# Quality Assurance Project Plan

# Kennewick Irrigation District Groundwater Storage Assessment

May 2025

State of Washington Department of Ecology
Office of Columbia River
Agreement No. WRYBIP-2325-KennID-00056

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# Publication Information

Each study conducted by the Washington State Department of Ecology (Ecology) must have an approved Quality Assurance Project Plan (QAPP). The QAPP describes the objectives of the study and the procedures to be followed to achieve those objectives.

This QAPP was prepared by a licensed geologist. A signed and stamped copy of the report is available upon request. This QAPP is available via Ecology's publication database and upon request. The Ecology publication number for this QAPP is 25-12-009. This QAPP is valid through May 14, 2030.

Field data collected for this project will be uploaded to Ecology's Environmental Information Management (EIM) database under Study ID: WRYBIP-2325-KennID-00056

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# Contact Information

The authors for this QAPP can be contacted as follows:
Silas Sleeper, LG, Aspect Consulting, (206) 453-6058, Silas.Sleeper@aspectconsulting.com
Tyson Carlson, LHG, Aspect Consulting, (509) 895-5923, Tyson.Carlson@aspectconsulting.com

For more information contact:

Jeff Dermond
Project Manager – Office of Columbia River
1250 W Alder St, Union Gap, WA 98903
Phone: (509) 268-1784

Washington State Department of Ecology – https://Ecology.wa.gov

- Headquarters, Olympia 360-407-6000
- Northwest Regional Office, Bellevue 425-649-7000
- Southwest Regional Office, Olympia 360-407-6300
- Central Regional Office, Union Gap 509-575-2490
- Eastern Regional Office, Spokane 509-329-3400

**Cover photo**: Irrigated agriculture in Badger Coulee. (Photo by: Kennewick Irrigation District).

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Ecology OCR Agreement Number: WRYBIP-2325-KennID-00056

Published July 2024

Approved by:

| | |
|---|---|
| Signature: | Date: 5/13/25 |
| Silas Sleeper, LG, Professional Geologist, Aspect Consulting, Co-Author | |
| Signature: | Date: 5/13/25 |
| Tyson Carlson, LHG, Sr. Principal Hydrogeologist, Aspect Consulting, Principal Investigator | |
| Signature: | Date: 5/13/25 |
| Daniel Tissell, P.E., Engineering Manager, Kennewick Irrigation District, Project Manager | |
| Signature: | Date: 05/15/25 |
| Jeff Dermond, Office of Columbia River, Project Manager | |
| Signature: McKenna Murray | Date: 05/15/25 |
| McKenna Murray, Office of Columbia River, Quality Assurance Coordinator | |

# 1.0 Table of Contents

# List of Figures



# List of Tables

# 2.0 Abstract

This Quality Assurance Project Plan (QAPP) was prepared by Aspect Consulting (Aspect) for the Kennewick Irrigation District (KID) to outline the procedures for data collection to support a groundwater storage assessment (Study) on the surficial unconsolidated aquifer within KID's service area (specifically Badger Coulee). The geographic, hydrogeologic setting, and existing infrastructure of the KID service area indicate that Badger Coulee may be a suitable location for groundwater storage. Groundwater storage has the potential to address multiple goals of the Yakima Basin Integrated Plan (YBIP), including drought resiliency and expansion of both instream and out of stream uses.

The proposed Study aims to refine the hydrogeologic conceptual model of Badger Coulee's unconsolidated aquifer system from previous studies. The refined hydrogeologic conceptual model includes a comprehensive water budget analysis, documentation of the physical characteristics contributing to groundwater storage, and the legal framework surrounding the use of artificially recharged groundwater.

In addition, the Study will also focus on the assessment of site-specific locations within Badger Coulee for recharge via managed aquifer recharge (MAR) as one mechanism of groundwater recharge. During the preliminary phases of this Study KID has identified several potential MAR locations. These MAR locations take advantage of the existing water delivery infrastructure (canals and ponds) that could be incorporated into a future aquifer recharge program.

We expect the Study will rely largely on existing information supported by targeted field work of potential MAR sites. The proposed field work includes infiltration testing, collection of discharge measurements, and water level monitoring.

# 3.0 Background

## 3.1 Introduction and problem statement

Groundwater storage has the potential to address multiple goals of the Yakima Basin Integrated Plan (YBIP), including drought resiliency and expansion of both instream and out of stream uses.

Badger Coulee has long been identified as a potential location for MAR due to its favorable geographic and hydrogeologic setting. In 2019 the YBIP Groundwater Subcommittee allocated funds (to Central Washington University) to complete a geochemical evaluation of groundwater and surface water within Badger Coulee to inform future groundwater storage projects.

This study is the second YBIP-funded groundwater storage project in Badger Coulee. The purpose of this study is to build on the existing work (completed by Central Washington University) including the advancement of both the basin-wide concepts (e.g., recharge regimes, groundwater storage potential, and the hydrogeologic conceptual model) and the site-specific identification and assessment of MAR locations.

## 3.2 Study area and surroundings

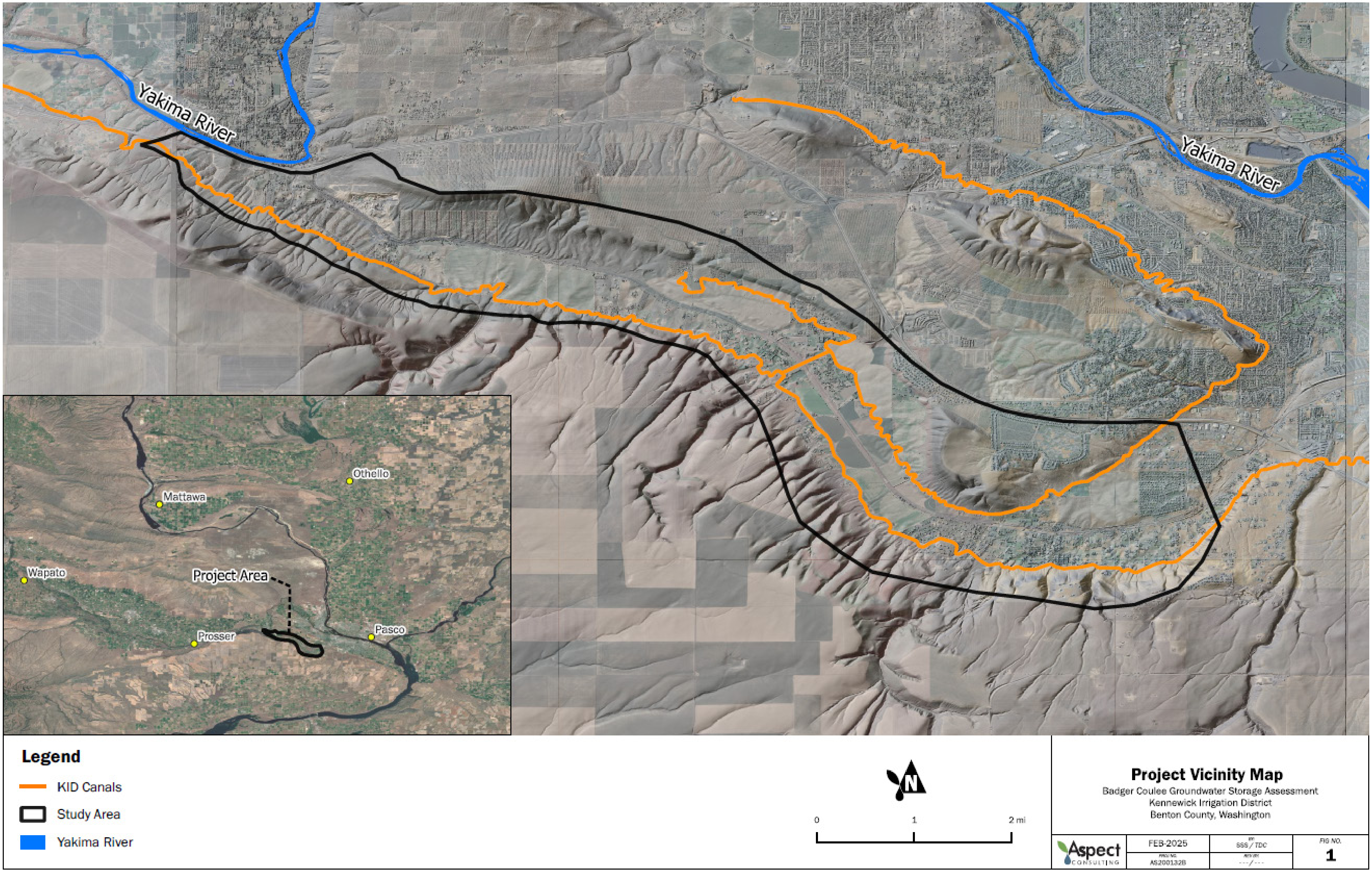
The Study area lies within the Yakima Fold Belt sub-province of the Columbia Plateau (Reidel et. al., 1994). The region is characterized by the Columbia River Basalts that flooded the landscape and were subsequently folded, forming part of the surrounding topography.

