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# TECHNICAL MEMORANDUM

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| **TO:** | Bruce Beauchene/City of Kennewick<br>Dave Nazy/Washington Department of Ecology | **DATE:** | March 31, 2009 |
| **FR:** | Phil Brown/Golder Associates Inc.<br>Steven Humphrey/Golder Associates Inc. | **OUR REF:** | 0839974201 |
| **RE:** | CITY OF KENNEWICK ASR FEASIBILITY STUDY<br>PROJECT DESCRIPTION – SUPPORTING INFORMATION FOR THE RESERVOIR PERMIT APPLICATION | | |

## 1.0 INTRODUCTION

The City of Kennewick, Washington (City) entered into an August 2008 Grant Agreement (State Grant Number G0900011) with the Washington State Department of Ecology (Ecology) to complete an Aquifer Storage and Recovery (ASR) feasibility study. That Agreement defined four phases of the project, with the first phase titled: Phase One Reservoir Permit Application and Preliminary Permit, which describes the requirement to apply for a reservoir permit in accordance with RCW 90.03.370. The Agreement acknowledges hydrogeologic feasibility work completed prior to this study will be the primary body of data to support the application, and the additional site-specific information that is required will be collected in project phases two and three of the project. The project structure is described in more detail in Section 4.0. The City of Kennewick has retained the Golder Associates Inc. (Golder) team to complete the ASR feasibility study.

This document is intended to provide a general narrative of the current project understanding and approach to support the reservoir permit application, sufficient for Ecology to proceed with the public notice requirements of RCW 90.03.280.

### 1.1 Project Background

The City of Kennewick plans to develop an ASR project to support the water demands for the growing population in the area. The project proposes to withdraw water from the Columbia River using the Quad Cities water right under permit S430976P during the winter months, store it in a deep basalt aquifer in the Southridge area, and recover the water to supplement peak demands during the summer months. Previous studies on the feasibility for an ASR program have been completed for the City of Kennewick and areas of a similar setting (GSI, 2009; Aspect, 2005; Golder, 2001). Detailed information on the hydrogeologic system, water quality and the potential for ASR was provided in these studies, which serve as background information for this assessment. Golder has summarized that information below, and encourage the reader to refer to these documents should additional detail be required.

This feasibility study will focus on identifying an ASR storage zone that strikes the best balance between:

- Drilling and well construction costs;
- Water quality and temperature;
- The potential for well interference and interaction with shallower zones;
- Ease of permitting.

The general approach will be to drill to the maximum target depth that funding will support in Phase Two of the project. During drilling, field measurements will be completed to assess zones of permeability and to characterize groundwater quality. Drilling cuttings will be examined in the field and submitted for XRF analysis to classify the basalt flows based on whole rock geochemistry and established correlations. If field measurements indicate a potentially suitable target storage zone has been encountered, a recommendation for constructing the test well will be developed. If questionable or otherwise unsuitable conditions are encountered, test well construction will be delayed until a proposal for drilling to a deeper target can be developed, approved, and funded.

## 2.0 PROJECT DESCRIPTION

The City and Ecology have worked to develop a feasibility study project approach that would evaluate the potential for developing an ASR system. The project will be considered successful according to the following measures:

- The project meets permitting requirements;
- Water is captured during high-flow for later beneficial use during low-flow periods;
- Measurable benefits to streamflow occur during low-flow periods;
- Water quality issues are successfully addressed
- The ASR project remains economically feasible relative to other supply alternatives when these issues are addressed; and
- The project is operated and managed to provide mitigation for the appropriation under Permit #S4-30976P.

The project approach to assess the feasibility of an ASR system for the City of Kennewick involves four phases:

Phase 1 - Reservoir permit application, preliminary permit for drilling, Phase two scope and Quality Assurance Project Plan (QAPP);

Phase 2 - Test well construction, aquifer testing and technical report;

Phase 3 - Project monitoring plan, conditioned reservoir permit, pilot well construction, development, and storage cycle testing;

Phase 4- Preparation of plans and documents for the complete reservoir permit application.

These phases are described in more detail below.

### 2.1 Phase I: Reservoir Permit Application, Preliminary Permit, Phase Two Scope and QAPP

This phase will develop a preliminary Reservoir Permit Application; a preliminary permit to drill a test well; a work plan for drilling, testing, and sampling; a Quality Assurance Project Plan (QAPP); and an initial AKART analysis to evaluate water treatment and quality objectives and approaches.

#### 2.1.1 Task 1 – Reservoir Permit Application

This task involves preparing a draft Reservoir Permit Application using existing information from the USGS, Department of Ecology, consultant reports, and this report (ASR Assessment) completed for the City. Golder will evaluate the need for a mitigation plan based on a conceptual hydrogeologic model and the environmental assessment. An application will be prepared and submitted to Ecology, then updated after Phase 3. This document represents the supporting information for the initial permit application. It is recognized that substantial additional information will be required for approval, and that this project has been structured to develop that information during the second and third phases of the project.

#### 2.1.2 Task 2 – Preliminary Permit

A narrative will be submitted as a request to drill a test well to be used for ASR pilot testing. General information on the well location, anticipated depth/construction, and pumping test description will be included in the narrative. The narrative will reference the production of a detailed scope of work to be approved by Ecology prior to Phase Two of the project. The Preliminary Permit for the test well will be issued and published for a 30-day public notice period.

