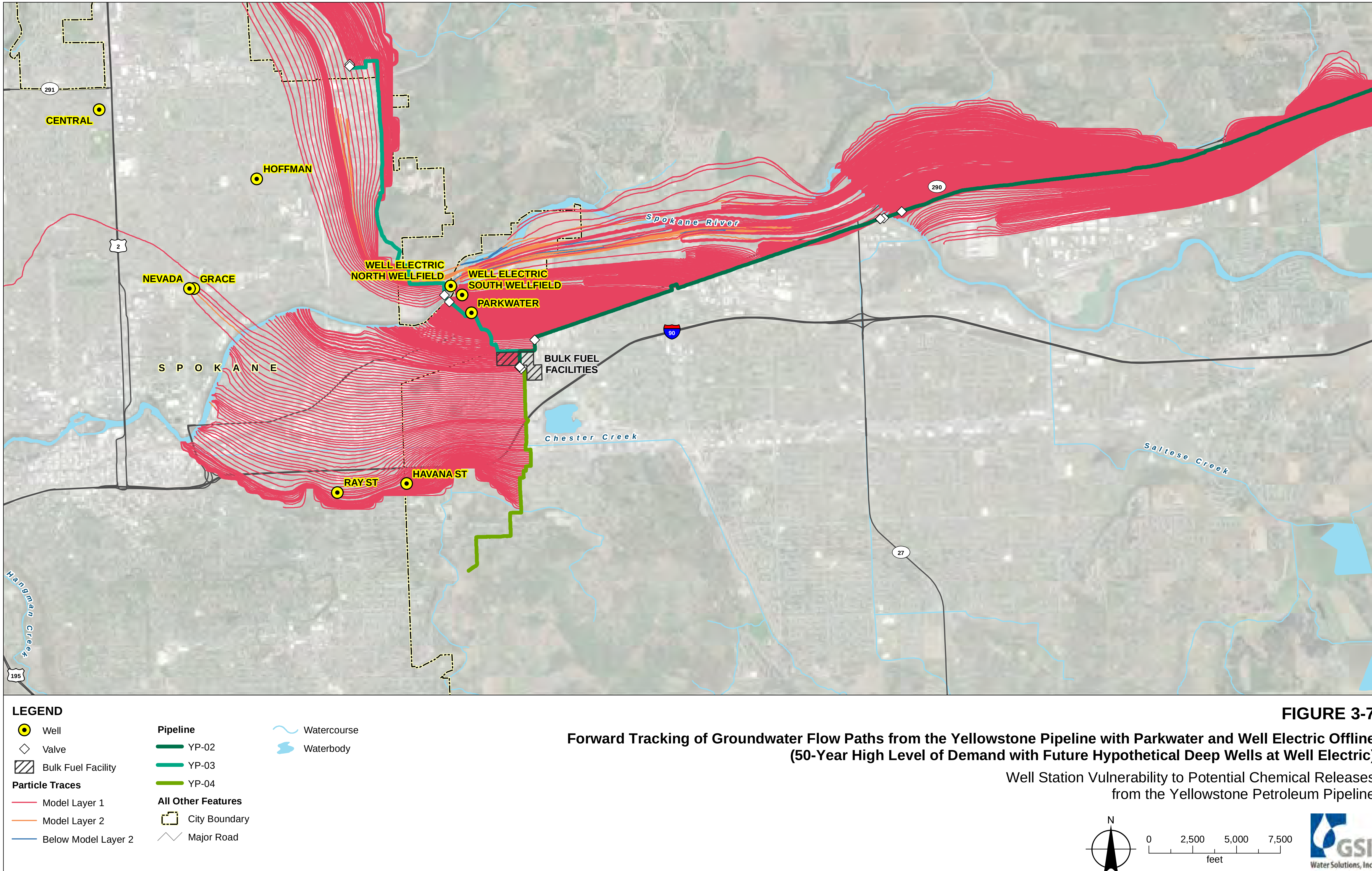
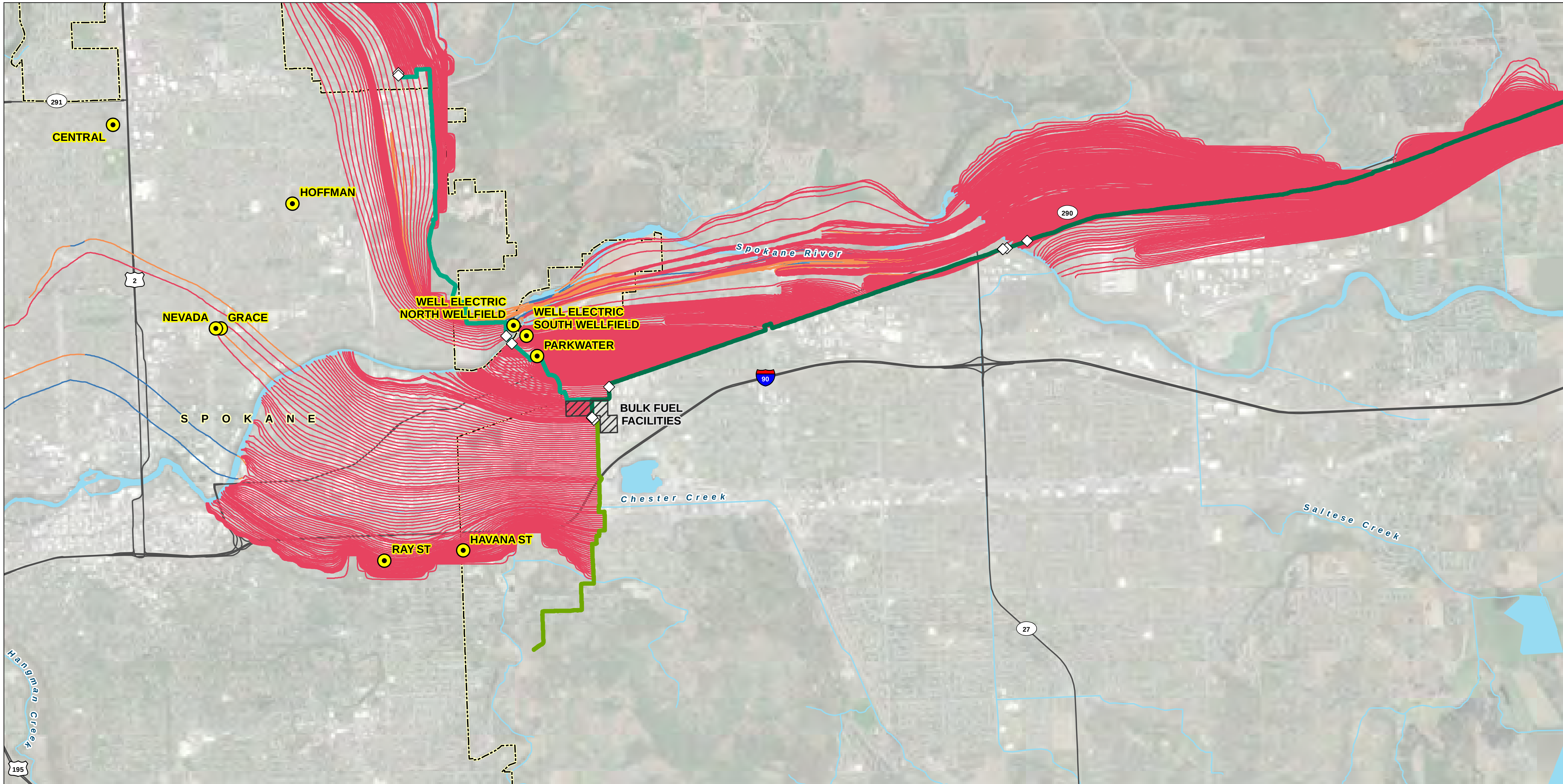


FIGURE 3-7

Forward Tracking of Groundwater Flow Paths from the Yellowstone Pipeline with Parkwater and Well Electric Offline (50-Year High Level of Demand with Future Hypothetical Deep Wells at Well Electric)

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

Document Path: Y:\0436_City_of_Spokane\Source_Figures\010_Yellowstone_Pipeline\Well_Station_Vulnerability\Figure3-7_Forward_Tracking_Parkwater_Well_Electric.mxd, npalmer



LEGEND

- Well
- Valve
- Bulk Fuel Facility

Particle Traces

- Model Layer 1
- Model Layer 2
- Below Model Layer 2

Pipeline

- YP-02
- YP-03
- YP-04

All Other Features

- City Boundary
- Major Road
- Watercourse
- Waterbody

FIGURE 3-8

Forward Tracking of Groundwater Flow Paths from the Yellowstone Pipeline with Ray Street and Havana Street Offline (50-Year High Level of Demand with Future Hypothetical Deep Wells at Well Electric)

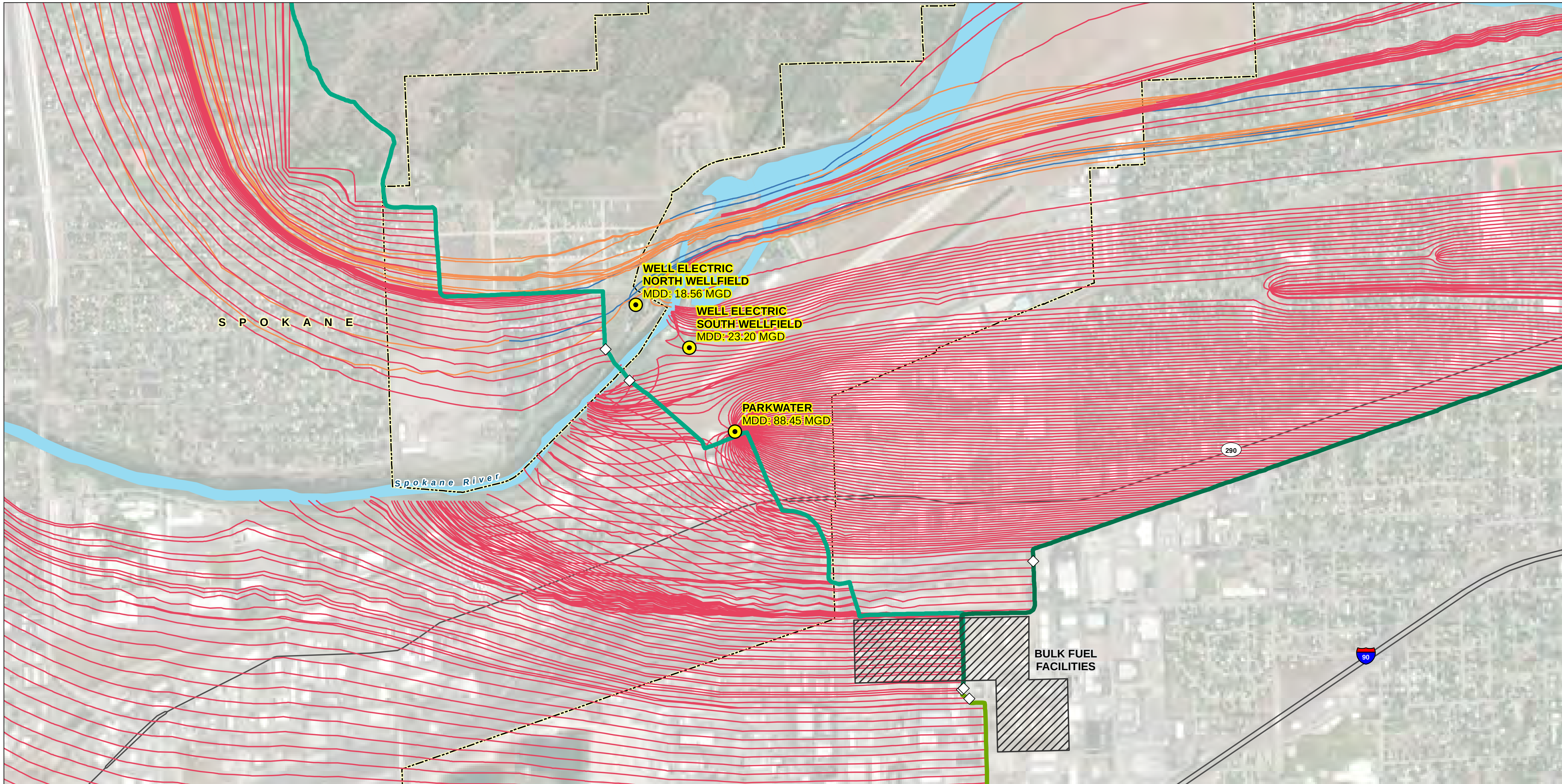
Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

N

0 2,500 5,000 7,500 feet

GSI Water Solutions, Inc.

Document Path: Y:\0436_City_of_Spokane\Source_Figures\010_Yellowstone_Pipeline\Well_Station_Vulnerability\Figure3-8_Forward_Tracking_Ray_Havana.mxd, npalmer



LEGEND

- Well
- Valve
- Bulk Fuel Facility

Particle Traces

- Model Layer 1
- Model Layer 2
- Below Model Layer 2

Pipeline

- YP-02
- YP-03
- YP-04

All Other Features

- City Boundary
- Major Road

- Watercourse
- Waterbody

NOTES

MDD: maximum day demand
MGD: millions of gallons per day

N

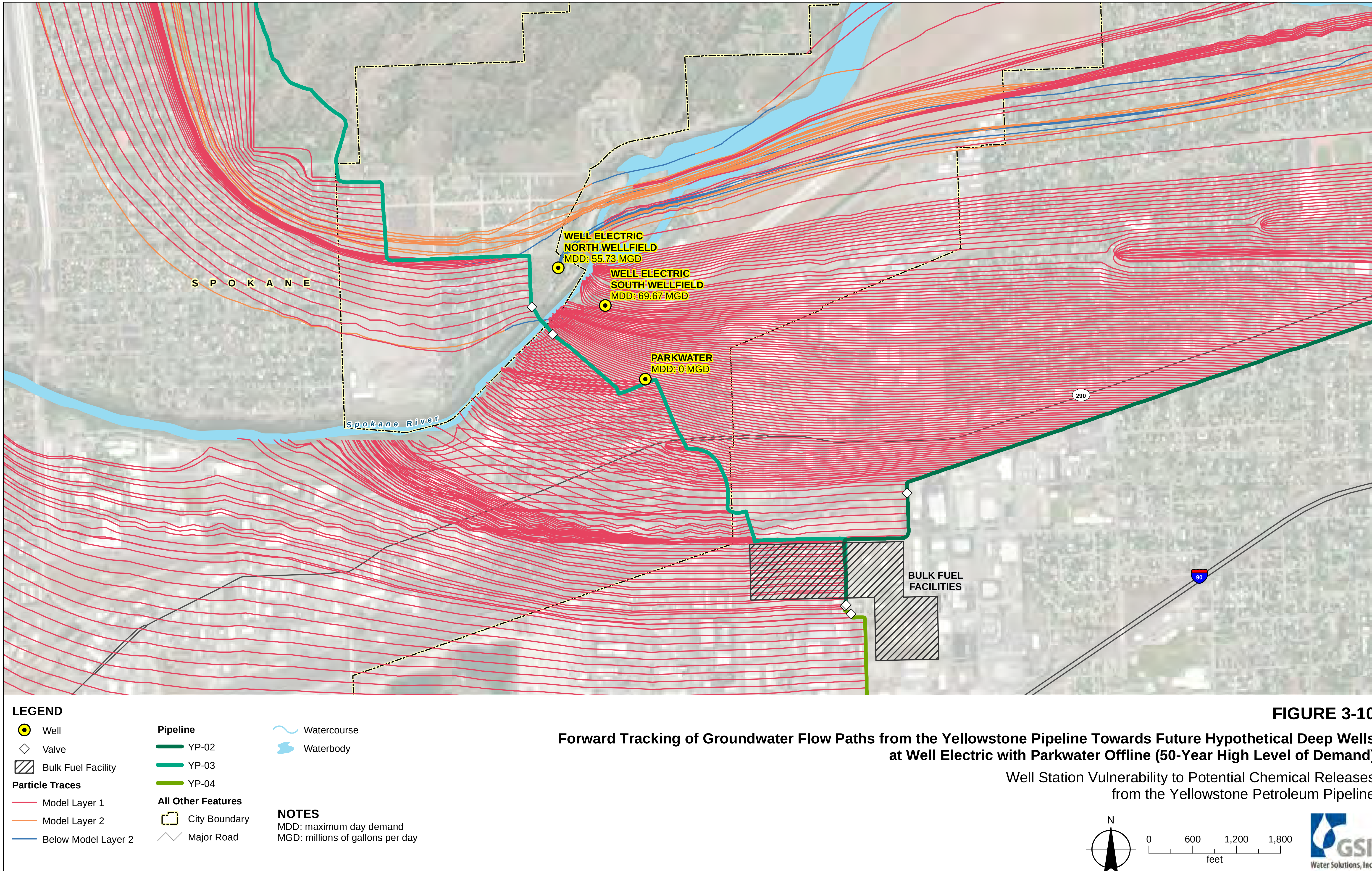
0 600 1,200 1,800
feet

GSI Water Solutions, Inc.

FIGURE 3-9

Forward Tracking of Groundwater Flow Paths from the Yellowstone Pipeline Towards Future Hypothetical Deep Wells at Well Electric Under Non-Emergency Operations (50-Year High Level of Demand)

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline



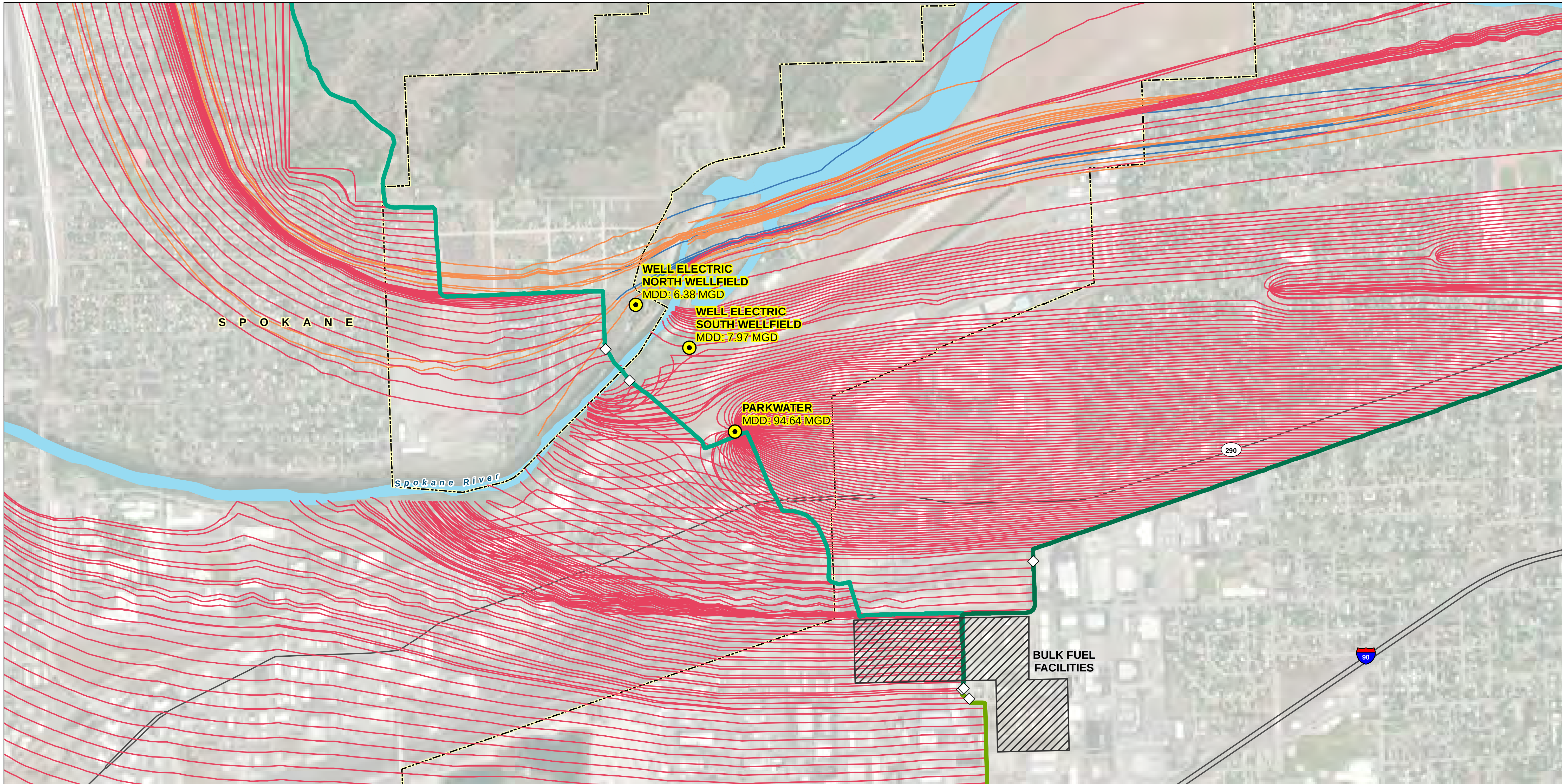
NOTES

MDD: maximum day demand
MGD: millions of gallons per day

FIGURE 3-10

Forward Tracking of Groundwater Flow Paths from the Yellowstone Pipeline Towards Future Hypothetical Deep Wells at Well Electric with Parkwater Offline (50-Year High Level of Demand)

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline



LEGEND

- Well
- Valve
- Bulk Fuel Facility

Particle Traces

- Model Layer 1
- Model Layer 2
- Below Model Layer 2

Pipeline

- YP-02
- YP-03
- YP-04

All Other Features

- City Boundary
- Major Road

- Watercourse
- Waterbody

NOTES

MDD: maximum day demand
MGD: millions of gallons per day

N

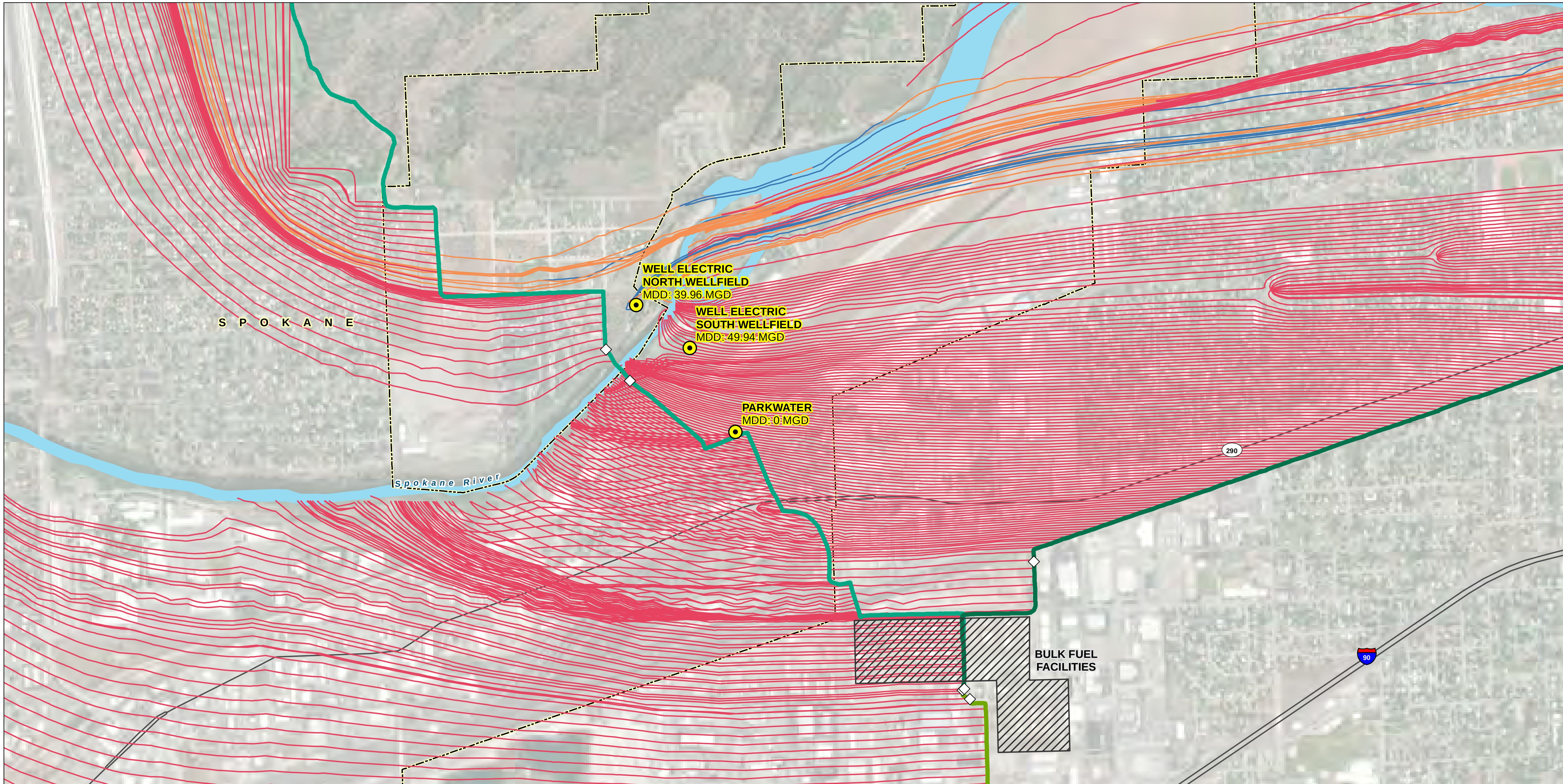
0 600 1,200 1,800
feet

GSI Water Solutions, Inc.

FIGURE 3-11

Forward Tracking of Groundwater Flow Paths from the Yellowstone Pipeline Towards Future Hypothetical Deep Wells at Well Electric with Well Electric Offline (50-Year High Level of Demand)

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline



LEGEND

- Well
- Valve
- Bulk Fuel Facility

Particle Traces

- Model Layer 1
- Model Layer 2
- Below Model Layer 2

Pipeline

- YP-02
- YP-03
- YP-04

All Other Features

- City Boundary
- Major Road
- Watercourse
- Waterbody

NOTES

MDD: maximum day demand
MGD: millions of gallons per day

N

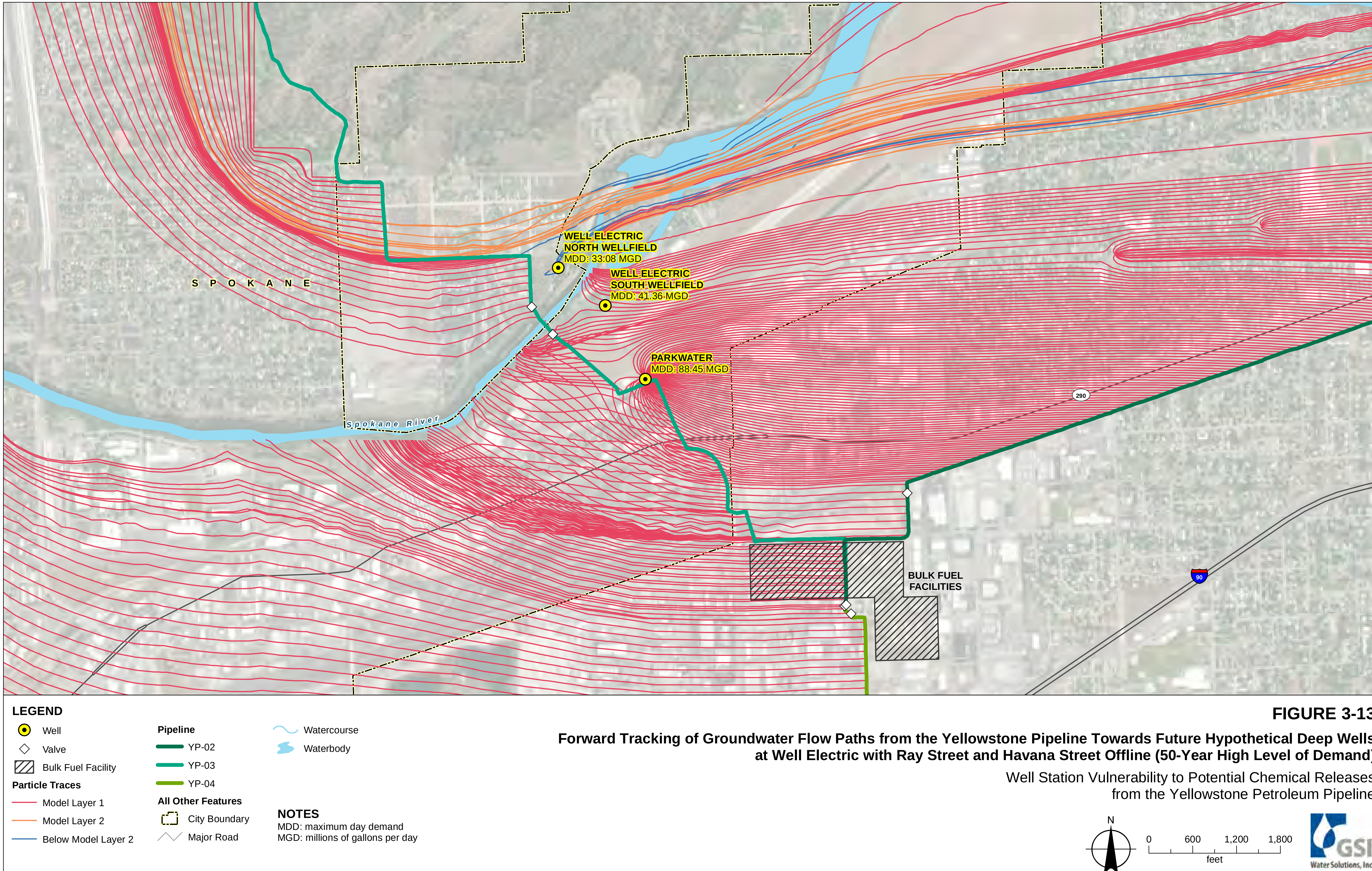
0 600 1,200 1,800
feet

GSI Water Solutions, Inc.

FIGURE 3-12

Forward Tracking of Groundwater Flow Paths from the Yellowstone Pipeline Towards Future Hypothetical Deep Wells at Well Electric with Parkwater and Well Electric Offline (50-Year High Level of Demand)

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline



NOTES
MDD: maximum day demand
MGD: millions of gallons per day

FIGURE 3-13

Forward Tracking of Groundwater Flow Paths from the Yellowstone Pipeline Towards Future Hypothetical Deep Wells at Well Electric with Ray Street and Havana Street Offline (50-Year High Level of Demand)

Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline

APPENDICES

APPENDIX A

Development of Monthly Distributions for Groundwater Pumping at City of Spokane Well Stations Under Future Water Demand Scenarios

GSI Water Solutions, Inc.

APPENDIX A

Development of Monthly Distributions for Groundwater Pumping at City of Spokane Well Stations Under Future Water Demand Scenarios

December 2024

Introduction

This appendix describes the methodology that was used by GSI Water Solutions, Inc. (GSI), to translate average day demand (ADD) and maximum day demand (MDD) projections of future City of Spokane (City) water demands into monthly distributions of groundwater pumping system-wide and at each of the City's well stations. The monthly distributions described in this appendix were used in groundwater modeling analyses of the vulnerability of the City's well stations to potential chemical releases from the Yellowstone petroleum pipeline.

Summary of Available Demand Projections

Three demand scenarios were used for the groundwater modeling analyses. The three scenarios consisted of a 20-year demand projection by HDR (2022) that GSI adjusted for climate change influences, and two 50-year demand projections by HDR (2023) that GSI also adjusted for climate-change influences. Table A-1 shows the system-wide ADD and MDD values for recent historical usage (the average of demands from 2015 through 2020), each of HDR's three future demand scenarios, and the three climate-adjusted future demand scenarios that were simulated in the groundwater flow model for this study.

Table A-1. Water Demand Values for Recent Historical Usage and Future Demand Scenarios

Demand Scenario	ADD	MDD
Recent Historical Usage (Average for 2015 through 2020)	63.56	141.30
20-Year Projection (HDR, 2022), No Climate Change	73.90	173.41
20-Year Projection with 2070–2099 Climate Change (GSI)	91.47	186.42
50-Year Projection: Scenario 4 (HDR's Modest Level of Demand) ▪ Demographics: Baseline ▪ Conservation: Standard ▪ Climate Change: Limited	78.28	208.30
50-Year Projection: Scenario 4 (GSI's Modest Level of Demand) ▪ Demographics: Baseline ▪ Conservation: Standard ▪ Climate Change: Aggressive (RCP 8.5, 2070–2099)	95.32	217.40

Demand Scenario	ADD	MDD
50-Year Projection: Scenario 3 (HDR's High Level of Demand) ▪ Demographics: High Growth/High Commercial ▪ Conservation: No Change from Current Conditions ▪ Climate Change: Limited	104.91	251.27
50-Year Projection: Scenario 3 (GSI's High Level of Demand) ▪ Demographics: High Growth/High Commercial ▪ Conservation: No Change from Current Conditions ▪ Climate Change: Aggressive (RCP 8.5, 2070–2099)	127.06	259.75

Notes

All values are in units of millions of gallons per day (mgd). See HDR (2023) for the 50-year demand projections.
ADD = average day demand GSI = GSI Water Solutions, Inc. MDD = maximum day demand
RCP = Representative Concentration Pathway for future global greenhouse gas emissions

Process for Calculating Monthly Pumping Rates for Each City Well Station

For each of the three future water demand scenarios, the process for calculating monthly pumping at each of the City's well stations required consideration of four factors:

- **Published Demand Projections:** The analysis used the published ADD and MDD values for each specific demand scenario.
- **Climate Influences on Demands:** Factors were used to scale up the amount of water demand arising from future changes in temperatures and future changes in the length of the growing season, both of which will affect outdoor irrigation water demands.
- **Distribution of Pumping Between City Well Stations:** The historical percentage usage of each City well station in a given month was evaluated during all 12 months of the calendar year under recent historical demands and system operations and was extrapolated to future conditions.
- **Water Rights:** Pumping rates and volumes were checked against instantaneous pumping rates and annual production volumes specified in the City's water rights.

The second and third factors listed above are discussed below.

Climate Influences on Demands

Table A-2 shows details regarding the changes in the growing season and the changes in the number of days above certain temperature and heat-index thresholds that are projected to occur by the year 2070 under the RCP 4.5 and RCP 8.5 greenhouse gas (GHG) emissions scenarios.[1] Although the groundwater modeling analysis focused solely on the RCP 8.5 scenario, both the RCP 4.5 and RCP 8.5 scenarios are shown in Table A-2 to provide an indication of the potential range of climate futures for the growing season and the temperature thresholds of interest. GSI obtained these data using the "Future Climate Scenarios" tool on the Climate Toolbox website.[2] The values in Table A-2 represent the mean of the 20 climate models for which data

[1] RCP 4.5 and RCP 8.5 each describe a specific "Representative Concentration Pathway" (RCP) for future GHG emissions. Under RCP 4.5, GHG emissions stabilize by the year 2050 and then decline steadily; this can be thought of as a somewhat optimistic scenario for future GHG emissions. Under RCP 8.5, GHG emissions do not decline and continue at their historical rates, resulting in continued accumulation of GHGs in the atmosphere; this can be thought of as a "business as usual" scenario for future GHG emissions.
[2] The Climate Toolbox website is accessible at https://climatetoolbox.org/.

are available in the Climate Toolbox.[3] The growing-season and heat-index projections have been compiled and programmed into the Climate Toolbox by researchers at the University of California Merced using procedures described by Abatzoglou and Brown (2012) and are available at an approximately 2.5-mile by 2.5-mile resolution. The data presented in this table are for Spokane, Washington, at latitude 47.6588 degrees North (°N) and 117.4260 degrees West (°W).

Table A-2. Growing Season and Temperature Projections for Spokane, Washington

	Date of Last Spring Freeze	Date of First Fall Freeze	Length of Growing Season (Days)	No. of Days Above 86°F	No. of Days with Heat Index Above 90°F	No. of Days with Heat Index Above 100°F	No. of Days with Heat Index Above 105°F
RCP 4.5							
Historical (1950–2005)	Apr. 25	Oct. 9	166.65	37	11	0.2	0
2070–2099	Mar. 9	Oct. 10	215.44	68.34	37.2	6.1	1.3
Change (No. of Days)	**-47**	**1**	**48.8**	**31.3**	**26.2**	**5.9**	**1.3**
RCP 8.5							
Historical (1950–2005)	Apr. 25	Oct. 9	166.65	37	11	0.2	0
2070–2099	Feb. 15	Oct. 26	252.29	91.21	61.4	22.7	10.1
Change (No. of Days)	**-69**	**17**	**85.6**	**54.2**	**50.4**	**22.5**	**10.1**

Notes

°F = degrees Fahrenheit

RCP = Representative Concentration Pathway for future global greenhouse gas emissions

As shown in Table A-2, compared with present conditions the date of the last spring freeze is projected to occur 1.5 to 2 months sooner, and the growing season is projected to be approximately 1.5 months to nearly 3 months longer in duration. The number of days with a heat index above 90°F is projected to be 26 to 50 days more than at present. These changes mean that irrigation water demands will begin in March rather than currently beginning in April or May, and these demands will continue through at least October and likely into early or even mid-November. Accordingly, GSI estimates that the changes in total water demands for any given month will follow the pattern presented in Table A-3. The monthly pattern in climate-driven increases also raises peak-month (July and August) demands by 5.0 to 7.5 percent based on the observation that the projected number of days with a heat index above 90°F is likely to be at least three times greater than historical conditions under RCP 4.5 and 5 to 6 times greater under RCP 8.5.

[3] The 20 climate models used in the Climate Toolbox are locally downscaled versions of 20 global climate models that are made available to the research community by the World Climate Research Programme through its Coupled Model Intercomparison Project (CMIP). The version of the models used in the Climate Toolbox are from a Phase 5 update of the climate models, which was released in 2013 and is commonly referred to as CMIP5.

Table A-3. Estimated Effect of 2070–2099 Climate Change on Monthly Water Demands in Spokane

Month	RCP 4.5	RCP 8.5
January	Unchanged	Unchanged
February	Unchanged	2.5% Below Historical Feb–March Average
March	Same as Historical April	2.5% Above Historical April
April	Same as Historical May	5.0% Above Historical May
May	2.5% Above Historical June	5.0% Above Historical June
June	2.5% Above Historical July	5.0% Above Historical July
July	5.0% Above Historical July	7.5% Above Historical July
August	5.0% Above Historical August	7.5% Above Historical August
September	5.0% Above Historical Sept	7.5% Above Historical Aug–Sept Average
October	5.0% Above Historical Sept–Oct Average	7.5% Above Historical Sept–Oct Average
November	2.5% Above Historical Oct–Nov Average	3.5% Above Historical Oct–Nov Average
December	Unchanged	Unchanged
Annual	16.5% Above Historical Annual Average	23.8% Above Historical Annual Average

Note

RCP = Representative Concentration Pathway for future global greenhouse gas emissions

Distribution of Pumping Between City Well Stations

The translation of ADD and MDD values into monthly demands system-wide and the allocation of pumping between wells was based on an assumption that the future monthly and seasonal operations of each City well station would be similar to recent historical operations. Table A-4 shows the percentage of total water supply that on average was provided from each City well station each month, during the period of calendar years 2015 through 2020. On a percentage basis, the Well Electric and Parkwater well stations have provided almost all water supply during the winter months. Beginning in April, the remaining City well stations have provided a gradually increasing percentage of the City's water supply until reaching maximum production (on a percentage basis) during July and August. By October, the Well Electric and Parkwater well stations return to providing 85 percent or more of the City's water supply.

Table A-4. Monthly Contribution of Each City Well Station to Total Water Supply (Historical Average, 2015–2020)

Month	Well Electric	Parkwater	Nevada	Grace	Hoffman	Central	Havana Street	Ray Street
Jan	36.35%	63.13%	0.06%	0.11%	0.12%	0.05%	0.09%	0.09%
Feb	25.46%	64.78%	0.09%	6.41%	0%	2.29%	0.48%	0.48%
Mar	28.31%	62.99%	0.10%	7.39%	0.17%	0.77%	0.14%	0.14%
Apr	13.85%	65.01%	0.81%	12.51%	0.53%	4.98%	1.15%	1.15%
May	14.81%	51.35%	4.11%	11.75%	2.26%	9.24%	3.24%	3.24%
Jun	24.65%	38.80%	7.43%	9.81%	1.23%	9.08%	4.50%	4.50%
Jul	21.28%	28.80%	14.26%	10.36%	3.06%	9.34%	6.44%	6.44%
Aug	15.57%	25.16%	23.07%	10.54%	3.88%	9.43%	6.18%	6.18%
Sept	19.67%	33.38%	19.11%	7.27%	2.97%	9.48%	4.06%	4.06%
Oct	30.53%	57.30%	3.00%	1.37%	0.68%	6.18%	0.46%	0.46%
Nov	34.21%	64.52%	0.10%	0.34%	0%	0.76%	0.04%	0.04%
Dec	36.04%	62.84%	0.34%	0.54%	0.01%	0.11%	0.06%	0.06%
Annual	22.57%	43.77%	9.74%	8.03%	1.91%	6.98%	3.50%	3.50%

Note
The first phase of the Havana Street Well Station came online in 2024. The second phase is currently under construction. This table shows how the actual historical percentage at the Ray Street Well Station is assumed to be distributed equally between Ray Street and Havana Street in the future.

Monthly Pumping Rates System-Wide and By Well Station

The climate scenarios presented in Table A-1 and Table A-3 were coupled together to develop the system-wide pumping profile shown in Table A-5 for each month of the year under each of the three demand scenarios. For comparison purposes, Table A-5 also shows the recent historical average production, based on actual recorded water uses during the 6-year period of 2015 through 2020. Month-by-month values of average daily production for each City well station and each scenario are presented in units of millions of gallons per day (mgd) in Tables A-6 through A-15:

- **Pumping under historical conditions**, which is the historical average for calendar years 2015 through 2020 (Table A-6)
- **Pumping under the 20-year demand projection** under no climate change (Table A-7) and under RCP 8.5 climate change (Table A-8)
- **Pumping under the 50-year modest demand projection** under no climate change (Table A-9) and under RCP 8.5 climate change (Table A-10)
- **Pumping under the 50-year high demand projection** under no climate change (Table A-11) and under RCP 8.5 climate change (Table A-12)

Table A-5. Monthly System-Wide Demand for Recent Historical Average Conditions and Three Future Demand Scenarios

	Current Average Use (2015–2020)	20-Year Projection		50-Year Modest-Demand Projection (Scenario 4)		50-Year High-Demand Projection (Scenario 3)	
Month	No Climate Change	No Climate Change	RCP 8.5 Climate Change	No Climate Change	RCP 8.5 Climate Change	No Climate Change	RCP 8.5 Climate Change
Jan	34.74	40.40	40.40	42.10	42.10	56.12	56.12
Feb	34.76	40.41	42.15	42.11	43.92	56.14	58.55
Mar	35.77	41.59	49.54	43.34	51.63	57.78	68.82
Apr	42.95	49.94	92.45	52.05	96.34	69.38	128.42
May	73.28	85.21	117.14	88.79	122.07	118.36	162.73
Jun	99.15	115.28	152.70	120.14	159.13	160.14	212.12
Jul	121.04	140.74	151.30	146.66	157.66	195.51	210.17
Aug	120.27	139.84	150.33	145.73	156.66	194.26	208.83
Sept	85.58	99.51	131.16	103.70	136.68	138.24	182.20
Oct	44.91	52.22	79.83	54.42	83.19	72.55	110.90
Nov	33.60	39.07	48.14	40.71	50.17	54.27	66.88
Dec	34.07	39.61	39.61	41.28	41.28	55.02	55.02
ADD	**63.56**	**73.90**	**91.47**	**77.01**	**95.32**	**102.66**	**127.06**
MDD	**141.30** (in 2022)	**173.41**	**186.42**	**202.23**	**217.40**	**241.63**	**259.75**

Notes
All values are in units of millions of gallons per day (mgd).
ADD = average day demand MDD = maximum day demand

Table A-6. Average Daily Production from Each City Well Station (2015–2020 Average Actual Historical Usage)

Month	Well Electric	Parkwater	Nevada	Grace	Hoffman	Central	Havana	Ray	Total
Jan	12.63	21.93	0.02	0.04	0.04	0.02	0	0.06	**34.74**
Feb	8.85	22.51	0.03	2.23	0	0.80	0	0.34	**34.76**
Mar	10.13	22.53	0.03	2.64	0.06	0.28	0	0.10	**35.77**
Apr	5.95	27.93	0.35	5.37	0.23	2.14	0	0.99	**42.96**
May	10.85	37.63	3.01	8.61	1.66	6.77	0	4.75	**73.28**
Jun	24.44	38.47	7.36	9.73	1.22	9.00	0	8.93	**99.15**
Jul	25.76	34.86	17.26	12.55	3.71	11.31	0	15.59	**121.04**
Aug	18.72	30.26	27.74	12.68	4.67	11.34	0	14.86	**120.27**
Sept	16.84	28.57	16.35	6.22	2.54	8.11	0	6.95	**85.58**
Oct	13.71	25.74	1.35	0.62	0.31	2.78	0	0.41	**44.92**
Nov	11.49	21.68	0.04	0.11	0	0.25	0	0.02	**33.59**
Dec	12.28	21.41	0.12	0.18	<0.01	0.04	0	0.04	**34.07**
Average	**14.34**	**27.82**	**6.19**	**5.10**	**1.21**	**4.43**	**0**	**4.46**	**63.56**

Note
All values are in units of millions of gallons per day (mgd).

Table A-7. Average Daily Production from Each City Well Station for the 20-Year Demand Projection with No Climate Change

Month	Well Electric	Parkwater	Nevada	Grace	Hoffman	Central	Havana	Ray	Total
Jan	14.68	25.50	0.03	0.04	0.05	0.02	0.04	0.04	**40.40**
Feb	10.29	26.18	0.04	2.59	0	0.93	0.19	0.19	**40.41**
Mar	11.77	26.20	0.04	3.07	0.07	0.32	0.06	0.06	**41.59**
Apr	6.92	32.47	0.40	6.25	0.26	2.49	0.58	0.58	**49.95**
May	12.62	43.75	3.50	10.01	1.93	7.87	2.76	2.76	**85.20**
Jun	28.42	44.73	8.56	11.31	1.41	10.46	5.19	5.19	**115.27**
Jul	29.96	40.54	20.07	14.59	4.31	13.15	9.07	9.07	**140.76**
Aug	21.77	35.18	32.26	14.75	5.43	13.19	8.64	8.64	**139.86**
Sept	19.58	33.22	19.01	7.24	2.96	9.43	4.04	4.04	**99.52**
Oct	15.95	29.93	1.57	0.72	0.36	3.23	0.24	0.24	**52.24**
Nov	13.36	25.21	0.04	0.13	0	0.30	0.01	0.01	**39.06**
Dec	14.27	24.89	0.13	0.21	<0.01	0.04	0.02	0.02	**39.58**
Average	**16.68**	**32.35**	**7.20**	**5.93**	**1.41**	**5.15**	**2.59**	**2.59**	**73.90**

Note
All values are in units of millions of gallons per day (mgd).

Table A-8. Average Daily Production from Each City Well Station for the 20-Year Demand Projection with RCP 8.5 Climate Change

Month	Well Electric	Parkwater	Nevada	Grace	Hoffman	Central	Havana	Ray	Total
Jan	14.68	25.50	0.03	0.04	0.05	0.02	0.04	0.04	**40.40**
Feb	10.73	27.30	0.04	2.70	0	0.97	0.20	0.20	**42.14**
Mar	14.03	31.21	0.05	3.66	0.08	0.38	0.07	0.07	**49.55**
Apr	12.81	60.10	0.75	11.57	0.49	4.61	1.07	1.07	**92.47**
May	17.35	60.15	4.82	13.77	2.65	10.82	3.80	3.80	**117.16**
Jun	37.64	59.25	11.34	14.98	1.87	13.86	6.88	6.88	**152.70**
Jul	32.20	43.58	21.57	15.68	4.64	14.13	9.75	9.75	**151.30**
Aug	23.40	37.82	34.68	15.85	5.83	14.18	9.29	9.29	**150.34**
Sept	25.80	43.78	25.06	9.54	3.90	12.43	5.33	5.33	**131.17**
Oct	24.38	45.75	2.40	1.10	0.55	4.94	0.37	0.37	**79.86**
Nov	16.47	31.06	0.05	0.16	0	0.36	0.02	0.02	**48.14**
Dec	14.27	24.89	0.13	0.21	<0.01	0.04	0.02	0.02	**39.58**
Average	**20.36**	**40.89**	**8.47**	**7.46**	**1.69**	**6.42**	**3.09**	**3.09**	**91.47**

Note
All values are in units of millions of gallons per day (mgd).

Table A-9. Average Daily Production from Each City Well Station for the 50-Year Modest Demand Projection with No Climate Change

Month	Well Electric	Parkwater	Nevada	Grace	Hoffman	Central	Havana	Ray	Total
Jan	15.30	26.58	0.03	0.04	0.05	0.02	0.04	0.04	**42.10**
Feb	10.72	27.28	0.04	2.70	0	0.97	0.20	0.20	**42.11**
Mar	12.27	27.30	0.04	3.20	0.07	0.34	0.06	0.06	**43.34**
Apr	7.21	33.84	0.42	6.51	0.27	2.59	0.60	0.60	**52.04**
May	13.15	45.60	3.65	10.43	2.01	8.20	2.88	2.88	**88.80**
Jun	29.61	46.61	8.92	11.79	1.47	10.90	5.41	5.41	**120.12**
Jul	31.22	42.25	20.91	15.20	4.50	13.70	9.45	9.45	**146.68**
Aug	22.68	36.66	33.62	15.37	5.66	13.75	9.00	9.00	**145.74**
Sept	20.40	34.62	19.81	7.54	3.08	9.83	4.21	4.21	**103.70**
Oct	16.62	31.19	1.63	0.75	0.37	3.37	0.25	0.25	**54.43**
Nov	13.93	26.27	0.04	0.14	0	0.31	0.01	0.01	**40.71**
Dec	14.87	25.94	0.14	0.22	<0.01	0.05	0.03	0.03	**41.28**
Average	**17.38**	**33.71**	**7.50**	**6.18**	**1.47**	**5.36**	**2.70**	**2.70**	**77.01**

Note
All values are in units of millions of gallons per day (mgd).

Table A-10. Average Daily Production from Each City Well Station for the 50-Year Modest Demand Projection with RCP 8.5 Climate Change

Month	Well Electric	Parkwater	Nevada	Grace	Hoffman	Central	Havana	Ray	Total
Jan	15.30	26.58	0.03	0.04	0.05	0.02	0.04	0.04	**42.10**
Feb	11.18	28.45	0.04	2.82	0	1.01	0.21	0.21	**43.92**
Mar	14.62	32.52	0.05	3.82	0.09	0.40	0.07	0.07	**51.64**
Apr	13.34	62.63	0.78	12.05	0.51	4.80	1.11	1.11	**96.33**
May	18.08	62.68	5.02	14.35	2.76	11.27	3.96	3.96	**122.08**
Jun	39.23	61.74	11.82	15.61	1.95	14.44	7.17	7.17	**159.13**
Jul	33.56	45.41	22.48	16.34	4.83	14.73	10.16	10.16	**157.67**
Aug	24.38	39.41	36.14	16.52	6.08	14.78	9.68	9.68	**156.67**
Sept	26.89	45.62	26.11	9.94	4.06	12.95	5.55	5.55	**136.67**
Oct	25.40	47.67	2.50	1.14	0.57	5.15	0.38	0.38	**83.19**
Nov	17.16	32.37	0.05	0.17	0	0.38	0.02	0.02	**50.17**
Dec	14.87	25.94	0.14	0.22	<0.01	0.05	0.03	0.03	**41.28**
Average	**21.22**	**42.61**	**8.82**	**7.77**	**1.76**	**6.69**	**3.22**	**3.22**	**95.32**

Note
All values are in units of millions of gallons per day (mgd).

Table A-11. Average Daily Production from Each City Well Station for the 50-Year High Demand Projection with No Climate Change

Month	Well Electric	Parkwater	Nevada	Grace	Hoffman	Central	Havana	Ray	Total
Jan	20.40	35.43	0.04	0.06	0.07	0.03	0.05	0.05	**56.13**
Feb	14.29	36.37	0.05	3.60	0	1.29	0.27	0.27	**56.14**
Mar	16.36	36.39	0.06	4.27	0.10	0.45	0.08	0.08	**57.79**
Apr	9.61	45.11	0.56	8.68	0.37	3.46	0.80	0.80	**69.39**
May	17.53	60.78	4.87	13.91	2.67	10.93	3.84	3.84	**118.37**
Jun	39.48	62.13	11.90	15.71	1.96	14.54	7.21	7.21	**160.14**
Jul	41.61	56.31	27.87	20.26	5.99	18.26	12.59	12.59	**195.48**
Aug	30.24	48.87	44.81	20.48	7.54	18.32	12.00	12.00	**194.26**
Sept	27.19	46.14	26.41	10.05	4.11	13.10	5.61	5.61	**138.22**
Oct	22.15	41.57	2.18	1.00	0.50	4.49	0.33	0.33	**72.55**
Nov	18.56	35.02	0.06	0.18	0	0.41	0.02	0.02	**54.27**
Dec	19.83	34.58	0.19	0.30	<0.01	0.06	0.03	0.03	**55.02**
Average	**23.17**	**44.94**	**10.00**	**8.24**	**1.96**	**7.15**	**3.60**	**3.60**	**102.66**

Note
All values are in units of millions of gallons per day (mgd).

Table A-12. Average Daily Production from Each City Well Station for the 50-Year High Demand Projection with RCP 8.5 Climate Change

Month	Well Electric	Parkwater	Nevada	Grace	Hoffman	Central	Havana	Ray	Total
Jan	20.40	35.43	0.04	0.06	0.07	0.03	0.05	0.05	**56.13**
Feb	14.91	37.93	0.05	3.76	0	1.34	0.28	0.28	**58.55**
Mar	19.48	43.35	0.07	5.09	0.12	0.53	0.09	0.09	**68.82**
Apr	17.79	83.49	1.04	16.07	0.68	6.40	1.48	1.48	**128.43**
May	24.09	83.56	6.69	19.12	3.68	15.03	5.28	5.28	**162.73**
Jun	52.29	82.30	15.76	20.81	2.60	19.25	9.55	9.55	**212.11**
Jul	44.73	60.54	29.96	21.78	6.44	19.63	13.54	13.54	**210.16**
Aug	32.50	52.54	48.17	22.02	8.10	19.70	12.90	12.90	**208.83**
Sept	35.84	60.82	34.81	13.25	5.42	17.26	7.40	7.40	**182.20**
Oct	33.86	63.55	3.33	1.52	0.76	6.86	0.51	0.51	**110.90**
Nov	22.88	43.15	0.07	0.23	0	0.51	0.02	0.02	**66.88**
Dec	19.83	34.58	0.19	0.30	<0.01	0.06	0.03	0.03	**55.02**
Average	**28.28**	**56.81**	**11.76**	**10.36**	**2.34**	**8.92**	**4.29**	**4.29**	**127.06**

Note
All values are in units of millions of gallons per day (mgd).

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APPENDIX B

Development of Climate-Change Factors for Groundwater Modeling Analyses of Future Conditions at City of Spokane Well Stations

APPENDIX B

Development of Climate-Change Factors for Groundwater Modeling Analyses of Future Conditions at City of Spokane Well Stations

December 2024

Introduction

This appendix describes the methodology that was used by GSI Water Solutions, Inc. (GSI), to obtain, process, and simulate climate-change influences on future municipal water demands and the natural hydrologic processes occurring in the Spokane River and the Spokane Valley-Rathdrum Prairie (SVRP) Aquifer. The climate-change projections described in this appendix were used in groundwater modeling analyses of future groundwater conditions at each municipal water supply well station owned and operated by the City of Spokane (City) and the vulnerability of well station to potential chemical releases from the Yellowstone petroleum pipeline.

The groundwater model simulated multiple scenarios of climate-driven changes in (1) future surface water flows at the headwaters of the Spokane River at Post Falls, Idaho, (2) inflows (runoff) from tributaries adjoining the SVRP Aquifer, and (3) changes in groundwater pumping arising from increased irrigation demands caused by a longer growing season and hotter temperatures. The climate projections were obtained from an online data portal called The Climate Toolbox, which is accessible at https://climatetoolbox.org/. The Climate Toolbox provides climate-change projections for two future global greenhouse gas (GHG) emissions pathways, which are called Representative Concentration Pathway (RCP) 4.5 and RCP 8.5. Projections are available for a range of future climates under each GHG emissions pathway and for multiple time frames (including the 3-decade periods of 2010–2039, 2040–2069, and 2070–2099). For streamflows and runoff, the projections on The Climate Toolbox website are projections from 10 individual spatially downscaled global climate models,[1] as well as a projection that is the average condition simulated by the full suite of global climate models. For growing season and temperature projections, 20 global climate models are available, as well as the average of the 20 models. The projections available on The Climate Toolbox website were processed and downscaled by the National Atmospheric and Oceanic Administration's Climate Impacts Research Consortium at Oregon State University (Mote et al., 2014) and made available to the public on The Climate Toolbox website by Hegewisch and Abatzoglou (2022).

GSI downloaded climate projections for each of these three hydrologic variables (Spokane River flows, runoff from adjoining tributaries, and growing season length and temperatures) in October 2022 and focused on the period 2070–2099 for this study, because the City designs its capital improvements to water infrastructure to last for 50 years or longer. Following are discussions of the projections for Spokane River flows and runoff

[1] These 10 global climate models are listed in the downloaded runoff data sets as the bcc-csm1-1m, CanESM2, CCSM4, CNRM-CM5, CSIRO-Mk3-6-0, HadGEM2-CC365, HadGEM2-ES365, IPSL-CM5A-MR, MICOR5, and NorESM1-M models. The output from these large-scale global climate-models has been downscaled to a 1/16th-degree grid resolution for publication on the Climate Toolbox website.

from adjoining tributaries. See Appendix A to the GSI report titled *Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline* for details regarding the growing season.

Projections of Spokane River Flows at Post Falls, Idaho

Historical and future streamflow projections are available for two gages on the Spokane River: at Coeur d'Alene, Idaho (representing inflow to Coeur d'Alene Lake) and at Post Falls, Idaho (representing outflow from Coeur d'Alene Lake that provides inflow into the first portion of the river to enter the SVRP Aquifer area). The projections were developed by Mote et al. (2014) using a streamflow routing model developed by Lohmann et al. (1996). GSI downloaded streamflow projections for the Spokane River at Post Falls to provide direct input to the groundwater flow model where the river first crosses over the SVRP Aquifer.[2]

These streamflow projections are available from the "Future Streamflows" tool in the "Water" application menu on The Climate Toolbox website. The Climate Toolbox contains two sets of streamflow projections: bias-corrected and non-bias-corrected. The non-bias-corrected data route gridded data from hydrologic rainfall-runoff models into stream channels, with less regard for historical streamflow observations than are applied to the bias-corrected data sets. Therefore, GSI used the bias-corrected projections for the Spokane River at Post Falls in the groundwater model simulations.

Table B-1 and Figure B-1 show the projected changes in Spokane River flows at Post Falls on a monthly basis. The highest percentage increases in flow (compared with historical average conditions for the period 1950–2005) are projected to occur from December through March, potentially doubling (exceeding 100 percent increase) under the highest-flow scenarios but also being small changes under the lowest-flow scenarios. Percentage decreases dominate the period of April through November, with the greatest percentage decreases occurring during the transitional month of June (following the spring freshet) and also during the seasonal-low flow months of July through September. Note that although the groundwater modeling analysis focused solely on the RCP 8.5 scenario, both the RCP 4.5 and RCP 8.5 scenarios are shown in Table B-1 and Figure B-1 to provide an indication of the potential range of climate futures for Spokane River streamflows.

Runoff Projections (Recharge from Tributary Valley Inflows)

Historical and future projections of total runoff by quarter were used to calculate monthly changes in inflows from tributaries that drain into the SVRP Aquifer at its margins. GSI used the 10-model-mean projected runoff values for Spokane County in 2070–2099 (as obtained from The Climate Toolbox) in the groundwater modeling analyses for the City's well stations.

The spatially downloaded data consisted of projected amounts of rainfall that become runoff, expressed in measurement units of depths in inches. For the 3-decade period 2070–2099, these runoff projections are available as 3-month averages for the time periods December through February, March through May, June through August, and September through November (Hegewisch and Abatzoglou, 2022). The data were obtained from the "Future Boxplots" tool in the "Water" application menu on The Climate Toolbox website. For a given 3-month period and a given GHG emission pathway, this tool provides the runoff depths as the minimum, 5th percentile, median (50th percentile), 95th percentile, and maximum values simulated by the 10 global climate models as a group, As shown in Table B-2, GSI converted these quarterly runoff depths into (1) percentage changes by month and (2) monthly multipliers that GSI applied to historical long-term average tributary inflows already programmed into a steady-state version of the groundwater flow model.

[2] The Climate Toolbox refers to this location as Spokane River at Post Falls, Washington. This is in contrast with stream gaging measurements, which are collected at a dedicated stream gaging station identified by the U.S. Geological Survey (USGS) as Spokane River at Post Falls, Idaho (USGS gage number 12419000).

For both RCP 4.5 and RCP 8.5, the runoff depths for each quarter are shown in Figure B-2, and the percentage changes in runoff are shown in Figure B-3. The figures show that 2070–2099 runoff is expected to be greater than historical runoff during the fall and winter seasons and lower than historical runoff during the spring and summer seasons. During the latter part of the 21st century, runoff during the December–February quarter is projected to be (approximately) 20 to 30 percent higher under RCP 4.5 and 25 to 35 percent higher under RCP 8.5. Spring runoff during the latter part of the 21st century is projected to be (approximately) 1 to 12 percent lower under RCP 4.5 and 3 to 15 percent lower under RCP 8.5. Note that although the groundwater modeling analysis focused solely on the RCP 8.5 scenario, both the RCP 4.5 and RCP 8.5 scenarios are shown in Figure B-2 to provide an indication of the potential range of climate futures for runoff.

Degrees of Climate Change

For modeling and presentation purposes, the future projections of Spokane River streamflows and runoff entering the aquifer from tributary valleys were combined in a specific manner as to create analyses that reflect differing degrees of climate change influences on the regional aquifer system during the latter part of the 21st century (the years 2070 through 2099). Specifically:

- **Spokane River Streamflows.** Changes in Spokane River streamflows during the late spring through early fall seasons were used to define the degree of climate change, given that the concerns about future water levels at City wells are focused on the summer season. Each climate-change model projects that for the months of May through October, the 2070–2099 streamflows will be lower than historical average flows. The least degree of reduction in May through October streamflows is classified in the model as a "low" degree of climate change, while the greatest degree of reduction is classified as a "high" degree of climate change. The median projected streamflows in all months comprise the "median" degree of climate change.
  - Because of the significant influence of snowpack in the Spokane River's watershed, the months of November through April are simulated with the highest projected streamflows for the "low" degree of climate change and the lowest projected streamflows for the "high" degree of climate change.
- **Recharge from Tributary Valley Inflows.** The late fall and winter seasons were used for classifying the degree of climate change related to recharge from tributary valley inflows. Each climate-change model projects that for the months of September through February, the 2070–2099 runoff from tributary valleys will be higher than historical average runoff, because of rising temperatures and the subsequent increase in the influence of rainfall rather than snowmelt on the magnitudes and timing of runoff from tributary valleys. The smallest increase in September through February tributary inflows is classified in the model as a "low" degree of climate change, while the greatest increase in September through February tributary inflows is classified as a "high" degree of climate change. The median projected tributary inflows in all months comprise the "median" degree of climate change.
  - The months of March through August are projected to have reduced tributary inflows because of rising temperatures and evaporative demands. Accordingly, these months are simulated with smaller reductions in tributary inflows for the "low" degree of climate change and larger reductions in tributary inflows for the "high" degree of climate change.

In summary:

- The low degree of climate change involves the smallest reductions in projected dry-season Spokane River streamflows, the highest projected wet-season streamflows in the Spokane River, the smallest projected increases in September through February tributary inflows, and the smallest projected reductions in March through August tributary inflows.

- The median degree of climate change involves the median projected changes in Spokane River streamflows and tributary inflows in all months.
- The high degree of climate change involves the largest reductions in projected dry-season Spokane River streamflows, the lowest projected wet-season streamflows in the Spokane River, the largest projected increases in September through February tributary inflows, and the largest projected reductions in March through August tributary inflows.