More recently, as the Pleistocene glaciation was ending (approximately 10,000 to 15,000 years ago), multiple outburst floods occurred following repeated failure of ice dams in the Columbia River system. These outburst floods transported large quantities of unconsolidated silt, sand, and gravel into the Badger Coulee area. These flood deposits are generally divided into two categories, high-energy deposits consisting of coarse-grained sediment (Pasco Gravels) and overlying low-energy, slack water deposits consisting of fine-grained sediment (Touchet Beds). Together these two sedimentary deposits make up the unconsolidated aquifer in Badger Coulee which is the main source of drinking water in the Study area.

The Study area is located south of the main stem Yakima River at River Mile 30, in Benton County Washington. The Study area is commonly referred to as Badger Coulee and is a box-shaped canyon with steep bedrock walls running along the north and south edges of the canyon. The coulee is approximately 9-miles long and 1-mile wide with a flat valley floor.

KID delivers irrigation water to approximately 5,000 acres within Badger Coulee. KID sources the irrigation water from a diversion on the Yakima River near Prosser, Washington. The diverted irrigation water is then conveyed approximately 14 miles east to the Study area where it is delivered to local water users via a series of canals and laterals that run along the north and south edge of the coulee. A map of the Study area and existing canal infrastructure is included as Figure 1.

**Figure 1. Map of Study Area.**



### 3.2.1 History of study area

For approximately 70 years, KID has conveyed water from the Yakima River to Badger Coulee to support the area's agricultural and domestic irrigation needs. Historically, land use (and water use) in the Study area has consisted predominantly of irrigated agriculture. However, due to population growth in the region, there has been a gradual transition in land use from irrigated agriculture to residential over the past 20 years. Currently, the majority of the residential users in Badger Coulee receive drinking water from the unconsolidated aquifer and irrigation water from KID deliveries.

Parallel to the land use transition, over the last 20 years KID has received numerous WaterSmart Grants from the Bureau of Reclamation that have allowed them to line their existing canal system in Badger Coulee. Prior to these canal lining efforts, historical data collected by KID estimate that the Main Canal was losing water at an average rate of 1.06 cubic feet per second (cfs) per mile. Therefore, the recent lining efforts in conjunction with a reduction in irrigated lands across the Study area (due to land use changes) suggest a coulee-wide decrease in groundwater recharge to the unconsolidated aquifer.

This inferred reduction in groundwater recharge across the coulee combined with the favorable geologic setting suggests that there is an opportunity to develop a groundwater storage in the Study area.

### 3.2.2 Summary of previous studies and existing data

A comprehensive summary of previous studies and existing data is documented in Aspect's 2025 Technical Memorandum "Badger Coulee Groundwater Study – Data Requirements Review" (Aspect, 2025). The sections below provide a summary of the data that will be used to support additional field data collection.

#### Water level data

The USGS National Water Information System (NWIS) and Ecology's Environmental Information Management System (EIM) and Well Log database provide publicly available groundwater levels within the Study area. The USGS National Water Dashboard reported no active groundwater monitoring sites within the Study area; however, the NWIS historical database contained over 50 groundwater wells located in the Study area and completed within the unconsolidated sediments (Touchet Beds and the Pasco Gravels). These groundwater wells document (discontinuous) groundwater levels over a period spanning from 1940 to 2002.

Based on a review of the EIM database (Ecology, 2024a), there are over 70 wells with groundwater monitoring data within the Study area. However, a majority of this data solely consists of water quality data related to the Benton County Conservation District nitrate monitoring (EIM Study ID's WQC-2020-00080 and WQC2015BentCD00102).

Ecology's Well Log database also provides publicly available groundwater levels within the Study area. Based on a review of the dataset (Ecology, 2024b), there are over 800 well logs in the Study area. Of the 800 well logs, approximately 660 well logs are between 25 and 350 feet below ground surface (bgs). The depth range was placed on the dataset to filter out shallow environmental monitoring wells and deep basalt wells.

In addition to the publicly available datasets, a pressure transducer was deployed in a KID-owned well in 2021 as part of Central Washington University's Groundwater Storage Study (CWU, 2023). The pressure transducer has collected over 3.5 years of water level data from the unconsolidated aquifer. This data shows seasonal variation of groundwater levels, with high groundwater occurring in the spring and low groundwater occurring in the fall.

### Soil infiltrations rat

The United Stated Department of Agriculture (USDA) National Resource Conservation Service (NRCS) maintains an online spatial database that delineates soil units within the United States. Based on a delineation of the Study area, the Warden soil unit is the predominant soil group in Badger Coulee accounting for more than 90 percent of the surface area.

Each soil unit contains information regarding the soil type and physical soil properties. Two soil properties that can help inform the proposed Study include hydraulic soil groups and saturated hydraulic conductivity estimates.

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms. The Warden soil group is a Group B soil which is defined as:

> "Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission."

In addition, the NRCS provides an estimate of saturated hydraulic conductivity (Ksat) which refers to the ease with which pores in a saturated soil transmit water. The NRCS estimate of Ksat for the Warden soil group is 9 micrometers per second which is approximately 2.55 feet per day (ft/day).

This dataset will be used to compare vertical hydraulic conductivity when evaluating results from the infiltration tests.

### Hydrogeologic properties of the surface geologic unit

As described in the Data Requirements Review (Aspect 2025), regional and site-specific studies were also evaluated to estimate the hydrogeologic properties (including horizontal hydraulic conductivity) of the unconsolidated aquifer system. This data will be used to estimate vertical hydraulic conductivity when evaluating results from the infiltration tests. A summary of hydrogeologic properties for the surficial geologic unit is presented below in Table 1.

**Table 1. Aquifer Properties for the Touchet Beds**

| Study Area | Study Reference | Horizontal Hydraulic Conductivity (ft/d) | Specific Yield (unitless) |
|---|---|---|---|
| Pasco/ Benton | Drost et al., 1997 | 9 | 0.08 |
| Badger Coulee | Drost et al., 1997 | 7.9 – 10.8 | 0.1 |

**Notes:** ft/d = feet per day; $ft^2/d$ = square feet per day

### Canal discharge data

The United States Bureau of Reclamation (USBR) measures and documents water supply data throughout the Yakima River Basin to help inform and manage irrigation water throughout the Basin. Included in this data set is discharge measurements for the Kennewick Canal at the Prosser Diversion. This data set documents discharge (in cubic feet per second) every 15 minutes in the Kennewick Canal and has records dating back to the 1985 irrigation season. This dataset is publicly available on the USBR Yakima Hydromet website (Hydromet Pacific Northwest Region | Bureau of Reclamation).

This data set will be used in conjunction with KID delivery data to evaluate trends of long term water deliveries to the area.

### KID delivery data

As part of their daily operation and record keeping, KID maintains delivery data for individual turnouts along their canal system. Each turnout is equipped with a flatblade weir and is measured daily by the canal ditchrider during the irrigation season. There are approximately 60 turnouts within the Study area with delivery data spanning back to 2012. This data set will be used to help inform discharge measurement locations within unlined canal sections.

### Canal seepage data

Both the USBR and KID completed discharge measurements (prior to canal lining) to quantify seepage rates (or infiltration rates) in the Kennewick Main Canal. The USBR conducted infiltration tests in 1954 and 1955 on a 225-foot-long test section of the canal.

Based on the infiltration testing USBR estimated an average seepage rate of 0.5 ft/day. In the 1980's KID completed a seepage test of the canal section between the Chandler Siphon and Amon Pump. This test indicated that 19 cfs were lost along approximately 18 miles of unlined canal (1.06 cfs per mile).

Canal infiltration rates measured under this study will be compared to the historic infiltration rates discussed above.

### Water Chemistry

Central Washington University (CWU) recently completed a groundwater storage study in Badger Coulee focusing on the groundwater and surface water chemistry. The CWU study includes 20 groundwater samples from the basalts, 13 groundwater samples from the Pasco Gravel Aquifer, 11 surface water samples, and 12 addition groundwater samples with no identified well log. The CWU chemistry data included major cations, major anions, trace metals, field parameters, and stable isotopes.

This recent data produced by CWU suggest that there are five geochemical groups that make up the groundwater in the study area. The basalt groundwater is categorized by three geochemical groups. The Pasco Gravels groundwater is primarily composed of two geochemical groups that are isotopically indistinguishable from Yakima River water. The two geochemical groups are further categorized by their nitrogen content, with high nitrogen contents linked irrigation return flows and low nitrogen content linked to canal leakage. This geochemical data indicates the two main recharge mechanisms for the Pasco Gravels Aquifer are reliant on the importation of irrigation surface water into Badger Coulee.

Furthermore, mixing models used in the study suggest that the Badger Coulee gravel aquifer contains up to 50 to 90 percent Yakima River derived water.

### Water Quality

No water quality sampling is proposed to be collected under this study. However a summary of existing water quality data is included below.