#### 2.1.3 Task 3 – Prepare Phase II Scope of Work

A Phase Two Scope of Work and QAPP will be developed to ensure Phase 2 will meet the technical, permitting and budget objectives of the project. The elements included in the scope will be an environmental assessment and analysis report; a plan for test well construction and development; technical report documenting results of the test well drilling and aquifer testing program; an outline of the AKART analysis; and a QAPP.

### 2.2 Phase II: Test Well Construction, Aquifer Testing and Technical Report

This phase will begin with an Environmental Assessment and Analysis (EAA) that may include a State Environmental Policy Act checklist and address the potential environmental impacts. This will be followed by a test well drilling program to collect geochemical, stratigraphic, and hydraulic information to support the Phase 2 Technical Report.

#### 2.2.1 Task 1 – Environmental Assessment and Analysis Report

The EAA Report will be prepared in compliance with the requirements of WAC 173-157-150 (1) and (2), and will be supplemented with a mitigation plan if impacts are anticipated based on the Phase 1 modeling work.

#### 2.2.2 Task 2 – Test Well Construction

This task requires selecting a drilling contractor followed by the drilling and sampling of an ASR test well. Requested bids received from drilling contractors will be reviewed with Ecology and the City to select the most responsive bidder based on qualifications, cost, and schedule.

It is anticipated that the test well will be drilled by reverse circulation air-rotary methods. During drilling, cuttings will be sampled for an XRF analysis in an on-site laboratory and a detailed geologic classification will be developed for the well log. Borehole geophysical logging to characterize lithology, permeability, and formation water quality will be conducted if an open-borehole section exists upon completion of the well.

#### 2.2.3 Task 3 – Aquifer Testing

The pumping test for the test well will be conducted in three stages; baseline monitoring, constant rate testing, and recovery monitoring. The pumping period will be set by the ASR Project Team to balance objectives, the final well capacity, water management requirements, and cost. An observation network of nearby wells will be established to monitor the aquifer's hydraulic response in the vicinity of the test well and proposed ASR facility. Testing data will be collected per the Preliminary Permit and QAPP.

#### 2.2.4 Task 4 – Technical Report

Golder will prepare a technical report describing the drilling, testing, sampling, analyses and results. The draft technical report will be submitted for Ecology review, and the final report will be prepared after addressing all comments received from Ecology. Following completion of the final technical report, the ASR Project Team will meet with Ecology to review the Phase 2 test results and recommendations and agree on a second Preliminary Permit to authorize additional testing.

### 2.3 Phase III: Project Monitoring Plan, Conditioned Reservoir Permit, Pilot Well Construction, Development, and Storage Cycle Testing

This Phase begins with the development of a conditioned reservoir permit supported by a Scope of Work and QAPP. An ASR Pilot well will be installed, operational ASR facilities will be constructed, and ASR pilot testing will be completed to determine water quality, reservoir capacity, groundwater system hydraulic response to storage and recovery, well performance issues, and storage zone development.

#### 2.3.1 Task 1 – Scope of Work for Phase 3

The Scope of Work for Phase 3 will be prepared including proposed tasks, methods, deliverables, and an anticipated schedule. A QAPP and project monitoring plan will detail the objectives and methods for the Phase 3 work to be completed.

#### 2.3.2 Task 2 – ASR Pilot Well Construction

Task 2 will consist of constructing and developing an ASR pilot well that will target the storage zone evaluated by the test well. The ASR pilot well will be outfitted with pumping and injection equipment to facilitate subsequent ASR cycle testing. The City will convey water from their distribution system to the ASR well to facilitate the cycle testing operations, and, depending on the results of the AKART analysis, may incorporate a temporary water treatment facility at the wellhouse facility. The Golder Project Team will work with the City, Department of Ecology, and Department of Health to determine whether the extracted water throughout the pilot testing will be placed into the distribution system or used for other purposes.

After completing construction and baseline testing of the ASR pilot well, the Golder team will prepare a technical report consistent with the Phase 3 Scope of Work and conditioned reservoir permit that describes all work completed and results obtained.

#### 2.3.3 Task 3 – ASR Cycle Testing

ASR cycle testing will commence at the pilot well per the conditions of the conditioned reservoir permit. The first ASR cycle will consist of a recharge, storage, and recovery phase as outlined in the permit. It is anticipated that the approach for objectives, schedule and monitoring details will be largely consistent with the one previously developed by Golder and Ecology for the Yakima pilot test (Golder, 2001).

Water quality samples will be collected during the recharge, storage, and recovery phases to document recharge water quality, any near-well changes during the storage period, and recovered water quality through the far side of the mixing zone. At the end of the first year of ASR cycle testing, a draft annual report would be prepared to document the work completed, results obtained, and recommendations for further project development and build-out.

### 2.4 Phase IV: Preparation of Plans and Documents for the Complete Reservoir Permit Application

The goal of Phase 4 is to develop and compile all the documents necessary to complete the reservoir permit application package meeting the requirements of Chapter 173-157 WAC, which may include reference to existing reports that meet application requirements. Data collection and compilation to support Phase 4 may be completed concurrently with Phase 3, though the approach, budget, and schedule are likely to be collaboratively developed by the ASR Project Team after evaluating the longer pilot test results completed in Phase 3.

