TECHNICAL MEMORANDUM

Client:	GSI Water Solutions, Inc.		
Project:	City of Pasco Aquifer Storage and Recovery Study		
Project File:	GSI 20.0142.00.0003	Project Manager:	Paul Cross, PE
Composed by:	Ryan Withers, PE, Andrew B. Dunn LG, LHG, CWRE, and Barney Santiago, PE		
Reviewed by:	Paul Cross, PE		
Subject:	Task 3 – Source Option Analysis		
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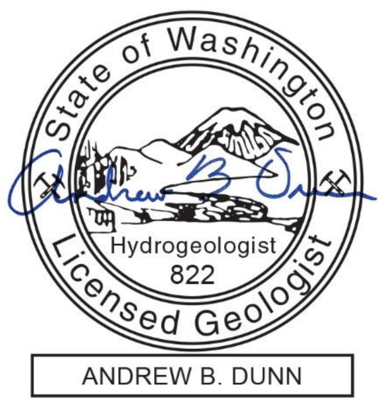


Signed: 05/11/2021 Signed: 05/11/2021 Signed: 05/11/2021

This technical memorandum provides preliminary estimates of:

- The City of Pasco's (City) water right attributes as compared with installed physical capacity and current water use;
- Where, when, and how much storage capacity is needed to meet current and future demands for the City's potable and non-potable systems; and
- Potential source water options for Aquifer Storage and Recovery (ASR) recharge in support of the Task 2 Hydrogeologic Feasibility Assessment.

Water Rights

The City currently holds water rights for its regional potable water system (potable system), water rights for its regional irrigation water system (irrigation system), and water rights for standalone systems such as individual park irrigation and supplemental irrigation water for disposal of effluent at the Pasco Process Water Reuse Facility.

For this study, and because RH2 Engineering, Inc., (RH2) lacks information on the use of water from the standalone systems and the proposed water right changes have not yet been approved (See **Future Water Right Considerations** section below), the focus will be on the potable and irrigation systems.

The layout of the water system, wells, and surface water diversions for both the potable and irrigation systems are shown on **Figure 1**. **Figure 1** also presents four ASR recharge/recovery areas that were evaluated in the *Task 2 – Hydrogeologic Feasibility Assessment* (GSI Water Solution, Inc., December 2020). The *Hydrogeologic Feasibility Assessment* identified Areas A, B, and C as the favorable ASR recharge/recovery areas for additional consideration.

Regional Potable System Water Right Summary

The City currently holds ten water rights for its existing potable system. These water rights total 32,223 gallons per minute (gpm) (46.40 million gallons per day (MGD)), and 19,655.75 acre-feet per year (afy) (6.40 billion gallons (BG)) (**Table 1**).

Table 1

City of Pasco Potable System Water Rights

			Instantaneous Rate (gpm)		Annual Volume (afy)
Water Right Number	**Water Right Stage**	**Point of Diversion**	**Additive**	**Non-Additive**	**Additive**
G3-*10704C(A) [GWC 7205-A]	Superseding Certificate	West Pasco and Butterfield	375	0	76.2
G3-*10704(B) [GWP 10192(B)]	Permit	Butterfield	0	375	132.8
G3-25177C(A)	Superseding Certificate	West Pasco and Butterfield	300	0	0
G3-25177C(B)	Superseding Certificate	West Pasco and Butterfield	0	300	158.7
G3-26081C(A)	Superseding Certificate	West Pasco and Butterfield	400	0	291.3
G3-26081C(B)	Superseding Certificate	West Pasco and Butterfield	0	400	190
S3-*17908C [SWC 11660]	Superseding Certificate	West Pasco and Butterfield	15,709	0	7,000
S4-30976 - First Increment	Permit	West Pasco and Butterfield	1,122	0	1,806.75
S4-33044(A)	Permit	West Pasco and Butterfield	3,097	0	5,000
S3-30852	ROE completed	West Pasco and Butterfield	11,220	0	5,000
	Total		**32,223**	**-**	**19,655.75**

The potable system water rights can be used year round and the place of use is the City's water service area, which can be changed through updates of its water system plan.

Table 1 does not include the 2,244 gpm (3.23 MGD) and 3,613.5 afy (1.18 BG) identified as being used under the first increment of the Quad Cities permit through agreement with the other cities (Murrysmith, 2019). Also missing from **Table 1** is the City's share of the remainder of the Quad Cities water right (S4-30976), discussed as follows.

Quad Cities Interruptible Potable Water Right

The City is presumed to be one-quarter owner of the Quad Cities water right (S4-30976). The Quad Cities water right was initially issued for 178 cubic feet per second (cfs) (79,892 gpm; 115 MGD) and

96,619 afy (31.48 BG). The City's portion of this water right is presumed to equal 44.5 cfs (19,973 gpm; 28.76 MGD) and 24,154.75 afy (7.87 BG). The Washington State Department of Ecology (Ecology) provided mitigation that allowed the Quad Cities to utilize the first increment from the water right on an uninterruptible basis. Each city's portion of that first increment was 1,122 gpm and 1,806.75 afy (**Table 1**).

The undeveloped portion of the Quad Cities water right remaining after the first increment was 168 cfs and 89,392 afy, of which 42 cfs (18,850 gpm; 27.15 MGD) and 22,348 afy (7.28 BG) is the City's portion.