Based on a review of Ecology's EIM database (Ecology, 2024a) there are over 70 wells with groundwater monitoring data within the Study area. All the EIM data are associated with the Benton County Conservation District nitrate monitoring studies (EIM Study IDs: WQC-2020-00080 and WQC2015BentCD00102). Based on the reported well depths, approximately 40 wells are likely completed in the Pasco Gravel Aquifer.

The Benton County Conservation District nitrate monitoring studies is a county led effort to track nitrate concentrations in public drinking water aquifers. Based on a preliminary review of the available water chemistry data from the Benton County studies, approximately 50 percent of the sampled wells have nitrate concentrations that exceed the maximum contaminant level (MCL) of 10 mg/L. These high nitrate concentrations are consistent with data reported in the CWU (2023) report which document several nitrate exceedances from wells sampled in Badger Coulee.

Aside from nitrate, data from the studies discussed above do not document any other water quality analyte with exceedances in Badger Coulee groundwater.

## 3.2.3 Parameters of interest and potential sources

Water quality data will not be collected under this study. However, based off of the geochemical groups identified in the CWU (2023) study, areas of high nitrate concentrations can be used to inform site-specific recharge regimes (e.g., canal leakage vs agricultural return flow). Therefore, although nitrate data will not be collected under this study, existing nitrate data will be a parameter of interest.

As discussed in the Benton County Groundwater Community Action Plan (2018) the primary potential sources of nitrate in groundwater are livestock, agricultural fertilization activities, urban wastewater, septic systems, residential landscape fertilization and urban landscape fertilization practices. It should be noted that no dairy or feedlots are located in Badger Coulee.

A future groundwater recharge project in the area may have the potential to dilute existing nitrate concentrations in the Pasco Gravel Aquifer. However, during future design of a groundwater recharge project the likelihood of nitrate dilution and or mobilization will be considered.

### 3.2.4 Regulatory criteria or standards

Not applicable. Water quality samples will not be collected under this study.

## 3.3 Water quality impairment studies

Not applicable.

## 3.4 Effectiveness monitoring studies

Not applicable.

# 4.0 Project Description

The proposed groundwater storage assessment aims to refine the hydrogeologic conceptual model of Badger Coulee's unconsolidated aquifer system. The refined hydrogeologic conceptual model will document the physical characteristics contributing to groundwater storage, and include the legal framework surrounding the use of artificially recharged groundwater.

In addition, this study will evaluate the suitability of site-specific MAR locations identified by KID. Assessment of these potential MAR locations will be completed via infiltration testing, (opportunistic) water level monitoring and the collection of discharge measurements.

## 4.1 Project goals

Project goals for the proposed Study under this QAPP include but are not limited to:

- Advance the existing hydrogeologic conceptual model through collection of site-specific data
- Quantify the available storage in the unconsolidated aquifer
- Identify major recharge mechanisms and where recharge is occurring
- Determine the change in groundwater recharge due to recent changes in land use and infrastructure improvements
- Identify and asses potential MAR locations

## 4.2 Project objectives

Specific field activities the Study intends to accomplish include but are not limited to:

- Complete groundwater level monitoring of up to 10 wells to confirm groundwater flow directions and assess seasonal variation in the unconsolidated aquifer.
- Complete pilot infiltration testing at potential MAR locations to determine recharge potential.
- Complete discharge measurements within the canals to inform infiltration rates for sections of unlined canals or unlined storage ponds.
- Complete surface water level monitoring (in conjunction with discharge measurements) at two locations to assess infiltration potential at select irrigation storage ponds or canal sections.

## 4.3 Information needed and sources

Additional information regarding site-specific infiltration rates is needed to quantify recharge potential within the Study area. In addition, water level monitoring is needed to confirm groundwater levels and groundwater flow directions in the unconsolidated aquifer.

## 4.4 Tasks required

The objectives related to data collection under this Study require completing the following tasks:

### Task 1. Pilot infiltration testing

Pilot Infiltration Tests (PITs) are necessary to inform the feasibility and design of future infiltration infrastructure. The PITs for shallow infiltration require excavating a test pit (approximately 3 feet deep ,3 feet wide, and 4 feet long) and infiltrating water at a constant flow rate for up to 8 hours. During test pitting soil samples will be logged by a licensed geologist.

PITs will be completed at potential MAR locations identified by KID (discussed and mapped in Section 7.2 below).

### Task 2. Discharge measurements

Discharge measurements (i.e., seepage runs) will be collected by hand at multiple points along unlined sections of KID-owned canals to inform infiltration rates in unlined canal sections. This information will help quantify the changes in recharge over time due to canal lining projects. This information will also assess the existing unlined canals as potential MAR locations.

Discharge measurement will be completed along two canal reaches identified by KID (discussed and mapped in Section 7.2 below).

### Task 3. Surface water level monitoring

Surface water level monitoring may be completed in conjunction with discharge measurements to assess infiltration potential at select irrigation storage ponds or canal sections. Surface water level monitoring will use automated data loggers in conjunction with a staff gage.

Surface water level monitoring will be completed at one pond and one canal reach identified by KID (discussed and mapped in Section 7.2 below).

### Task 4. Groundwater level monitoring

Groundwater level monitoring is necessary to confirm groundwater flow directions and assess seasonal variation in the unconsolidated aquifer. Groundwater level monitoring will be completed opportunistically based on access to domestic wells completed in the unconsolidated aquifer. KID is currently in the process of reaching out to select homeowners to discuss groundwater level monitoring on their property. Assuming access to domestic wells is granted, up to 5 representative groundwater wells in select locations throughout the Study area (additional details regarding monitoring locations discussed in Section 7.2 below).

### Task 5. Reporting and Analyses

This task includes the refinement of the hydrogeologic conceptual model and aquifer parameters, delineation of the target aquifer, and estimation of potential storage volumes. Figures will be prepared, including hydrogeologic cross-sections, maps showing the extent of the target aquifer, water level hydrographs, and summary tables of aquifer parameters.

In addition, this task will document the methodology, results, and analyses of field data collected under this Study (as described in Task Nos. 1 – 4 above).

## 4.5 Systematic planning process

This QAPP has been prepared to satisfy the systematic planning needs for this project.

# 5.0 Organization and Schedule

# 5.1 Key individuals and their responsibilities

Table 2 shows the responsibilities of those who will be involved in this project.

**Table 2. Organization of project staff and responsibilities.**

| Staff | Title | Responsibilities |
|---|---|---|
| **Jeff Dermond Department of Ecology, Office of the Columbia River**<br>Phone: 509-268-1784 | Project Manager, OCR | Provides oversight of the Study and Ecology Grant. Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP. |
| **McKenna Murray Department of Ecology, Office of the Columbia River**<br>Phone: 509-329-3539 | Quality Assurance Coordinator | Provides review of all copies of the QAPP and approves the final QAPP. |
| **Daniel Tissell Engineering Manager Kennewick Irrigation Distric**t<br>Phone: 509-586-6012 | Project Manager | Reviews the draft and final QAPP and project deliverables, manages the project budget, and submits deliverables for the Ecology grant. |
| **Tyson Carlson Aspect Consulting**<br>Phone: 509-895-5923 | Principal Investigator | Co-author of QAPP and Aspect Project Manager. Oversees approach development, data analysis, and QA/QC. Reviews final ASR feasibility report. |
| **Adam Perine Aspect Consulting**<br>Phone: 206-780-3635 | Senior Hydrogeologist | Conducts oversight of field program development and execution. Performs review of data, analyses, and hydrogeologic interpretations. Co-authors the draft and final ASR feasibility reports. |
| **Silas Sleeper Aspect Consulting**<br>Phone: 206-453-6058 | Project Geologist | Co-author of QAPP. Develops and oversees field program. Schedules field work and logistics. Collects field data. Performs review, analyses, and interpretation of data. Co-authors the draft and final ASR feasibility reports. |
| **Stephen Bartlett Aspect Consulting**<br>Phone: 509-834-7040 | Field Scientist | Performs field work and water quality sampling. Performs data entry and field logging. |
| **Lea Beard Aspect Consulting**<br>Phone: 206-780-7749 | Data Scientist | Reviews and uploads EIM data. |

QAPP: Quality Assurance Project Plan

## 5.2 Special training and certifications

A hydrogeologist or geologist licensed in the State of Washington will review all analysis and interpretation of field data and provide oversight of geologic data collection. All field staff involved in this project have either the relevant experience in the required standard operating procedures (SOPs) or will be trained by more senior field staff or the project manager who has the required experience. The experienced staff will then lead the field data collection and oversee/mentor less-experienced staff.

## 5.3 Organization chart

See Table 3.

## 5.4 Proposed project schedule

Table 3 below provides the anticipated schedule proposed under this project.