## 3.0 ASR PROJECT SETTING

The City of Kennewick is located on the west side of the Columbia River in southeastern Washington. Kennewick is located within the Pasco Basin at the foothills of the Horse Heaven Hills at an elevation of approximately 1,000 feet above mean seal level (amsl). The prospective ASR site is termed Southridge due to the close proximity of the Southridge High School located southwest of downtown Kennewick off Union Loop Rd (Figure 1).

In this memorandum, the term “Project Area” refers to the Southridge site, approximately 6 miles south of the Columbia River. The term “Region” refers to an area within a circle of approximately 6 to 10 miles radius of the Southridge site – sufficient distance to encompass the nearby structural features (folds and faults) and the Columbia River. An actual radius of influence (area subject to hydraulic influence from ASR operations) will be estimated on the basis of the aquifer test completed in Phase Two. That area may be either larger or smaller than the area described as in the region of the project in this memorandum.

### 3.1 Geology

The geology of the project area consists of Pleistocene sedimentary deposits at the surface underlain by the Columbia River Basalt Group (CRBG), which is comprised of a series of massive basalt flows. The stratigraphy beneath the project area has been interpreted from over 30 geologic logs from previously drilled wells (Aspect, 2005). The CRBG is composed of the Saddle Mountains, Wanapum, Grande Ronde, Picture Gorge and Imnaha Basalt Formations (Bauer and Hansen, 2000). From the several studies that have characterized the hydrogeology of the CRBG, the basalt stratigraphy is generally well known, and the extent of the basalt formations can be applied to a broad area. The specific formations and their depths at the Southridge site will be assessed by the Phase Two drilling program.

The Saddle Mountains and Wanapum Basalt Formations have been described by others as exhibiting hydrogeologic and geochemical characteristics that may be suitable for large-scale ASR (Aspect, 2005). In the vicinity of the Southridge site, the basalts of the Saddle Mountains and Wanapum formations are expected to comprise the upper 1,500 to 2,000 feet of the CRBG, with the basalts of the Grande Ronde occurring below that (Golder, 2001). Though the Grande Ronde basalts have not been assessed near the Southridge site, they are interpreted as having the potential for both increased salinity and temperature in this area (Hearn and others, 1985). In other parts of the Columbia Basin, basalts of the Grand Ronde are both more permeable and have relatively better water quality than the overlying Saddle Mountains and Wanapum. Because of the combined the risk of elevated temperature and salinity and the additional expense of deeper exploratory drilling, this project will elect to focus on indentifying an ASR storage zone ("reservoir") above the Grande Ronde formation.

## 3.2 Hydrogeology

The hydrogeology of the study area and ASR target zone mainly consists of the aquifers of the CRBG. The CRBG is a large scale regional aquifer system composed of series of volcanic flows typically containing a vesicular flow base/top with intervening entablature. Where not fractured by faults and folding, the basalts typically exhibit high horizontal and vertical hydraulic conductivities in vesicular/fractured, and weathered zones associated with flow tops (i.e. horizontal contacts or interflows), and low horizontal and vertical hydraulic conductivities in the entablature (flow interior, Figure 2). Lateral groundwater movement is primarily within the interflows. Where flows are laterally extensive, there is little vertical hydraulic connectivity between flows.

An ideal ASR storage zone would have the potential to store a large quantity (several hundred million gallons) of recharge water and permit the recovery of most if not all of the water with little impact on nearby groundwater users and surface water. A confined ASR storage zone minimizes impacts to other aquifer systems and limits the potential for leakage to nearby surface water. A laterally extensive high-transmissivity storage zone allows for a large volume of water to be stored and recovered without large changes in piezometric pressure (groundwater level).

Pumping tests have been used to calculate CRBG transmissivities in this area with the highest values (84,000 gpd/ft) attributed to the Wanapum Formation (US DOE, 1982). Testing completed by Golder at the Willowbrook well located in Richland (Golder, 2001) calculated similar values (67,000 gpd/ft). Currently, several wells that have been completed in the CRBG Wanapum Formation are pumped at high rates (200 to 1,200 gpm) which reliably support a variety of uses (Aspect, 2005).

### 3.2.1 ASR Storage Zone(s)

Water is typically stored in a basalt aquifer within an interflow or several combined interflows. An interflow is the area between two flows stacked upon each other and usually contains the most permeable water-bearing zone (Bauer and others, 1985) (Figure 2). The upper section of the Wanapum Formation was identified in a previous study as the best candidate aquifer for storage on the basis of depth and reported permeability. In addition, temperature distribution information suggests that groundwater in the Wanapum basalts may be 5 degrees (F) cooler than both the overlying Saddle Mountains and the underlying Grand Ronde (Hearn, 1985). This suggests that fluid-driven thermal transport is the primary mechanism for the thermal regime rather than a shallow heat source. In this setting, the ASR system could be effective in creating a cool water storage zone in the Wanapum.