Water rights S4-33044(A) and S3-30852 utilize the Lake Roosevelt Incremental Storage Release Water as mitigation, offered by the Office of Columbia River. These water rights add 10,000 afy to the City's water rights portfolio and their approvals contain the following provision, "In accordance with the MOA Section 5 (b)(ii), equal annual use under permit S4-30976P shall be reduced in equal amount in exchange for developing water supplies with mitigation requirements under…" these two permits.

Subtracting the 10,000 afy from the City's portion of the undeveloped portion of the Quad Cities water right leaves 12,348 afy (4.02 BG) that is available to the City under this water right, but that is currently interruptible since it is unmitigated.

The Quad Cities water right contains Provisions A through I. These provisions are provided here in italics as they appear on the permit, along with a description of the Cities' compliance and any impacts that the provision has on water availability.

Provision A. The Quad Cities shall provide municipal water to all municipal, industrial, and commercial users and uses within their urban service areas based on the Quad Cities' six-year updates of their Regional Water Forecast and Conservation Plan (RWFCP) described in Provision H.5.

> Under the Municipal Water Law, the Cities have a duty to serve within their retail service areas and are doing so.

Provision B. This authorization is subject to Washington Department of Fish and Wildlife juvenile salmon and gamefish screening criteria (pursuant to RCW 75.20.040). Permit holders should contact the Department of Fish and Wildlife, 600 Capitol Way N., Olympia, WA 98501-1091, Attention: Habitat Management Division, Phone: (360) 753-3318 or call (509)575-2734 for the Yakima Screen Shop to obtain specific gamefish (trout, bass, etc.) requirements for their projects.

> All of the Quad Cities' points of diversion from the Columbia River have fish screens that meet the screening requirements.

Provision C. An approved measuring device shall be installed and maintained for each of the sources authorized by this water right in accordance with the rule "Requirements for Measuring and Reporting Water Use", WAC 173-173.

Water use data shall be recorded daily. The maximum monthly rate of diversion/withdrawal and the monthly total volume shall be submitted to Ecology by January 31st of each calendar year. Ecology is requiring submittal of monthly meter readings to collect seasonal information for water resource planning, management and compliance.

The following information shall be included with each submittal of water use data: owner, contact name if different, mailing address, daytime phone number, WRIA, Permit/Certificate, source name, annual quantity used including units, maximum rate of diversion including units, monthly meter readings including units, peak monthly flow including units, Department of Health WFI water system number and source number(s), purpose of use, fish screen status, open channel flow or pressurized diversion and period of use. In the future, Ecology may require additional parameters to be reported or more frequent reporting. Ecology prefers web based data entry, but does accept hard copies. Ecology will provide forms and electronic data entry information.

Chapter 173-173 WAC describes the requirements for data accuracy, device installation and operation, and information reporting. It also allows a water user to petition Ecology for modifications to some of the requirements. Installation, operation and maintenance requirements are enclosed as a document entitled "Water Measurement Device Installation and Operation Requirements".

Department of Ecology personnel, upon presentation of proper credentials, shall have access at reasonable times, to the records of water use that are kept to meet the above conditions, and to inspect at reasonable times any measuring device used to meet the above conditions.

> All of the Quad Cities' point of diversion and points of withdrawal authorized under the Quad Cities permit have source meters installed. The meters are read via the Cities' SCADA systems. The Quad Cities have been collecting and submitting data to Ecology on an annual basis, consistent with this requirement.

Provision D. Following each six-year period, Ecology will issue a certificate for the amount of water put to beneficial use during that period after an investigation has been conducted. Compliance with any Ecology Order issued as part of the water use associated with the six-year period is a requirement of the certificate for that six-year increment.

> The Quad Cities right remains fully in permit stage. Ecology has not yet issued a certificate for the rate and volume of water that has been put to beneficial use under this permit since it was issued in 2003.

Provision E. Unless a new instream flow rule for the mainstem Columbia River is promulgated and Ecology approves an application by the Quad Cities to substitute these flows as conditions to this water right, the following flow objectives apply:

Water may be appropriated under this permit ONLY when the following minimum instream flow requirements are EQUALLED OR EXCEEDED, or when the consumptive water use associated with appropriations under this permit are fully mitigated:

> *1. Between April 10 and June 30, the minimum flow measured at McNary Dam will depend on the April-September runoff forecast at The Dalles Dam, such that:*
>
> *a. if the forecast is 80 million acre-feet (MAF) or less, the minimum flow is 220,000 cfs;*
>
> *b. if the forecast is greater than 80 MAF and less than 92 MAF, the minimum flow is 220,000+((40(forecast-80)/12)x1000) cfs;*
>
> *c. if the forecast is greater than 92 MAF, the minimum flow is 260,000 cfs.*
>
> *2. Between July 1 and August 31, the minimum flow measured at McNary Dam is 200,000 cfs*

3. From September 1 through October 31, the minimum flow measured at McNary Dam is 80,000 cfs.

4. Between November 1 and April 9, the minimum flow measured at Bonneville Dam will range from 125,000 to 160,000 cfs, with the specific flow objective to be set by the FCRPS Technical Management Team every two weeks during that period.