**Table 3. Tentative Project Schedule**

| Task | Target Completion Date | Notes |
|---|---|---|
| Technical memorandum of existing data and data gaps | Completed | Completed |
| Project QAPP (this document) | April 2025 | -- |
| Infiltration Testing<br>(April-August 2025) | May 2025 | Requires approval of QAPP |
| Discharge Measurements<br>(April-August 2025) | May 2025 | Requires approval of QAPP and diversion of water into the canals |
| Surface Water Level Monitoring<br>(April-August 2025) | May 2025 | Requires approval of QAPP and diversion of water into the canals |
| Groundwater Level Monitoring<br>(April-August 2025) | May 2025 | Requires approval of QAPP and voluntary participation of local well owners |
| Complete Data Analyses | August 2024 | -- |
| Draft Project Report | September 1, 2025 | For Ecology review |
| Final Project Report | September 30, 2025 | -- |
| EIM Data Load | September 30, 2025 | Upload new field data to EIM |

## 5.5 Budget and funding

KID has received a grant from Ecology OCR (Agreement No. WRYBIP-2325-KennID-00056) to complete all tasks described in Section 4.4. Aspect is under contract with KID to prepare this QAPP and complete the Study.

# 6.0 Quality Objectives

# 6.1 Data quality objectives [1]

The main Data Quality Objective (DQO) for this field investigation is to collect representative water levels and flow rates, during the completion of infiltration testing, groundwater level monitoring and discharge measurements at specific sites throughout the Study area. The analysis will use standard methods to evaluate infiltration rates and discharge measurements that meet the measurement quality objectives (MQOs) described below.

# 6.2 Measurement quality objectives

MQOs 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 field investigation will be conducted to measure water levels and flow rates. The accuracy, resolution, and range of the field investigation are ultimately limited by the field equipment used to collect measurements as noted by the factory specifications (Table 4). Together with the standard operating procedures the field methods MQOs can be defined.

### 6.2.1 Targets for precision, bias, and sensitivity

The data collection instrumentation will meet the MQOs listed in Table 4.

[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.

**Table 4. Field Method MQOs and Field Equipment Information**

| Parameter | Equipment/Method | Bias (median) | Precision Field Duplicates (median) | Equipment Information | | | Expected Range |
|---|---|---|---|---|---|---|---|
| | | | | Accuracy | Resolution | Range | |
| **Air Monitoring** | | | | | | | |
| Temperature | Van Essen Baro-Diver | -- | -- | 0.1°C | 0.01°C | -10 to 50°C | -7 to 31°C |
| Barometric Pressure | Van Essen Baro-Diver | -- | -- | 0.016 ft-$H_2O$ | 0.001 ft-$H_2O$ | -- | 50 to 300 ft- $H_2O$ |
| **Water Level Monitoring** | | | | | | | |
| Temperature | Van Essen TD-Diver D1801 | -- | -- | 0.1°C | 0.01°C | 0 to 50°C | 1 to 25°C |
| Pressure | Van Essen TD-Diver D1801 | -- | -- | 0.016 ft-$H_2O$ | 0.007 ft-$H_2O$ | Max 330 ft-$H_2O$ | 10 to 300 ft-$H_2O$ |
| Depth to Water | Waterline Envirotech 800-ft Water Level Meter | -- | -- | 0.05 ft | 0.01 ft | 0.5 to 800 ft | 50 to 300 ft |
| Staff Gage | -- | -- | -- | 0.02 ft | 0.02 ft | 0 to 5 ft | 1 to 3 ft |
| Wellhead Position (GPS) | Trimble R1 GNSS Receiver | -- | -- | <3.3 feet | 0.01 ft | -- | -- |
| **Infiltration Testing Monitoring** | | | | | | | |
| Temperature | Van Essen TD-Diver D1801 | -- | -- | 0.1°C | 0.01°C | 0 to 50°C | 1 to 25°C |
| Pressure | Van Essen TD-Diver D1801 | -- | -- | 0.016 ft-$H_2O$ | 0.007 ft-$H_2O$ | Max 330 ft-$H_2O$ | 0.5 to 300 ft-$H_2O$ |

| Parameter | Equipment/Method | Bias (median) | Precision Field Duplicates (median) | Equipment Information | | | Expected Range |
|---|---|---|---|---|---|---|---|
| | | | | Accuracy | Resolution | Range | |
| Depth to Water | Waterline Envirotech 800-ft Water Level Meter Tape | -- | -- | 0.05 ft | 0.01 ft | 0.5 to 800 ft | 50 to 300 ft |
| Discharge Rate | Soundwater Orcas T31-C7 Ultrasonic Flowmeter | -- | -- | ± 2.0% | 0.01 gpm | 0 to 60 ft/s (0 to >5000 gpm in 6-inch | 50 to 500 gpm |
| Discharge Rate | Seametrics 50 gpm MJR-200-50G | -- | -- | +1.5% FS | -- | 1.98 to 132 gpm | 2 to 100 gpm |
| **Discharge Measurements** | | | | | | | |
| Discharge | 5-gallon bucket | -- | -- | -- | -- | -- | 1 to 50 gpm |
| Flow Rate | Swoffer 3000 Current Flow Meter | -- | -- | 1% | 0.001 ft/sec | 0.1 to 25 ft/sec | 1 to 20 ft/sec |

#### 6.2.1.1 Precision

Precision is defined as the degree of agreement between or among independent, similar, or repeated measurements. Precision is a measure of variability in the results of replicate measurements due to random error. Precision is usually assessed by analyzing duplicate field measurements and random error is imparted by the variation in field procedures.

Precision of discharge measurements and water level measurements will be assessed by collection of replicate measurements at a rate of approximately 25 percent of all measurements.

The acceptable precision for field replicates will be relative percent difference (RPD) of 15 percent. The acceptable precision for calculated values (i.e., infiltration rate) will be RPD of 20 percent. Therefore, in order to meet the precision target for calculated values the associated field measurements (i.e., discharge rate and surface area) may require a higher degree of precision compared to other field measurements.

#### 6.2.1.2 Bias

Bias is the difference between the population mean and the true value of the parameter being measured. Although bias is usually encountered as a result of inadequate calibration of water quality field equipment. As discussed above, no water quality data will be collected as part of this Study.

For this Study, potential sources of field bias in measurements include improper measurement procedure, instrument drift and the inability to measure all forms of the parameter of interest. Field staff will minimize bias in field measurements by strictly following measurement protocols. Field staff will also collect manual water level measurements to assess possible instrument drift associated pressure transducers.

#### 6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of the field method and instrument used to detect a change. It is described by its range, accuracy, and resolution. This information is (typically reported for each instrument by the manufacture) summarized above in Table 4.

### 6.2.2 Targets for comparability, representativeness, and completeness

#### 6.2.2.1 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.), standard operating procedures SOPs, and instrumentation sensitivity. Field staff will adhere to common field protocols and all field measurements will follow SOPs to improve comparability.

A complete list and discussion of SOPs is included below in the Field Procedures section (Section 8).

#### 6.2.2.2 Representativeness

Representativeness is the degree to which sample results represent the system under Study. This component is generally considered during the design phase of a project.

The Study is designed to collect sufficient data to evaluate site-specific infiltration rates and water levels. Continuous monitoring equipment used during infiltration tests and water level monitoring will capture the representativeness of the physical habitat's characteristics at the specific deployment locations. Additionally, collected field data will be compared to historical data available for the site / parameter.

#### 6.2.2.3 Completeness

Completeness will be calculated as follows:

$$Completeness\ (\%) = \frac{V}{P} \times 100$$

where:

V = number of valid measurements

P = number of planned measurements

Valid and invalid data (i.e., data qualified with the R flag [rejected]) will be identified during data verification (Section 13).

The goal for the field investigation Study is to correctly collect and analyze 100 percent of the samples for each project. However, problems occasionally arise during data collection, such as site access or equipment malfunction that cannot be controlled; thus, a completeness of 95 percent is acceptable for discrete measurements.

For continuous deployed measurements, additional variables can negatively impact completeness, including vandalism/theft/tampering, equipment failure, unacceptable fouling or drift, and unpredictable hydrologic events (large storms or steep drops in water level between visits). For these reasons, a completeness of 80 percent is acceptable for continuous measurements.

## 6.3 Acceptance criteria for quality of existing data

The availability of existing data is summarized above in Section 3.2.2 and includes water levels, soil infiltration rates, aquifer parameters, canal seepage rates and water delivery data.

For the purposes of this Study the following data sources will be accepted:

- Published data that has gone through internal review will be accepted. This includes published academic journals, government investigation reports, and geologic maps.

- Data used and collected during the previous KID groundwater assessment (CWU, 2023)
- Ecology data documented on the EIM database
- USGS data documented on the National Water Information System database
- Publicly available USBR discharge measurements for the Kennewick Main Canal
- Historic USBR canal infiltration rates for the Kennewick Main Canal
- Historic KID canal seepage rates for the Kennewick Main Canal

The data sources above are known to represent high quality data that are produced by reliable organizations using appropriate scientific methodology for the intended purpose. The data sets presented above are used commonly by government organizations (e.g., USBR, USGS, etc.) to inform background hydrogeologic conditions.