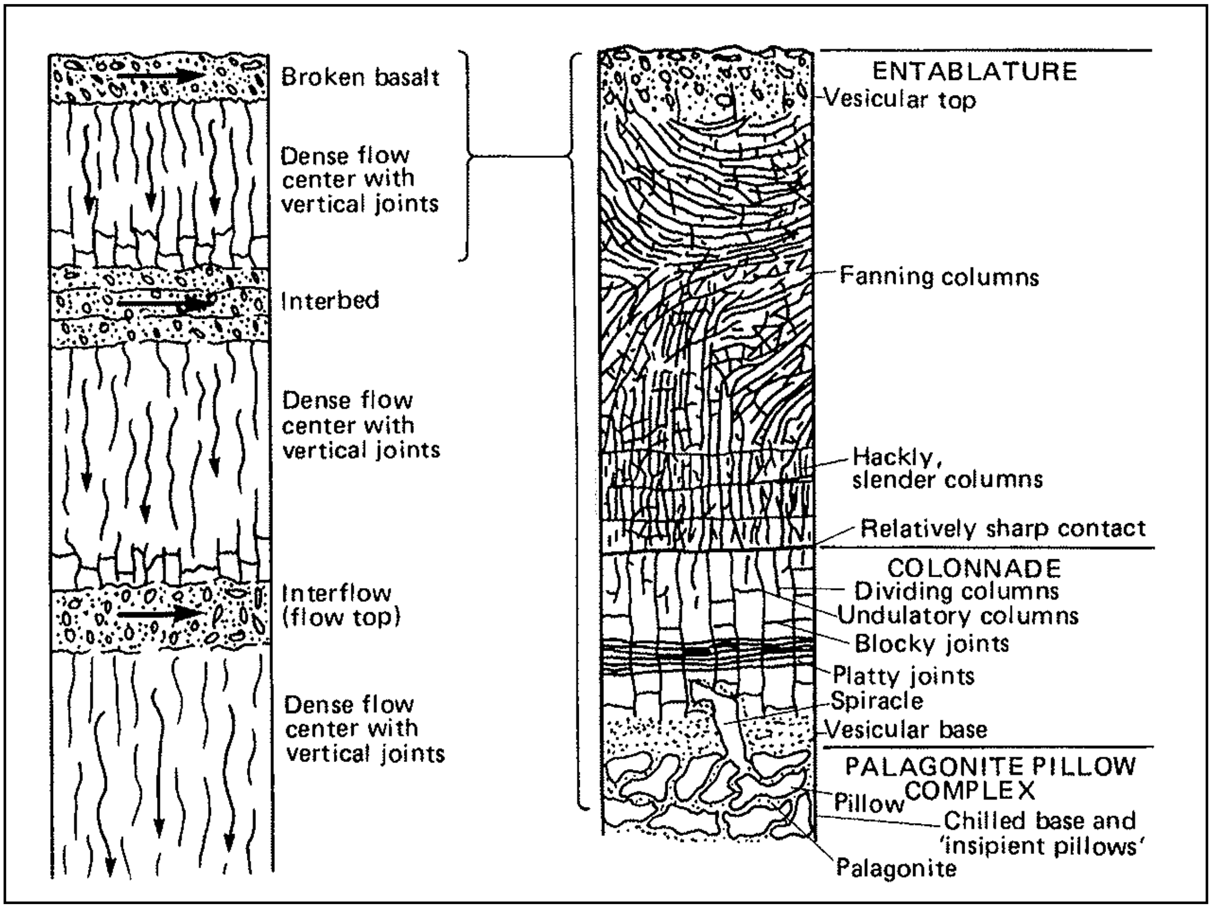


Figure 2: Common CRBG interflow structure and groundwater flow direction (from Steinkampf and others, 1985).

The Wanapum Formation is laterally extensive throughout much of Washington and Oregon, each containing multiple basalt interflows that may serve as potential ASR storage zones. Average thickness of the Wanapum Basalt is around 400 feet, but can be over 1000 feet thick in some areas (Steinkampf and Hearn, 1996). There is some uncertainty regarding the depth of the Wanapum Basalt in the Southridge area. It has been reported to be roughly 600 to 800 feet bgs (Jones and Vaccaro, 2008). However, there are indications that it is 140 to 260 feet deeper than has been depicted previously (Figure 3, pers. comm. with Hoselton, 2008).