Any future proposed mitigation plans submitted by the Quad-Cities for review by Ecology shall be governed by the following terms:

- *Mitigation for appropriations beyond the first ten cfs will be according to the following "fifty percent or more/fifty percent or less" formula: fifty percent or more of water consumptively used by the Quad Cities during times when flows established in Provision E are not met will be mitigated by flow replacement water upstream of the McNary Dam in the Columbia River system; the balance of the mitigation will be accounted for by fish habitat improvements that benefit Columbia River system fish at least to the same extent as would replacement water.*
- *For any habitat project mitigation proposed by the Quad-Cities under this provision, the Quad-Cities will demonstrate based upon best available science and other applicable legal requirements that the proposed mitigation will benefit Columbia River system fish at least to the same extent as would replacement water.*
- *In determining whether any habitat project mitigation proposed under this provision is acceptable, Ecology will consult with and give a high degree of deference to the Washington State Department of Fish and Wildlife, the Confederated Tribes and Bands of the Yakama Nation, the Nez Perce Tribe, the Confederated Tribes of the Umatilla Indian Reservation, and the Confederated Tribes of the Warm Springs Reservation of Oregon.*
- *Any time Ecology approves the use of mitigation to offset diversion increments after the first increment (the first increment is defined as the first 10 cfs of diverted water), Ecology shall issue an order that is subject to appeal to the Pollution Control Hearings Board or any successor body with jurisdiction to hear appeals from Ecology water right decisions.*
- *To determine the amount of perpetual mitigation for the first increment of water use, Ecology has used an 80 percent consumptive use estimate; i.e., Ecology has assumed that for the first 10 cfs of diverted water, there will be a consumptive use of 8 cfs. Concurrent with the times that the Quad Cities submit each successive Regional Water Forecast and Conservation Plan (RWFCP) Ecology will reevaluate this 80 percent consumptive use estimate based on then-current metering and other data showing actual water returning to the system, and will assume that the appropriate amount of water-for-water mitigation is in place. If consumptive use increases above 80%, in order to keep the diversion for the first 10 cfs not subject to interruption, Ecology will transfer into trust additional water rights from the McNary Pool to offset the additional consumptive use.*

Provision E remains in effect since no new instream flow rules have been promulgated. The first phase of the permit consisting of 10 cfs and 7,227 afy was fully mitigated and can be used by the Quad Cities on an uninterruptible basis. The remaining portion of the permit is currently unmitigated and is interruptible based on the minimum flows identified. The minimum instream flows are discussed in detail here as well as the BiOp Compliance plan included in the 2016 RWFCP update and shown graphically in **Figure 3**. It contains the following language:

> "Water may be appropriated under this permit ONLY when the following minimum instream flow requirements are EQUALLED OR EXCEEDED, or when the consumptive water use associated with appropriations under this permit are fully mitigated." We believe this language provides the Quad Cities with the ability to use a portion of the water right on an interruptible basis, at its discretion.

Provision F. If a new instream flow rule for the mainstem Columbia River is promulgated, the Quad Cities may apply to Ecology to have these new flows substituted as permit conditions for the above flows. The application must be in a form and manner that sufficiently explains the basis for the request and the effect of the request on the public interest, existing rights and water availability. Upon approval by Ecology, the new flow objectives will replace the conditions described above. Until different instream flow objectives are established through formal rulemaking and Ecology approval of an application by Quad Cities to have these flows applied as new conditions to this water right, the flows set forth above shall remain in effect for the duration of the permit.

> Ecology has not promulgated a new instream flow rule for the mainstem Columbia River, so Provision E remains in effect.

Provision G. Based on the flow replacement mitigation agreed to be supplied by Ecology for the first six-year increment, the maximum water diversion allowed under this permit shall be 10 cfs. If additional water is required prior to 2008, the process to obtain it is the same as that described in Provisions E and H.

> The Quad Cities are still within this initial phase of the permit that allows 10 cfs and 7,227 afy of mitigated, uninterruptible, water use. Questions asked of Ecology in the 2016 RWFCP remain unanswered.

Provision H. To access water beyond the initial 10 cfs, the Quad Cities shall submit an updated RWFCP to the Department of Health and the Department of Ecology on a six-year schedule consistent with the schedule for review of water right quantities. The Quad Cities shall coordinate the preparation and completion of their individual water system plans and related supply, demand, and conservation programs. Prior to completion of the plans, the RWFCP will be completed jointly by the Quad Cities to compare demand to available supply and to evaluate the conservation achieved and the conservation projected resulting from implementation of the program described in section 6. The Quad Cities may submit the RWFCP for access to additional water, under the same process described in this condition, prior to any six-year interval if demand forecasts or other circumstances warrant earlier review. The full quantities of water recommended for a permit in this report may be appropriated in six-year increments associated with submittal of the RWFCP, and only when the applicable minimum instream flow is equaled or exceeded, or when the consumptive water use associated with appropriations under this permit is mitigated. Ecology will review the demand estimates, the water conservation elements of the plan, return flow estimates, and other relevant information contained in the plan that comprises the mitigation or flow replacement proposal. Following public comment, Ecology would approve, conditionally approve, or deny the proposed mitigation plan through an Order. If the Order denies the proposed mitigation or flow replacement proposal, then the appropriation for that 6-year increment would be subject to interruption when the flow objectives in this permit are not met, as described in Provision E.