Data sources with known data gaps and their proposed acceptance criteria are presented in Table 5 below:

**Table 5. Data Gaps and Proposed Acceptance Criteria**

| Data Source | Parameter used in report | Identified Data Gap | Proposed acceptance criteria |
|---|---|---|---|
| Ecology's Well Log Database | Groundwater levels and geology descriptions | Potentially incorrect well log locations based on Township Range and Section information | Aspect will locate wells using information provided on the well log, aerial imagery and the County's parcel database. Aspect will only include wells that can be confidently located to a ¼¼ section |
| Ecology's Well Log Database | Groundwater levels and geology descriptions | Potentially incorrect geologic descriptions and incomplete well data | During a review of local well logs, significant outliers regarding geologic descriptions will be flagged and excluded during creation of maps and cross sections |
| KID Turnout Deliver Data | Discharge measurements | Incomplete or outlying discharge data | KID weir inspection during 2025 irrigation season |
| Existing Groundwater Level Monitoring in KID Well | Groundwater levels | Existing pressure transducer data | Data is collected consistent with methodology and equipment specified in this QAPP |

## 6.4 Model quality objectives

Not applicable.

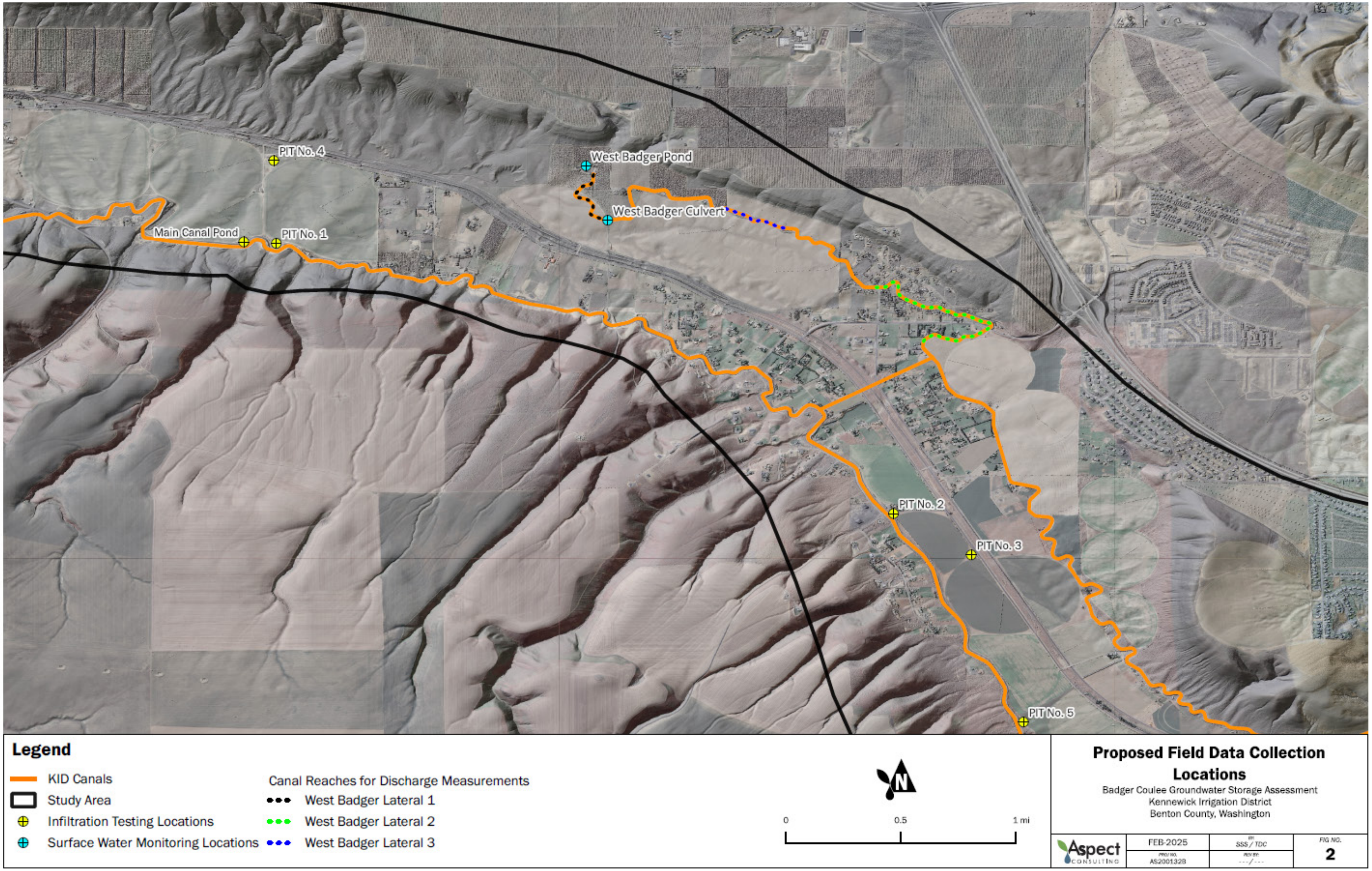
# 7.0 Study Design

A narrative of the overall Study design is provided in Section 4. This section provides the details of the data collection and analysis.

# 7.1 Study boundaries

The approximate Study area is shown on Figure 1. Infiltration testing locations, surface water level monitoring locations, and discharge measurement locations are mapped below in Figure 2. Aside from the existing KID-owned well, groundwater level monitoring locations are dependent on participation of local property owners and have not been identified yet.

**Figure 2. Map showing locations of proposed field data collection**



## 7.2 Field data collection

Specific field parameters to be collected under this Study are listed in Table 4 and are grouped into four main categories: (1) Air Monitoring, (2) Water Level Monitoring, (3) Infiltration Testing Monitoring, and (4) Discharge Measurements.

### 7.2.1 Sampling locations and frequency

Proposed field work locations for infiltration testing were identified based on land ownership, proximity to existing KID canals, and recommendations from KID. The primary and alternate infiltration testing locations are included below in Table 6. As discussed in section 5.4 above, the target timeframe for completion of infiltration testing will be from April to August 2025.

**Table 6. Proposed Infiltration Testing Locations**

| Location Name | Location Coordinates | Parcel No. | Ownership |
|---|---|---|---|
| PIT No. 1 | 46.222824°, -119.421219° | 63300 | KID Currently Leasing Land |
| PIT No. 2 | 46.198294°, -119.365132 | 307778 | KID Reservoir Property |
| PIT No. 3 | 46.194457°, -119.358136° | 307778 | KID Reservoir Property |
| West Badger Lateral Pond | 46.229873°, -119.393077° | 54613 | Private Landowner |
| PIT No. 4 | 46.230345°, -119.421449° | 63300 | KID Currently Leasing Land |
| PIT No. 5 | 46.179549°, -119.353514° | 47221 | KID Reservoir Property |
| Main Canal Pond | 46.222964°, -119.424177° | 63318 | Private Landowner |

**Notes:** Highlighted cells represent alternative testing locations in case testing at the primary locations is not possible.

The purpose of discharge measurements is to quantify recharge rates (seepage) in unlined canal sections to evaluate existing unlined canal sections as potential MAR locations. In addition, the collection of discharge measurements (and calculation of seepage rates) will help inform the effects of canal lining for the coulee-wide water budget analysis.

Based on discussions with KID, the West Badger Lateral is one of the remaining unlined canals in the Study area. The West Badger Canal is approximately 3 miles long and diverts between 1 and 5 cfs during the irrigation season. The West Badger Canal runs along the north edge of Badger Coulee and terminates at an irrigation storage pond located on Parcel No. 54613. As discussed in section 5.4 above, the target timeframe for completion of discharge measurements will be from April to August 2025. Proposed reaches (of the West Badger Canal) for collection of discharge measurements are included below in Table 7 and illustrated on Figure 2.

Although the main Kennewick Canal contains a few unlined reaches it was not included as a proposed field work location due to high flows and associated safety concerns.

**Table 7. Proposed Discharge Measurement Locations**

| Location Name | Starting Point | End Point | Reach Length | Number of Discharge Measurements |
|---|---|---|---|---|
| West Badger Lateral 1 | 46.224928°, -119.391101° | 46.228992°, -119.392377° | 2,100 feet | 3 |
| West Badger Lateral 2 | 46.213789°, -119.362416° | 46.218840°, -119.366733° | 1.0 miles | 4 |
| West Badger Lateral 3 | 46.224196°, -119.374890° | 46.225952°, -119.380302° | 1,500 feet | 3 |

**Notes:** Highlighted cells represent alternative measurement locations in the case that measurement at the primary locations is not possible.

Two surface water level monitoring locations were identified and are located at the terminal section of the West Badger Lateral. The surface water monitoring locations are intended to document water levels in the canal and terminal storage pond which will be used in conjunction with discharge measurements to inform site-specific infiltration rates. Surface monitoring locations are presented below in Table 8.

**Table 8. Surface Water Monitoring Locations**

| Location Name | Location Coordinates | Parcel | Measurement Location |
|---|---|---|---|
| West Badger Lateral Culvert | 46.224928°, -119.391101° | N/A | Culvert |
| West Badger Lateral Pond | 46.229873°, -119.393077° | 54613 | Terminal Storage Pond |

Groundwater monitoring of KID's North Well (located at latitude, longitude: 46.183248, -119.306105), which was initially established as part of CWU's study (CWU, 2023) will continue under this Study.