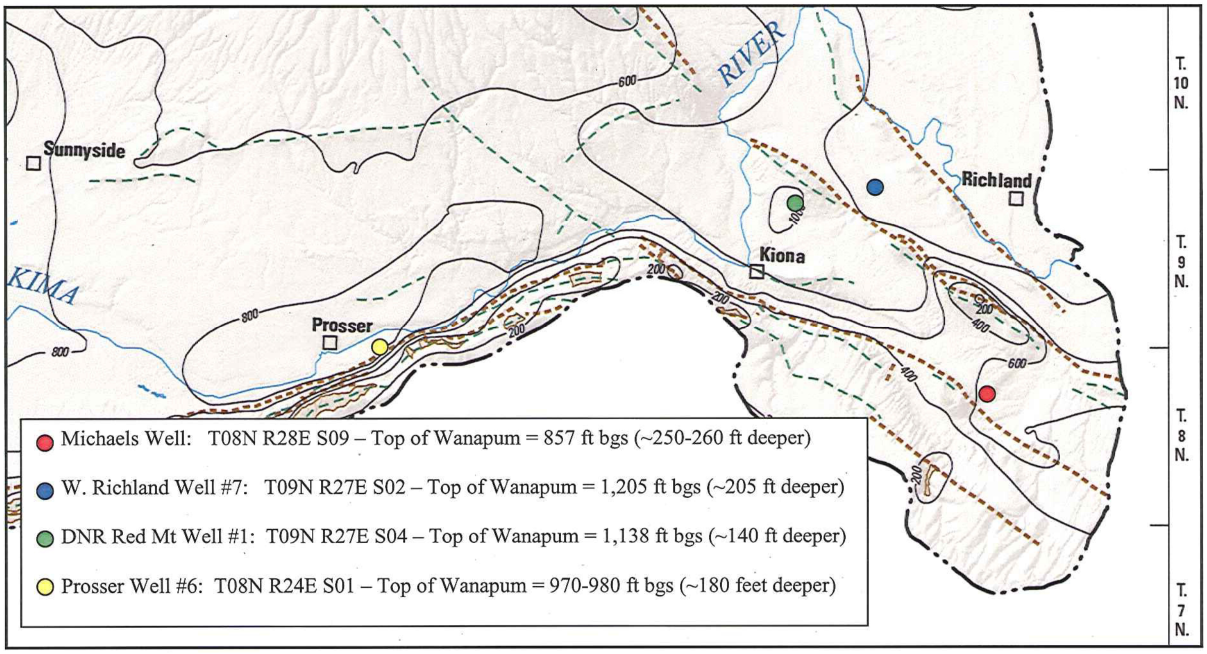

Figure 3: Alternative depths for the top of the Wanapum Basalt. The Kennewick Southridge site lies a short distance east of this mapped area. (Draft Ecology Corrections to Jones and Vaccaro, 2008; provided by WDOE in Draft form, 2009).

The issues with depth and position-related variability in groundwater quality, potential reactivity, and variable temperature regimes could make storage zone development and control a key element of ASR feasibility. Projecting water quality changes over successive ASR pilot testing cycles and distinguishing mixing from other water quality processes (water-water or rock-water interactions), is key to understanding recovery of stored water and subsurface processes. The approach to evaluating geochemistry and recovery efficiency will be developed as part of a drilling and testing work plan included in the QAPP to be submitted to Ecology for approval at the end of Phase One. This information will be evaluated prior to proceeding with any ASR pilot testing activities, and if an ASR well is developed, operational data will be assessed prior to finalizing this reservoir permit application.

Some geologic structures near the Southridge site may present either barriers to groundwater movement or zones of enhanced groundwater flow. There are two major thrust faults located in the foothills to the Horse Heaven Hills, which may have abundant clay and fault gauge, properties known to impede groundwater flow. However, previous studies have associated water chemistry and temperature with proximity to these faults (Aspect, 2005), suggesting the potential for some vertical groundwater movement within the fault zones. Experience has shown that some of these features can act in both modes (enhanced vertical permeability and flow barrier) depending on the relative position: the enhanced permeability may be associated with one side of the fault but not the other. Folds within the study area also have the tendency to affect the occurrence and movement of groundwater flow. This can occur through either change in elevation head as confined water-bearing layers rise or fall along the limbs of the fold, or as the result of increased fracture permeability that sometimes occurs along the axis of a fold. The drilling and testing program implemented in Phase Two of this project will be designed to assess the hydraulic influence of these features and their effects on an ASR system.

### 3.3 Water Quality

The geochemical interaction between the source water, groundwater, and aquifer matrix has the potential to affect the recovered water quality and groundwater quality in the vicinity of the storage zone. Background groundwater quality measured in wells near the Southridge site is reported to be variable, though water samples taken from the area generally meets drinking water standards (Aspect, 2005). During Phase Two drilling, water quality will be assessed for broad physical indicators of relative water quality: temperature, electrical conductivity, oxidation reduction potential (ORP or Eh), pH, color, odor, etc. At least three water chemistry types have been identified in wells in the Kennewick/Richland area, so water quality samples will be collected from the test well to evaluate the background groundwater quality prior to pilot testing activities.

Though reactions between waters or between the source water and the aquifer have not been an issue at other projects in the region (Pendleton, Walla Walla, Yakima), it is possible that trace elements (for example metal sulfides) within the rocks of the storage zone may be oxidized in the presence of recharge water and cause increases in sulfate and trace metals in the recovered water.

## 4.0 CONCEPTUAL ASR SYSTEM

### 4.1 ASR Project Area

The area targeted for ASR development will be called the Southridge site (T8N R29E, Sec. 17, NE ¼ SE ¼ ), located on West 36th Avenue (proposed to be changed to Ridgeline Dr.) off Union Loop Road, near the Southridge High School (Figure 1). The City has acquired property access/ownership for well drilling, testing, and ASR pilot testing at this site. This site has the practical advantages of being near a water delivery pipeline capable of supplying water to the ASR well and is in an area of planned development where increased peaking supply will be advantageous for the City.

