Quality Assurance Project Plan

Cowiche Creek Shallow Aquifer Recharge for Streamflows Study

July 2024

Washington Department of Ecology, Office of Columbia River

Grant Agreement WRYBIP-2325-TroUnl-00043

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Publication Information

Each study funded by, and conducted on behalf of, the Washington State Department of Ecology must have an approved Quality Assurance Project Plan (QAPP). The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, the final report will be made publicly available on a forthcoming YBIP Groundwater Subcommittee website, which is slated to come online in late 2024. This QAPP is valid through March 31, 2028.

This Quality Assurance Project Plan is on Ecology's website at https://apps.ecology.wa.gov/publications/SummaryPages/2412007.html. Data for this project will be available on Ecology's Environmental Information Management (EIM) website: https://fortress.wa.gov/ecy/eimreporting. Search Study ID: WRYBIP-2325-TroUnl-00043.

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2.0 Abstract

In 2023, Trout Unlimited (TU) received a grant from Office of Columbia River entitled Cowiche Creek Shallow Aquifer Recharge Study (WRYBIP-2325-TroUnl-00043). This Quality Assurance Project Plan (QAPP) was prepared by Forsgren Associates (Forsgren) and American Land and Water Consulting, LLC (American) on behalf of TU to outline procedures for data collection and analysis for a hydrogeologic study of the South Fork of Cowiche Creek (SFCC) in Yakima County, Washington. The Cowiche Creek watershed drains the foothills of the eastern Cascade Mountains as a subbasin within Water Resources Inventory Area (WRIA) 38 (Naches).

The Cowiche Creek Shallow Aquifer Recharge Study (project) will evaluate the feasibility of using shallow aquifer recharge (SAR) to enhance streamflows with the goal of improving late season (late-July through September) flows by ≥10%—at least 0.1 to 0.2 cubic feet per second (cfs)—near the confluence of the North-South Forks Cowiche Creek. The project drivers are low flows (minimum flows below 1 cfs and average flows below 2 cfs) in August and September. The project will use desktop and field investigations to develop a hydrogeologic conceptual model of SFCC and the shallow unconsolidated aquifer within the study area that will be used to assess the feasibility of implementing SAR via gravity flow.

3.0 Background

3.1 Introduction and Problem Statement

Cowiche Creek is critical habitat for Mid-Columbia Steelhead, Coho salmon, and resident Rainbow and Westslope Cutthroat trout, and is flow-limited due to irrigation and domestic uses. Presently, anadromous fish use Cowiche Creek but exceptionally low flows (less than 0.5 cfs) in the SFCC from late summer through early fall, combined with warm water temperatures, limit the amount of available fish habitat; these exceptionally low flows will limit fish restoration in Cowiche Creek until corrected. Figure 1 shows mean and minimum discharge in SFCC for the period 2014 through 2022 based on unpublished data from Washington Department of Fish and Wildlife (WDFW, 2023).

The project will require coordination with local landowners and water users, the Yakima Tieton Irrigation District (YTID), and Cowiche Canyon Conservancy (CCC). YTID is a large irrigation district that surrounds Cowiche Creek and whose infrastructure will be evaluated to convey water for aquifer recharge. CCC is the landowner of a proposed aquifer recharge area at the upstream end of the project area. TU has discussed the project concept with YTID and CCC, and both entities are receptive to proceeding. To determine feasibility for this project, TU has contracted with Forsgren and American (Consultants) to complete the work.

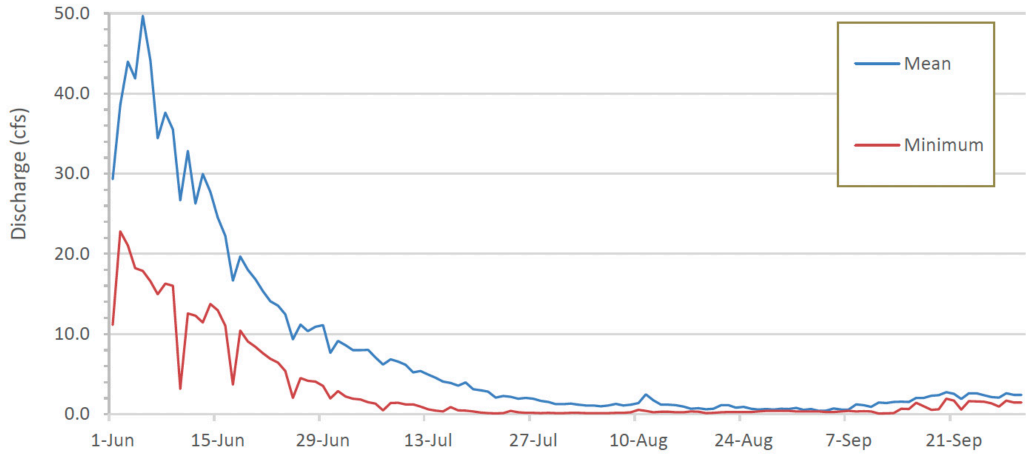


Figure 1. South Fork Cowiche Creek average and minimum daily mean discharge from 2014 through 2022, near RM 0.05 at Pioneer Way crossing near confluence of South and North Forks (WDFW, unpublished data, 2023). Figure credit: Trout Unlimited.

This study seeks to understand the following conditions:

- Gaining, losing, neutral stream characteristics of SFCC from Snow Mountain Ranch (~ RM 4.0) to its confluence (RM 0.0) with North Fork Cowiche Creek (NFCC);
- Characteristics of the shallow aquifer underlying SFCC, including soils, infiltration rates, hydraulic conductivity, and groundwater flow directions and gradients;
- Identification of potential SAR infiltration sites including infiltration characteristics of water conveyance infrastructure on both the north and south sides of the floodplain, with an initial focus on the south side;
- Identification of stream reaches where SAR is predicted to augment streamflows, estimated benefit of SAR augmentation, and timing from SAR infiltration site to the augmentation reach;
- Potential to retrofit conveyance systems to transport and deliver water for SAR;
- Legal and financial requirements to supply and infiltrate the water (e.g., water rights and easements review and analysis);
- Water physical availability and quality considerations (e.g., records/analysis from Ecology);
- Unknown limitations to SAR implementation (e.g., potential sources of groundwater contamination and impacts to wells and septic systems); and
- Emerging issues/questions as identified by the Yakima Basin Integrated Plan (YBIP) Groundwater Subcommittee.

3.2 Study Area and Surroundings

An approximate 4-mile stream reach between CCC's Snow Mountain Ranch and the confluence of the North and South Forks of Cowiche Creek is targeted for benefits. The overall project area of the valley floor is about 1,190 acres (Figure 2). The Study Area generally comprises the region within 0.5 mile north and south of SFCC within Sections 31, 32, 33, and 34, T. 14 N., R. 17 E.W.M. and Sections 3, 4, and 5, T. 13 N., R. 17 E.W.M. in Yakima County.

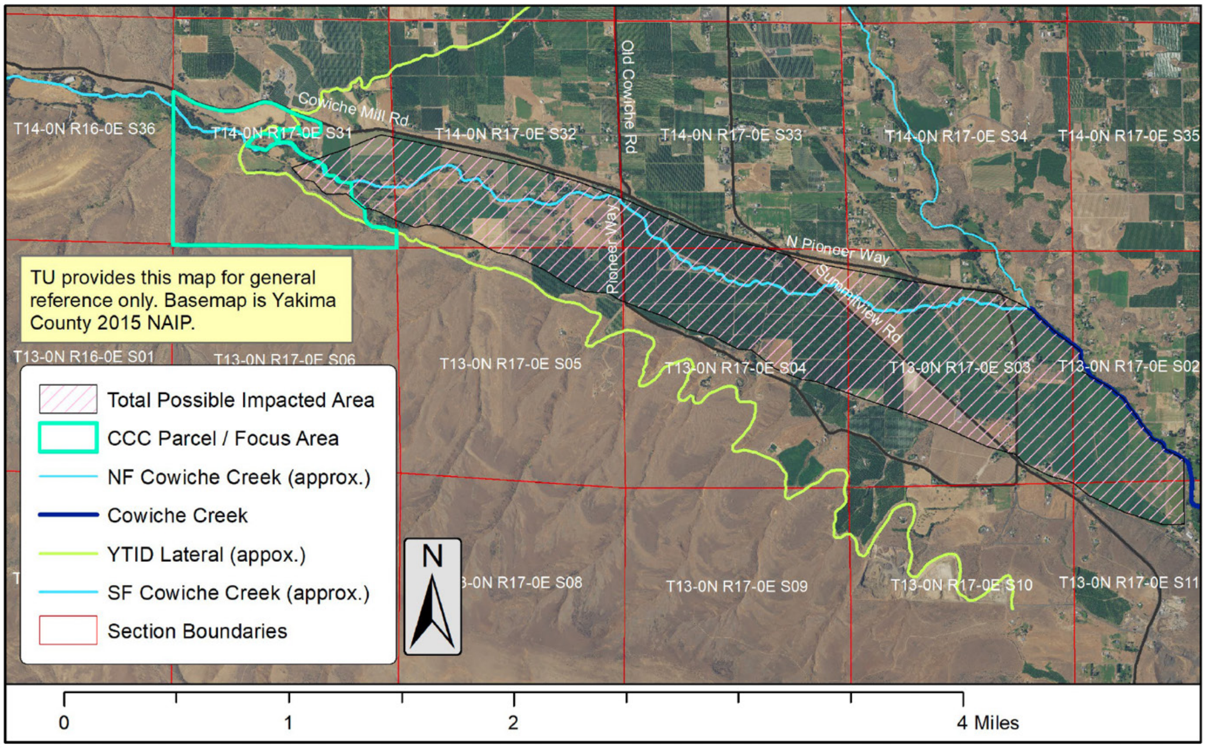


Figure 2. 2015 NAIP-based general project location map showing the North and South Forks of Cowiche Creek, key roads, and section boundaries, with the focus area outlined in light green. Figure credit: Trout Unlimited.

Preliminary examination of topographic and geologic maps and well logs in Ecology's database indicates unconsolidated sediments are present overlying bedrock across much of the Study Area. These sediments appear to be water bearing in some areas (e.g., near the stream) comprising what is referred to in this QAPP as the shallow aquifer or the Target Aquifer for SAR. The Study Area was delineated based on the approximate location of a groundwater divide for the shallow aquifer on either side of SFCC estimated from land surface topography. Actual study area boundaries are subject to change as more information (e.g., groundwater level data) becomes available.

Land use in the Study Area is primarily irrigated agriculture (consisting of hay and tree fruit crops) and scattered residences. Irrigation water is supplied by YTID and privately owned water rights authorizing withdrawal from SFCC, the Tieton River, and groundwater. Water for domestic use is supplied by private wells.

The focus area for recharge is a former YTID lateral crossing of CCC's Snow Mountain Ranch, that crosses from the north to the south side of South Fork Cowiche Creek, then along the base of the hills to the south (yellow line, Figure 2). Historically, the canal to the south of SFCC was an open, earthen ditch. Open portions of the canal and related open laterals are no longer used. The feasibility of an additional/alternate pathway along the north side of the floodplain will also be evaluated.

3.2.1 History of Study Area

Historic land use in the Study Area is consistent with existing land use.

Efforts to improve instream habitat and water quality within the Cowiche Creek watershed have been ongoing for more than three decades and involve numerous stakeholders.

The CCC was incorporated as a non-profit in 1985 and began acquiring lands within the Cowiche Creek watershed in 1987. The CCC purchased the 2,000-acre Snow Mountain Ranch property in 2005 (https://www.cowichecanyon.org/who-we-are/).

The North Yakima Conservation District has been working in the Cowiche Creek watershed since 2004 and has implemented various projects to improve streamflow, fish passage, and riparian habitat.

The Salmon Recovery Portal shows that 19 projects to restore habitat and improve fish passage in the Cowiche Creek watershed were completed since 2002 (https://srp.rco.wa.gov/project/300/10673).

3.2.2 Summary of Previous Studies and Existing Data

Previous studies completed by Ecology in the watershed consist of the *Upper Naches River and Cowiche Creek Temperature Total Maximum Daily Load: Volume 2, Implementation Strategy* (Peterschmidt, 2010) and the *Cowiche Creek Vegetation and Shade Study* (Urmos-Berry, 2019). No groundwater studies were identified for the Study Area. Examples of regional geologic and groundwater studies include Bingham and Grolier (1966) and Vaccaro et al. (2009).

In 2014, a multi-partner surface water source switch project was completed that helped restore streamflows in the South Fork and mainstem Cowiche Creek. The project switched the source of water for some surface water users (totaling approximately 7 cfs) from SFCC to the Tieton River. The Tieton River water is now delivered by YTID and may provide a source of supplemental return flows to SFCC that also help support streamflows. The project demonstrated three key items:

1. When capacity is available, YTID can deliver Tieton River water to the Cowiche Creek subbasin;
2. Streamflow improvements in Cowiche Creek are possible through modest changes to water use/delivery; and
3. Future projects will require a combination approach of Tieton River water delivery through infrastructure modifications.