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Tables

Table B-1. Spokane River Streamflows at Post Falls, Idaho

		RCP 4.5					
	Historical	2070-2099 Streamflow			2070-2099 % Change in Streamflow		
Month	Streamflow	Low Streamflow	Average Streamflow	High Streamflow	Low Streamflow	Average Streamflow	High Streamflow
Jan	5,236	4,869	6,884	8,690	-7.02%	31.47%	65.96%
Feb	7,463	7,819	12,274	16,039	4.77%	64.46%	114.91%
Mar	8,941	9,166	11,558	14,068	2.52%	29.26%	57.34%
Apr	15,394	11,086	14,714	17,831	-27.99%	-4.42%	15.83%
May	17,408	7,236	10,278	13,064	-58.43%	-40.96%	-24.95%
Jun	9,118	1,675	2,436	3,484	-81.63%	-73.29%	-61.79%
Jul	2,381	595	741	971	-75.03%	-68.88%	-59.21%
Aug	877	195	297	388	-77.81%	-66.10%	-55.70%
Sep	798	236	318	411	-70.43%	-60.10%	-48.53%
Oct	1,368	632	740	886	-53.80%	-45.94%	-35.23%
Nov	2,903	1,999	2,824	3,642	-31.15%	-2.72%	25.47%
Dec	4,646	4,869	6,414	9,570	4.81%	38.05%	105.99%
Annual Average	6,361	4,173	5,744	7,361	-34.40%	-9.70%	15.72%

		RCP 8.5					
	Historical	2070-2099 Streamflow			2070-2099 % Change in Streamflow		
Month	Streamflow	Low Streamflow	Average Streamflow	High Streamflow	Low Streamflow	Average Streamflow	High Streamflow
Jan	5,236	6,530	7,874	8,731	24.72%	50.38%	66.76%
Feb	7,463	12,044	14,007	17,239	61.39%	87.69%	130.99%
Mar	8,941	8,290	11,640	15,357	-7.28%	30.19%	71.76%
Apr	15,394	7,742	12,974	17,121	-49.71%	-15.72%	11.22%
May	17,408	3,152	6,420	9,846	-81.89%	-63.12%	-43.44%
Jun	9,118	931	1,410	2,181	-89.78%	-84.54%	-76.08%
Jul	2,381	396	543	754	-83.39%	-77.21%	-68.35%
Aug	877	132	207	348	-84.89%	-76.39%	-60.30%
Sep	798	160	233	344	-79.99%	-70.85%	-56.90%
Oct	1,368	494	600	793	-63.92%	-56.13%	-42.01%
Nov	2,903	1,953	2,529	3,600	-32.72%	-12.87%	24.00%
Dec	4,646	5,327	7,194	9,984	14.66%	54.84%	114.88%
Annual Average	6,361	3,876	5,412	7,124	-39.07%	-14.92%	11.99%

Note

The streamflow value for any given month is the average rate of flow, in cubic feet per second (cfs).

Table B-2. Translation of Runoff Depth Projections into Recharge Multipliers for Tributary Valley Inflows

Runoff Depths (inches) Downloaded from The Climate Toolbox

RCP 4.5

Quarter	2070-2099 Projected Depth of Runoff (inches)			
	Historical Avg.	Low	Median	High
Dec-Feb	1.779	2.126	2.205	2.281
Mar-May	2.213	1.950	2.074	2.185
Jun-Aug	1.360	1.230	1.271	1.315
Sept-Nov	1.471	1.627	1.708	1.803
Annual Average	1.706	1.733	1.815	1.896

RCP 4.5

Quarter	2070-2099 Projected % Change in Runoff		
	Low	Median	High
Dec-Feb	19.51%	23.93%	28.22%
Mar-May	-11.89%	-6.27%	-1.25%
Jun-Aug	-9.56%	-6.53%	-3.32%
Sept-Nov	10.59%	16.14%	22.58%
Annual Average	1.61%	6.38%	11.16%

RCP 8.5

Quarter	2070-2099 Projected Depth of Runoff (inches)			
	Historical Avg.	Low	Median	High
Dec-Feb	1.779	2.197	2.306	2.411
Mar-May	2.213	1.880	2.012	2.134
Jun-Aug	1.360	1.194	1.243	1.284
Sept-Nov	1.471	1.700	1.763	1.798
Annual Average	1.706	1.743	1.831	1.907

RCP 8.5

Quarter	2070-2099 Projected % Change in Runoff		
	Low	Median	High
Dec-Feb	23.49%	29.62%	35.53%
Mar-May	-15.05%	-9.05%	-3.57%
Jun-Aug	-12.20%	-8.60%	-5.62%
Sept-Nov	15.56%	19.83%	22.22%
Annual Average	2.17%	7.35%	11.78%

Calculated Recharge Multipliers

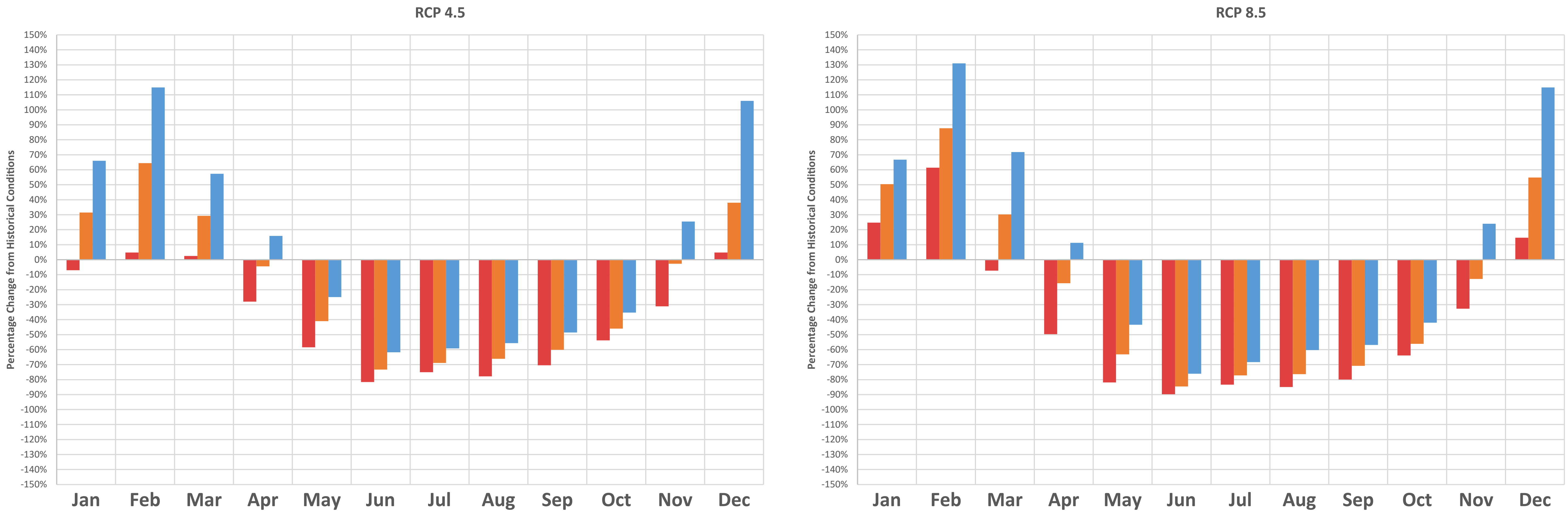
RCP 4.5

Month	Historical Multiplier	2070-2099 Projected % Change in Runoff			2070-2099 Multiplier		
		Low	Median	High	Low	Median	High
January	2.523	19.51%	23.93%	28.22%	3.015	3.127	3.235
February	1.676	19.51%	23.93%	28.22%	2.003	2.077	2.149
March	1.009	-11.89%	-6.27%	-1.25%	0.889	0.946	0.996
April	0.174	-11.89%	-6.27%	-1.25%	0.153	0.163	0.172
May	0.336	-11.89%	-6.27%	-1.25%	0.296	0.315	0.332
June	0.174	-9.56%	-6.53%	-3.32%	0.157	0.163	0.168
July	0.336	-9.56%	-6.53%	-3.32%	0.304	0.314	0.325
August	0	-9.56%	-6.53%	-3.32%	0	0	0
September	0	10.59%	16.14%	22.58%	0	0	0
October	0.841	10.59%	16.14%	22.58%	0.93	0.977	1.031
November	2.26	10.59%	16.14%	22.58%	2.499	2.625	2.77
December	2.691	19.51%	23.93%	28.22%	3.216	3.335	3.45

RCP 8.5

Month	Historical Multiplier	2070-2099 Projected % Change in Runoff			2070-2099 Multiplier		
		Low	Median	High	Low	Median	High
January	2.523	23.49%	29.62%	35.53%	3.116	3.27	3.419
February	1.676	23.49%	29.62%	35.53%	2.07	2.172	2.271
March	1.009	-15.05%	-9.05%	-3.57%	0.857	0.918	0.973
April	0.174	-15.05%	-9.05%	-3.57%	0.148	0.158	0.168
May	0.336	-15.05%	-9.05%	-3.57%	0.285	0.306	0.324
June	0.174	-12.20%	-8.60%	-5.62%	0.153	0.159	0.164
July	0.336	-12.20%	-8.60%	-5.62%	0.295	0.307	0.317
August	0	-12.20%	-8.60%	-5.62%	0	0	0
September	0	15.56%	19.83%	22.22%	0	0	0
October	0.841	15.56%	19.83%	22.22%	0.972	1.008	1.028
November	2.26	15.56%	19.83%	22.22%	2.612	2.708	2.762
December	2.691	23.49%	29.62%	35.53%	3.323	3.488	3.647

Figures



LEGEND

Low Streamlow

Average Streamflow

High Streamflow

FIGURE B-1

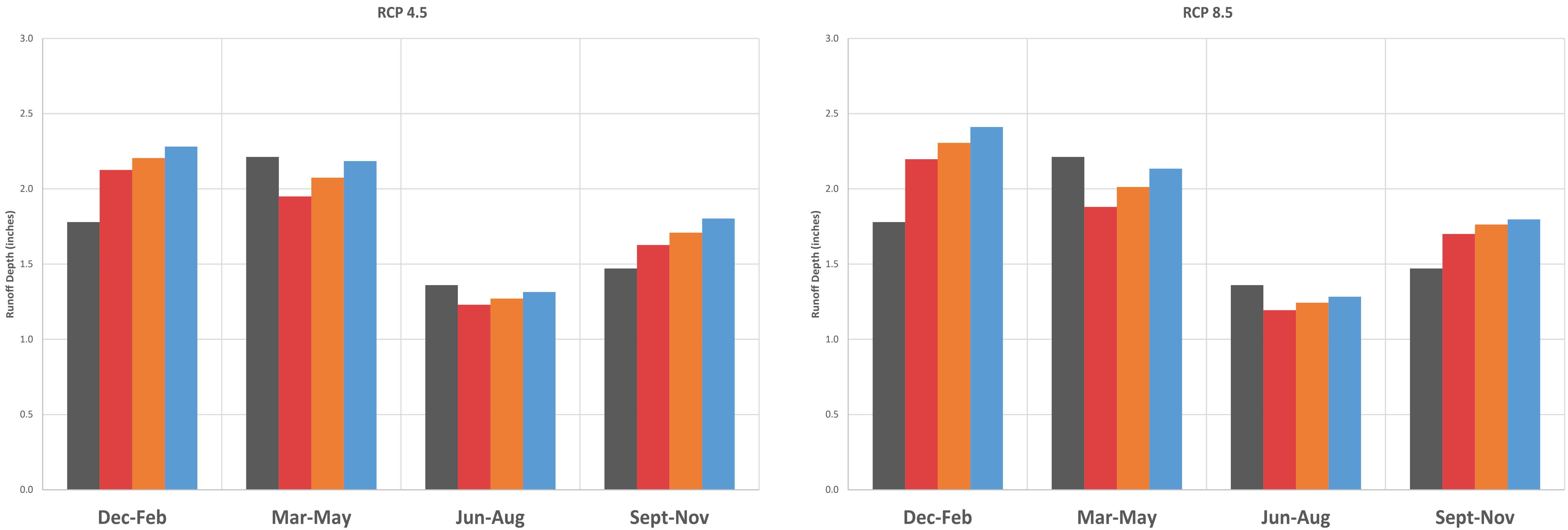
Projected Monthly Percentage Changes in 2070–2099
Spokane River Streamflows at Post Falls, Idaho

Development of Climate-Change Factors for Groundwater Modeling Analyses of Future Conditions at City of Spokane Well Stations

GSI Water Solutions, Inc.

NOTE

RCP stands for Representative Concentration Pathway for future global greenhouse gas emissions.



LEGEND

- High 2070-2099 Recharge
- Median 2070-2099 Recharge
- Low 2070-2099 Recharge
- Historical Average Recharge (1950-2005)

NOTE

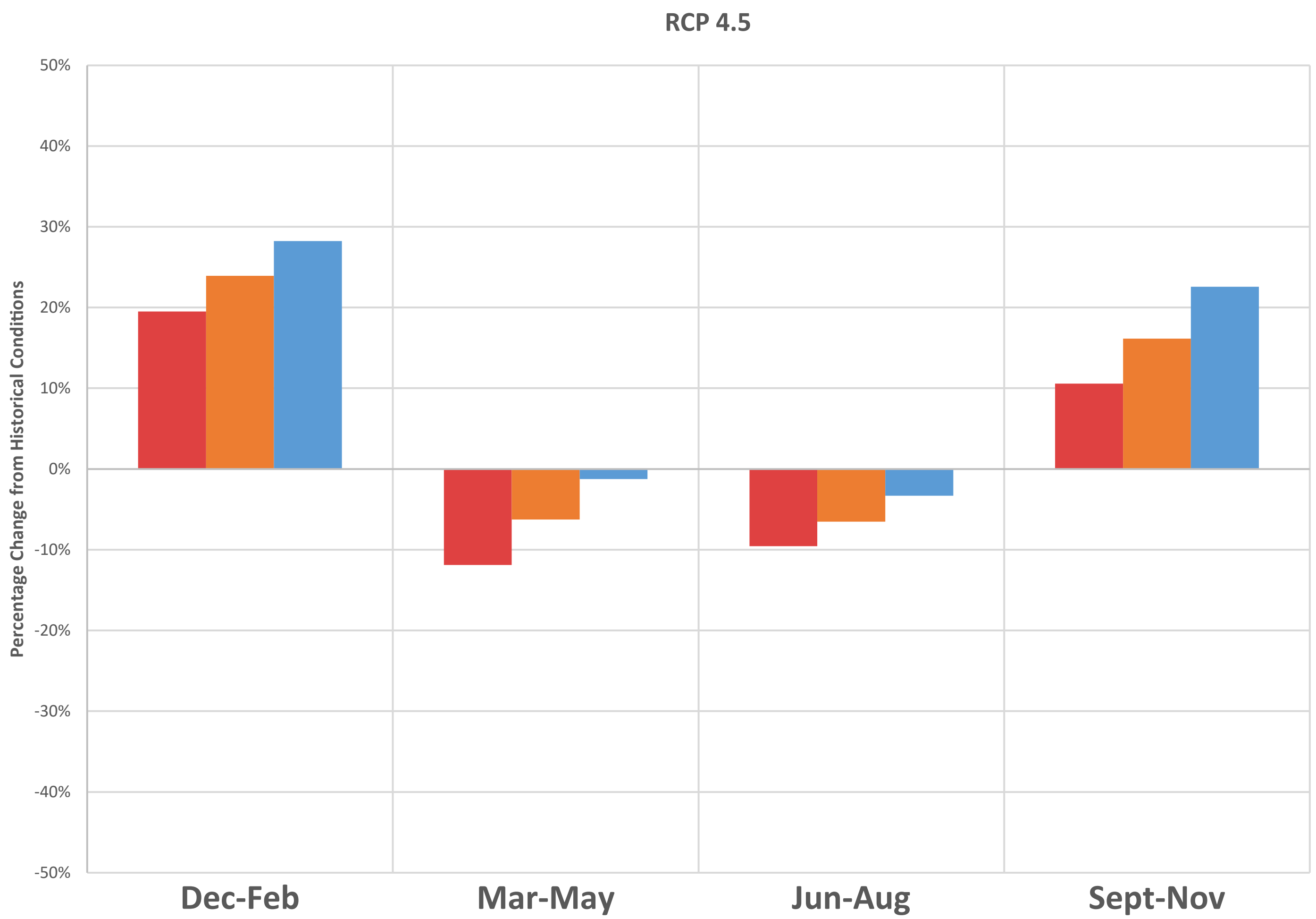
RCP stands for Representative Concentration Pathway for future global greenhouse gas emissions.

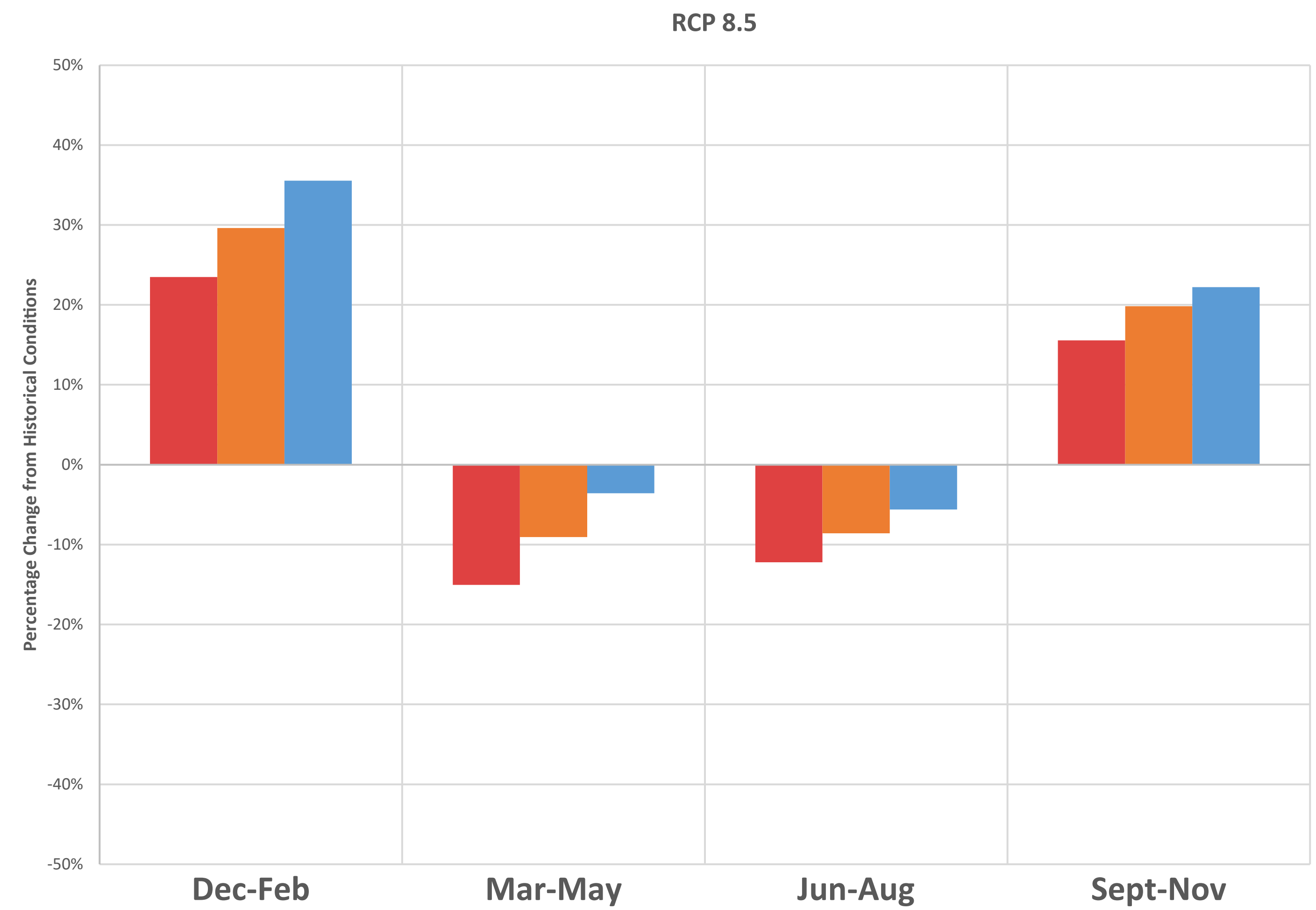
FIGURE B-2

Recharge from Tributary Inflows in 2070–2099
(Expressed as Runoff in Inches)

Development of Climate-Change Factors for Groundwater Modeling Analyses of Future Conditions at City of Spokane Well Stations

GSI Water Solutions, Inc.





LEGEND

- High 2070-2099 Recharge
- Median 2070-2099 Recharge
- Low 2070-2099 Recharge

FIGURE B-3

Projected Monthly Percentage Changes in 2070–2099
Recharge from Tributary Inflows

Development of Climate-Change Factors for Groundwater Modeling Analyses of Future Conditions at City of Spokane Well Stations

GSI Water Solutions, Inc.

NOTE

RCP stands for Representative Concentration Pathway for future global greenhouse gas emissions.

APPENDIX C

Groundwater Flow Model Development for the City of Spokane

APPENDIX C

Groundwater Flow Model Development for the City of Spokane

December 2024

Introduction

On behalf of the City of Spokane (City), GSI Water Solutions, Inc. (GSI), has developed an updated three-dimensional numerical groundwater flow model of the Spokane Valley-Rathdrum Prairie (SVRP) Aquifer to support the City's ongoing long-range groundwater supply source planning efforts, which are focused on capital improvements planning. This model builds upon prior groundwater models developed by the City (CH2M HILL, 1998; GSI, 2012) and by the U.S. Geological Survey (USGS) (Hsieh et al., 2007) and incorporates hydrogeologic data collected by the City in more recent years. Figure C-1 shows the locations of the City's well stations, each of which contain multiple caisson wells that are spaced closely together and can pump large quantities of groundwater with minimal drawdown because of the prolific water-yielding capabilities of the highly permeable SVRP Aquifer.

The City's updated groundwater flow model uses the USGS software MODFLOW-USG (Panday et al., 2013; Panday, 2023) and replaces a model that was first developed during the mid-1990s (CH2M HILL, 1998) using the European MicroFEM finite-element software (Hemker and de Boer, 2003 and 2017). The City's groundwater flow model simulates the occurrence and movement of groundwater flow in the SVRP Aquifer, which predominantly contains a thick sequence of highly permeable gravel, cobble, and sand deposits, but with sandier and siltier deposits in tributary drainages and in deep portions of the aquifer in a limited area along the Spokane River in the eastern portion of the City. The model simulates groundwater flow processes and groundwater budgets in the SVRP Aquifer, as well as the aquifer's connection to the Spokane River, the Little Spokane River, and lakes that adjoin the outer boundaries of the aquifer. The model uses multiple layers to provide a three-dimensional representation of groundwater movement horizontally within individual model layers and vertical movement between layers.

This appendix describes the design and calibration of the City's new groundwater flow model and is organized into the following sections that discuss:

- Groundwater modeling software, including its benefits
- Design of the model grid, both horizontally and vertically (i.e., its three-dimensional layering)
- Boundary conditions and the groundwater system attributes they represent
- Assignment of values for the SVRP Aquifer's hydraulic properties (hydraulic conductivity, specific yield, and storage coefficient)
- Model calibration
- Model applicability for groundwater resource management
- Model limitations, and recommendations for model maintenance and improvements

Description and Benefits of the MODFLOW-USG Groundwater Modeling Software

MODFLOW-USG was selected as the software code for the development of the City's new model because it has particularly robust groundwater simulation capabilities, including detailed and flexible solvers; is well-supported by graphical user interfaces (GUIs) that help the modeler visualize and manage the modeling process; has the ability to communicate with other software packages such as geographic information systems (GIS) software; and has broad familiarity by—and support within—the groundwater modeling community. Although MicroFEM also had effective simulation capabilities, MODFLOW-USG offers the following benefits:

- It is part of the MODFLOW family of software tools, which are the most widely known models in the groundwater and hydrologic modeling community. These tools are widely used and are supported by multiple GUIs and visualization programs that facilitate the pre-processing, post-processing, information management, and visualization aspects of groundwater modeling efforts. The USGS provides ongoing support and continued development of the MODFLOW family of modeling codes, and training programs and conferences are widely available through the USGS and other public and private entities.
- MODFLOW-USG provides a variety of flexible gridding methods and grid types that allow a grid to have high spatial resolution where needed (such as the finite-element method built into MicroFEM), without adding more grid nodes/cells in places where higher resolution is unnecessary. These gridding methods also provide the capability to simulate the thinning and pinching out of model layers/geologic units in a more robust manner than is available with other software codes.
- MODFLOW-USG provides more detailed and sophisticated methods of representing stream/aquifer interactions than are available in MicroFEM, including in particular the ability to calculate flow rates and instream channel hydraulics during the groundwater solution process.
- MODFLOW-USG has a robust Connected Linear Network (CLN) package that greatly facilitates the process of simulating water levels in production wells. This package is similar to the Multi-Node Well (MNW2) package (Konikow et al., 2009) that is used in software codes that use structured grids. However, the CLN package allows for specification of well efficiency values, whereas MNW2 makes use of empirical well-loss coefficients that are often unmeasured or harder to derive from commonly used aquifer test analysis methods than well efficiency estimates. MicroFEM simulates water levels only in the aquifer formation adjacent to a pumping well, which requires that calculations of water levels in a pumping well must be conducted as a manual post-processing calculation procedure outside of the model simulation environment.
- MODFLOW-USG provides the capability to simulate the movement and concentration of inorganic (geochemical) constituents and organic chemicals in groundwater, using the Block-Centered Transport process documented by Panday (2023).

Version 8 of Groundwater Vistas (GV) is the GUI that was used to develop the model and manage the modeling process (ESI, 2020). GV is a popular and widely used program for managing model simulations and has an enhanced level of support for MODFLOW-USG. GV supports the entire family of MODFLOW codes for groundwater flow, particle-tracking, and solute transport. GV also supports certain codes developed by parties other than the USGS, including (1) the mod-PATH3DU particle-tracking code (Muffels et al., 2018) developed specifically for MODFLOW-USG and (2) the PEST suite of utilities for model calibration (Doherty and Hunt, 2010; Doherty et al., 2010a and 2010b). The simulations developed to date with the new regional model (using GV Version 8) are expected to be readily usable in newer versions of GV, based on its long record of compatibility importing existing models into new updated versions of the GV software.

Grid Design

Horizontal Grid Design

The grid for the City's groundwater flow model consists of square cells having a 400-foot regular grid spacing regionally (in the parent grid), with imbedded grids that have refined (i.e., higher-resolution) spacing of 200 feet along the Spokane River and 50 feet at and around each of the City's well stations. Figure C-2 shows the active portion of the parent grid in the uppermost model layer (layer 1), before refined grids were introduced along the Spokane River and at the City's well stations. The areal extent of the active grid covers the same geographic area as the original MicroFEM model, which conforms to the SVRP Aquifer boundary and covers both the Washington and Idaho portions of the aquifer. Figures C-3 and C-4 show the grid in and around the City after imbedding finer grids along the Spokane River and at the City's well stations. The model grid is georeferenced to the Washington State Plane, North American Datum of 1983 (NAD83) High Accuracy Reference Network (HARN) coordinate system.

Vertical Grid Design

The model uses eight layers to represent the full saturated thickness of the SVRP Aquifer. The vertical datum is the North American Vertical Datum of 1988 (NAVD 88).

The 2012 version of the City's MicroFEM model (GSI, 2012) used three layers to represent the significant spatial variability in the aquifer's thickness, and also to represent the partially penetrating nature of groundwater production wells throughout most of the SVRP Aquifer. Because few wells, if any, penetrate the full saturated thickness of the SVRP Aquifer, its thickness has been estimated primarily from regional- and subregional-scale geophysical surveys and hydrogeologic studies (see Hsieh et al., 2007; Kahle and Bartolino, 2007) and from exploratory drilling by the City at its Havana Street and Well Electric well stations (GSI et al., 2017 and 2019a).

Because of the aquifer's prolific ability to yield water, most production wells are shallow, pumping only from the upper 100 feet of the aquifer (as measured from the average water table depth). Accordingly, the layering scheme in the 2012 version of the MicroFEM model was as follows:

- Where the aquifer's saturated thickness exceeds 200 feet, model layers 1 and 2 (the upper two model layers) were each 100 feet thick, and model layer 3 (the deepest layer in the 2012 version of the model) simulated the remaining saturated thickness of the SVRP aquifer.
- Where the saturated thickness is greater than 100 feet, but does not exceed 200 feet, model layer 1 was 100 feet thick, model layer 2 simulated the remaining saturated thickness of the SVRP aquifer, and model layer 3 was inactive.
- Where the saturated thickness is 100 feet or less, model layer 1 simulated the full saturated thickness of the SVRP aquifer, and model layers 2 and 3 were inactive.

As discussed by GSI (2019a and 2019b), the MicroFEM model's layering was later further subdivided to support well condition assessments and capital improvement planning at three of the City's well stations (Hoffman, Ray Street, and Well Electric). This resulted in eight model layers, which are carried over to the City's new MODFLOW-USG groundwater flow model. This layering scheme is as follows:

- The upper two model layers (layers 1 and 2) are each 75 feet thick, and all existing pumping wells in the SVRP Aquifer are completed in one or both of these two layers.
- Model layers 3 through 7 simulate the underlying system in 50-foot-thick layers, from a depth of 150 feet to a depth of 400 feet. Model layer 8 simulates the remaining saturated thickness of the SVRP Aquifer wherever the base of the aquifer lies more than 400 feet below the water table.

- As with the three-layer model, at any given location in the eight-layer model where the saturated thickness is low enough that the aquifer does not penetrate into a particular model layer, that layer is inactive in the model at that location.

Currently, none of the City's well station facilities penetrate more than 75 feet below the water table. Therefore, all pumping by the City's existing production wells is simulated as occurring from the uppermost model layer (layer 1). Outside the City limits, production wells pump almost exclusively from model layer 1, though 17 wells pump from both model layers 1 and 2.[1]

Boundary Conditions

The new regional model uses no-flow boundary conditions to define inactive cells within the model grid. The model also uses the following MODFLOW-USG packages for boundary conditions that relate to specific hydrologic processes. These packages are the following:

- **The Streamflow-Routing (SFR7) package** uses head-dependent boundary conditions for computing groundwater/surface water exchanges in the Spokane River, specifying inflows to the river from the various outfalls for treated groundwater discharges, and routing streamflow between model grid cells for water-balance tracking purposes. Streambed elevations were derived from digital elevation models, and streambed hydraulic conductivity values were derived from the City's MicroFEM model (GSI, 2012) and checked against values used in the USGS-developed Bi-State groundwater flow model (Hsieh et al., 2007). Monthly variations in flow rates at the headwaters of the Spokane River (the outlet from Coeur d'Alene Lake, near Post Falls, Idaho) are historical average flow rates since 1979 and are summarized in Table C-1.[2] Table C-2 lists inflows to the Spokane River from water reclamation facilities and from one major tributary (Latah Creek) that were programmed into the SFR7 package and were assumed to be constant throughout the year.
- **The River (RIV) package** uses head-dependent boundary conditions for computing groundwater/surface water exchanges in the Little Spokane River. Unlike the SFR7 package, the RIV package does not specify inflows to the river or route and calculate streamflow rates. Head values for the RIV package were assigned using digital elevation models for each grid cell containing the Little Spokane River.
- **The Recharge (RCH) package** uses specified-flux boundary conditions to represent deep percolation of rainfall, river storm flows, and land-applied water. Values for long-term average annual recharge rates were imported directly from the MicroFEM model (GSI, 2012); these rates were developed by the USGS for the period of 1991 through 2005 (Bartolino, 2007; Hsieh et al., 2007). For simulating the effects of climate change on groundwater resources, the average recharge rate was then translated into monthly-variable recharge rates using multipliers that range between zero in the summer months to values (during December and January) as high as 2.5 to 2.7 times the annual average recharge rate (based on analyses for Spokane Airport published by the USGS; see Bartolino, 2007).
- **The Well (WEL) package** – The WEL package is primarily used as a specified-flux boundary condition to specify the rate of inflow into the SVRP Aquifer from the tributary valleys of contributing watersheds (including those draining from Fernan Lake and Hauser Lake in Idaho, and Newman and Liberty Lake in Washington). The WEL package also defines pumping rates for all groundwater supply wells. The same wells and pumping rates used in the City's MicroFEM model were used in the new MODFLOW-USG model; these rates are long-term average rates of groundwater pumping by municipal and private well owners, as

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[1] These wells are the City of Millwood's New Park well; Consolidated Irrigation District's wellfields 4, 5, 6, 8, 9, 10, and 11; Model Irrigation District Well 6; Pasadena Park Irrigation District Well 2; the Riverside well; Spokane County Water District 3's Freeway&Vista well; and Vera Water and Power's wells 3, 9, 21, 22, and 33.

[2] These values were obtained in October 2022 from The Climate Toolbox website at https://climatetoolbox.org.

derived from production records for 2012 and 2013 and from other data sources, as described by GSI (2012).

- **The Connected Linear Network (CLN) package** uses head-dependent boundary conditions to simulate flow exchanges between the aquifer matrix and the small number of groundwater production wells that span both of the upper two model layers.
- **The Time-Variant Specified-Head (CHD) package** uses specified-head boundary conditions to hold the groundwater elevation steady (at elevation 1,527 feet) where the SVRP Aquifer naturally discharges groundwater beneath Long Lake at the northwestern model boundary.
- **The General-Head Boundary (GHB) package** uses head-dependent boundary conditions to compute subsurface inflows into the SVRP Aquifer from four lakes in Idaho that bound the SVRP Aquifer along its outer margins. In this package, groundwater elevations on the GHB boundary are set at values reflective of groundwater elevations displayed in contour maps developed by the USGS (Kahle and Bartolino, 2007) and are held steady at all times during model simulations.[3]

Table C-1. Monthly Streamflow Rates for the Spokane River from Coeur d'Alene Lake (Historical Average for 1950–2005)

Month	Specified Flow Rate at Post Falls, Idaho (cfs)
January	5,236
February	7,463
March	8,941
April	15,394
May	17,408
June	9,118
July	2,381
August	877
September	798
October	1,368
November	2,903
December	4,646

Note

cfs = cubic feet per second

[3] These head values (elevations in the NAVD 88 datum) are 2,050 feet at Lake Pend Oreille and Coeur d'Alene Lake; 2,120 feet at Hayden Lake; and 2,140 feet at Twin Lakes.

Table C-2. Specified Inflows into the Spokane River from Point Sources

Source of Inflow	Segment Number in SFR7 Package	Specified Flow Rate (mgd)	Specified Flow Rate (cfs)
Liberty Lake Sewer & Water District WRF	3	1.8	2.8
Kaiser Trentwood Outfall	7	2.4	3.7
Inland Empire Paper Outfall	10	5.7	8.8
Spokane County WRF	13	8.0	12.4
Latah Creek	19	151.9	235
City of Spokane WRF	21	29.1	45.0

Notes

cfs = cubic feet per second mgd = millions of gallons per day WRF = water reclamation facility

Aquifer Hydraulic Properties

Following are discussions of the assignment of hydraulic conductivity, specific yield, and storage coefficient.

Hydraulic Conductivity

Figures C-5 through C-11 show the spatial distribution of horizontal hydraulic conductivity in each model layer, as well as the geographic extent of the SVRP Aquifer in each model layer. In each layer, the horizontal hydraulic conductivity increases from the City upgradient to the state line and is highest along much of the Idaho portion of the aquifer situated between the state line and Lake Pend Oreille. Hydraulic conductivity values are notably lower at and downgradient of Coeur d'Alene Lake and in the western and northwestern edges of the SVRP Aquifer. In most areas, the horizontal hydraulic conductivity is uniform in each model layer. A notable exception is north of the City limits in Hillyard Trough, where a clay layer is known to bifurcate the SVRP Aquifer into an upper section and a lower section (CH2M HILL, 1998; Kahle and Bartolino, 2007). This clay layer is simulated as being present in model layer 2 (see Figure C-6), with a horizontal (and vertical) hydraulic conductivity value of 1×10^{-8} feet/day based on the USGS Bi-State model's calibration (Hsieh et al., 2007). Beneath this clay layer, the horizontal hydraulic conductivity is set at 200 feet/day in Hillyard Trough, based on the USGS Bi-State model. Along the Little Spokane River, the aquifer sediments in model layers 3 through 8 (beneath the clay layer) are assigned a horizontal hydraulic conductivity of 6,000 feet/day to allow groundwater in these deeper layers to discharge at the downgradient basin boundary at Long Lake.

In the Washington portion of the SVRP Aquifer, horizontal hydraulic conductivity values in the City's MicroFEM model (GSI, 2012) progressed in an upgradient direction from 1,000 feet/day in the northern and northwestern portions of the SVRP Aquifer to 7,000 feet/day at the Washington/Idaho state line. These values were based on limited testing conducted at City well stations during and before the 1990s. Hydrogeologic investigations at four City well stations between 2016 and 2019 included more sophisticated tests that identified much higher values for the hydraulic conductivity of the gravel deposits penetrated by the City's well stations. In particular, a 5-day controlled aquifer test from a test well at the Havana Street Well Station resulted in a hydraulic conductivity estimate of 15,000 feet/day (GSI et al., 2017). Performance testing at the Ray Street Well Station in fall 2017 produced a similar estimate. Performance testing of two caisson wells at the City's Well Electric Well Station in fall 2017 resulted in hydraulic conductivity estimates ranging between 12,500 and 31,000 feet/day, based on analytical and numerical modeling of the test results. These values are similar in their general order of magnitude to those used in the USGS Bi-State model (Hsieh et al., 2007), which ranged from 1,980 feet/day to 22,100 feet/day in much of the Washington portion of the SVRP Aquifer, and between 7,470 feet/day and 22,100 feet/day across the area extending from the state line downgradient to the northern City limits.

In the Idaho portion of the SVRP Aquifer, horizontal hydraulic conductivity values in the City's MicroFEM model (GSI, 2012) decreased in an upgradient direction from 9,100 feet/day near the state line, to 5,005 feet/day in central Rathdrum Prairie, 7,085 feet/day in the West (Main) Channel, and between 2,500 and 5,400 feet/day from there to Lake Pend Oreille. The effort to calibrate the City's new MODFLOW-USG model has resulted in hydraulic conductivity values that are higher and are largely the same magnitude as used in the USGS Bi-State model (Hsieh et al., 2007).

In areas where the horizontal hydraulic conductivity values exceed 200 feet/day, the vertical hydraulic conductivity is one-tenth of the horizontal hydraulic conductivity value. The ratio of 10:1 for horizontal-to-vertical hydraulic conductivity was used in the City's MicroFEM model and was found to not warrant adjustment during calibration of the City's new MODFLOW-USG model.

Specific Yield and Storage Coefficient

At the beginning of the model calibration process, the specific yield of the SVRP Aquifer's sediments is set at 0.35, based on the prevalence of gravels and cobbles with large pore spaces. This value is used to calculate groundwater levels in the uppermost saturated layer of the model (layer 1). The model was assigned a storage coefficient of 0.0001 in each underlying model layer at the beginning of the model calibration process. Both the specific yield and the storage coefficient are dimensionless coefficients (i.e., they have no unit of measurement) and were found to not warrant adjustment during model calibration.

Model Calibration

The calibration process consisted of constructing a 5-year simulation that varied natural recharge terms, groundwater pumping, and Spokane River flows on a monthly basis (using the same set of monthly variations from one year to the next). This simulation was used to conduct a general check of the model's ability to simulate conditions during the summer low-flow season, as described for regional groundwater levels by the USGS (Kahle and Bartolino, 2007) and as described for Spokane River gains and losses by the USGS (Kahle and Bartolino, 2007; Hsieh et al., 2007) and in unpublished data provided to the City from Spokane County during the City's development of its wellhead protection program.

Adjustments to horizontal hydraulic conductivity values in the SVRP Aquifer and streambed hydraulic conductivity values for the Spokane River were made to improve the initial model fit to these data sets. A summary of the calibration quality of the City's updated groundwater flow model is as follows:

- **Groundwater Elevations.** Figure C-12 compares the simulated seasonal-low groundwater levels against the September 2004 seasonal-low groundwater elevation contour map published by the USGS (Kahle and Bartolino, 2007). The shapes of the groundwater elevation contours are similar, and groundwater elevations are generally similar except for slight over-predictions of groundwater levels just east of the state line and extending upgradient roughly to a point halfway between the state line and Lake Pend Oreille. Groundwater elevations are generally well-matched near Coeur d'Alene and Hayden Lakes in Idaho and in the Washington portion of the SVRP Aquifer.
- **Spokane River Gains/Losses.** Table C-3 compares the simulated and field-measured estimates of the rates of Spokane River gains and losses for four major reaches of the river across the SVRP Aquifer. Values are shown in units of cubic feet per second (cfs). In general, the model provides a reasonable representation of gains and losses, despite the difficulty in interpretation that arises below Sullivan Road due to differences in the reaches used for reporting purposes and disagreements of some data sets about whether the river is gaining or losing in the reaches below Greene Street. Specific observations are:

- In the prominent upper losing reach of the river (extending from Post Falls to Sullivan Road), the calibrated model simulates a similar loss as the USGS Bi-State model and the Spokane County unpublished estimate, all of which show less loss than was estimated from field measurements by the USGS.
- From Sullivan Road to Green Street, the model simulates somewhat more gain than is estimated by the USGS and Spokane County, though the general order of magnitude is correct (i.e., in the hundreds of cfs, rather than tens or thousands of cfs).
- From Greene Street to Monroe Street, the model may be over-predicting the amount of gain occurring in this reach.
- From Monroe Street to Nine Mile Falls, the model simulates somewhat less gain in Spokane River flows than is estimated by the USGS, and does not simulate a losing condition as suggested by the unpublished data from Spokane County.

Table C-3. Model Calibration to Spokane River Gains/Losses During Low-Flow Month

<table>
<tr><th>Reach</th><th>Spokane County Unpublished Data for 1995</th><th>USGS Field Measurements for Sept. 2004</th><th>USGS Bi-State Model for Sept. 2004</th><th>Calibrated Version of New City Model</th></tr>
<tr><td>Post Falls to Sullivan Road</td><td>-207 to -319</td><td>-606</td><td>-377</td><td>-302</td></tr>
<tr><td>Sullivan Road to Greene St.</td><td>+416 to +537</td><td>+593</td><td rowspan="2">+623</td><td>+760</td></tr>
<tr><td>Greene St. to Monroe St.</td><td>+63 to +122</td><td>-112</td><td>+37</td></tr>
<tr><td>Monroe St. to Nine Mile Falls</td><td>-57 to -80</td><td>+268</td><td>+283</td><td>+358</td></tr>
</table>

Notes

All values are in units of cubic feet per second.

USGS = U.S. Geological Survey

Model Applicability for Groundwater Resource Management

The City's new groundwater flow model (like previous models) has been created through a detailed process of planning, construction, and calibration, which has resulted in a model that is well-suited for a variety of applications related to wellfield evaluation and planning and aquifer resource management. The City's new MODFLOW-USG groundwater flow model is an improvement over the City's prior groundwater model because of the flexible gridding capabilities of the software, the more robust numerical solvers for computing groundwater elevations and groundwater budgets, and the more sophisticated method of simulating groundwater/surface water interactions.

Additionally, the City's new model incorporates the results of aquifer tests and single-well tests that were not available until recently—the data from which significantly improved the understanding of the general order of magnitude of hydraulic conductivity values in the SVRP Aquifer. Unlike previous models, which used either one or three layers to simulate the aquifer system, this model uses eight layers, which allows for greater vertical resolution in simulating the direction and magnitudes of vertical gradients in the aquifer at any given location, and for more accurately representing the exchanges between the shallowest portions of the aquifer system and the Spokane River. The model also provides good replication of the important attributes of the system, including groundwater elevations, groundwater flow directions, and the rates and locations of Spokane River gains and losses.

Model Limitations and Recommended Maintenance and Improvements

Despite its detail and the in-depth nature of the calibration and validation process, the City's new groundwater flow model is a simplification of a complex hydrogeologic system and has been designed with certain built-in assumptions. Like any model, it is not perfect and should be used with care. Predictive simulation results should be examined by qualified and experienced hydrogeologists and water resource managers. Future modeling analyses, interpretations, and conclusions should not be viewed as absolute results and could change as the model is refined in the future as new data becomes available.

Additionally, the City has developed this model with the intention of beginning a process to improve groundwater modeling tools and capabilities in the SVRP Aquifer. The City does not view this model as the final model of the aquifer system, but rather a first step in building an updated model across the region. This model development effort did not alter several hydrologic inputs to the model outside of the City—in particular, the spatial distribution and magnitude of areal recharge, which is controlled by precipitation, evaporation, septic system discharges, and deep percolation from irrigated agricultural areas and irrigated urban landscapes. Additionally, certain boundary conditions such as inflows from lakes and tributary valleys were retained from prior models (particularly the USGS Bi-State model) without evaluation of whether those boundary conditions should be modified to reflect current hydrologic conditions. Furthermore, detailed calibration to long-term groundwater-level data across the geographic extent of the aquifer has not been conducted since the USGS developed the Bi-State model during the mid-2000s.

Continued maintenance of the model is recommended, to ensure that it will continue to be useful for future groundwater resource planning and wellfield evaluation needs. Maintenance activities should be determined by the City and other local municipal groundwater users based on how they plan to use the model to support long-term programs (such as water supply planning, capital improvements planning, and groundwater resource protection) and to support near-term decision making on matters such as wellfield operations, site development impacts on groundwater, or other specific resource management topics. Maintenance activities could include one or more of the following activities:

- **Updating and checking calibration as new data becomes available.** This can be thought of as a "calibration check" process, for which the objective is to evaluate the model's ability to simulate new water use and hydrologic information that is collected as time progresses. Events that could warrant an extension of the calibration period include not only the continued collection of information at existing wells and existing monitoring locations in the aquifer and in the river systems, but also (1) the collection of data at new locations and (2) the occurrence of different groundwater conditions than those experienced in the past (e.g., if the onset of an extended drought were to cause decreased pumping at some wells, the need to increase pumping elsewhere, lower recharge to the aquifer, and accordant changes in observed groundwater levels). Additionally, whenever new production wells are installed, long-term water-level monitoring should commence in the well, and controlled pumping tests should be conducted to provide quantitative estimates of aquifer properties—particularly in areas where wells have not been recently constructed and tested. Incorporating new data sets into the model provides opportunities to incorporate refinements to the model-specified hydraulic parameters that are used in localized areas for the aquifer and/or the Spokane River.
- **Upgrades to model software.** New versions of the MODFLOW family of software tools periodically become available that add/improve existing MODFLOW packages and/or improve solver capabilities and reduce model run times. These updates can occur every few years. Additionally, updates to the GUI (GV) occur frequently, although major upgrades in its features occur only every few years. Updates to MODFLOW and

GV do not need to be conducted on a regular schedule for the model to remain functional and suitable for its desired uses. If municipal water providers elect to use the model in an updated version of MODFLOW or under a major update of GV, the model should be run with the new software to confirm that it converges and runs properly, and to check that simulation results are similar to those obtained from the earlier software.

- **Model-sharing and cooperative efforts with local stakeholders and other government agencies.** When a municipality or water provider has developed a detailed numerical groundwater model of a regional aquifer system, it is common to receive requests for the model from local landowners/stakeholders or other government agencies.

Keeping the model updated with recent software and a calibration that is not several years old is helpful for increasing the confidence of groundwater users and other stakeholders, and for providing the model's keepers with opportunities to ensure that the model is being used correctly. Accordingly, GSI and the City recommend that the City and other SVRP groundwater users work together to further update and improve the model in the coming years to support planning activities occurring at both local and regional scales.

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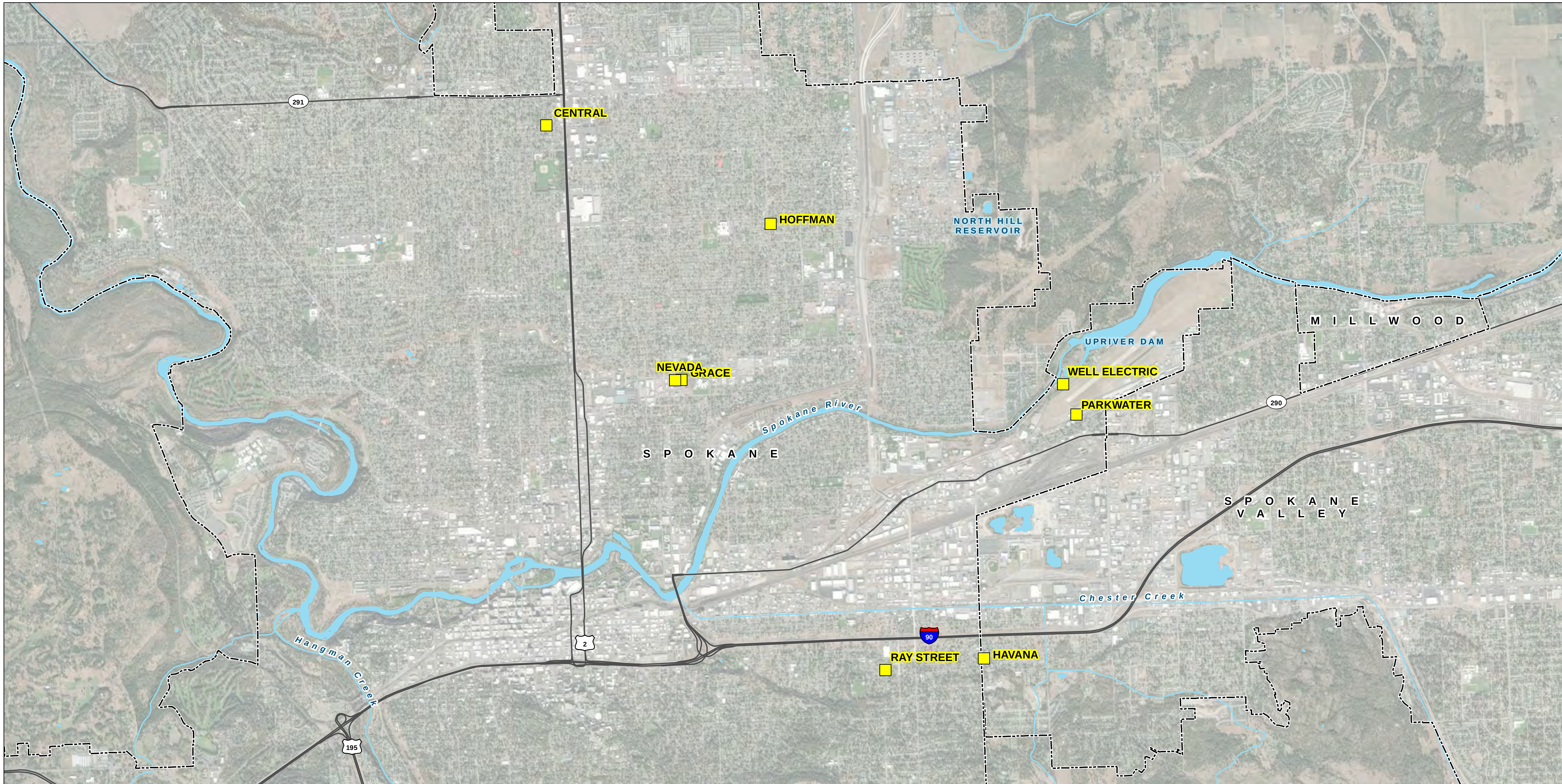
Figures



LEGEND

- Well Station
- City Boundary
- Major Road
- Watercourse
- Waterbody

FIGURE C-1

Location Map for City Well Stations

Groundwater Flow Model Development for the City of Spokane

N

0 2,000 4,000 6,000

feet

GSI Water Solutions, Inc.

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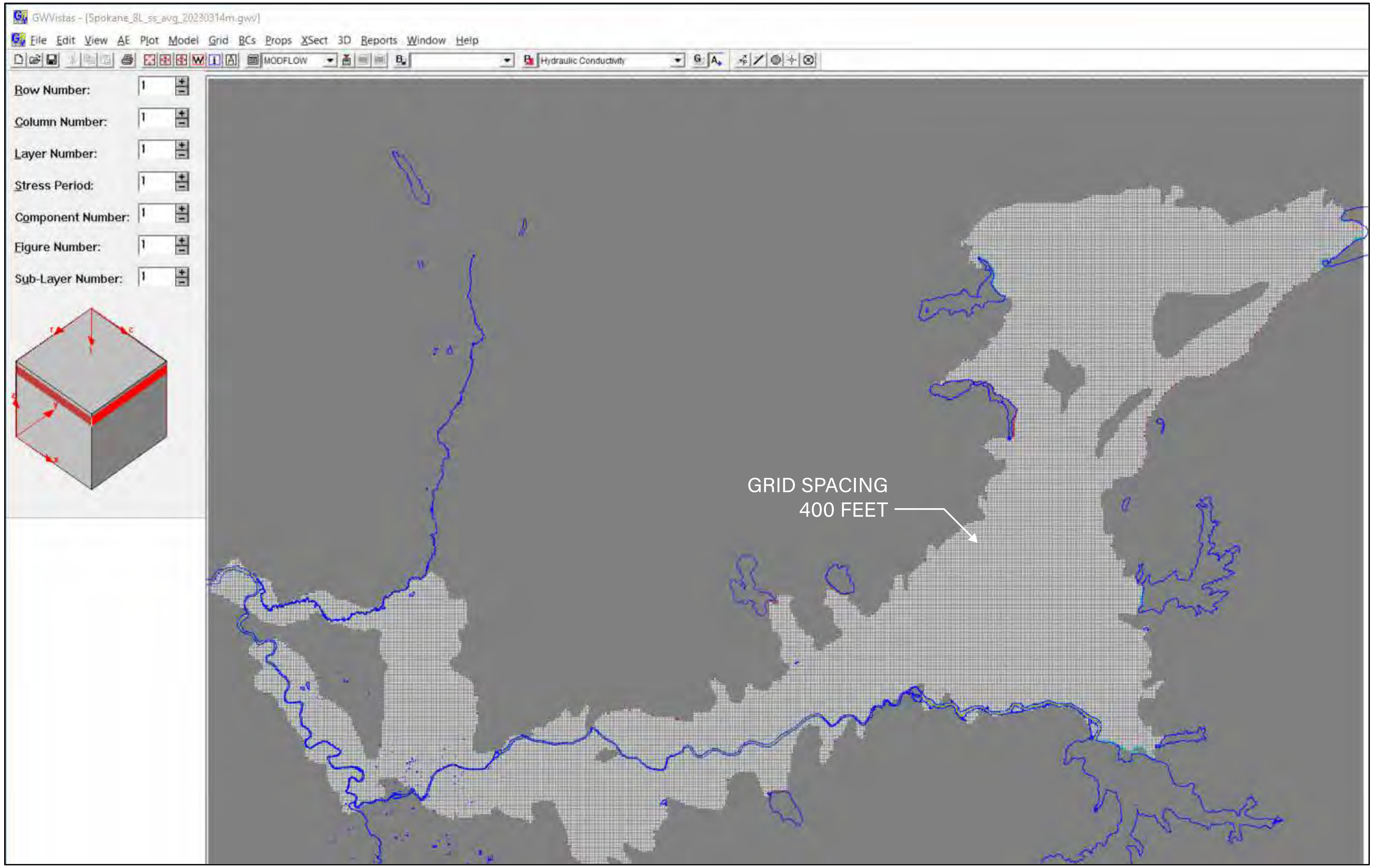

FIGURE C-2

Parent Model Grid for Entire SVRP Aquifer

Groundwater Flow Model Development for the City of Spokane

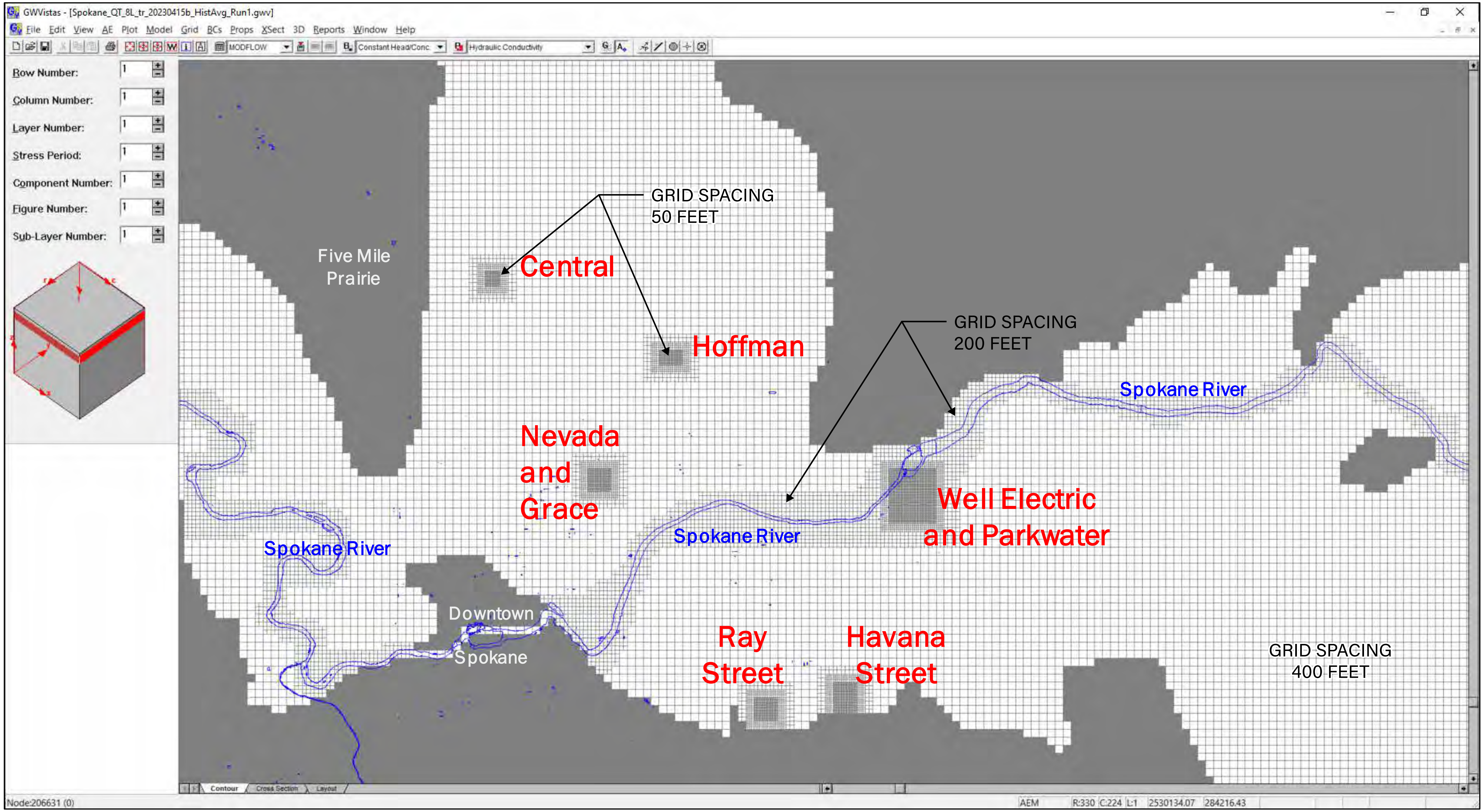

FIGURE C-3

View of Irregular Grid Imbedded Inside the Parent Grid, Along the Spokane River and Around City of Spokane Well Stations

Groundwater Flow Model Development for the City of Spokane

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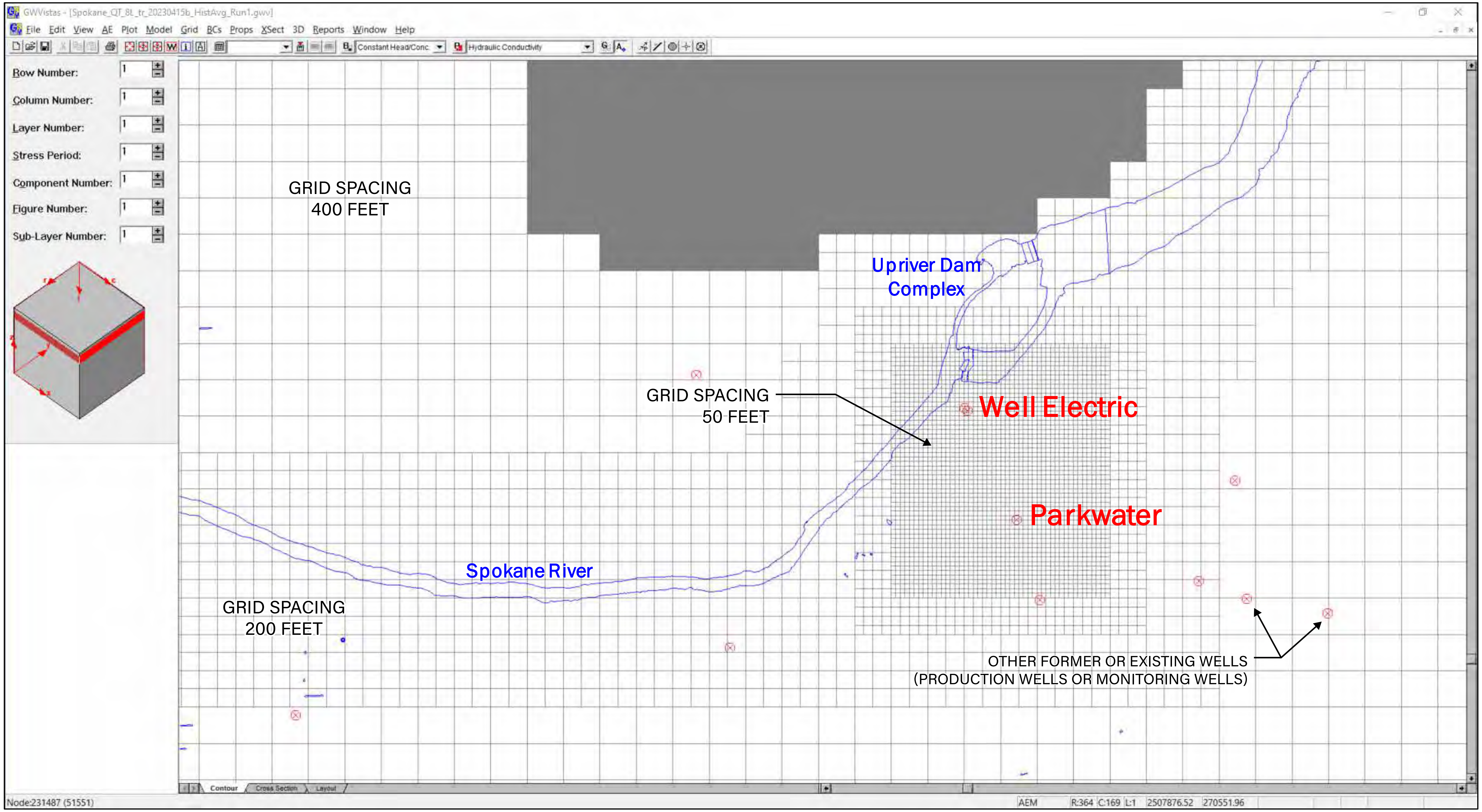

FIGURE C-4

View of Irregular Grid Along the Spokane River and at the Well Electric and Parkwater Well Stations

Groundwater Flow Model Development for the City of Spokane

GSI Water Solutions, Inc.