### 4.2 Source Water

The source of water for the proposed ASR project will be the Columbia River, and will come from the City's non-mitigated portion of the Quad Cities Water Right (permit number S4-30976P) that is jointly held with the Cities of Pasco, Richland, and West Richland. The maximum diversion rate for this water right is 178 cfs, of which the first 10 cfs is considered mitigated and has a priority date of June 24, 1980. There is a priority date of September 23, 1991 for the remaining portion. The Cities agreed to divide this initial 10 cfs amount equally (2.5 cfs to each City) and then laid out in an agreement of how additional future allocations would be shared. Because the objective of the ultimate ASR program is to divert and store water during non-peak periods (winter months), and put the water to beneficial use in the summer months, two benefits to the system will result; 1) the summer demand on the intake will be reduced by the amount available from the ASR well through direct replacement, 2) the return flow to the river will increase during the low-flow period. If the need for additional mitigation becomes apparent through the EAA and other project phases, the project benefits to other portion of the regional hydrology can be further assessed. The Golder team will work with the City to prepare documentation that winter appropriations will occur when flow objectives are met, and return flows will benefit the summer flow regime.

### 4.3 Anticipated Effects during ASR

With any ASR system, there is the potential for nearby surface water and wells to experience effects from the recharge, storage and recovery of water. The effects are either physical (changes in water level and quantity) or chemical (changes in water quality).Given the depth of the ASR well, the degree of confinement of the basalt interflow zones, the presence of faults that may restrict groundwater movement, and the distance from the Columbia River, we do not anticipate impacts to surface water will occur. Once aquifer characteristics are evaluated through the completion of pumping test, an evaluation of the hydraulic effects of storage and recovery, the radius of the storage zone, and the radius of hydraulic influence will be assessed.

The physical effect of ASR on the groundwater system is interference: water level buildup during the recharge period, and drawdown during the recovery period. Because the ASR project will be operated to avoid a negative impact on the annual water balance (recovery volumes will not exceed storage volumes), no long term trends in groundwater levels or regional recharge/discharge relationships are expected.

The chemical effects on the groundwater system are related to groundwater quality. During recharge, treated drinking water injected into the basalt aquifer will displace native groundwater in the area surrounding the ASR well. Advection and dispersion will result in some mixing of recharge water and groundwater as the recharge water spreads in the aquifer. Because the geochemical characteristics of recharge water are likely to be different from the groundwater, there is the potential for the recharge water and groundwater to react when mixed. Geochemical modeling simulations are a reliable method used to anticipate the possible reactions that occur during groundwater mixing. Based on previous modeling results (using PHREEQC) from a geochemical evaluation of injecting recharge water in to the Willowbrook Well basalt aquifer, no adverse affects to the aquifer water quality were predicted to occur (Golder, 2001). A similar evaluation will be completed as part of this project.

If a storage zone of high-quality drinking water is developed within an aquifer containing relatively lower quality background groundwater, there is the potential for water quality changes down-gradient from the ASR systems because not all of the stored water would be recovered each year. These changes could include water quality improvement down-gradient of the ASR well location (e.g. cooler, lower TDS water) or the appearance of constituents not present in background groundwater (e.g. low levels of nitrate or disinfection byproducts). Because the ASR storage zone will not be selected until Phase Two drilling is completed, the existing wells that may be influenced by ASR cannot be identified at this stage. It is possible that a shallow ASR well could result in some interference or water quality changes at locations near the project site, and a deep well would have reduced potential for any changes to occur. The process for evaluating the potential for effects/changes will be detailed in the AKART analysis scope of work to be completed at the end of Phase One. The general elements of this analysis will include:

1. Characterization of background groundwater quality.
2. Characterization of source water quality.
3. Compare Projected water quality to:
    a. Drinking water standards.
    b. Background groundwater quality.
    c. Identify any data gaps.
    d. Identify any constituents that exceed background groundwater quality.
4. Evaluate Treatment Methods/Technologies to remove constituents of concern prior to recharge.
5. Prepare cost estimate to implement wellhead pre-recharge treatment, including capital and O&M.
6. Develop alternatives matrix.

7. Develop recommendations for project development.

In an effort to understand the impacts of the ASR system to the existing groundwater system, regular sampling for water quality analyses during pilot testing will be conducted. In the low-oxygen low-TOC conditions typically found in basalt aquifers of the CRBG, formation potential for DBPs should be limited and attenuation of DBP's should be rapid (Fram et al, 2003). In addition, historical water quality results for the Willowbrook Well (located near Kennewick) indicated reducing conditions for the aquifer, which are also favorable conditions for reduced formation potential and natural attenuation of DBPs (Golder, 2001).

Previous experience with CRBG fractured basalt aquifers have shown little interaction between the rock matrix and recharge water, and little potential for clogging of the area around the well from reactions with the recharge water. Geochemical modeling evaluations for the Willowbrook well considered the possibility of pyrite mineral oxidation, though the results indicated that any arsenic released would likely be attenuated by adsorption to iron-oxide minerals (Golder, 2001). The project will assess any potential issues by collecting rock samples, looking at whole chemistry, modeling the potential for rock-water interactions and seeing how they might affect both recovered and background water quality.

### 4.4 Approach to ASR System Development

Once the storage zone is characterized and a decision to move forward with additional feasibility testing is made, Phase Three of the project will be implemented to develop an ASR well for pilot testing. Phase Three will include the following major elements:

- A Quality Assurance Project Plan (QAPP) that will detail the objectives and methods for the Phase 3 data collection and reporting tasks. The QAPP will specify data collection and database management procedures that are consistent with Ecology's EIM database.
- A project monitoring plan (complying with WAC 173-157-170(1) and (2)) describing how the ASR project will be monitored to evaluate efficacy and feasibility, and to verify the conceptual model.
- A draft Scope of Work for Phase 3 will submitted to Ecology for review and comment. Mutual agreement between all parties will be reached on the Scope of Work prior to the issuance of a conditioned reservoir permit and prior to proceeding to Task 2.