Development of new groundwater level monitoring locations are dependent on participation of local property owners and have not been identified yet. KID has initiated outreach to over 50 select property owners in the Study area.

Assuming participation of local landowners, up to 5 groundwater wells will be monitored as part of this study. The monitoring wells will be completed in the gravel aquifer. The existing groundwater level data from the KID-owned wells are located in the east portion of the Study area and therefore new groundwater level monitoring locations will ideally be located in the center and northwest portion of the Study area. Groundwater level monitoring will be conducted opportunistically throughout the duration of the field data collection phase (April to August 2025). Similar to the previously completed CWU Study, groundwater monitoring established during this project will likely continue past the project completion date.

Air monitoring will be completed at all locations that require the use of a submerged pressure transducer. This includes surface water monitoring locations, groundwater monitoring locations, and infiltration testing locations. Air monitoring dataloggers will be programed to record every 15 minutes and will be downloaded during each field visit to that specific site.

### 7.2.2 Field parameters and laboratory analytes to be measured

Field parameters to be collected are presented in Table 4 and include, air temperature, barometric pressure, total pressure, flow rate, water level measurements, and discharge measurements.

Water quality will not be measured under the proposed Study.

## 7.3 Modeling and analysis design

Not applicable.

### 7.3.1 Analytical framework

Not applicable.

### 7.3.2 Model setup and data needs

Not applicable.

## 7.4 Assumptions of study design

This Study assumes that:

- KID operators will be available to excavate test pits and provide a water source for infiltration testing.
- Infiltration rates measured at the proposed field locations (Table 6) are representative of the tested geologic unit (e.g., Touchet Beds).
- The equipment used in the infiltration tests (flow meters, pressure transducers, water level data loggers, water level indicators, etc.) give accurate readings when they are installed and used properly.
- Discharge measurements and associated infiltration rates in the unlined canal is representative of infiltration rates in other unlined sections of the canal system.

## 7.5 Possible challenges and contingencies

### 7.5.1 Logistical problems

Logistical problems that interfere with measurement collection may occur during field work. These problems include:

- Inability to access domestic wells due to refusal by private landowners.
- Inability to access domestic wells due to inadequate wellhead access or obstructions within the well casing (e.g., wires, pump column etc.).
- Inability to access infiltration testing locations due to refusal by private landowners.

Contingencies for property access issues include additional outreach to private landowners (e.g., send additional letters, additional KID communication, home visits). No contingency has been identified for inadequate well access. However, if groundwater monitoring locations are severely reduced due to the logistical problems discussed above, additional effort will be required to extract and process water level data from available well logs within the Study area.

### 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. Funding opportunities are typically the greatest limitation to collection of field data.

### 7.5.3 Schedule limitations

The main schedule limitation to the collection of field data includes the time required for QAPP review and approval. In addition, the completion date of the project (September 30th, 2025) presents a slight schedule limitation and reduces the ability to assess seasonal variability in the unconsolidated aquifer system. These schedule limitations are noted above in Table 3.

# 8.0 Field Procedures

The field investigation entails three major components: infiltration testing, collection of discharge measurements and water level monitoring. The procedures to collect measurements are described below.

## 8.1 Invasive species evaluation

Aspect field staff will follow Ecology's SOP EAP070 (publicly available in digital format on Ecology's website; Ecology, 2023a) for minimizing the spread of invasive species for areas of both moderate and extreme concern.

At the end of each field visit, field staff will minimize the spread of invasive species 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 clear water either from the site or brought for that purpose. The process will continue until all equipment is clean.
- Draining all water in 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 take steps to prevent debris from leaving the equipment and potentially spreading invasive species during transit or cleaning.

Established Ecology procedures will be followed if an unexpected contamination incident occurs.

## 8.2 Measurement and sampling procedures

The procedures used in this Study are typical for any hydrogeologic investigations. SOPs to be followed are publicly available in digital format online and include the following:

- SOP EAP052, Version 1.4 – Manual Well-Depth and Depth-to-Water Measurements (Ecology, 2023b)
- SOP EAP074, Version 1.2 – Use of Submersible Pressure Transducers During Groundwater Studies (Ecology, 2019a)
- Standard Operating Procedure EAP070, Version 2.3 – Minimize the Spread of Invasive Species (Ecology, 2023a)
- Standard Operating Procedure EAP056, Version 1.3: Measuring and Calculating Stream Discharge (Ecology, 2018a)
- Standard Operating Procedure EAP056, Version 1.2: Measuring Gage Height of Streams (Ecology, 2018b)
- 2024 Stormwater Management Manual for Eastern Washington (Ecology, 2024c)

### 8.2.1 Infiltration testing

The 2024 Stormwater Management Manual for Eastern Washington (Ecology, 2024c) describes the methodology for small scale pilot infiltration tests (PITs) on page 518 and 519. Water for infiltration testing will be sourced from KID Canals or KID-owned water trucks.

The stormwater manual methodology will be followed during the completion of infiltration tests. This methodology is summarized below:

- A test pit will be excavated with a horizontal bottom of 12 to 32 square feet. The excavation depth is no lower than the anticipated base of the proposed infiltration facility (2 to 5 feet bgs). It is important to have a level bottom of known geometry for the test. Depending on soil characteristics and the depth of the excavation, the side walls of the excavation may need to be laid back at a 50 percent slope for safety and to allow access to the pit.
- Monitoring equipment (e.g., inline flow meter, staff gage and data logger) are installed to measure discharge into the pit and changes in water levels. Data loggers will be programmed to record every 1 minute during the completion of infiltration testing.
- Water is added to the test pit for a minimum of 6 hours, with stable water level and flow conditions maintained for at least the final hour (this is the “constant-rate” portion of the PIT)[2]. The water level within the test pit should remain constant at a level equal to or less than the design water level depth.
- At the conclusion of constant-rate portion of the PIT, the “falling-head” portion of the test is measured.
- At the conclusion of the test the test pit is over-excavated to the maximum extent allowed by the equipment to assess subsurface mounding or “perching” of test water within 1 hour of falling head test.

### 8.2.2 Groundwater level monitoring

Groundwater levels will be measured at available groundwater wells with both manual electronic water level indicator and with automated pressure transducers installed in each well. Long term monitoring data will be collected with a pressure transducer installed below the anticipated minimum water level of the well. Barometric pressure loggers will collect paired atmospheric observations, which will be used to correct pressure transducer data into gauged submergence pressure (feet of water above the sensor). Both the submerged and atmospheric pressure transducers will be programmed to record every 15 minutes. Transducers will be downloaded opportunistically based on landowner access to the site/ wellhead.

Manual measurements will be made during deployment and recovery of pressure transducers to provide manual verification and calibration of automated transducer data.

[2] Throughout the PIT, water levels should be maintained as constant as possible, with flow rates being adjusted by no more than 5 percent during the constant-rate portion of the test.

Water levels will be collected using an electrical water level meter with a precision of 0.01-ft and estimated accuracy of 0.05-ft. Water levels will be measured from the existing measurement point (MP) at each well to ensure data comparability. If an MP does not exist, then we will establish one based on the following procedure:

1. MPs are normally established on the north side of 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 ground surface around the well.
5. Measure the height of the MP in feet relative to the LSD. Generally, MPs are established to the nearest 0.1-ft 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 established MP. The MP value will be used to convert measurements into values that are relative to land surface.

After a permanent MP is established for each well, continue sampling using the following process:

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.
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). If the well was airtight, wait a few minutes for the water level to return to equilibrium with atmospheric pressure.
3. Turn the water level meter on and slowly lower the probe into the well until it makes a tone indicated contact with the water level. To confirm contact, 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 of water against the MP and mark the date and time the reading was made.

4. 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.
5. Repeat the measurement to ensure that the water level is stable (not rising or falling over time).
6. 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 brush or paper towel, then rinse with distilled water and 10 percent bleach.

On occasion, condensation on the interior casing of the well 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.

### 8.2.3 Atmospheric pressure monitoring

Barometric pressure transducers and dataloggers will be deployed at select locations throughout the Study area. Data from these transducers will be used to correct measured well water levels for barometric effects groundwater and surface water monitoring locations. Dataloggers will be programed to take readings at 15-minute intervals. Barometric efficiency can affect the representativeness of water level measurements from vented and unvented transducers (Spane, 2002). Corrections for barometric efficiency of wells will be made, as appropriate.