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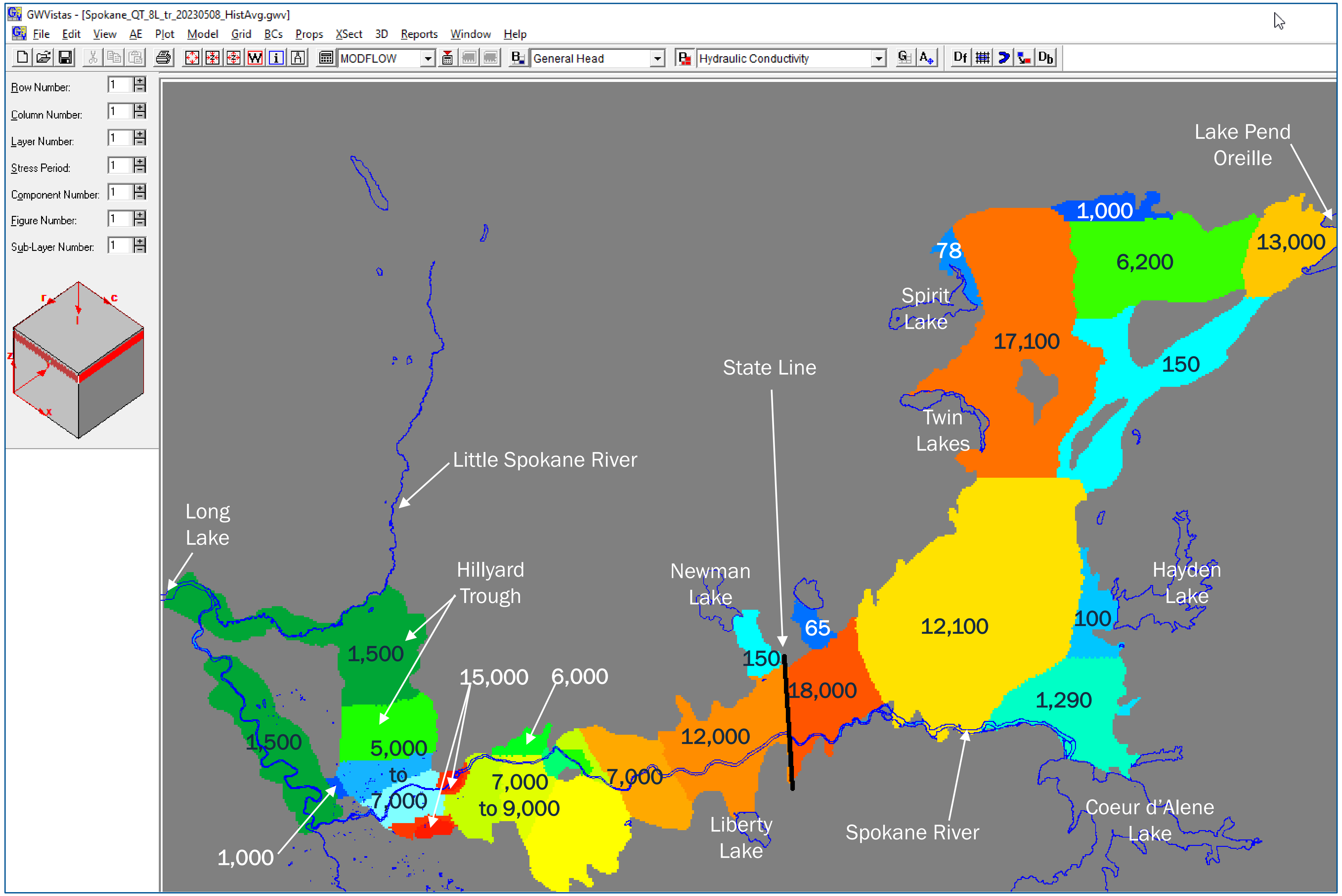

FIGURE C-5

Spatial Distribution of Horizontal Hydraulic Conductivity (feet/day) in Model Layer 1

Groundwater Flow Model Development for the City of Spokane

GSI Water Solutions, Inc.

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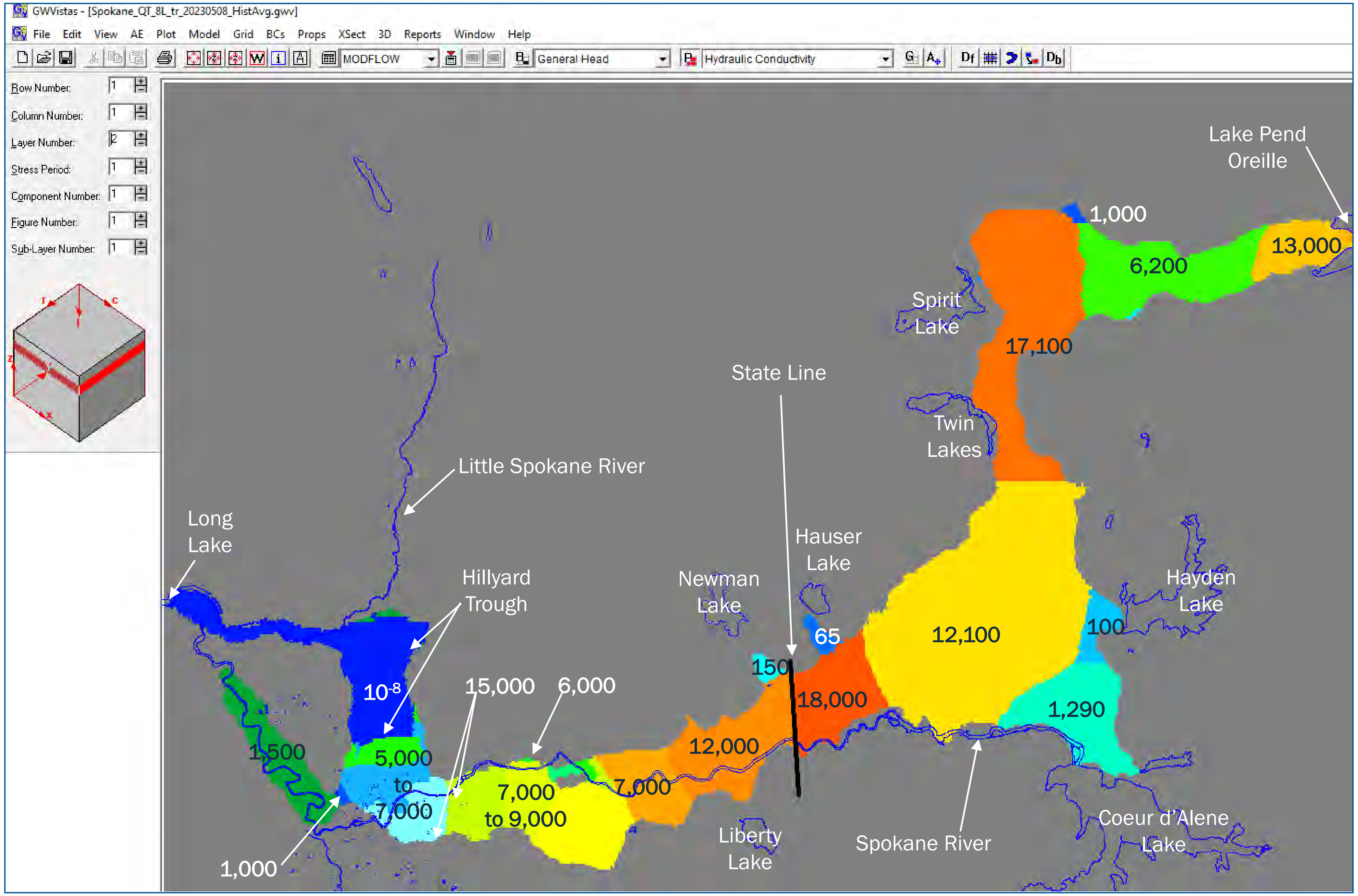

FIGURE C-6

Spatial Distribution of Horizontal Hydraulic Conductivity (feet/day) in Model Layer 2

Groundwater Flow Model Development for the City of Spokane

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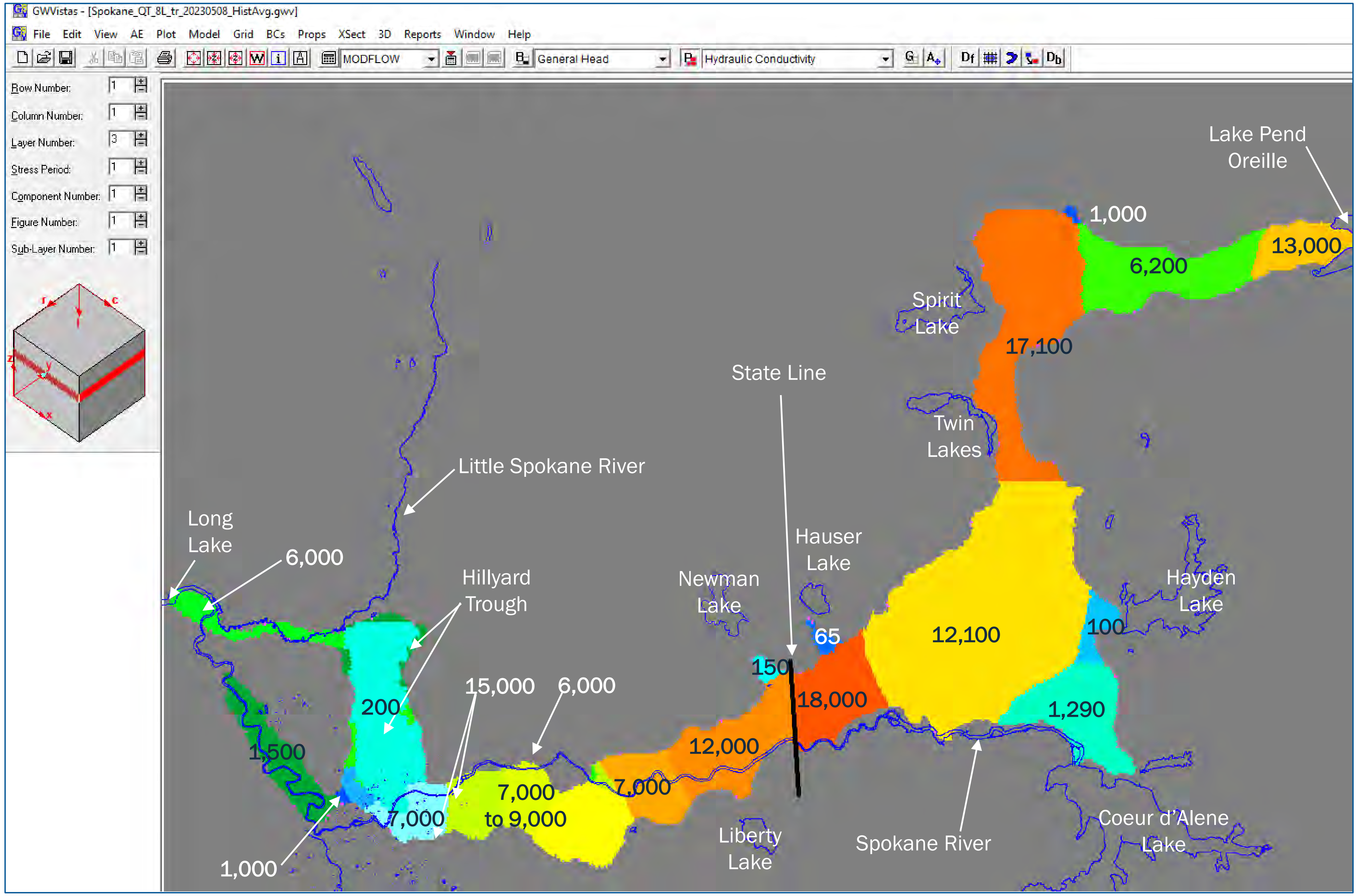

FIGURE C-7

Spatial Distribution of Horizontal Hydraulic Conductivity (feet/day) in Model Layers 3 and 4

Groundwater Flow Model Development for the City of Spokane

GSI Water Solutions, Inc.

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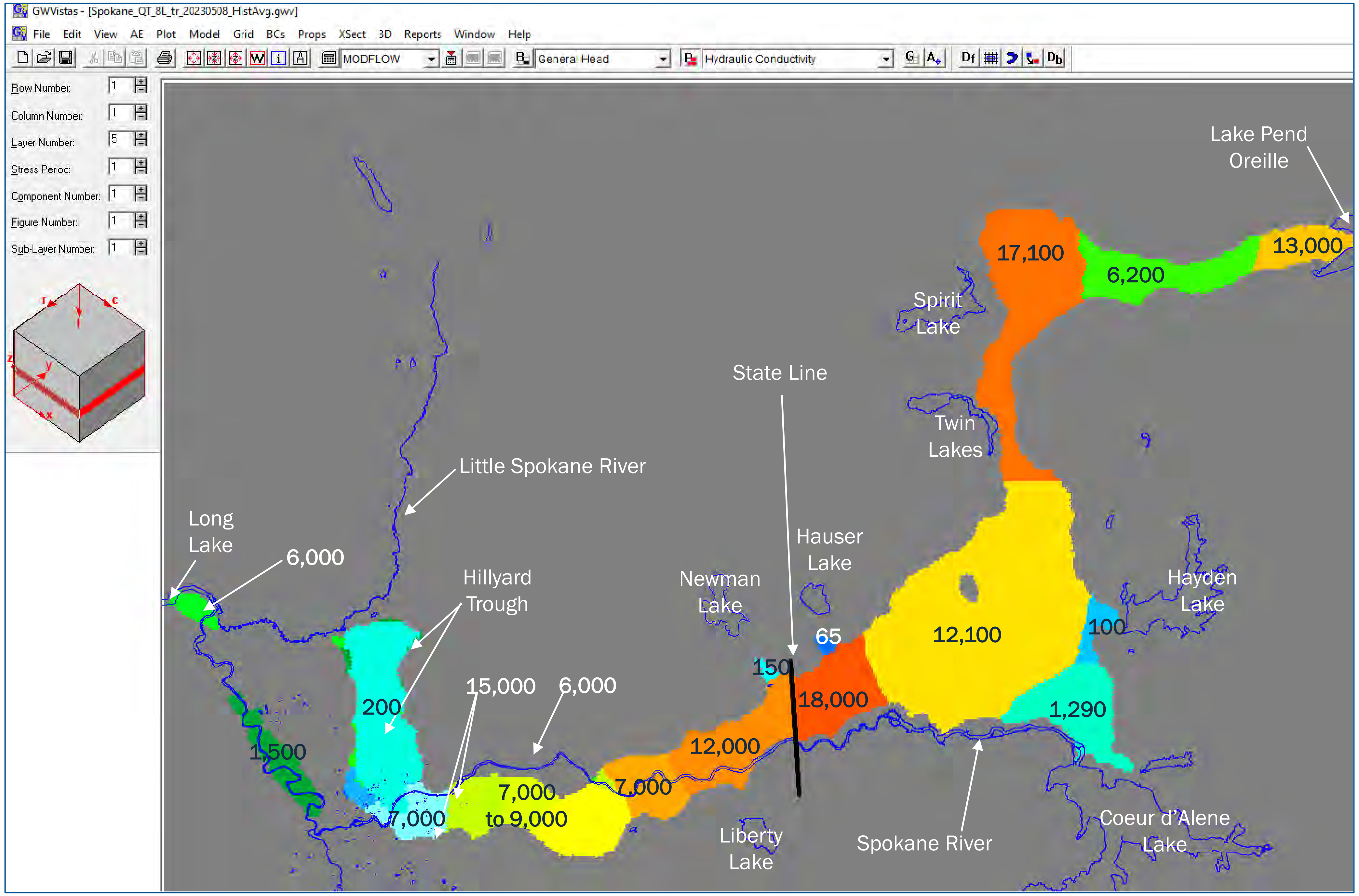

FIGURE C-8

Spatial Distribution of Horizontal Hydraulic Conductivity (feet/day) in Model Layer 5

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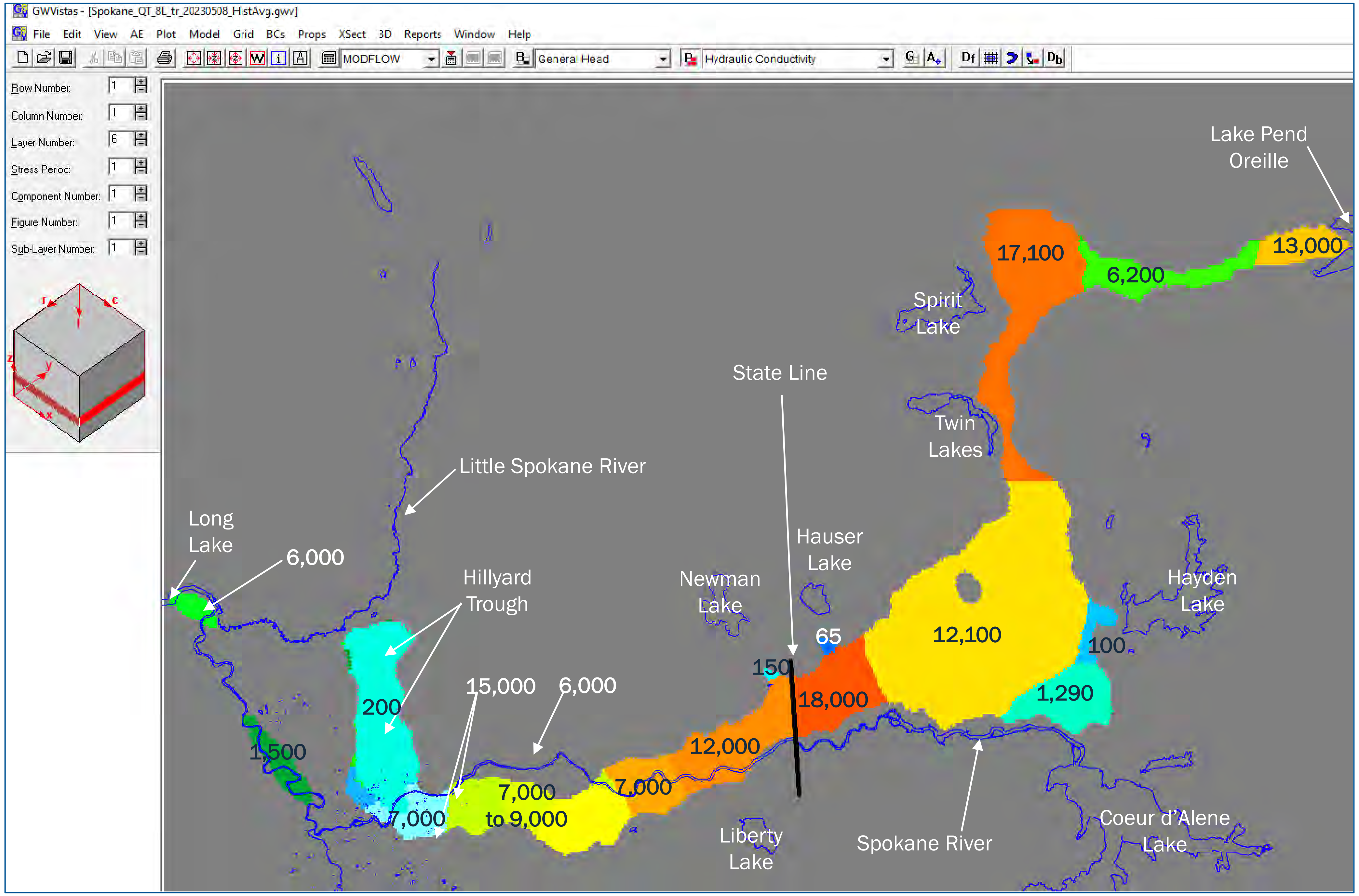

FIGURE C-9

Spatial Distribution of Horizontal Hydraulic Conductivity (feet/day) in Model Layer 6

Groundwater Flow Model Development for the City of Spokane

GSI Water Solutions, Inc.

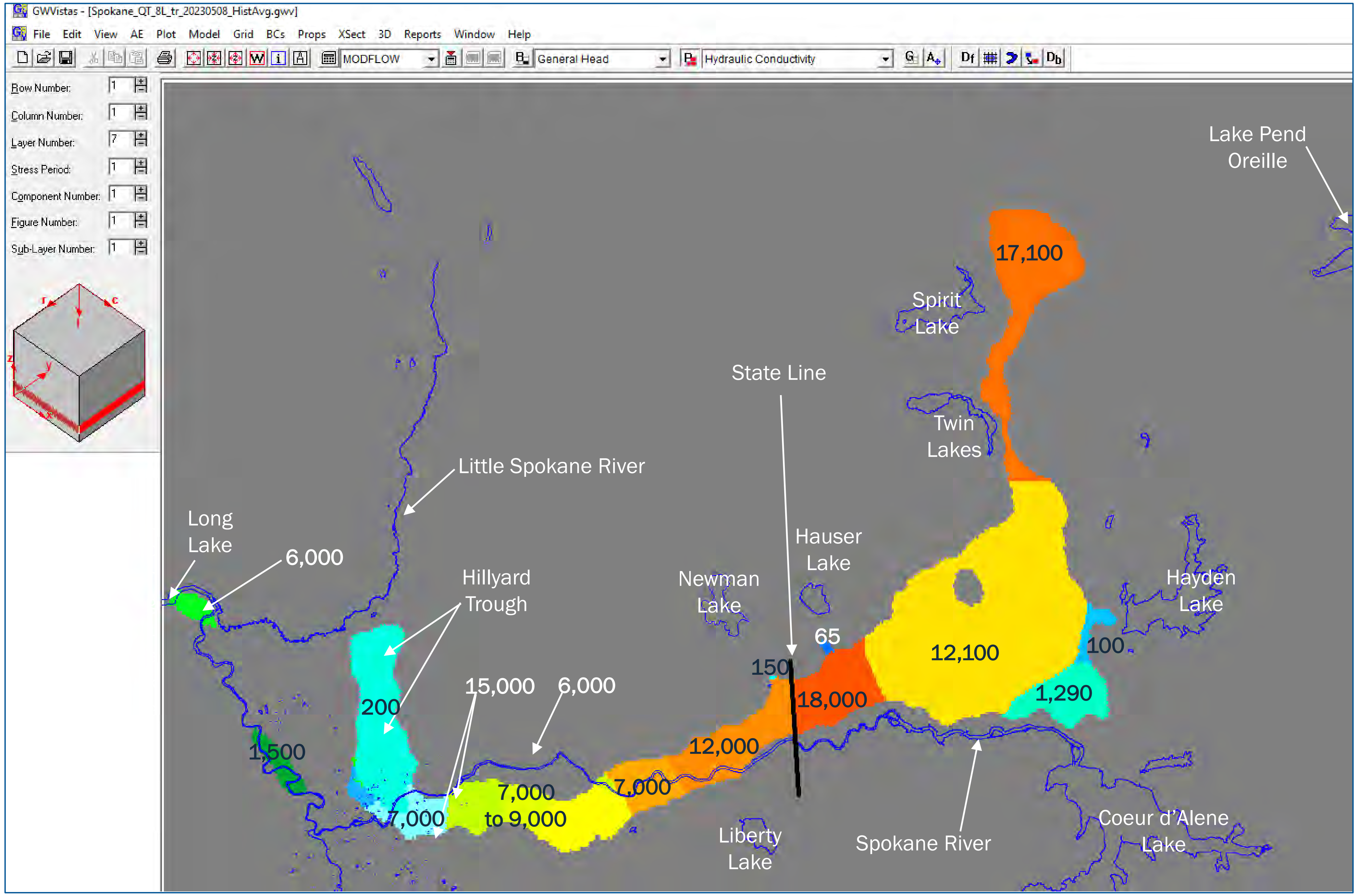

FIGURE C-10

Spatial Distribution of Horizontal Hydraulic Conductivity (feet/day) in Model Layer 7

Groundwater Flow Model Development for the City of Spokane

GSI Water Solutions, Inc.

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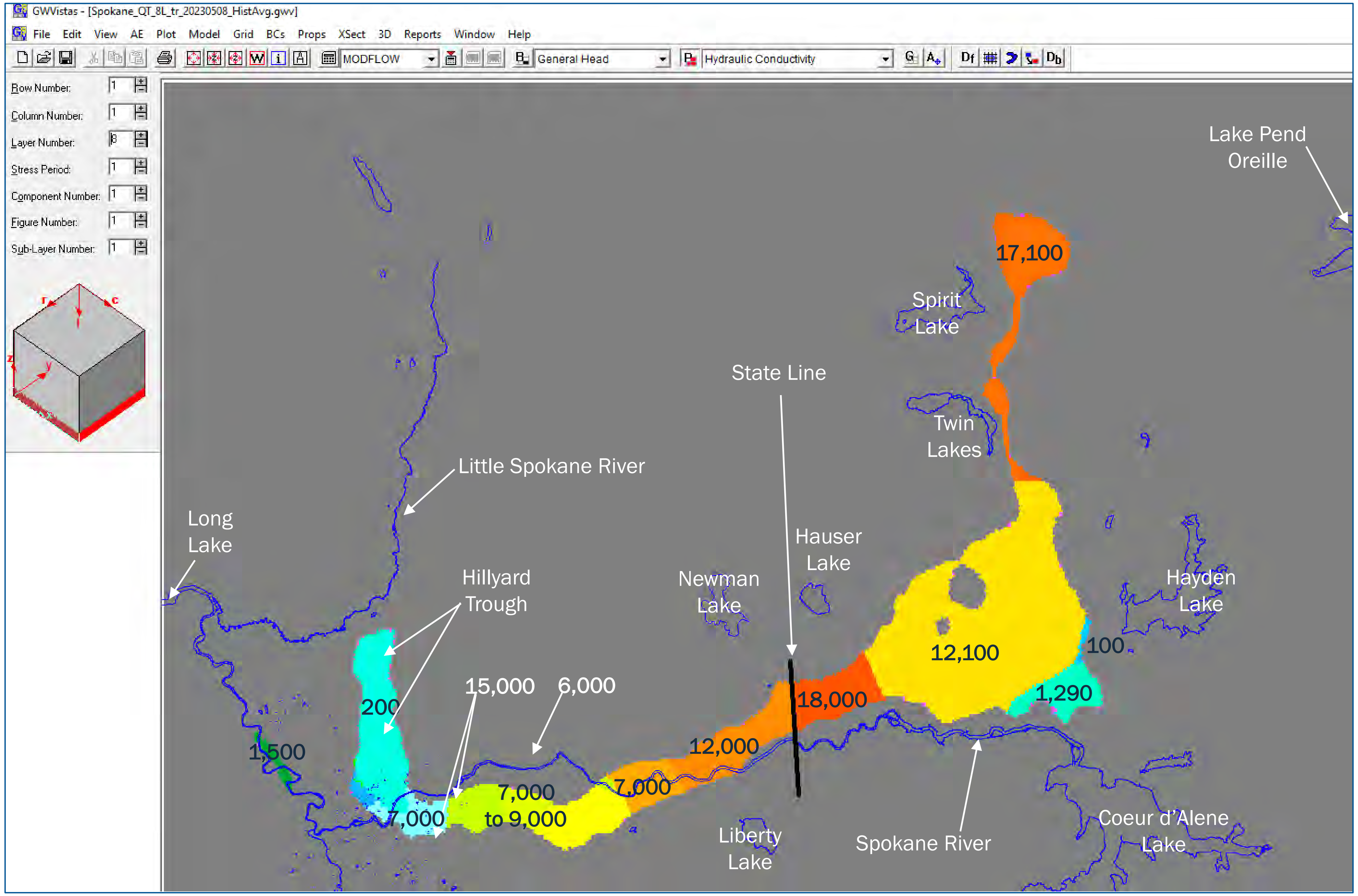


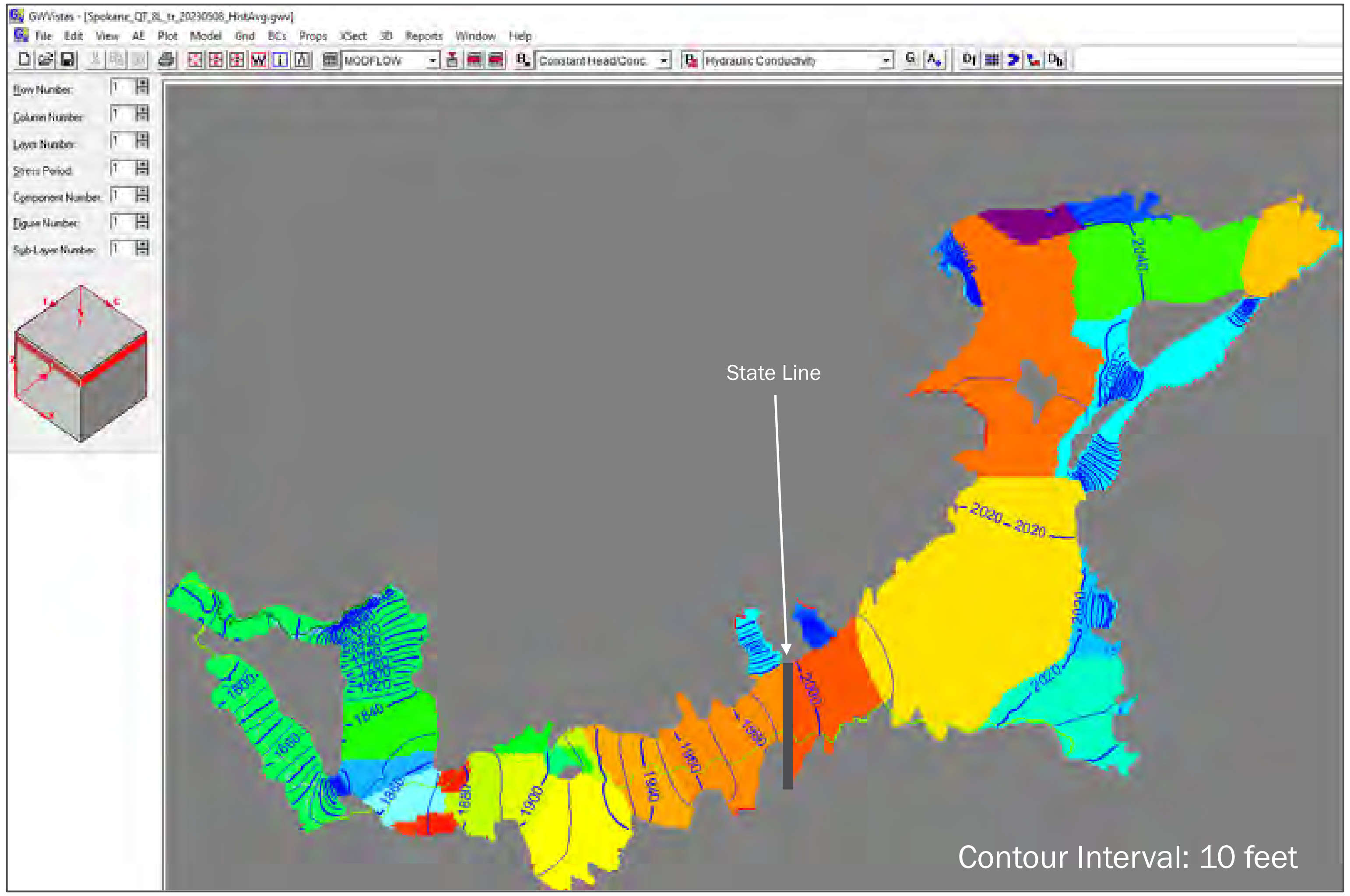
FIGURE C-11

Spatial Distribution of Horizontal Hydraulic Conductivity (feet/day) in Model Layer 8

Groundwater Flow Model Development for the City of Spokane

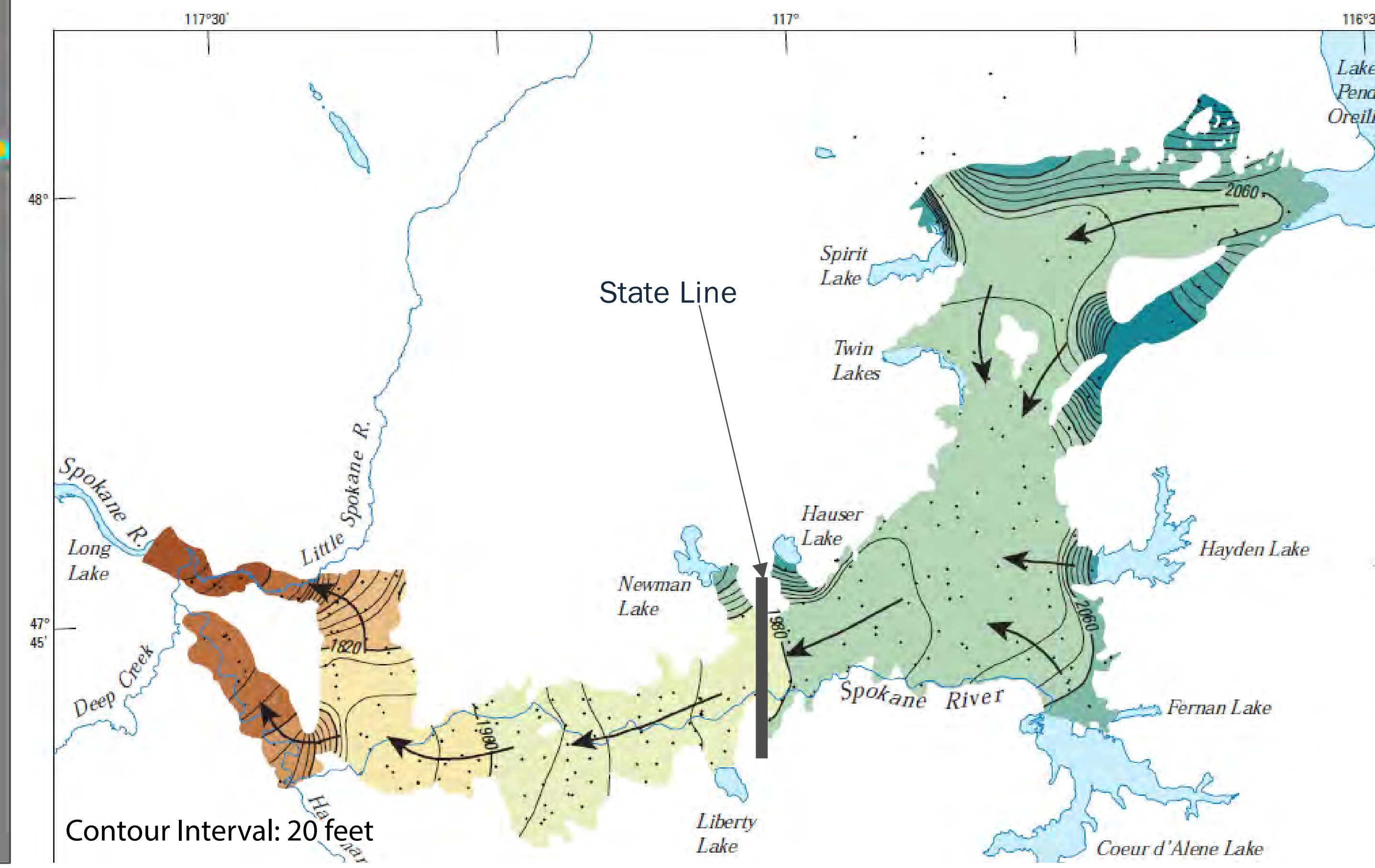
GSI Water Solutions, Inc.

Modeled Groundwater Elevations



NOTE
Colors in the map of modeled groundwater elevations represent zones showing the differences in the spatial distribution of the aquifer's hydraulic conductivity.

Measured Groundwater Elevations (September 2004)



NOTE
Colors in the map of measured groundwater elevations represent the spatial distribution of groundwater elevations (with the highest values in green and the lowest values in brown).

SOURCE
Kahle, S.C., and Bartolino, J.R., 2007. Hydrogeologic Framework and Ground-Water Budget of the Spokane Valley-Rathdrum Prairie Aquifer, Spokane County, Washington, and Bonner and Kootenai Counties, Idaho. U.S. Geological Survey Scientific Investigations Report 2007-5041, 48 p., 2 pls.

FIGURE C-12

Modeled and Measured Groundwater Elevation Contours for Seasonal-Low Conditions

Groundwater Flow Model Development for the City of Spokane

GSI Water Solutions, Inc.

APPENDIX D

Methodology for Developing Pumping Distributions Between Well Stations Under Emergency Operating Scenarios (City of Spokane Yellowstone Petroleum Pipeline Vulnerability Study)

Water Solutions, Inc.

APPENDIX D

Methodology for Developing Pumping Distributions Between Well Stations Under Emergency Operating Scenarios (City of Spokane Yellowstone Petroleum Pipeline Vulnerability Study)

December 2024

Introduction

This appendix describes the methodology that was used by GSI Water Solutions, Inc. (GSI), to take water distribution system modeling results (developed by Consor North America, Inc. [Consor]) and translate them into operating scenarios for four emergency conditions that could arise if a release of petroleum products were to occur from the Phillips 66 Yellowstone petroleum pipeline and threaten certain well stations that the City of Spokane (City) relies on for its groundwater supplies. The four emergency scenarios for specific City well stations are:

- Parkwater is offline
- Well Electric is offline
- Both Parkwater and Well Electric are offline
- Both Ray Street and Havana Street are offline

Consor used its water distribution system model to provide GSI with maximum day demand (MDD) pumping rates for each pump in each City well station for all four operating scenarios and for a baseline (non-emergency operating condition). Consor's analyses were conducted for the current configuration and limitations of the City's water distribution system and for a near-term/current level of demand. GSI used this information to extrapolate emergency and non-emergency operations under three sets of higher (future) water demands. A key input to this extrapolation process was the assignment of target demands in each of the City's three primary supply zones (the Low, Intermediate, and North Hill primary supply zones). The analysis also considered the operating limitations of each pump under current conditions or (at certain well stations) under future improvements that have been developed and used by the City for capital improvements planning.

A detailed calculation process was required to transform the pump-by-pump values under current conditions to values under future conditions. This appendix presents the details of the calculation methodology.

Demand Scenarios

Four demand scenarios are considered in this analysis: current conditions (provided by Consor), a 20-year demand projection (HDR, 2022; this was modified by GSI to account for climate change), and two 50-year demand projections (HDR, 2023; these were modified by GSI to account for climate change). Total system demands for the average day demand (ADD) and for the MDD are summarized in Table D-1 for each of these demand scenarios.

Table D-1. Demand Scenarios

Demand Scenario	ADD	MDD
Current Conditions (from City staff)	—	184.32
Current Conditions (from Consor)	—	138.48
20-year Projection (from City staff)	—	218.02
20-year Projection (HDR, 2022), No Climate Change	73.90	173.41
20-year Projection with 2070–2099 Climate Change (GSI)	91.47	186.42
50-year Projection: Scenario 4 (HDR's Modest Level of Demand) • Demographics: Baseline • Conservation: Standard • Climate Change: Limited	78.28	208.30
50-year Projection: Scenario 4 (GSI's Modest Level of Demand) • Demographics: Baseline • Conservation: Standard • Climate Change: Aggressive (RCP 8.5, 2070–2099)	95.32	217.40
50-year Projection: Scenario 3 (HDR's High Level of Demand) • Demographics: High Growth/High Commercial • Conservation: No Change from Current Conditions • Climate change: Limited	104.91	251.27
50-year Projection: Scenario 3 (GSI's High Level of Demand) • Demographics: High Growth/High Commercial • Conservation: No Change from Current Conditions • Climate change: Aggressive (RCP 8.5, 2070–2099)	127.06	259.75

Notes

All values are in units of millions of gallons per day (mgd).
— = not applicable ADD = average day demand GSI = GSI Water Solutions, Inc.
MDD = maximum day demand RCP = Representative Concentration Pathway for future global greenhouse gas emissions

MDD values for each of the City's three primary supply zones in its water distribution system were provided by Consor for current conditions (personal communication, Joe Foote/Consor to John Porcello/GSI, December 1, 2023) and by the City for the 20-year demand projection (personal communication, Beryl Fredrickson/City to John Porcello/GSI, January 10, 2023) and are summarized in Table D-2.

Table D-2. MDD Values for Each Primary Supply Zone (Current Conditions and 20-Year Projection)

Primary Supply Zone	Current Conditions from Consor (mgd)	20-Year Projection from City (mgd)	20-Year Projection from HDR (mgd)	Current Conditions from Consor (%)	20-Year Projection from City (%)	20-Year Projection from HDR (%)
Intermediate	36.83	49.25	39.17	26.6%	22.59%	22.59%
Low	49.70	106.85	84.99	35.9%	49.01%	49.01%
North Hill	51.95	61.92	49.25	37.5%	28.40%	28.40%
Total	**138.48**	**218.02**	**173.41**	**100.0%**	**100.0%**	**100.0%**

Notes

mgd = millions of gallons per day

For this analysis, GSI assumed that the distribution of demands between the three primary supply zones for the 20-year projection (on a percentage basis) also would apply to the two 50-year demand projections. Under that assumption, Table D-3 compares the MDD values for the 20-year projection and the two 50-year projections, after incorporating aggressive climate change into HDR's original MDD values for these three projections.

Table D-3. MDD Values for Each Primary Supply Zone (20-Year and Two 50-Year Demand Projections)

Primary Supply Zone	HDR's 20-Year Demand Projection (mgd)	GSI's 20-Year Demand Projection (mgd)	HDR's Modest 50-Year Demand Projection (mgd)	GSI's Modest 50-Year Demand Projection (mgd)	HDR's High 50-Year Demand Projection (mgd)	GSI's High 50-Year Demand Projection (mgd)
Intermediate	39.17	42.11	47.05	49.12	56.76	58.68
Low	84.99	91.37	102.09	106.54	123.15	127.30
North Hill	49.25	52.94	58.89	61.74	71.36	73.77
Total	**173.41**	**186.42**	**208.30**	**217.40**	**251.27**	**259.75**

Notes

mgd = millions of gallons per day

MDD Pumping Distribution from Each Well Station Under Present-Day Demands

Consor conducted modeling analyses of the City's existing water transmission system at present-day levels of demand, to identify target amounts of MDD pumping under non-emergency operating conditions and under each of the four emergency operating conditions. Consor's analyses used the current MDD demands required in each of the City's three primary supply zones (Low, Intermediate, and North Hill) and identified the specific pumps that would operate at each well station, along with the production rates. Attachment D1 presents five tables (one for each of these operating conditions) that present the supply and demand details.

While the focus of the tables in Attachment D1 is on present-day levels of demand, the 20-year level of demand (i.e., for year 2042) in each of the City's three primary supply zones (shown in the two right-hand columns in Table D-2) is also shown in each table in Attachment D1 for comparison purposes, based on the City email described previously (personal communication, Beryl Fredrickson/City to John Porcello/GSI, January

10, 2023). The effort to extrapolate the emergency and non-emergency pumping details under current demands to future levels of demand in each primary supply zone and future pumping needs from each well station is described below.

MDD Pumping Distribution from Each Well Station Under 20- and 50-Year Demands

The percentage distributions of demand between each of the three primary supply zones for the 20-year demand scenario (as displayed in Attachment D1) were assumed to also apply to the two 50-year demand scenarios. For all three demand scenarios, Tables D2-1 through D2-3 in Attachment D2 display the calculation procedure for distributing MDD pumping between each well station under non-emergency (baseline) conditions and the four emergency scenarios. A 7-step process was used, as follows:

- **Step 1.** For each well station, this table calculates the total pumping for the well station by reading (and adding up) the "MDD (gpm)" rates shown in the left-hand tables in Attachment D1 for each individual pump that is operating at a given well station. These values are for current MDD values and the current water transmission system, which means the Step 1 entries are the same in all three Attachment D2 tables.
- **Step 2.** The MDD values in Step 1 are used to calculate the percentage of supply coming from each well station. These values are for current MDD values and the current water transmission system, which means the Step 2 entries are the same in all three Attachment D2 tables.
- **Step 3.** An initial estimate of the MDD pumping rates under the future level of demand is calculated in Step 3 for each well station and each primary supply zone served by a given well station. These calculations use the percentages from Step 2 and the total system-wide MDD value for future demands (which is 186.42 mgd for the 20-year projection, 217.40 mgd for 50-year Scenario 4, and 259.75 mgd for 50-year Scenario 3).
- **Step 4.** This step compares the Step 3 MDD pumping rates to the future pumping capacity of each well station. Cases where the Step 3 MDD pumping rate exceeds the future capacity are shown in the Step 4 tables as negative values in red font and with a light pink background. Details about the values of the future pumping capacities are as follows:
  - The future pumping capacity for the Havana well station assumes that all six wells will be brought online in the next few years. Currently, three wells have been installed and are housed together in a single building that is nearing completion.
  - The pumping capacity for the Ray Street well station adds 6,850 gpm to current capacity, based on pumping system improvements at the existing caisson well that are described in a 2019 Concept Plan for this well station (GSI et al., 2019a). The resulting increased capacity of 23,414 gpm (33.72 mgd) does not include the new vertical wellfield that is described in the concept plan (which by itself would add another 17,500 gpm [25 mgd] of pumping capacity from this well station).
  - The pumping capacity for the Hoffman well station is the capacity that will be obtained after pumping system improvements described in a 2019 concept plan for this well station (GSI et al, 2019b) are implemented.
  - The pumping capacity for the Well Electric well station is based in part on a 2019 concept plan (GSI et al., 2019c) that describes the installation of a multi-well vertical wellfield in a deep sand unit that underlies the surficial SVRP gravels. However, the values shown in the Step 4 tables also reflect how many deep vertical wells (operating at or near 5,000 gpm per well) would be needed to provide sufficient supply to each primary supply zone, with the capacity value for a given primary supply zone reflecting the emergency operating scenario in which the demand in that primary supply zone is greatest. Because few well stations serve the Low and Intermediate primary supply zones, certain emergency scenarios will require the operation of the deep vertical wellfield at Well Electric, even in

the two scenarios that contemplate Well Electric being offline because of a hypothetical future contamination release to the surficial gravel unit from the Yellowstone petroleum pipeline.

- **Step 5.** This step rebalances the MDD pumping distribution between each well station, to honor the demand needs in each of the three primary supply zones while also imposing the constraint of not exceeding the future pumping capacity of each well station. For the four emergency operating scenarios, MDD pumping was assumed to be uniform at the Grace, Hoffman, and Central wells unless the capacity at Hoffman was rate-limiting (in which case Grace and Central would pump higher amounts). For all four scenarios, the Nevada well station was operated at its full capacity for the MDD.
- **Step 6.** The upper half of each Step 6 table reads the MDD values from Step 3 (which are called the "Target" values in Step 6) and the MDD values from Step 5 (which are called the "Rebalanced" values in Step 6) on a primary-supply-zone by primary-supply-zone basis. This is done for the non-emergency and emergency scenarios to confirm that the rebalancing process produced the same MDD values for each of these scenarios. The lower half of the table computes the percentages of system-wide pumping that are directed to each primary supply zone; these values are checked to make sure they match the MDD percentage values shown in the right-most columns of the Attachment D1 tables.
- **Step 7.** This step computes the percentage of MDD supply that comes from each well station under the final redistribution scenarios shown in the Step 5 tables. These final MDD values for each well station and each scenario are summarized in Table D-4 for the 20-year demand projection, Table D-5 for the modest 50-year demand projection, and Table D-6 for the high 50-year demand projection. This information is fed into separate calculations that provide the monthly production from each well station, as described below.

Table D-4. MDD Values for Each Well Station and Pipeline Scenario (20-Year Demand Projection)

Well Station	Non-Emergency Conditions (mgd)	Parkwater Offline (mgd)	Well Electric Offline (mgd)	Parkwater and Well Electric Offline (mgd)	Ray Street and Havana Street Offline (mgd)
Well Electric	28.82	76.94	0	45.58	43.75
Parkwater	65.03	0	63.15	0	64.67
Havana Street	14.25	16.62	9.97	17.06	0
Ray Street	12.03	16.15	14.57	25.05	0
Nevada	34.10	45.79	45.79	45.79	45.79
Grace	10.73	10.31	18.61	18.61	10.74
Hoffman	10.73	10.30	15.72	15.72	10.73
Central	10.73	10.31	18.61	18.61	10.74
Total	**186.42**	**186.42**	**186.42**	**186.42**	**186.42**

Notes

mgd = millions of gallons per day

Table D-5. MDD Values for Each Well Station and Pipeline Scenario (50-Year Modest-Demand Projection)

Well Station	Non-Emergency Conditions (mgd)	Parkwater Offline (mgd)	Well Electric Offline (mgd)	Parkwater and Well Electric Offline (mgd)	Ray Street and Havana Street Offline (mgd)
Well Electric	33.36	97.49	0	60.75	54.20
Parkwater	76.09	0	79.84	0	79.84
Havana Street	16.62	19.39	12.34	19.90	0
Ray Street	14.03	18.84	17.70	29.22	0
Nevada	39.76	45.79	45.79	45.79	45.79
Grace	12.52	11.97	23.01	23.01	12.53
Hoffman	12.51	11.96	15.72	15.72	12.52
Central	12.51	11.96	23.01	23.01	12.52
Total	**217.40**	**217.40**	**217.40**	**217.40**	**217.40**

Notes

mgd = millions of gallons per day

Table D-6. MDD Values for Each Well Station and Pipeline Scenario (50-Year High-Demand Projection)

Well Station	Non-Emergency Conditions (mgd)	Parkwater Offline (mgd)	Well Electric Offline (mgd)	Parkwater and Well Electric Offline (mgd)	Ray Street and Havana Street Offline (mgd)
Well Electric	41.76	125.40	14.35	89.90	74.44
Parkwater	88.45	0	94.64	0	94.64
Havana Street	19.85	23.16	16.60	24.96	0
Ray Street	16.77	22.51	22.99	33.72	0
Nevada	45.79	45.79	45.79	45.79	45.79
Grace	15.71	14.30	24.20	24.20	14.96
Hoffman	15.71	14.29	15.72	15.72	14.96
Central	15.71	14.30	25.46	25.46	14.96
Total	**259.75**	**259.75**	**259.75**	**259.75**	**259.75**

Notes

mgd = millions of gallons per day

Monthly Pumping Distribution from Each Well Station Under Future Demands

The information presented in the Step 5 and Step 7 tables in Attachment D2 was then used to develop daily average pumping rates during each month of the year from each individual well station. The pumping rates were calculated by reading the Step 7 values in the Attachment D2 tables and applying them to all months of the year. This calculation procedure assumed that future demands (whether under emergency or non-emergency conditions) will be apportioned between each well station by the same percentage amounts in each and every month of the year. For example, under the 50-year high demand scenario, the Nevada well station provides 17.63 percent of total system demand in January, 17.63 percent of total system demand in February, et cetera. This is different than current operations, which are characterized by nearly all off-season pumping coming from Parkwater and Well Electric, and the other well stations contributing flow only during the summer and the spring and fall shoulder seasons. The assumption of a uniform percent-usage of a given well from one month to the next is considered a reasonable assumption for the purposes of how the 20- and 50-year demand projections were used to calculate groundwater capture zones for this vulnerability study.

The calculations apply these percentages to the MDD and ADD values listed above in Table D-1 for the three future demand scenarios (20-year, 50-year modest demand, and 50-year high demand). Calculations were conducted in a manner that verified that the actual rates loaded into the groundwater flow model match the target ADD and MDD values listed in Table D-1. The computed rates for each month and each well station were then converted into the measurement units used by the groundwater flow model (negative values in units of cubic feet per day).

References

GSI Water Solutions, Inc.; Landau Associates; and Murray, Smith & Associates. 2019a. *Concept Plan for Facility Improvements at the Ray Street Well Station*. Prepared for City of Spokane Department of Integrated Capital Management. August 2019.

GSI Water Solutions, Inc.; Landau Associates; and Murray, Smith & Associates. 2019b. *Concept Plan for Facility Improvements at the Hoffman Well Station*. Prepared for City of Spokane Department of Integrated Capital Management. August 2019.

GSI Water Solutions, Inc.; Landau Associates; and Murray, Smith & Associates. 2019c. *Concept Plan for Facility Improvements at the Well Electric Well Station*. Prepared for City of Spokane Department of Integrated Capital Management. August 2019.

Attachment D1

Tables Containing Consor's Analysis of Emergency and Non-Emergency Operations for City of Spokane Under the Present-Day Water Transmission System

Table D1-1
Consor's Analysis for City of Spokane Non-Emergency Operations (Under the Present-Day Water Transmission System)

Supply Capacity / Flowrate Analysis					
Supply Sources	**Capacity (gpm)**	**Control**	**Initial Status**	**MDD (gpm)**	**MDD (%)**
Intermediate Primary Supply Zone					
Havana P4	3,750		Open	2,880	
Havana P5	3,750		Open	2,880	
Havana P6	3,750		Open	2,880	
Ray P1	7,047	Lincoln Height No. 1	Closed		
Ray P2	5,630	Lincoln Height No. 1	Open	4,324	
Ray P3	3,887	Lincoln Height No. 1	Open	2,985	
Parkwater P1	7,079	Lincoln Height No. 1	Closed		
Parkwater P2	6,181	Lincoln Height No. 1	Open	4,747	
Well Electric P1	6,358	Lincoln Height No. 1	Open	4,883	
Total	**47,432**				
Operating Total	**33,306**	Sufficient Supply		**25,578**	**26.6%**
Low Primary Supply Zone					
Nevada P1	5,345	Rockwood Vista	Closed		
Nevada P2	10,475	Rockwood Vista	Open	6,583	
Nevada P3	10,060	Shadle Park	Open	6,322	
Nevada P4	5,916	Rockwood Vista	Closed		
Parkwater P3	8,393	Rockwood Vista	Open	5,275	
Parkwater P4	8,779	Rockwood Vista	Open	5,517	
Parkwater P5	8,038	Rockwood Vista	Open	5,051	
Parkwater P6	9,174	Rockwood Vista	Open	5,765	
Parkwater P7	8,858	Rockwood Vista	Closed		
Parkwater P8	9,223	Rockwood Vista	Closed		
Well Electric P3	14,486	Rockwood Vista	Closed		
Total	**98,747**				
Operating Total	**54,919**	Sufficient Supply		**34,514**	**35.9%**
North Hill Primary Supply Zone					
Well Electric P2	8,861	Five Mile	Open	6,765	
Well Electric P4	9,637	Five Mile	Open	7,358	
Grace P1	8,359	Five Mile	Closed		
Grace P2	8,447	Five Mile	Closed		
Hoffman P1	5,572	Five Mile	Open	4,254	
Hoffman P2	5,500	Five Mile	Open	4,199	
Central P1	8,745	Five Mile	Open	6,677	
Central P2	8,937	Five Mile	Open	6,823	
Total	**64,058**				
Operating Total	**47,252**	Sufficient Supply		**36,076**	**37.5%**
All Primary Supply Zones					
Total	210,237				
Operating Total	135,477				
Demand	96,168				

Demand Required						
Zone Name	**MDD (gpm)**	**MDD (mgd)**	**MDD (%)**	**2042 MDD (%)**	**2042 MDD (gpm)**	**2042 MDD (mgd)**
Intermediate Primary Supply Zone						
Intermediate	***5,272***					
Glennaire	810					
High	6,855					
South View	74					
Top	12,567					
Subtotal	**25,578**	**36.83**	**26.6%**	**22.59%**	**27,200**	**39.17**
Low Primary Supply Zone						
Low	***24,451***					
Cedar Hills	224					
Eagle Ridge 1	578					
Eagle Ridge 2	1,046					
Highland	687					
SIA	3,455					
West Plains	3,650					
Woodland Heights	423					
Subtotal	**34,514**	**49.70**	**35.9%**	**49.01%**	**59,020**	**84.99**
North Hill Primary Supply Zone						
North Hill	***30,625***					
Five Mile	2,973					
Indian Hills	68					
Kempe	1,279					
Midbank	773					
Shawnee	209					
Woodridge	150					
Subtotal	**36,076**	**51.95**	**37.5%**	**28.40%**	**34,200**	**49.25**
All Primary Supply Zones						
Grand Total	**96,168**	**138.48**	**100.0%**	**100.0%**	**120,420**	**173.41**
2042 MDD	**120,420**					
2042 MDD	**129,454**			**(All Values in These Columns are From a City Email Dated January 10, 2023)**		

Table D1-2

Consor's Analysis for City of Spokane Emergency Operations With Parkwater Well Station Offline (Under the Present-Day Water Transmission System)

Supply Capacity / Flowrate Analysis

Supply Sources	Capacity (gpm)	Control	Baseline Status	Baseline Operating Capacity % (combined supply source)	Emergency Scenario Status	Emergency Scenario Operating Capacity % (combined supply source)	Total Assumed Flowrate (from % of available capacity) (NOTE only operating to provide MDD)	Average Demand (GPM)	Baseline (GPM)
Intermediate Primary Supply Zone									
Havana P4	3,750		Open		Open			3360.5	
Havana P5	3,750		Open		Open			3360.5	
Havana P6	3,750		Open	33.8%	Open	39.4%	10081.6	3360.5	
Ray P1	7,047	Lincoln Height No. 1	Closed		Open			6315.1	
Ray P2	5,630	Lincoln Height No. 1	Open		Closed				
Ray P3	3,887	Lincoln Height No. 1	Open	28.6%	Open	38.3%	9798.4	3483.3	
Parkwater P1	7,079	Lincoln Height No. 1	Closed		Closed				
Parkwater P2	6,181	Lincoln Height No. 1	Open	18.6%	Closed	0%			
Well Electric P1	6,358	Lincoln Height No. 1	Open	19.1%	Open	22.3%	5697.6	5697.6	
Total	**47,432**						Total (Check vs MDD)	25,577.6	25,577.6
Available Operating Capacity (Baseline)	**33,306**								
Available Operating Capacity (Emergency)	**28,542**	Available Capacity for MDD + FF?	Deficient by 1035 gpm						
		Available Capacity for MDD *only*?	Sufficient Supply of 2964 gpm						
Low Primary Supply Zone									
Nevada P1	5,345	Rockwood Vista	Closed		Open			3985.9	
Nevada P2	10,475	Rockwood Vista	Open		Open			7811.5	
Nevada P3	10,060	Shadle Park	Open		Open			7502.0	
Nevada P4	5,916	Rockwood Vista	Closed	37.4%	Open	68.7%	23711.1	4411.7	
Parkwater P3	8,393	Rockwood Vista	Open		Closed				
Parkwater P4	8,779	Rockwood Vista	Open		Closed				
Parkwater P5	8,038	Rockwood Vista	Open		Closed				
Parkwater P6	9,174	Rockwood Vista	Open		Closed				
Parkwater P7	8,858	Rockwood Vista	Closed		Closed				
Parkwater P8	9,223	Rockwood Vista	Closed	62.6%	Closed	0%			
Well Electric P3	14,486	Rockwood Vista	Closed	0%	Open	31%	10802.6	10802.6	
Total	**98,747**						Total (Check vs MDD)	34,513.7	34,513.7
Available Operating Capacity (Baseline)	**54,919**								
Available Operating Capacity (Emergency)	**46,282**	Available Capacity for MDD + FF?	Sufficient Supply of 5768 gpm						
		Available Capacity for MDD *only*?	Sufficient Supply of 11768 gpm						
North Hill Primary Supply Zone									
Well Electric P2	8,861	Five Mile	Open		Open			7225.7	
Well Electric P4	9,637	Five Mile	Open	39.1%	Open	41.8%	15084.1	7858.5	
Grace P1	8,359	Five Mile	Closed		Open			6816.3	
Grace P2	8,447	Five Mile	Closed	0%	Open	38.0%	13704.4	6888.1	
Hoffman P1	5,572	Five Mile	Open		Closed				
Hoffman P2	5,500	Five Mile	Open	23.4%	Closed	0%			
Central P1	8,745	Five Mile	Open		Closed				
Central P2	8,937	Five Mile	Open	37.4%	Open	20.2%	7287.7	7287.7	
Total	**64,058**						Total (Check vs MDD)	36,076.2	36,076.2
Available Operating Capacity (Baseline)	**47,252**								
Available Operating Capacity (Emergency)	**44,241**	Available Capacity for MDD + FF?	Sufficient Supply of 2164 gpm						
		Available Capacity for MDD *only*?	Sufficient Supply of 8164 gpm				Total (All Primary Supply Zones)	96,167.5	96,167.5

Demand Required

Zone Name	MDD (gpm)	MDD (%)	2042 MDD (%)	2042 MDD (gpm)	2042 MDD (mgd)
Intermediate Primary Supply Zone					
Intermediate	***5,272***				
Glennaire	810				
High	6,855				
South View	74				
Top	12,567				
Subtotal	**25,578**	**26.6%**	**22.59%**	**27,200**	**39.17**
Low Primary Supply Zone					
Low	***24,451***				
Cedar Hills	224				
Eagle Ridge 1	578				
Eagle Ridge 2	1,046				
Highland	687				
SIA	3,455				
West Plains	3,650				
Woodland Heights	423				
Subtotal	**34,514**	**35.9%**	**49.01%**	**59,020**	**84.99**
North Hill Primary Supply Zone					
North Hill	***30,625***				
Five Mile	2,973				
Indian Hills	68				
Kempe	1,279				
Midbank	773				
Shawnee	209				
Woodridge	150				
Subtotal	**36,076**	**37.5%**	**28.40%**	**34,200**	**49.25**
All Primary Supply Zones					
Grand Total	**96,168**	**100.0%**	**100.0%**	**120,420**	**173.41**
2042 MDD (no climate change)	**120,420**				
2042 MDD (with climate change)	**129,454**		(All Values in These Columns are From a City Email Dated January 10, 2023)		

Table D1-3

Consor's Analysis for City of Spokane Emergency Operations With Well Electric Well Station Offline (Under the Present-Day Water Transmission System)

Supply Capacity / Flowrate Analysis

Supply Sources	Capacity (gpm)	Control	Baseline Status	Baseline Operating Capacity % (combined supply source)	Emergency Scenario Status	Emergency Scenario Operating Capacity % (combined supply source)	Total Assumed Flowrate (from % of available capacity) (NOTE only operating to provide MDD)	Average Demand (GPM)	Baseline (GPM)
Intermediate Primary Supply Zone									
Havana P4	3,750		Open		Closed				
Havana P5	3,750		Open		Open			3026.3	
Havana P6	3,750		Open	33.8%	Open	23.7%	6052.6	3026.3	
Ray P1	7,047	Lincoln Height No. 1	Closed		Open			5687.0	
Ray P2	5,630	Lincoln Height No. 1	Open		Closed				
Ray P3	3,887	Lincoln Height No. 1	Open	28.6%	Open	34.5%	8823.9	3136.9	
Parkwater P1	7,079	Lincoln Height No. 1	Closed		Open			5712.9	
Parkwater P2	6,181	Lincoln Height No. 1	Open	18.6%	Open	41.8%	10701.0	4988.2	
Well Electric P1	6,358	Lincoln Height No. 1	Open	19.1%	Closed	0%			
Total	**47,432**						Total (Check vs MDD)	**25,577.6**	**25,577.6**
Available Operating Capacity (Baseline)	**33,306**	Sufficient Supply							
Available Operating Capacity (Emergency)	**31,694**	Available Capacity for MDD + FF?	Sufficient Supply of 2116 gpm						
		Available Capacity for MDD only?	Sufficient Supply of 6116 gpm						
Low Primary Supply Zone									
Nevada P1	5,345	Rockwood Vista	Closed		Closed				
Nevada P2	10,475	Rockwood Vista	Open		Open			8430.8	
Nevada P3	10,060	Shadle Park	Open		Open			8096.8	
Nevada P4	5,916	Rockwood Vista	Closed	37.4%	Open	61.7%	21289.2	4761.5	
Parkwater P3	8,393	Rockwood Vista	Open		Open			6755.1	
Parkwater P4	8,779	Rockwood Vista	Open		Closed				
Parkwater P5	8,038	Rockwood Vista	Open	62.6%	Open	38.3%	13224.5	6469.4	
Parkwater P6	9,174	Rockwood Vista	Open		Closed				
Parkwater P7	8,858	Rockwood Vista	Closed		Closed				
Parkwater P8	9,223	Rockwood Vista	Closed		Closed				
Well Electric P3	14,486	Rockwood Vista	Closed	0%	Closed	0%			
Total	**98,747**						Total (Check vs MDD)	**34,513.7**	**34,513.7**
Available Operating Capacity (Baseline)	**54,919**								
Available Operating Capacity (Emergency)	**42,882**	Available Capacity for MDD + FF?	Sufficient Supply of 2368 gpm						
		Available Capacity for MDD only?	Sufficient Supply of 8368 gpm						
North Hill Primary Supply Zone									
Well Electric P2	8,861	Five Mile	Open		Closed				
Well Electric P4	9,637	Five Mile	Open	39.1%	Closed	0.0%			
Grace P1	8,359	Five Mile	Closed		Open			6619.0	
Grace P2	8,447	Five Mile	Closed	0%	Open	36.9%	13307.7	6688.7	
Hoffman P1	5,572	Five Mile	Open		Open			4412.1	
Hoffman P2	5,500	Five Mile	Open	23.4%	Open	24.3%	8767.2	4355.1	
Central P1	8,745	Five Mile	Open		Open			6924.6	
Central P2	8,937	Five Mile	Open	37.4%	Open	38.8%	14001.3	7076.7	
Total	**64,058**						Total (Check vs MDD)	**36,076.2**	**36,076.2**
Available Operating Capacity (Baseline)	**47,252**								
Available Operating Capacity (Emergency)	**45,560**	Available Capacity for MDD + FF?	Sufficient Supply of 3483 gpm						
		Available Capacity for MDD only?	Sufficient Supply of 9483 gpm				Total (All Primary Supply Zones)	**96,167.5**	**96,167.5**

Demand Required

Zone Name	MDD (gpm)	MDD (%)	2042 MDD (%)	2042 MDD (gpm)	2042 MDD (mgd)
Intermediate Primary Supply Zone					
Intermediate	***5,272***				
Glennaire	810				
High	6,855				
South View	74				
Top	12,567				
Subtotal	**25,578**	**26.6%**	**22.59%**	**27,200**	**39.17**
Low Primary Supply Zone					
Low	***24,451***				
Cedar Hills	224				
Eagle Ridge 1	578				
Eagle Ridge 2	1,046				
Highland	687				
SIA	3,455				
West Plains	3,650				
Woodland Heights	423				
Subtotal	**34,514**	**35.9%**	**49.01%**	**59,020**	**84.99**
North Hill Primary Supply Zone					
North Hill	***30,625***				
Five Mile	2,973				
Indian Hills	68				
Kempe	1,279				
Midbank	773				
Shawnee	209				
Woodridge	150				
Subtotal	**36,076**	**37.5%**	**28.40%**	**34,200**	**49.25**
All Primary Supply Zones					
Grand Total	**96,168**	**100.0%**	**100.0%**	**120,420**	**173.41**
2042 MDD (no climate change)	**120,420**		↑	↑	↑
2042 MDD (with climate change)	**129,454**		(All Values in These Columns are From a City Email Dated January 10, 2023)		