1. The non-interruptibility of water use beyond the first 10 cfs requires that the Quad Cities submit a mitigation plan to Ecology for approval. Unless extraordinary circumstances exist, when the Quad Cities propose a mitigation plan for future diversion increments under their water right, the Quad Cities will submit their plan at least one year before the Quad Cities need a final decision from Ecology. Ecology will use this one year period for public notice, consultation, and to accomplish any necessary water right trust transfers. For purposes of this section "extraordinary circumstances" is defined only as factual circumstances that establish the need for an Ecology response time of less than one year. In no case will Ecology shorten its review and decision time so as to preclude Ecology from fulfilling its public notice and consultation obligations. The mitigation required for withdrawals of water in the succeeding six-year periods shall be proposed by the Quad Cities in their six-year FWFCPs for approval by the Department of Ecology.

2. Upon issuance of an Order by Ecology approving, in conformance with Provision E of this permit, one or more trust water rights or approving another replacement water program or a mitigation program proposed by the permittee to offset the full projected consumptive use during periods when flow objectives are not met, the six-year appropriation will not be conditioned as interruptible.

3. The maximum quantity of withdrawals of water requiring mitigation during the succeeding six-year periods will be presented in the RWFCPs and determined by subtracting estimated return flow from the maximum diversion amount. Return flow calculations shall be based on best available science and shall reflect seasonal conditions. During the course of that six-year period, actual quantities to be mitigated will depend on daily recording and monthly reporting of actual use under this permit, return flow estimates corresponding to the season of water use, and whether or not the then current flow objectives are achieved during that period.

4. Each RWFCP shall include a Conservation Plan demonstrating how the best available and reasonable conservation technology will be implemented in the subsequent six-year period. The Conservation Program shall meet, as a minimum for the entire life of the permit, current (as of date prepared) Department of Health requirements as well as the conservation conditions described below. In addition, the RWFCP with its Conservation Program shall be submitted to the Department of Ecology for review and approval consistent with the six-year schedule for reviewing water rights. The RWFCP shall propose and implement water conservation activities in the following areas: reducing leakage and unaccounted for water from the municipal water supply system; and monitoring, accounting for (separately) and reducing commercial, industrial, residential (indoor) and landscape water use. The Conservation Program shall include a detailed profile of current water use characteristics for each conservation category defined above including their total annual demand, average demand, unit demand and peak demand. Compliance with the Conservation Program for each six year period shall be a condition of the permit.

5. The Quad Cities RWFCP shall comply with Department of Health rules (Conservation Planning Requirements, Washington State Department of Health PUB 331-008, March 1994) which currently require that these plans contain, as a minimum:

- Water Use Data Collection Requirements. Systems must report the best currently available data on water use for the categories of use, which are identified by the department.

- Water Demand Forecast. A complete forecast, including an estimate of reduction of water use from implementation of water conservation measures, must be developed.

- Conservation Program. A Conservation Program must be developed and implemented. The Conservation Program elements must include: Conservation Objectives; Evaluation and Conservation Measures; and Identification of Selected Conservation Activities.

If the Department of Health adopts more stringent rules relating to water conservation, the Quad Cities will plan and implement their plans to meet or exceed the more stringent rules.

6. In addition to the general water conservation requirements described above, the following Conservation Program activities are required as conditions of this permit. The Quad Cities will initiate development of the following programs within one year after issuance of the permit and will adopt them for implementation within two years of the date of permit issuance.

For the purpose of the following conservation program elements, the term "implement" means obtaining and expending funding for capital facilities and operational staff, program assessment, and monitoring and reporting associated with each program element in a manner and on a schedule to achieve, and once achieved to maintain, the stated goal or target.

i. Leak Detection Program – The Quad Cities shall implement a program to reduce leakage and unaccounted for water for each water supply system within the Quad Cities area. Leakage and unaccounted for water includes water loss due to leaking water mains and smaller distribution lines and inefficient fixtures, including inaccurate metering. Unaccounted for or unmetered water consumption also includes uses such as street sweeping, contractors, flushing hydrants, dust control, and erosion control by the Cities, County and private parties. The goal of the program is to reduce unaccounted for water to no more than 10% of the total diversion by 12/21/2010. The improvements to achieve the goal that are not concluded by 2010 must be identified and incorporated in the State approved Water System Plan for the city's capital improvement program with a completion date of no more than 2016.

ii. Large Meter Testing Program – The Quad Cities shall implement a program by December 31, 2005 to test all large meters (greater than 2-inches diameter, primarily used in commercial/industrial connections) and repair or replace all meters found to be defective. The testing and maintenance program will continue after the December 31, 2005 date on a schedule consistent with the manufacturer's recommendations.

iii. Residential Meter Repair/Replacement Program – The Quad Cities shall implement a program by December 31, 2005 to test and repair or replace all residential water meters on a schedule consistent with manufacturers' recommendations. The testing and replacement program will continue after December 31, 2005 date on an appropriate schedule to ensure that the users meters are reasonably accurate.

iv. Residential Retrofit Program – The Quad Cities shall implement a residential retrofit program by December 31, 2004 to provide the public with low-flow shower heads, toilet tank displacement bags, leak detection tablets and other residential water conservation measures. The initial program will be completed by December 31, 2008.

v. Source Metering Replacement and Improvement - The Quad Cities shall implement a source metering and replacement and improvement program by December 31, 2005 to ensure that all water sources are accurately monitored.