Further supporting the potential of the aquifer recharge are the Acquavella Adjudication Cowiche Creek Subbasin documents that suggest, historically, natural springs in Cowiche Creek experienced flow increases when the large earthen ditches/laterals in the area were full of water. Inadvertent shallow aquifer recharge was likely contributing to springs and streamflows. Over time, more efficient water conveyance and uses likely reduced sources of SAR.

TU completed, with assistance from the YBIP Groundwater Subcommittee technical experts, a conservative, unofficial estimate of available storage by reviewing well logs to determine the depth to groundwater in the Cowiche Creek area. TU averaged the static water level (SWL) from a sample of 17 well logs within the upper, middle, and lower project area. The average SWL was about 40 to 41 feet below ground surface (bgs), with a range from <10 feet bgs (one noted potential artesian conditions) to over 95 feet bgs. Assuming a 20% porosity and approximate surface area of about 1,190 acres. This gave a rough estimate of about 9,650 acre-feet of storage could be available, a more detailed assessment will be needed to confirm (Trout Unlimited, personal communication, 2023). Assuming a 1 to 2 cfs constant delivery/infiltration rate, a storage goal of about 396 to 792 acre-feet could be possible.

Anecdotal evidence from Acquavella Adjudication documents suggests that springs in the Cowiche Creek subbasin experienced higher flows during the irrigation season compared to the non-irrigation season. As such, it is anticipated that supplemented water will provide benefits within a relatively short time frame (weeks to months).

3.2.3 Parameters of Interest and Potential Sources

The parameters of interest are:

- Surface water elevation in SFCC
- Stream discharge seepage runs
- Streambed hydraulic gradient
- Water quality parameters: temperature, dissolved oxygen, specific conductance, pH, and oxidation/reduction potential
- Groundwater elevation in wells

Surface Water Elevation in SFCC

Measurements of surface water elevation in SFCC are required to assess the connectivity between surface water and ground water elevations and for computing stream gradient. Surface water will be measured at a minimum of 20 locations along SFCC to develop an elevation profile of the surface water from Snow Mountain Ranch to the confluence with NFCC. One round of surface water elevation measurements will be collected contemporaneously with groundwater elevations in wells during late summer (one round of surface water elevations is expected to be sufficient because fluctuations in creek stage are not expected to be significant enough to warrant two rounds). Water level elevations will be measured using a high-accuracy and high-precision Trimble GPS receiver system.

Stream Discharge Seepage Runs

Seepage runs consisting of contemporaneous streamflow measurements at 5 to 10 stations will be completed along the project reach to assess variations in discharge that will be used to identify stream reaches that are gaining from, or losing to, groundwater, or are neutral. Four rounds of seepage runs will be completed, with one round per season (spring, summer, autumn, winter) to assess seepage under different flow conditions.

Streambed Hydraulic Gradient

Shallow streambed hydraulic gradients will be measured relative to surface water contemporaneously with seepage runs to provide an additional line of evidence to identify gaining/losing/neutral reaches of the stream. This will be accomplished using a temporary hand-driven mini-piezometer at stations where discharge is measured during seepage runs. Mini-piezometers will consist of a 1-inch steel pipe with conical end point driven 2 to 3 feet into the streambed using a tee-post hammer. The lower portion of the pipe will be fitted with ¼-inch holes on 3-inch spacing to allow shallow hyporheic groundwater to enter. An electronic water level measurement tape (e-tape) will be used to measure the depth to water inside and outside of the mini-piezometer. A steel tape can also be used to measure water level outside of the mini-piezometer.

Water Quality Parameters

Limited water quality/water chemistry parameters will be collected contemporaneously with summer seepage runs to provide an additional line of evidence to identify gaining/losing/neutral reaches of the stream. Water quality parameters including temperature, dissolved oxygen, specific conductance, pH, and oxidation/reduction potential in surface water in the project reach will be measured in the field using a handheld YSI-556 water quality meter. Water quality parameters will be collected at up to 20 stations, including where discharge measurements are collected during seepage runs. Additionally, these water quality parameters will be field measured in groundwater pumped from three wells completed in the shallow aquifer to identify a water quality/chemistry profile to compare with measurements collected from surface water. No surface or groundwater water samples will be submitted for laboratory analysis.

Groundwater Elevation in Wells

Mapping the elevation of the groundwater in the shallow unconsolidated aquifer within the Study Area is required to assess groundwater-surface water interaction with SFCC. The resulting potentiometric surface maps will be used to identify groundwater flow directions and gradients and as an additional line of evidence to identify gaining/losing/neutral reaches of the stream. Groundwater elevations will be determined from static water levels measured in 10 to 20 wells completed in the shallow unconsolidated aquifer using an e-tape. The exact number of wells to be used will depend on property access. Groundwater levels will be collected in the spring and late summer. Up to three wells will be instrumented with pressure transducer dataloggers in the spring to continuously record seasonal water level fluctuations throughout the duration of the study. Wells will be selected for instrumentation based on representativeness of groundwater conditions in the shallow aquifer. Groundwater measuring point elevations (e.g., top of well casing) will be measured using a high-accuracy Trimble GPS receiver system.

3.2.4 Regulatory Criteria or Standards

Field work required to collect parameters of interest outlined in Section 3.2.3 of this QAPP is not subject to regulatory requirements. The feasibility study will identify important regulatory considerations for infiltrating to groundwater.

3.3 Water Quality Impairment Studies

N/A. This project is not a water quality impairment study.

3.4 Effectiveness Monitoring Studies

N/A. This project is not an effectiveness monitoring study.

4.0 Project Description

The project concept is to divert water from SFCC or the Tieton River during a high-flow period and convey it to an infiltration site for aquifer recharge. Managed aquifer recharge/shallow aquifer recharge (SAR) projects are highly dependent on the local hydrogeologic details, and thus this study is proposing this initial research/report to define these specific details and assess the project's feasibility. Specifically, this study proposes to evaluate whether the site is suitable for SAR and the extent that any SAR recharge might benefit streamflows in SFCC. This study will also analyze potential sources of recharge water (Tieton River system or Cowiche Creek) for the best legal and physical availability of fit for this project. Potential infiltration sites will be identified and evaluated.

Should water be sourced from the Tieton River, it may be conveyed via YTID's system to a SAR infiltration site. The unlined and unused historic portions of YTID canals provide a potentially cost-effective opportunity to repurpose them into SAR infiltration sites. At present, YTID lacks capacity to easily deliver water for SAR, so some level of system modifications and conveyance practice changes is anticipated. Capital improvement costs, operations and maintenance costs, and annual water delivery costs will be considered as part of this study.

4.1 Project Goals

The project will answer questions on the feasibility of supplementing the shallow aquifer in the study area to achieve stream ecosystem (flow/temperature) benefits. The collection, review, and synthesis of relevant data and some field work is required for project completion.

The project deliverables will consist of a draft and final hydrogeologic and engineering feasibility study report, files from limited hydrogeologic modeling, and geospatial information (e.g., GIS mapping files) suitable for importation to Ecology's Environmental Information Management (EIM) database. The final report will provide an evaluation of the feasibility of SAR to meet project goals and recommend next steps. It will include methods, analysis, results, conclusions, and detailed information on the hydrogeologic conceptual model.

The overall goal for SAR is to enhance streamflows by improving late season (late-July through September) flows in SFCC by ≥10%—at least 0.1 to 0.2 cfs near the confluence of the North-South Forks Cowiche Creek.

The goal of this study is to evaluate the feasibility of implementing SAR in the lower ~4 miles of SFCC to meet the overall streamflow enhancement goal. This includes:

- Characterizing of hydrogeology of the shallow aquifer to assess its suitability to infiltrate, store, and convey SAR augmentation water to SFCC
- Identifying SFCC reaches where SAR augmentation is expected to benefit streamflows and estimating potential benefits

- Identifying potential sources for SAR augmentation water and potential locations for SAR infiltration sites
- Identifying potential risks related to a SAR project

4.2 Project Objectives

Study goals will primarily be accomplished by developing a hydrogeologic conceptual model for the Study Area based on existing and newly collected data. The hydrogeologic conceptual model will be used to accomplish the following objectives:

- Characterize hydrogeology and estimate hydraulic properties of the shallow unconsolidated aquifer (Target Aquifer) including vertical infiltration rates for SAR, hydraulic conductivity, transmissivity; porosity; groundwater flow direction and gradient.
- Characterize thickness, composition, and properties of the vadose (unsaturated) zone overlying the existing water table within the Target Aquifer, including identification of strata influencing vertical and horizontal flow (coarse-grained and restrictive layers and shallow bedrock).
- Characterize groundwater-surface water interactions in SFCC to identify whether and where groundwater in the Target Aquifer discharges to the SFCC.
- Identify potential locations for SAR infiltration sites.
- Provide boundary conditions and input parameters for groundwater flow path modeling to estimate potential streamflow benefits (described in Section 4.4 of this QAPP).
- Preliminarily identify potential risks related to a SAR project, including water quality considerations and potential impacts of an elevated groundwater table on septic systems/drain fields, wells, low-lying property, and slope stability.

4.3 Information Needed and Sources

The study will utilize information from existing sources to develop a hydrogeologic conceptual model that will be updated throughout the study with newly collected data. Field-collected data and estimates derived from the hydrogeologic conceptual model will be used to develop a numerical groundwater flow model to predict the potential for streamflow augmentation. Sources of existing information include:

- Driller’s logs for wells in the study area (lithology, water level, yield, drawdown) in Ecology’s well log database
- Static water levels in groundwater wells at the time of drilling from driller’s logs in Ecology’s well log database
- Historic Streamflow measurements for SFCC and Cowiche Creek collected by WDFW, Ecology, and the United States Geological Survey (USGS)

- Previous hydrologic/hydrogeologic reports for the vicinity from USGS (e.g., Vaccaro et al., 2009)
- Topographic, LiDAR, and geologic mapping from Washington Department of Natural Resources (DNR) and USGS
- Water conveyance system information provided by YTID

Newly collected data will include:

- Parameters of interest described in Section 3.2.3 of this QAPP
- Well locations obtained from observations made from public rights-of-way for wells where landowner permission has not been obtained. These locations will be used in conjunction with LiDAR mapping to estimate wellhead elevations used to characterize hydrostratigraphy and develop stratigraphic cross sections. There are approximately 150 wells shown in Ecology's database within the Study Area

4.4 Tasks Required

Tasks required to collect necessary data outlined in Section 4.3 include:

- Compile and review driller's logs in Ecology's database. Organize logs by quarter-quarter section, completion unit, and completeness and clarity of recorded information. Identify logs containing sufficient information to determine the approximate location of the well (parcel number, address, etc.). Locate these wells in the field from public rights-of-way to estimate their coordinates on a map.

- Obtain permission from well owners and measure groundwater levels in a subset of up to 20 spatially distributed wells with preference on wells completed in the Target Aquifer. Groundwater levels will be measured in late summer and early to mid-spring. Measure elevations of groundwater level measurement points to support development of a potentiometric surface map.

- Install pressure transducer dataloggers in up to three wells to monitor seasonal groundwater level trends. Download data during subsequent site visits.

- Conduct four seepage runs on SFCC (one during each season) consisting of contemporaneous discharge measurements at up to 10 stations to identify gaining/losing/neutral reaches.

- Complete measurements of limited water quality parameters in SFCC using a handheld water quality meter and temporary installation of mini-piezometers at the discharge measurement stations to provide additional data for identifying gaining/losing/neutral reaches in SFCC.

- Complete measurements of limited water quality parameters from three wells completed in the Target Aquifer for hydrogeochemical profiling and comparison to surface water. Note that it might be also necessary to collect water quality measurements in three wells completed in bedrock for comparison to surface water.

- Compile and evaluate available historic streamflow data for SFCC and Cowiche Creek to characterize discharge trends.
- Conduct reconnaissance of YTID infrastructure and potential SAR infiltration sites.

4.5 Systematic Planning Process

Preparation of this QAPP shall be adequate systematic planning for this project.

5.0 Organization and Schedule

5.1 Key Individuals and Their Responsibilities

Project staff are listed below, along with their responsibilities and relevant expertise.

Table 1. Organization of project staff and responsibilities.

Staff[1]	Title	Responsibilities
Justin Bezold Trout Unlimited (509) 881-5464	Project Manager	• Clarifies scope of the project. • Provides internal review of the QAPP. • Approves the final QAPP as prepared for TU. • Approves the draft report and final report.
Gary Ashby, PE Forsgren Associates (208) 342-3144	Principal Investigator (Engineering)	• Reviews the QAPP. • Conducts QA review of data, analyzes and interprets data, and enters data into EIM. • Oversees field sampling of engineering components of the project. • Writes engineering components of the draft report and final report.
Bill Sullivan, LHG American Land and Water Consulting, LLC (509) 888-8081	Principal Investigator (Hydrogeologic)	• Writes the QAPP. • Conducts QA review of data, analyzes and interprets data, and enters data into EIM. • Oversees data collection and analysis of hydrogeologic and surface water components of the project. • Writes hydrogeologic components of the draft report and final report.
Jonathan Kohr WA Dept. of Fish and Wildlife Phone: (509) 307-2871	Field Assistant (Water Science Team)	• Performs streamflow survey to measure discharge in Cowiche Creek (e.g., seepage runs). • Reviews and confirms accuracy and completeness of data collected.
Jeff Dermond WA State Dept. of Ecology Phone: (509) 268-1784	OCR Project Manager (Hydrogeologist)	• Reviews the QAPP. • Reviews and confirms accuracy and completeness of hydrogeologic data collected. • Reviews the draft and final report.
Scott Tarbutton, LHG WA State Dept. of Ecology Phone: (509) 867-6534	Quality Assurance Coordinator (Hydrogeologist)	Reviews and approves the draft QAPP and the final QAPP.