Table D1-4

Consor's Analysis for City of Spokane Emergency Operations With Parkwater and Well Electric Well Stations Offline (Under the Present-Day Water Transmission System)

Supply Capacity / Flowrate Analysis

Supply Sources	Capacity (gpm)	Control	Baseline Status	Baseline Operating Capacity % (combined supply source)	Emergency Scenario Status	Emergency Scenario Operating Capacity % (combined supply source)	Total Assumed Flowrate (from % of available capacity) (NOTE only operating to provide MDD)	Average Demand (GPM)	Baseline (GPM)
Intermediate Primary Supply Zone									
Havana P4	3,750		Open		Open			3448.5	
Havana P5	3,750		Open		Open			3448.5	
Havana P6	3,750		Open	33.8%	Open	40.4%	10345.4	3448.5	
Ray P1	7,047	Lincoln Height No. 1	Closed		Open			6480.4	
Ray P2	5,630	Lincoln Height No. 1	Open		Open			5177.3	
Ray P3	3,887	Lincoln Height No. 1	Open	28.6%	Open	59.6%	15232.2	3574.5	
Parkwater P1	7,079	Lincoln Height No. 1	Closed		Closed				
Parkwater P2	6,181	Lincoln Height No. 1	Open	18.6%	Closed	0%			
Well Electric P1	6,358	Lincoln Height No. 1	Open	19.1%	Closed	0%			
Total	**47,432**						Total (Check vs MDD)	25,577.6	25,577.6
Available Operating Capacity (Baseline)	**33,306**								
Available Operating Capacity (Emergency)	**27,814**	Available Capacity for MDD + FF?	Deficient by 1763 gpm						
		Available Capacity for MDD only?	Sufficient Supply of 2236 gpm						
Low Primary Supply Zone									
Nevada P1	5,345	Rockwood Vista	Closed		Open			5,345	
Nevada P2	10,475	Rockwood Vista	Open		Open			10,475	
Nevada P3	10,060	Shadle Park	Open		Open			10,060	
Nevada P4	5,916	Rockwood Vista	Closed	37.4%	Open	100.0%	34513.72	5,916	
Parkwater P3	8,393	Rockwood Vista	Open		Closed				
Parkwater P4	8,779	Rockwood Vista	Open		Closed				
Parkwater P5	8,038	Rockwood Vista	Open	62.6%	Closed	0%			
Parkwater P6	9,174	Rockwood Vista	Open		Closed				
Parkwater P7	8,858	Rockwood Vista	Closed		Closed				
Parkwater P8	9,223	Rockwood Vista	Closed		Closed				
Well Electric P3	14,486	Rockwood Vista	Closed	0%	Closed	0%			
Total	**98,747**						Total (Check vs MDD)	31,796.0	34,513.7
Available Operating Capacity (Baseline)	**54,919**								
Available Operating Capacity (Emergency)	**31,796**	Available Capacity for MDD + FF?	Deficient by 8717 gpm						
		Available Capacity for MDD only?	Deficient by 2717 gpm						
North Hill Primary Supply Zone									
Well Electric P2	8,861	Five Mile	Open		Closed				
Well Electric P4	9,637	Five Mile	Open	39.1%	Closed	0.0%			
Grace P1	8,359	Five Mile	Closed		Open			6619.0	
Grace P2	8,447	Five Mile	Closed	0%	Open	36.9%	13307.7	6688.7	
Hoffman P1	5,572	Five Mile	Open		Open			4412.1	
Hoffman P2	5,500	Five Mile	Open	23.4%	Open	24.3%	8767.2	4355.1	
Central P1	8,745	Five Mile	Open		Open			6924.6	
Central P2	8,937	Five Mile	Open	37.4%	Open	38.8%	14001.3	7076.7	
Total	**64,058**						Total (Check vs MDD)	36,076.2	36,076.2
Available Operating Capacity (Baseline)	**47,252**								
Available Operating Capacity (Emergency)	**45,560**	Available Capacity for MDD + FF?	Sufficient Supply of 3483 gpm						
		Available Capacity for MDD only?	Sufficient Supply of 9483 gpm				Total (All Primary Supply Zones)	93,449.8	96,167.5

Demand Required

Zone Name	MDD (gpm)	MDD (%)	2042 MDD (%)	2042 MDD (gpm)	2042 MDD (mgd)
Intermediate Primary Supply Zone					
Intermediate	***5,272***				
Glennaire	810				
High	6,855				
South View	74				
Top	12,567				
Subtotal	**25,578**	26.6%	22.59%	27,200	39.17
Low Primary Supply Zone					
Low	***24,451***				
Cedar Hills	224				
Eagle Ridge 1	578				
Eagle Ridge 2	1,046				
Highland	687				
SIA	3,455				
West Plains	3,650				
Woodland Heights	423				
Subtotal	**34,514**	35.9%	49.01%	59,020	84.99
North Hill Primary Supply Zone					
North Hill	***30,625***				
Five Mile	2,973				
Indian Hills	68				
Kempe	1,279				
Midbank	773				
Shawnee	209				
Woodridge	150				
Subtotal	**36,076**	37.5%	28.40%	34,200	49.25
All Primary Supply Zones					
Grand Total	96,168	100.0%	100.0%	120,420	173.41
2042 MDD (no climate change)	120,420		↑	↑	↑
2042 MDD (with climate change)	129,454		(All Values in These Columns are From a City Email Dated January 10, 2023)		

Table D1-5

Consor's Analysis for City of Spokane Emergency Operations With Havana Street and Ray Street Well Stations Offline (Under the Present-Day Water Transmission System)

Supply Capacity / Flowrate Analysis

Supply Sources	Capacity (gpm)	Control	Baseline Status	Baseline Operating Capacity % (combined supply source)	Emergency Scenario Status	Emergency Scenario Operating Capacity % (combined supply source)	Total Assumed Flowrate (from % of available capacity) (NOTE only operating to provide MDD)	Average Demand (GPM)	Baseline (GPM)
Intermediate Primary Supply Zone									
Havana P4	3,750		Open		Closed				
Havana P5	3,750		Open		Closed				
Havana P6	3,750		Open	33.8%	Closed				
Ray P1	7,047	Lincoln Height No. 1	Closed		Closed				
Ray P2	5,630	Lincoln Height No. 1	Open		Closed				
Ray P3	3,887	Lincoln Height No. 1	Open	28.6%	Closed				
Parkwater P1	7,079	Lincoln Height No. 1	Closed		Open			7,079	
Parkwater P2	6,181	Lincoln Height No. 1	Open	18.6%	Open	67.6%	13260.0	6,181	
Well Electric P1	6,358	Lincoln Height No. 1	Open	19.1%	Open	32.4%	6358.0	6,358	
Total	**47,432**						Total (Check vs MDD)	19,618.0	25,577.6
Available Operating Capacity (Baseline)	**33,306**								
Available Operating Capacity (Emergency)	**19,618**	Available Capacity for MDD + FF?	Deficient by 9959 gpm						
		Available Capacity for MDD only?	Deficient by 5959 gpm						
Low Primary Supply Zone									
Nevada P1	5,345	Rockwood Vista	Closed		Closed				
Nevada P2	10,475	Rockwood Vista	Open		Open			8200.2	
Nevada P3	10,060	Shadle Park	Open		Open			7875.3	
Nevada P4	5,916	Rockwood Vista	Closed	37.4%	Open	60.0%	20706.8	4631.3	
Parkwater P3	8,393	Rockwood Vista	Open		Closed				
Parkwater P4	8,779	Rockwood Vista	Open		Open			6872.5	
Parkwater P5	8,038	Rockwood Vista	Open		Closed				
Parkwater P6	9,174	Rockwood Vista	Open		Closed				
Parkwater P7	8,858	Rockwood Vista	Closed	62.6%	Open	40.0%	13806.9	6934.4	
Parkwater P8	9,223	Rockwood Vista	Closed		Closed				
Well Electric P3	14,486	Rockwood Vista	Closed	0%	Closed	0.0%			
Total	**98,747**						Total (Check vs MDD)	34,513.7	34,513.7
Available Operating Capacity (Baseline)	**54,919**								
Available Operating Capacity (Emergency)	**44,088**	Available Capacity for MDD + FF?	Sufficient Supply of 3574 gpm						
		Available Capacity for MDD only?	Sufficient Supply of 9574 gpm						
North Hill Primary Supply Zone									
Well Electric P2	8,861	Five Mile	Open		Open			6765.2	
Well Electric P4	9,637	Five Mile	Open	39.1%	Open	39.1%	14123.0	7357.7	
Grace P1	8,359	Five Mile	Closed		Closed				
Grace P2	8,447	Five Mile	Closed	0%	Closed	0%			
Hoffman P1	5,572	Five Mile	Open		Open			4254.1	
Hoffman P2	5,500	Five Mile	Open	23.4%	Open	23.4%	8453.3	4199.2	
Central P1	8,745	Five Mile	Open		Open			6676.7	
Central P2	8,937	Five Mile	Open	37.4%	Open	37.4%	13499.9	6823.3	
Total	**64,058**						Total (Check vs MDD)	36,076.2	36,076.2
Available Operating Capacity (Baseline)	**47,252**								
Available Operating Capacity (Emergency)	**47,252**	Available Capacity for MDD + FF?	Sufficient Supply of 5175 gpm						
		Available Capacity for MDD only?	Sufficient Supply of 11175 gpm				Total (All Primary Supply Zones)	90,207.9	96,167.5

Demand Required

Zone Name	MDD (gpm)	MDD (%)	2042 MDD (%)	2042 MDD (gpm)	2042 MDD (mgd)
Intermediate Primary Supply Zone					
Intermediate	***5,272***				
Glennaire	810				
High	6,855				
South View	74				
Top	12,567				
Subtotal	**25,578**	26.6%	22.59%	27,200	39.17
Low Primary Supply Zone					
Low	***24,451***				
Cedar Hills	224				
Eagle Ridge 1	578				
Eagle Ridge 2	1,046				
Highland	687				
SIA	3,455				
West Plains	3,650				
Woodland Heights	423				
Subtotal	**34,514**	35.9%	49.01%	59,020	84.99
North Hill Primary Supply Zone					
North Hill	***30,625***				
Five Mile	2,973				
Indian Hills	68				
Kempe	1,279				
Midbank	773				
Shawnee	209				
Woodridge	150				
Subtotal	**36,076**	37.5%	28.40%	34,200	49.25
All Primary Supply Zones					
Grand Total	96,168	100.0%	100.0%	120,420	173.41
2042 MDD (no climate change)	120,420				
2042 MDD (with climate change)	129,454		(All Values in These Columns are From a City Email Dated January 10, 2023)		

Attachment D2

Calculation of Well-by-Well Pumping Distributions for City of Spokane Maximum Day Demands under Emergency and Non-Emergency Operations

Table D2-1

Development of Well-by-Well Pumping Distribution

20-Year Demand Projection Under RCP 8.5 Climate Change (MDD = 186.42 mgd)

Yellowstone Pipeline Vulnerability Study (City of Spokane)

Step 1 - Tabulate Data by Well Station Under Current Conditions

Well Station	Primary Supply Zones	Rated Capacities of Current Pumps		Operating Capacity (gpm) Under Existing Infrastructure				
		gpm	mgd	Baseline	Parkwater Offline	Well Electric Offline	PW & WE Offline	Havana & Ray Offline
Havana	Int	22,500	32.40	8,640	10,082	6,053	10,346	0
Ray	Int	16,564	23.85	7,309	9,798	8,824	15,232	0
Parkwater	Int	13,260	19.09	4,747	0	10,701	0	13,260
	Low	52,465	75.55	21,609	0	13,225	0	13,807
	Total	65,725	94.64	26,355	0	23,926	0	27,067
Well Electric	Int	6,358	9.16	4,883	5,698	0	0	6,358
	Low	14,486	20.86	0	10,803	0	0	0
	N. Hill	18,498	26.64	14,123	15,084	0	0	14,123
	Total	39,342	56.65	19,006	31,584	0	0	20,481
Nevada	Low	31,796	45.79	12,905	23,711	21,289	31,796	20,707
Grace	N. Hill	16,806	24.20	0	13,704	13,308	13,308	0
Hoffman	N. Hill	11,072	15.94	8,453	0	8,767	8,767	8,453
Central	N. Hill	17,682	25.46	13,500	7,288	14,001	14,001	13,500
Operating Total		**221,487**	**318.93**	**96,168**	**96,168**	**96,168**	**93,450**	**90,208**

Step 2 - Calculate Percentage Contributions from Each Well Station Under Current Conditions

Well Station	Primary Supply Zones	Rated Capacities of Current Pumps		Percentage Contribution to Operating Total Under Existing Infrastructure				
		%		Baseline	Parkwater Offline	Well Electric Offline	PW & WE Offline	Havana & Ray Offline
Havana	Int	10.2%		9.0%	10.5%	6.3%	11.1%	0.0%
Ray	Int	7.5%		7.6%	10.2%	9.2%	16.3%	0.0%
Parkwater	Int	6.0%		4.9%	0.0%	11.1%	0.0%	14.7%
	Low	23.7%		22.5%	0.0%	13.8%	0.0%	15.3%
	Total	29.7%		27.4%	0.0%	24.9%	0.0%	30.0%
Well Electric	Int	2.9%		5.1%	5.9%	0.0%	0.0%	7.0%
	Low	6.5%		0.0%	11.2%	0.0%	0.0%	0.0%
	N. Hill	8.4%		14.7%	15.6%	0.0%	0.0%	15.7%
	Total	17.8%		19.8%	32.7%	0.0%	0.0%	22.7%
Nevada	Low	14.4%		13.4%	24.7%	22.1%	34.0%	22.9%
Grace	N. Hill	7.6%		0.0%	14.3%	13.8%	14.2%	0.0%
Hoffman	N. Hill	4.9%		8.8%	0.0%	9.1%	9.4%	9.4%
Central	N. Hill	8.0%		14.0%	7.6%	14.6%	15.0%	15.0%
Total		**100.1%**		**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Step 3 - Calculate Initial Pumping Distribution Under 20-Year Demands and Infrastructure

Well Station	Primary Supply Zones	Rated Capacities of Future Pumps		MDD (mgd) Under 20-Year Demands and Infrastructure				
		gpm	mgd	Baseline	Parkwater Offline	Well Electric Offline	PW & WE Offline	Havana & Ray Offline
Havana	Int	22,500	32.40	14.25	16.62	9.97	17.06	0.00
Ray	Int	23,414	33.72	12.03	16.15	14.57	25.05	0.00
Parkwater	Int	13,260	19.09	7.76	0.00	17.57	0.00	28.53
	Low	52,465	75.55	57.27	0.00	35.13	0.00	36.60
	Total	65,725	94.64	65.03	0.00	52.70	0.00	65.13
Well Electric	Int	6,358	9.16	8.07	9.34	0.00	0.00	13.58
	Low	14,486	20.86	0.00	28.51	0.00	0.00	0.00
	N. Hill	18,498	26.64	20.75	22.02	0.00	0.00	20.73
	Total	39,342	56.65	28.82	59.87	0.00	0.00	34.31
Nevada	Low	31,796	45.79	34.10	62.86	56.24	91.37	54.77
Grace	N. Hill	16,806	24.20	0.00	20.19	19.48	19.48	0.00
Hoffman	N. Hill	11,072	15.94	12.42	0.00	12.85	12.89	12.41
Central	N. Hill	17,682	25.46	19.77	10.73	20.61	20.57	19.80
Total		**333,404**	**480.10**	**186.42**	**186.42**	**186.42**	**186.42**	**186.42**

Step 4 - Compare Initial 20-Year Pumping Distribution with Rated Capacities of Future Pumps

Well Station	Primary Supply Zones	Rated Capacities of Future Pumps		Pump Capacity minus MDD (mgd) Under 20-Year Demands and Infrastructure				
		gpm	mgd	Baseline	Parkwater Offline	Well Electric Offline	PW & WE Offline	Havana & Ray Offline
Havana	Int	22,500	32.40	18.15	15.78	22.43	15.34	0.00
Ray	Int	23,414	33.72	21.69	17.57	19.15	8.67	0.00
Parkwater	Int	13,260	19.09	11.33	0.00	1.52	0.00	-9.44
	Low	52,465	75.55	18.28	0.00	40.42	0.00	38.95
	Total	65,725	94.64	29.61	0.00	41.94	0.00	29.51
Well Electric	Int	20,000	29.00	1.09	19.66	0.00	0.00	15.42
	Low	35,000	50.00	0.00	21.49	0.00	0.00	0.00
	N. Hill	20,000	29.00	5.89	6.98	0.00	0.00	8.27
	Total	75,000	108.00	27.83	48.13	0.00	0.00	73.69
Nevada	Low	31,796	45.79	11.69	-17.07	-10.45	-45.58	-8.98
Grace	N. Hill	16,806	24.20	0.00	4.01	4.72	4.72	0.00
Hoffman	N. Hill	10,920	15.72	3.52	0.00	2.87	2.83	3.31
Central	N. Hill	17,682	25.46	5.69	14.73	4.85	4.89	5.66
Total		**263,843**	**379.93**	**118.18**	**83.15**	**85.51**	**-9.13**	**103.19**

Table D2-1

Development of Well-by-Well Pumping Distribution

20-Year Demand Projection Under RCP 8.5 Climate Change (MDD = 186.42 mgd)

Yellowstone Pipeline Vulnerability Study (City of Spokane)

Step 5 - Rebalance Pumping Distribution Under 20-Year Demands and Infrastructure

Well Station	Primary Supply Zones	Rated Capacities of Future Pumps (gpm)	Rated Capacities of Future Pumps (mgd)	MDD (mgd) Under 20-Year Demands and Infrastructure: Baseline	Parkwater Offline	Well Electric Offline	PW & WE Offline	Havana & Ray Offline
Havana	Int	22,500	32.40	14.25	16.62	9.97	17.06	0.00
Ray	Int	23,414	33.72	12.03	16.15	14.57	25.05	0.00
Parkwater	Int	13,260	19.09	7.76	0.00	17.57	0.00	19.09
	Low	52,465	75.55	57.27	0.00	45.58	0.00	45.58
	Total	65,725	94.64	65.03	0.00	63.15	0.00	64.67
Well Electric	Int	20,000	29.00	8.07	9.34	0.00	0.00	23.02
	Low	35,000	50.00	0.00	45.58	0.00	45.58	0.00
	N. Hill	20,000	29.00	20.75	22.02	0.00	0.00	20.73
	Total	75,000	108.00	28.82	76.94	0.00	45.58	43.75
Nevada	Low	31,796	45.79	34.10	45.79	45.79	45.79	45.79
Grace	N. Hill	16,806	24.20	10.73	10.31	18.61	18.61	10.74
Hoffman	N. Hill	10,920	15.72	10.73	10.30	15.72	15.72	10.73
Central	N. Hill	17,682	25.46	10.73	10.31	18.61	18.61	10.74
Total		**263,843**	**379.93**	**186.42**	**186.42**	**186.42**	**186.42**	**186.42**

Step 6 - Double-Check MDD (mgd) by Pressure Zone Under 50-Year Demands and Infrastructure

Primary Supply Zone	Values	Units		Baseline	Parkwater Offline	Well Electric Offline	PW & WE Offline	Havana & Ray Offline
Intermediate	Target	mgd		42.11	42.11	42.11	42.11	42.11
	Rebalanced	mgd		42.11	42.11	42.11	42.11	42.11
Low	Target	mgd		91.37	91.37	91.37	91.37	91.37
	Rebalanced	mgd		91.37	91.37	91.37	91.37	91.37
North Hill	Target	mgd		52.94	52.94	52.94	52.94	52.94
	Rebalanced	mgd		52.94	52.94	52.94	52.94	52.94
Total	**Target**	**mgd**		**186.42**	**186.42**	**186.42**	**186.42**	**186.42**
	Rebalanced	**mgd**		**186.42**	**186.42**	**186.42**	**186.42**	**186.42**
Intermediate	Target	Percent		22.59%	22.59%	22.59%	22.59%	22.59%
	Rebalanced			22.59%	22.59%	22.59%	22.59%	22.59%
Low	Target	Percent		49.01%	49.01%	49.01%	49.01%	49.01%
	Rebalanced			49.01%	49.01%	49.01%	49.01%	49.01%
North Hill	Target	Percent		28.40%	28.40%	28.40%	28.40%	28.40%
	Rebalanced			28.40%	28.40%	28.40%	28.40%	28.40%

Step 7 - Calculate Final Percentage Contributions Under 20-Year Demands and Infrastructure

Well Station	Primary Supply Zones	Rated Capacities of Future Pumps (gpm)	Rated Capacities of Future Pumps (mgd)	MDD (mgd) Under 20-Year Demands and Infrastructure: Baseline	Parkwater Offline	Well Electric Offline	PW & WE Offline	Havana & Ray Offline
Havana	Int	22,500	32.40	7.64%	8.92%	5.35%	9.15%	0.00%
Ray	Int	23,414	33.72	6.45%	8.66%	7.82%	13.44%	0.00%
Parkwater	Int	13,260	19.09	4.16%	0.00%	9.42%	0.00%	10.24%
	Low	52,465	75.55	30.72%	0.00%	24.45%	0.00%	24.45%
	Total	65,725	94.64	34.88%	0.00%	33.87%	0.00%	34.69%
Well Electric	Int	20,000	29.00	4.33%	5.01%	0.00%	0.00%	12.35%
	Low	35,000	50.00	0.00%	24.45%	0.00%	24.45%	0.00%
	N. Hill	20,000	29.00	11.13%	11.81%	0.00%	0.00%	11.12%
	Total	75,000	108.00	15.46%	41.27%	0.00%	24.45%	23.47%
Nevada	Low	31,796	45.79	18.29%	24.56%	24.56%	24.56%	24.56%
Grace	N. Hill	16,806	24.20	5.76%	5.53%	9.98%	9.98%	5.76%
Hoffman	N. Hill	10,920	15.72	5.76%	5.53%	8.44%	8.44%	5.76%
Central	N. Hill	17,682	25.46	5.76%	5.53%	9.98%	9.98%	5.76%
Total		**263,843**	**379.93**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table D2-2

Development of Well-by-Well Pumping Distribution

50-Year Modest Demand Projection Under RCP 8.5 Climate Change (MDD = 217.40 mgd)

Yellowstone Pipeline Vulnerability Study (City of Spokane)

Step 1 - Tabulate Data by Well Station Under Current Conditions

	Primary	Rated Capacities of Current Pumps		Operating Capacity (gpm) Under Existing Infrastructure				
Well Station	**Supply Zones**	**gpm**	**mgd**	**Baseline**	**Parkwater Offline**	**Well Electric Offline**	**PW & WE Offline**	**Havana & Ray Offline**
Havana	Int	22,500	32.40	8,640	10,082	6,053	10,346	0
Ray	Int	16,564	23.85	7,309	9,798	8,824	15,232	0
Parkwater	Int	13,260	19.09	4,747	0	10,701	0	13,260
	Low	52,465	75.55	21,609	0	13,225	0	13,807
	Total	65,725	94.64	26,355	0	23,926	0	27,067
Well Electric	Int	6,358	9.16	4,883	5,698	0	0	6,358
	Low	14,486	20.86	0	10,803	0	0	0
	N. Hill	18,498	26.64	14,123	15,084	0	0	14,123
	Total	39,342	56.65	19,006	31,584	0	0	20,481
Nevada	Low	31,796	45.79	12,905	23,712	21,289	31,796	20,707
Grace	N. Hill	16,806	24.20	0	13,704	13,308	13,308	0
Hoffman	N. Hill	11,072	15.94	8,453	0	8,767	8,767	8,453
Central	N. Hill	17,682	25.46	13,500	7,288	14,001	14,001	13,500
Operating Total		**221,487**	**318.93**	**96,168**	**96,169**	**96,168**	**93,450**	**90,208**

Step 2 - Calculate Percentage Contributions from Each Well Station Under Current Conditions

	Primary	Rated Capacities of Current Pumps		Percentage Contribution to Operating Total Under Existing Infrastructure				
Well Station	**Supply Zones**	**%**		**Baseline**	**Parkwater Offline**	**Well Electric Offline**	**PW & WE Offline**	**Havana & Ray Offline**
Havana	Int	10.2%		9.0%	10.5%	6.3%	11.1%	0.0%
Ray	Int	7.5%		7.6%	10.2%	9.2%	16.3%	0.0%
Parkwater	Int	6.0%		4.9%	0.0%	11.1%	0.0%	14.7%
	Low	23.7%		22.5%	0.0%	13.8%	0.0%	15.3%
	Total	29.7%		27.4%	0.0%	24.9%	0.0%	30.0%
Well Electric	Int	2.9%		5.1%	5.9%	0.0%	0.0%	7.0%
	Low	6.5%		0.0%	11.2%	0.0%	0.0%	0.0%
	N. Hill	8.4%		14.7%	15.7%	0.0%	0.0%	15.7%
	Total	17.8%		19.8%	32.8%	0.0%	0.0%	22.7%
Nevada	Low	14.4%		13.4%	24.7%	22.1%	34.0%	22.9%
Grace	N. Hill	7.6%		0.0%	14.2%	13.8%	14.2%	0.0%
Hoffman	N. Hill	4.9%		8.8%	0.0%	9.1%	9.4%	9.4%
Central	N. Hill	8.0%		14.0%	7.6%	14.6%	15.0%	15.0%
Total		**100.1%**		**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Step 3 - Calculate Initial Pumping Distribution Under 50-Year Demands and Infrastructure

	Primary	Rated Capacities of Future Pumps		MDD (mgd) Under 50-Year Modest Demand Scenario and Infrastructure				
Well Station	**Supply Zones**	**gpm**	**mgd**	**Baseline**	**Parkwater Offline**	**Well Electric Offline**	**PW & WE Offline**	**Havana & Ray Offline**
Havana	Int	22,500	32.40	16.62	19.39	11.63	19.90	0.00
Ray	Int	23,414	33.72	14.03	18.84	16.99	29.22	0.00
Parkwater	Int	13,260	19.09	9.05	0.00	20.50	0.00	33.27
	Low	52,465	75.55	66.78	0.00	40.95	0.00	42.67
	Total	65,725	94.64	75.83	0.00	61.45	0.00	75.94
Well Electric	Int	6,358	9.16	9.42	10.89	0.00	0.00	15.85
	Low	14,486	20.86	0.00	33.24	0.00	0.00	0.00
	N. Hill	18,498	26.64	24.20	25.85	0.00	0.00	24.17
	Total	39,342	56.65	33.62	69.98	0.00	0.00	40.02
Nevada	Low	31,796	45.79	39.76	73.30	65.59	106.54	63.87
Grace	N. Hill	16,806	24.20	0.00	23.38	22.72	22.71	0.00
Hoffman	N. Hill	11,072	15.94	14.49	0.00	14.98	15.04	14.47
Central	N. Hill	17,682	25.46	23.05	12.51	24.04	23.99	23.10
Total		**333,404**	**480.10**	**217.40**	**217.40**	**217.40**	**217.40**	**217.40**

Step 4 - Compare Initial 50-Year Pumping Distribution with Rated Capacities of Future Pumps

	Primary	Rated Capacities of Future Pumps		Pump Capacity minus MDD (mgd) Under 50-Year Modest Demand Scenario and Infrastructure				
Well Station	**Supply Zones**	**gpm**	**mgd**	**Baseline**	**Parkwater Offline**	**Well Electric Offline**	**PW & WE Offline**	**Havana & Ray Offline**
Havana	Int	22,500	32.40	15.78	13.01	20.77	12.50	0.00
Ray	Int	23,414	33.72	19.69	14.88	16.73	4.50	0.00
Parkwater	Int	13,260	19.09	10.04	0.00	-1.41	0.00	-14.18
	Low	52,465	75.55	8.77	0.00	34.60	0.00	32.88
	Total	65,725	94.64	18.81	0.00	33.19	0.00	18.70
Well Electric	Int	21,200	31.00	-0.26	20.11	0.00	0.00	15.15
	Low	42,400	61.00	0.00	27.76	0.00	0.00	0.00
	N. Hill	18,000	26.00	2.44	0.15	0.00	0.00	1.83
	Total	81,600	118.00	23.03	48.02	0.00	0.00	77.98
Nevada	Low	31,796	45.79	6.03	-27.51	-19.80	-60.75	-18.08
Grace	N. Hill	16,806	24.20	0.00	0.82	1.48	1.49	0.00
Hoffman	N. Hill	10,920	15.72	1.45	0.00	0.74	0.68	1.25
Central	N. Hill	17,682	25.46	2.41	12.95	1.42	1.47	2.36
Total		**270,443**	**389.93**	**87.20**	**62.17**	**54.53**	**-40.11**	**82.21**

Table D2-2

Development of Well-by-Well Pumping Distribution

50-Year Modest Demand Projection Under RCP 8.5 Climate Change (MDD = 217.40 mgd)

Yellowstone Pipeline Vulnerability Study (City of Spokane)

Step 5 - Rebalance Pumping Distribution Under 50-Year Demands and Infrastructure

	Primary	Rated Capacities of Future Pumps		MDD (mgd) Under 50-Year Modest Demand Scenario and Infrastructure				
Well Station	**Supply Zones**	**gpm**	**mgd**	**Baseline**	**Parkwater Offline**	**Well Electric Offline**	**PW & WE Offline**	**Havana & Ray Offline**
Havana	Int	22,500	32.40	16.62	19.39	12.34	19.90	0.00
Ray	Int	23,414	33.72	14.03	18.84	17.70	29.22	0.00
Parkwater	Int	13,260	19.09	9.31	0.00	19.09	0.00	19.09
	Low	52,465	75.55	66.78	0.00	60.75	0.00	60.75
	Total	65,725	94.64	76.09	0.00	79.84	0.00	79.84
Well Electric	Int	21,200	31.00	9.16	10.89	0.00	0.00	30.03
	Low	42,400	61.00	0.00	60.75	0.00	60.75	0.00
	N. Hill	18,000	26.00	24.20	25.85	0.00	0.00	24.17
	Total	81,600	118.00	33.36	97.49	0.00	60.75	54.20
Nevada	Low	31,796	45.79	39.76	45.79	45.79	45.79	45.79
Grace	N. Hill	16,806	24.20	12.52	11.97	23.01	23.01	12.53
Hoffman	N. Hill	10,920	15.72	12.51	11.96	15.72	15.72	12.52
Central	N. Hill	17,682	25.46	12.51	11.96	23.01	23.01	12.52
Total		**270,443**	**389.93**	**217.40**	**217.40**	**217.40**	**217.40**	**217.40**

Step 6 - Double-Check MDD (mgd) by Pressure Zone Under 50-Year Demands and Infrastructure

Primary Supply Zone	**Values**			**Baseline**	**Parkwater Offline**	**Well Electric Offline**	**PW & WE Offline**	**Havana & Ray Offline**
Intermediate	Target			49.12	49.12	49.12	49.12	49.12
	Rebalanced			49.12	49.12	49.12	49.12	49.12
Low	Target			106.54	106.54	106.54	106.54	106.54
	Rebalanced			106.54	106.54	106.54	106.54	106.54
North Hill	Target			61.74	61.74	61.74	61.74	61.74
	Rebalanced			61.74	61.74	61.74	61.74	61.74
Total	**Target**			**217.40**	**217.40**	**217.40**	**217.40**	**217.40**
	Rebalanced			**217.40**	**217.40**	**217.40**	**217.40**	**217.40**
Intermediate	Target	Percent		22.59%	22.59%	22.59%	22.59%	22.59%
	Rebalanced			22.59%	22.59%	22.59%	22.59%	22.59%
Low	Target	Percent		49.01%	49.01%	49.01%	49.01%	49.01%
	Rebalanced			49.01%	49.01%	49.01%	49.01%	49.01%
North Hill	Target	Percent		28.40%	28.40%	28.40%	28.40%	28.40%
	Rebalanced			28.40%	28.40%	28.40%	28.40%	28.40%

Step 7 - Calculate Final Percentage Contributions Under 50-Year Demands and Infrastructure

	Primary	Rated Capacities of Future Pumps		MDD (mgd) Under 50-Year Modest Demand Scenario and Infrastructure				
Well Station	**Supply Zones**	**gpm**	**mgd**	**Baseline**	**Parkwater Offline**	**Well Electric Offline**	**PW & WE Offline**	**Havana & Ray Offline**
Havana	Int	22,500	32.40	7.64%	8.92%	5.67%	9.15%	0.00%
Ray	Int	23,414	33.72	6.45%	8.67%	8.14%	13.44%	0.00%
Parkwater	Int	13,260	19.09	4.28%	0.00%	8.78%	0.00%	8.78%
	Low	52,465	75.55	30.72%	0.00%	27.94%	0.00%	27.94%
	Total	65,725	94.64	35.00%	0.00%	36.72%	0.00%	36.72%
Well Electric	Int	21,200	31.00	4.21%	5.01%	0.00%	0.00%	13.82%
	Low	42,400	61.00	0.00%	27.94%	0.00%	27.94%	0.00%
	N. Hill	18,000	26.00	11.13%	11.89%	0.00%	0.00%	11.12%
	Total	81,600	118.00	15.34%	44.84%	0.00%	27.94%	24.94%
Nevada	Low	31,796	45.79	18.29%	21.06%	21.06%	21.06%	21.06%
Grace	N. Hill	16,806	24.20	5.76%	5.51%	10.59%	10.59%	5.76%
Hoffman	N. Hill	10,920	15.72	5.76%	5.50%	7.23%	7.23%	5.76%
Central	N. Hill	17,682	25.46	5.76%	5.50%	10.59%	10.59%	5.76%
Total		**270,443**	**389.93**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table D2-3

Development of Well-by-Well Pumping Distribution

50-Year High Demand Projection Under RCP 8.5 Climate Change (MDD = 259.75 mgd)

Yellowstone Pipeline Vulnerability Study (City of Spokane)

Step 1 - Tabulate Data by Well Station Under Current Conditions

	Primary	Rated Capacities of Current Pumps		Operating Capacity (gpm) Under Existing Infrastructure				
Well Station	**Supply Zones**	**gpm**	**mgd**	**Baseline**	**Parkwater Offline**	**Well Electric Offline**	**PW & WE Offline**	**Havana & Ray Offline**
Havana	Int	22,500	32.40	8,640	10,082	6,053	10,346	0
Ray	Int	16,564	23.85	7,309	9,798	8,824	15,232	0
Parkwater	Int	13,260	19.09	4,747	0	10,701	0	13,260
	Low	52,465	75.55	21,609	0	13,225	0	13,807
	Total	65,725	94.64	26,355	0	23,926	0	27,067
Well Electric	Int	6,358	9.16	4,883	5,698	0	0	6,358
	Low	14,486	20.86	0	10,803	0	0	0
	N. Hill	18,498	26.64	14,123	15,084	0	0	14,123
	Total	39,342	56.65	19,006	31,584	0	0	20,481
Nevada	Low	31,796	45.79	12,905	23,712	21,289	31,796	20,707
Grace	N. Hill	16,806	24.20	0	13,704	13,308	13,308	0
Hoffman	N. Hill	11,072	15.94	8,453	0	8,767	8,767	8,453
Central	N. Hill	17,682	25.46	13,500	7,288	14,001	14,001	13,500
Operating Total		**221,487**	**318.93**	**96,168**	**96,169**	**96,168**	**93,450**	**90,208**

Step 2 - Calculate Percentage Contributions from Each Well Station Under Current Conditions

	Primary	Rated Capacities of Current Pumps		Percentage Contribution to Operating Total Under Existing Infrastructure				
Well Station	**Supply Zones**	**%**		**Baseline**	**Parkwater Offline**	**Well Electric Offline**	**PW & WE Offline**	**Havana & Ray Offline**
Havana	Int	10.2%		9.0%	10.5%	6.3%	11.1%	0.0%
Ray	Int	7.5%		7.6%	10.2%	9.2%	16.3%	0.0%
Parkwater	Int	6.0%		4.9%	0.0%	11.1%	0.0%	14.7%
	Low	23.7%		22.5%	0.0%	13.8%	0.0%	15.3%
	Total	29.7%		27.4%	0.0%	24.9%	0.0%	30.0%
Well Electric	Int	2.9%		5.1%	5.9%	0.0%	0.0%	7.0%
	Low	6.5%		0.0%	11.2%	0.0%	0.0%	0.0%
	N. Hill	8.4%		14.7%	15.7%	0.0%	0.0%	15.7%
	Total	17.8%		19.8%	32.8%	0.0%	0.0%	22.7%
Nevada	Low	14.4%		13.4%	24.7%	22.1%	34.0%	22.9%
Grace	N. Hill	7.6%		0.0%	14.2%	13.8%	14.2%	0.0%
Hoffman	N. Hill	4.9%		8.8%	0.0%	9.1%	9.4%	9.4%
Central	N. Hill	8.0%		14.0%	7.6%	14.6%	15.0%	15.0%
Total		**100.1%**		**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Step 3 - Calculate Initial Pumping Distribution Under 50-Year Demands and Infrastructure

	Primary	Rated Capacities of Future Pumps		MDD (mgd) Under 50-Year High Demand Scenario and Infrastructure				
Well Station	**Supply Zones**	**gpm**	**mgd**	**Baseline**	**Parkwater Offline**	**Well Electric Offline**	**PW & WE Offline**	**Havana & Ray Offline**
Havana	Int	22,500	32.40	19.85	23.16	13.90	23.77	0.00
Ray	Int	23,414	33.72	16.77	22.51	20.29	34.91	0.00
Parkwater	Int	13,260	19.09	10.81	0.00	24.49	0.00	39.75
	Low	52,465	75.55	79.79	0.00	48.94	0.00	50.99
	Total	65,725	94.64	90.60	0.00	73.43	0.00	90.74
Well Electric	Int	6,358	9.16	11.25	13.01	0.00	0.00	18.93
	Low	14,486	20.86	0.00	39.72	0.00	0.00	0.00
	N. Hill	18,498	26.64	28.92	30.88	0.00	0.00	28.89
	Total	39,342	56.65	40.17	83.61	0.00	0.00	47.82
Nevada	Low	31,796	45.79	47.51	87.58	78.36	127.30	76.31
Grace	N. Hill	16,806	24.20	0.00	27.94	27.15	27.14	0.00
Hoffman	N. Hill	11,072	15.94	17.31	0.00	17.90	17.96	17.29
Central	N. Hill	17,682	25.46	27.54	14.95	28.72	28.67	27.59
Total		**333,404**	**480.10**	**259.75**	**259.75**	**259.75**	**259.75**	**259.75**

Step 4 - Compare Initial 50-Year Pumping Distribution with Rated Capacities of Future Pumps

	Primary	Rated Capacities of Future Pumps		Pump Capacity minus MDD (mgd) Under 50-Year High Demand Scenario and Infrastructure				
Well Station	**Supply Zones**	**gpm**	**mgd**	**Baseline**	**Parkwater Offline**	**Well Electric Offline**	**PW & WE Offline**	**Havana & Ray Offline**
Havana	Int	22,500	32.40	12.55	9.24	18.50	8.63	0.00
Ray	Int	23,414	33.72	16.95	11.21	13.43	-1.19	0.00
Parkwater	Int	13,260	19.09	8.28	0.00	-5.40	0.00	-20.66
	Low	52,465	75.55	-4.24	0.00	26.61	0.00	24.56
	Total	65,725	94.64	4.04	0.00	21.21	0.00	3.90
Well Electric	Int	27,600	40.00	-2.09	26.99	0.00	0.00	21.07
	Low	57,600	83.00	0.00	43.28	0.00	0.00	0.00
	N. Hill	21,200	31.00	-2.28	0.12	0.00	0.00	2.11
	Total	106,400	153.00	16.48	69.39	0.00	0.00	105.18
Nevada	Low	31,796	45.79	-1.72	-41.79	-32.57	-81.51	-30.52
Grace	N. Hill	16,806	24.20	0.00	-3.74	-2.95	-2.94	0.00
Hoffman	N. Hill	10,920	15.72	-1.37	0.00	-2.18	-2.24	-1.57
Central	N. Hill	17,682	25.46	-2.08	10.51	-3.26	-3.21	-2.13
Total		**295,243**	**424.93**	**44.85**	**54.82**	**12.18**	**-82.46**	**74.86**

Table D2-3

Development of Well-by-Well Pumping Distribution

50-Year High Demand Projection Under RCP 8.5 Climate Change (MDD = 259.75 mgd)

Yellowstone Pipeline Vulnerability Study (City of Spokane)

Step 5 - Rebalance Pumping Distribution Under 50-Year Demands and Infrastructure

Well Station	Primary Supply Zones	Rated Capacities of Future Pumps		MDD (mgd) Under 50-Year High Demand Scenario and Infrastructure				
		gpm	mgd	Baseline	Parkwater Offline	Well Electric Offline	PW & WE Offline	Havana & Ray Offline
Havana	Int	22,500	32.40	19.85	23.16	16.60	24.96	0.00
Ray	Int	23,414	33.72	16.77	22.51	22.99	33.72	0.00
Parkwater	Int	13,260	19.09	12.90	0.00	19.09	0.00	19.09
	Low	52,465	75.55	75.55	0.00	75.55	0.00	75.55
	Total	65,725	94.64	88.45	0.00	94.64	0.00	94.64
Well Electric	Int	27,600	40.00	9.16	13.01	0.00	0.00	39.59
	Low	57,600	83.00	5.96	81.51	5.96	81.51	5.96
	N. Hill	21,200	31.00	26.64	30.88	8.39	8.39	28.89
	Total	106,400	153.00	41.76	125.40	14.35	89.90	74.44
Nevada	Low	31,796	45.79	45.79	45.79	45.79	45.79	45.79
Grace	N. Hill	16,806	24.20	15.71	14.30	24.20	24.20	14.96
Hoffman	N. Hill	10,920	15.72	15.71	14.29	15.72	15.72	14.96
Central	N. Hill	17,682	25.46	15.71	14.30	25.46	25.46	14.96
Total		**295,243**	**424.93**	**259.75**	**259.75**	**259.75**	**259.75**	**259.75**

Step 6 - Double-Check MDD (mgd) by Pressure Zone Under 50-Year Demands and Infrastructure

Primary Supply Zone	Values			Baseline	Parkwater Offline	Well Electric Offline	PW & WE Offline	Havana & Ray Offline
Intermediate	Target			58.68	58.68	58.68	58.68	58.68
	Rebalanced			58.68	58.68	58.68	58.68	58.68
Low	Target			127.30	127.30	127.30	127.30	127.30
	Rebalanced			127.30	127.30	127.30	127.30	127.30
North Hill	Target			73.77	73.77	73.77	73.77	73.77
	Rebalanced			73.77	73.77	73.77	73.77	73.77
Total	**Target**			**259.75**	**259.75**	**259.75**	**259.75**	**259.75**
	Rebalanced			**259.75**	**259.75**	**259.75**	**259.75**	**259.75**
Intermediate	Target	Percent		22.59%	22.59%	22.59%	22.59%	22.59%
	Rebalanced			22.59%	22.59%	22.59%	22.59%	22.59%
Low	Target	Percent		49.01%	49.01%	49.01%	49.01%	49.01%
	Rebalanced			49.01%	49.01%	49.01%	49.01%	49.01%
North Hill	Target	Percent		28.40%	28.40%	28.40%	28.40%	28.40%
	Rebalanced			28.40%	28.40%	28.40%	28.40%	28.40%

Step 7 - Calculate Final Percentage Contributions Under 50-Year Demands and Infrastructure

Well Station	Primary Supply Zones	Rated Capacities of Future Pumps		MDD (mgd) Under 50-Year High Demand Scenario and Infrastructure				
		gpm	mgd	Baseline	Parkwater Offline	Well Electric Offline	PW & WE Offline	Havana & Ray Offline
Havana	Int	22,500	32.40	7.64%	8.92%	6.39%	9.61%	0.00%
Ray	Int	23,414	33.72	6.45%	8.67%	8.85%	12.98%	0.00%
Parkwater	Int	13,260	19.09	4.96%	0.00%	7.35%	0.00%	7.35%
	Low	52,465	75.55	29.09%	0.00%	29.09%	0.00%	29.09%
	Total	65,725	94.64	34.05%	0.00%	36.44%	0.00%	36.44%
Well Electric	Int	27,600	40.00	3.53%	5.01%	0.00%	0.00%	15.24%
	Low	57,600	83.00	2.29%	31.38%	2.29%	31.38%	2.29%
	N. Hill	21,200	31.00	10.26%	11.89%	3.23%	3.23%	11.12%
	Total	106,400	153.00	16.08%	48.28%	5.52%	34.61%	28.65%
Nevada	Low	31,796	45.79	17.63%	17.63%	17.63%	17.63%	17.63%
Grace	N. Hill	16,806	24.20	6.05%	5.50%	9.32%	9.32%	5.76%
Hoffman	N. Hill	10,920	15.72	6.05%	5.50%	6.05%	6.05%	5.76%
Central	N. Hill	17,682	25.46	6.05%	5.50%	9.80%	9.80%	5.76%
Total		**295,243**	**424.93**	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

APPENDIX E

Task 2 and Task 8: Baseline and Emergency Operations Modeling Results

Technical Memorandum

Date: December 16, 2024

Project: Yellowstone Pipe Line Vulnerability Assessment

To: John Porcello,
GSI Water Solutions, Inc.

From: Elisheva Walters, PE
Joshua Ishimwe
Consor North America

Reviewed By: Marcela Duran, PE
Adam Schuyler, PE
Consor North America

Re: Task 2 and Task 8: Baseline and Emergency Operations Modeling Results

Introduction

The City of Spokane (City) is conducting an assessment of the vulnerability of its groundwater supply facilities (Assessment 2024) to potential future chemical releases from the Yellowstone Pipe Line Company Petroleum Pipe Line (Yellowstone Pipe Line). The City contracted with GSI Water Solutions, Inc. (GSI) to perform this study, and GSI subsequently subcontracted with Consor to leverage the City's existing distribution system model as part of this effort. Impacts to the distribution system performance given a loss of supply due to a contamination event were evaluated. An overview of the outcomes for Tasks 2 and 8 of the Assessment 2024 scope, including distribution modeling of conditions during baseline/typical scenarios, emergency scenarios, and possible emergency response scenarios are summarized in this technical memorandum (TM).

System improvements to boost the system's resilience to a contamination event were identified for City consideration to incorporate into the Capital Improvement Plan (CIP). Supply deficit estimates were established for contamination scenarios to help the City aim public education or campaigns towards specific demand curtailment goals.

The analysis and results presented in this TM were used to inform the City's Distribution System Contamination Response Plan (DSCRP), developed by Consor in parallel as Task 6 of the Assessment 2024. This TM is intended to be used as a basis for the City to develop specific water system operational response procedures during a contamination event.

System Description

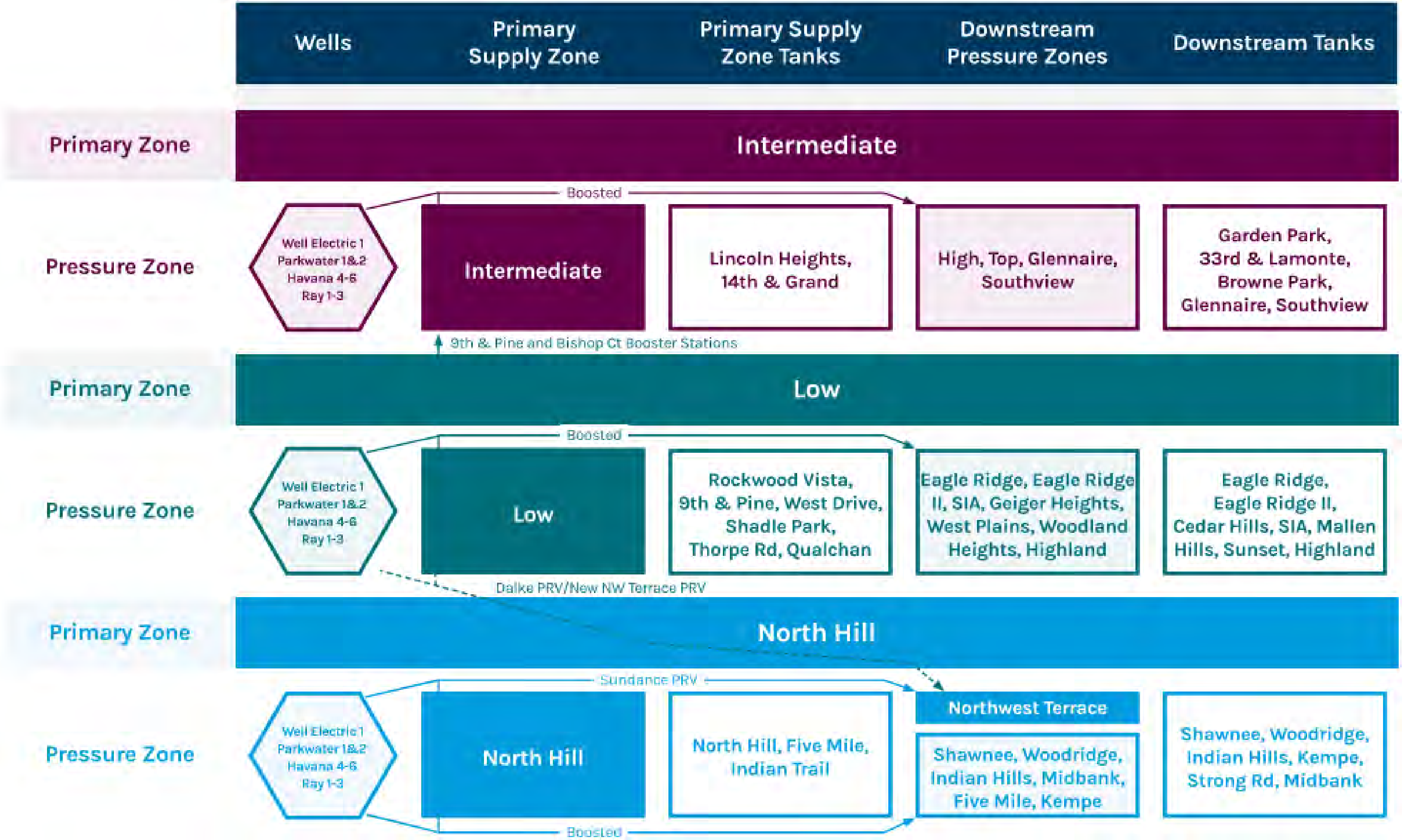
The City relies entirely on groundwater supply via eight wells located mostly on the eastern side of the water system. A schematic summary of the system is shown as **Figure 1**. Each well serves one of three primary pressure zones: the North Hill zone, Intermediate zone, and Low zone. All other pressure zones receive water from one of the primary supply zones via booster stations or pressure reducing valve stations (PRVs). This TM will refer to system pressure zones as follows, for language simplicity:

- "Primary supply zone" refers to one of the pressure zones supplied directly by a well source: the North Hill, Intermediate, or Low pressure zones.
- "Primary zone" refers to a primary supply zone and its downstream pressure zones as a group. The City sometimes refers to primary zones as "systems" (e.g. "The Low System").
- "Pressure zone" refers to any pressure zone downstream of a primary supply zone.

The Bishop Court and 9th & Pine booster stations typically move flow from the Low primary zone to the Intermediate primary supply zone since the Parkwater well station (the largest City well station) supplies the Low primary supply zone.

A majority of the pressure zones served by PRVs are small and have little effect on system supply operations. However, the large Northwest Terrace pressure zone served by two different PRV stations is in the northwest part of the system, some distance away from City sources. The southern Northwest Terrace "Dalke" PRV is served by the Low primary supply zone and the northern Northwest Terrace "Sundance" PRV is served by the North Hill primary supply zone. During typical operations, Northwest Terrace supply is split evenly between the two PRVs. The City is currently adding a new PRV supplying Northwest Terrace from the Low primary supply zone including transmission improvements to facilitate more supply from the Low primary supply zone. This PRV will likely typically be operated instead of the Dalke PRV.

Figure 1 | System Schematic



Analysis Approach

In emergency resilience modeling, the analysis team cannot predict or duplicate all combinations of variables for all emergency scenarios. Therefore, representative or case-study system conditions were selected to mimic response measures to increase the resilience of the City's water system.

The City's distribution system performance outcomes during a loss of supply were evaluated in the City's Autodesk InfoWater Pro® hydraulic model using the following approach:

1. Define the distribution system performance required during an emergency.
2. Model the baseline distribution system to evaluate system behavior and performance during typical operations. The "baseline" scenarios were defined as a maximum-use summer day based on 2020 calibration and demand data.
3. Model emergency (contamination) loss of supply scenarios. Evaluate how the system behaves and performance outcomes during a contamination event when a supply source must be shut off. The following emergency scenarios were evaluated:
   a. Parkwater wells Offline
   b. Well Electric wells Offline
   c. Havana and Ray wells Offline
   d. Parkwater and Well Electric wells Offline
4. Model emergency response scenarios. Evaluate how the system behaves and performance outcomes if the City were to successfully implement certain system resilience and/or emergency response measures. Review of the baseline and emergency scenarios, along with feasibility discussions with the City, led to the following emergency response scenarios.
   a. Emergency Response A: Installation of backflow PRVs at Intermediate-Low primary supply zone booster stations to divert supply from the Intermediate primary supply zone to the Low primary supply zone.
   b. Emergency Response B: Conduct a customer education campaign to curtail demand in the Low primary supply zone.

Performance Criteria

The distribution system was evaluated against the following criteria for modeled scenarios.

Table 1 | Analysis Evaluation Criteria

<table>
<tr><th>Condition</th><th>Typical Criteria</th><th>Emergency Criteria</th><th>Source</th></tr>
<tr><td>Fire flow availability</td><td colspan="2">Industrial hydrant: 6,000 gallons per minute (gpm) during maximum day demand (MDD)
Commercial hydrant: 4,000 gpm during MDD</td><td>International Fire Code</td></tr>
<tr><td>Minimum pressure during fire flow</td><td colspan="2">20 pounds per square inch (psi)</td><td>Department of Health (DOH)</td></tr>
<tr><td>Minimum pressure during peak hour demand (PHD)[1]</td><td>40 psi</td><td>30 psi</td><td>DOH, City Level of Service Goals</td></tr>
<tr><td>Supply</td><td>Average daily supply must meet MDD.
Fire flow should be supplied by storage.</td><td>Average daily supply must meet MDD.
Fire flow should be supplied by storage but can be supplemented by excess supply.</td><td>DOH</td></tr>
<tr><td>Transmission main maximum headloss</td><td colspan="2">3.5 ft per 1,000 ft of pipeline</td><td>City 2023 Water System Plan (2023 WSP)</td></tr>
<tr><td>Tank minimum volume level</td><td colspan="2">Tanks should not drop below the minimum level needed to provide minimum pressure to the highest customer served.</td><td>Same as minimum pressure requirements.</td></tr>
<tr><td>Tank recovery minimum volume level</td><td>Tanks should recover to their maximum operating level (typically 100%) during low-use times.</td><td>Tanks should cycle in a stable manner and use as much storage volume as possible.</td><td>Typical industry goal for systems where tanks are filled during non-peak timeframes.</td></tr>
</table>

Note:

The City's 2023 WSP notes 40 psi as their performance goal, but the DOH requirement of 30 psi was chosen for the emergency level of service.

Analysis Assumptions

Emergency Duration

The groundwater modeling analysis performed by GSI predict that a Yellowstone Pipe Line leak near the wells will leak contaminates to the well supply within one day to 18 months, depending on the well. **Figure 2** is a summary of the estimated contamination to well supply travel times.

Figure 2 | Contaminant Travel Time Summary

Parkwater Critical Well	• 1 - 2 DAYS (pipeline segment to south) • 2.5 – 3 months (pipeline segment to east)
Well Electric Critical Well	• 6 – 7 months • From east if pumping from shallow zone
Havana St.	• 3 – 4 months • From east if pumping from shallow zone
Ray St.	• 6 – 7 months
Nevada and Grace	• 12 months
Central and Hoffman	• Surface water • 9 - 18 months at deeper zone

The City will likely have a few weeks to several months to implement response measures required for non-Parkwater loss-of-supply scenarios. It is assumed that it would take several months or possibly years to clean contaminants out of a well field capture zone enough to allow well operation which means that the water system will have to operate under “emergency” conditions for an extended period.

Demand

The analysis is based on a 2018 to 2020 three-year average MDD, and assumes multiple days of MDD in a row for the extended period simulation (EPS) scenarios. Based on the 2020 EPS model calibration, MDD is approximately 10 percent larger than typical summer demand.

While this assumption may seem overly conservative, it is reasonable to assume a multi-day MDD event because the City has recently experienced record temperatures multiple days in a row in the summer.

The groundwater modeling portion of the Assessment 2024 accounts for demands far into the future, but future demand modeling for the distribution system was not feasible without creating generous assumptions around future transmission capacity. Due to the sensitivity of operations to transmission capacity, such assumptions produce less-than-useful results for determining emergency mitigation measures. Therefore, an existing MDD-based EPS analysis was selected as the most conservative reasonable scenario for evaluating the operational consequences of a loss of supply.

Spokane’s MDD to average day demand (ADD) peaking factor ratios range from 2.4 to 4.7 according to Table 2.6 of the City’s 2023 WSP. Since the most conservative emergency loss-of-supply scenario comprises a loss of 50 percent of the City’s supply, the remaining 50 percent was assumed to be adequate to cover non-summer demand, which is typically less than half of MDD. Therefore, ADD and winter demands were not evaluated.

Fire Flow

In 2023, urban wildfires demanded large volumes of City water for extended periods of time, a real-life scenario stressing the water system more than the most conservative DOH distribution system performance criteria. Therefore, the analysis team deemed the probability of a fire occurring simultaneously with a multiple-day high-use demand condition as not unlikely. Fire flow was not modeled since fire flow availability primarily relies on storage availability. Fire flow was, however, included in the mass balance results to asses the ability of the supply sources to supplement fire flow availability.

Existing Facilities

The following is a list of recently constructed or soon-to-be completed capital improvements that were included as active in the analysis.

- Havana well pumps 4 through 6
- New SIA elevated tank
- Hoffman well Pump 2

The following facilities were not included:

- Proposed Havana well pumps 1 through 3
- New Hamblen elevated tank
- New Marshall Road transmission main
- Proposed Ray Street well pump 4
- New Thorpe Road tank

Baseline Distribution System Analysis

Baseline summer day system conditions were modeled as a benchmark for emergency conditions. Without baseline modeling data, it is difficult to identify which system outcomes are a result of emergency conditions, model setup, or are existing in the non-emergency condition. The detailed baseline analysis is included as **Appendix A**.

The original scope included an evaluation of the baseline distribution system performance using a steady-state simulation; however, steady-state modeling does not allow time for tank volume to drain and fill when a supply source is offline. Consor restructured the analysis around the EPS tank graphs and the supply-demand mass balance, which demonstrate the ability of the system to remain stable and quantify storage resilience during a loss of supply.

The EPS tank graphs were evaluated for minimum tank level, maximum fill level, and corresponding minimum pressures at the highest customer meters. Maximum modeled tank fill level is assumed to correlate to maximum usable tank volume, since some tanks struggle to fill completely even when supply is adequate. A loss of a supply source means that flow is more concentrated in a particular part of the system as it tries to travel from a well to a tank which results in larger head losses. Even if the volume of available nominal supply is larger than demand, a tank may be forced to stay partially empty because the tank inlet pressure is not high enough for the tank to fill. This loss of usable storage impacts fire flow and equalization storage availability.

Due to normal headlosses in the system between tanks, the Qualchan tank and Rockwood tank, both in the Low primary supply zone, have hydraulic grade lines (HGLs) that differ by as much as 17 feet. The North Hill primary supply zone tanks differ by as much as 12 feet in HGL during typical summer conditions. The typical

HGL differences in the Low primary supply zone and North Hill primary supply zone tank levels are a system risk factor for the petroleum contamination event. Even if the City has enough supply in the system to cover an emergency well shutoff during contamination, the tanks located farthest away from the City's supplies may struggle to maintain acceptable levels if there are fewer path options for flow to travel to fill the tank. The City is continuously evaluating the cost-benefit balance between building storage improvements to boost storage resilience versus building transmission capacity to boost supply resilience.

Further baseline results on the remainder of the tanks in the system are included as **Appendix B**; note that the tanks in the Intermediate primary supply zone maintain similar HGLs (unlike the North Hill and Low tanks). This demonstrates low headloss between tanks in those primary supply zones.

Emergency Loss of Supply Modeling

After establishing a basis for comparison in the baseline model scenarios, select supply sources were turned off in the model to evaluate system behavior if certain wells must be inoperative due to a contamination event. The following scenarios were configured in the model:

a. Parkwater wells Offline
b. Well Electric wells Offline
c. Havana and Ray wells Offline
d. Parkwater and Well Electric wells Offline

In some cases, alternate supply sources that were not needed in the baseline scenario to satisfy demand were turned on to make up for loss of supply from the contaminated wells. **Table 2** details which supply sources were online for each emergency scenario. Other operating conditions match the baseline EPS scenario unless otherwise noted. These modeling assumptions could be used as a starting point for the City to identify which wells would be turned on if a contaminated well was inoperable.

Table 2 | Supply Summary

Scenario→ Supply Zone↓	Supply Well Pump	Baseline/ Typical Operations	Parkwater Wells Offline	Well Electric Wells Offline	Havana and Ray Wells Offline	Parkwater & Well Electric Wells Offline
Intermediate	Havana 4	•[1]	•	X	X	•
	Havana 5	•	•	•	X	•
	Havana 6	•	•	•	X	•
	Ray 1	X	•	•	X	•
	Ray 2	•	X	X	X	•
	Ray 3	•	•	•	X	•
	Future Ray 4	Not included in analysis				
	Parkwater 1	X	X[2]	•	•	X
	Parkwater 2	•	X	•	•	X
	Well Electric 1	•	•[3]	X	•	X
	MDD (gpm)	25,578				
	Supply - Demand Surplus or Deficit (gpm)	1,547	2,964	6,116	(5,960)[4]	2,236
Low	Nevada 1	X	•	X	X	•
	Nevada 2	•	•	•	•	•
	Nevada 3	•	•	•	•	•
	Nevada 4	X	•	•	X	•
	Parkwater 3	•	X	•	X	X
	Parkwater 4	•	X	X	•	X
	Parkwater 5	•	X	•	X	X
	Parkwater 6	•	X	X	•	X
	Parkwater 7	X	X	X	•	X
	Parkwater 8	X	X	X	X	X
	Well Electric 3	X	•	X	X	X
	Future Havana 1-3	Not included in analysis				
	MDD (gpm)	34,514				
	Supply - Demand Surplus or Deficit (gpm)	11,626	11,768	8,368	12,832	(2,718)[4]
North Hill	Well Electric 2	•	•	X	•	X
	Well Electric 4	•	•	X	•	X
	Grace 1	X	X	•	X	•
	Grace 2	X	X	•	X	•
	Hoffman 1	•	•	•	•	•
	Hoffman 2	•	•	•	•	•
	Central 1	•	•	•	•	•
	Central 2	•	•	•	•	•
	MDD (gpm)	36,076				
	Supply - Demand Surplus or Deficit (gpm)	11,176	8,165	9,484	11,176	9,484

Notes:

1. Bullet symbol denotes a well online, "X" denotes a well offline
2. Highlighted "Offline" points to wells that are offline due to the contamination emergency. Other wells are offline for mass balance or distribution optimization reasons.
3. The well is online/available; however, the model simulation automatically turns the well off due to excess supply.
4. See note on Low-Intermediate mass balance in Table 3.