vi. Develop a Water Audit Program for Large Water Users - The Quad Cities shall develop and implement water audit program for large (commercial, industrial and institutional) water users. At least 50% of the large water users will be audited by December 31, 2007 and the remainder of the audits completed by 2010. The water audit program shall continue on an ongoing repeat schedule for those large customers where the audit suggests that reasonable additional water user reduction is possible.

vii. Develop a Joint Plan with Irrigation Districts to address Urban Area Irrigation Needs – The Quad Cities shall pursue development of a Joint Plan with Irrigation Districts whose service areas overlap with the Quad Cities service area. The Plan shall address irrigation water supplies for landscape use (e.g., which entity supplies landscape water and Quad Cities policies on serving those areas) and landscape water demands during water-short periods when Irrigation Districts may prorate their water users. This plan will be completed by December 31, 2009.

viii. Develop an Integrated Water Shortage and Drought Response Plan – The Quad Cities shall develop an integrated Water Shortage and Drought Response Plan for periods when water demand exceeds allowed diversions. This plan will be completed by December 31, 2007.

ix. Develop a recommended School Education Program – The Quad Cities will work with the school districts within the UGA for the Quad Cities to define appropriate classroom materials and assist the school districts with implementation of the program. The plan will be outlined and a recommended program be adopted for initial implementation by the cities within two years from the issuance of the permit. The implementation int eh schools will be on the schedule approved by the school districts.

x. Develop a General Public Education Program – The Quad Cities will develop a public education program as committed to in the Regional Water Supply Plan that will include outreach to all customers emphasizing the efficient use of both indoor and outdoor watering, consumptive use records on water bills, the promotion of water efficient devices such as low flow shower heads, and regional publications explaining conservation programs. This program shall be developed by December 31, 2005 and implemented on an on-going basis.

This provision requires the Quad Cities to prepare and submit an updated RWFCP to access water beyond the initial 10 cfs and on the 6-year schedule (which at the time was consistent with the water system plan update timeline) in addition to other requirements related to efficiency. Each of the required plans and programs were initiated by the required dates and are detailed in the 2016 RWFCP.

The Cities provided Ecology with the 2005 Interim Regional Water Forecast and Conservation Plan, then the first non-interim plan was prepared in 2008. In 2015, meetings were held between Ecology and the Quad Cities in preparation of updating the RWFCP. On January 29, 2016, the Quad Cities provided Ecology (Keith Stoffel (ERO Section Manager), Trevor Hutton (CRO Section Manager), and Mark Schuppe (OCR Section Manager)) with an update to the RWFCP, as required by Provision H. In the updated RWFCP, the final section of the plan was, "Request for Additional Authorization Under QCWR." Within this section, five requests were made of Ecology.

1. Increase the instantaneous rate authorized to physically enable the Quad Cities to use the mitigation water secured by Ecology.
2. Process water right application S4-33044(A) for the City of Pasco. Ecology has done this, in addition to issuing the subsequent S3-30852.
3. Agree to which mitigation alternative is to be used.
4. Determine whether it is appropriate to only mitigate 80 percent of the time (consistent with the 2001 drought condition).
5. Depending on the answers to the above requests, determine how much of the original Phase 1 water can be used to mitigate into Phase 2.

The Quad Cities requested that Ecology review and approve the plan. Follow-up calls and/or emails were sent to Mark Schuppe on March 24, 2016, May 25, 2016, May 31, 2016, June 1, 2016, June 9, 2016, and June 15, 2016 trying to see if any additional information was needed and to ask when a decision would be issued. Ecology never issued an approval or denial of the plan. The inaction by Ecology forced the Quad Cities to move forward with the January 2016 plan, with the unanswered requests in order to meet water system planning deadlines with DOH.

Provision I. This permit herein recommended is specifically subordinate to any future permits that may be issued under applications No. S4-29956, S4-30052, R4-30102, S4-30465, and S4-30584.

Statement of subordination of this permit to other water right. No actions need to be taken by the Quad Cities.

That concludes the discussion of the Quad Cities water right provisions and compliance.

In a recent email exchange with Ecology's Office of Columbia River (Tom Tebb), it was generally agreed that the 6-year RWFCP review schedule no longer makes sense since DOH has moved to reviewing water system plans on a 10-year schedule. A request was made of Ecology to change this provision. Ecology agreed that the provision should be changed. However, the proper mechanism for changing that provision has not yet been determined by Ecology and the Quad Cities.

Due to the passage of time, changes in other agency practices, issuance of stand-alone water rights for the City, and staff turnover at both the City and Ecology, the Quad Cities and Ecology should meet to discuss the Quad Cities permit, its provisions, and compliance.

Therefore, this undeveloped portion of the water right is subject to minimum instream flow limitations as specified in the permit provisions (**Figure 2**).

The approved points of diversion under this water right for the City are the West Pasco and Butterfield Intake locations (**Figure 1**).

Using the BiOp Compliance Plan contained within the January 2016 *Regional Water Forecast and Conservation Plan* (RH2, 2016), the probability of water being available each month over the period of 2005 through 2019 water years is contained in **Table 2** and **Figure 3**.

Table 2
Quad Cities Interruptible Water Right Water Availability

Month	Percent Time Water Available
October	83%
November	58%
December	85%
January	91%
February	88%
March	88%
April	62%
May	73%
June	64%
July	38%
August	9%
September	76%

The period of highest availability for the interruptible water right is the period of December through March, which has an average water availability of 88 percent over this 4-month period.