An ASR pilot well will be constructed and outfitted with pumping and injection equipment to facilitate subsequent ASR cycle testing. The City will convey water from their distribution system to the ASR well to facilitate the cycle testing operations, and, depending on the results of the AKART analysis, may incorporate a temporary water treatment facility at the wellhouse facility. The ASR facility will be designed and constructed with a waste discharge system to allow source water piping to be flushed prior to initiating recharge and allow the ASR well to be pumped to waste during ASR operations. The ability to pump to waste is a key design feature so that the ASR well can be backflushed periodically to maintain well performance during recharge operations, and so that water recovered during the first ASR cycle can be discharged to allow for water quality/potability evaluations.

The Golder Team will design and provide construction assistance for the pilot test well facility to accomplish the monitoring and testing required during the cycle testing. The Team's approach throughout the project will be to keep the pilot facility as simple and flexible as possible in order to reduce costs, while anticipating the needs and efficiencies of planning and designing for the permanent facility. System hydraulic modeling will be conducted to identify the system curves for proper facility sizing, as well as identify any water system changes that hydraulically occur with the addition of a new source of supply in the water system, such as PRV settings and interaction between pressure zones. An existing 16-inch diameter waterline in W.36th Ave. (Hildebrandt) will be extended to the ASR facility and plumbed for both recharge and extraction. The Team will work with the City, Department of Ecology, and Department of Health to determine whether the extracted water throughout the pilot testing will be placed into the distribution system or used for other purposes. The City is considering the costs and time of permitting the new source and treatment requirements of the pilot facility compared with options for disposal, such as local irrigation, adjacent conveyance ways, and the local drainage structures leading towards the East Amon Creek. The pump-to-waste routing will be evaluated for both the pilot and the permanent facility and be required for design. Pump sizing will be determined through the well development and construction. The results of the AKART analysis and whether the extracted water from the well will enter the distribution system will determine the necessity for water treatment. This could be as simple as a temporary disinfection tank and metering pump, to more complex requirements of dechlorination or chemical water treatment (odor, taste, corrosion, pH).

The baseline hydraulic tests will include brief injection and pumping tests to confirm functionality of the constructed ASR wellhead facility and controls and to develop operational criteria for Task 3 ASR cycle testing. Baseline water quality samples will be collected to document ambient groundwater quality and recharge source water at the wellhead. These data will provide a reference to evaluate whether well clogging is occurring as a result of recharge operations. These tests would provide the baseline data from which to evaluate long-term well performance during the cycle tests. The nearby test well and vibrating-wire piezometer as well as any other similarly completed observation wells would be monitored during baseline testing to evaluate hydraulic response.

After completing construction and baseline testing of the ASR pilot well, the Golder team will prepare a technical report consistent with the Phase 3 Scope of Work and conditioned reservoir permit that describes all work completed and results obtained. The technical report will document the following:

- The drilling and well construction program for the ASR pilot test well, including a detailed geologic log and as-built well construction diagram.
- Results of the baseline hydraulic tests, including baseline injection and pumping well performance (specific capacity), confirmation of aquifer properties, hydrogeologic conceptual model, and a summary of water quality analyses.
- Recommendations for target injection and pumping rates for the ASR pilot well to be implemented during Task 3 ASR cycle testing.

A draft technical report will be submitted for Ecology review and comment. A final report will be prepared after addressing all comments received from Ecology.

Following completion of the baseline hydraulic tests and confirmation of ASR system functionality, additional ASR cycle testing will commence at the pilot well per the conditions of the conditioned reservoir permit. The first ASR cycle will consist of a recharge, storage, and recovery phase as outlined in the permit. The broad objectives of the first cycle will include:

- Store sufficient volume to evaluate aquifer hydraulic response to recharge operations;
- Allow the water to remain in storage sufficiently long to fully evaluate the attenuation or development of constituents of interest, and;

- Confirm the recovered water meets drinking water standards and meets the City's requirements for taste, odor, and temperature.

Although the objectives, schedule, and monitoring details will be developed by the ASR Project Team, we anticipate the approach will be largely consistent with the one previously developed by Golder and Ecology for the Yakima pilot test. There, a 30-day storage target was selected and recovery volumes were roughly twice the stored volume to fully evaluate the volume and quality of water in the buffer zone where advective dispersion creates a mixture of the stored and recovered water. The target storage volume will be selected with consideration of beneficial use of the recovered water, the water management approach, and an assessment of the hydraulic gradient and potential drift during the storage period. Injection rates will initially be maintained at approximately 75% of the planned production rate to keep the ability to maintain well performance through higher exit velocities until the potential for clogging is fully understood.