Mass Balance Summary

Available supply was compared to MDD for each emergency scenario in each of the City's primary pressure zones. Once the MDD mass balance was calculated, the highest minimum required fire flow in each system was evaluated to see if any excess supply capacity in each system could cover fire flow when storage is unavailable. The system should meet the City's service goals if the following conditions are met:

The average supply into the system each day is equal to the average demand each day

- The transmission grid is adequate for flow to reach the tanks during their fill cycles
- The transmission grid is adequate for flow to reach the customers during peak use
- Enough fire flow storage is available to fully supply water for the fire duration

Table 3 shows the mass balance calculation for the scenarios. A mass balance for the PHD condition is not included since most systems are designed for system storage to supply the difference between MDD and PHD. The system should meet the City's service goals if the following conditions are met:

- The average supply into the system each day is equal to the average demand each day
- The transmission grid is adequate for flow to reach the tanks during their fill cycles
- The transmission grid is adequate for flow to reach the customers during peak use
- Enough fire flow storage is available to fully supply water for the fire duration

Table 3 | Emergency Loss of Supply Mass Balance Summary

Scenario	Primary Zone	Supply Capacity (gpm)[1]	MDD (gpm)[2]	Fire Flow (FF, gpm)	MDD Mass Balance (gpm)	MDD + FF Mass Balance (gpm)
Baseline Conditions	Intermediate	27,125	25,578	4,000	1,547	(2,453)[3]
	Low	46,140	34,514	6,000	11,626	5,626
	North Hill	47,252	36,076	6,000	11,176	5,176
Parkwater Wells Offline	Intermediate	28,542	25,578	4,000	2,964	(1,036)[3]
	Low	46,282	34,514	6,000	11,768	5,768
	North Hill	44,241	36,076	6,000	11,176	5,176
Well Electric Wells Offline	Intermediate	31,694	25,578	4,000	6,116	2,116
	Low	42,882	34,514	6,000	8,368	2,368
	North Hill	45,560	36,076	6,000	9,484	3,484
Havana and Ray Wells Offline	Intermediate	19,618	25,578	4,000	(5,960)[3]	(9,960)[3]
	Low	47,346	34,514	6,000	12,832	6,832
	North Hill	47,252	36,076	6,000	11,176	5,176
Parkwater & Well Electric Wells Offline	Intermediate	27,814	25,578	4,000	2,236	(1,764)[3]
	Low	31,796	34,514	6,000	(2,718)	(8,718)
	North Hill	45,560	36,076	6,000	9,484	3,484

Notes:

1. Supply capacity is based on City flow test data. Pump flows will vary based on system conditions.
2. For simplicity, the mass balance analysis assumed all Northwest Terrace pressure zone demand to be served by the North Hill primary supply zone. However, the model EPS simulations do split flow to the Northwest Terrace pressure zone (unless otherwise noted) and account for the correct supply scheme to this pressure zone.
3. Intermediate mass balances do not include flow from 9th & Pine or the Bishop Court Booster Stations, but the model EPS scenarios do include flow through these stations unless otherwise noted.

The worst-case emergency scenario is the "Parkwater and Well Electric wells Offline" and is illustrated as **Figure 4**. The Low primary zone is the most impacted as it will lack sufficient supply to meet MDD.

Figure 3 | North Hill System Mass Balance: MDD

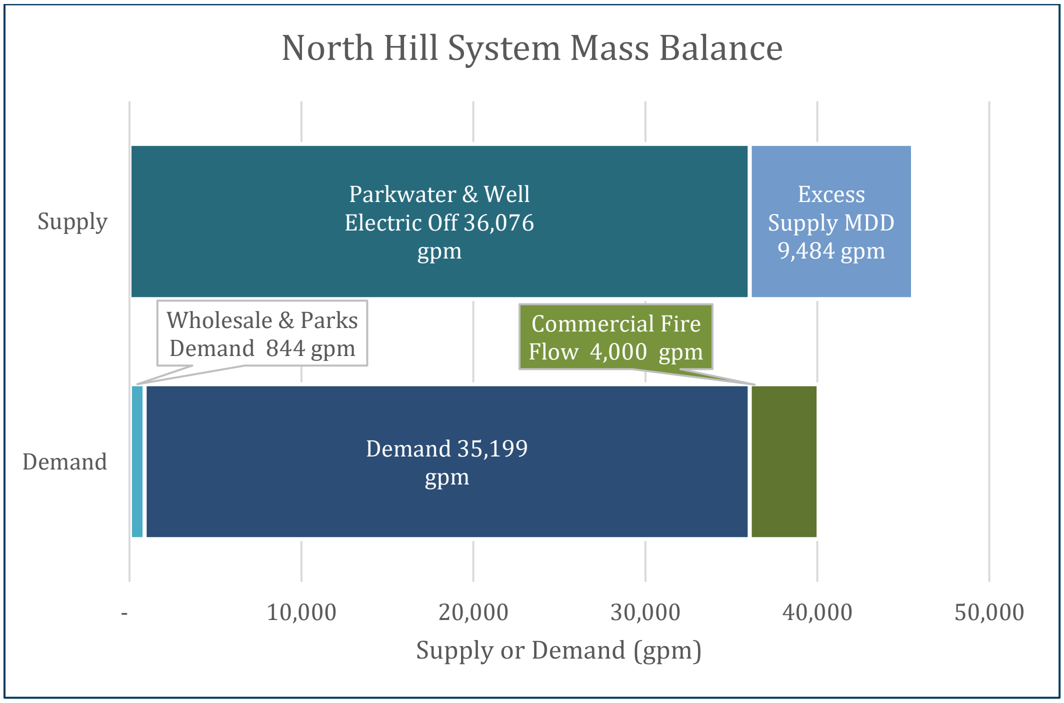
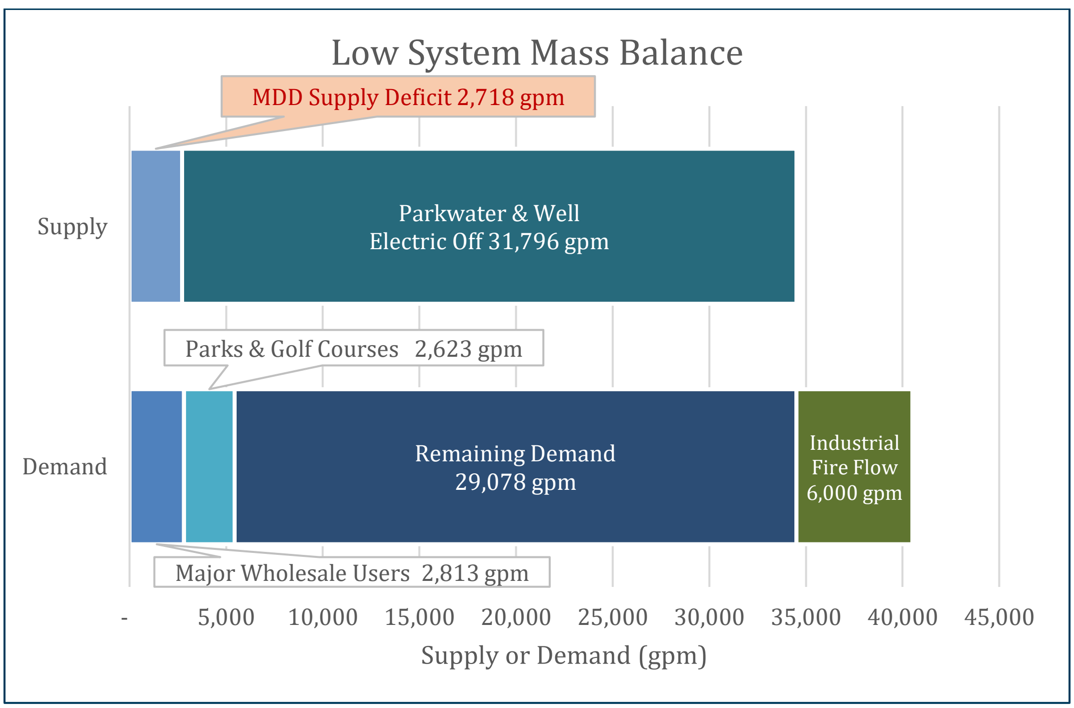
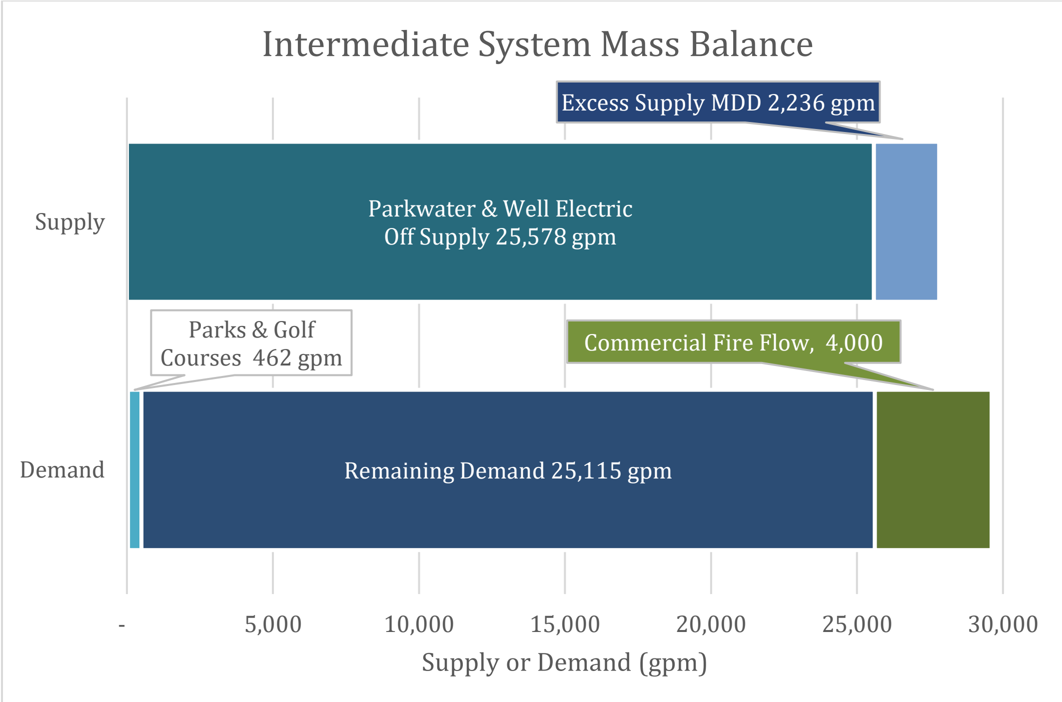


Figure 4 | Low System Mass Balance: MDD*



*Does not include Low System flow to the Northwest Terrace pressure zone or flow through Bishop Court and 9th & Pine BS.

Figure 5 | Intermediate System Mass Balance



Scenario Results

Although the mass balance analysis shows nominal supply is adequate for system demands, in some cases headloss in the system can prevent tanks located far away from supply sources from remaining at acceptable volume levels. Therefore, the model's predicted tank volume graphs for each scenario were reviewed. **Figure 6** illustrates the emergency scenarios and key results. **Table 4** summarizes the performance outcomes for each emergency scenario. The full graphical results are included as **Appendix B**.

Figure 6 | Emergency Scenarios Summary

Parkwater Wells Offline	Well Electric Havana Ray Nevada Grace Hoffman Central	19% Intermediate Zone Supply Lost 63% Low Zone Supply Lost	Tanks Affected: Qualchan	No MDD deficiency	-
Well Electric Wells Offline	Parkwater Havana Ray Nevada Grace Hoffman Central	19% Intermediate Zone Supply Lost 15% Low Zone Supply Lost 39% North Hill Zone Supply Lost	Tanks Affected: Qualchan 9th & Pine Thorpe Rd Five Mile Indian Trail	No MDD deficiency	Low primary zone further impacted via to booster stations and Northwest Terrace PRV
Havana and Ray Wells Offline	Well Electric Parkwater Nevada Grace Hoffman Central	63% Intermediate Zone Supply Lost	Tanks Affected: Qualchan 9th&Pine 14th&Grand Rockwood Vista Shadle Park West Drive Lincoln Heights	Intermediate MDD deficiency	Low primary zone impacted via booster stations and Northwest Terrace PRV
Parkwater and Well Electric Wells Offline	Havana Ray Nevada Grace Hoffman Central	38% Intermediate Zone Supply Lost 77% Low Zone Supply Lost 39% North Hill Zone Supply Lost	Low primary zone tanks begin to drain completely at 32 hours.	Low MDD deficiency	Low primary zone deficiency worses due to booster stations and Northwest Terrace PRV

Table 4 | Emergency Loss of Supply Results

<table>
<tr><th>Criteria</th><th>Baseline</th><th>Parkwater Wells Offline</th><th>Well Electric Wells Offline</th><th>Havana and Ray Wells Offline</th><th>Parkwater & Well Electric Wells Offline</th></tr>
<tr><td>Primary zones with failed MDD mass balance</td><td>None</td><td>None</td><td>None</td><td>Intermediate (supplemented from Low primary zone)</td><td>Low</td></tr>
<tr><td>% customers with pressures < 30 psi</td><td>0.2%</td><td>Negligible change</td><td>Negligible change</td><td>Negligible change</td><td>100%</td></tr>
<tr><td>Primary supply zone tanks[1] that fail to reach 95% tank volume</td><td>Indian Trail
Qualchan
9th & Pine
Rockwood Vista
Shadle Park
Thorpe Road
West Drive</td><td colspan="2">Tank max fill levels impact is limited (see below)</td><td>Baseline Tanks
14th & Grand</td><td rowspan="4">Low primary zone tanks begin to drain completely at 32 hours.</td></tr>
<tr><td>Approx % tank recovery volume lost</td><td>N/A, compare to baseline</td><td>Qualchan: 6%</td><td>Five Mile: 5%
Indian Trail: 7%
9th&Pine: 9%
Thorpe Rd: 11%
Qualchan: 9%</td><td>9th & Pine: 39%
14th&Grand: 39%
Rockwood Vista: 4%
Lincoln Heights: 31%
Shadle Park: 6%
Qualchan: 9%
West Drive: 19%</td></tr>
<tr><td>Tanks where the minimum level decreases by >5%</td><td>N/A, compare to baseline</td><td>None</td><td>Qualchan
Thorpe Rd</td><td>9th&Pine
14th&Grand
Thorpe Rd
Rockwood Vista
Lincoln Heights
Qualchan</td></tr>
<tr><td>Tanks that drain to empty</td><td>None</td><td>None</td><td>None</td><td>None</td></tr>
<tr><td>Primary zones affected</td><td>N/A</td><td>Low</td><td>Low
North Hill</td><td>Intermediate
Low</td><td>Intermediate
Low
North Hill</td></tr>
<tr><td>Transmission Impacts</td><td>N/A</td><td>Limited</td><td>Losses in North Hill</td><td>Excessive loss across Spokane River at Parkwater</td><td>Losses in North Hill</td></tr>
</table>

Note:
1. The primary supply zone tanks are the first tanks to experience the effects of a loss-of-supply event; tanks in upper pressure zones are not affected until their supply booster stations are shut off or unable to flow due to inadequate suction pressure. Therefore, the analysis focuses on the behavior of the primary supply zone tanks.

Parkwater Wells Offline EPS Results

The City's Parkwater well station is the largest-capacity well station in the system and comprises more than half of the City's typical supply. Two of the well pumps serve the Intermediate System and the other six well pumps serve the Low System. Due to electrical limitations at the well station, the City noted that only six of the eight pumps can be operated simultaneously. However, as the mass balance analysis predicts, there is enough supply in the system from the Nevada and Well Electric Low System wells to make up for a summer loss of the Parkwater well station for current demands. The change of flow source location appears to have a limited impact on the tanks' recharge volume compared to baseline. See **Appendix B** for full results. As demands grow, the transmission grid will need adequate capacity to maintain the City's minimum emergency tank levels to support emergency changes in supply location.

Well Electric Wells Offline EPS Results

The Well Electric well station serves all three supply zones, however, as the mass balance analysis predicts, the other system wells can cover a loss of Well Electric supply for current demands. The change in flow paths does impact the recharge volumes of the Five Mile and Indian Trail tanks by about five to seven percent each. The scenario also causes recharge problems for the smaller Shawnee tank supplied by the North Hill supply zone. This tank is so small that it is extremely sensitive to changes in system flows and pressures, and the operation of the Indian Trail tank.

Havana and Ray Wells Offline EPS Results

The model predicts stable tank cycling for this scenario since the Intermediate primary zone receives flow from the Low primary zone via the 9th & Pine and Bishop Court booster stations (BSs). However, the usable volume in the Lincoln Heights tanks is reduced by over 25 percent, likely due to excessive losses in the transmission main crossing the Spokane River north of the Parkwater well stations. The headloss in this transmission main increases by more than 10 feet in the model compared to baseline when both Intermediate supply pumps (Pumps 1 & 2) at Parkwater are used simultaneously.

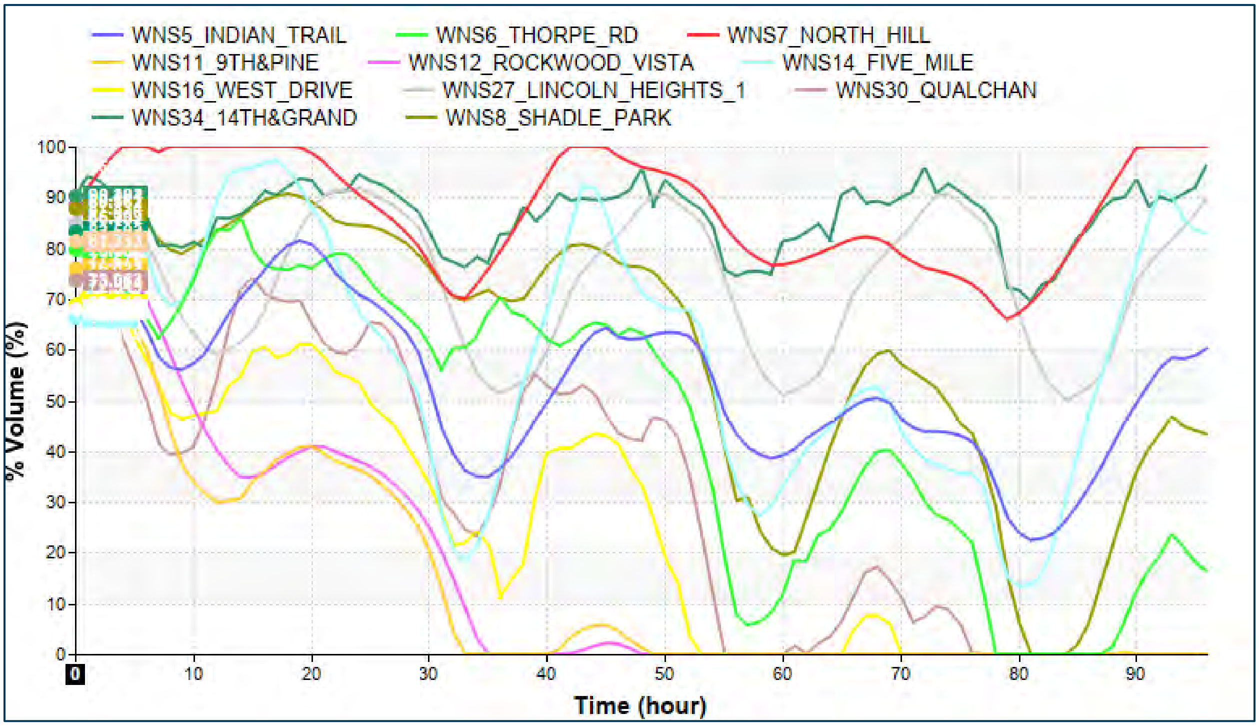
It is important that there is enough supply to the Low primary zone in this scenario to supplement the Intermediate wells from the inter-system booster stations.

Well Electric and Parkwater Wells Offline EPS Results

Many of the tanks located in the Low primary supply zones drain completely starting at the second day for the Parkwater and Well Electric Offline scenario due to the supply-demand imbalance. One example of this is shown as **Figure 7**, where the supply zone tanks drain completely approximately 32 hours after the start of the model simulation. Some of the supply zone tanks recover after the highest demand part of the day, but some remain empty. The Intermediate primary supply zone tanks show a downward trend meaning that usable storage volume will be reduced after a few days of emergency operation. For the primary zones where the MDD mass balance is negative, a longer simulation shows that all Low primary zone tanks, including tanks in boosted zones eventually completely drain as the system continues to take more water from storage during peak use times than it can replenish when demands are low.

The model analysis assumed continued operation of the Bishop Court and 9th & Pine BSs sending flow from the Low primary zone to the Intermediate primary zone, which exacerbates the Low primary zone supply deficiency. Further time could be bought for the Low primary supply zone by turning these stations off; however, this would further reduce usable storage in the Intermediate primary supply zone. This operational change is explored in the emergency response scenarios. The remaining results are included as **Appendix B**.

Figure 7 | Parkwater and Well Electric Wells Offline: Supply Zone Tanks



Emergency Response Scenarios

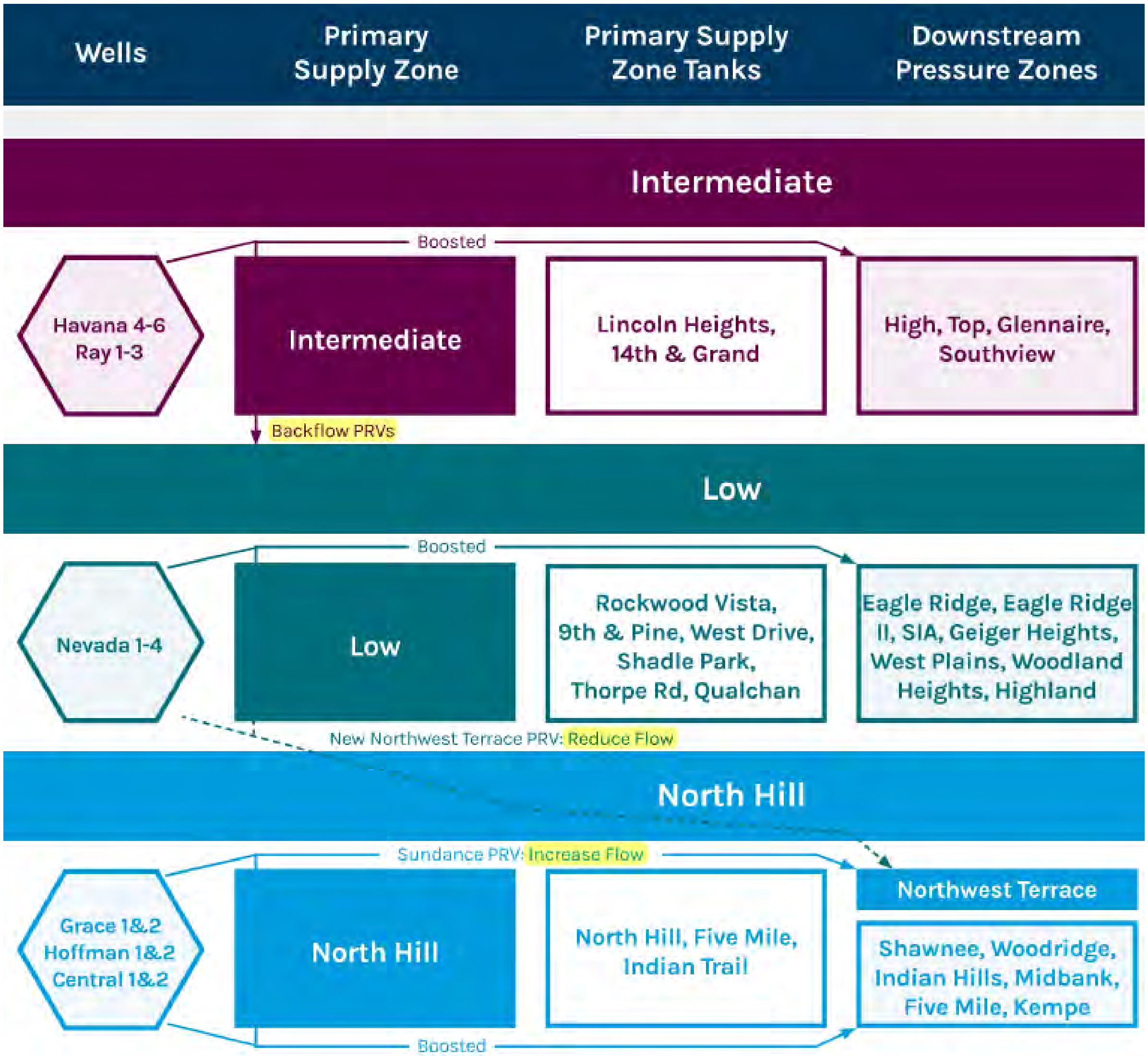
After reviewing distribution system behavior after an emergency loss of supply due to a contamination event, two feasible emergency responses for the worst-case , Parkwater and Well Electric wells Offline supply scenario were identified:

- Emergency Response 1: Backflow from Intermediate to Low primary zone
- Emergency Response 2: Demand Curtailment

Backflow from Intermediate to Low Primary Zone

The mass balance analysis shows that the Low primary zone is the only primary zone in the worst-case emergency scenario that experiences an overall daily nominal supply deficiency in the absence of a fire. Therefore, the effects of the loss of the Parkwater and Well Electric wells can be lessened by sending excess supply from the Intermediate primary zone to the Low primary zone. To implement this response, the City needs to confirm the feasibility of operating PRVs with a pressure sustaining control feature at key boundaries between the two zones. The Bishop Ct. and 9th & Pine BSs will likely be the most straightforward locations for these installations. **Figure 8** illustrates the proposed system configuration under this scenario.

Figure 8 | Backflow Response Schematic



PRVs at these two locations as a possible emergency response measure were modeled. The PRVs may require a pressure sustaining feature since the typical Intermediate HGL is higher than the Low primary supply zone HGL. Without the sustaining feature, flow may enter the Low primary supply zone in an uncontrolled manner and affect customer pressures in the Intermediate primary zone.

The pressure setting at the existing Low to Northwest Terrace PRV Station was adjusted in the model to the minimum manufacturer's setting of 3 psi to limit flow through the valve. Ideally, the North Hill primary zone would take over full supply to the Northwest Terrace pressure zone; however, due to transmission limitations in the Northwest Terrace and North Hill pressure zones, customers do not receive adequate pressures without flow through the PRV from the Low primary supply zone. The existing PRV's reducing pilot springs are likely not able to accommodate such a low pressure setting, so a secondary pilot system with an alternate spring will need to be installed on the valve. The pilot systems will be toggled by a manual ball valve or solenoid valve. Further analysis and manufacturer coordination should be conducted to verify the required field setting and retrofit requirements.

Demand Curtailment Summary

While the City would like to avoid demand curtailment, reducing demand could stabilize the system during an emergency loss of supply. A reduction of demand will likely necessitate a public demand curtailment campaign. As such, the City has for guidance on the volume of demand curtailment needed. As the mass balance summary demonstrates, the Low primary zone supply is deficient by 8 percent for the worst-case Parkwater and Well Electric wells Offline scenario.

As in the Emergency Response 1 scenario, the Dalke PRV Station located at West Regency Lane and North Park View Lane was modeled with a reduced pressure reducing setting to limit Low primary zone supply to the Northwest Terrace pressure zone. Under this scenario, the North Hill primary zone will take over more supply to the Northwest Terrace pressure zone. The model estimated that the Dalke PRV would need to provide a minimum of 1,400 gpm average flow throughout a high use summer day to meet minimum emergency pressures. The City is currently constructing a new PRV in parallel with the Dalke PRV, including a transmission improvement downstream of the new PRV station. This operational configuration is similar to the new Northwest Terrace PRV, though the pressure setting requires further evaluation, and more flow may be feasible through the new PRV with the transmission improvement being made to the Northwest Terrace pressure zone.

Eight percent demand curtailment plus a 1,400-gpm curtailment (total 12 percent curtailment) to account for the reduction in Northwest Terrace demand via the Dalke PRV and the remaining Low primary zone supply deficiency was modeled. Curtailment was spread across the Low primary zone (which includes downstream boosted zones) in an EPS scenario. If location-specific demand curtailment efforts are not realistic or if Northwest Terrace supply cannot be modified to increase supply from the North Hill primary zone, the City could target at least 12 percent curtailment City-wide. City-wide curtailment was not modeled.

City billing records were reviewed and a rough estimate of the City Parks Department (Parks) including golf course irrigation demand compared to overall MDD was calculated, and accounts for approximately eight percent of demand for the Low primary zone. To set an example for other City irrigators and to provide a time buffer for the City to conduct a City-wide demand curtailment campaign, the Water Department could potentially coordinate with the Parks Department to temporarily stop irrigation and cover most of the supply-demand balance deficit.

Operational Conditions

Table 5 summarizes key assumptions and condition changes made for the emergency response scenarios compared to the baseline EPS scenario and worst-case emergency loss of supply scenario.

Table 5 | Emergency Response Modeling Scenarios

<table>
<tr><th>Scenario→
Condition↓</th><th>Baseline EPS</th><th>Emergency Scenario D: Parkwater & Well Electric Wells Offline</th><th>Backflow: Intermediate to Low</th><th>Demand Curtailment</th></tr>
<tr><td>Supply Configuration</td><td>Baseline</td><td colspan="3">Parkwater & Well Electric wells Offline</td></tr>
<tr><td>Demand</td><td colspan="3">MDD with typical summer diurnals</td><td>Typical Summer Demand with 12% curtailment in Low System</td></tr>
<tr><td>Inter-Zone Connections</td><td colspan="2">Bishop Court BS, 9th & Pine BS ONLINE.
W Regency Ln & N Park View Ln Dalke PRV ONLINE.</td><td colspan="2">Bishop Court BS, 9th & Pine BS OFFLINE.
W Regency Ln & N Park View Ln Dalke PRV ONLINE with Low primary zone pressure sustaining feature.</td></tr>
<tr><td>Proposed New Facilities</td><td>None</td><td>None</td><td>PRVs with sustaining feature at Bishop Court. and 9th & Pine BSs</td><td>None</td></tr>
</table>

Results

Figure 9 and **Figure 10** show the primary supply zone tanks percent volume graphs for both response scenarios. Both emergency response scenarios allow the system tanks to cycle without crashing, however, the tanks in the Low primary supply zone are unable to fill to baseline tank levels due to increased headloss in the system. In the Backflow scenario, the Rockwood Vista and 9th & Pine tanks lose approximately 33 percent and 50 percent of their storage capacity, respectively, compared to baseline because headlosses are too high in the system for the tanks to fill to baseline levels.

In Emergency response 2, assuming a 12percent demand curtailment, approximately 34 percent and 51 percent of storage capacity is lost, respectively, in the Rockwood Vista and 9th & Pine tanks due to increased losses.

Appendix B includes tank graphs showing the EPS modeling results for each emergency response scenario.

Figure 9 | Backflow Emergency Response: Primary Supply Zone Tanks

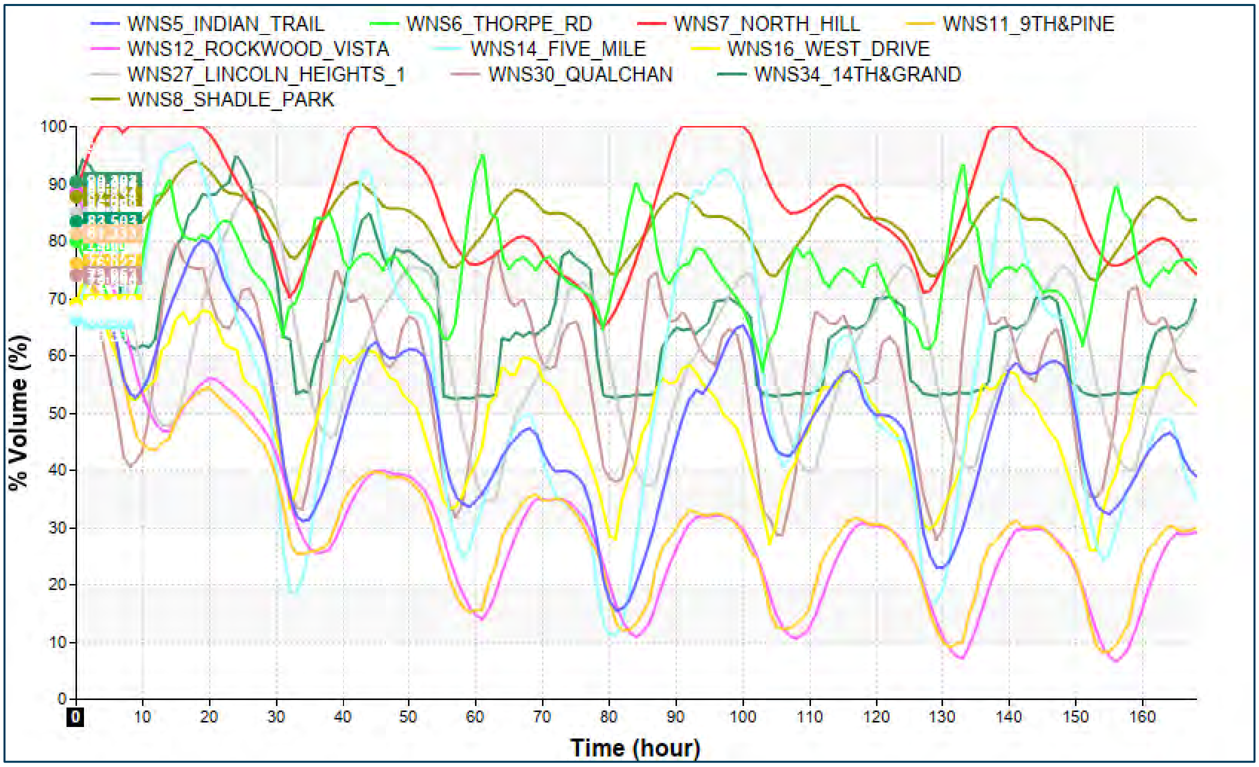


Figure 10 | Demand Curtailment Emergency Response: Primary Supply Zone Tanks

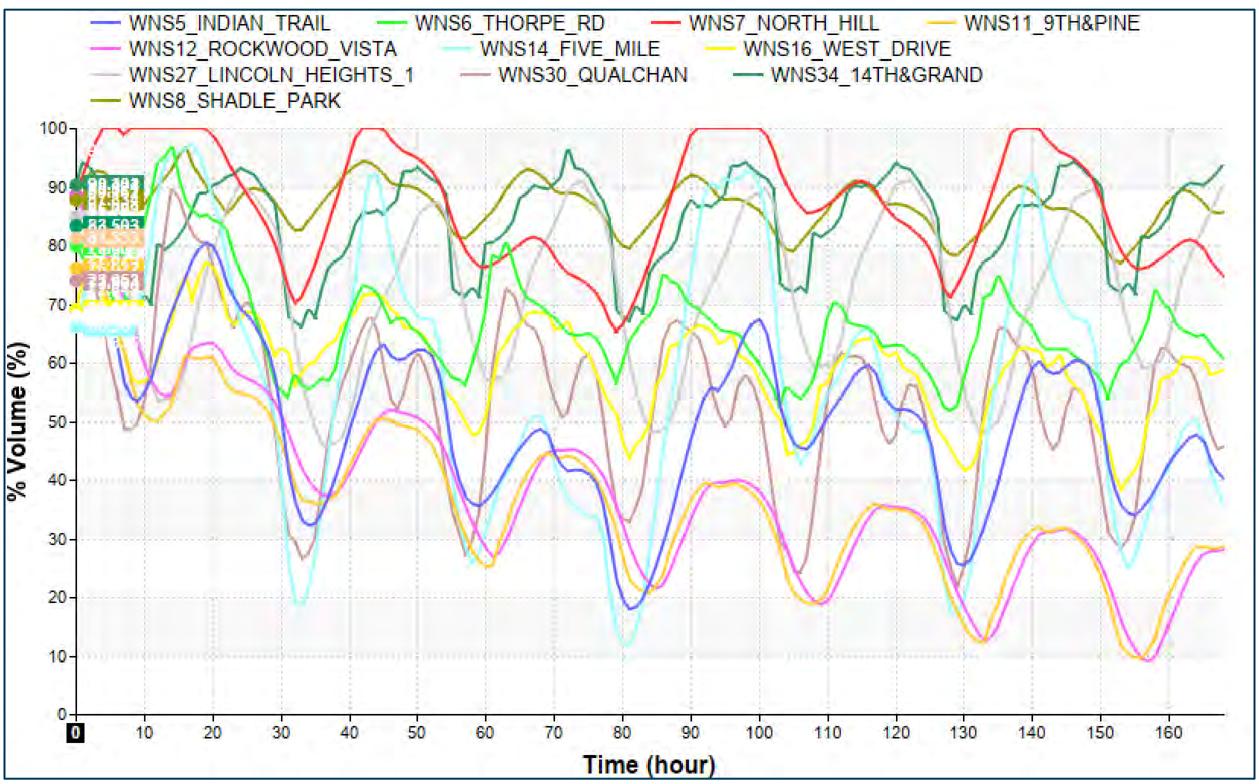
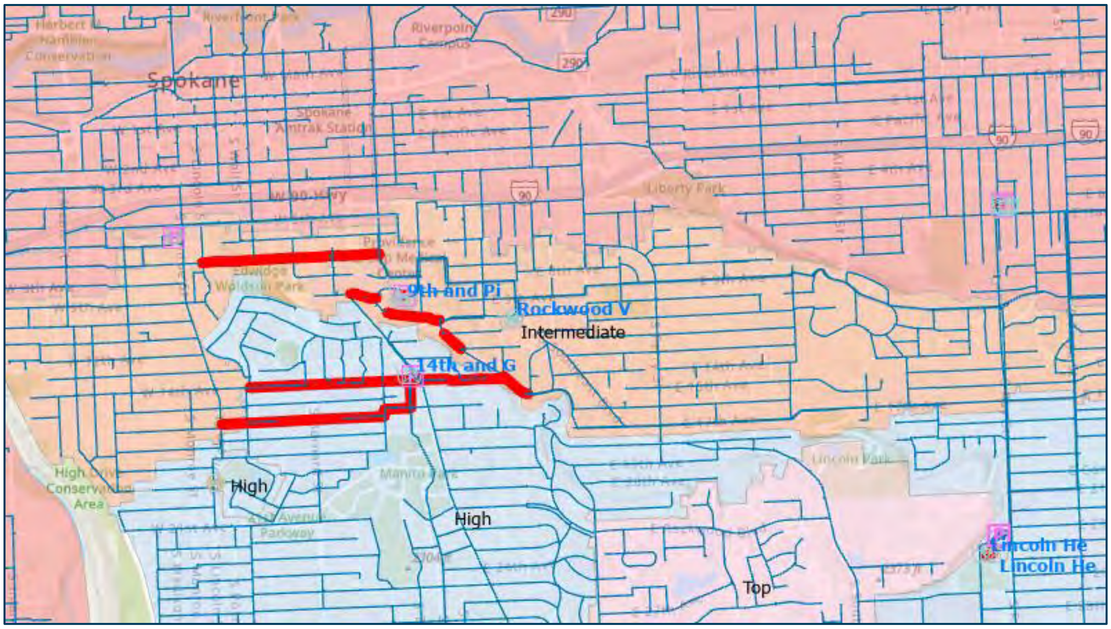


Table 6 | Emergency Response Results Summary

Criteria	Emergency Scenario: Parkwater & Well Electric Wells Offline	Emergency Response 1: Backflow Intermediate to Low	Emergency Response 2: Demand Curtailment
Primary zones with failed MDD mass balance	Low	None	None
% customers with pressures < 30 psi	100% of Low customers	+0.2% from baseline	0.1% from baseline
Primary supply zone tanks that fail to reach 95% tank volume	100%: Intermediate and Low primary supply zone tanks begin draining completely starting at 32 hours	Baseline Tanks 14th & Grand	Thorpe Rd
Approximate % tank recovery volume lost		Indian Trail: 18% West Drive: 19% 9th & Pine: 50% 14th & Grand: 21% Rockwood Vista: 33% Lincoln Heights: 8% Shadle Park: 8% Five Mile: 6% Qualchan: 8%	Indian Trail: 18% West Drive: 16% 9th & Pine: 51% Thorpe Rd: 19% Rockwood Vista: 34% Shadle Park: 7% Five Mile: 6% Qualchan: 14%
Tanks where the minimum level decreases by >5%		9th & Pine 14th & Grand Thorpe Rd Rockwood Vista Lincoln Heights Qualchan	9th & Pine 14th & Grand Thorpe Rd Rockwood Vista Qualchan
Tanks that drain to empty		None	None
Primary zones affected	Intermediate Low North Hill	Intermediate Low North Hill	Intermediate Low North Hill
Transmission Impacts	Losses in North Hill	Losses near 9th & Pine and 14th & Grand	Losses between Nevada and Rockwood Vista

Table 6 provides a summary of the evaluation criteria results for each scenario. **Figure 11** shows an area of the system where transmission main unit headloss during the Emergency Response 1 scenario increases above 3.5 feet/1,000 feet compared to the baseline operation scenario. Emergency Response 2 scenario does not cause transmission main unit headloss to exceed the 3.5 feet/1,000 feet maximum; however, both emergency scenarios cause unit headloss in the transmission main between the Nevada wells and the Rockwood Vista and 9th & Pine tanks to double. The headloss prevent the tanks from filling to baseline operational levels.

Figure 11 | Backflow Scenario Excessive Losses



Analysis Key Takeaways

The analysis demonstrates the following insights regarding distribution system vulnerability to a contamination event.

- Even when the Mass Balance Analysis shows that the system can provide adequate supply volume for MDD, tanks are not necessarily able to conserve enough volume to provide fire flow after peak use times.

- The Shawnee tank, though downstream from the primary supply zones, is sensitive to changes in system supply and requires a backup fill source. The City recently constructed an intertie to supply the Shawnee tank from the Kempe pressure zone.

- The Intermediate primary zone cannot leverage full Parkwater capacity due to excessive transmission main headloss.

- During loss of supply to the Intermediate primary zone, booster pumping from the Low primary zone can potentially rectify a supply-demand balance deficiency but usable tank volumes in both zones may be reduced by up to 40 percent.

- During loss of supply to the Low primary zone, the City could leverage excess supply in the Intermediate primary zone and/or force supply to Northwest Terrace from the North Hill primary zone. However, this strategy does not allow baseline tank recharge levels and therefore reduces the overall usable storage volume of the system. Further analysis could be conducted to determine if excess North Hill supply could be directed to the Low primary zone. However, there is not an existing natural connection between the zones and this may require high capital investment.

- 12 percent demand curtailment in the Low primary zone stabilizes system tank cycling but does not allow baseline tank recharge levels and therefore reduces the overall usable storage volume of the system.

Emergency Response Plan Measures

The City can take several steps to decrease the vulnerability of the distribution system to an aquifer contamination event. Table 7 lists both mitigation and emergency response measures that the modeling analysis showed to be effective in maintaining an acceptable level of service for an emergency supply configuration. The table is intended to support the City's capital improvement planning and provide a basis for the City to develop specific operational response procedures. Note that the modeling analysis focused on the distribution system behavior during a high-use summer day; therefore, less extreme measures are required during a cooler part of the year.

Table 7 | Emergency Mitigation Measures

Measure	Proactive or Reactive?	Mitigates which Scenario?	Notes
Demand Curtailment: Temporarily stop Parks irrigation	Reactive	Any	Request that Parks Dept temporarily stop irrigation until city-wide demand curtailment campaign complete
Demand Curtailment: 12% minimum in the Low system during summer[1]	Reactive	Any	Irrigation reduction campaign to all customers but focus on Low system customers
Install/operate backflow PRVs between Low and Intermediate primary supply zones	Proactive (Installation) Reactive Operational Measure	Parkwater & Well Electric Offline Parkwater Offline	PRVs may require a sustaining feature to prevent excessive flow from Intermediate primary zone. Existing 4-inch PRV in Bishop Court BS may need upsizing. Future 9th & Pine BS should include PRV in design.
Install/operate secondary reducing pilot at new Northwest Terrace PRV	Proactive Reactive Operational Measure	Parkwater & Well Electric Offline Parkwater Offline	Design should allow for lower emergency PRV setting on new PRVs serving Northwest Terrace pressure zone.
Utilize the Kempe-Shawnee intertie	Reactive	Well Electric Offline	Operators should be ready to supplement recovery of the Shawnee tank during peak use times from the Kempe tank during emergency supply scenarios.
Supply Improvements	Proactive	Any	Prioritize supply improvements to Low primary zone including Havana pumps 1-3 and deep Well Electric wells.
Transmission System Improvements: Parkwater Intermediate 24-inch diameter discharge	Proactive	Havana & Ray Offline	This emergency scenario requires the use of both Intermediate Parkwater pumps 1 & 2
Transmission System Improvements: Northwest Terrace pressure zone and Indian Trails Area	Proactive	Parkwater & Well Electric Offline Parkwater Offline	With transmission upgrades here, the Sundance North Hill PRV to Northwest Terrace could take over from the Low PRV if Low supply is lost. Some transmission upgrades in this area are already in design/construction.
Transmission System Improvements: Low primary supply zone	Proactive	Parkwater & Well Electric Offline Parkwater Offline	Increased transmission capacity in the Low primary supply zone would allow the system more flexibility to leverage the Nevada wells. The ongoing Marshall Road transmission improvements will contribute to this end.
Review summertime usable storage	Proactive	Any	Ensure adequate emergency storage is available after summer operational/equalizing storage depleted.

Note:

1. Demand curtailment assumed in all pressure zones served by the Low primary supply zone. Citywide demand curtailment campaign would likely not isolate curtailment to one zone, but the minimum amount of curtailment was assumed for the model scenario.

Demand Curtailment

A demand curtailment campaign response to this emergency should target a curtailment percentage of at least 12 percent for customers served by the Low supply zone only. However, the City indicated that a curtailment campaign would be conducted for all customers. If the campaign includes strategies for certain customers, the following customers should be considered, as they have the biggest impact on Low primary zone operations:

1. Northwest Terrace customers
2. Low primary zone customers
3. High users such as factories, golf courses, and parks

Valve Improvements

Low-Intermediate Backflow PRVs

The City should consider retrofitting the 9th & Pine and Bishop Court BSs with backflow PRVs to allow flexibility to send flow from the Intermediate primary zone to the Low primary zone, since the Low primary zone is particularly vulnerable to loss of supply during a contamination event. The Bishop Court BS already includes a 4-inch PRV, but this may be undersized for providing supplemental flow to the Low primary zone.

Further analysis should be conducted to determine whether pressure sustaining features are required to use these PRVs to avoid causing excessive pressure loss in the Intermediate primary zone during backflow.

Northwest Terrace PRV Operation

The City noted that typical supply to the Northwest Terrace pressure zone should be prioritized from the Low primary zone due to excessive headloss through the Indian Trails area of the system. The City may want to reduce supply from the Low primary zone if there is a supply deficiency due to a contamination event. Per the Northwest System CIP Analysis conducted in 2023, the transmission capacity upgrades to the Indian Trails area and Northwest Terrace area and the new PRV station planned to serve the zone will improve its supply redundancy. The proposed PRV could be fitted with a secondary reducing pilot system with a spring that allows for an extremely small pressure setting to limit flow through the station, conserving flow from the Low zone during an emergency.

Kempe-Shawnee Intertie

Because the Shawnee tank is small compared to the other tanks in the system, it is more sensitive to changes in losses, supply sources, and flows. The newly installed intertie between the Kempe well and the Woodridge pressure zone will allow the City to send additional flow to the Shawnee tank when it drains too low during an emergency scenario.

Supply Improvements

The analysis demonstrated that the Low primary zone is more vulnerable to a contamination event compared to the other primary zones. Therefore, supply improvements to the Low primary supply zone could be prioritized to ease vulnerability. The analysis also demonstrates the value in redundant supplies located in different parts of the system. Because contamination typically affects a certain area of the aquifer, a redundant well located in a different part of the aquifer provides more resilience than redundant wells in the same location. Furthermore, flexibility in supply locations puts less strain on the transmission system and allows for better use of the system's storage volumes during high demand periods. This points to the benefits of prioritizing the Havana well Pumps 1-3 over the Well Electric deep well improvements.

Transmission System Improvements

Parkwater Intermediate Supply Transmission

The City currently avoids operating the Parkwater Pumps 1 and 2 simultaneously due to known headloss in the transmission main immediately downstream of the pumps. An upgrade to this portion of the Intermediate transmission system would increase the resilience of the system to a contamination event by enabling the pumps to be used at the same time without unacceptable headloss.

Northwest System Transmission

A detailed analysis on CIP improvements needed in the Indian Trails and Northwest Terrace area of the system was conducted in 2023. The emergency response distribution system analysis further supports the case for adding transmission capacity in the Northwest area of the system so that the Northwest Terrace customers are less vulnerable to a loss of supply in the Low primary zone.

Low Primary Supply Zone Transmission

The emergency response scenario indicated increased average losses between the Nevada wells and the Rockwood Vista and 9th & Pine tanks. Increased transmission capacity or grid capacity in this area would allow the system more flexibility to leverage the Nevada wells during a loss of supply in the Low primary zone.

Fire Flow Storage Review

The City may want to consider reviewing emergency storage availability based on actual operational tank levels during summer instead of nominal tank volumes. For example, because the Indian Trail tank does not typically fill higher than 75 or 80 percent during baseline summer conditions, there is less excess storage available after a hot summer morning to provide fire flow or standby storage during an emergency.

APPENDIX A
BASELINE MODELING RESULTS

APPENDIX A

Baseline Modeling Results

The baseline modeling analysis was more extensive than what is described in this memorandum. Steady state and EPS baseline modeling was necessary to establish baseline system conditions and tank cycling behavior to evaluate how the system changes due to the emergency conditions. The level of detail shown in this appendix was not required to demonstrate the approach and takeaways of the analysis but is documented here for transparency and in case the analysis is built upon or replicated.

Baseline summer day system conditions were modeled as a comparison benchmark for emergency conditions. Without baseline modeling data, it is difficult to identify which system outcomes are a result of the emergency conditions, an error in model setup, or are existing in the non-emergency condition.

A.1 Operational Conditions

The term "operational conditions" refers to the assumptions and operational status of the facilities in each scenario. Each scenario is made up of a different set of operational conditions and modeling assumptions such as the amount and timing of demand, how full the storage tanks are, and which supply sources are online.

System pressures and fire flow availability were evaluated under the maximum day demand (MDD) + fire flow (FF) scenario. System pressures were evaluated under the PHD scenario. Consor also performed an extended period simulation (EPS) for a typical summer day based on 2018-2021 supervisory control and data acquisition (SCADA), supply production, and billing data. The EPS baseline scenario establishes the typical behavior of the system's tanks for comparison to the emergency scenarios. The scenarios are documented Table A-1.

Consor also modified the Rockwood Vista tank control scheme as part of the setup for the analysis scenarios. During the calibration, additional headloss was observed during the tank's fill cycle compared to the drain cycle, and this behavior was confirmed as typical by the City. A valve with a flow-headloss curve was added to the model fill line and a check valve to the model drain line which enabled the tank to mimic field conditions to a satisfactory level. However, when the model was used for hypothetical analysis scenarios (instead of a calibration scenario), the drain check valve did not open when expected and the tank remained full/closed for the duration of the simulation. Consor removed the Rockwood Vista tank controls, a decision which ignores the 2-3-foot fill cycle headloss in the field, but allowed the model to cycle the tank under hypothetical analysis scenarios.

Table A-1 | Baseline Modeling Scenarios Operational Conditions

Scenario→ Condition↓	MDD + FF Scenario	PHD Scenario	EPS Summer Scenario
Steady-State or EPS	Steady-state	Steady-state	EPS
Demand Set	2021 MDD with FF at highest industrial hydrant in Low primary zone	2021 Peak Hour Demand	MDD with typical summer day diurnal (by-hour) fluctuations[1]
Storage Tank Levels	Bottom of fire flow storage	Bottom of equalizing storage	Tank level fluctuation matches typical summer day based on 2021 calibration.
New Facilities	New City Facilities included in model simulations: New SIA tank, Hoffman well pump 2, Havana well pumps 4-6		
Inter-Primary-Zone Connections	Bishop Court Booster Station (BS), 9th & Pine BS ONLINE. W Regency Lane & N Park View Lane Dalke PRV ONLINE.		
Other	Latah BS Online		Latah BS Online, mimics speed settings from 2021 calibration.
Supply Sources: Intermediate primary zone	OFFLINE: Ray pump 1 Parkwater pump 1 ONLINE: All other wells	OFFLINE: Ray pump 2 ONLINE: All other wells	OFFLINE: Ray pump 1 Parkwater pump 1 Parkwater pump 2 ONLINE: All other wells
Supply Sources: Low primary zone	OFFLINE: Nevada pump 1 Nevada pump 4 Parkwater pump 7 Parkwater pump 8 Well Electric pump 3 ONLINE: All other wells	OFFLINE: Parkwater pump 3 Parkwater pump 4 Parkwater pump 5 ONLINE: All other wells	OFFLINE: Nevada pump 1 Nevada pump 4 Well Electric pump 3 Parkwater pump 4 Parkwater pump 7 Parkwater pump 8 ONLINE: All other wells
Supply Sources: North Hill primary zone	OFFLINE: Grace pump 1 Grace pump 2 ONLINE: All other wells	ONLINE: All wells	OFFLINE: Grace pump 1 Grace pump 2 ONLINE: All other wells

Note:

1. The summer EPS model demands were calibrated to a typical summer week in July 2021, but for consistency with the MDD mass balance analysis, all EPS demands were increased from typical summer values by 5.4%.

A.2 Results

Results for the evaluation of the baseline modeling are presented in Figure A-1 through Figure A-3. In Figure A-1 and Figure A-2, system pressures are presented as contours with service pressures below 20 psi presented as red dots. The figures also note initial storage levels in three primary supply zones, the North Hill, Low, and Intermediate, and well pumps in operation. Given the status of storage tank levels and well pumps that are operating, the system does appear to be in good shape with only a few troubling spots in the Intermediate primary supply zone and North Hill primary supply zone as illustrated in Figure A-3. In both figures, the other low-pressure areas are in the vicinity of storage tanks or along distribution lines that are not directly connected to customers. The baseline steady state scenario also indicated that most industrial and commercial hydrants meet their minimum flow availability requirements.

Consor also reviewed the steady-state MDD + FF and peak hour demand (PHD) emergency loss of supply scenarios against the evaluation criteria. However, because a steady-state simulation calculates results for an instantaneous snapshot in time, the emergency steady-state scenarios did not allow the system enough time for the tanks to respond to the loss of supply. Instead, the tanks drained as fast as necessary to provide fire flow and/or PHD. Minimal effects were observed to fire flow availability or PHD. This matches the Department of Health (DOH) recommendation that fire flow and/or PHD should be supplied by storage, not by supply sources, and demonstrates that fire flow availability and PHD pressures rely primarily on having the right amount of storage available at the right time. If the tank levels are too low at the beginning of a fire or at peak use times, fire flow availability and system pressures will likely be impacted. Therefore, the emergency analysis is focused on the behavior of the tanks and associated impacts to system pressures.

Figure A-1 | Baseline Scenario: Maximum Day Demand Plus Fire Flow (MDD + FF)

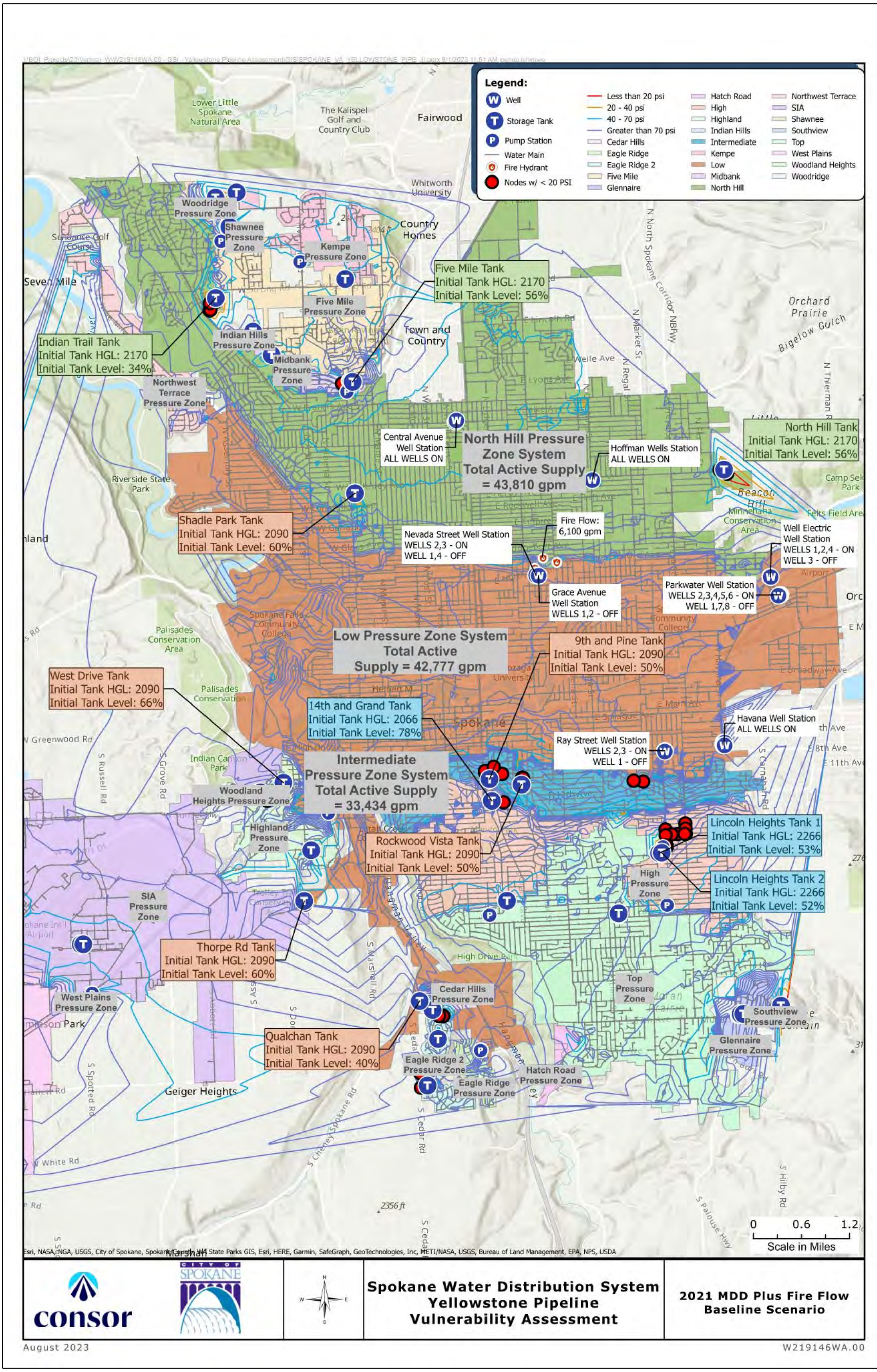


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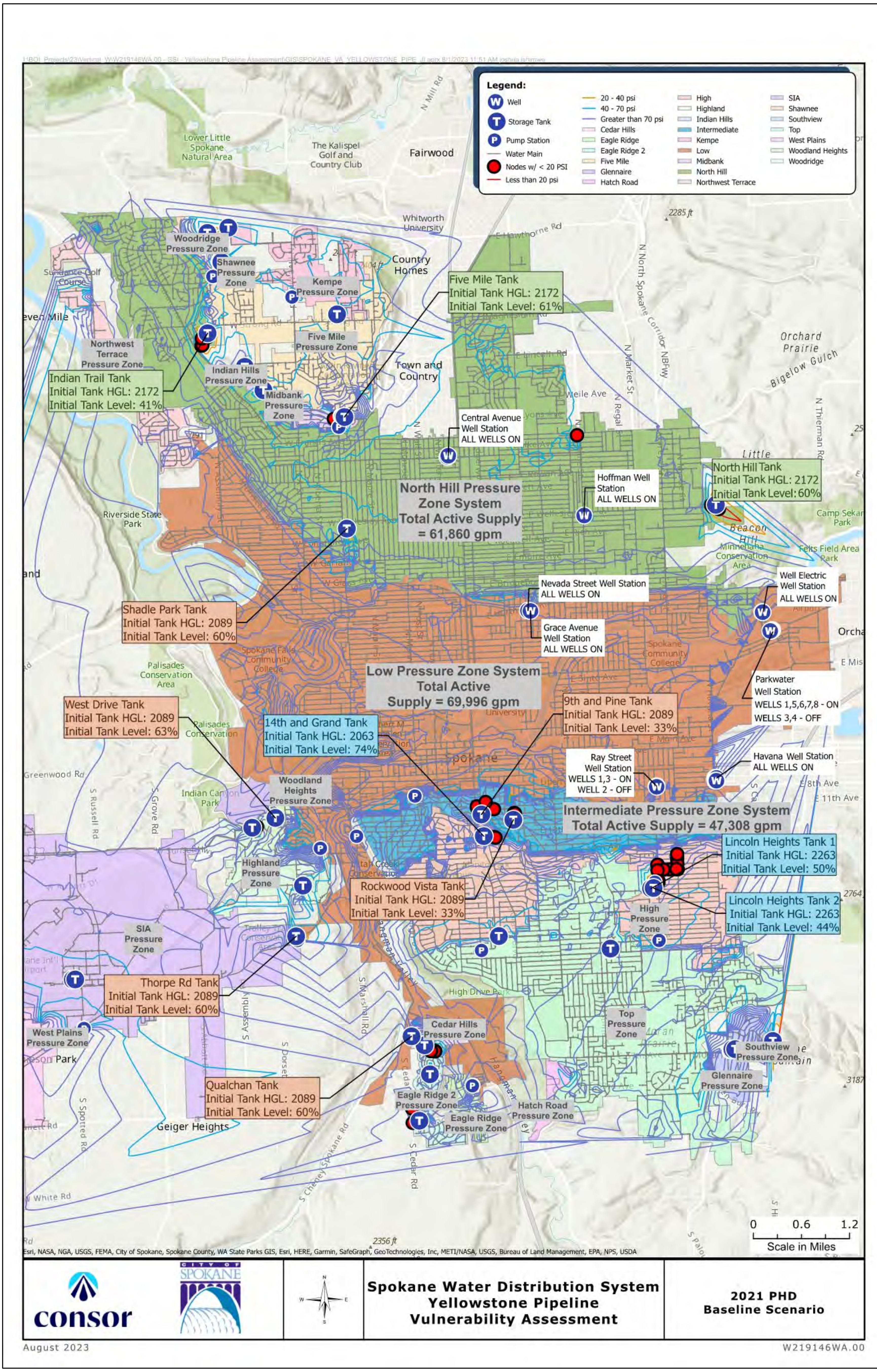
Figure A-2 | Baseline Scenario: Peak Hour Demand (PHD)