If the City can add the Columbia River Intake as an additional point of diversion under the Quad City water right, it could utilize both the potable and irrigation systems to pump water from the Columbia River to the ASR storage sites.

Regional Irrigation System Water Right Summary

The City currently holds 24 water rights for its existing irrigation system. These water rights total 17,608 gpm (25.36 MGD) and 7,216.7 acre-feet per year (2.35 BG) (**Table 3**). The irrigation system water rights currently are pumped from 11 wells (First Place, Desert Sunset, Island Estates, Sirocco, Road 52, Village of Pasco Heights, Northwest Commons, Desert Estates, Linda Loviisa, I-182, and Powerline Road) and 2 surface water diversions (Columbia River Intake and the Butterfield Intake).

Table 3
Regional Irrigation System Water Rights

Water Right Number	Water Right Stage	Point of Withdrawal or Diversion	Period of Use	Instantaneous Rate (gpm)	Annual Volume (afy)	Chapter 173-563 WAC Interruptible	508-14 Provision	FFWA Provision
G3-01243C	Certificate	First Place Well	Year Round	1,400	558	No	No	No
G3-20242(A)	Superseding Permit	Road 52 Well	2/1 to 10/1	1,431	636	No	Yes	No
G3-20242C(B)	Certificate	Island Estates Well	2/1 to 10/1	140	62	No	No	No
G3-20242(C)	Superseding Permit	Road 52 Well	2/1 to 10/31	1,134	504	No	Yes	No
G3-20243(A)	Superseding Permit	Northwest Commons Well	2/1 to 10/31	1,612	483.6	No	Yes	No
G3-20243(B)	Superseding Permit	Desert Sunset, Sirocco, and Northwest Commons Wells	2/1 to 10/31	214	107.9	No	Yes	No
G3-20243(C)	Superseding Permit	Desert Sunset Well	2/1 to 10/31	1,174	441.6	No	Yes	No
G3-20244C(A)	Superseding Certificate	Linda Loviisa Well	2/1 to 10/31	1,300	525.8	No	No	No
G3-20244C(C)	Superseding Certificate	Linda Loviisa Well	2/1 to 10/31	580	234	No	No	No
G3-23525C	Certificate	Village of Pasco Heights Well	3/1 to 11/1	1,300	660	No	No	No
G3-24978C	Certificate	Linda Loviisa and I-182 Wells	2/1 to 12/31	1,600	660	No	No	No
G3-24981C(A)	Certificate	Desert Estates Well	Year Round	80	41.9	No	No	No
G3-24981C(B)	Certificate	Desert Estates Well	Year Round	400	160	No	No	No
G3-26368C	Superseding Certificate	Linda Loviisa and I-182 Wells	Year Round	400	164	No	No	Yes
G3-27413(B)	Superseding Permit	Powerline Road Well	Seasonal	270	108.1	No	Yes	No
G3-27413(C)	Superseding Permit	Powerline Road Well and Columbia River Intake and Butterfield Intake	Seasonal	573.75	203.4	No	Yes	No
G3-27413(D)	Superseding Permit	Powerline Road	Seasonal	281.25	112.4	No	Yes	No
G3-27413(F)	Superseding Permit	Powerline Road	Seasonal	270	108	No	Yes	No
G3-28452C	Certificate	Columbia River Intake	Seasonal	450	170	No	No	Yes
S3-28615C	Certificate	Columbia River Intake	Unspecified	1,643	732	Yes	No	Yes
S3-28788C	Certificate	Columbia River Intake	Unspecified	139	56	Yes	No	Yes
S3-28789C	Certificate	Columbia River Intake	Unspecified	121	48	Yes	No	Yes
S3-28790C	Certificate	Columbia River Intake	Seasonal	498	200	Yes	No	Yes
S3-28932C	Certificate	Columbia River Intake	Unspecified	597	240	Yes	No	Yes
		Total		**17,608**	**7,216.7**			

Table 3 does not include G3-26578 (Burbank Irrigation District water right), since the change authorization to transfer this water right to the City for withdrawal from the First Place Well, as approved by the Franklin County Water Conservancy Board under FRAN-19-04 and CG3-26578C@1, was denied by Ecology and currently is under appeal to the Pollution Control Hearings Board (PCHB) as Case No. P20-068.

The period of use of the irrigation system water rights are variable, and some are unspecified or general in nature, such as "seasonal."

Interruptible Irrigation Water Rights

Five of the City's surface water rights for diversion from its Columbia River Intake, totaling 2,998 gpm (4.32 MGD) and 1,276 afy (0.42 BG), are interruptible based on the Instream Resources Protection Program for the mainstem Columbia River in Washington State, which is Chapter 173-563 Washington Administrative Code (WAC) (**Table 4**). The water rights are only interruptible if the March 1st forecast for the April through September runoff at The Dalles, Oregon (as published by the National Weather Service in Water Supply Outlook for the Western United States) is 60 million acre-feet (MAF) or less. If the forecast is below this threshold volume, the water rights are subject to regulation (not allowed to divert) by Ecology when the gauged flows are predicted by the Bonneville Power Administration (BPA)

30-Day Power Operation Plan to be less than the minimum flows provided in the provision at downstream control stations including McNary Dam, John Day Dam, and The Dalles. Over the past 60 years (1961 through 2020), the March 1st forecast has only been 60 MAF or less on two occasions, in 1977 and 2001, which is a frequency of once every 30 years. The provision on the water right suggests regulation will occur at least once every 20 years.