5.2 Special Training and Certifications

A licensed engineer and a licensed hydrogeologist will be leading this project as principal investigators. All field staff involved in this study must have either the relevant experience in the required standard operating procedures (SOPs) or be trained and directly supervised by more senior field staff or the project manager who have the required experience. Any staff helping in the field who lack sufficient experience will always be paired with someone who has the necessary training and experience. The experienced staff will then lead the field data collection and oversee/mentor less-experienced staff.

5.3 Organization Chart

See Table 2. In addition to the people and organizations shown in Table 2, the feasibility study will be supported by staff from the CCC, YTID, and Yakama Nation. The YBIP Groundwater Subcommittee will also provide project feedback.

5.4 Proposed Project Schedule

Table 3 shows the proposed project schedule, organized by task.

Prior to conducting any field work, a kickoff meeting will be held among TU and the Consultants to review existing data sources and plans for field work. Additional meetings to discuss data collection and analysis will be scheduled, as needed, during the study.

Table 2. Proposed schedule for completing field and laboratory work and reports.

Field Work	Due Date	Lead Staff
Match driller's logs, field-locate wells, install pressure transducer dataloggers in wells	August 1, 2024	Bill Sullivan, LHG
Low-water groundwater level monitoring and limited water quality monitoring at wells	August/Sept. 2024 April 2025	Bill Sullivan, LHG
Elevation measurements of groundwater measurement points and surface water in SFCC	August/Sept. 2024	Bill Sullivan, LHG
Conduct seepage runs on SFCC (4 times)	August/Sept. 2024 (Summer) December 2024 (Autumn) February 2025 (Winter) April 2025 (Spring)	Bill Sullivan, LHG
Limited water quality monitoring and installation of temporary piezometers in SFCC	August/Sept. 2024	Bill Sullivan, LHG
Reconnaissance of YTID infrastructure and potential SAR infiltration sites	October 2024	Gary Ashby, PE
High-water groundwater level monitoring and limited water quality monitoring at wells	April 2025	Bill Sullivan, LHG

Field Work	Due Date	Lead Staff
Task Deliverables and EIM Database	**Due Date**	**Lead Staff**
Draft hydrogeologic conceptual model and narrative report	October 1, 2024	Bill Sullivan, LHG
Complete groundwater flow simulation modeling	November 1, 2024	Bill Sullivan, LHG
GIS mapping development of field data and analysis results	Jan. 31, 2025	Gary Ashby, PE
Input field data and GIS mapping to EIM	June 30, 2025	Gary Ashby, PE
Final Report with Recommendations	**Due Date**	**Lead Staff**
Draft due for internal review	Feb. 28, 2025	Gary Ashby, PE
Draft due to TU	March 31, 2025	Gary Ashby, PE
Final report due to TU	May 31, 2025	Gary Ashby, PE
Final report due to Ecology	June 30, 2025	Justin Bezold

5.5 Budget and Funding

Funding for this feasibility study is provided by Ecology's Office of Columbia River Grant No. WRYBIP-2325-TroUnl-00043. The following budget table is for tasks included in the grant agreement (Table 4). Contracted tasks addressed in this QAPP are shown in **bolded** text. These proposed task budgets will not be exceeded without written approval from Ecology.

Table 3. Project budget and funding.

Task / Description	Not-to-Exceed
1. Scope of Work Memo	$8,590
2. QAPP Preparation	$5,320
3. Hydrogeologic Conceptual Model Development	**$35,360**
4. Identify Potential SAR Infiltration Sites	$20,460
5. Assess Sources of Water	$9,070
6. Alternative Evaluation and Cost Estimating	$18,440
7. GIS Data/Database Development and Mapping/EIM Entry	**$18,080**
8. Reporting and Recommendations	$23,770
Equipment and Project Expenses	$10,000
Total	***$149,090***

6.0 Quality Objectives

6.1 Data Quality Objectives[1]

Quality objectives are statements of the precision, bias, and lower measurement limits necessary to meet the study objectives. Precision and bias together express data accuracy; whereas, other considerations include the representativeness, completeness, and comparability of the data.

The main data quality objective (DQO) for this project is to collect new and compile existing data sufficient to develop the hydrogeologic conceptual model and provide input to groundwater model simulations, which is described in Section 7. The analysis will use standard methods to meet measurement quality objectives (MQOs) that are described below.

6.2 Measurement Quality Objectives

The MQOs for the field investigation are described by the analytical methods and field equipment used to collect measurements, and the standard operating procedures employed to make description in the field (Table 5). MQOs for field data collection of parameters of significance listed in Section 3.2.3 of this QAPP are listed below.

Surface Water Elevations in SFCC

Surface water elevations will be measured at the water's edge in SFCC using a Trimble real-time kinematics (RTK) GPS receiver system capable of sub-centimeter precision. For the purposes of this study, acceptable accuracy will be no more than 0.5 feet for latitude/longitude and no more than 0.1 feet for elevation.

Stream Discharge Seepage Runs

Stream discharge measurements for seepage runs will be collected by WDFW's Stream Science Team that has extensive experience measuring streams in eastern Washington. The Stream Science Team uses methods established by the USGS (Rantz et al., 1982) and Ecology SOP EAP056. These methods establish an acceptable accuracy of +/- 10 percent for discharge. Based on site factors, staff will give the discharge measurement a qualitative accuracy rating of poor, fair, good, or excellent based on field staff's professional judgment of conditions potentially

[1] DQO can also refer to ***Decision*** Quality Objectives. The need to identify Decision Quality Objectives during the planning phase of a project is less common. For projects that do lead to important decisions, DQOs are often expressed as tolerable limits on the probability or chance (risk) of the collected data leading to an erroneous decision. And for projects that intend to estimate present or future conditions, DQOs are often expressed in terms of acceptable uncertainty (e.g., width of an uncertainty band or interval) associated with a point estimate at a desired level of statistical confidence.

affecting accuracy and the ability to achieve the accuracy goal. Under optimal conditions, discharge accuracy will be controlled by the accuracy of the electronic current flow meter used that is typically 5 percent (for example, Flow Tracker or similar acoustic doppler).

Streambed Hydraulic Gradient

An electronic measuring tape will be used to measure the hydraulic gradient of shallow hyporheic water (groundwater) in the streambed by measuring water levels inside and outside of temporary mini-piezometers. The Waterline e-tape to be used in this study has a measurement resolution of 0.01 feet. Acceptable accuracy is expected to be 0.02 feet. Accuracy of water measured outside of the mini-piezometer (stream water in SFCC) will be controlled by fluctuations on the surface of the stream water adjacent to the mini-piezometer.

Water Quality Parameters

The primary method for measuring water quality in the field will be a YSI-556 handheld meter. Table 5 summarizes the accuracy and resolution for temperature, DO, specific conductance, pH, and oxidation/reduction potential.

Groundwater Elevations in Wells

Groundwater levels in wells will be collected twice (spring and late summer) using a Waterline e-tape with measurement resolution of 0.01 feet. The e-tape will be used in accordance with Ecology's SOP EAP052 (*Manual Well-Depth and Depth-to-Water Measurements*; Marti, 2023). A measuring point (MP) will be added to the top of casing of each well location, using a thick Sharpie type pen, file, paint, marker, etc. Field staff will use these manual measurements as an accuracy check of water level data loggers and for the conversions to groundwater surface elevation. A precise elevation for the MP will be measured using a GPS as described for measuring surface water elevations (above).

Continuous water level monitoring in up to three wells will be collected throughout the study using a Van Essen TD Diver pressure transducer datalogger having 1.0-centimeter resolution. The TD Diver will be deployed in accordance with Ecology's SOP EAP074 (*Use of Submersible Pressure Transducers During Groundwater Studies*; Sinclair and Pitz, 2019). Expected accuracy for continuously recorded groundwater levels is 0.02 feet and acceptable accuracy will be no more than 0.25 feet. Note that water levels measured using the TD Diver will be barometrically compensated using a Van Essen Barologger barometric datalogger located within the study area. Table 5 summarizes the accuracy and resolution for the Barologger.

Table 4. Field Method MQOs and Field Equipment Information

Parameter	Equipment and Method	Bias (median)	Precision Field Duplicates (median)	Equipment Information			Expected Range
				Accuracy	Resolution	Range	
Air Monitoring (to correct for atmospheric changes influencing continuously monitored groundwater levels)							
Temperature	Van Essen Baro-Diver (D1800)	--	--	+/- 0.1°C	0.01°C	-20 to 80°C	-7 to 31°C
Barometric Pressure	Van Essen Baro-Diver (D1800)	--	--	+/- 0.5 cm H_20	--	1.5 m	757 to 767 mm Hg
Groundwater Level Measurements (in wells)							
Temperature	Van Essen TD-Diver (D1805)	--	--	+/- 0.1°C	0.01°C	-20 to 80°C	1 to 25°C
Pressure	Van Essen TD-Diver (D1805)	--	--	+/- 2.5 cm H_20	1.0 cm H_20	5,000 cm	5,000-20,000 cm
Depth to Water Table	Waterline Envirotech Electric Tape	--	--	0.01 ft	0.01 ft	--	0 to 100 ft
Water Quality Parameters (surface and groundwater)							
pH	YSI 556 MPS	--	--	0.2 SU	0.01 SU	0 to 14 SU	6.5 to 8.5 SU
Specific conductivity		--	--	±0.5%	0.001 mS/cm	0 to 200 mS/cm	0.1 to 1.0 mS/cm
Dissolved oxygen		--	--	±2%	0.1% air sat	0 to 50 mg/L	0 to 15 mg/L
Oxidation-Reduction Potential		--	--	±20 mV	0.1 mV	-1999 to +1999 mV	-300 to +300 mV
Temperature		--	--	±0.2°C	--	-5 to 45°C	1 to 25°C
Geographic Parameters							
Latitude, Longitude, and Elevation	Groundwater level measurement points and surface water stage in SFCC will be surveyed using a Trimble GNSS RTK receiver system including R10 base station receiver, R12i roving receiver, and S6 robotic total station capable of sub-centimeter precision (+/- 0.8 cm plus 1 ppm) and accuracy (+/- 2 cm plus 2 ppm). For these measurements, acceptable accuracy will be no more than 0.5 feet for lat/long and 0.1 feet for elevation, or 15.2 cm and 3.1 cm, respectively.						
Stream Discharge (in SFCC)							
Discharge	Acceptable accuracy for discharge measurements will be no more than 10% consistent with Ecology SOP EAP056						

6.2.1 Targets for Precision, Bias, and Sensitivity

Precision

Precision of manual groundwater level measurements collected using an e-tape will be established by recording two consecutive measurements spaced by 3 minutes. The threshold for acceptable groundwater level precision is no more than 0.02 feet change between the two measurements for static water level measurements. A water level MP will be discreetly marked by a “V” shape using a permanent pen and noted to ensure consistency among measurements. If there is evidence of movement of a groundwater well MP the location will be resurveyed.

Precision of points surveyed using the Trimble GPS receiver listed in Table 5 (well MPs and surface water in SFCC) will be assessed based on the ability to obtain acceptable solutions determined by the GPS’s installed software.

Precision in stream discharge measurements during seepage runs will be maximized by adhering to established procedures, using consistent discharge measurement stations, and, to the extent possible, using the same field staff. Discharge measurement stations will be selected based on the likelihood that they can be used at various stream stages during the four planned seepage runs. Post-processing of discharge data provides another opportunity to assess precision.

Bias

Field staff will minimize bias in field measurements by calibrating instruments daily before use and following field measurement protocols to ensure operational consistency. Potential sources of field bias in measurements include locations selected for measurement, measurement procedure, and calibration problems.

Bias in groundwater level measurements, recorded by the pressure transducer datalogger, will be assessed by comparing manual measurements of the distance between the top of casing and the water surface upon installation in a well and at the time of downloading data.

Bias of water quality parameters measured using a handheld YSI-556 multi-parameter meter will be assessed during daily calibration of the instrument, by observing readings during field work to identify any erroneous or unexpected results, and by conducting one field check during deployment for pH and specific conductance using standard calibration solutions.

Bias in stream discharge measurements during seepage runs will be assessed by ensuring adherence to established discharge measurement procedures and that the electronic current velocity meter has been calibrated and remains operational.

Sensitivity

Sensitivity is a measure of the capability of the field method and instrument used to detect a change or substance. It is described by its resolution. This is usually reported for each instrument by the manufacturer. This information is provided in Table 5.

For the purposes of this effort, sensitivity is assessed relative to the magnitude of expected changes in the measured parameter. The following instruments have manufacturer-listed sensitivities that are less than the magnitude of expected change in the measured parameter: e-tape and pressure transducers for groundwater level measurements, GPS for elevation measurements, water quality meter, and current velocity meter for stream discharge measurements.