Water quality samples will be collected during the recharge, storage, and recovery phases to document recharge water quality, any near-well changes during the storage period, and recovered water quality through the far side of the mixing zone. Parameters would include geochemical constituents, metals, contaminants, and disinfection by-products. An evaluation of water quality changes during mixing between the stored recharge water and ambient groundwater will be conducted using a chemical mass-balance approach from the geochemical data. Upon completion of the first cycle, the pilot testing data would be compiled and analyzed to evaluate the results and develop recommendations for subsequent cycle tests. If ambient water quality and mixed water quality are acceptable from both regulatory and beneficial use perspectives, subsequent tests are expected to increase in scale and duration and influence larger portions of the aquifer system. At the end of the first year of ASR cycle testing, a draft annual report would be prepared to document the work completed, results obtained, and recommendations for further project development and build-out. The annual report will include discussions regarding ASR operations, water quality changes, well performance, aquifer hydraulic response, and changes in aquifer water budget, an assessment of overall project feasibility and economics, and potential for system expansion. The draft report will be submitted to Ecology and finalized collaboratively with the ASR Project Team.

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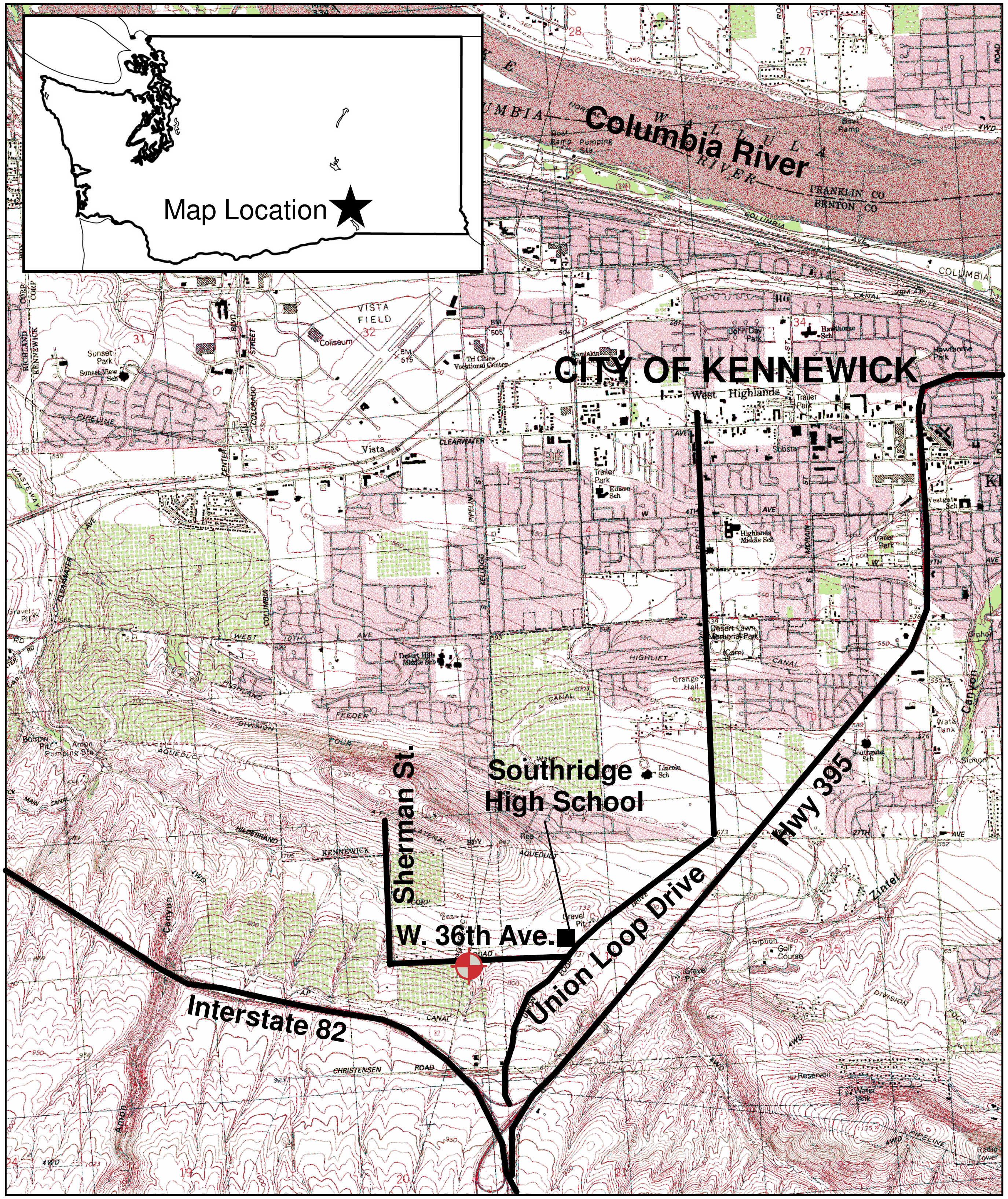


LEGEND

Proposed Test Well Location (Southridge Site)

0 0.25 0.5 1 Miles

Map Projection:
NAD 1927 UTM Zone 11N, Feet

Source: Washington Dept. of Ecology,

This figure was originally produced in color. Reproduction in black and white may result in a loss of information.

N

**Site Map**

FIGURE **1**

**083-9974201**

KENNEWICK ASR FEASIBILITY STUDY

Figure1.mxd | MOD: 3/30/2009 | SLH

**Golder Associates**