Table 4
Minimum Instream Flow Provisioned Water Rights

Water Right Number	Water Right Stage	Point of Withdrawal or Diversion	Period of Use	Instantaneous Rate (gpm)	Annual Volume (afy)
S3-28615C	Certificate	Columbia River Intake	Unspecified	1,643	732
S3-28788C	Certificate	Columbia River Intake	Unspecified	139	56
S3-28789C	Certificate	Columbia River Intake	Unspecified	121	48
S3-28790C	Certificate	Columbia River Intake	Seasonal	498	200
S3-28932C	Certificate	Columbia River Intake	Unspecified	597	240
			Total	**2,998**	**1,276**

508-14 Area Irrigation Water Rights

The 508-14 Area is an administrative boundary established by Ecology under Chapter 508-14 of the WAC. Water rights issued by Ecology within the 508-14 Area must remain in permit stage indefinitely until it can be determined if the water tapped is public water (in which case a certificate could be issued), or if it is artificially stored groundwater of the Columbia Basin Project. Although the remedy for tapping artificially stored groundwater has not been decided, it likely would be similar to the Quincy Basin Subarea (in which the water right holder would have to enter into a license with the United States Bureau of Reclamation (Reclamation) for use of that water). The 508-14 Area is generally located north and east of the City proper. The boundary runs generally from west to east starting from the east quarter corner of Section 11, Township 9 North, Range 28 East W.M. at the Columbia River to the center of Section 12, Township 9 North, Range 30 East, W.M. (roughly along the Sandifur Parkway alignment), at which point it turns generally south and runs to the north bank of Lake Wallula (Snake River arm), at which point it follows the north shoreline of the Snake River upstream.

The City currently operates three irrigation wells as part of its irrigation system within the 508-14 Area (Powerline Road, Road 52, and Northwest Commons Wells).

Typically, Ecology does not authorize water rights for wells completed within the 508-14 Area to be changed to include wells or surface water diversions outside of the 508-14 Area since the administrative rules are different in those locations. However, at least two water rights held by the City include points of withdrawal both inside and outside of this administrative boundary (G3-20243(B) and G3-27413(C)); so, there is precedent.

The City currently holds nine 508-14 provisioned water rights as part of its irrigation system, totaling 6,960 gpm (10.02 MGD) and 2,705 afy (0.88 BG) (**Table 5**).

Table 5

508-14 Area Provisioned Water Rights

Water Right Number	Water Right Stage	Point of Withdrawal or Diversion	Period of Use	Instantaneous Rate (gpm)	Annual Volume (afy)
G3-20242(A)	Superseding Permit	Road 52 Well	2/1 to 10/1	1,431	636
G3-20242(C)	Superseding Permit	Road 52 Well	2/1 to 10/31	1,134	504
G3-20243(A)	Superseding Permit	Northwest Commons We	2/1 to 10/31	1,612	483.6
G3-20243(B)	Superseding Permit	Desert Sunset, Sirocco, and Northwest Commons Wells	2/1 to 10/31	214	107.9
G3-20243(C)	Superseding Permit	Desert Sunset Well	2/1 to 10/31	1,174	441.6
G3-27413(B)	Superseding Permit	Powerline Road Well	Seasonal	270	108.1
G3-27413(C)	Superseding Permit	Powerline Road Well and Columbia River Intake and Butterfield Intake	Seasonal	573.75	203.4
G3-27413(D)	Superseding Permit	Powerline Road	Seasonal	281.25	112.4
G3-27413(F)	Superseding Permit	Powerline Road	Seasonal	270	108
			Total	**6,960**	**2,705**

Family Farm Water Act Irrigation Water Rights

The Family Farm Water Act (FFWA), codified in Chapter 90.66 Revised Code of Washington (RCW), was passed as an initiative on November 8, 1977, and was amended in 1979 and 2001. This statute set limits on the number of agricultural acres that can be irrigated by one person or entity with water rights obtained after passage of the law. The intent was to protect the family farmer in Washington State. There are many different types of Family Farm Water Rights as defined in RCW 90.66.050, and each type has specific conditions for its use. The City currently holds 7 FFWA provisioned water rights within its irrigation system portfolio, totaling 3,848 gpm (5.54 MGD) and 1,610 afy (0.52 BG) (**Table 6**).

Table 6

Family Farm Water Act Provisioned Water Rights

Water Right Number	Farmily Farm Permit Type	Water Right Stage	Point of Withdrawal or Diversion	Period of Use	Instantaneous Rate (gpm)	Annual Volume (afy)
G3-26368C	Family Farm Development Permit	Superseding Certificate	Linda Loviisa and I-182 Wells	Year Round	400	164
G3-28452C	Family Farm Permit	Certificate	Columbia River Intake	Seasonal	450	170
S3-28615C	Public Water Entity Permit	Certificate	Columbia River Intake	Unspecified	1,643	732
S3-28788C	Public Water Entity Permit	Certificate	Columbia River Intake	Unspecified	139	56
S3-28789C	Public Water Entity Permit	Certificate	Columbia River Intake	Unspecified	121	48
S3-28790C	Public Water Entity Permit	Certificate	Columbia River Intake	Seasonal	498	200
S3-28932C	Public Water Entity Permit	Certificate	Columbia River Intake	Unspecified	597	240
				Total	**3,848**	**1,610**

If these water rights are used to supply the water for storage, the subsequent use of the water after retrieval from storage likely would need to continue to conform to the definitions of the use of water as authorized under the FFWA.