6.2.2 Targets for Comparability, Representativeness, and Completeness

Comparability

Factors that influence comparability between studies can include the availability and extent of previous data, training of field staff, field data-collection similarities (location, duration, time of year, weather conditions, etc.), SOPs, and instrumentation. Field staff will adhere to common field protocols and all field measurements will follow SOPs listed in this QAPP to improve comparability between this and similar studies.

Within this monitoring effort, data will be comparable across various timeframes based on synchronous data collection timing (e.g., water level).

Variations in annual climate make it difficult to compare water level data over a short timeframe, but the aim is that monitoring data collection will support the detection of implementation effects on stream discharge, groundwater levels, and groundwater storage that are beyond inter-annual climate variability.

Representativeness

Representativeness is a function of individual study design. Representativeness is largely limited by project budget forcing decisions to be made regarding which data to collect, where, and how often to collect it. For the purpose of this project, data collection parameters, locations, and timing were carefully selected to maximize representativeness of each environmental parameter to support a comprehensive feasibility assessment of SAR implementation. We expect that a sufficient number of environmental parameters and locations for data collection in SFCC are established to provide a multiple-lines-of-evidence approach to identifying stream reaches that are gaining/losing/neutral with regards to groundwater. This characterization of the stream will be key to estimating where SAR augmentation water will benefit the stream and by how much. Likewise, numbers of wells where groundwater levels will be measured is expected to be sufficient to map the potentiometric surface and characterize hydrogeologic conditions, provided that spacing of these wells is appropriately distributed throughout the study area. As for timing, data collection taking place in the spring/early summer was chosen to profile higher water level conditions in groundwater and surface water while late summer measurements target low water conditions when SAR augmentation will be most beneficial.

Completeness

The U.S. Environmental Protection Agency (EPA) has defined completeness as a measure of the amount of valid data needed to be obtained from a measurement system to meet project objectives (Lombard and Kirchmer, 2004). The goal for the study is to correctly collect and analyze data for all parameters from 100 percent of the field data collection locations. However, problems occasionally arise during data collection, such as site access problems or equipment malfunction that cannot be controlled. This project has been designed to accommodate some data loss and still meet project goals and objectives; thus, a completeness of 80% is expected to be acceptable for discrete measurements. If equipment fails or a site cannot be accessed, staff will attempt to recollect the data under similar conditions, such as the following day, if possible.

For continuous deployed measurements (pressure transducers installed in wells), additional variables can negatively impact completeness including vandalism/theft/tampering, equipment failure, unacceptable fouling or drift, and unpredictable events. For these reasons, a completeness of 80% is acceptable for continuous measurements. Given these difficulties, redundancy is an important component when designing studies with continuous data collection, particularly at important boundary conditions and within the most critical areas. Redundancy will be achieved by deploying instruments in three wells.

If completeness targets are not achieved, staff will determine whether the data that were successfully collected are sufficient to meet project needs/acceptable standards. This will depend on a number of factors, such as the needs of the analysis framework, and the times and locations where data were lost. If successfully collected data are not sufficient, then one or a combination of the following approaches will be used:

- Estimate missing data values from existing data, if this can be done with reasonable confidence.
- Conduct targeted additional sampling to fill data gaps (budget permitting).
- Re-collect all or a portion of data (budget permitting).

If completeness targets are not met, the study report will analyze the effect of the incomplete data on meeting the study objectives, account for data completeness (or incompleteness) in any data analyses, and document data completeness and its consequences in any study reports.

6.3 Acceptance Criteria for Quality of Existing Data

No co-located groundwater data currently exist for the study area. Limited surface water discharge data are available for SFCC. These data will be analyzed using the same acceptance criteria as for newly collected discharge data of no more than +/- 10 percent. These data will also be analyzed for completeness to determine their usability for the study.

6.4 Model Quality Objectives

This project will include limited environmental modeling to estimate the potential for SAR infiltration to benefit streamflows in SFCC meeting project goals. A groundwater simulation modeling software, MODFLOW-based GSFLOW, is expected to be used based on input parameters from new data collected during this study and development of the hydrogeologic conceptual model. While the hydrogeologic conceptual model will be a combination of qualitative and quantitative characterization, simulation modeling will be numerical. Acceptance criteria for field-collected environmental parameters previously discussed were selected so that they will be appropriate to be used as model input. Input derived from the hydrogeologic conceptual model (e.g., boundary conditions, aquifer thickness, etc.) will be evaluated based on the professional judgement of a hydrogeologist consistent with study area conditions and literature values. The precision and accuracy of model output will be evaluated and adjusted through an iterative approach including sensitivity analysis. Acceptable criteria for model output will consider completeness and quality of input data, error, goodness-of-fit with observed conditions, and level of uncertainty. The following model quality objectives apply:

- Output should be consistent with the hydrogeologic conceptual model that will be based on field data and applicable literature values where data are absent. Specifically, numerical model output should be consistent with potentiometric mapping (elevations, gradients), observed locations of gaining/losing/neutral stream reaches, hydrostratigraphy, and surface water locations/elevations.

- Output should be consistent with input parameters including volumes, rates, and timing of simulated SAR augmentation infiltration events.

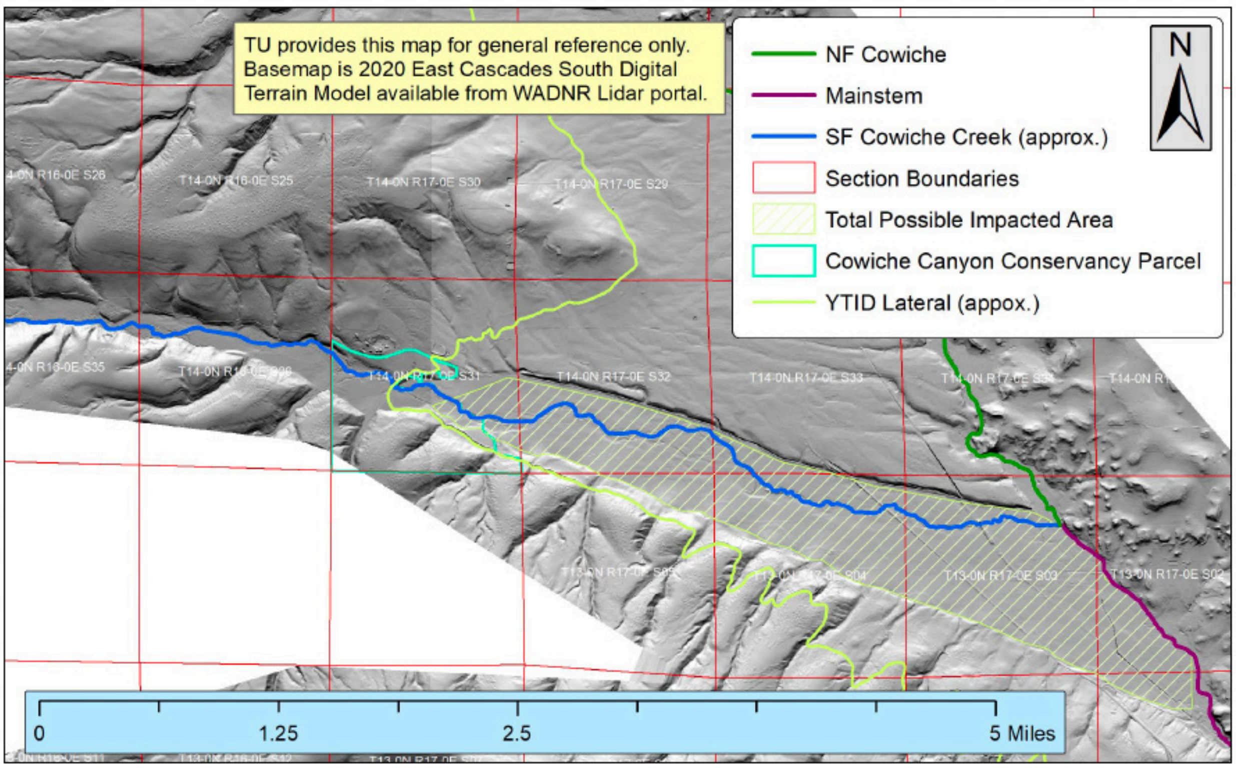
- Changes in modeled output should be consistent in magnitude with changes to input parameters made during iterative simulations.

7.0 Study Design

7.1 Study Boundaries

The overall project area covers about 1,190 acres of the SFCC valley floor downstream from the CCC's Snow Mountain Ranch to the confluence with the NFCC (Figure 3). The focus area for recharge is a former YTID lateral crossing of CCC's Snow Mountain Ranch. The Study Area boundary is expected to follow the groundwater divide of the shallow unconsolidated aquifer that generally lies within 0.5 mile of each side of SFCC. The Study Area was determined based on preliminary review of topographic and geologic mapping and well logs in Ecology's database.

Figure 3. Map showing approximate boundary of project study area using the 2020 Digital Terrain Model from WA DNR LiDAR portal and historic ditches/laterals (still present on the landscape) relative to the South and North Forks and the mainstem of Cowiche Creek and the CCC's Snow Mountain Ranch (S. 31, T. 14 N., R 17 E.W.M.). Figure credit: Trout Unlimited.



7.2 Field Data Collection

Field data will be used to develop a hydrogeologic conceptual model that will be used to inform model simulations using a USGS MODFLOW-based system (GSFLOW or similar) to estimate groundwater residence time in the shallow aquifer, groundwater flow paths, and potential stream augmentation rates.

The types and numbers of field data to be collected were determined based on preliminary review of available data in the Study Area that mostly consists of water well logs in Ecology's database. Preliminary review of information listed in well logs indicates:

1. An unconsolidated layer of sediment overlies bedrock across most of the Study Area.
2. The unconsolidated layer is saturated in places forming a shallow aquifer (primarily near the center of the Study Area and near the stream).
3. Most wells in the Study Area are completed in bedrock.

7.2.1 Sampling Locations and Frequency

The first step of the data collection project is to identify specific measurement locations as described below and obtain permission from property owners. Once the measurement locations where groundwater levels and stream flows, etc. can be readily measured are established, the terrain at each location will be examined to determine the appropriate equipment installation and/or method.

Measurement frequency was selected to meet project goals considering available budget. Spring and late summer are particularly important periods for data collection. Spring is expected to be the time when surplus water is most likely available for SAR infiltration and groundwater levels are expected to be highest. Late summer is when SAR augmentation can provide the greatest benefit to streamflows (TU, 2023) and groundwater levels are expected to be near their lowest.

Some parameters only need to be measured once during the study to obtain complete and representative data while other parameters require multiple measurements. Groundwater level monitoring will occur twice, in late summer and spring, to characterize expected low and high groundwater conditions, respectively. A small subset of wells will be instrumented to continuously monitor water levels through the study. Seepage runs will be conducted during each season of the year to characterize the various discharge rates and contribution of baseflow from groundwater relative to surface water runoff. Data from limited water quality monitoring and temporary installation of mini-piezometers will be collected once, during late summer. The contrast between groundwater and surface water (measured primarily by differences in temperature) is expected to be greatest during the late summer low flow period.

Groundwater level measurement collection will occur in up to 20 wells once in spring (April) and late summer (August-September) to capture high and low water conditions. Locations of groundwater level monitoring wells will be determined based on preliminary development of the hydrogeologic conceptual model with preference to wells that are completed in the Target Aquifer. Three wells completed in the Target Aquifer will be fitted with a pressure-transducer datalogger to continuously record seasonal groundwater level trends through the study. All wells will be selected based on spatial distribution and representativeness of conditions within the Target Aquifer.

Seepage runs will be conducted once during each season for 1 year (summer, autumn, winter, spring). Seepage runs will occur at 10 stations along the lower 4 miles of SFCC. The planned number of stations will maximize characterization groundwater-surface water interactions in the stream while limiting the effort by field staff to a single day during each season. Precise station locations will be determined in the field based on access and suitability for measuring discharge. Stream measurement locations will be as equally spaced as possible to supporting identifying reaches that are potentially gaining/losing/neutral.

Field staff conducting seepage runs will be briefed on any known or suspected locations of diversions, springs, and any tributaries and will inventory any of these observed in the field noting their attributes (pump size, pipe diameter, flow rate, etc.). Where diversions, springs, and tributaries appear to be withdrawing/contributing more than about 0.2 cfs, field staff will attempt to collect additional discharge measurements immediately above and below these features to quantify their impact on streamflow.

Limited water quality measurements and temporary piezometer installation will occur once in the summer at up to 20 locations in SFCC including locations of stream measurement stations.