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APPENDIX B

ANALYSIS RESULTS TANK GRAPHS

APPENDIX B

Analysis Results Tank Graphs

B.1 Baseline Scenario

Figure B-1 | EPS Baseline Tank Graph: Primary Supply Zone Tanks

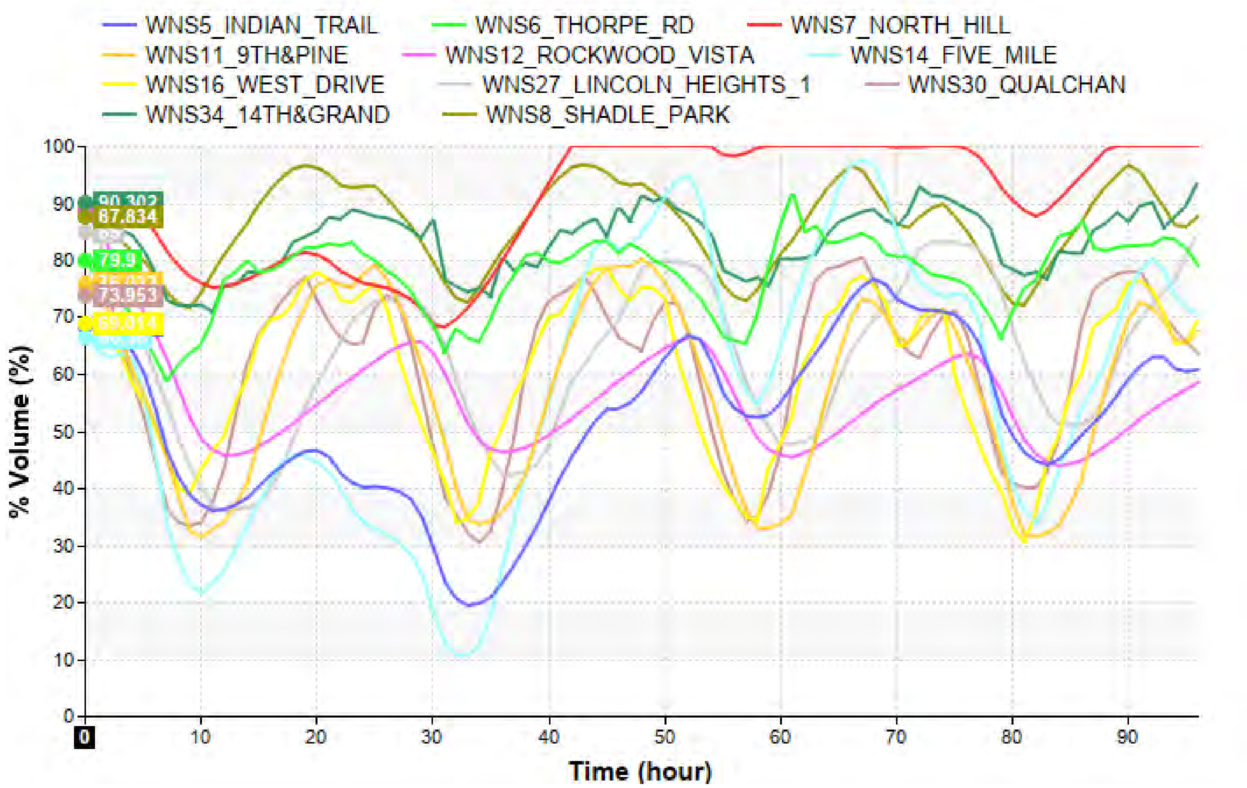


Figure B-2 | EPS Baseline Tank Graph: Intermediate Primary Zone Tanks

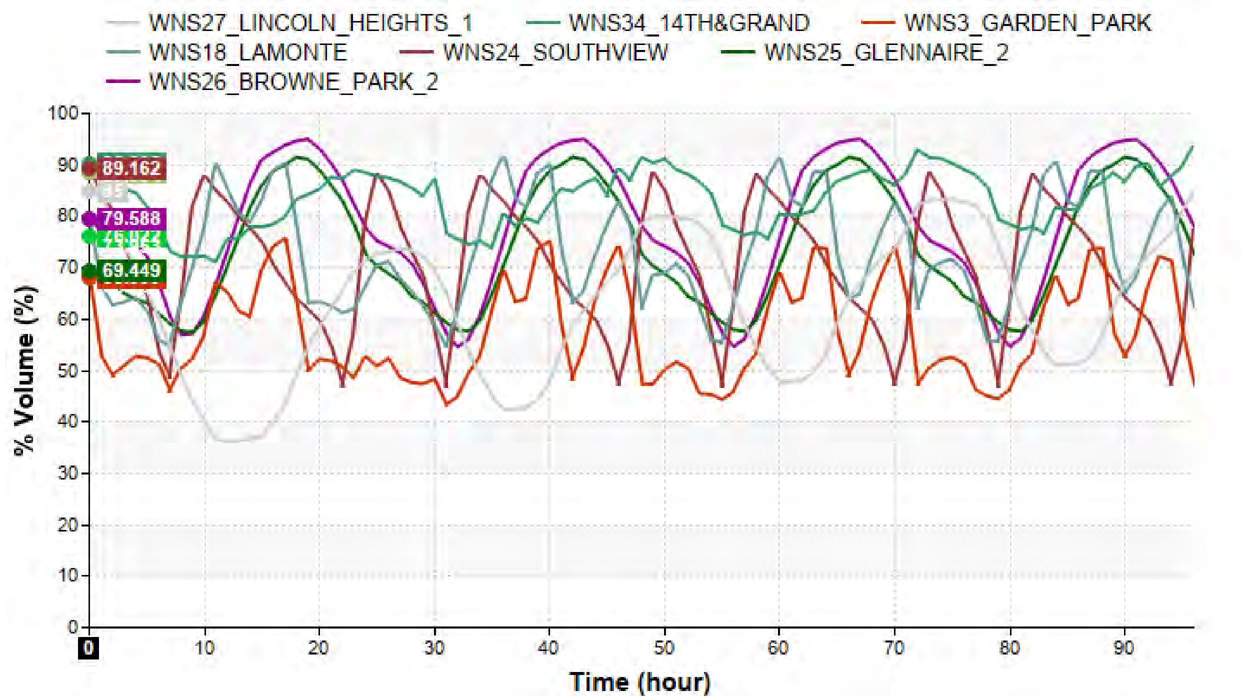


Figure B-3 | EPS Baseline Tank Graph: Low Primary Zone Tanks

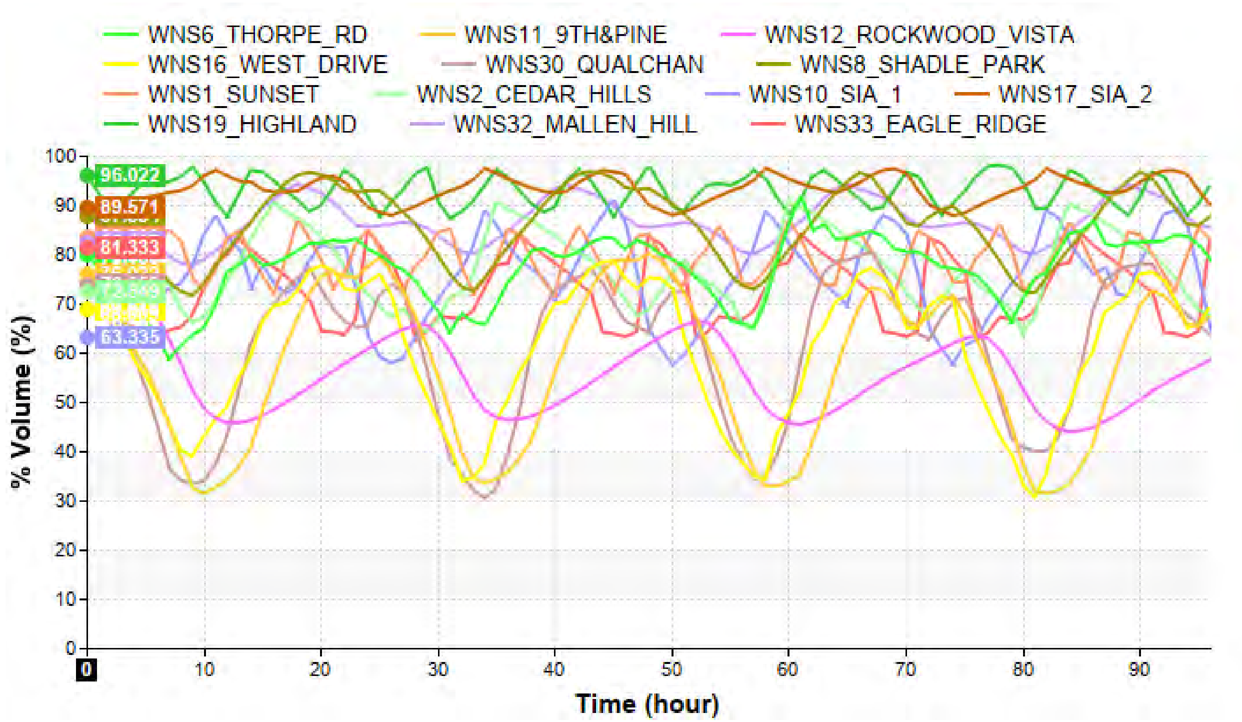


Figure B-4 | EPS Baseline Tank Graph: North Hill Primary Zone Tanks

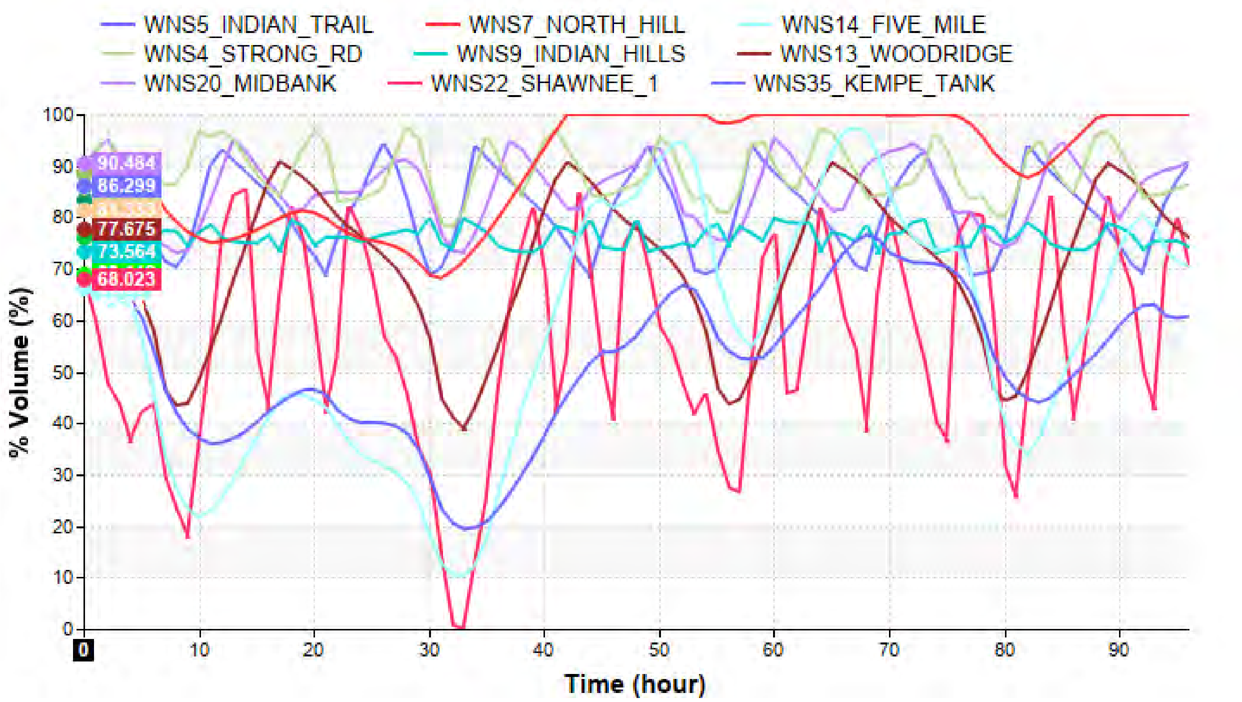


Figure B-5 | EPS Baseline Tank Graph: Intermediate Primary Supply Zone HGL

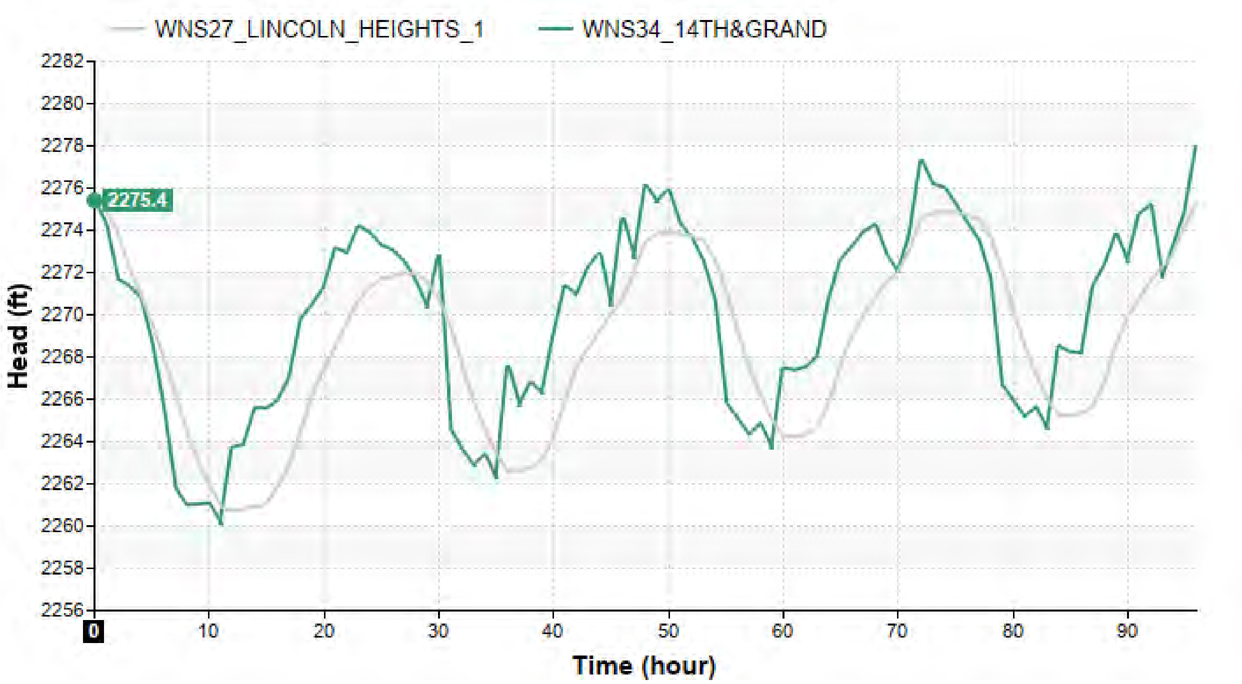


Figure B-6 | EPS Baseline Tank Graph: Low Primary Supply Zone HGL

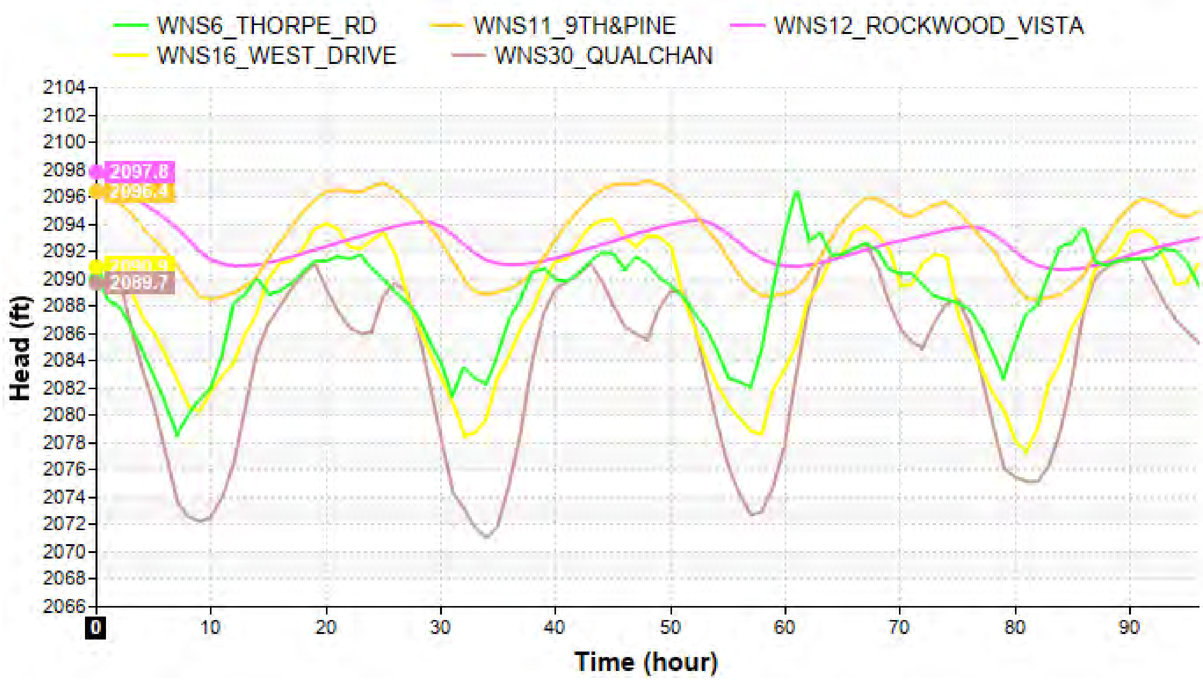
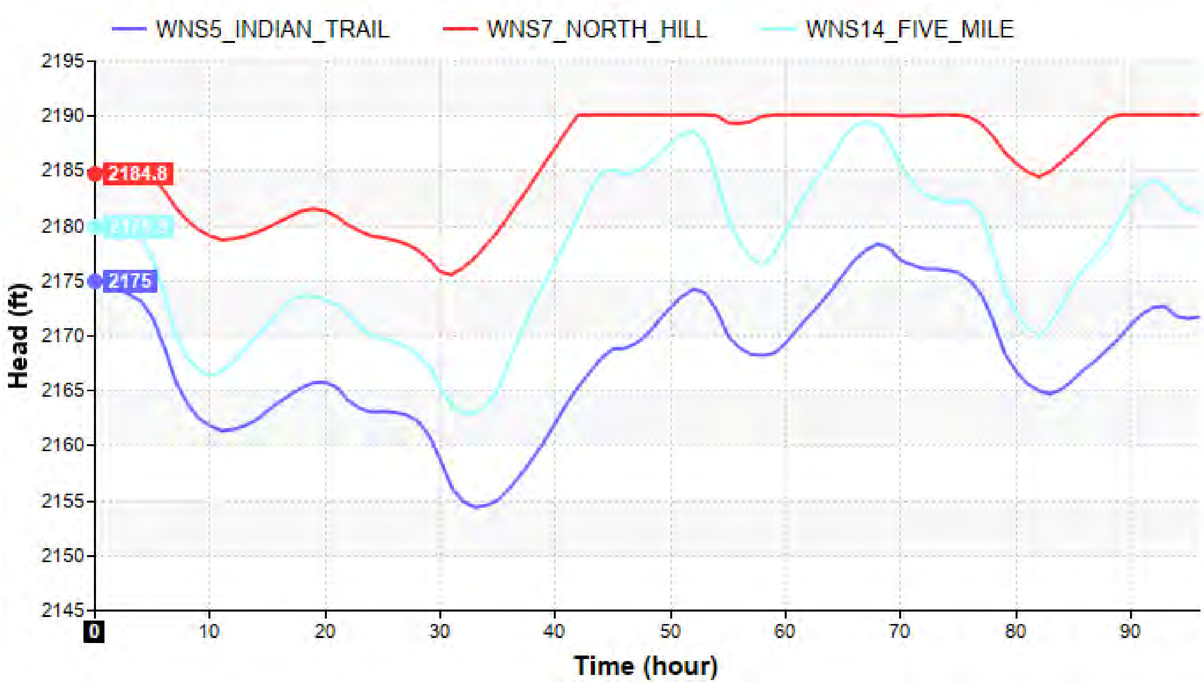


Figure B-7 | EPS Baseline Tank Graph: North Hill Primary Supply Zone HGL



B.2 Parkwater Wells Offline

Figure B-8 | Parkwater Wells Offline Tank Graph: Primary Supply Zone Tanks

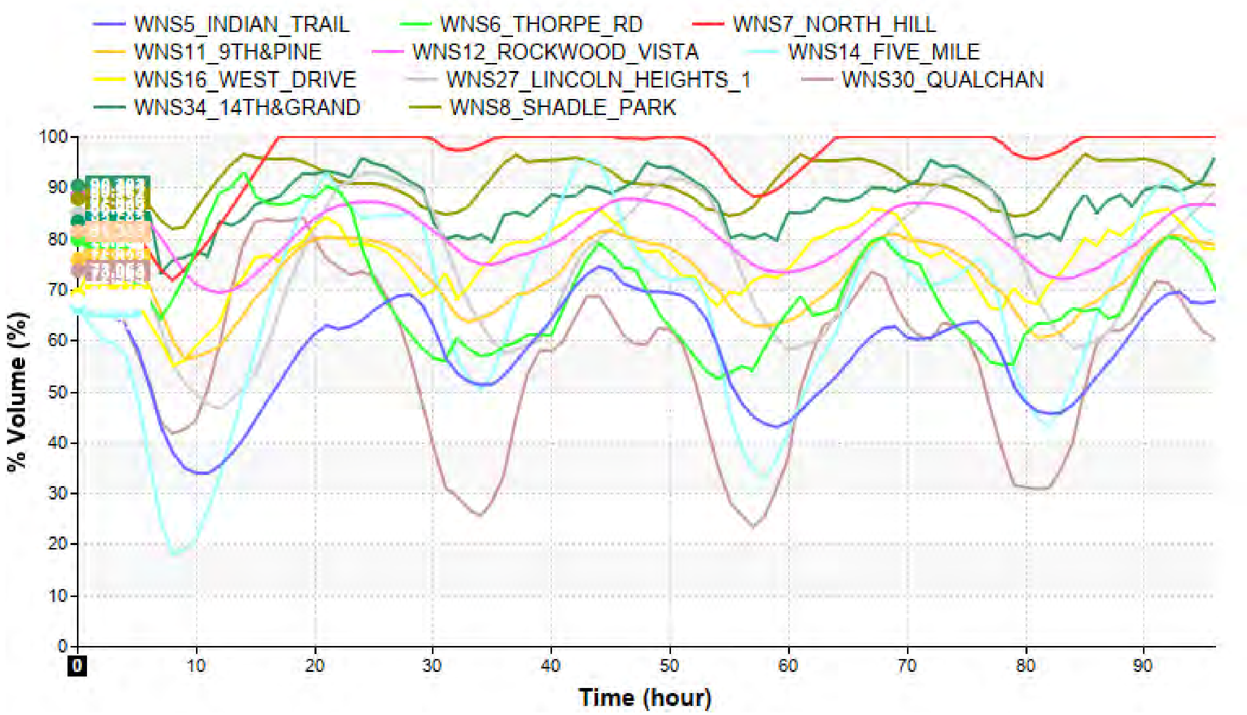


Figure B-9 |Parkwater Wells Offline Tank Graph: Intermediate Primary Zone Tanks

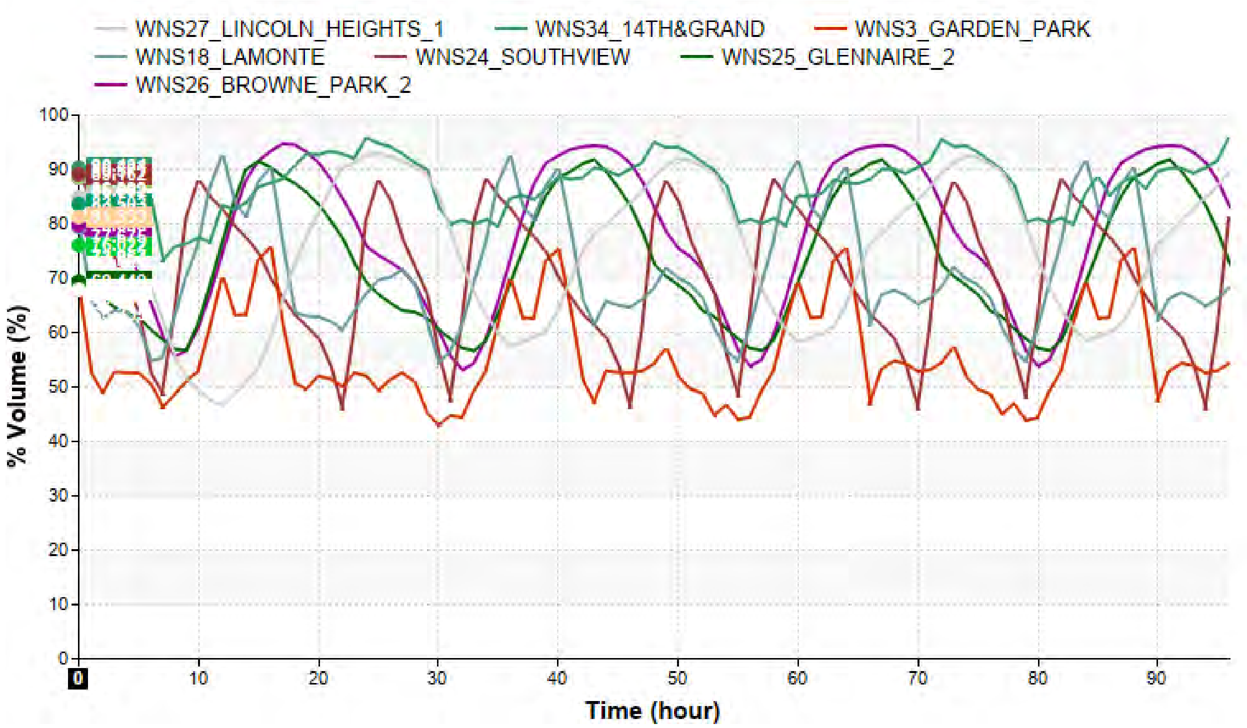


Figure B-10 | Parkwater Wells Offline Tank Graph: Low Primary Zone Tanks

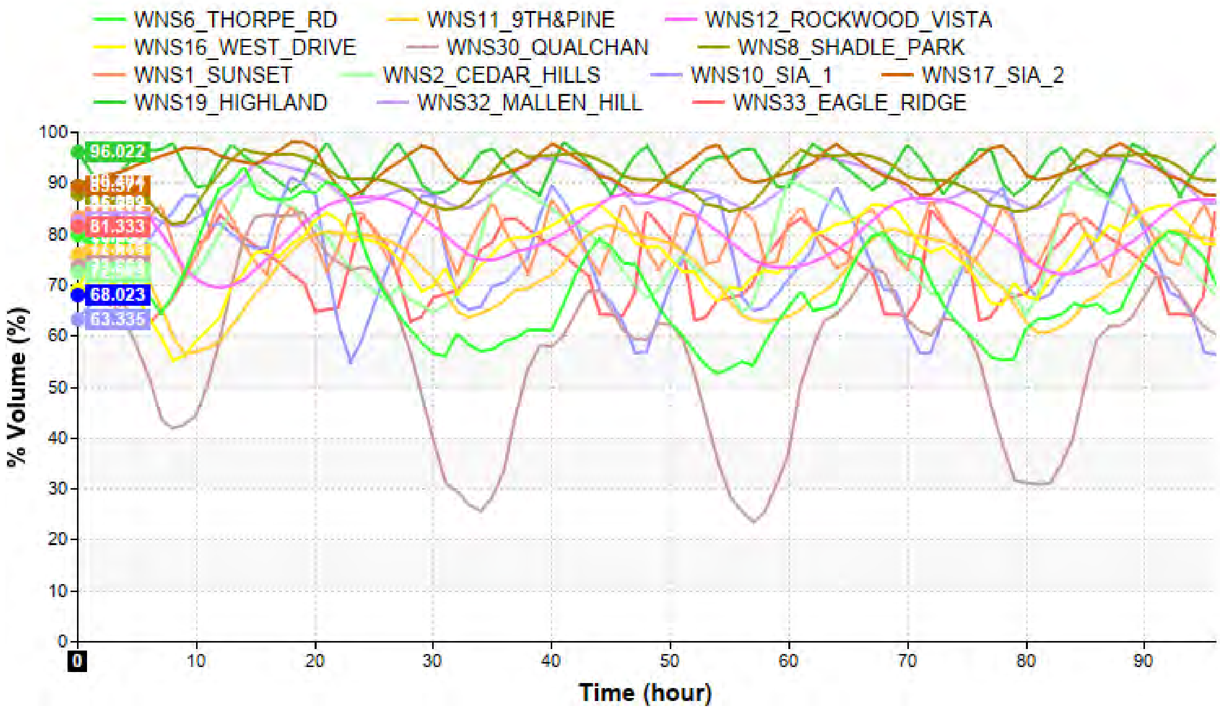


Figure B-11 | Parkwater Wells Offline Tank Graph: North Hill Primary Zone Tanks

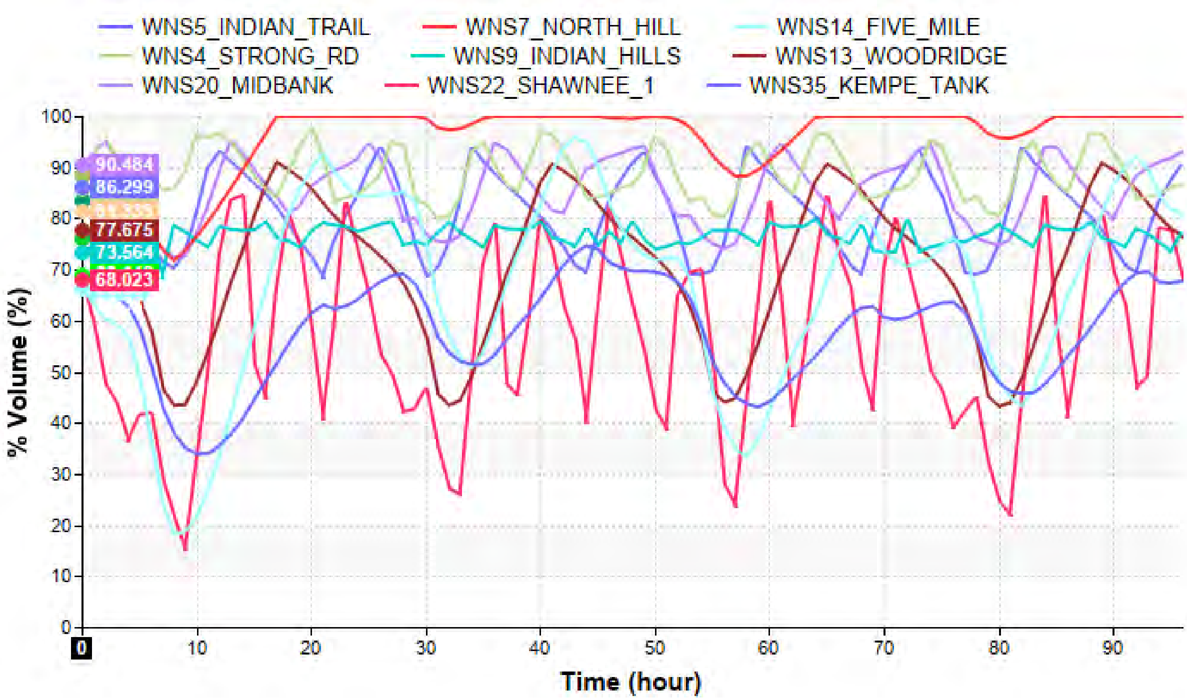
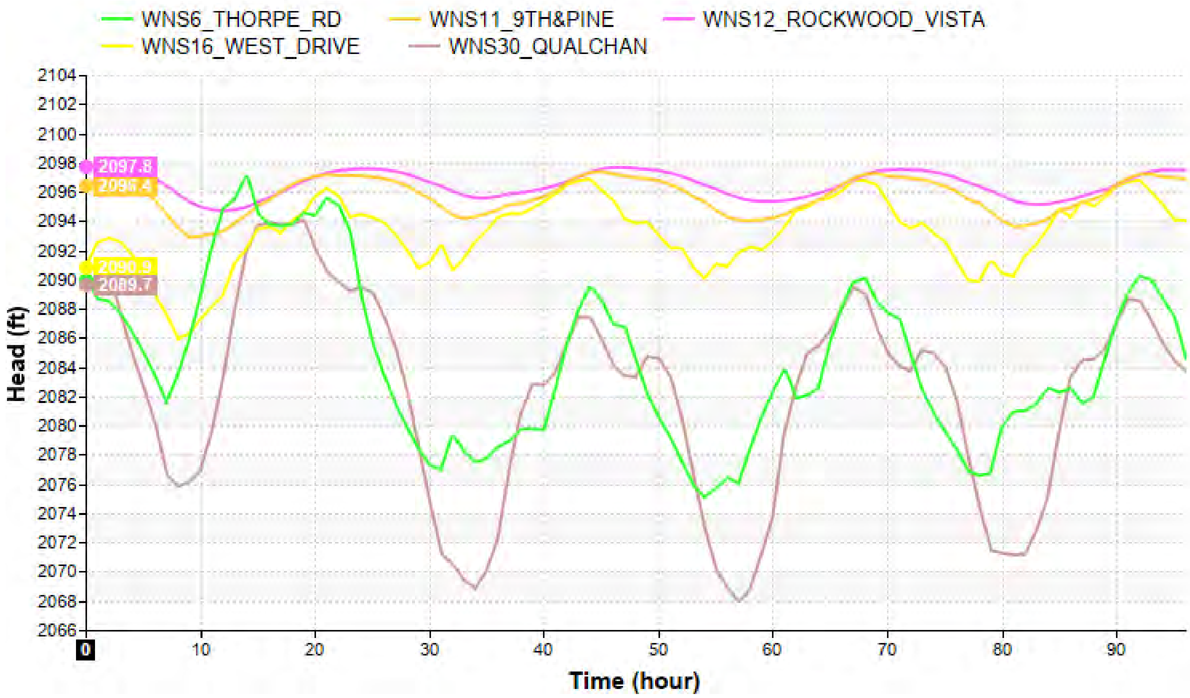


Figure B-12 | Parkwater Wells Offline Tank Graph: Low Primary Supply Zone HGL



B.3 Well Electric Wells Offline

Figure B-13 | Well Electric Wells Offline Tank Graph: Primary Supply Zone Tanks

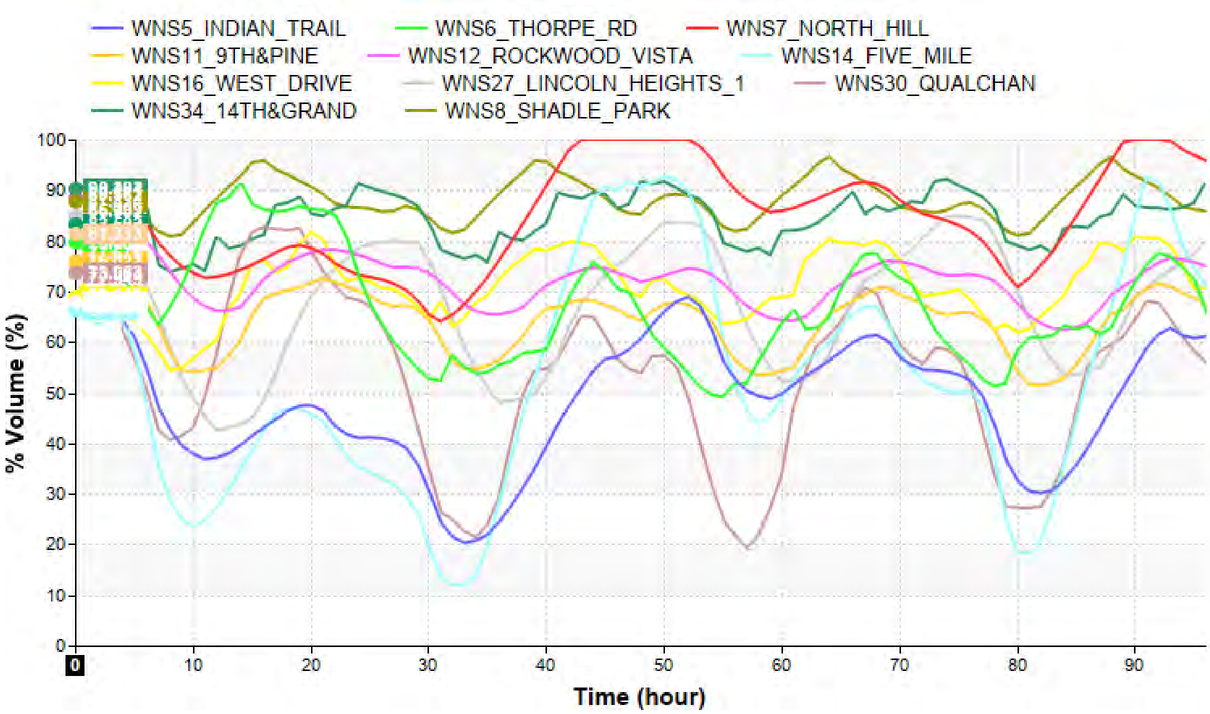


Figure B-14 | Well Electric Wells Offline Tank Graph: Intermediate Primary Zone Tanks

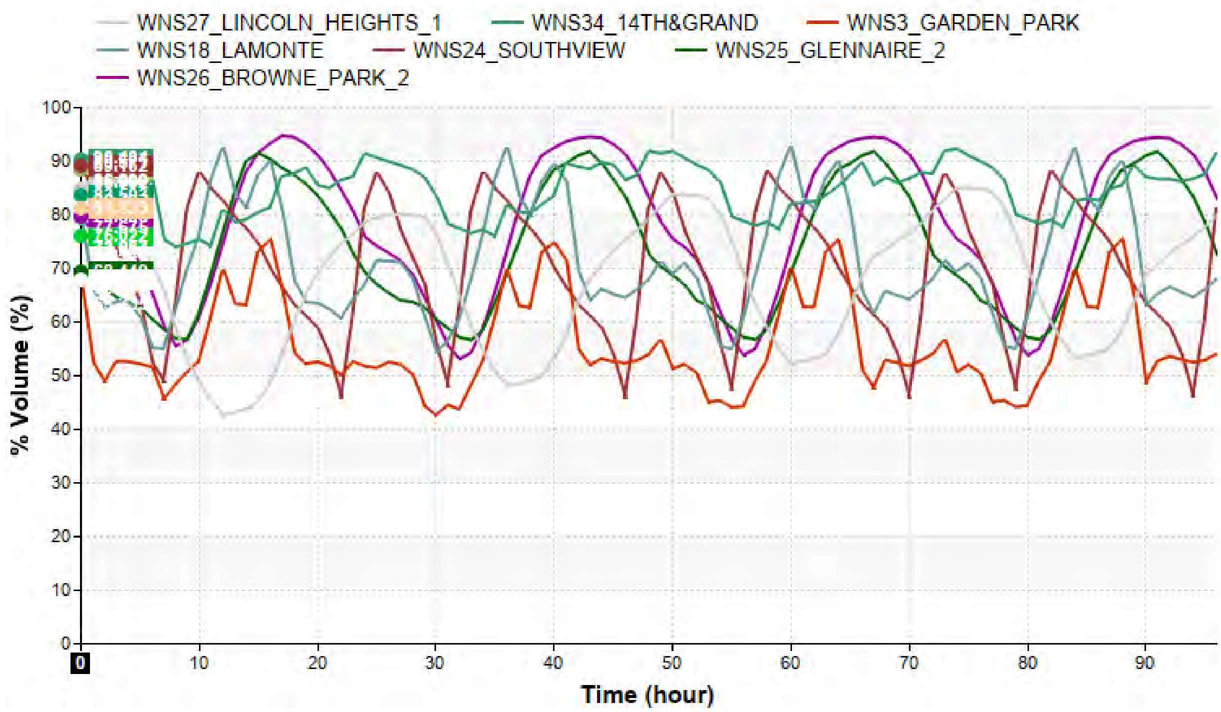


Figure B-15 | Well Electric Wells Offline Tank Graph: Low Primary Zone Tanks

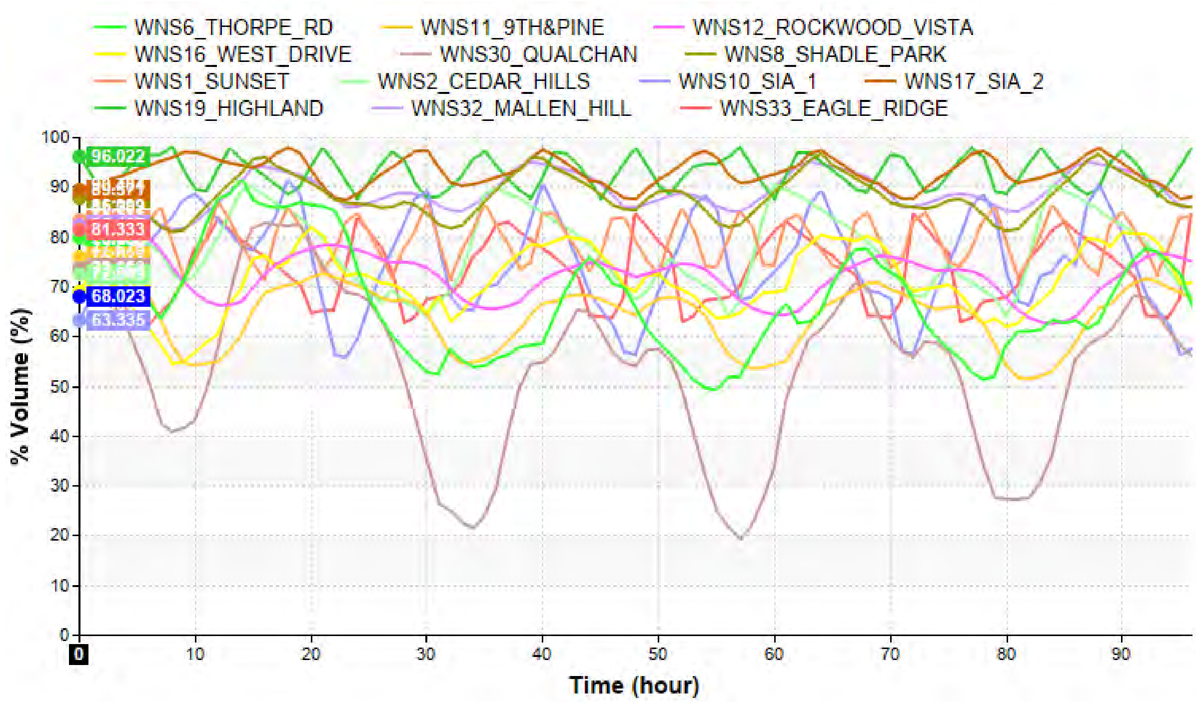


Figure B-16 | Well Electric Wells Offline Tank Graph: North Hill Primary Zone Tanks

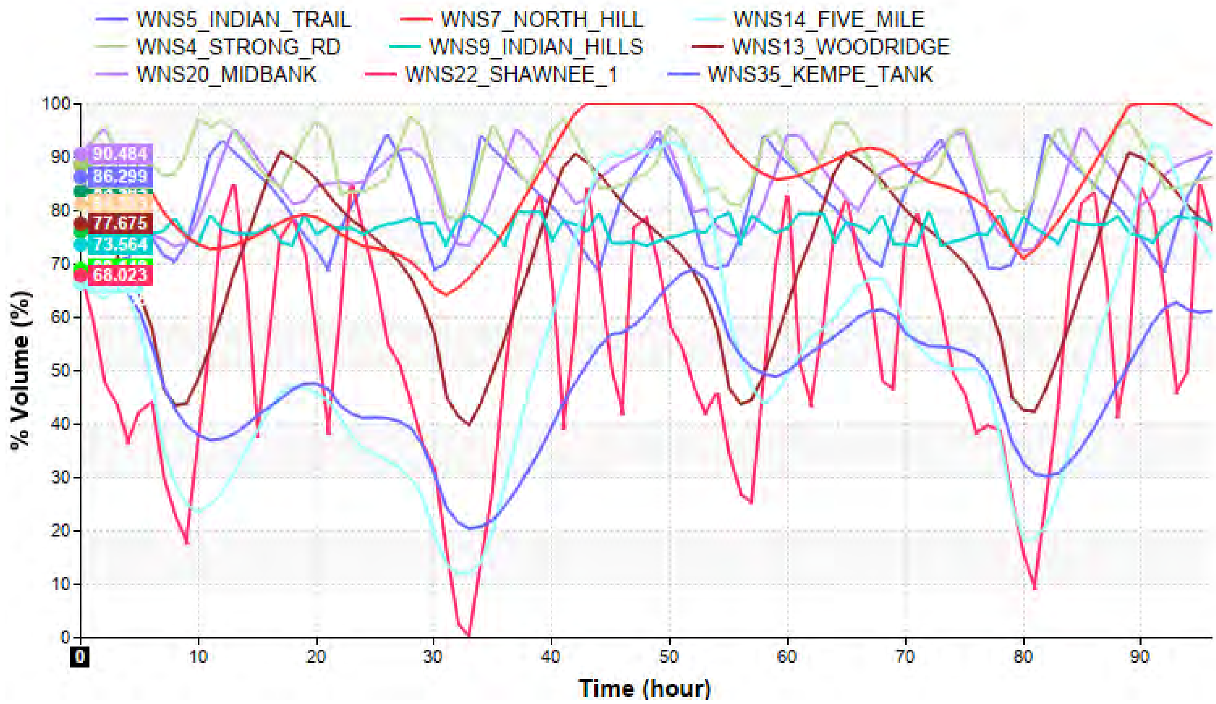


Figure B-17 | Well Electric Wells Offline Tank Graph: Low Primary Supply Zone HGL

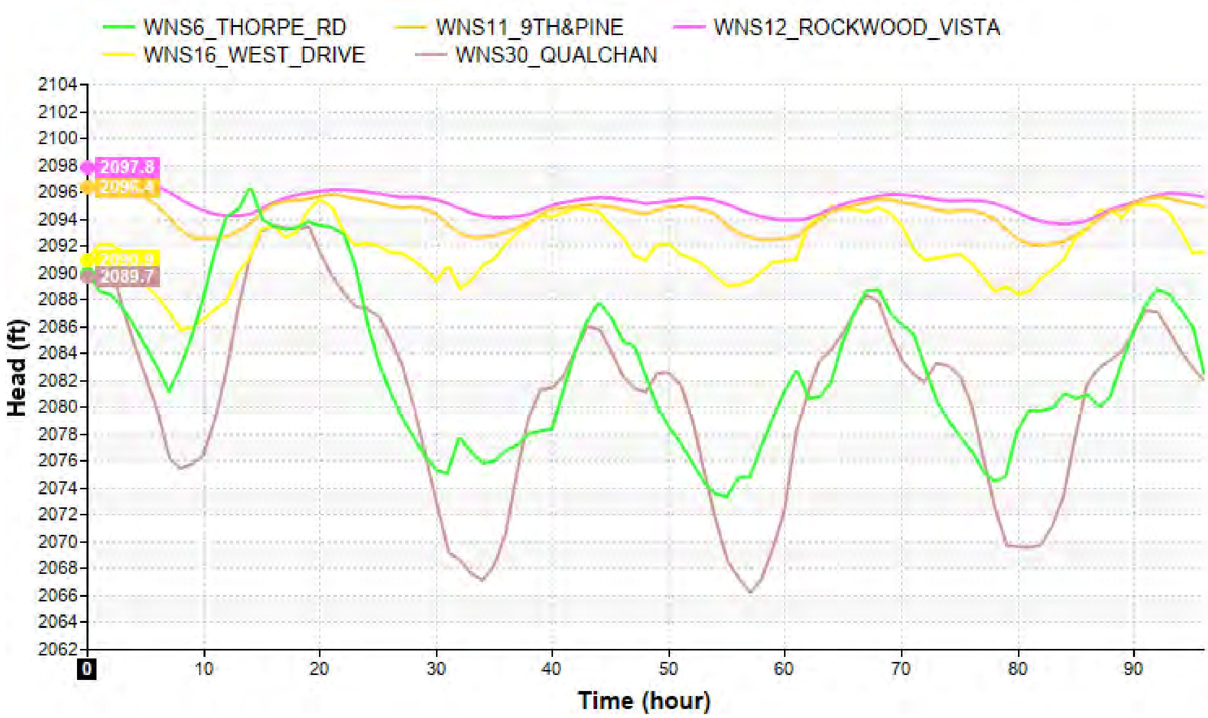


Figure B-18 | Well Electric Wells Offline Tank Graph: North Hill Primary Supply Zone HGL

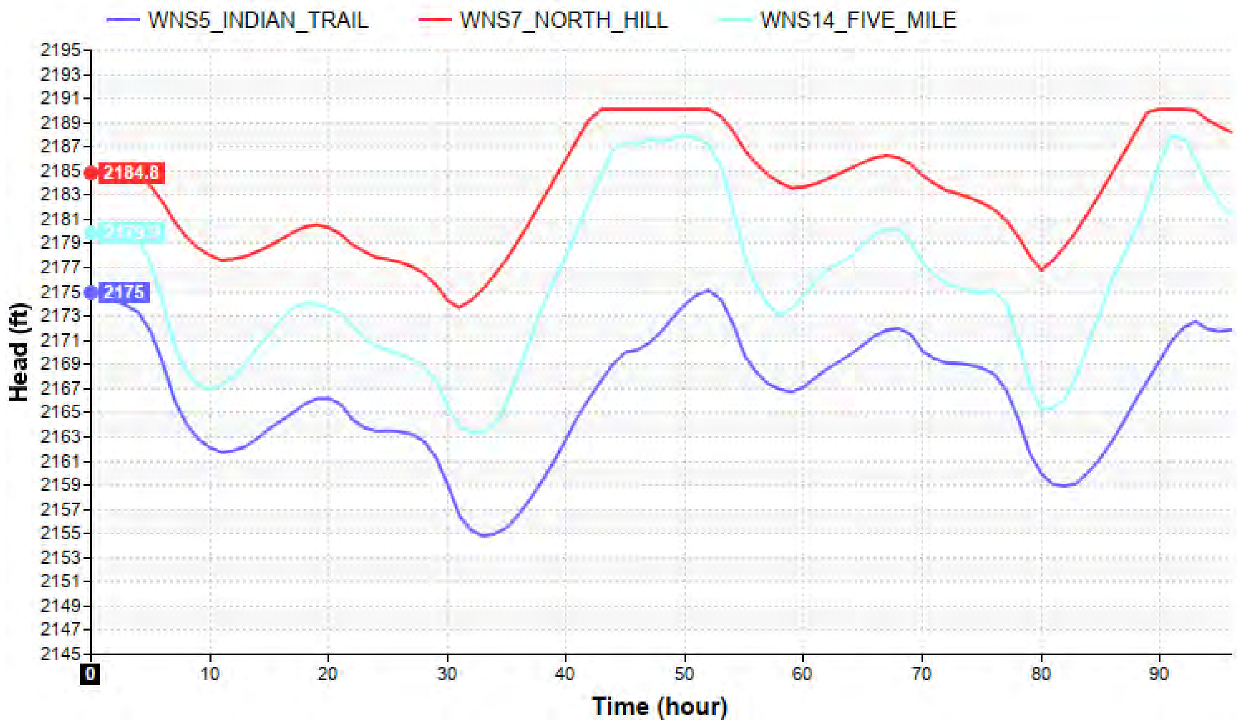
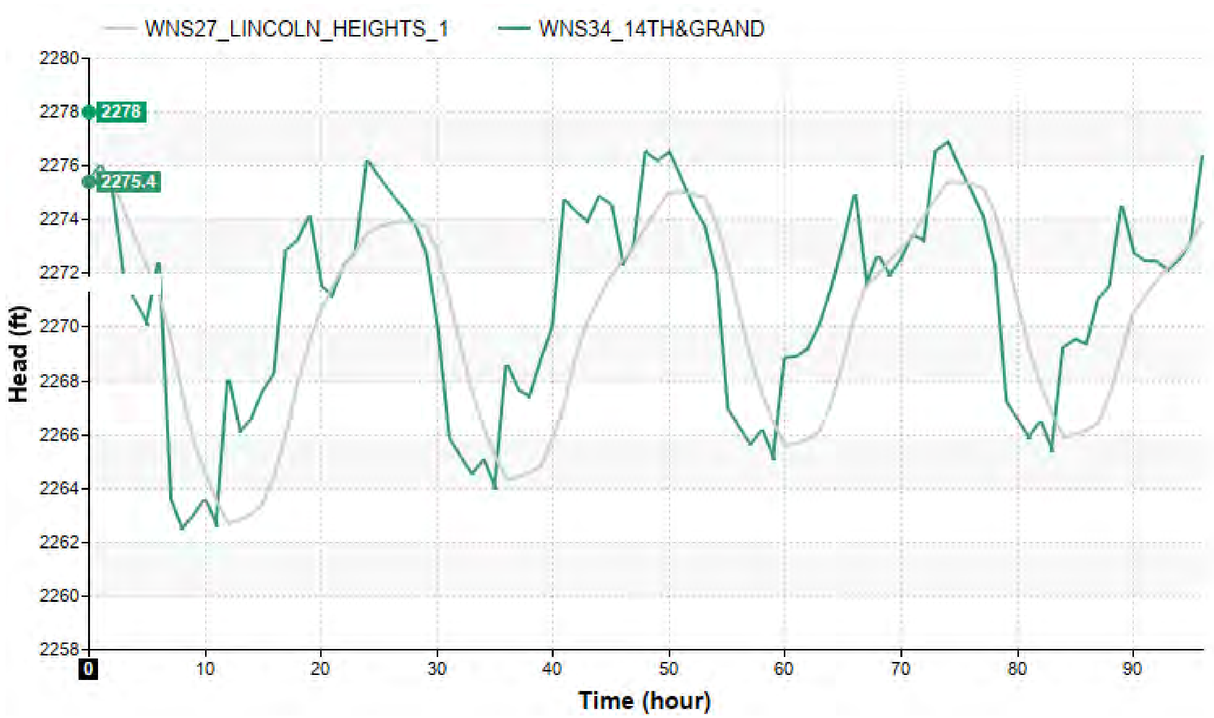


Figure B-19 | Well Electric Wells Offline Tank Graph: Intermediate Primary Supply Zone HGL



B.4 Havana and Ray Wells Offline

Figure B-20 | Havana and Ray Wells Offline Tank Graph: Primary Supply Zone Tanks

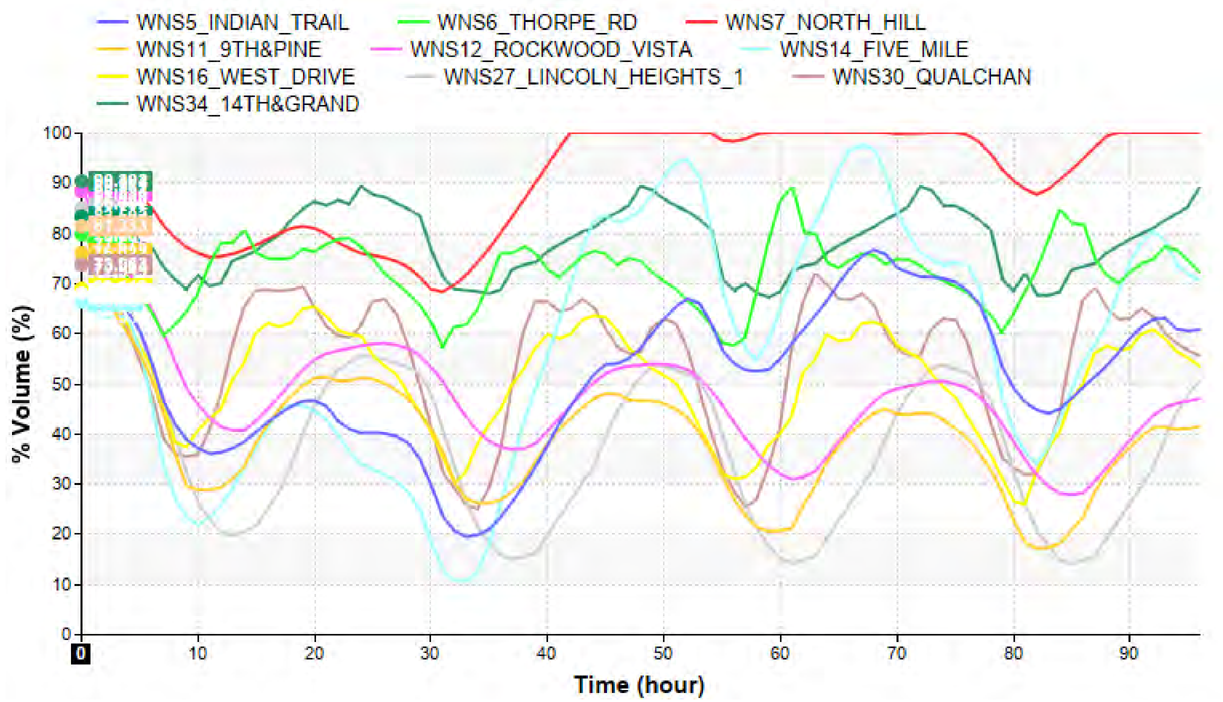


Figure B-21 | Havana and Ray Wells Offline Tank Graph: Intermediate Primary Zone Tanks

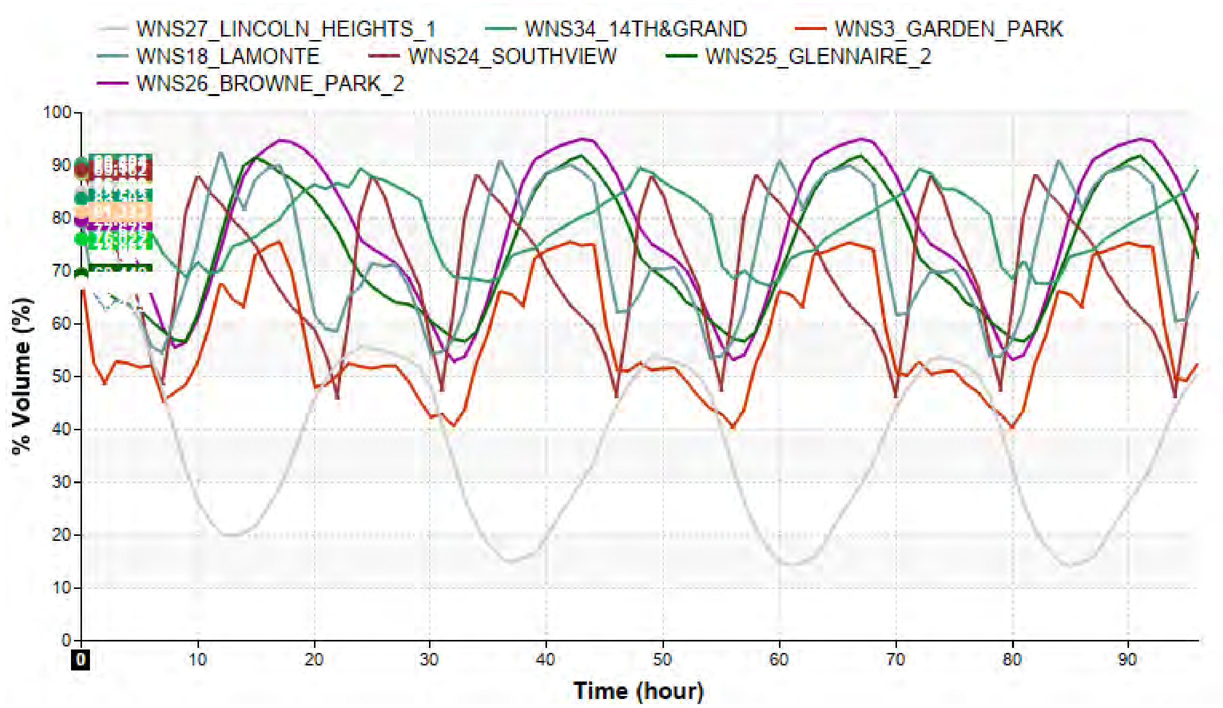


Figure B-22 | Havana and Ray Wells Offline Tank Graph: Low Primary Zone Tanks

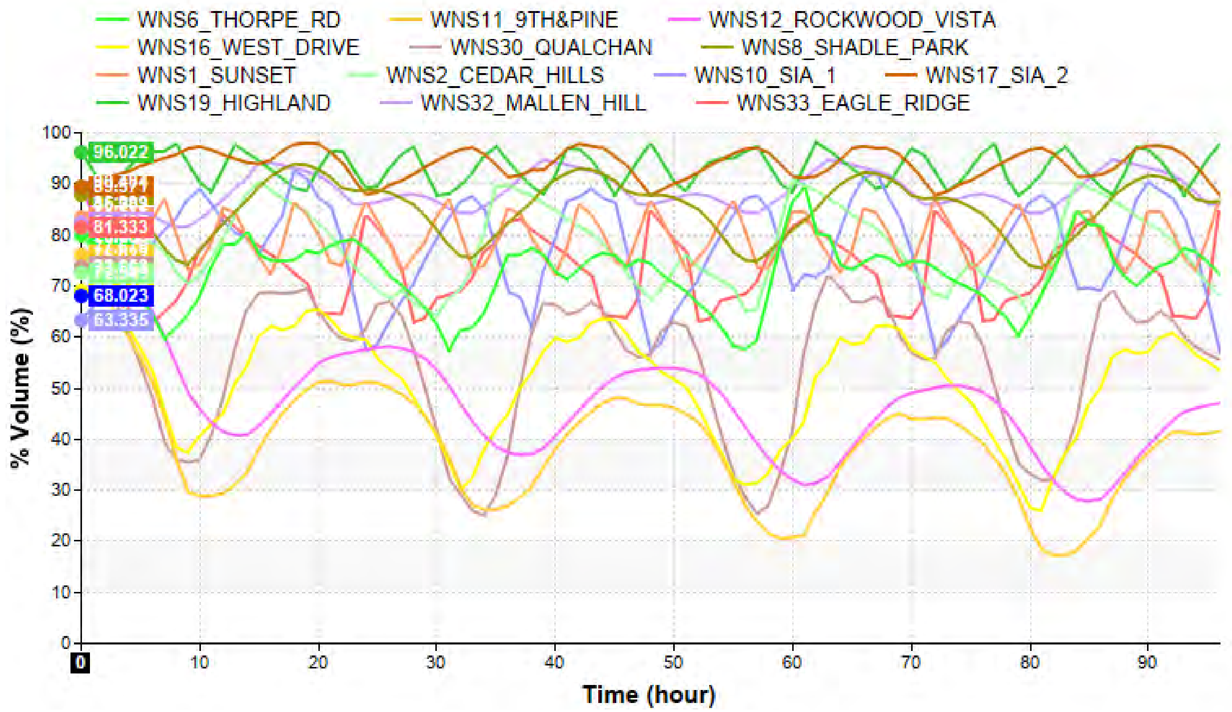


Figure B-23 | Havana and Ray Wells Offline Tank Graph: North Hill Primary Zone Tanks

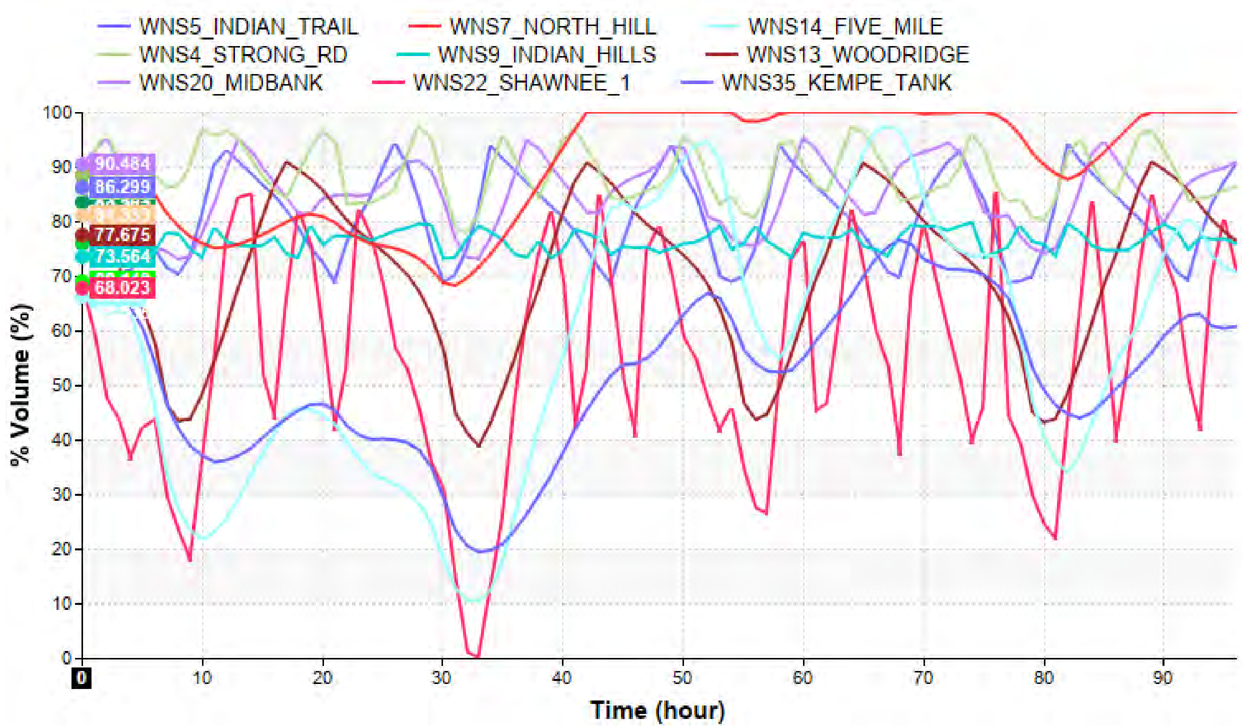
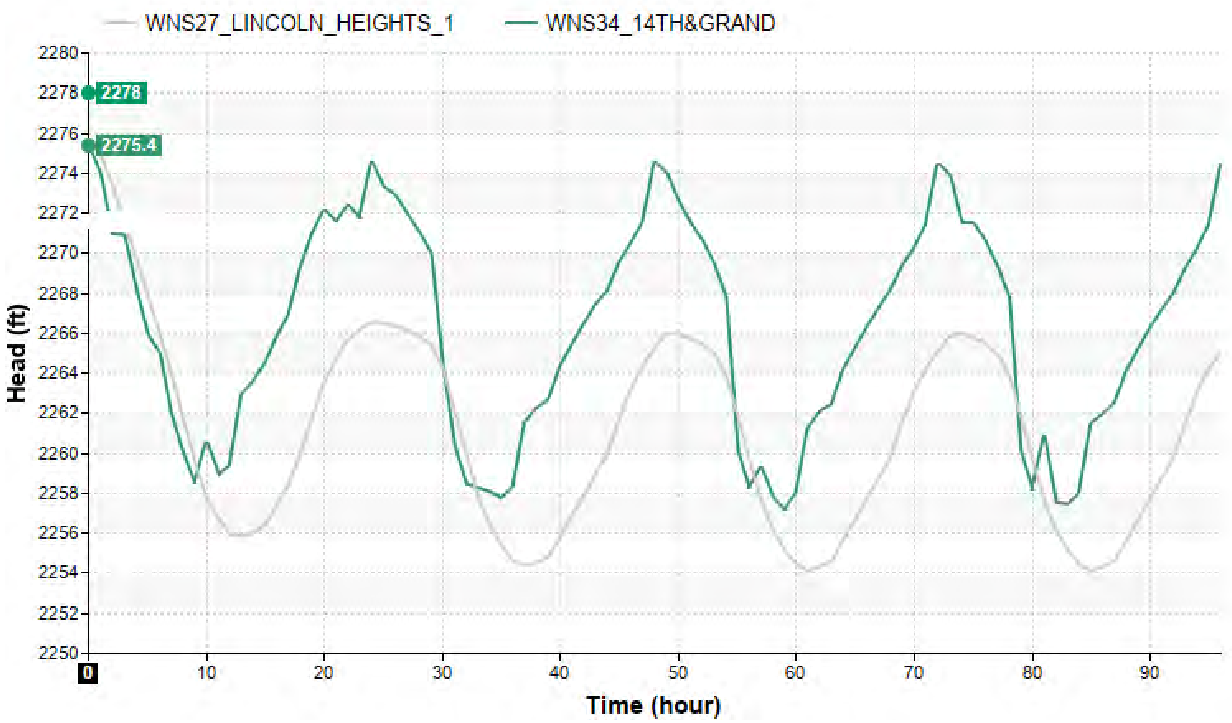