### 8.2.4 Discharge measurements

Discharge measurements will be conducted along two reaches in the West Badger Lateral (Table 7) to quantify infiltration (i.e., seepage) rates. Manual discharge measurements will be taken by hand using a Swoffer 3000 Current Flow Meter (Table 4). Discharge measurements will generally follow methodology presented in Ecology's SOP EAP056. This methodology is summarized below:

- Before conducting a discharge measurement, field staff will stretch a measuring tape or marked tag line across the measurement cross section. The tape or tag line extends across the channel perpendicular or normal to the direction of flow.
- Field staff will document the cross section location using a handheld GPS (Table 4) and take photographs of the canal reach and surrounding area.
- The field staff will then note the width of the canal at the cross section and divide it into measurable segments. Divide the cross section such that approximately 5 percent and no more than 10 percent of the total flow comprises any one segment. The width of a measurement segment should not be less than three tenths of a foot.
- Once segments have been determined, the field staff will take velocity measurements across the width of the cross section. Velocity measurements will utilize the six-tenths method:
    - Six-tenths method: Sample velocities at sixth tenths of the depth from the water surface. Assume velocity samples at six tenths of depth represent the average velocity through the water column. Use the six-tenths method at stream

segments less than 1.5 feet in depth. Use the six-tenths method at all depths when stage is fluctuating rapidly.

- The handheld flow meter will be programmed to take 40-second velocity samples to address variations in velocity over time at a single measurement point.
- Field staff will pay close attention to the direction of flow when using mechanical current meters. To calculate discharge correctly determine the velocity of the current normal or perpendicular to the cross section.
- Discharge measurements for each cross section will be calculated using the Midsection method. Details regarding the midsection method are included in Ecology's SOP EAP056.

Discharge measurements along selected stream reaches will be completed consecutively to limit temporal variations in flow. Infiltration rates along the canal reaches will be calculated by subtracting the inflow (upstream discharge measurement) from the outflow (downstream discharge measurement + evaporation).

### 8.2.5 Surface Water Level Monitoring

Surface water monitoring will be completed in conjunction with discharge measurements to assess infiltration rates in canal section and in terminal irrigation ponds. As discussed in section 5.4 above, the target timeframe for completion of surface water level monitoring will be from April to August 2025.

The collection of manual surface water levels will generally follow methodology presented in Ecology's SOP EAP042. The proposed methodology is summarized below:

- Field staff will install a staff gage at the surface water monitoring location and establish a gage datum. At most stations, a datum is arbitrarily assigned corresponding to the elevation of the primary gage index. Primary gages are installed such that the assumed zero point of the primary gage is below the point of zero flow and expected scour of the channel.
- Field staff will install a secondary staff gage at the monitoring location. The secondary station will act as a contingency and be used to manually measure the stage of the water body if the primary staff gage is removed or damaged.
- For the purposes of the proposed Study, it is expected that staff gages will be mounted to wooden or metal fence posts driven into the shallow sediments.
- A vertical standing staff gage consists of a singular or a successive series of steel plates mounted to a secure structure (i.e., fence post). The staff plates will be graduated in 0.02 feet increments. Staff-gage observations are recorded to 0.01 feet resolution.
- Each staff gage will be equipped with a submersible data logger to collect continuous water level (i.e., stage) measurements. The submerged water level logger will be installed in a slotted polyvinyl chloride (PVC) pipe stilling well and attached to the primary staff gage.

    - The proposed data loggers (Table 4) are self-contained non-vented units that utilize an absolute pressure sensor. As such, a reference pressure logger will be installed at surface water monitoring locations to account for variations in atmospheric barometric pressure.
- During each site visit, field staff will:
    - Document the time, date, and gage height relative to the gage datum on both the primary and secondary staff gages.
    - Download and redeploy data loggers.
    - Note any observed changes to the staff gage (e.g., movement or damage) and make corrections if necessary.

## 8.3 Containers, preservation methods, holding times

Not applicable.

## 8.4 Equipment decontamination

Not applicable. No water quality samples will be collected.

## 8.5 Sample ID

Not applicable.

## 8.6 Chain of custody

Not applicable.

## 8.7 Field log requirements

During the collection of any field samples, accompanying field documentation must be made that clearly states:

- Name and location of project
- Field personnel
- Sequence of events
- Any changes or deviations from the QAPP or SOPs
- Environmental conditions
- Field measurement results
- Unusual circumstances that might affect interpretation of results

For this Study, data collected in the field will be contained in a field log (a binder backed by electronic scans of documents) that will consist of field notes (freehand notes) and Aspect field data sheets (Appendix A).

Field notes will be bound, waterproof notebooks with prenumbered pages (Rite in the Rain®). Permanent, waterproof ink should be used for all entries. Corrections will be made with single-line strikethroughs, initials, and date of correction. Use of white-out or correction fluid is not permitted.

## 8.8 Other activities

Not applicable.

# 9.0 Laboratory Procedures

## 9.1 Lab procedures table

Not applicable.

## 9.2 Sample preparation method(s)

Not applicable.

## 9.3 Special method requirements

Not applicable.

## 9.4 Laboratories accredited for methods

Not applicable.

# 10.0 Quality Control Procedures

Implementing QC procedures provides the information needed to assess the quality of the data that is collected. These procedures also help identify problems or issues associated with data collection or data analysis while the project is underway.

## 10.1 Table of field and laboratory quality control

As discussed above in Section 8.2.1, manual water level measurements will be collected to verify transducer data. In addition, as discussed above in Section 6.2.1.1, replicate manual measurements (for discharge and water levels) will be collected at a rate of approximately 25 percent of all measurements.

The verification of automated measurements and replication of manual measurements will be used to minimize bias and assess precision of field measurements.

## 10.2 Corrective action processes

QC results may indicate problems with data during the course of the project. The following corrective action processes will be used if:

- Activities are inconsistent with the QAPP
    - Aspect Project Manager will review the inconsistency and determine if activities performed negatively affect the DQOs or project objectives outlined above. If so, activities will be flagged in the report and (if possible) the field work collection will be repeated.
- Field instruments yield unusual results
    - Field staff will recalibrate the instrument. If the instrument is still yielding unusual results after recalibration the instrument will be sent back to the manufacturer for inspection. During that time Aspect will collect the field data using a replacement instrument that have identical or similar ratings for accuracy, resolution and range (as documented in Table 4).
- Results do not meet MQOs or performance expectations
    - The data will be flagged in the report and (if possible) the associated field data collection will be repeated to meet the MQOs. This may include the deployment or use of alternate equipment.
- If some other unforeseen problem arises
    - Appropriate corrective action will be completed as determined by relevant project staff.

# 11.0 Data Management Procedures

## 11.1 Data recording and reporting requirements

Field technicians will record all field data in a water-resistant field notebook, electronic data forms, or Aspect's standard field data sheet. Before leaving each site, staff will check field notebooks, data sheets, or electronic data forms for missing or improbable measurements. Field technicians will enter field-generated data into spreadsheets or a project database as soon as practical after they return from the field. For data collected electronically, data will be backed up on servers when staff return from the field. Raw data files will be stored separate from processed data files.

The Aspect field geologist (or hydrogeologist) and field technician will check data entry against the field notebook data for errors and omissions. The geologist will notify the Aspect Project Manager of missing or unusual data.

Data will be uploaded to Ecology's EIM database as described in Section 11.4.

## 11.2 Laboratory data package requirements

Not applicable.

## 11.3 Electronic transfer requirements

Not applicable.

## 11.4 Data upload procedures

Following completion of the QC procedures described in Section 10, all quality assured data will be formatted and uploaded to Ecology's EIM database by an Aspect data scientist using Study ID: WRYBIP-2325-KennID-00056.

## 11.5 Model information management

Not applicable.

# 12.0 Audits and Reports

## 12.1 Audits

Field technicians will be required to review this QAPP prior to each field event and to maintain a copy of the QAPP and its appendices in the field. Field technicians may be audited at any time by the appropriate project manager or the Aspect data manager (Table 2) to check that field work is being completed according to this QAPP, work plan, and published SOPs.

## 12.2 Responsible personnel

Personnel responsible for the audits are as follows:

- Field audit: Aspect Project Manager
- Field consistency review: experienced (at least 3 years) staff (senior hydrogeologist or project manager)
- Data analysis: Aspect hydrogeologists (project, senior, and principal, as required for specific analysis)

Personnel assigned to these roles are listed in Table 2.

## 12.3 Frequency and distribution of reports

Results of the field data collection, data quality assessment, and any data analysis will be documented in a published report. The final report will be distributed to all other stakeholders involved or interested in the Study as determined by KID and Ecology.

Field data will be entered into EIM when data collection is complete and Quality Control assessment has been finished.

## 12.4 Responsibility for reports

The Aspect Project Manager is responsible for verifying data completeness and usability before the data are used in the technical report and entered into the EIM database. The Aspect Project Manager is also responsible for writing the final technical report or memo, unless an alternate author is agreed upon and documented prior to the start of the report.

The Aspect Project Manager is responsible for assigning a peer reviewer with the appropriate expertise to review technical report. A draft report will be prepared and submitted to Ecology, then a final report will be prepared that addresses Ecology's comments. The peer reviewer is responsible for working with the author to resolve or clarify any issues with the report.