7.2.2 Field Parameters and Laboratory Analytes to be Measured

No samples will be submitted for laboratory analysis. The following measurements will be collected in the field within the study area:

- Surface water stage/elevation will be measured at a minimum of 20 locations along SFCC to develop an elevation profile of the surface water from Snow Mountain Ranch to the confluence with NFCC.
- Seepage runs consisting of contemporaneous streamflow discharge measurements at 5 to 10 stations will be completed along the project reach to assess variations in discharge that will be used to identify stream reaches that are gaining from or losing to groundwater, or are neutral. WDFW's Stream Science Team will complete seepage runs using methods established by the United States Geological Survey (Rantz et al., 1982) and Ecology SOP EAP056 (Shedd, 2018a).
- An electronic measuring tape will be used to measure the hydraulic gradient of shallow hyporheic water (groundwater) in the SFCC streambed by measuring water levels inside and outside of temporary mini-piezometers installed and decommissioned using methods established in SOP EAP061 (Sinclair and Pitz, 2018).
- Limited water quality parameters will be measured in the field using a YSI 556 multi-parameter instrument. Water quality parameters will be collected at up to 20 stations in SFCC including where discharge measurements are collected during seepage runs and in three wells. The following water quality parameters will be measured:
    - Water Temperature
    - Dissolved Oxygen

    - Specific Conductivity
    - pH
    - Oxidation/reduction potential

    It is acknowledged that pH and dissolved oxygen are particularly prone to changes resulting from processes other than groundwater seepage. During analysis, these data will be evaluated for their utility in identifying gaining/losing/neutral reaches based on conditions observed in the field and in the context of other collected data.

- Static water level elevations will be measured in 10 to 20 groundwater wells using Ecology SOPs EAP052 (Marti, 2023) and EAP074 (Sinclair and Pitz, 2019).

7.3 Modeling and Analysis Design

The work described in this QAPP does not involve creating new simulation modeling software. Rather, it involves developing and applying an existing model, GSFLOW, which was selected because it is publicly available and routinely used as a hydrogeologic modeling software tool.

Environmental simulation models are simplified mathematical representations of complex real-world systems. Models cannot accurately depict the multitude of processes occurring at all physical and temporal scales. Models can, however, make use of known interrelationships among variables to predict how a given quantity or variable would change in response to a change in an interdependent variable or forcing function. In this way, models can be useful frameworks for investigating how a system would likely respond to a perturbation from its current state.

This study will include limited numerical modeling to predict the extent that SAR could enhance streamflows in SFCC. Modeling will be applied to assess the feasibility of using potential SAR infiltration sites identified during the study. Modeling will be used to estimate groundwater mounding at infiltration sites, flow paths, travel times, and rates of discharge from potential SAR infiltration sites to SFCC. Follow-up numerical modeling is expected to be required to support design of a SAR project, which is beyond the scope of the feasibility study.

7.3.1 Analytical Framework

GSFLOW is a coupled groundwater and surface-water model based on the integration of the USGS Precipitation-Runoff Modeling System (PRMS-V) and the USGS Modular Groundwater Flow Model (MODFLOW-2005 and MODFLOW-NWT). GSFLOW was developed as MODFLOW module to simulate groundwater/surface-water interactions in one or more watersheds by simultaneously simulating flow across the land surface and within subsurface saturated and unsaturated materials. An important aspect of GSFLOW is the ability to conserve water mass and provide water budgets. Required inputs to GSFLOW include boundary conditions (barriers, inputs/outputs to the system), climatic data, groundwater stresses (inputs/outputs).

Inputs to modeling will primarily be based on the hydrogeologic conceptual model and applicable literature values where data are absent. Inputs will include boundary (e.g., flow boundary, constant head boundary), hydrostratigraphy, hydraulic properties (e.g. vertical infiltration rates, hydraulic conductivity), and recharge/discharge conditions of the Target Aquifer. Other model inputs will include spatial features derived from GIS (e.g., land surface elevations), climatic data, locations of potential SAR infiltration sites, and volumes, rates, and timing of water applied for infiltration. Potential locations for SAR infiltration sites will be identified considering multiple factors including hydrogeology, engineering elements, property ownership, etc.

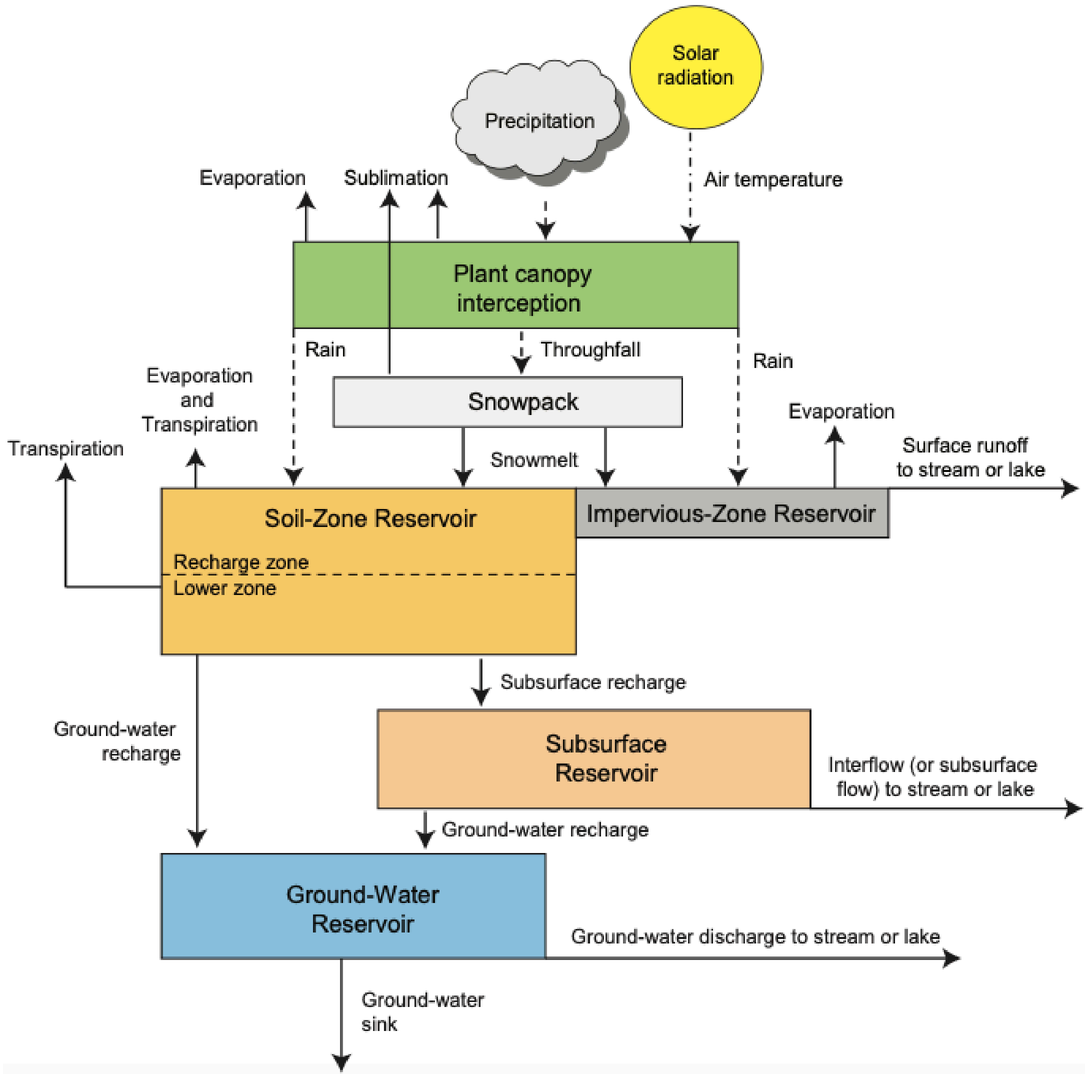
Output values will be discharge volumes of SAR augmentation water seeping to the stream over a time step (averaged and converted to a rate in cubic feet per second).

GSFLOW simulates hydrogeologic conditions within three general regions of a watershed:

- Plant canopy to bottom of soil zone
- Subsurface zone beneath the soil zone
- Streams and lakes

A simplified illustration of the surface runoff, interflow, and groundwater discharge components modeled by GSFLOW is shown on Figure 4.

Figure 4. Schematic diagram of a watershed and its climate inputs (precipitation, air temperature, and solar radiation). Figure credit: USGS.



GSFLOW software, documentation, and additional resources are available from the USGS at: https://www.usgs.gov/software/gsflow-coupled-groundwater-and-surface-water-flow-model.

The software is packaged for personal computers using one of the Linux or Microsoft Windows operating systems and supported by the USGS. Instructions for installation, execution, and testing of GSFLOW are provided at: https://water.usgs.gov/water-resources/software/gsflow/Readme.txt.

7.3.2 Model Setup and Data Needs

The model will be developed within the Study Area that is bounded by topography and groundwater divides defining the shallow unconsolidated Target Aquifer. Specific areas where the model will be developed and applied have not yet been defined. These will be determined based on study findings including development of the hydrogeologic conceptual model (aquifer thickness, boundary conditions, etc.), identification of gaining/losing/neutral reaches in SFCC, and identification potential SAR infiltration sites. The spatial extent of the modeled area will encompass the SAR infiltration site and the expected flow path to the stream reach where SAR augmentation water is expected to seep to the stream. Factors to be used in determining required grid size include 1) density of available data (e.g., groundwater level measurement points used to develop the potentiometric map) and 2) location and length of stream reach targeted for augmentation.

At a minimum, temporal application of modeling will include annual simulations of SAR infiltration (expected to begin in the spring and run through early summer) and SAR streamflow augmentation during low flows (late summer). Daily to weekly time steps are expected to be adequate to yield desired predictions. It is recognized that SAR infiltration might initially be required for 1 or more years to "prime" the Target Aquifer before annual infiltration events result in steady-state streamflow augmentation. This could require running multi-year simulations.

Input requirements for GSFLOW and specific input parameters that will be used in developing the model are listed in Section 7.3.1. Data collection needed to define input parameters and assess the model quality objectives are described in Sections 7.2.1 and 7.2.2.

7.4 Assumptions Underlying Design

The Study assumes field staff will have access to nearby groundwater wells, Cowiche Creek, public and private property, and the recommended water level and streamflow monitoring equipment. The Study is also dependent on the availability and completeness of existing streamflow discharge data for SFCC, regional groundwater reports, and groundwater data (e.g., well logs) supporting statistical analysis.

7.5 Possible Challenges and Contingencies

7.5.1 Logistical Problems

Site conditions that interfere with measurement collection may occur during field work. This could include the inability to install pressure transducers or measure water levels due to property access, well conditions (such as well obstructions or damage), or to measure stream flow during certain conditions (such as very high discharge). Incomplete well log data or well log records can also inhibit development of a hydrogeologic conceptual model. Water well logs in Ecology's database have been preliminarily examined for potential construction issues and current conditions will be assessed in the field. No issues have been identified to date that would preclude installing water level monitoring equipment, collecting groundwater level measurements, or completing stream flow measurements for seepage runs.

7.5.2 Practical Constraints

Practical constraints that can interfere with a project include scheduling problems with personnel, equipment failure, or availability of adequate resources—both human and budgetary. Additional constraints may arise related to availability of materials and equipment needed to monitoring groundwater. Constraints associated with data collection include the distribution of groundwater wells within the study area, lack of access to wells completed in the target aquifer, and physical access to stream reaches to take discharge measurements needed to determine gaining/losing analysis.

7.5.3 Schedule Limitations

Scheduling complications could arise for unforeseen reasons related to availability of staff due to illness or injury or to the limited availability of equipment due to loss, theft, or damage, or from inability to arrange access to private property in advance of planned field collection activities.

8.0 Field Procedures

8.1 Invasive Species Evaluation

For in-water work, field staff will use Ecology's SOP EAP070, Version 2.3, *Minimize the Spread of Invasive Species* (Parsons, 2023), to minimize the risk of spreading any organisms—especially aquatic invasive species (AIS)—within or between waterbodies or other field sites as a result of fieldwork, reconnaissance activities, or other operations.

Field staff will minimize the spread of invasive species after conducting field work by:

- Inspecting and cleaning all equipment by removing any visible soil, vegetation, vertebrates, invertebrates, plants, algae, or sediment. If necessary, a scrub brush will be used and then rinsed with clean water either from the site or brought for that purpose. The process will be continued until all equipment is clean.
- Draining all water in samplers or other equipment that may harbor water from the site. This step will take place before leaving the sampling site or at an interim site. If cleaning after leaving the sampling site, field staff will ensure that no debris will leave the equipment and potentially spread invasive species during transit or cleaning.

Staff will be given laminated sheets outlining the above steps for inclusion in their field books. Staff will follow established Ecology procedures if an unexpected contamination incident occurs.