Figure B-24 | Havana and Ray Wells Offline Tank Graph: Intermediate Primary Supply Zone HGL



B.5 Parkwater & Well Electric Wells Offline

Figure B-25 | Parkwater and Well Electric Wells Offline Tank Graph: Primary Supply Zone Tanks

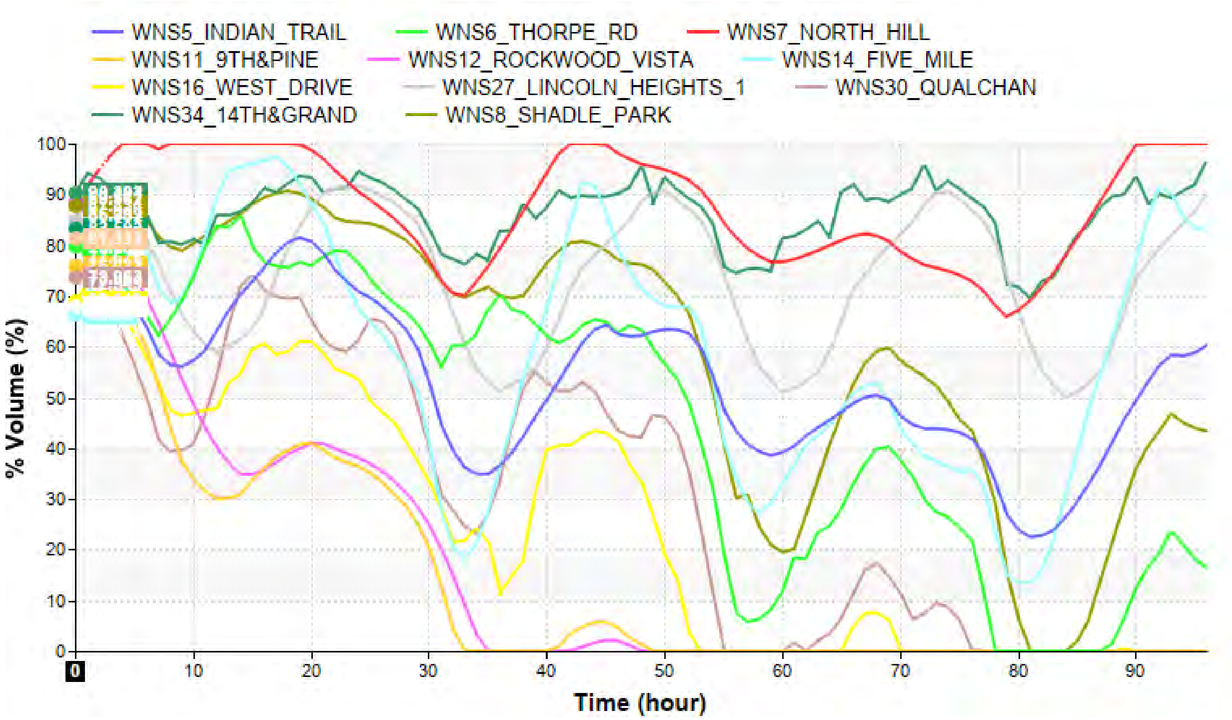


Figure B-26 | Parkwater and Well Electric Wells Offline Tank Graph: Intermediate Primary Zone Tanks

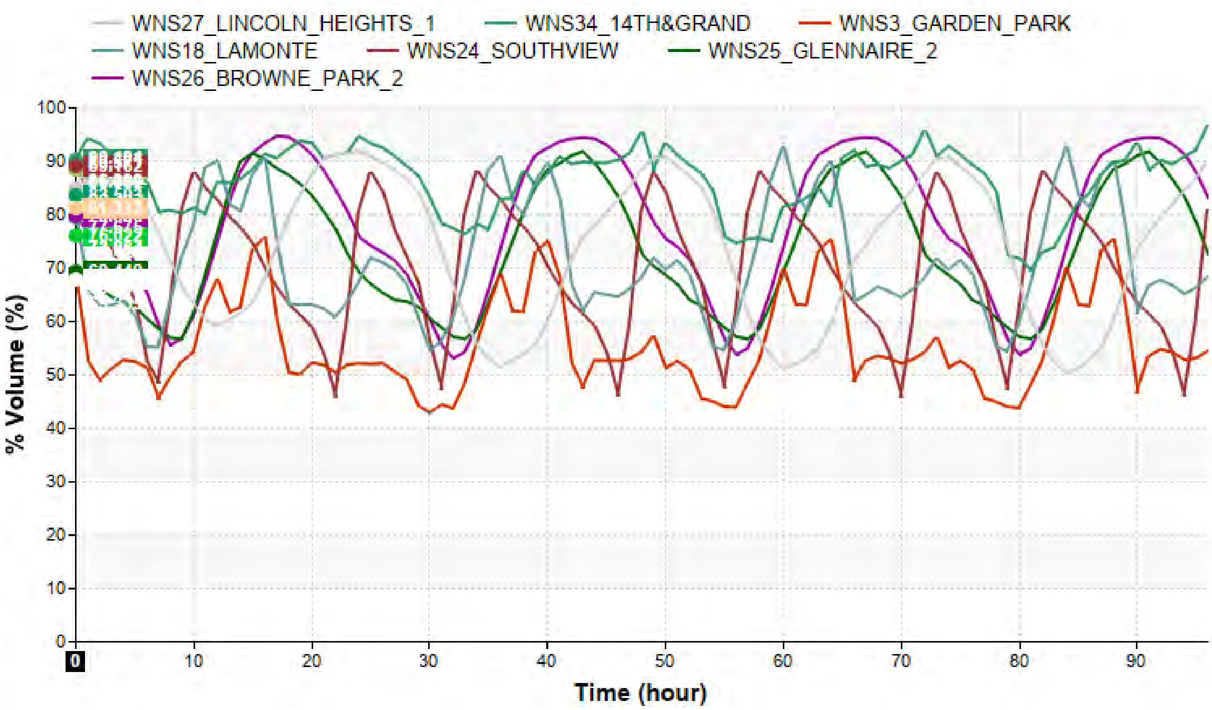


Figure B-27 | Parkwater and Well Electric Wells Offline Tank Graph: Low Primary Zone Tanks

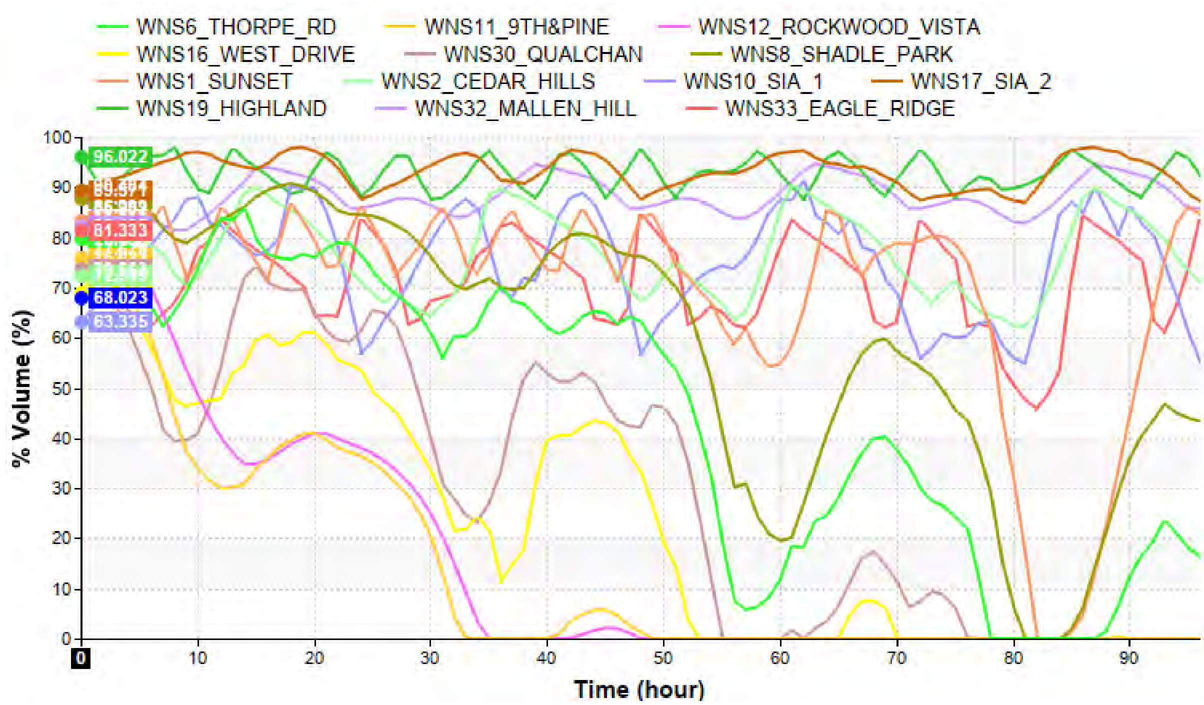


Figure B-28 | Parkwater and Well Electric Wells Offline Tank Graph: North Hill Primary Zone Tanks

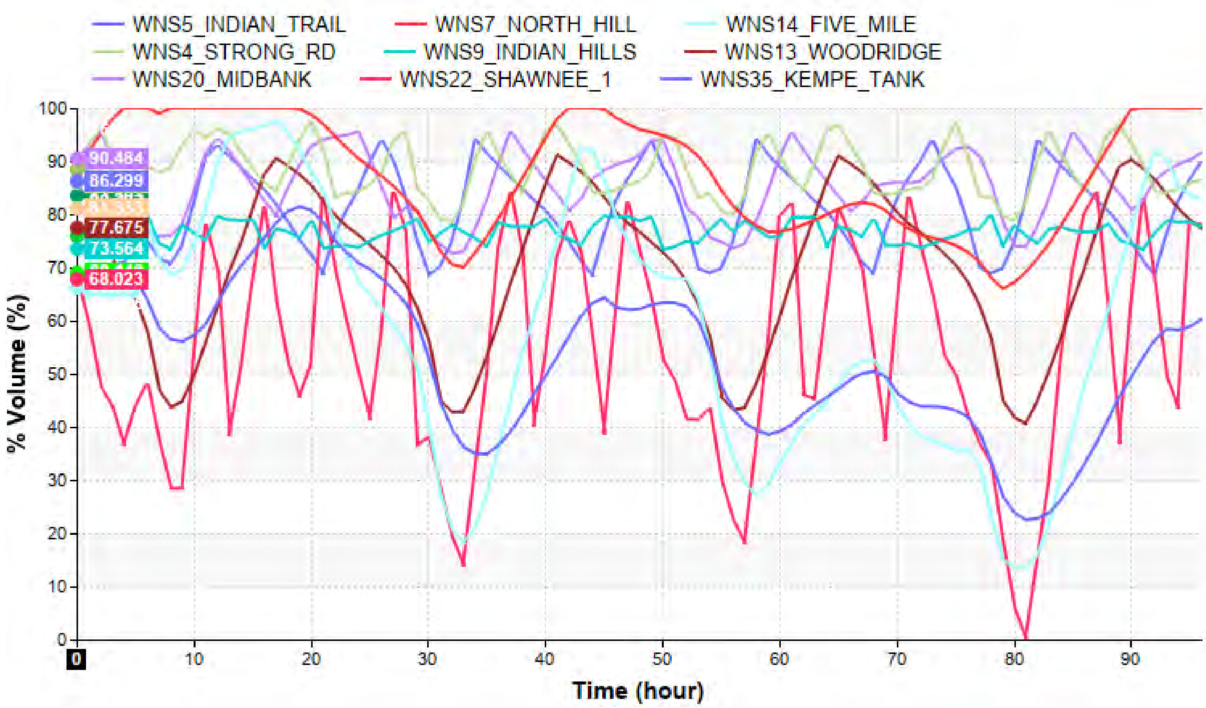


Figure B-29 | Parkwater and Well Electric Wells Offline Tank Graph: Low Primary Supply Zone HGL

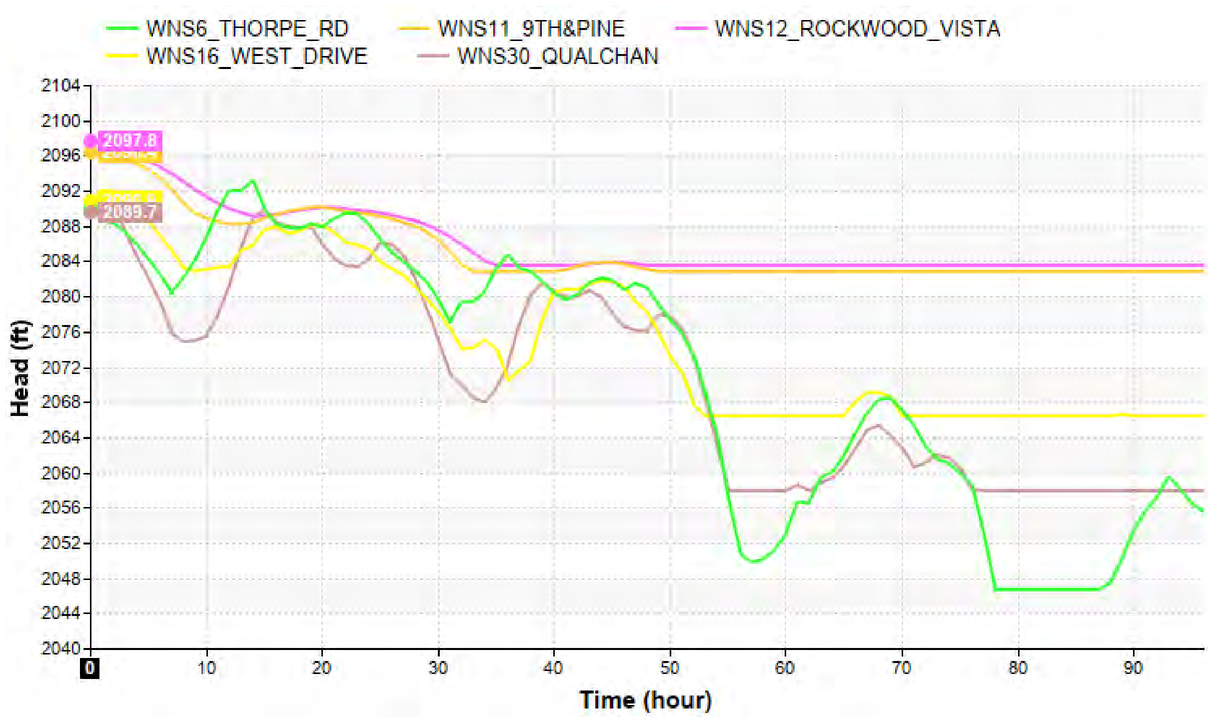


Figure B-30 | Parkwater and Well Electric Wells Offline Tank Graph: North Hill Primary Supply Zone HGL

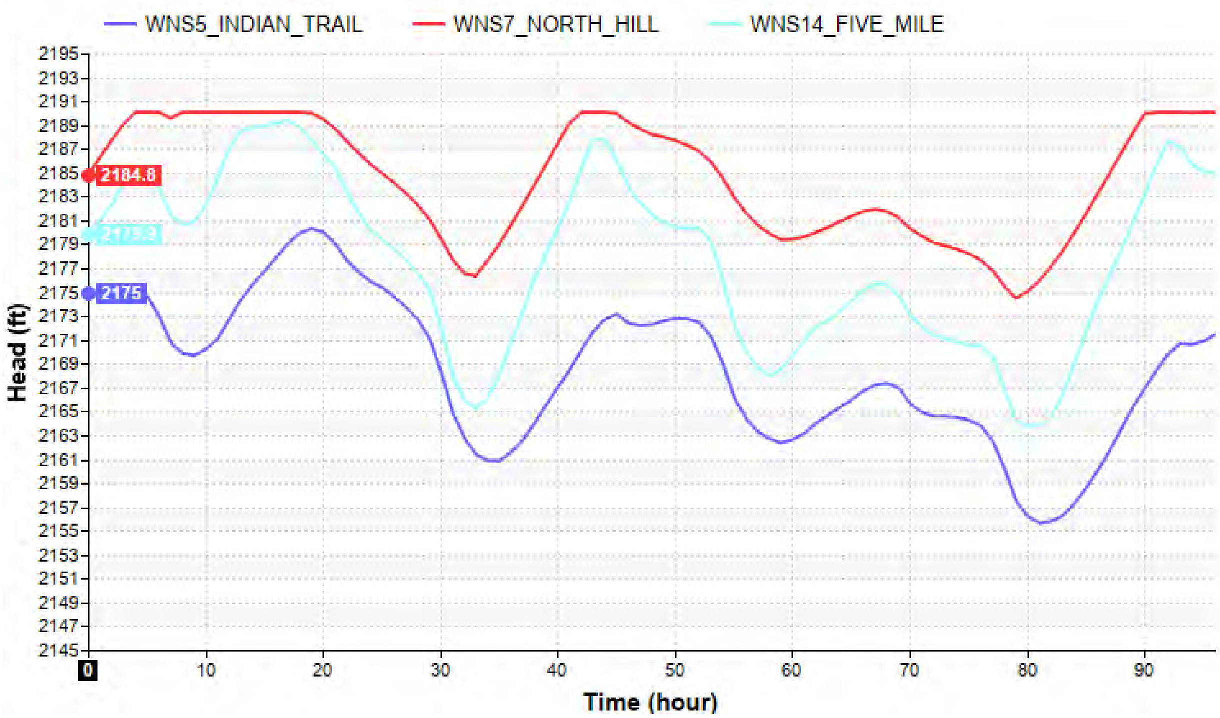
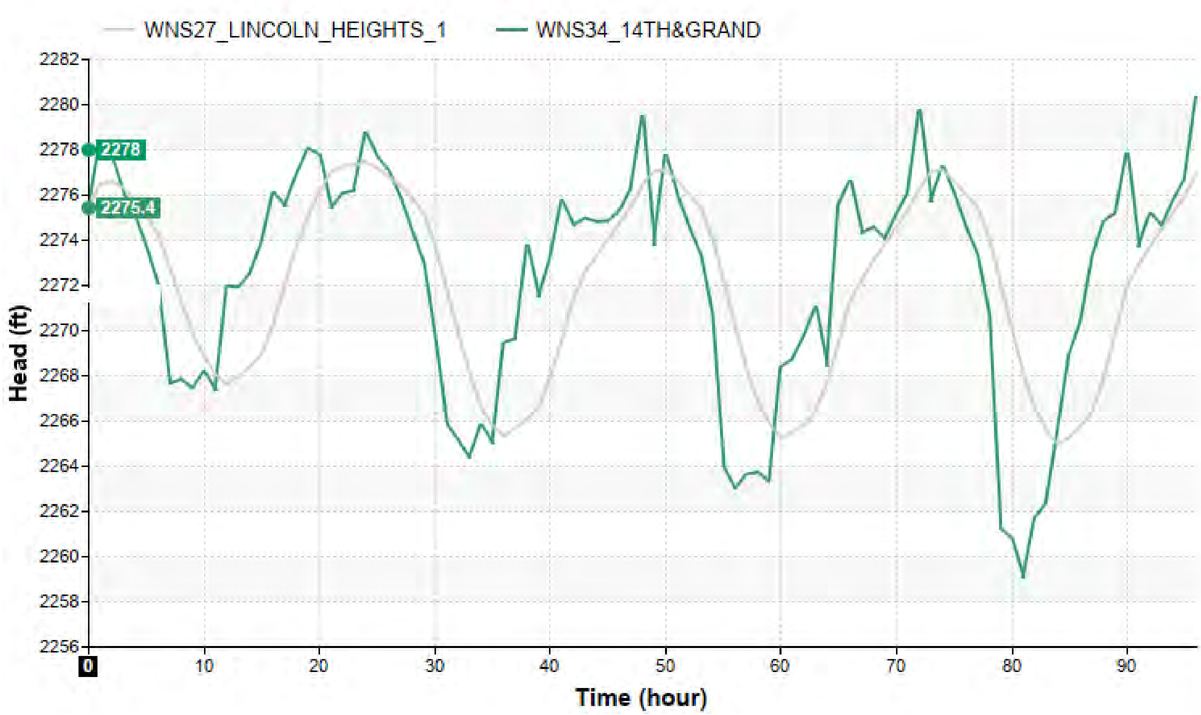


Figure B-31 | Parkwater and Well Electric Wells Offline Tank Graph: Intermediate Primary Supply Zone HGL



B.6 Backflow from Intermediate to Low Zone

Figure B-32 | Backflow Intermediate to Low Zone Tank Graph: Primary Supply Zone Tanks

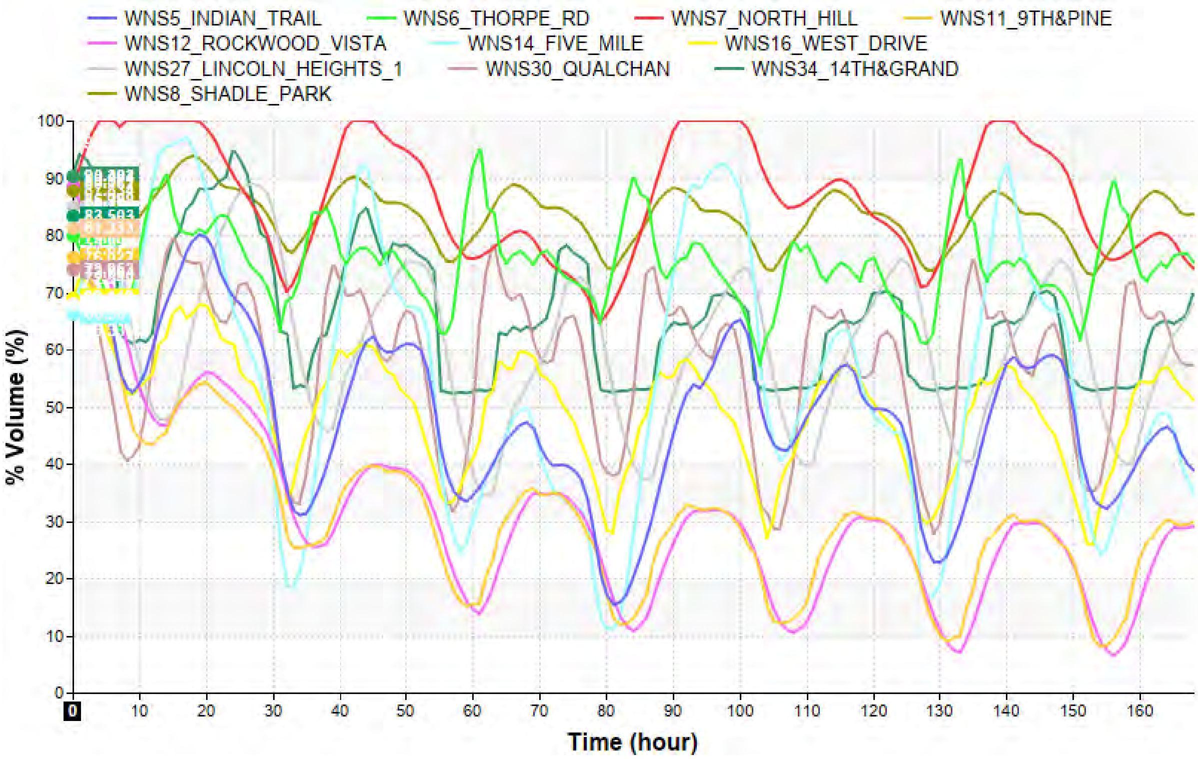


Figure B-33 | Low Intermediate to Low Zone Tank Graph: Intermediate Primary Zone Tanks

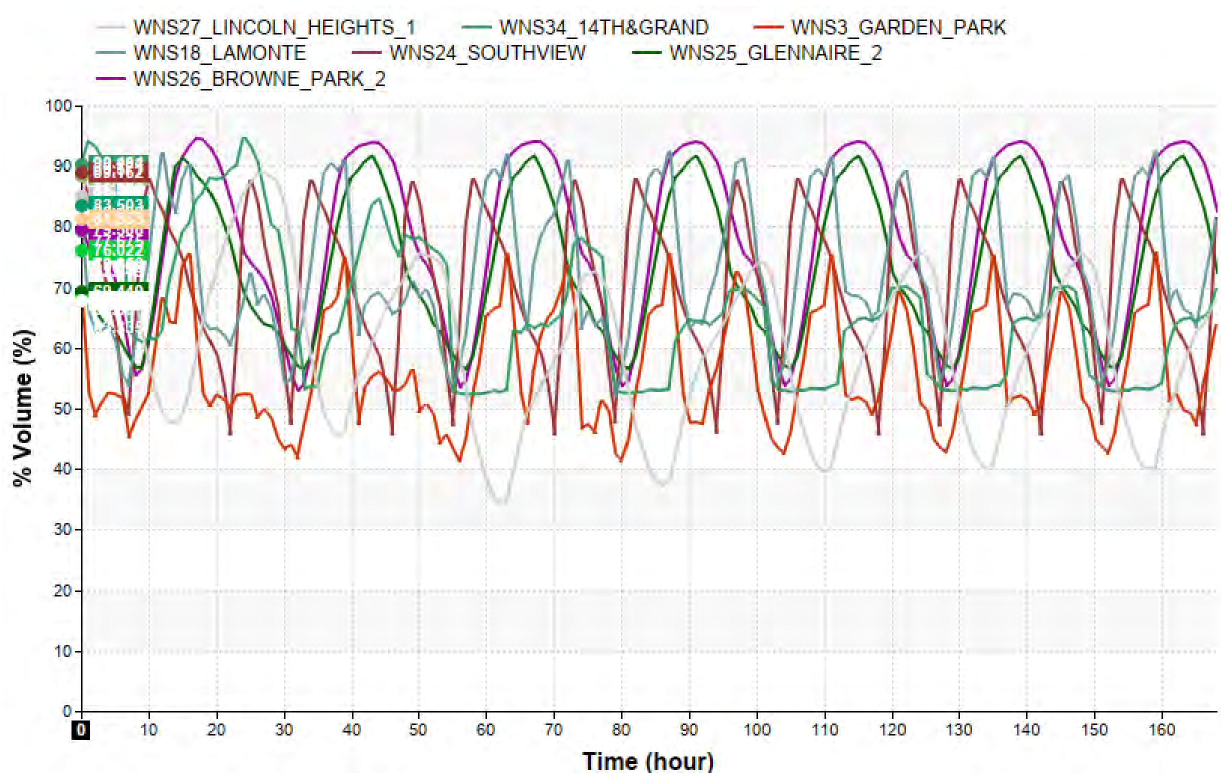


Figure B-34 | Low Intermediate to Low Zone Tank Graph: Low Primary Zone Tanks

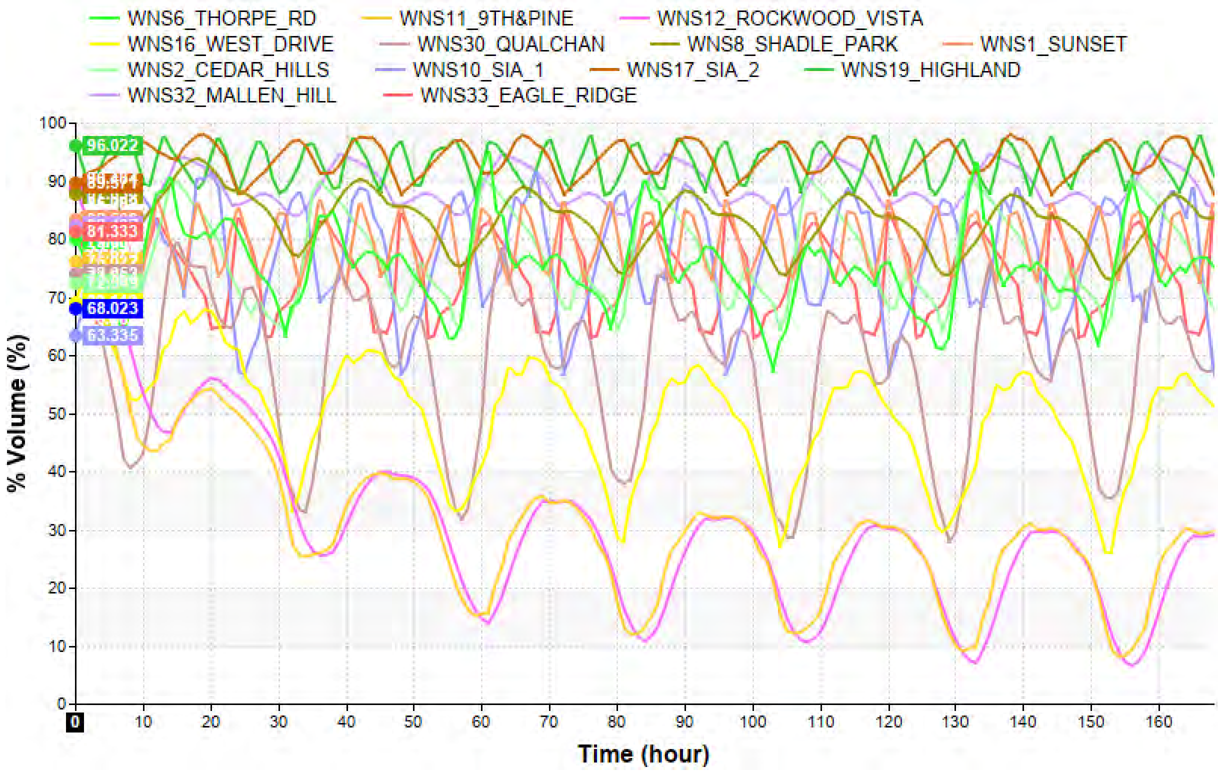


Figure B-35 | Low Intermediate to Low Zone Tank Graph: North Hill Primary Zone Tanks

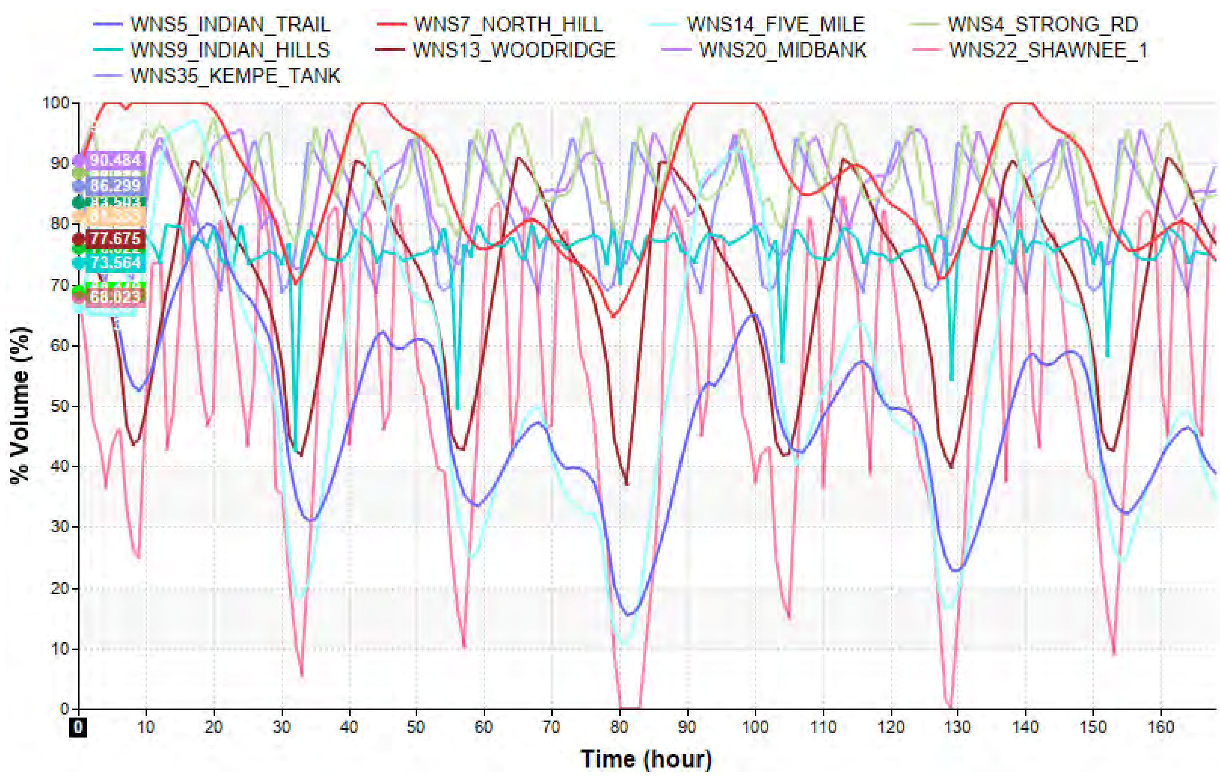


Figure B-36 | Low Intermediate to Low Zone Tank Graph: Intermediate Primary Supply Zone HGL

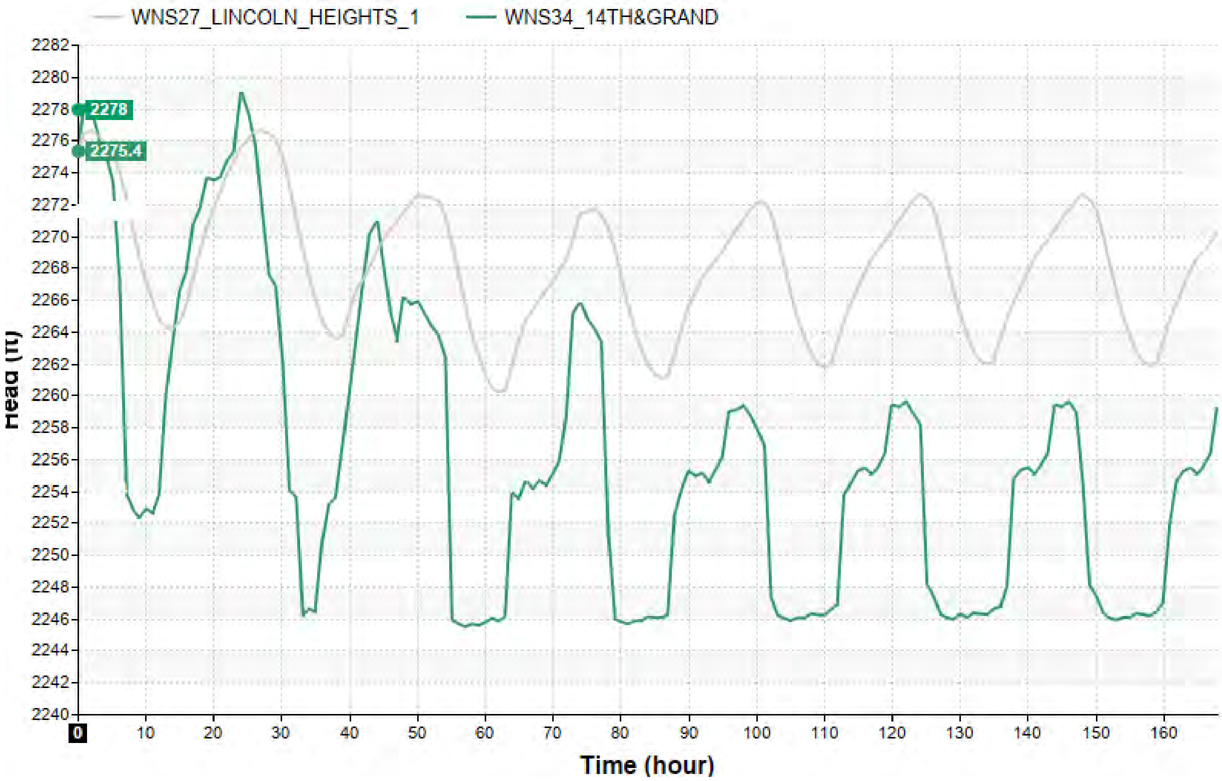


Figure B-37 | Low Intermediate to Low Zone Tank Graph: Low Primary Supply Zone HGL

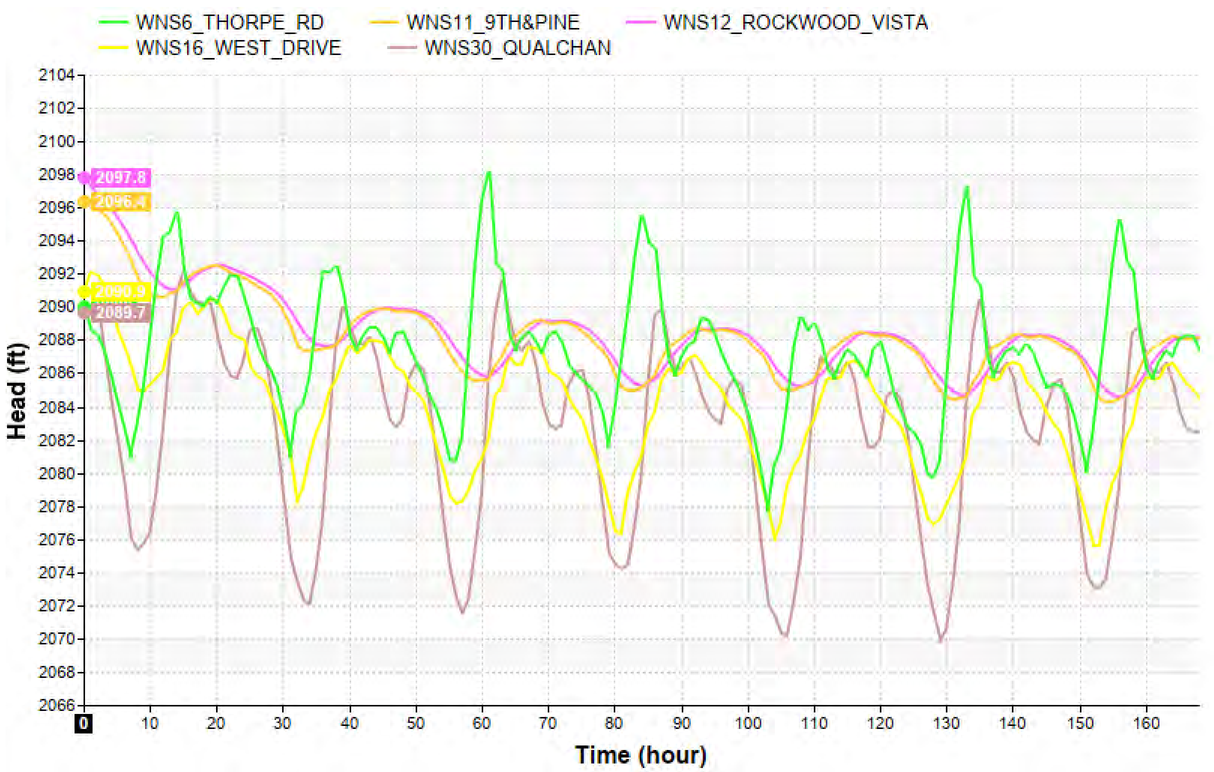
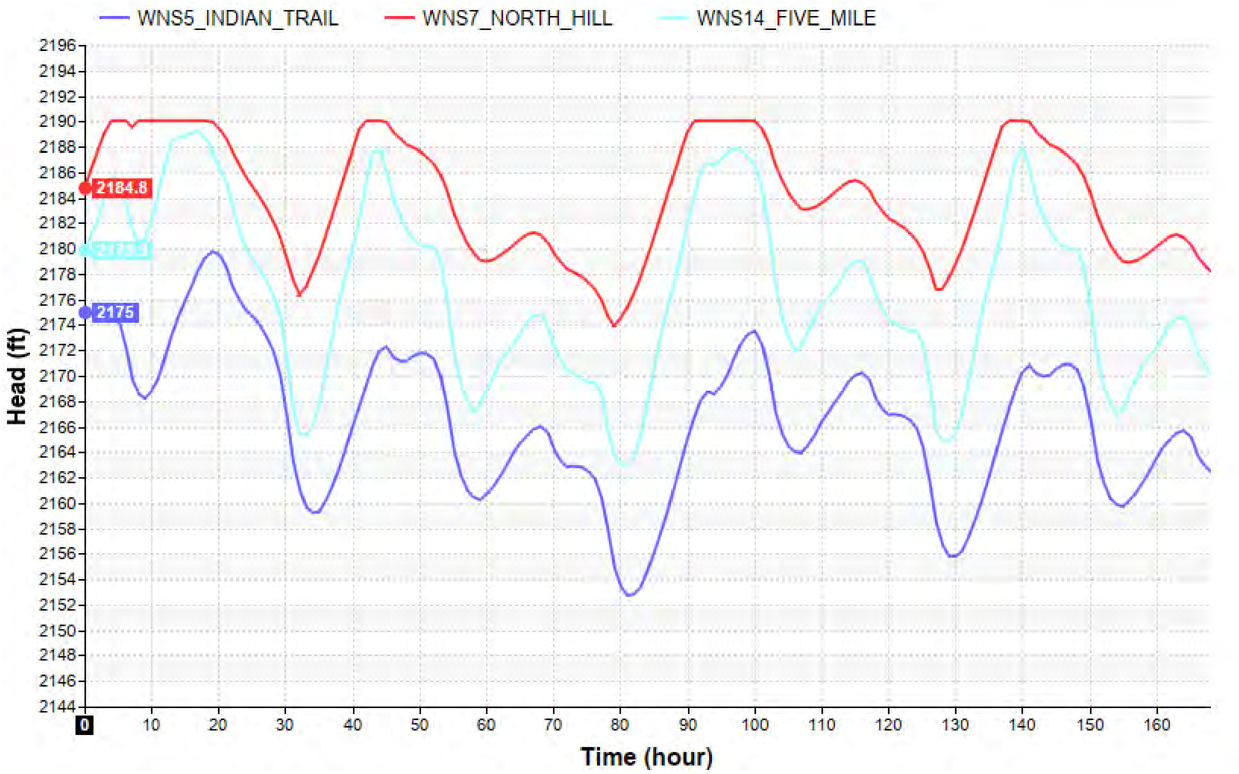


Figure B-38 | Intermediate to Low Zone Tank Graph: North Hill Primary Supply Zone



B.7 Demand Curtailment

Figure B-39 | Demand Curtailment Tank Graph: Primary Supply Zone Tanks

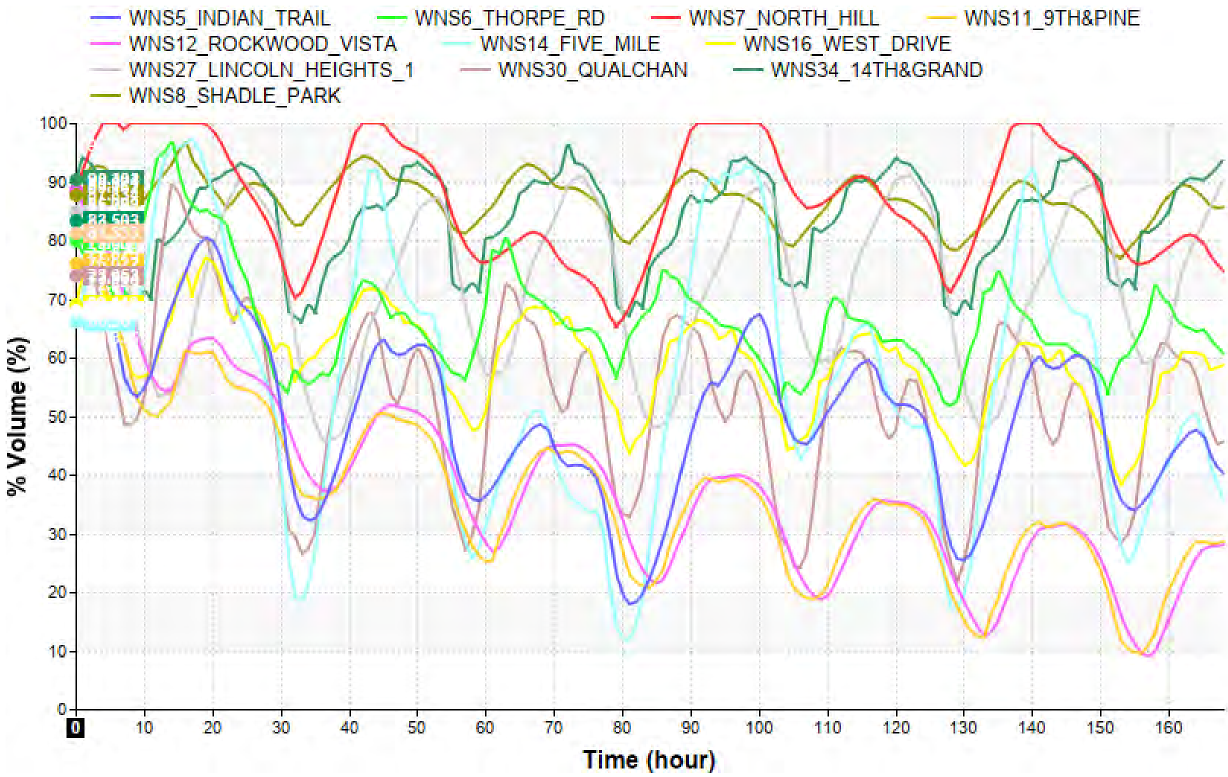


Figure B-40 | Demand Curtailment Tank Graph: Intermediate Primary Zone Tanks

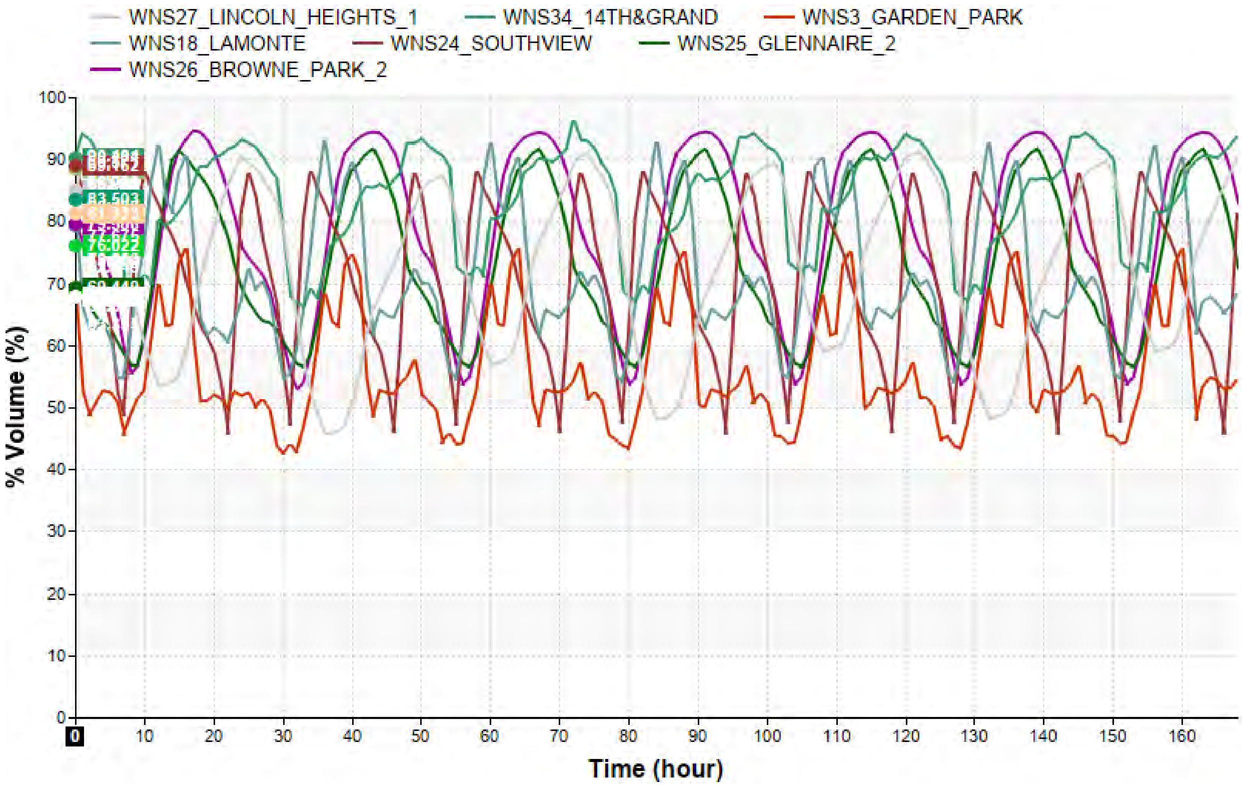


Figure B-41 | Demand Curtailment Tank Graph: Low Primary Zone Tanks

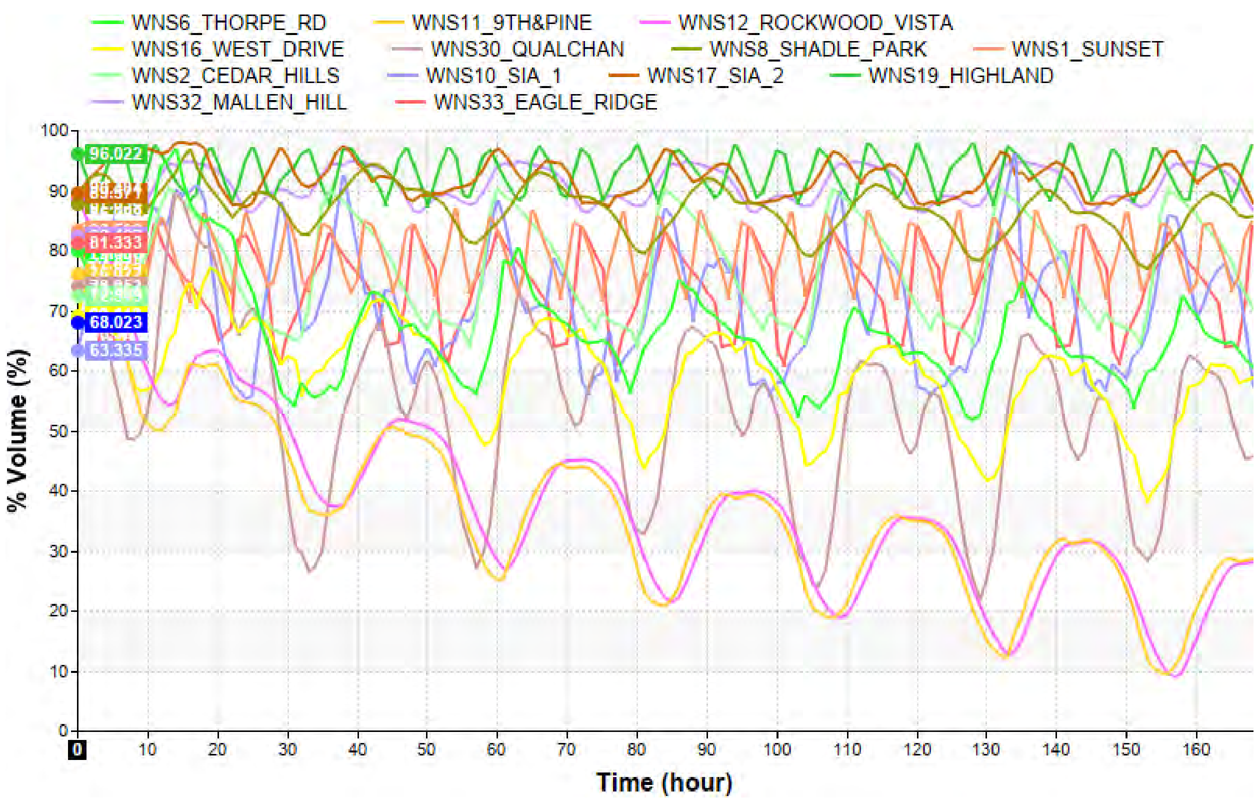


Figure B-42 | Demand Curtailment Tank Graph: North Hill Primary Zone Tanks

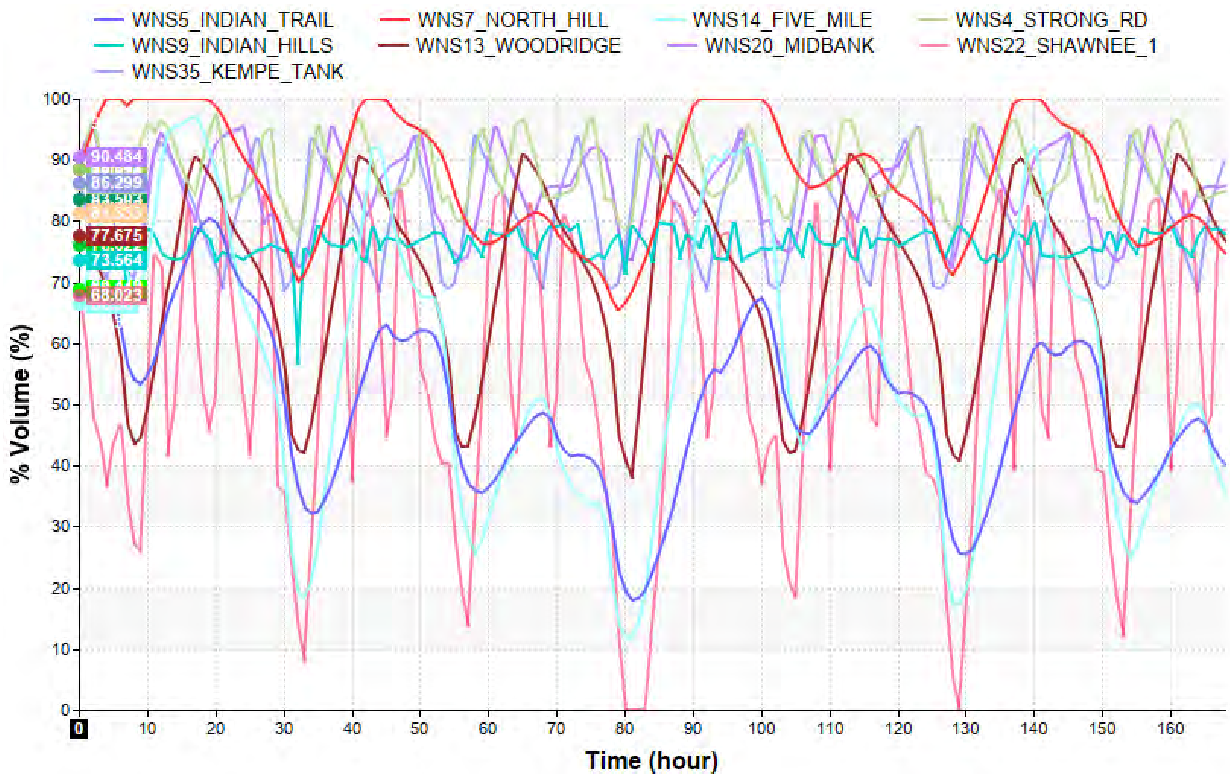


Figure B-43 | Demand Curtailment Tank Graph: Intermediate Primary Supply Zone HGL

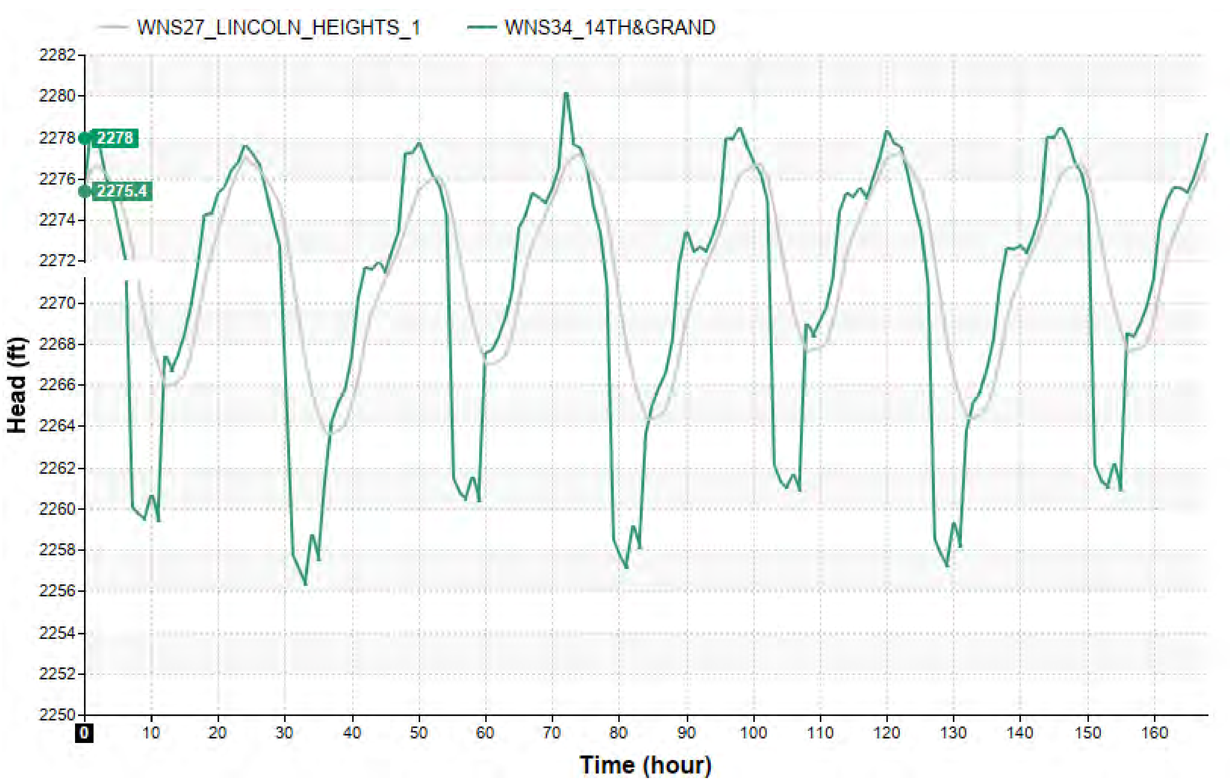


Figure B-44 | Demand Curtailment Tank Graph: Low Primary Supply Zone HGL

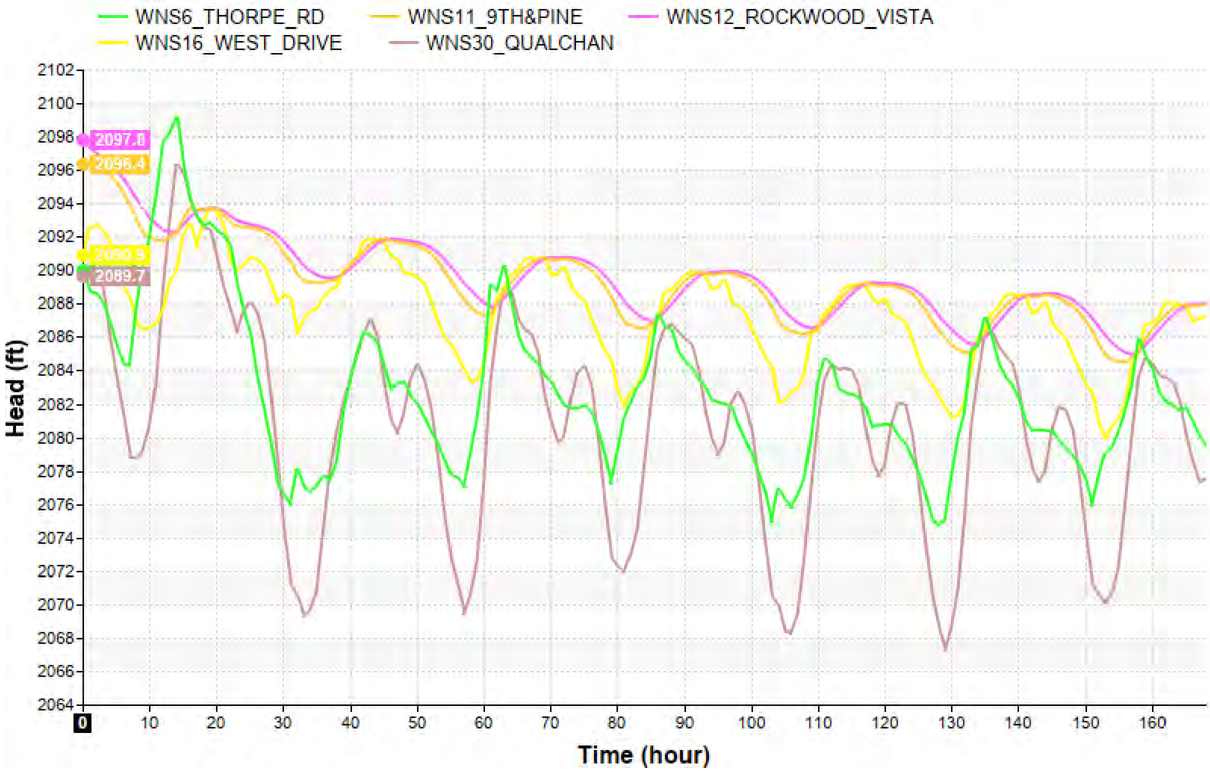
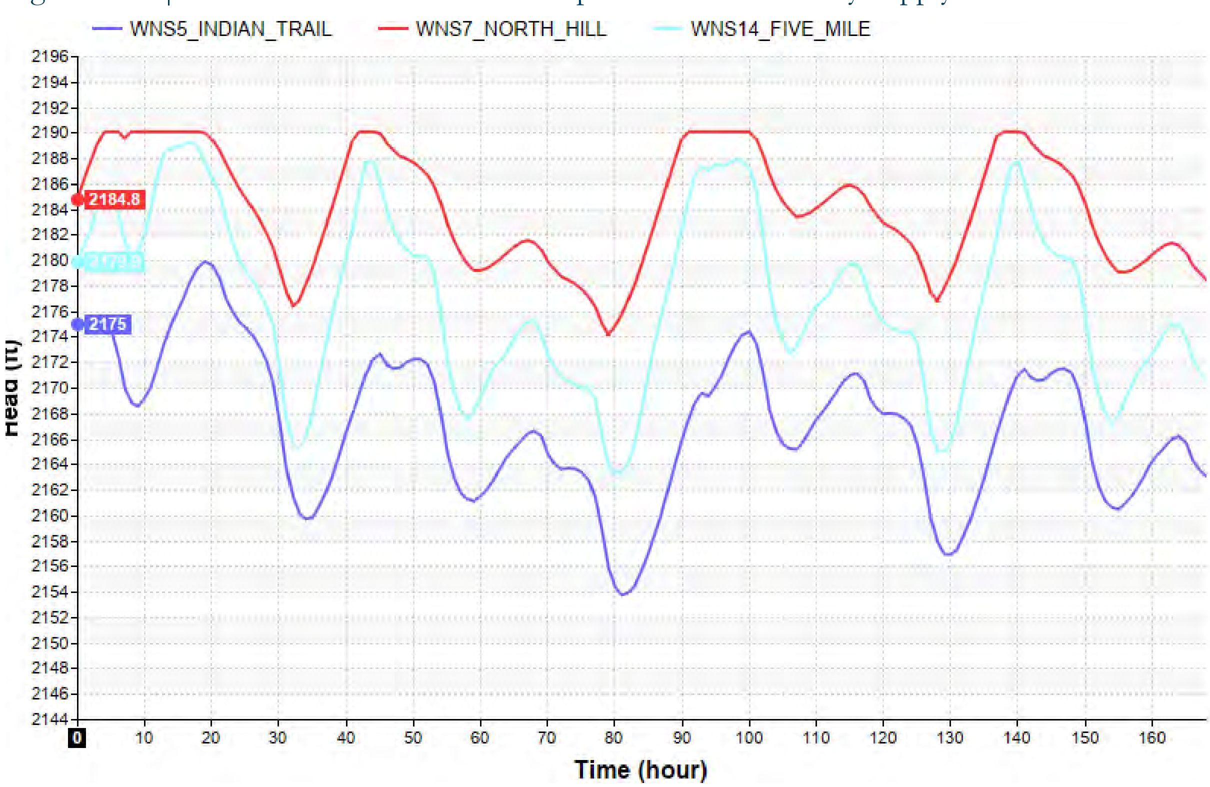


Figure B-45 | Demand Curtailment Tank Graph: North Hill Primary Supply Zone HGL



APPENDIX F

Distribution System Contamination Response Procedure (DSCRP)

Appendix F

Distribution System Contamination Response Procedure (DSCRP)

City of Spokane

December 2024

Consor

421 W Riverside Ave Suite 762
Spokane, WA 99201

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Version Number	Date	Approved by	Changes

*Document and version control is critical

** Attention should be given to ensure proper measures are taken to avoid disclosing sensitive information

SECTION 1

Introduction

The Distribution System Contamination Response Procedure (DSCRP) for the City of Spokane, Washington (City) is presented in this document. A DSCRP provides instructions and procedures unique to responding to a contamination event. This DSCRP has been developed specifically for the City of Spokane staff to respond to a potential leak from the Yellowstone Petroleum Pipeline and subsequent contamination event impacting the Spokane Valley-Rathdrum Prairie Aquifer (“Aquifer”).