# 13.0 Data Verification

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

## 13.1 Field data verification, requirements, and responsibilities

Field notebooks, data sheets, and electronic information storage will be checked for missing or improbable measurements, and initial data will be verified before leaving each site. This process involves checking the data sheet (written or electronic) for omissions or outliers. If measurement data are missing or a measurement is determined to be an outlier, the measurement will be flagged on the data sheet and repeated if possible. The field hydrogeologist or field technician is responsible for in-field data verification.

Upon returning from the field, data are either manually entered (data recorded on paper) or downloaded from instruments and then uploaded into the appropriate database or project folder (see Section 11). Manually entered data will be verified/checked by a staff member who did not enter the data. Downloaded electronic data files will also be checked for completeness and appropriate metadata (such as file name and time code).

Following data entry verification, raw field measurement data will undergo a quality analysis (consistent with MQOs listed in Section 6) verification process to evaluate the performance of the sensors.

Duplicate measurements will be used to determine if the collected field data meets the precision standards stated in Section 6.2.1.1. Based on the calculated precision, field measurements will either be qualified, rejected, or accepted as appropriate.

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 the process described below.

**Review Discrete Field QC Checks**

The field check of instrumentation will consist of a manual measurement for water levels. The post-check data from the field QC instrument check (water level) will be reviewed, and the result will be qualified, rejected, or accepted as appropriate.

**Review/Adjust Time Series (Continuous) Data**

1. Plot raw time series with field checks.
2. Reject data based on deployment/retrieval times, site visit disruption, blatant fouling events, and sensor/equipment failure.
3. Review sensor offsets for post-deployment. Flag any potential chronic drift or bias issues specific to the instrument.

4. If applicable, review fouling check and make drift adjustment, if necessary. In some situations, an event fouling adjustment may be warranted.
5. 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, then accept, reject, or qualify the field checks. Potential data adjustments include:
   a. **Bias** – Data are adjusted by the average difference between the QC checks and deployed instrument. The majority of QC checks must show bias to use this method.
   b. **Regression** – Data are 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 five data points and an $R^2$ value of >0.95 to use for adjustment. Do not extrapolate regressions beyond the range of the QC checks.
   c. **Calibration/Sensor Drift** – Data are adjusted using linear regression with time from calibration or deployment to post-check or retrieval. The majority of QC checks, particularly post-checks, must confirm pattern of drift.
6. 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.
7. If the evidence is weak, or inconclusive, do not adjust the data.

It will be noted in the final report if any data is adjusted. Data adjustment must be performed or reviewed by the Aspect Project Manager or personnel with the appropriate training and experience in processing raw sensor data.

## 13.2 Laboratory data verification

Not applicable.

## 13.3 Validation requirements, if necessary

Not applicable.

## 13.4 Model quality assessment

Not applicable.

### 13.4.1 Calibration and validation

Not applicable.

#### 13.4.1.1 Precision

Not applicable.

#### 13.4.1.2 Bias

Not applicable.

#### 13.4.1.3 Representativeness

Not applicable.

#### 13.4.1.4 Qualitative assessment

Not applicable.

### 13.4.2 Analysis of sensitivity and uncertainty

Not applicable.

# 14.0 Data Quality (Usability) Assessment

## 14.1 Process for determining project objectives were met

The Aspect Project Manager will assess all data (qualified and unqualified), results or verification, compliance with MQOs, and the overall quality of the data set to provide a final determination regarding usability in the context of the project-specific goals and objectives. The final report will document whether the final, acceptable-quality data set meets the needs of the project (allows desired conclusion/decisions to be made with the desired level of certainty).

## 14.2 Treatment of non-detects

Not applicable.

## 14.3 Data analysis and presentation methods

Data found to be of acceptable quality for project objectives will be analyzed before being summarized. Any relevant and interesting data analysis will be presented in the final report using a combination of tables and plots of various kinds, such as time-series plots, histograms, and box plots.

The report will contain a summary table of infiltration rates, figures of continuous data (water level hydrographs, discharge data, etc.), discussion of results pertaining to each sample location, and a map of the Study area.

## 14.4 Sampling design evaluation

The Aspect Project Manager will decide whether (1) the data package meets the MQOs, and criteria for completeness, representativeness, and comparability; and (2) meaningful conclusions (with enough statistical power) can be drawn from summary statistics. If so, the sampling design will be considered effective. If the sampling design is found ineffective, the approach will be modified in accordance with Ecology, and/or the Study will be halted for redesign.

## 14.5 Documentation of assessment

In the final report, the Aspect Project Manager will include a summary and detailed description of the data quality assessment and model quality evaluation findings. This summary is usually included in the Data Quality section. The final report will also provide results of the data analysis, uncertainty analysis, and margin of safety.

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# 16.0 Appendices

# Appendix A. Aspect Field Data Sheets

# DAILY REPORT

350 Madison Avenue North
Bainbridge Island, Washington 98110
(206) 780-9370

710 Second Avenue, Suite 550
Seattle, Washington 98104
(206) 328-7443

| | | |
|---|---|---|
| **DATE:** | **PROJECT NO.** | **WEATHER:** |
| **PROJECT NAME:** | | **CLIENT:** |
| **EQUIPMENT USED:** | | **PROJECT LOCATION:** |

**THE FOLLOWING WAS NOTED:**

| | |
|---|---|
| **COPIES TO:** | **Aspect Consulting PROJECT MANAGER:** |
| | **Page 1 of 1** **FIELD REP.:** |

Bainbridge, Bellingham, Portland,
Seattle, Wenatchee, Yakima

**PIT Field Form**

Page 1 of ___

Project Name and No:
PIT Number:
PIT Dimensions (W x L x H):
Field Staff:

| Date Time | ET (Min) | Water Level | Totalizer | Qi | Comments |
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*https://geosyntec-my.sharepoint.com/personal/silas_sleeper_aspectconsulting_com/Documents/Desktop/Work/Field Forms/PIT Field Form*
*9/26/17*

# Appendix B. Glossaries, Acronyms, and Abbreviations

## Glossary of General Terms

**Reach:** A specific portion or segment of a stream.

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

**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.

## Acronyms and Abbreviations

| | |
|---|---|
| e.g. | For example |
| Ecology | Washington State Department of Ecology |
| EIM | Environmental Information Management database |
| EPA | U.S. Environmental Protection Agency |
| et al. | And others |
| FS | Feasibility Study |
| GPS | Global Positioning System |
| i.e. | In other words |
| MQO | Measurement quality objective |
| NPDES | National Pollutant Discharge Elimination System |
| QA | Quality assurance |
| QC | Quality control |
| RPD | Relative percent difference |
| RSD | Relative standard deviation |
| SOP | Standard operating procedures |
| TOC | Total organic carbon |
| USGS | United States Geological Survey |
| WAC | Washington Administrative Code |

## Units of Measurement

| | |
|---|---|
| °C | degrees centigrade |

| | |
|---|---|
| cfs | cubic feet per second |
| ft | feet |
| g | gram, a unit of mass |
| kcfs | 1000 cubic feet per second |
| kg | kilograms, a unit of mass equal to 1,000 grams |
| km | kilometer, a unit of length equal to 1,000 meters |
| m | meter |
| mg | milligram |
| mL | milliliter |
| µm | micrometer |

## 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 (Kammin, 2010). For Ecology, it is defined according to WAC 173-50-040: "Formal recognition by [Ecology] that an environmental laboratory is capable of producing accurate and defensible analytical data."

**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* (USEPA, 2014).

**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:** Discrepancy between the expected value of an estimator and the population parameter being estimated (Gilbert, 1987; USEPA, 2014).

**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, 2014; USEPA, 2020).

**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, 2014; USEPA 2020).

**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:** The process of determining that the data satisfy the requirements as defined by the data user (USEPA, 2020). There are various levels of data validation (USEPA, 2009).

**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, 2014).

**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)/LCS duplicate:** 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. Monitors a lab's performance for bias and precision (USEPA, 2014).

**Matrix spike/Matrix spike duplicate:** A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias and precision errors 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 (USEPA, 2001).

**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):** The minimum measured concentration of a substance that can be reported with 99% confidence that the measured concentration is distinguishable from method blank results (USEPA, 2016). MDL is a measure of the capability of an analytical method of distinguished samples that do not contain a specific analyte from a sample that contains a low concentration of the analyte (USEPA, 2020).

**Minimum level:** Either the sample concentration equivalent to the lowest calibration point in a method or a multiple of the method detection limit (MDL), whichever is higher. For the purposes of NPDES compliance monitoring, EPA considers the following terms to be synonymous: "quantitation limit," "reporting limit," and "minimum level" (40 CFR 136).

**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:

$$RPD = [Abs(a-b)/((a + b)/2)] * 100\%$$

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).

**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).

**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).

**Reporting level:** Unless specified otherwise by a regulatory authority or in a discharge permit, results for analytes that meet the identification criteria (i.e., rules for determining qualitative presence/absence of an analyte) are reported down to the concentration of the minimum level established by the laboratory through calibration of the instrument. EPA considers the terms "reporting limit," "quantitation limit," and "minimum level" to be synonymous (40 CFR 136).

**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, 1992).

**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, 2014).

**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, 2014).

**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).

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