8.2 Measurement and Sampling Procedures

The procedures used in this study are typical for hydrogeologic investigations:

- Ecology Publication #96-02, *Implementation Guidance for the Ground Water Quality Standards* (Ecology, 1996)
- Guidelines Establishing Test Procedures for the Analysis of Pollutants contained in 40 CFR Part 136
- SOP EAP052, Version 1.2, *Manual Well-Depth and Depth and Depth-to-Water Measurements* (Marti, 2023)
- SOP EAP074, Version 1.2, *Use of Submersible Pressure Transducers During Groundwater Studies* (Sinclair and Pitz, 2019)
- SOP EAP056, Version 1.3: *Measuring and Calculating Stream Discharge* (Shedd, 2018a)
- SOP EAP061, Version 2.1: Installing, Monitoring, and Decommissioning Hand-driven In-water Piezometers (Sinclair and Pitz, 2018)
- SOP EAP098, Version 1.1: Collecting Groundwater Samples for Metals Analysis from Water Supply Wells (Pitz, 2019)

8.2.1 Groundwater Level Monitoring

Prior to commencing field work, property owners of groundwater level measuring and sampling locations will be contacted for permission to access the site and collect measurements. We anticipate coordinating with Cowiche Canyon Conservancy to assist with this task. If permission to a site is not granted, or if the site appears to be unfeasible upon talking with the property owner or field inspection, then an alternate site providing similar representative hydrologic conditions will be pursued for sampling. Sampling may be considered unfeasible if one of the following criteria is not met:

- Well drillers report (well log) must be available for drilled wells. This requirement does not apply to hand-dug wells that will likely not have well logs available.
- Water levels will only be collected in wells that are easily accessed for water level measurements; however, a well will not necessarily be eliminated from sampling based on water level access.
- For up to three wells where water quality parameters will be measured, well should have an easily accessed, non-treated spigot for water quality sampling. The sampling spigot should not draw water from storage that cannot be by-passed or purged during sampling.

Water levels will be monitored in 10 to 20 wells using an e-tape. Pressure-transducer data loggers will be used for continuous water level (and temperature) monitoring in up to three wells. Water level measurements and sampling will occur twice: spring/early summer and late summer. Water levels should be collected using an e-tape with engineer's scale accurate to a hundredth of a foot (0.01 feet). A permanent measuring point (MP) from which all depth-to-water/water levels will be measured must be established for each well to ensure data comparability.

Establish a permanent measuring point (MP) via the method below:

1. MPs are normally established on the top rim of the actual well casing; this position is commonly referred to as "top of casing" (TOC). Locate the MP at a convenient place from which to measure the water level. If the TOC is level, collect the measurement from the north edge.

2. Clearly mark the MP. The MP must be as permanent as possible and be clearly visible and easily located. The MP may be marked using a permanent black marker, bright colored paint stick, or with a notch filed into the TOC.

3. Describe the position of the MP clearly in the field-data sheets.

4. The MP height is established in reference to a land surface datum (LSD). The LSD is generally chosen to be approximately equivalent to the average altitude of the ground surface around the well. For the purpose of this study, the elevation of the MP will be

measured directly where possible using a high-accuracy GPS receiver. Where the MP cannot be directly measured, the LSD will be determined using a GPS.

5. Measure the height of the MP in feet relative to the LSD. Generally, MPs are established to the nearest 0.1 feet using a pocket tape to measure the distance from the MP to the LSD. Note that values for measuring points that lie below land surface should be preceded by a minus sign (-). Record the height of the MP and the date it was established.

6. MPs and the LSD may change over time, the distance between the two should be checked whenever there have been activities, such as land development that could have affected either the MP or LSD at the site. Such changes must be measured as accurately as possible, documented and dated in field-data sheets, and in any database(s) into which the water-level data are entered.

All subsequent water level measurements should be referenced to the MP. The MP value will be used to convert measurements into elevation values that are relative to land surface.

For each aboveground well:

1. Open the top of the well and note any popping sounds that would indicate pressure buildup, any odors, and the condition of the well head. Look and listen for indications that the pump may be running to avoid measuring water level during drawdown.

2. If there is a pressure transducer attached to the well cap carefully note the initial position of the cap (mark cap position on casing with permanent marker).

3. If the well was airtight, wait a few minutes for the water level to return to equilibrium with atmospheric pressure.

4. Turn the water level meter on and slowly lower the probe into the well until it makes a tone indicating contact with the water level. To confirm contact with the distinct water boundary, slowly raise and lower the electric-tape probe in and out of the water column. If necessary, adjust the sensitivity setting of the meter to provide a “crisp” indication of the water surface. Measure the depth to water against the MP and mark down the date and time the reading was made.

5. At the precise location the indicator shows contact with the water surface, pinch the tape between your fingernails at the MP. Read the depth-to-water.

6. Repeat measurement to ensure that the water level is stable (not rising or falling over time). Wait 3 minutes between measurements. Static water can be determined when water level is changing no more than +/- 0.02 feet.

7. Turn the water level meter off and lower the probe to the bottom of the well and collect a total depth measurement. Make note of whether the bottom contact feels hard or soft to determine if sediment is accumulating at the bottom of the well. When the probe is pulled back up, make a note of any mud, staining, or anything else on the tip. Before moving on to the next well, decontaminate the probe with a phosphorus-free detergent and brush or paper towel, then rinse with distilled water.

When measuring depth to water in small-diameter (<2 inches) wells, select an electric tape with a small probe. Large probes can raise the static water level in a well by displacing the water. On occasion, condensation on the interior casing wall and probe can prematurely trigger the electric-tape indicator giving a false positive reading. In this situation it can help to center the tape in the well casing above the water level and lightly shake the tape to remove the excess water on the probe.

8.2.2 Stream Stage Measurement

We do not anticipate installing a stream stage staff plate during this study; however, this field description is included to support WDFW's Stream Science Team installing a staff plate for future data collection in SFCC. By doing this, WDFW will be able to take advantage of discharge/stage measurements collected during this study that could be used to develop a rating curve. Stream stage should be measured to an accuracy of ±0.01 foot with staff gages. Staff gages will be affixed to a rigid object such as a fence post driven into the streambed, or other appropriate equipment installation. Measurements will be made in a manner consistent with Ecology's SOP EAP042, Version 1.1, *Measuring Gage Height of Streams (Historical)* (Shedd, 2018b).

8.2.3 Stream Discharge Measurements

For wade-able streams, discharge is measured using the 6/10s method (Rantz, 1982), which assumes that mean stream velocity occurs at 60 percent of depth below the surface. Stream velocity is measured at the 60 percent depth at about 20 stations across the channel. An open-reel tape marked in tenths of feet should be used for measuring station locations across the channel section. The tape should begin on the left bank looking upstream. Velocity measurements should be taken from left to right. Transect locations should be selected to minimize turbulence, avoid eddies, and be wade-able for the stream conditions encountered. Locations where water flows beneath an overhanging stream bank should also be avoided.

Discharge is calculated as:

$$Q = \sum_{i=1}^{n} \frac{v_i\,(x_{i+1} - x_{i-1})\, d_i}{2}, \text{ where}$$

Q = discharge,

i = station number,

n = number of stations,

x_i = station position,

v_i = measured velocity at station i, and

d_i = depth at station i.

8.2.4 Temporary Mini-Piezometer Installation and Measurement

Hand-driven drive-point mini-piezometers will be temporarily installed to depth of 2 to 3 feet into the streambed to measure vertical gradients between shallow hyporheic groundwater and surface water (reference SOP EAP061). Wherever possible, mini-piezometers should be driven to a depth of 3 feet depending on substrate. Mini-piezometers will consist of a 5-foot section of threaded 1-inch diameter steel pipe with the driven end forged into a wedge shape to minimize refusal. The bottom 1.5 feet of the pipe will be fitted with ¼-inch holes on two sides spaced 0.3 feet apart.

- Select a location where surface water in the stream is relatively laminar to avoid large surface water measurement fluctuations. Water depth <1 foot is generally desired to avoid running out of room to drive the mini-piezometer.

- Attach a sacrificial steel coupler to the non-driving end of pipe. Drive the mini-piezometer into the streambed to a depth of 2 to 3 feet using a tee-post hammer. The holes in the end of the mini-piezometer should be well within the substrate (1 foot) to allow entry of shallow groundwater but not surface water.

- Remove the steel coupler using a pipe wrench. Using an e-tape, measure the depth of water inside the pipe to the nearest 0.01 feet at a marked MP located on the top of the threaded section. Measure the surface water in the stream with the e-tape or steel measuring tape using the marked MP. Record measurements.

- Using a pipe wrench, if necessary, extract the mini-piezometer from the streambed by twisting and pulling.

8.2.5 Pressure Transducer Installation

Water-level in groundwater will be recorded by pressure transducers with onboard data loggers at three wells (SOP EAP074; Sinclair and Pitz, 2019). Dataloggers will be downloaded during each site visit. Guidance for the installation and use of pressure transducers is presented below.

1. Manually measure water level and total depth in the well using an e-tape.

2. Suspend the transducer in the water column using thin, stainless steel cable or non-elastic cord or manufacture's communication cable made of inert material secured to the well head.

3. Install the pressure transducer as low as possible in the well to ensure the pressure transducer captures as much water level change possible. Do not rest it on the bottom.

4. The transducer should be attached by securing it to some immobile piece of the well casing or well cap. Tuck the cable end into the well casing and secure to the well casing with zip-ties necessary to prevent it from falling into the well.

5. Program the pressure transducers to collect a reading on 15-minute intervals.

6. Measure the depth-to-water using an e-tape and record. Compare manual water level to barometrically compensated water level recorded by the datalogger at the time the manual measurement was taken and record.

7. During subsequent site visits, download datalogger by connecting communication cable to laptop. Do not reprogram or start/stop the datalogger unless necessary. Gently tuck the communication cable end into the well casing. Continue with steps 6 and 9.

8. Measure the depth-to-water prior to pressure transducer removal to quantify potential movement of the transducer or transducer drift. Accurately record date and time prior to transducer removal, download, and reinstallation.

9. Replace the well cap.

10. Install one dedicated pressure transducer as a barometric datalogger in a protected, drained location in the study area (e.g., a tree). The sensor will collect barometric readings of atmospheric pressure, which allows water pressure to be isolated from total pressure recorded by the submerged transducers. This is accomplished within the Diver program when both pressure transducer and barometric data are downloaded. The barometer should be the first transducer installed and the last to be downloaded during subsequent site visits to avoid creating data gaps in the data record.

8.2.6 Water Quality Parameter Measurements

Water quality parameters will be measured in the field using the YSI-556 multi-parameter sensor in accordance with manufacturer's specifications. See attached YSI manual in Appendix B for detailed instructions on calibration, logging measurements, and other operation. For surface water in SFCC, place the YSI probe directly into the flowing water to obtain measurements. For groundwater in wells, sample from a yard spigot (after first recording static water level) that is located upstream from any water treatment (softener, etc.). Attach the YSI probe to a flow-through cell to connected to the spigot. Prior to recording water quality parameters, allow readings to stabilize as shown below. If readings do not stabilize, make a note and attempt to collect a new reading at a nearby location and consider re-calibrating the instrument for the unstable parameter.

Field parameters are considered stable when three consecutive readings fall within the following criteria (SOP EAP 098):

- pH ± 0.1 standard units
- Specific Conductance ± 10.0 µmhos/cm for values < 1000 µmhos/cm and ± 20.0 µmhos/cm for values > 1000 µmhos/cm
- Dissolved Oxygen ± 0.05 mg/L for values < 1 mg/L and ± 0.2 mg/L for values > 1 mg/L
- Temperature ± 0.1° Celsius
- ORP ± 10 millivolts

8.3 Containers, Preservation Methods, Holding Times

N/A. No samples will be collected, preserved, or held as part of this study.

8.4 Equipment Decontamination

Electrical water meter and sampling equipment will be decontaminated between wells using an industry standard, non-phosphorus detergent and rinsed with distilled water. Refer to Ecology's SOP EAP090, *Decontamination of Sampling Equipment for Use in Collecting Toxic Chemical Samples* (Friese, 2021).

8.5 Sample ID

N/A. No samples will be collected, preserved, or held as part of this study.

8.6 Chain of Custody

N/A. No samples will be collected, preserved, or held as part of this study.

8.7 Field Log Requirements

Field logs shall be maintained by the field staff. Digital copies shall be provided to the respective Principal Investigator (engineering or hydrogeology) following completion of each sampling event.

A field log is an important component of many projects. It is used to record irreplaceable information, such as:

- Name and location of project

- Field personnel
- Sequence of events
- Any changes or deviations from the QAPP
- Environmental conditions
- Date, time, location, ID, and description of each sample
- Field instrument calibration procedures
- Field measurement results
- Identity of QC samples collected, if applicable
- Unusual circumstances that might affect interpretation of results

Best practices for field logs consist of the following:

- Use field logs that are bound, waterproof notebooks with pre-numbered pages.
- Use permanent, waterproof ink for all entries.
- Make corrections with single line strikethroughs; initial and date corrections. Do not use correction fluid such as White-Out.
- Electronic field logs may be used if they demonstrate equivalent security to a waterproof, bound notebook.

8.8 Other Activities

No other activities not included under previous sections are anticipated at this time.

9.0 Laboratory Procedures

N/A. No samples will be collected, preserved, or held for laboratory analysis as part of this study.

9.1 Lab procedures table

9.2 Sample preparation method(s)

9.3 Special method requirements

9.4 Laboratories accredited for methods

10.0 Quality Control Procedures

Quality control (QC) will be applied to statistical procedures to evaluate and control the accuracy of measurement data. Data collected in the field will be evaluated as soon as possible following monitoring events to confirm accuracy.

Verification of accurate records of sampling site ownership/contact information and well logs will be checked prior to commencing and will be confirmed during field work.

For well-monitoring sites, all drilled wells should have a well log available to meet sampling site selection criteria. To confirm well logs are accurately matched to well in the field, information contained in well log records will be checked against site ownership records, a field inspection of the well, and information gathered by speaking with the property owner.