The document framework is based on the United States Environmental Protection Agency's (EPA) Distribution System Contamination Resource Procedure guidance. The information within this DSCRP was developed collaboratively between the City and the Yellowstone Pipe Line Co. The following resources were used to provide background, information, and context for the DSCRP:

- EPA Distribution System Contamination Resource Procedure. (Update June 2024); Website: https://www.epa.gov/waterresilience/water-contamination-response-resources.
- City of Spokane Water Emergency Response Plan – Water (ERP) (ERP September 2020).
- City of Spokane Water System Plan (WSP) (2023).
- City of Spokane Water Emergency Communication Plan (October 2013).
- City of Spokane Water Department Standard Operating Procedures (March 1990).
- City of Spokane Wellhead Protection Plan Phase 1 Technical Report (Appendix of City ERP, February 1998).
- City of Spokane Wellhead Protection Plan Phase 2 Implementation Report (September 2020).
- City of Spokane and Yellowstone Pipe Line Co.’s Yellowstone Petroleum Pipeline Franchise Ordinance C35924 (Renewal-2022).
- Phillips 66’s Integrated Contingency Plan (ICP) for the Eastern Response Area (May 2022).
    - Appendix 8b: Emergency Response Action Plan (ERAP) - Field Document (May 2022).
    - Note: The Yellowstone Pipe Line Co. has an updated (2024) ICP. With the exception of qualified contacts, this version of DSCRP reflects the 2022 ICP.
- Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline (2024) (“Vulnerability Assessment, 2024”)

1.1 Purpose

The DSCRP is intended to be a reference document to supplement the City’s Emergency Response Plan (ERP) (ERP September 2020) and help City staff prepare for and respond to a contamination event impacting the Aquifer.

This report is divided into **nine sections** describing the City's and Yellowstone Pipe Line Co. plans, procedures, system, and resources to prepare for and respond to a failure and subsequent leak from the Yellowstone Petroleum Pipeline. The nine sections are presented as follows:

- **Section 1**, this section presents the authority, priorities, and communication specific to a potential leak along the Yellowstone Petroleum Pipeline. It also includes a high-level summary of the City's and Yellowstone Pipe Line Co. infrastructure within the Aquifer.
- **Section 2** details the roles, responsibilities, and the current Aquifer and pipeline monitoring programs.
- **Section 3** highlights the sampling plans, locations, and laboratory capabilities available to respond to an event.
- **Section 4** provides an overview of the response to an event.
- **Section 5** details the initial investigation and response phase.
- **Section 6** details the changes in the operation of the City's distribution in response to the event.
- **Section 7** details risk communication and public notifications.
- **Section 8** describes the remediation and recovery efforts subsequent to an event.
- **Section 9** provides mitigation actions the City and Yellowstone Pipe Line Co. may consider incorporating into their plans and procedures to reduce risk to the system and protect public safety.

Within each section, the intended approaches or planning actions are clearly differentiated between the City and Yellowstone Pipe Line Co.

This is a City specific document. Yellowstone Pipe Line Co. incorporated documents provided procedures such that the City will be aware of Yellowstone Pipe Line Co. responsibilities as defined within their ICP.

1.2 Scope

The scope of this DSCRP is specific to projected impacts and the City's emergency response operations triggered by a failure and subsequent leak from the Yellowstone Petroleum Pipeline.

The DSCRP is intended to be a living document and should be updated as new information is identified, polices and response procedures are updated, and infrastructure improvements are completed. The City may elect to scale the DSCRP to be more inclusive and encompass other potential contamination events.

This document is intended to receive regular updates concurrent with regular planned updates to the City's ERP.

1.3 Authority

The DSCRP was reviewed by City and Yellowstone Pipe Line Co. staff. Review comments provided were incorporated. Additional reviews will be needed by stakeholders as revisions to the document occur.

1.3.1 City of Spokane

The City Water & Hydroelectric Services Department ("Water Department") provides all potable water to citizens within the City limits and some outside the City. State law requires that the City operates the system under the Washington State Public Water System Identification No. 83100K. The City of Spokane operates under the laws of the State of Washington as a first-class municipal corporation.

The Federal Safe Drinking Water Act ("SDWA") directs the Water Department's water quality monitoring program. The water quality monitoring program is based on compliance with the Washington Administrative Code 246-290300, Public Water System Rules and Regulations, as established by the State Board of Health and the EPA. Enforcement of the program is the responsibility of the Washington State Department of Health (DOH), specifically DOH's Eastern Regional office located in Spokane. The Safe Drinking Water Act, as it is implemented and enforced through the EPA, at times drives City monitoring directly because programs such as the Unregulated Contaminant Monitoring Rule require preemptive monitoring of potential emerging contaminant threats.

1.3.2 Yellowstone Pipe Line Co.

The City of Spokane and the Yellowstone Pipe Line Co. entered into a Petroleum Franchise Ordinance C35924 (Renewal-2022) granting the Yellowstone Pipe Line Co. the nonexclusive right, privilege, authority and franchise to construct, operate, maintain, remove, replace and repair existing pipeline facilities, together with equipment and appurtenances.

The Yellowstone Pipe Line Co.'s ICP (May 2022) is intended to satisfy the requirements of regulatory agencies mandating written procedures to address planning and response to emergencies. Regulatory compliance details can be found in the ICP Section I-4.

1.4 Priorities

1.4.1 City of Spokane

The City's main priority is safeguarding its potable water system, ensuring ample fire protection capabilities, and effectively communicating with the citizens and all customers of the Water Department during emergencies.

1.4.2 Yellowstone Pipe Line Co.

According to the ICP (May 2022), the primary purpose is to ensure an effective, comprehensive response and prevent injury or damage to company employees, the public, and the environment. The specific objectives of the ICP are listed in Section I-1 (May 2022).

1.5 Systems and Utility Background

1.5.1 City of Spokane

The City's drinking water comes solely from the Spokane Valley-Rathdrum Prairie Aquifer. Eight well stations draw water directly from the Aquifer. If a leak from the Yellowstone Petroleum Pipeline were to occur, the well stations that would most likely be impacted are:

- Well Electric
- Parkwater

- Havana St.
- Ray St.

Section 6 of this report provides more detailed impacts to specific wells and the distribution system.

Aquifer impacts triggered by a failure depend on the various factors, including, but not limited to, the location of the failure, the volume and type of product released, Yellowstone Pipe Line Co.'s leak identification, and operational response.

1.5.2 Yellowstone Pipe Line Co.

In accordance with Section 5.1b of the Yellowstone Pipe Line Co.'s Franchise Ordinance C35924 (Renewal-2022), the Yellowstone Pipe Line Co. stipulates that the Aquifer is a "High Consequence Area" and an "unusually sensitive area" as defined in applicable regulations of jurisdictional agencies.

The Yellowstone Petroleum Pipeline is constructed of 10-inch diameter electric resistance welded pipe from pre-1970, and is jointly owned by Phillips 66, Par Pacific, and Energy Transfer Partners. The Yellowstone Pipe Line Co. operates the Yellowstone Petroleum Pipeline extending 644 miles from Billings, MT, to Moses Lake, WA. The ICP (May 2022) covers the Yellowstone Petroleum Pipeline from the Idaho/Montana border to Moses Lake, WA.

Additionally, the system includes storage terminals that receive products into above-ground storage tanks where the fuel is then transferred to tanker trucks. A complete listing of the Yellowstone Petroleum Pipeline infrastructure, including detailed facility information, diagrams, and maps can be found in the ICP Appendix 1b: Facility & Locality Information (May 2022).

Also provided in the Yellowstone Pipe Line Co ICP, Appendix 1b: Facility & Locality Information (May 2022) was a list of the following petroleum products shipped on the Yellowstone Petroleum Pipeline.

- Gasoline
- Commercial Jet Fuel (JFA) #1 Fuel Oil
- No. 1 Fuel Oil (VA3)

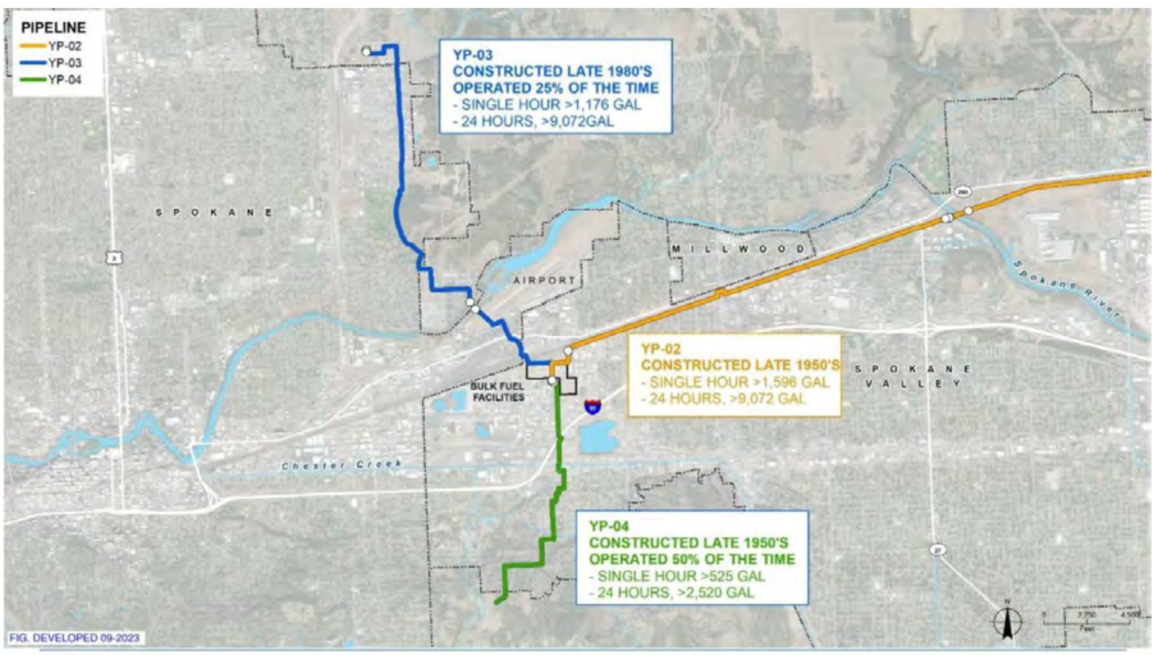
As part of developing the Vulnerability Assessment (2024), the current chemical constituents were evaluated and detailed the Section 1.2 of that report as gasoline (approximately 40 percent of product), #2 diesel fuel (approximately 40 percent of product), and jet fuel (approximately 20 percent of product). Oxygenates and other petroleum additives have not been added to these fuel blends.

The DSCRP is focused only on the pipeline segments within the Aquifer boundary that may impact the City's drinking water wells. Phillips 66 owned and operated terminals, tanks, and other assets were not addressed.

Table 1-1 | Yellowstone Petroleum Pipeline Segments Within the Spokane Valley-Rathdrum Prairie Aquifer

Segment Name and Section	Length between MOV*
Yellowstone West (YP-02)	
Pines Rd. to Spokane Terminal	5.0 miles
Parkwater to N. Spokane Terminal (PKWTR) (YP-03)	
Spokane Terminal to Spokane River S. Side	1.3 miles
Spokane River S. Side to Spokane River N. Side	1.0 miles
Spokane River N. Side to Y 10-4A N. Spokane	3.5 miles
Yellowstone West (YP-04)	
Spokane Terminal to Geiger Junction (Hangman Cr.)	15.5 miles
*MOV = Motorized Operating Valve	

Figure 1-1 | Yellowstone Petroleum Pipeline Segments and Flow Volume



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1.6 Communications and Information Management

1.6.1 City of Spokane

For water system specific emergencies, the City's ERP (Sept 2020) includes a Water Department emergency notification flow chart, see **Figure 7-2**. The flow chart lists the personnel to be notified in the event of a major emergency.

In addition to the emergency notification flow chart, the Water Department office and Upriver Control Center has at least one person available 24 hours per day. Phone numbers and radio dispatch frequencies are included in the City's ERP, Resilience Strategies (Sept. 2020).

The Water Department has developed a Water Emergency Communications Plan (October 2013) to communicate effectively with all Water Department customers during emergencies that impact the quality of their drinking water. The Plan is included as **Appendix 6.5.1** of the City's ERP (September 2020). The plan includes the following documents:

- Communications Checklist
- Communication Action Plan
- Sample News Release and Messaging
- Fast Facts about the Water Department/Water System
- Emergency Contact Information

It is noted that most of the documents within the Water Emergency Communications Plan (Oct 2013) focus on positive coliform incidents.

The City may consider appending, and continually refining the Water Emergency Communications Plan (October 2013) to include communications and public notifications as detailed in **Section 7**. Additional suggested updates have been included in **Section 9** of this document.

1.6.2 Yellowstone Pipe Line Co.

The Yellowstone Pipe Line Co. will initiate the first external notification that a potential leak has occurred. In accordance with their ICP Section II-5.21 Groundwater Spill Response Strategy Guide (May 2022), see **Figure 5.3**. The Yellowstone Pipe Line Co. will notify federal, state, and local agencies once the initial assessment has been completed and potential groundwater impacts have been confirmed.

The Yellowstone Pipe Line Co. external notification will vary depending on the type of incident, type and quantity of material released, and the direct consequences. Currently, the Yellowstone Pipe Line Co. uses a notification call down list that is found in the ICP Appendix 2b (May 2022). Additional details are discussed in **Section 5** and **Section 7** of this document.

Suggested updates to Yellowstone Pipe Line Co.'s external notification procedures have been included in **Section 9** of this document. It is intended to provide early notification to the Water Departments emergency contacts when the initial pipeline leak assessment teams are dispatched to high priority areas of the Aquifer.

1.7 Health and Safety

1.7.1 City of Spokane

A comprehensive Safety Program is implemented and maintained by the City of Spokane Risk Management Department (Risk Management) for all city employees. Risk Management maintains and updates the City of Spokane Safety Policy Manual and is its own separate document is included in the ERP appendices.

As part of the City's ERP (September 2020), the Water Department Safety Rules and Regulations are included as part of the Standard Operation Procedures (SOP) Manual to comply with WAC 296-155 Safety Standards for Construction, WAC 296-24 General Safety and Health Standards, the City of Spokane Safety Policy Manual and WAC 296-62 Occupational Safety and Health Standards. The Water Department Standard Operating Procedures Manual is included in the ERP appendices.

1.7.2 Yellowstone Pipe Line Co.

Phillips 66 Core Plan Sec. II-16 Site Safety and Health Plan describes the health and safety guidelines developed for the response operations to protect personnel, visitors, and the public from harm and exposure to hazardous materials or wastes. The plan covers all personnel, including Phillips 66 employees, contractors, subcontractors, government employees, and visitors.

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SECTION 2

Roles and Responsibilities

2.1.1 City of Spokane

The paramount goal of the City's Water Department and Integrated Capital Management Department is "to provide affordable high quality water with high quality water with excellent customer service and ample fire protection." The Water Department Director has general oversight of the Water Department.

According to the City's Wellhead Protection Program – Technical Assessment, Section 5.3: Emergency Event, "in all cases of emergencies, (including the rupture of a surface or subsurface petroleum pipeline) the Water/Hydroelectric Services Department Director fully participates with the primary emergency response teams for the City of Spokane and Spokane County incidents."

At the time this document was developed, there was not a Water Department specific Incident Command System Decision Tree. Identified in **Section 9** of this document, a response decision tree, similar to Figure 5-1 in the City's Wellhead Protection Program detailing the City's approach to groundwater monitoring well contamination event, should be considered as part of future updates to City's ERP.

2.1.2 Yellowstone Pipe Line Co.

As part of the Yellowstone Petroleum Pipeline Franchise Ordinance C35924 (Renewal-2022), Section 9 – Leaks, Spills, Ruptures, and Emergency Response, the Yellowstone Pipe Line Co. is primarily responsible for monitoring, assessing, responding to and clean-up operations as a result of a release, spills, or ruptures from the Yellowstone Petroleum Pipeline.

The Yellowstone Pipe Line Co.'s initial response roles are identified in the ICP Section II-3 (May 2022). For the initial response the On-Scene Incident Commander/Qualified Individual's responsibility is to first make the appropriate notifications, and then to initiate response operations. The ICP, Section II-3 Response Management System, describes the specific duties and responsibilities of the members of the Yellowstone Pipe Line Co.'s Incident Management Team (IMT).

Figure 2-1 provides Yellowstone Pipe Line Co.'s Qualified Contacts/Individuals for the Yellowstone Petroleum Pipelines Eastern Washington Response Area.

Figure 2-1 | Yellowstone Pipe Line Co. Qualified Contacts

Qualified Individual/Alternate Qualified Individual	
Qualified Individual	Chris Church, Supervisor, Ops – Facl, Yellowstone West 253-227-7293 Cell
Alternate Qualified Individual	Brett DeVries, Lead Operator, Moses Lake 509-760-8486 Cell
Alternate Qualified Individual	Tara Geoeske, Lead Operator, Spokane 509-998-9104 Cell
Alternate Qualified Individual	Josh Lindstrom, Technician, Spokane 509-220-1994 Cell

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SECTION 3

Site Characterization, Sampling, and Analysis

3.1 Site Characteristics and Sampling Plan (SC&SP)

3.1.1 City of Spokane

The City's water quality monitoring program is detailed in the ERP, Incident-Specific Response Procedures (Sept. 2020).

The Water Department's Water Quality Section manages water quality and carries out field tests for the City. The section consists of two people with appropriate water quality expertise plus an in-house laboratory. Other branches of the water department assist on an as-needed basis. The City has raw water sample points at all well stations. During non-emergency situations, the samples are collected quarterly from the wells for required analytical work, such as volatile organic compounds. Currently, the City collects 180 representative samples per month from the distribution system.

3.1.2 Yellowstone Pipe Line Co.

At the time this document was developed, there was not an active Yellowstone Pipe Line Co. groundwater sampling or monitoring program for the Aquifer.

As part of the Yellowstone Pipe Line Co.'s ICP section II-5.21, Spills to Groundwater (May 2022), if the potential exists for a spill to reach groundwater, additional assessment activities should be conducted using specified equipment, including:

- Backhoes or Excavators – Excavate pits/trenches to determine penetration depth/groundwater impacts (limited to depths of 10-20 feet)
- Hand or Power Augers – Install borings to collect soil/water samples and can be used to install temporary wells (often limited to 15-30 feet)
- Direct Push Drilling Rigs – Install boring to collect soil/water samples and can be used to install temporary wells (often limited to 50-100 feet)
- Hollow stem Auger (HAS) or Rotary Drill Rigs – Install borings to collect soil/water samples and wells for groundwater samples (limited to 100-500 feet)

The type of method used often depends on equipment availability, depth to groundwater, and access to the spill area. If groundwater impacts are confirmed or expected, additional borings or wells should be installed by stepping out laterally from the spill area and boring primarily in the downgradient direction until the groundwater impacts area is delineated.

3.2 Filed Activities Report Forms

3.2.1 City of Spokane

At the time this document was developed, report forms to document a groundwater contamination event triggered by a leak from the Yellowstone Petroleum Pipeline have not been developed. In lieu of a Yellowstone Petroleum Pipeline specific incident report, **Figure 3-1** provides an EPA Rapid Test Form.

Figure 3-1 | EPA Rapid Test Form

Rapid Field Testing Report Form

General Information	
Site Name or ID:	Date:
Site Address:	Sample Collection Time:
Team Members:	Report Form ID:
Designated Contact (Name, Title, and Phone Number):	

Meter/Kit IDs

Field Quality Control (QC) Samples

Parameter	Blank or Background Result	QC Lot Number	QC True Value	QC Result	Acceptance Range

****STOP and REPORT****

If a field QC result is outside of acceptance range, report the result to the Designated Contact before proceeding.

Sample Results

Parameter	Units	Sample Result	Duplicate Result	Expected Range

****STOP and REPORT****

Verbally report results the Designated Contact.

Deviations from Standard Operating Procedures (SOPs) and Other Notes

Submitted By	
Report Submitted By (PRINT):	
Report Submitted By (Signature):	
Date:	

3.2.2 Yellowstone Pipe Line Co.

The Yellowstone Pipe Line Co. Section IV of their ICP (May 2022) provides Incident Reporting Forms, select Incident Command System Forms, and guidance to access additional documents online.

3.3 Field and Laboratory Capabilities

3.3.1 City of Spokane

The Water Department Water Quality Laboratory is certified by the Washington State Department of Ecology (Ecology) to perform both bacteriological and analytical tests. The City also puts out a Request for Proposals every three (3) years and awards a contract for water quality testing and is able to run samples through other State approved labs.

Ecology maintains a list of EPA-approved laboratories, their testing capabilities, and utilizes their services as necessary. Listed below are local laboratories that have previously provided testing support for the City, as noted in the City's ERP (Sept. 2020).

City of Spokane
Water Quality Laboratory
2701 N Waterworks St.
Spokane WA 99212

Anatek Labs
504 E Sprague Ave Ste D
Spokane WA 99202

Eurofins Lab
11922 E 1st Ave
Spokane Valley WA 9920

3.3.2 Yellowstone Pipe Line Co.

At the time this document was developed, the Yellowstone Pipe Line Co.'s ICP (May 2022) did not provide specific field and laboratory capabilities to support groundwater sampling efforts. However, it does indicate that contractors will be employed to supplement Phillip 66's response and recovery efforts.

3.4 Sampling Locations

3.4.1 City of Spokane

As aforementioned, the City has dedicated raw water sample points and upgradient monitoring wells for each source water well except the Havana Well Station. Each source well includes baylors for sampling.

3.4.2 Yellowstone Pipe Line Co.

At the development of this document the Yellowstone Pipe Line Co.'s ICP (May 2022) did not provide sampling locations.

3.5 Pipeline and Aquifer Monitoring

3.5.1 City of Spokane

At the time this document was developed, the City was not involved in monitoring the condition or detection of leaks in the Yellowstone Petroleum Pipeline.

3.5.2 Yellowstone Pipe Line Co.

Yellowstone Pipe Line Co.'s ICP Section II-6, Detection Procedures (May 2022), describes the procedures and equipment used to detect accidental discharges from the pipeline.

The system is designed to alert operators to alarms and provide automatic shut-in functions in the event of a release. The pipeline is continuously monitored from a Control Center via a Supervisory Control and Data Acquisition (SCADA) system. The SCADA system is linked to Programmable Logic Controllers (PLC) and Remote Terminal Units at selected points in the pipeline system. The PLCs are designed to provide on-site automatic control of pressure, flow rate, valve position, and other operating conditions. The system is configured with preset ranges that trigger alarms when monitored values fall outside preset ranges.

SECTION 4

Response Procedure Overview

This section presents an overview of the current response procedures for the City of Spokane and Yellowstone Pipe Line Co. to a suspected groundwater contamination event.

Further sections in this DSCRP explain in greater detail the investigation, operational response, and potential impacts to the City's distribution system, triggered by a leak from Yellowstone Petroleum Pipeline. Additionally, **Section 9** will present suggested updates to improve response and recovery efforts.

4.1.1 City of Spokane

The City's primary emergency response resource is the Water & Hydroelectric Services Department's ERP – Water (Sep 2020). It describes the Water Department's strategies, resources, plans, and procedures to prepare for and respond to various incidents that may impact the City's water department and facilities. It also includes comprehensive appendices of support resources, including:

- Emergency Contact Information
- Wellhead Protection Program
- Water Emergency Communication Plan
- Water Department Standard Operating Procedures
- Other Emergency Response Reference Materials

Section 5 combines relevant information from the ERP, appendices, and other City resources to investigate and respond to a major incident impacting the Aquifer.

4.1.2 Yellowstone Pipe Line Co.

Yellowstone Pipe Line Co.'s ICP (May 2022) follows the National Response Team's (NRT) Integrated Contingency Plan Guidance. It is intended to consolidate multiple plans Yellowstone Pipe Line Co. is required to maintain.

The ICP includes four sections and appendices.

- Section I (ICP Introduction Elements): Presents the ICP introduction, purpose, regulatory compliance, general facility information, and plan implementation procedures.

- Section II (Core Plan Elements): Contains the major components of the ICP. Such as incident detection, response and notification procedures, emergency equipment, testing and deployment. It also includes site safety, decontamination and follow-up procedures.

- Section III (Training and Exercise Program): Highlights the overall training and response exercise programs.

- Section IV (Forms): Includes Yellowstone Pipe Line Co. and industry example forms and how to access other resources.

- Appendices: Multiple appendices are included. The one of the most relevant is Appendix 8b, the Emergency Response Action Plan – Field Document for Eastern Washington Response Area (May 2022). This appendix is described in **Section 5**.

Most of the following sections in this DSCRP will focus on the ICP Section II (Core Plan Elements) and Appendix 8b.

Table 4-1 presents a correlation between relevant sections of Yellowstone Pipe Line Co.'s ICP document and this DSCRP.

Table 4-1 | Correlation of Key Yellowstone Pipe Line Co. ICP Sections

Yellowstone Pipe Line Co. ICP Key Sections	Correlated DSCRP Sections
Sec II-4: Notification Procedures	Sec 7: Risk Communication/Public Notification
Sec II-5: Response Procedures	Sec 5: Investigation and Response Phase
Sec II-6: Detection Procedures	Sec 5: Investigation and Response Phase
Sec II-7: Mitigation Procedures	Sec 9: Mitigation Approach
Sec II-11: Containment and Recovery	Sec 5: Investigation and Response Phase Sec 8: Remediation and Recovery Phase
Appendix 8a & 8b: ERAP	Sec 5: Investigation and Response Phase

The ICP Section II-5 Response Procedures (May 2022), includes response checklist/procedures to follow based on the type of incident at their facilities and related pipeline system. The level of required response is dependent upon the severity of the release, the size, potential environmental, social and economic impact, and the expected public interest in the event.

Some relevant response procedures included in the ICP Section II-5 (May 2020) are:

- Initial Discovery/Response Action Checklist
- General Initial Response procedures – Pipeline Maintenance Crews
- Unconfirmed Report of a Leak
- First Responder Emergency Response Guide - Pipeline Leak or Rupture

SECTION 5

Investigation and Response Phase

5.1 Investigation and Response Phase Decision Tree

5.1.1 City of Spokane

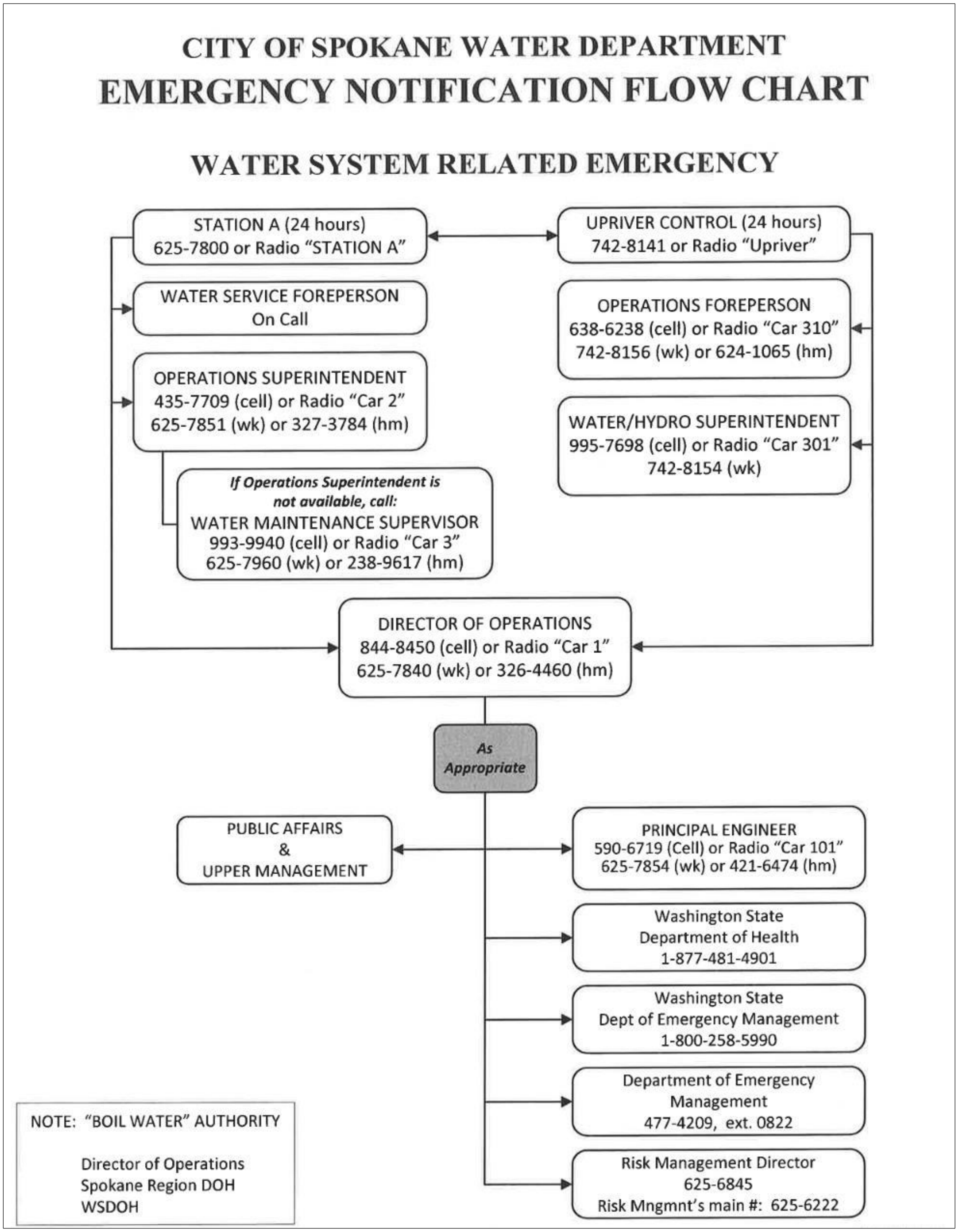
As described in the City's ERP Core Response Procedures (Sep 2020), any major disaster to the Aquifer, like pollution or contamination, will result in a potential crippling of the water supply. The City will have to resort to testing water from each individual well station and selectively pump from wells that have not been contaminated. Depending upon the type of contamination, City wide emergency notifications may need to be made warning the public against the use of water for domestic purposes.

The Water Department Standard Operating Procedures Manual (March 1990) includes general procedures necessary in the event of an emergency and is included as an appendix in the City's ERP (September 2020). The general elements of the plan include:

- Establishing and Operating a Command Post
- Internal Coordination and Communication
- News Media and Public Communication

The Emergency Notification flow chart, shown in **Figure 5-1**, is a vital part of the City's ERP as it lists the personnel to be notified in the event of a major emergency.

Figure 5-1 | City Emergency Notification Flow Chart



If a potential groundwater contamination event occurs, the City's Water Quality Section takes on a critical role. A sample of their roles and responsibilities are listed below, and a full list can be found in City's ERP (September 2020).

- Controls access to sampling points and maintains all water quality records.
- Carries out field tests and laboratory tests.
- Maintains and operates a certified drinking water laboratory.
- Maintains lists of EPA-approved laboratories, their testing capabilities, and utilizes their services as necessary.

Specific City response procedures are influenced by various factors, including but not limited to, the location of the failure, volume and type of product released, Yellowstone Pipe Line Co.'s leak identification and notification measures. The City's response operations will be triggered when Yellowstone Pipe Line Co. notifies the City of a potential pipeline leak. See **Section 6** for more information.

5.1.2 Yellowstone Pipe Line Co.

The Yellowstone Pipe Line Co. has developed their ICP to be capable of responding to a wide range of incidents impacting the Yellowstone Petroleum Pipeline. Most of the discovery, response, and recovery procedures are described in Section II of the ICP.

To explain their response capabilities to an emergency in the Eastern Washington Response Area, the Yellowstone Pipe Line Co. developed an Emergency Response Action Plan (ERAP) - Field Document (May 2022). It is included as Appendix 8b in the ICP (May 2022). The ERAP is intended to provide quick access to key types of information that are often required in the initial stage of a spill response.

Additionally, as part of Yellowstone Pipe Line Co. Franchise Ordinance C35924 (Renewal-2022), the Yellowstone Pipe Line Co. has response and recovery requirements to adhere to. Excerpts are summarized below, and a full description can be found in Section 9 – Leak, Spills, Ruptures and Emergency Response of the referenced ordinance.

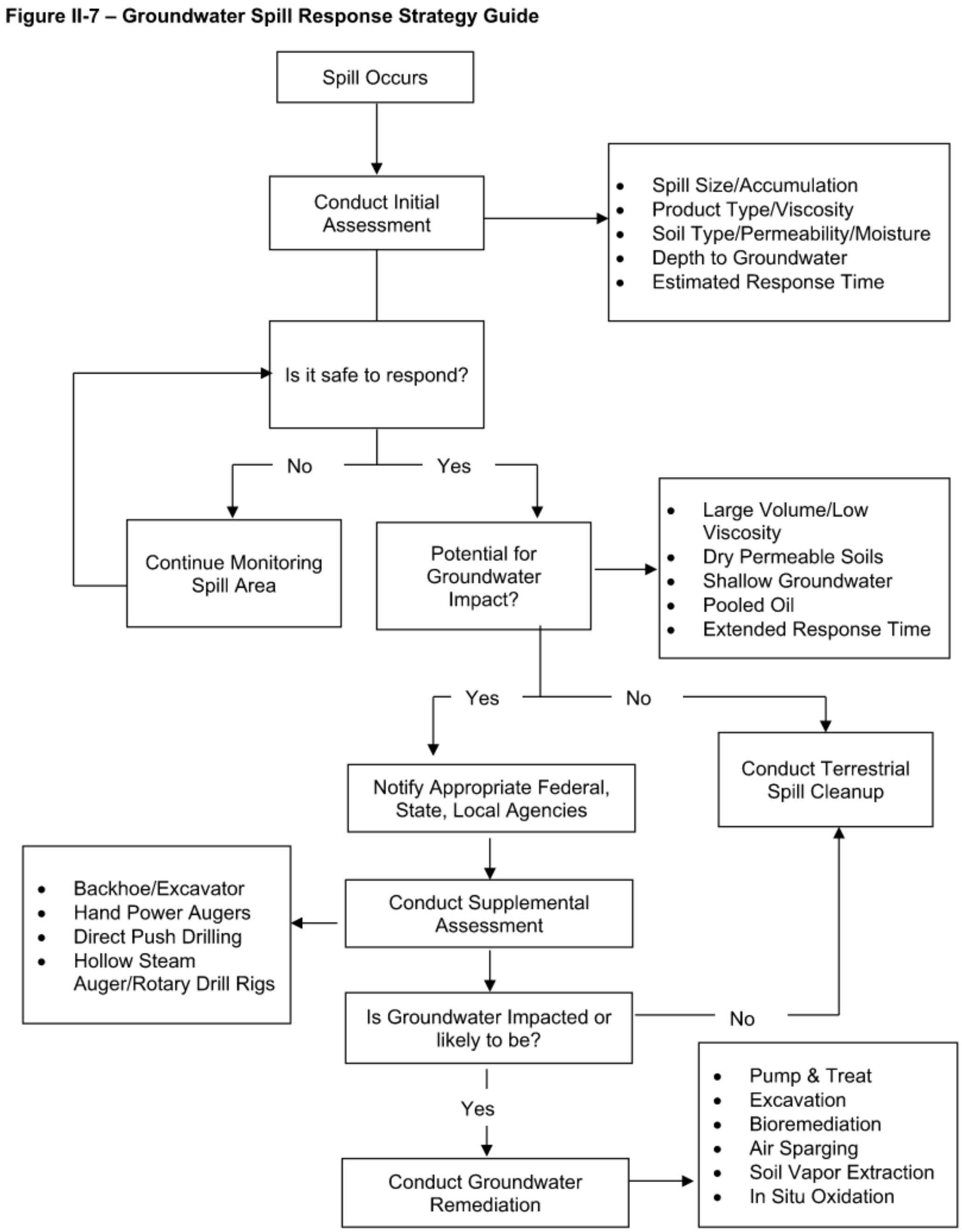
- The Yellowstone Pipe Line Co.'s Emergency Incident Response Plan shall designate a local emergency response official who shall be capable of immediate shutdown of their facilities.
- Maintain a Control Center's 24-hour phone number and update the City Representative and City Fire Marshall in writing if any changes to the contact number.
- Agrees to meet annually to review the Emergency Incident Response Plan and Incident Response Procedures.
- Have available or have access to sufficient emergency incident response equipment and materials to properly and completely response to any spill, leak, rupture or other release of petroleum products or hazard substances from their facilities.
- Expect to the extent an emergency incident is shown to be proximately caused by the negligence of the City, the Yellowstone Pipe Line Co. shall be solely responsible for all reasonable and necessary costs incurred by City, County, local and State agencies in responding to any spill, leak, rupture or other release from their facilities.

- Notification procedures of a spill, leak, rupture or other release:
  - In areas outside the City's Wellhead Influence Zone, the Yellowstone Pipe Line Co. shall notify the City in writing within one (1) business day of its observation or detection.
  - In areas inside the City's Wellhead Influence Zone, the City shall receive telephone notification immediately after the emergency incident is discovered and/or reported to jurisdictional agencies.

5.1.2.1 Initial Spill Discovery and Response Actions

In the event of a spill, there are several actions that should be taken to assess the spill and if groundwater is impacted, to initiate recovery to limit the extent of impacts. Figure 5-2 provides a decision guide that outlines the general response the Yellowstone Pipe Line Co. would take.

Figure 5-2 | Yellowstone Pipe Line Co. Groundwater Spill Response Strategy Guide



- Initial response actions/assessments are those taken by local personnel immediately upon becoming aware of a discharge or emergency incident and should include the assessment of health and safety hazards.

- Groundwater Impact Potential. Once the assessment is completed, the potential of the spill to impact underlying groundwater should be determined. The common factors that contribute to a spill having a higher or lower potential to impact groundwater are shown in **Figure 5-3**.

➢ Notify Appropriate Federal, State, Local Agencies: Once the potential for groundwater impact has been identified and validated, Yellowstone Pipe Line Co. shall proceed with notification procedures, further discussed in **Section 7**.

Figure 5-3 | Yellowstone Pipe Line Co. Groundwater Impact Potential

	Higher Potential
•	Shallow Groundwater (generally <20 ft)
•	Low Viscosity Oil (gasoline)
•	Dry Soil with Low Oil Retention Capacity
•	Highly Permeable Soils (sand, gravel, coarse grained mixed sediment)
•	Large Volume
•	Pooled Oil (creates hydraulic head that enhances penetration)
•	Response Time (several hours before pooled oil recovery begins)
	Lower Potential
•	Deep Groundwater (generally >20 ft)
•	Medium to High Viscosity Oil (industrial fuel oils, crude, lubricants, etc.)
•	Wet or Moist Soils with High Oil Retention Capacity
•	Low Permeability Soils (silts, clays, fine grained mixed sediment)
•	Small Volume
•	No Pooled Oil on Surface
•	Response Time (expeditious recovery of pooled oil or saturated soils)

➢ Included below are relevant Yellowstone Pipe Line Co.'s initial spill response checklists. There are overlapping elements, however, they provide an understanding of the Yellowstone Pipe Line Co. response approach.

- Immediate Action Checklist, **Figure 5-4**
- General Initial Response for Pipeline Maintenance Crews, **Figure 5-5**
- Unconfirmed Report of a Leak, **Figure 5-6**
- General Pipeline Leak Response Actions, **Figure 5-7**
- Leak Detection System, **Figure 5-8**

➢ An additional reference included in the Yellowstone Pipe Line Co.'s ICP, Section II-5.8 (May 2022) is the Pipeline Leak or Rupture First Responder Emergency Response Guide.

Figure 5-4 | Yellowstone Pipe Line Co. Immediate Action Checklist

Sec. II-5.2 Immediate Action Checklist

	Spill Observer/Dispatcher
•	If a pressure drop is noticed or a leak is suspected, notify the person in charge immediately and stop all product transfers.
•	To minimize damage, close all automatic isolation valves, if available.
•	Assist with initial response actions as directed.
	Line Flyer
•	Report all abnormal activity and dead vegetation in the vicinity of a pipeline.
•	If action requires immediate attention, report via radio.
•	In the event radio contact cannot be made; the line flyer will land and report to Company management by telephone.
	Person-in-Charge
•	Determine level of response needed, hazards of product(s) involved and proper response guidelines to be followed. (For additional information refer to Company Maintenance Manual (MPR) - MPR-4005.)
•	Work with local law enforcement to make sure all personnel/citizens are a safe distance away from the hazard area.
•	Notify Fire Department as appropriate.
•	Notify Company management as appropriate.
•	Dispatch response team to the site of the suspected leak and assume the position of IC. Implement ICS/UCS and establish a workable ICP and Communications Center. Determine the extent of spill or release, verify product type(s), identify material(s), estimate quantity spilled or released, approximate rate of discharge, estimate movement of the spill/vapor cloud, estimate the wind direction. (Report volume details to regulatory authorities in compliance with notification procedures in Appendix 3)
•	Instruct response team to eliminate sources of vapor cloud ignition. Shut down all engines and motors. (Refer to MPR-3001 and MPR-4003).
•	Review pipeline alignment sheets to become familiar with the location of mainline valves and elevation characteristics. Review environmentally sensitive area maps for the location of any sensitive area that may be impacted.
•	Advise response team on manual valves locations; order them closed if appropriate.
•	Note time of spill or time of first detection, location, source, and cause of spill.
•	Make a note of response actions taken and by whom.
•	Instruct response team to attend to injured personnel.
•	Call out cleanup or general contractors, as necessary.
•	Collect information necessary to complete the Incident Report Form.
•	Make appropriate notifications to local and state governmental agencies of the spill and proposed actions. Document names of agencies called, person who received the calls, and the times the calls were made.
•	Complete the Incident Report Form and notifications.
•	Advise neighboring property owners and operators of any threat to their property or personnel.
•	Direct initial response actions.
•	Call additional emergency response contractors as necessary.

Figure 5-5 | General Initial Response for Maintenance Crews

Sec. II-5.4 General Initial Response Procedures – Pipeline Maintenance Crews

These procedures have been designed to 1) provide safety to the public and company personnel when threatened by the release of hydrocarbons from a pipeline to the environment, and 2) to coordinate activities for prompt and safe repair of the pipeline and the return to normal operating conditions.

Events that require immediate response include:	
•	Extreme pressure reduction on the line
•	Extreme flow rate changes
•	Extreme measurement losses or gains
•	Receiving notices of an emergency nature such as: - Release of hazardous liquids from a pipeline facility - Operational malfunction causing a hazardous condition - Fire, explosion, or natural disaster involving pipeline facilities - Notification of a potential leak or hazard

Whenever any of the above conditions occur, the following emergency shutdown procedures should be initiated:	
•	Shutting in the line at the nearest block valves.
•	Notifying the nearest pump station and/or the appropriate control center.
•	Maintenance crewmembers should notify their immediate supervisor who will in turn notify appropriate Company contacts.
•	If the exact location of the leak is unknown, the Incident Commander will request a line flyer, or if it is at night, manpower might be used to walk the line.
•	Once a leak site has been located, the following information should be obtained: 1. Have all ignition sources been eliminated? 2. Are any schools, homes or commercial properties at risk and should they be evacuated? 3. Should access to the area be restricted (roads blocked)? If so, assistance should be requested from law enforcement agencies. 4. Have local response agencies been advised of the product's characteristics and handling precautions which are described in the SDS? 5. Are railroads or utility companies in the area and have they been notified? 6. Will product flow into any waterways or roadways? 7. Work with Company Environmental Services to conduct a natural resource damage assessment.
•	Notifications to be made: - The Duty Officer should be notified. - Federal and/or state agencies may need to be contacted if a spill or release meets the criteria outlined in this manual. - Following an assessment of the release site, an evaluation should be made regarding the effect of downtime on product scheduling. Appropriate Notifications will be made.

Figure 5-6 | Yellowstone Pipe Line Co. Unconfirmed Report of a Leak

Sec. II-5.7 Unconfirmed Report of a Leak

Following an unconfirmed report of a leak, or the substantial threat of a leak, the sequential response actions that should be implemented immediately are:

Unconfirmed Report of a Leak		
Procedures	**✓**	**Date/Time**
Contact the Control Center and request a line balance check and shut down line if a leak is suspected or pipeline integrity is compromised.	☐	___/___/___ ___:___
Conduct aerial or ground reconnaissance of the area at the first possible opportunity (incident may occur at night or in inclement weather) and contact the Control Center to shut down line if reconnaissance detects a potential leak.	☐	___/___/___ ___:___
Isolate line segment.	☐	___/___/___ ___:___
Start internal and external notification procedures.	☐	___/___/___ ___:___
Mobilize response and repair personnel.	☐	___/___/___ ___:___

Figure 5-7 | Yellowstone Pipe Line Co. General Pipeline Leak Response Actions

Core Plan — Core Section II: Core Plan Element

Sec. II-6.4.7 General Pipeline Leak Response Actions

General Pipeline Leak Response Actions		
Travel to Suspected Site of Leak		
•	A means of locating the leak site is necessary for minimum travel time. The general location of the leak may be known from reports.	
•	If precise directions are not available for finding the site, air surveillance and assistance from a helicopter or other aircraft may be necessary. Areas should maintain a list of companies with aircraft for charter.	
Find Leak		
•	If oil continues to escape from the line, the leak may be detected visually.	
•	If underwater, the leak can be found by having a diver survey the line. The line may have to be pressured up to force gas or oil out of the leak to aid in locating the leak.	
Determine Extent of Damage		
•	In determining the extent of damage, three basic conditions of the line must be determined: Degree of damage to the line Length of damaged line Misalignment angle if an underwater pipeline	
Report to Area Supervisor		
•	Once the extent of damage has been determined, the following information should be reported:	
	Location of leak Size of the line Type of coating Length of damaged section	Misalignment angle Water depth (if appropriate) Local terrain conditions
Begin Repair Preliminaries		
•	Perform whatever repair preliminaries are possible if it safe to do so.	

Figure 5-8 | Yellowstone Pipe Line Co. Leak Detection System

Levels of Leak Detection	
The Company currently uses the following three types of leak detection systems:	
•	Level I – Volume Balance
•	Level II – Flow Rate and Pressure Deviation
•	Level III – Pressure and Equipment Status Change

Sec. II-6.4.6 Level III – Pressure and Equipment Status Change

Level III – Pressure and Equipment Status Change	
General Technique	
Level III facilities are controlled from the Control Center and equipped with pump equipment status and discharge pressure indications. Facilities of lesser importance have local sensing of discharge pressure for shutdown on high or low pressure.	
Alarms are generated for the following applicable conditions:	
•	High line pressure (audible alarm)
•	Low line pressure
•	Excessive negative flow rate deviation
•	Equipment status changes not initiated by Control Center
Alarm settings are adjusted as required to eliminate spurious alarms due to normal system fluctuations. Many require settings for both steady state and dynamic (planned changes) conditions.	
Shutdown	
•	Local automatic shutdown on high or low pressure
•	Control Center manual shutdown on alarm evaluation
•	Isolate system to extent remote isolation valves are available. Call for manual isolation immediately upon confirmation of leak
•	For new systems, the number, location, and remote operability of isolation valves should be carefully evaluated to meet codes, regulatory, and hazard requirements

5.1.2.2 Potential Command Post

Locations for incident command posts have been determined within each operating area where adequate resources are available to command an incident and tend to be at existing Yellowstone Pipe Line Co. facilities. the ICP, Appendix 8b ERAP (May 2022) lists the potential primary and alternate command posts and staging areas for emergency events impacting the Yellowstone Petroleum Pipeline system. The likely Primary Command Post for a leak impacting the aquifer is located at the Spokane Product Terminal, 6317 E. Sharp Ave., Spokane, WA 99212.

5.1.2.3 Incident Commander/Qualified Individuals

On-scene incident commander's/qualified individual's responsibility is to first make the appropriate notifications and then initiate response operations. This individual will act as liaison with City, county, state, and federal agencies. They are also responsible for directing the operations of the Emergency Response Teams. **Figure 5-9** identifies the Qualified Individuals assigned to the Eastern Washington Response Area.

Figure 5-9 | Yellowstone Pipe Line Co. Pipeline Qualified Contacts

Qualified Individual/Alternate Qualified Individual	
Qualified Individual	Chris Church, Supervisor, Ops – Facl, Yellowstone West 253-227-7293 Cell
Alternate Qualified Individual	Brett DeVries, Lead Operator, Moses Lake 509-760-8486 Cell
Alternate Qualified Individual	Tara Geoeske, Lead Operator, Spokane 509-998-9104 Cell
Alternate Qualified Individual	Josh Lindstrom, Technician, Spokane 509-220-1994 Cell

5.1.2.4 Notification Procures

Emergency notification procedures and responsibilities will be addressed below in **Section 7**.

5.1.2.5 Supplemental Assessment

If the potential exists for a spill to reach groundwater, additional assessment activities need to be conducted to confirm groundwater has been impacted, and if so, assess the extent of impacts. Assessment activities commonly used by Yellowstone Pipe Line Co. are included as **Figure 5-10**.

Figure 5-10 | Yellowstone Pipe Line Co. Supplemental Assessment Activities

Sec. II-5.21.5 Supplemental Assessment

These activities commonly include:	
•	**Backhoes or Excavators** – excavate pits/trenches to determine penetration depth/groundwater impacts (limited to depths of 10–20 feet)
•	**Hand or Power Augers** – install borings to collect soil/water samples and can be used to install temporary wells (often limited to 15-30 feet)
•	**Direct Push Drilling Rigs** – install borings to collect soil/water samples and can be used to install temporary wells (often limited to 50-100 feet)
	Hollow Stem Auger (HAS) or rotary drill rigs - install borings to collect soil samples and wells for groundwater samples (limited to 100-500 feet)

5.1.2.6 Emergency Response Equipment and Contractors

- Noted in the Yellowstone Pipe Line Co. ICP Appendix 5.1.1 – Resource Utilization/OSROs (May 2020), onsite resources will generally be used for response to most small and some moderate spills and will likely be supplemented with contractor and/or cooperative (co-op) equipment and personnel. A full list of local and regional sources are found in the ICP Appendix 5.1.1.
- The Yellowstone Pipe Line Co. and Primary Response Contractor (PRC) owned equipment lists will be populated and maintained on the Western Regional Response List, and PRC contracts shall be available for inspection, if requested by the Department of Ecology.
- In the event of a major incident where the identified resources were inadequate to effectively handle the spill response, other local, regional, national and international resources can be mobilized.

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SECTION 6

Distribution System Operational Responses

The sole source aquifer classification and the proximity of the Yellowstone Pipeline facilities, requires an understanding of potential groundwater impacts and a quick operational response to a contamination event.

A report titled "Well Station Vulnerability to Potential Chemical Releases from the Yellowstone Petroleum Pipeline" (Vulnerability Assessment, 2024) was developed by GIS Water Solutions to assess the vulnerability of the groundwater supply and develop operational response recommendations. Section 5 of the Vulnerability Assessment (2024) provides a summary of suggested proactive and reactive emergency response measures that could empower the City to maintain service during a contamination event. **Section 9** presents suggested updates to the City's existing ERP.

6.1.1 City of Spokane

As described in the City's ERP Core Response Procedures (September 2020), any major disaster to the Aquifer, like pollution or contamination event, will result in the potential crippling of the water supply.

The level and type of required response is highly dependent upon the location and severity of the release. Therefore, two feasible emergency responses for the worst-case supply scenarios were identified (Parkwater and Well Electric Well Stations offline) as part of the Vulnerability Assessment (2024).

Suggested reactive operation response measures are summarized below from the Vulnerability Assessment (2024) Section 5.3 Recommended Operational Response Procedures, Mitigation Measures, and Plan Updates:

- Utilize the Kempe-Shawnee Intertie. Operators should be ready to supplement recovery of the Shawnee tank during peak use times from the Kempe tank during emergency supply scenarios.
- Demand Curtailment: 12% Minimum in the Low Primary Supply Zone
- Operate Backflow PRVs between Low and Intermediate Primary Supply Zones
- Operate pressure sustaining feature at the Dalke Pressure Reducing Valve station

The Vulnerability Assessment (2024) provides a baseline assessment necessary to develop a Parkwater Well-specific Emergency Containment Response Plan. It should include a list or table of concise pre-planned step-by-step operational procedures that can be quickly evaluated and implemented during an incident. The City's Dam Emergency Response Plan can be used as a template. The Emergency Containment Response Plan was not developed as part of this version of the DSCRP, however it should be considered a high priority for future updates.

6.1.2 Yellowstone Pipe Line Co.

It is not anticipated that the Yellowstone Pipe Line Co. will have an active role in the distribution system operational response. The Yellowstone Pipe Line Co.'s capabilities and emergency response to an incident impacting the Yellowstone Pipeline system are addressed elsewhere in the DSCRP.

SECTION 7

Risk Communication/Public Notification

7.1.1 City of Spokane

The City Water Department has developed a Water Emergency Communications Plan (October 2013) to communicate effectively with all Water Department customers during emergencies that impact the quality of their drinking water. The plan supports a comprehensive multi-media approach to reach customers in ways that are convenient for them. The Plan includes communication with critical customers and public notification templates. The plan is included as Appendix 6.5.1 in the City's ERP (September 2020).

Section 6.4 of the City's 2023 Water System Plan identifies that the Communications Manager will coordinate and lead the monitoring of media coverage and public response to the emergency event. Messaging will be made available for all staff and leadership providing responses, including talking points for interviews and news briefings, frequently asked questions linked to the website, social media responses, and talking points for customer service staff.

External notification will be coordinated in collaboration with the Yellowstone Pipe Line Co. and community and agency stakeholders.

7.1.2 Yellowstone Pipe Line Co.

Yellowstone Pipe Line Co.'s ICP Section II-4 (May 2022) states that immediate actions are required at the onset of an emergency response to limit the extent of a release, minimize the potential hazard to human health and the environment, and implement an effective response. The ICP, Section II-4 is intended to provide guidance for determining the appropriate initial response and notification actions that should be carried out in the event of a release or other emergency incident.

Yellowstone Pipe Line Co. will coordinate with local and state police to establish protected land routes that minimize traffic congestion during the movement of personnel and equipment.

7.2 Public Notification Decision Tree

7.2.1 City of Spokane

Section 6.4 of the City's 2023 Water System Plan includes an Action Plan Form which is included as **Figure 7-1**.

Figure 7-1 | City of Spokane (From 2023 WSP, Section 6.4)

Table 6.2 Action Plan Form

Action	Date/Time	Who	Time Completed	Notes
Notify Public Works Communications Manager of emergency with as many specifics as possible				
Communications Manager notifies (or confirms notification) Mayor, Public Works Director, Communications Director, Sr. Management and City Council				
Notify Department of Health Office of Drinking Water (877-481-4901) DOH Communications (360-236-4501)				
Communications (and other senior leadership) receive briefing from incident commander to determine communication response				
Develop internal and external messaging, strategy, timing				
Assess the need for communication with stakeholder and vulnerable audiences				
Review messaging and get approval by senior leadership				
Confirm notification of regulators and health officials. (SRHD, DOH)				
Coordinate messaging with regional, state, and national partner agencies for consistency.				
Distribute, implement, and execute approved Communications Plan				
Coordinate policy needs with City Council				
Establish ongoing update schedule with media and the public if necessary, depending on the expected timeline of emergency				
Assign staff to monitor and maintain documentation of information deployment and media coverage				
Prepare communications overview for after-action report exercise				

Additionally, the City's Emergency Notification Flow Chart is a vital part of the ERP. The notification chart is posted in both the Water Department Radio/Dispatch Room located at the department's business office at 914 E. North Foothills Drive and the Upriver Complex Water System Control Room located at 2701 N. Waterworks Street. The notification chart lists the personnel to be notified in the event of a major emergency and is revised as personnel changes occur. The notification chart is provided in **Section 5**, **Figure 5-1** and in the City's ERP appendices.

7.2.2 Yellowstone Pipe Line Co.

The Yellowstone Pipe Line Co.'s emergency notification chart for Eastern Washington's Emergency Response Action Plan (ERAP) - Field Document (May 2022) is provided as **Figure 7-2**.

ADD COMMENT ABOUT FRANCIZE AGREEMENT

Figure 7-2 | Yellowstone Pipe Line Co. Notification Flow List – Eastern WA Response

Washington State
Eastern Washington Response Area
Integrated Contingency Plan

Appendix 8b: ERAP

Notifications Flow List
Eastern Washington Response Zone
Spokane River and Latah Creek

Product in Water	Approx. Time into Water

Leak site: (Check one)

☐	Pines and Trent on the South side of Railroad Bridge. YPL Aerial Marker 527.5; Block of 13000 East Trent and North Pines.
☐	Downstream of Up-River Dam on transfer line; 5200 Waterworks AVE South Side BV, 5100 Upriver Drive North Side BV.
☐	Latah Creek Moses Lake Line YPL Aerial Marker 541; 7900 South Why 195 at White Road.

Contact	Phone Number	Date /Time
Local Supervisor/Qualified Individual		
Request Hazmat Team, Fire Department, City Police, County Sheriff.	911	
Duty Officer	800-231-2551.	
Local response team, (See Appendix 2 or 8).		
Upriver Dam Operations Room: (Give them product in river and time product entered river.)	509-742-8141	
Avista Dam Generation Control Center 24/7; downtown Spokane: (Give them product in river and time product entered river.)	509-495-8114 or 509-838-5810.	
Felts Field Airport Water Landing Runway Tower: (Request them to shut down water landing strip).	509-353-2946 (not 24hr)	
Spokane Airport (for shutdown of water landing); On-Duty Ops Supervisor: Airport Dispatch:	509-998-7269 or 509-455-6429	
BNSF: (to inform them of spill to river.)	509-536-2235 or 2492 509-995-0291	
US Ecology	(800) 899-4672	
Abel Clean Up:	509-466-5255	
MSRC:	1-800-645-7745	

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SECTION 8

Remediation and Recovery Phase

8.1.1 City of Spokane

The City expects the Yellowstone Pipe Line Co. in collaboration with Ecology to lead the remediation and recovery operations triggered by a Yellowstone Petroleum Pipeline leak.

If the City has a reasonable basis to believe a failure has occurred, the City's Representative may seek an investigation in accordance with Section 9.4 of the Yellowstone Pipe Line Co. Franchise Ordinance C35924 (Renewal-2022). The investigation may involve Yellowstone Pipe Line Co. staff excavating or using smart tracking tools to assess the pipeline for a failure.

8.1.2 Yellowstone Pipe Line Co.

Yellowstone Pipe Line Co. ICP Section II-5.21.6 Recover/Remediation provides the common groundwater remediation techniques in **Figure 8-1** below. The most appropriate remediation techniques depend on a number of factors, e.g. product type, soil type, depth to groundwater, site access, extent of impacts, and groundwater use.

Figure 8-1 | The Yellowstone Pipe Line Co. Common Groundwater Remediation Techniques

Some of the more common groundwater remediation techniques include:	
•	Pump and Treat
•	Excavation
•	Bioremediation
•	Air Sparging
•	Soil Vapor Extraction
•	In Situ Oxidation

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SECTION 9

Mitigation Approach

In accordance with Section 9.6 of the Yellowstone Pipeline Franchise Ordinance C35924 (Renewal-2022), the Yellowstone Pipe Line Co. has the sole and separate responsibility to take adequate precautions to avoid leaks, spills, or ruptures that might result in the release of petroleum products.

9.1 Existing Mitigation Procedures

9.1.1 City of Spokane

To support joint emergency responses and recovery operations resulting from a leak from the Yellowstone Petroleum Pipeline the City participates in the following collaboration efforts with Yellowstone Pipe Line Co.:

- Joint tabletop and emergency response exercises.
- Meets annually with Yellowstone Pipe Line Co. to review and provide comments on the Emergency Incident Response Plan and Incident Response Procedures.

9.1.2 Yellowstone Pipe Line Co.

As identified in **Section 3**, the Yellowstone Pipe Line Co. operates preventative pipeline monitoring systems designed to alert operators to alarms and provide automatic shut-in functions in the event of a release. The pipeline is continuously monitored from a Control Center that provides on-site automatic control of pressure, flow rate, valve position, and other operating conditions.

If a release was to occur, Section II-7.4 of the ICP (May 2022) includes source control mitigation guidelines for controlling a release near the source and mitigating the associated consequences. The guidelines are provided in **Figure 9-1**.

Figure 9-1 | The Yellowstone Pipe Line Co. Source Control Mitigation Guidelines

In the event of a spill involving a pipeline leak or rupture, the initial mitigation actions will likely consist of:	
•	Shutting down the pipeline
•	Relieving the pressure on the affected line section
•	Isolating the line section by closing the appropriate valves
•	Evacuating the remaining contents of the affected line section
•	Exposing the leak or rupture and installing a temporary patch

Section 9.1(c) of the Yellowstone Pipeline Franchise Ordinance C35924 (Renewal-2022), Yellowstone Pipe Line Co. will make periodic updates to its Emergency Incident Response Plan.

9.2 Recommended Mitigation and Response Update

This section provides a list of recommended operational response procedures and mitigation measures for Yellowstone Pipe Line Co. and the City to incorporate into their emergency response plans.

9.2.1 City of Spokane

- Be prepared to immediately conduct a demand curtailment campaign including coordination with the Parks Department on stopping Parks irrigation until other irrigators begin curtailment.
- Be prepared to operate backflow PRVs and/or a secondary CRD reducing pilot at Northwest Terrace to limit flow out of the Low primary zone.
- Be prepared to operate Kempe-Shawnee intertie during a loss of supply to the North Hill primary zone.
- Develop an Operational Response Planning Decision Tree demonstrating the Water Departments response to a pipeline leak.
    - Model after the City's existing Wellhead Protection Emergency Response Flow Chart.
    - Include a long term remediation and recover phase.
    - Include a Parkwater Well Station-specific Emergency Contaminant Response Plan as a list or table of concise pre-planned step-by-step operational procedures that can be quickly evaluated and implemented during an incident. The Vulnerability Assessment (2024), especially the distribution system analysis, is intended to provide a basis for developing such a procedure.
- Update the following City documents to incorporate current distribution system impacts, operational response and recovery measures, and the Yellowstone Pipe Line Co. Notification and Emergency Response Action Plan (ERAP) field document:
    - Water Department's Emergency Notification Flow Chart.
    - Water Department standard operating procedures.
    - Risk and Resiliency Assessment.
    - Wellhead Protection Plan.
    - Water Emergency Communications Plan (which is used to communicate with the public). This could be updated to reflect possible water restrictions, or a demand curtailment campaign based on which wells are impacted.
- Evaluate existing groundwater testing locations and capabilities for possible expansion improvements necessary to meet demands if a contamination event were to occur.
- Review existing water testing laboratory contracts and capabilities to confirm they can test for petroleum products and have the capacity to respond to increased sampling needs in a timely fashion.
- Continue to meet annually with Phillips 66 to review Yellowstone Pipe Line Co. Emergency Incident Response Plan and Incident Response Procedures. Use these meetings to review and discuss with Yellowstone Pipe Line Co. any updates on technologies that can be (or are being) implemented to quantify the lowest leakage rate (or range of rates) that can be detected in the pipeline, with appropriate qualifiers as needed to address measurement limitations/uncertainties and to acknowledge the variability in product mixes and operating conditions for the pipeline.

9.2.2 Yellowstone Pipe Line Co. Core Plan Update

- Update Phillip 66 ICP Section 2.8 and 2.9.4 to include timely notification to the Water Department's emergency Contacts:
  - Station A: 509-625-7800
  - Upriver Control: 509-742-8141
- Update the Emergency Response Action Plan (ERAP) (Appendix 8b of the ICP) to highlight the following:
  - If a release is suspected along pipeline segment YP-02 or YP-03 (both of which lie close to the Parkwater Well Station), provide timely notification to the Water Department's emergency contacts in concurrence with the Yellowstone Pipe Line Company's initial conditions assessment and as part of Phillips 66 execution of PHMSA's rule 49 CFR 195.402 for notifications on pipeline releases.
- Highlight that the Spokane Valley-Rathdrum Prairie Aquifer by name is a sole source aquifer in Appendix 3b (Section 3.2.31) of the Phillip 66's ICP.
- Develop and incorporate a remediation/decontamination strategy specific to the Spokane Valley-Rathdrum Prairie Aquifer.
- Continue to include the City in emergency operation response training exercises in accordance with the City of Spokane and Yellowstone Pipe Line Co. Franchise Ordinance (2022) and ICP Section 3.1. Yellowstone Pipe Line Co. encourages annual response training exercises to be the venue for annual review and discussion of the ICP and response procedures.
- Continue to meet annually with the Water Department to review Yellowstone Pipeline Co. Emergency Incident Response Plan and Incident Response Procedures and allow access to the plan through the third-party site Paradigm.