All field measurement equipment will be inspected prior to use to verify that they are working properly. Field meters will be calibrated in accordance with manufacturer's instructions at the beginning of the sampling day. Calibration solutions will be checked to ensure that they are fresh. Additionally, all devices will be thoroughly cleaned using the decontamination procedures described in Section 8 to preclude contaminant introduction into wells and to prevent cross-contamination between sampling sites. This includes all nondedicated sampling equipment (Y-fittings, hoses and tubing). Electronic water level indicators will be checked to confirm they have fresh batteries and water levels in wells will be recorded to the nearest 0.01-foot, with at least two successive measurements being made at each well, recorded a minimum of 3 minutes apart. The difference between measurements should not exceed 0.02-foot.

Standardized field forms will be used to describe all field procedures and to record data collected in the field.

10.1 Table of Field and Laboratory Quality Control

Staff will perform the following QC procedures on instrumentation to be used in the field: Pre and post calibration on field instrumentations.). To minimize bias, the following instruments will undergo a calibration check for the following parameters prior to and following deployment in the field.

- **Temperature:** The procedures for pre- and post-calibration described in SOP EAP080.
- **Pressure:** The procedures for pre- and post-calibration described in SOP EAP074.
- **Water Quality Parameters:** The procedures for pre- and post-calibration described in the YSI-556 manual (Appendix B).
- **Stream Flow (Velocity):** The procedures for pre- and post-calibration described in SOP EAP056. In addition, refer to velocity meter manufacturer recommendations for field QC checks.

No samples will be collected, preserved, or held as part of this study.

10.2 Corrective Action Processes

It is important to measure groundwater levels when they are static (not rising during recover or lowering during drawdown). Should a groundwater-level measurement be unexpectedly high or low, with comparison to previous measurements, the measurement will be collected again at that location to verify. Upon verification, if the measurement remains unexpectedly high or low, further analysis and investigation will ensue:

1. Water levels in other project area wells or streams will be analyzed for a trend in rise or loss of water level. In wells, pumping at the monitoring well or a nearby well can cause water levels to be drawn down or recover upon cessation of pumping.

2. Investigation for changes in the surrounding system will ensue.

3. If the analysis of other measurements have not explained the high or low water level measurement, the measurement will be flagged as "suspect."

4. If subsequent measurements confirm the water level and it can be confirmed in the field that there is no potential for a false reading, then it will be included in the analysis. An exception would be if there were a large pumping well in the vicinity that is causing drawdown over a relatively large area involving the monitoring well. This condition can be inferred by observing the vicinity of the monitoring well or by comparing water levels at the end of irrigation season when pumping has stopped (for irrigation wells).

5. If subsequent measurements do not confirm the measurement, or if the possibility of a false reading cannot be ruled out, the data will be flagged as "unusable."

Should a stream discharge measurement be significantly higher or lower than expected relative to a previous measurement collected at similar stream stage, consider the following:

1. Review recorded data in notes or software including velocity and depth measurements for each section to identify any anomalies, review numbers of sections in order to confirm there are no missing or duplicate measurements and confirm that the number and width of sections is appropriate for the given stream width.

2. Identify any visible inputs (e.g., tributaries) or outputs (e.g., diversions) to the stream present between the measurement station in question and the nearest upstream station.

Should water quality parameter measurements be significantly higher or lower than expected relative to a previous measurement collected in the same water source on the same day:

1. Repeat the measurement.

2. Repeat the purging procedure (for wells)

3. Verify that the water source is not impacted by external factors. Verify that the sample spigot is not drawing water from a water softener (for wells). Note that this step should be completed upon the initial site visit when determining whether and where to sample groundwater. For surface water, verify that the measurement is not being collected at location that is significantly different than others (e.g., in aerated water, shallow water, etc.)

4. Complete instrument calibration for the parameter in question.

11.0 Data Management Procedures

Field data will be recorded using the format described in Section 8.7 of this QAPP. Field data and notes and QC documentation will be entered into electronic format (MS Word and MS Excel spreadsheets) as soon as practicable after returning from the field. Field notes will be scanned and archived. All electronic documents will be backed up to a secure data-storage archive (i.e., a cloud-based server).

11.1 Data Recording and Reporting Requirements

For each location, data from each measurement event will be entered into a spreadsheet for subsequent data analysis and exported into a geographic information system (GIS) or other software applications that can be uploaded to Ecology's EIM (MS Excel). Data will be reviewed prior to upload to EIM. The measurement data will be reviewed in conjunction with field logs/notes to avoid transcription errors. Likewise, surveyed benchmark coordinates and elevations will be entered and reviewed. Comments regarding water and well access or other field-specific information will be entered. Copies of raw field notes will be retained.

11.2 Laboratory Data Package Requirements

N/A. No samples will be collected or analyzed as part of this study.

11.3 Electronic Transfer Requirements

N/A. No samples will be collected or analyzed as part of this study.

11.4 EIM/STORET Data Upload Procedures

Staff will formulate and submit all data funded by Ecology into Ecology's EIM data system using Study ID: WRYBIP-2325-TroUnl-00043. Staff will use EIM templates found in the EIM help center (https://apps.ecology.wa.gov/eim/help/HelpDocuments) to submit data including, location of cross-sections and wells, water level and temperature time-series data, and well water-level data.

11.5 Model Information Management

Electronic copies of the model input, output, and supporting files shall be maintained on a cloud-based server in a task subdirectory (subject to regular system backups). Final versions of modeling files shall be provided to Ecology for archiving at the completion of the project.

12.0 Audits and Reports

12.1 Field Audits

Regular and timely review of field data and monitoring measurements will be completed to ensure conformance with this QAPP and to make adjustments to the project approach as more information becomes available or as conditions change.

Initial audits will be conducted by field staff upon returning from data collection efforts. A qualitative technical systems audit will be completed by the Consultant's Project Manager after field data are uploaded and stored electronically. This will be completed following each field data collection. These post-field work audits should include a review and comparison of field notes and electronic files to ensure accuracy and completeness and to review notes that could explain any discrepancies or missing data. Quantitative values (e.g., water level measurements) should be compared to expected results and results of previous field work completed for the study.

A record of completion of audits will be maintained by the Project Manager and results will be discussed at the next update meeting with TU. Records should include the date of the audit, persons conducting the audit and field work, and notes describing any discrepancies or anomalous data, missing data, or data that was not collected in accordance with this QAPP or established procedures.

12.2 Responsible Personnel

Audits will be completed by the principal investigators for their area of expertise amongst the three general components of this study:

- Bill Sullivan – Hydrogeology
- Gary Ashby – Engineering
- Jonathan Kohr – Streamflow Discharge Measurements

12.3 Frequency and Distribution of Reports

See Table 2 for reporting deadlines. During the project kickoff, TU and the Consultants confirmed responsibility and schedule for reporting milestones. See Table 3 in Section 5.4.

12.4 Responsibility for Reports

Report writing will be the responsibility of the Contractors and approved by Justin Bezold of TU and Jeff Dermond of Ecology. Gary Ashby will be responsible for Engineering reporting prepared by Forsgren; Bill Sullivan will be responsible for Hydrogeologic reporting prepared by American.

13.0 Data Verification

Data verification is the process of evaluating the completeness, correctness, and conformance/compliance of a specific data set against the method, procedural, or contractual requirements.

13.1 Field Data Verification, Requirements, and Responsibilities

All data shall be verified prior to data analysis, distribution to an outside party, or posting to a publicly accessible database. The data shall be examined in detail to ensure that the MQOs for the project have been met.

The field lead is responsible for in-field data verification. Field data shall then be reviewed within 1 week of data collection. Data verification should be performed by a qualified person different from the field staff who generated the data.

Multiple lines of evidence will be used to confirm groundwater/surface water interactions and potential for SAR to benefit streamflows including seepage runs, water quality parameters, static water levels, and other parameters. Photographs of stream conditions will be used as additional lines of evidence and to support verification of field measurements. Measurements downloaded from pressure transducer data loggers in wells shall be checked against manual measurements.

Following data entry verification, staff will perform a quality analysis verification process on all raw field measurement data to evaluate the performance of the sensors used. Field measurement data may be adjusted for bias or drift (increasing bias over time) based on the results of fouling, field, or standards checks following general USGS guidelines (Wagner, 2007) and this process:

Review Discrete Field QC Checks

1. Review post-check data for field QC check instruments, reject data as appropriate.

2. Assign a quality rating to the field check values (excellent, good, fair, poor) based on the post-check in Table 12 of Ecology’s Programmatic Water Quality QAPP (McCarthy and Mathieu, 2017).

Review/Adjust Time Series (Continuous) Data

1. Plot raw time series with field checks. Reject data based on deployment/retrieval times, site visit disruption, blatant fouling events (e.g., well pumping), and sensor/equipment failure.

2. Review sensor offsets for both pre-calibration and post-deployment buffer/standard checks and against manual water level measurements in wells. Flag any potential chronic drift or bias issues specific to the instrument.

3. If applicable, review fouling check and make drift adjustment if necessary. In some situations, an event fouling adjustment may be warranted based on abrupt changes in streamflow, stage, sediment loading, well pumping, etc.

4. Review residuals from both field checks and post-checks, together referred to as QC checks. Adjust data as appropriate, using a weight-of-evidence approach. Give the most weight to post-checks with NIST standards, then field checks rated excellent, then good, and then fair. Do not use field checks rated poor. Potential data adjustments include:

    a. Bias – Data are adjusted by the average difference between the QC checks and deployed instrument. Majority of QC checks must show bias to use this method.

    b. Regression – Data adjusted using regression, typically linear, between QC checks and deployed instrument. This accounts for both a slope and bias adjustment. The regression must have at least 5 data points and an R2 value of >0.95 to use for adjustment. Do not extrapolate regressions beyond the range of the QC checks.

    c. Calibration/Sensor Drift – Data adjusted using linear regression with time from calibration or deployment to post-check or retrieval. Majority of QC checks, particularly post checks, must confirm pattern of drift. Typically, choose the adjustment that results in the smallest residuals and bias between the adjusted values and QC checks. Best professional judgement and visual review are necessary to confirm adjustment.

5. If the evidence is weak, or inconclusive, do not adjust the data.

6. It will be noted in the final report if any data is adjusted. Data adjustment must be performed or reviewed by a project manager, or personnel, with the appropriate training and experience in processing raw sensor data.

13.2 Laboratory Data Verification

N/A. No samples will be collected or analyzed as part of this study.

13.3 Validation Requirements, if necessary

N/A. No samples will be collected or analyzed as part of this study.

13.4 Model Quality Assessment

This study will include limited hydrologic modeling to estimate residence time, time of travel, and impact of SAR augmentation water on streamflow in SFCC using the MODFLOW-based GSFLOW.

13.4.1 Calibration and Validation

The model will be calibrated and verified/validated by running iterative simulations based on input derived from field data and the hydrogeologic conceptual model and comparing results to observed conditions. Goodness-of-fit will be determined by comparing modeling results to the mapped potentiometric surface (groundwater head, flow direction, gradient), measured surface water elevations in SFCC, land surface elevations from LiDAR, inferred stratigraphy, and stream discharge measurements and records. Model calibration/validation will be furthered by running sensitivity analyses to determine the degree of sensitivity of modeled results from ranges of measured and inferred input parameters. Uncertainty will be noted where applicable. Acceptable model results will minimize violations of observed conditions.

13.4.1.1 Precision

Model precision is usually assessed by comparing the “absolute distance” between modeled results and field measurements representing a similar time and location (positive and negative differences will be treated the same). Examples of metrics for precision include relative percent difference (RPD), relative standard deviation (RSD), and the root mean square error (RMSE) between paired modeled and observed results. Model precision will be assessed by comparing the magnitude of change in output values among iterations (e.g., volume or rate of groundwater seepage to the stream, timing or location of seepage) relative to the magnitude of change to input (e.g., infiltration rate, distance from stream). Iterations will be run by changing one input parameter at a time.

13.4.1.2 Bias

Bias is also usually assessed by comparing modeled results to field measurements from a similar time and location. However, bias is indicated by the average shift between the two (positive and negative differences “cancel out”) which helps determine how much precision deviates from being equally balanced. Metrics for bias include the mean error (average of paired observed-modeled values) or the percent error (average of paired observed-modeled values divided by observed value), using actual values and not absolute values. Bias will be assessed by evaluating input data derived from the hydrogeologic conceptual model (e.g., boundary conditions, completeness and quality of potentiometric or hydrostratigraphic data from well logs) and input parameters such as timing or duration of infiltrating augmentation water.

13.4.1.3 Representativeness

This study has been designed, within limitations of the budget, to provide sufficient field-collected data (e.g., groundwater levels in 20 wells) to support the limited modeling goals of the study of estimating groundwater residence time and degree of streamflow augmentation from SAR infiltration. Data collected in SFCC and in wells combined with other sources of data (e.g., stratigraphy listed in well logs) will be used to develop a hydrogeologic conceptual model that will be used to develop input parameters for simulation modeling that are expected to have a satisfactory degree of representativeness for groundwater conditions in the shallow aquifer and creek in the study area. Additionally, data will be collected during two different seasons/hydrologic regimes to characterize conditions when water might be diverted for SAR infiltration (spring/early summer) and when it is needed to augment the stream (late summer). Representativeness of the data, and thus the model, will be confirmed by comparing iterative simulations to observed conditions.

13.4.1.4 Qualitative assessment

Qualitive assessment of the model's precision, bias, and representativeness will be described based on results of simulations, degree of validation/goodness-of-fit, and other factors including field observations captured in notes (e.g., if a nearby large irrigation well is pumping), irrigation practices. and diurnal fluctuations in streamflow resulting from evapotranspiration.

13.4.2 Analysis of Sensitivity and Uncertainty

Sensitivities analyses will be completed and uncertainty will be both qualitatively and quantitatively estimated as described above. Analytical data will be compiled and evaluated against the project MQOs. Analytical precision will be evaluated using standard statistical techniques (relative percent difference [RPD], standard deviation [s], pooled standard deviations [sp], or percent relative standard deviation [%RSD]), as appropriate.

14.0 Data Quality (Usability) Assessment

14.1 Process for Determining Project Objectives Were Met

Following data verification, data will be assessed for usability in analysis.

1. Data will be assessed to confirm they meet the MQOs established in this QAPP.
2. Outlier data points and questionable data will be identified.
3. Field notes and other lines of evidence will be examined, consistent with the approach described above, to determine validity of outlier data.
4. Any data excluded from the analysis will be noted in data displays.
5. Data will be presented for analysis and reporting in the form of tables and charts. Anticipated displays include streamflow data for seepage runs in SFCC; water quality and mini-piezometer data identifying gaining/losing reaches in SFCC; well hydrographs for continuously monitored wells; streamflow hydrographs to assess water availability in SFCC, hydrostratigraphic cross sections and potentiometric surface maps and supporting groundwater elevation measurement data.

14.2 Treatment of Non-Detects

N/A. No samples will be collected or analyzed as part of this study.

14.3 Data Analysis and Presentation Methods

Data shall be saved as electronic files that can be used amongst members of the project team. Microsoft Office software (Excel, Word, and Powerpoint) will be the preferred methods for data analysis, reports, and presentations.

14.4 Sampling Design Evaluation

The project manager will assess, based on the input from technical experts, whether 1) the data package meets the MQOs, and criteria for completeness, representativeness, and comparability, and 2) meaningful conclusions can be drawn from data visualizations and summary statistics.

Given that the monitoring effort is designed to test and provide a feasibility assessment for the effectiveness of SAR infiltration to augment streamflow, the sampling/measurement design will be considered effective if the data are collected and are analyzed as intended resulting in a conclusive determination of SAR feasibility.

The sampling design presented in the QAPP also considers the data needs of analytical tools that will be used to complete future analysis, including potential additional numerical modeling and to support regulatory permitting. These efforts will likely require a subsequent QAPP. Compliance with this QAPP helps ensure that data collected during this project will be satisfactory to support use of future modeling/study tools and will meet project goals and objectives.

14.5 Documentation of Assessment

The data usability assessment will be documented in the final report.

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16.0 Appendices

Appendix A Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

Ambient: Background or away from point sources of contamination. Surrounding environmental condition.

Anthropogenic: Human-caused.

Bankfull stage: Formally defined as the stream level that "corresponds to the discharge at which channel maintenance is most effective, that is, the discharge at which moving sediment, forming or removing bars, forming or changing bends and meanders, and generally doing work that results in the average morphologic characteristics of channels (Dunne and Leopold, 1978).

Baseflow: The component of total streamflow that originates from direct groundwater discharges to a stream.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

Designated uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each water body or segment, regardless of whether or not the uses are currently attained.

Diel: Of, or pertaining to, a 24-hour period.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

Diurnal: Of, or pertaining to, a day or each day; daily. (1) Occurring during the daytime only, as different from nocturnal or crepuscular, or (2) Daily; related to actions which are completed in the course of a calendar day, and which typically recur every calendar day (e.g., diurnal temperature rises during the day, and falls during the night).

Effective shade: The fraction of incoming solar shortwave radiation that is blocked from reaching the surface of a stream or other defined area.

Fecal coliform (FC): That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform bacteria are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

Geometric mean: A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from 10 to 10,000 fold over a given period. The calculation is performed by either: (1) taking the nth root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

Hyporheic: The area beneath and adjacent to a stream where surface water and groundwater intermix.

National Pollutant Discharge Elimination System (NPDES): National program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Near-stream disturbance zone (NSDZ): The active channel area without riparian vegetation that includes features such as gravel bars.

Nonpoint source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface-water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Nutrient: Substance such as carbon, nitrogen, and phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Reach: A specific portion or segment of a stream.

Riparian: Relating to the banks along a natural course of water.

Salmonid: Fish that belong to the family *Salmonidae*. Species of salmon, trout, or char.

Sediment: Soil and organic matter that is covered with water (for example, river or lake bottom).

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Streamflow: Discharge of water in a surface stream (river or creek).

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and water courses within the jurisdiction of Washington State.

Synoptic survey: Data collected simultaneously or over a short period of time.

System-potential channel morphology: The more stable configuration that would occur with less human disturbance.

S**ystem-potential mature riparian vegetation:** Vegetation which can grow and reproduce on a site, given climate, elevation, soil properties, plant biology, and hydrologic processes.

System-potential riparian microclimate: The best estimate of air temperature reductions that are expected under mature riparian vegetation. System-potential riparian microclimate can also include expected changes to wind speed and relative humidity.

System-potential temperature: An approximation of the temperatures that would occur under natural conditions. System potential is our best understanding of natural conditions that can be supported by available analytical methods. The simulation of the system-potential condition uses best estimates of *mature riparian vegetation, system-potential channel morphology, and system-potential riparian microclimate* that would occur absent any human alteration.

Thalweg: The deepest and fastest moving portion of a stream.

Total suspended solids (TSS): Portion of solids retained by a filter.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

1-DMax or 1-day maximum temperature: The highest water temperature reached on any given day. This measure can be obtained using calibrated maximum/minimum thermometers or continuous monitoring probes having sampling intervals of thirty minutes or less.

303(d) list: Section 303(d) of the federal Clean Water Act, requiring Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited estuaries, lakes, and streams that fall short of state surface water quality standards and are not expected to improve within the next two years.

7-DADMax or 7-day average of the daily maximum temperatures: The arithmetic average of seven consecutive measures of daily maximum temperatures. The 7-DADMax for any individual day is calculated by averaging that day's daily maximum temperature with the daily maximum temperatures of the three days before and the three days after that date.

7Q2 flow: A typical low-flow condition. The 7Q2 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every other year on average. The 7Q2 flow is commonly used to represent the average low-flow condition in a water body and is typically calculated from long-term flow data collected in each basin. For temperature TMDL work, the 7Q2 is usually calculated for the months of July and August as these typically represent the critical months for temperature in our state.

7Q10 flow: A critical low-flow condition. The 7Q10 is a statistical estimate of the lowest 7-day average flow that can be expected to occur once every ten years on average. The 7Q10 flow is commonly used to represent the critical flow condition in a water body and is typically calculated from long-term flow data collected in each basin. For temperature TMDL work, the 7Q10 is usually calculated for the months of July and August as these typically represent the critical months for temperature in our state.

90th percentile: An estimated portion of a sample population based on a statistical determination of distribution characteristics. The 90th percentile value is a statistically derived estimate of the division between 90% of samples, which should be less than the value, and 10% of samples, which are expected to exceed the value.

Acronyms and Abbreviations

BMP	Best management practice
CCC	Cowiche Canyon Conservancy
DO	(see Glossary above)
DOC	Dissolved organic carbon
e.g.	for example
Ecology	Washington State Department of Ecology
EIM	Environnemental Information Management database
EPA	U.S. Environnemental Protection Agency
et al.	and others
FC	(see Glossary above)
GIS	Geographic Information System software
GPS	Global Positioning System
MQO	Measurement quality objective
NFCC	North Fork Cowiche Creek
QA	Quality assurance
QC	Quality control
RM	River mile
SAR	Shallow aquifer recharge
SFCC	South Fork Cowiche Creek
SOP	Standard operating procedures
TIR	Thermal infrared radiation
TOC	Total organic carbon
TSS	(See Glossary above)

USFS	United States Forest Service
USGS	United States Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area
YTID	Yakima Tieton Irrigation District

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second or cubic foot per second
cfu	colony forming units
cms	cubic meters per second, a unit of flow
dw	dry weight
ft	feet
g	gram, a unit of mass
kcfs	1,000 cubic feet per second
kg	kilograms, a unit of mass equal to 1,000 grams
kg/d	kilograms per day
km	kilometer, a unit of length equal to 1,000 meters
l/s	liters per second (0.03531 cubic foot per second)
m	meter
mm	millimeter
mg	milligram
mgd	million gallons per day
mg/d	milligrams per day
mg/kg	milligrams per kilogram (parts per million)
mg/L	milligrams per liter (parts per million)
mg/L/hr	milligrams per liter per hour
mL	milliliter
mmol	millimole or one-thousandth of a mole
mole	an International System of Units (IS) unit of matter

ng/g	nanograms per gram (parts per billion)
ng/kg	nanograms per kilogram (parts per trillion)
ng/L	nanograms per liter (parts per trillion)
NTU	nephelometric turbidity units
pg/g	picograms per gram (parts per trillion)
pg/L	picograms per liter (parts per quadrillion)
psu	practical salinity units
s.u.	standard units
µg/g	micrograms per gram (parts per million)
µg/kg	micrograms per kilogram (parts per billion)
µg/L	micrograms per liter (parts per billion)
µm	micrometer
µM	micromolar (a chemistry unit)
µmhos/cm	micromhos per centimeter
µS/cm	microsiemens per centimeter, a unit of conductivity
ww	wet weight

Quality Assurance Glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data. For Ecology, it is "Formal recognition by (Ecology)…that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin, 2010).

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms *precision* and *bias* be used to convey the information associated with the term *accuracy* (USGS, 1998).

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella (Kammin, 2010).

Bias: The difference between the sample mean and the true value. Bias usually describes a systematic difference reproducible over time and is characteristic of both the measurement system and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI) (Kammin, 2010; Ecology, 2004).

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process (USGS, 1998).

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured (Ecology, 2004).

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards but should be referred to by their actual designator, e.g., CRM, LCS (Kammin, 2010; Ecology, 2004).

Comparability: The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator (USEPA, 1997).

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator (USEPA, 1997).

Continuing Calibration Verification Standard (CCV): A quality control (QC) sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run (Kammin, 2010).

Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system (Kammin, 2010; Ecology 2004).

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean, action limits at +/- 3 standard deviations from the mean (Kammin, 2010).

Data integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading (Kammin, 2010).

Data quality indicators (DQI): Commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity (USEPA, 2006).

Data quality objectives (DQO): Qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions (USEPA, 2006).

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010).

Data validation: An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability, and integrity, as these criteria relate to the usability of the data set. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

- Use of raw or instrument data for evaluation.
- Use of third-party assessors.
- Data set is complex.
- Use of EPA Functional Guidelines or equivalent for review.

Examples of data types commonly validated would be:

- Gas Chromatography (GC).
- Gas Chromatography-Mass Spectrometry (GC-MS).
- Inductively Coupled Plasma (ICP).

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

- No qualifier – data are usable for intended purposes.
- J (or a J variant) – data are estimated, may be usable, may be biased high or low.
- REJ – data are rejected, cannot be used for intended purposes.
  (Kammin, 2010; Ecology, 2004).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set (Ecology, 2004).

Detection limit (limit of detection)**:** The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero (Ecology, 2004).

Duplicate samples: Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis (USEPA, 1997).

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport (Ecology, 2004).

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples (Kammin, 2010).

Laboratory Control Sample (LCS): A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples (USEPA, 1997).

Matrix spike: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects (Ecology, 2004).

Measurement Quality Objectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness (USEPA, 2006).

Measurement result: A value obtained by performing the procedure described in a method (Ecology, 2004).

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed (EPA, 1997).

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples (Ecology, 2004; Kammin, 2010).

Method Detection Limit (MDL): This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero (Federal Register, October 26, 1984).

Percent Relative Standard Deviation (%RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

$$\%RSD = (100 * s)/x$$

where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin, 2010).

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all parameters (Kammin, 2010; Ecology, 2004).

Population: The hypothetical set of all possible observations of the type being investigated (Ecology, 2004).

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator (USGS, 1998).

Quality assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data (Kammin, 2010).

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives (Kammin, 2010; Ecology, 2004).

Quality control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data (Ecology, 2004).

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

$$[Abs(a-b)/((a + b)/2)] * 100$$

where “Abs()” is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled (USGS, 1998).

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator (USGS, 1998).

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population (USGS, 1998).

Sample (statistical): A finite part or subset of a statistical population (USEPA, 1997).

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit (Ecology, 2004).

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method (USEPA, 1997).

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method’s recovery efficiency (USEPA, 1997).

Split sample: A discrete sample subdivided into portions, usually duplicates (Kammin, 2010).

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity (Kammin, 2010).

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis (Kammin, 2010).

Systematic planning: A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning (USEPA, 2006).

References for QA Glossary

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Appendix B YSI 556 MPS Operations Manual