However, the law does allow for FFWA provisioned water rights to be changed to municipal use if the place of use of the water right falls within the City's Urban Growth Area (UGA) (RCW 90.66.065).

Future Considerations

Pending Change Applications

The City currently has 43 pending water right change applications before the Franklin County Water Conservancy Board (FCWCB). The water right total for all of the water rights proposed to be changed is 39,142 gpm (56.36 MGD) and 16,368.6 afy (5.33 BG). This includes all of the irrigation system water rights (**Table 3**), plus 21,534 gpm (31.01 MGD) and 9,152 afy (2.98 BG) from other water rights. Source metering data would need to be analyzed to determine how much water might be unused under the other water rights that could be available to meet future demands.

The change applications were filed in either 2016 and amended in 2020 (7 change applications), or were filed in 2020 (36 change applications). Most water rights are in the City's name, but some are in other names. The 2020 change applications request to add all existing points of withdrawal and points of diversion to all water rights (33 in total), make the period of use year round, make the purpose of use municipal, and make the place of use the area served by the City.

If these water rights can be changed as requested, it could add significantly to the rate and volume of water available for direct use and/or for aquifer storage and recovery.

Physical Source Capacity

Irrigation System Capacity

The City's existing irrigation system has an approximate total supply capacity of 17,750 gpm (25.5 MGD), and is approximately at capacity as of Quarter 4 of 2020. The existing irrigation system heavily relies on all existing sources operating to meet peak demands, including the system's largest source (the Columbia River Intake) operating at its existing 3,000 gpm (4.3 MGD) capacity. The existing irrigation system has an existing firm capacity of 14,750 gpm (21.2 MGD), if the Columbia River Intake source is out of service or unavailable due to minimum instream flow regulations.

Source capacity improvements have been identified by RH2 in past technical memoranda to the City identifying increased source capacity (*Irrigation System Capacity Analysis Technical Memorandum*, RH2, October 31, 2018; and *Future Irrigation System Supply Technical Memorandum*, RH2, August 29, 2019). Specifically, the City has the ability to convert two Columbia River intake pumps that have been historically utilized for the potable water system to irrigation system use, resulting in an approximately 5,400 gpm (7.8 MGD) capacity increase. The City also has the ability to re-drill or refurbish multiple irrigation wells to improve their pumping rates. Relatedly, the City may be able to make water right adjustments to allow existing irrigation wells that are currently limited by instantaneous quantity (Qi) to be pumped at their physical capacity. Either of these physical or water right-related improvements are estimated to improve the irrigation system capacity by an additional 600 gpm (0.9 MGD).

The City is coordinating with the South Columbia Basin Irrigation District (SCBID) and Reclamation to determine the feasibility of municipal and industrial (M&I) water to meet future source capacity shortfalls (maximum of 20 cfs (9,000 gpm) and 2,500 afy). The City's initial request of 1,000 afy has been submitted to Reclamation and is currently under review. For the purposes of the supply analyses presented in the subsequent tables, no M&I water is included.

Growth within the irrigation system is anticipated to take place as infill within the existing irrigation system footprint occurs, with an estimated 907 gpm (1.3 MGD) of infill growth anticipated prior to 2036. Additional growth is anticipated within the City's UGA expansion area in the northwestern portion of the City. A portion of the UGA expansion area is located at higher elevations than the existing irrigation system customers and likely will require additional booster station facilities and/or storage facilities. Currently, no additional storage facilities are planned in the UGA expansion area. As such, future irrigation system supply facilities must be capable of meeting the peak hour demand in the UGA expansion area. The City's existing maximum day demand (MDD), projected infill demand on an MDD basis, and projected UGA expansion area demand on a peak hour demand (PHD) basis are shown in **Table 7** for the year 2036.

Table 7 also includes the City's irrigation system existing capacity on a total and firm capacity basis, as well as the additional surface and groundwater capacities based on previously identified improvement projects. Based on the capacity evaluation shown in **Table 7**, the irrigation system is estimated to have a 2036 supply deficiency of approximately 5,548 gpm (12.4 MGD) based on the system's total capacity, and approximately 8,548 gpm (19.0 MGD) based on the system's firm capacity.

Table 7
Irrigation System Supply Capacity Evaluation

2036 Capacity (Peak Season)

Description	Total Capacity (gpm)	Firm Capacity (gpm)
Source Capacity		
Existing Source Capacity	17,750	14,750
Additional Intake Pumping Capacity	5,400	5,400
Additional Groundwater Pumping Capacity	600	600
Total Source Capacity	**23,750**	**20,750**
Demands		
MDD	15,090	15,090
Infill Demand Projection (MDD)[1]	907	907
UGA Expansion Area (PHD)[1]	13,301	13,301
Total Demands	**29,298**	**29,298**
Surplus (or Deficient) Source Capacity		
Surplus (or Deficient) Source Capacity	**(5,548)**	**(8,548)**

(1) Existing system storage is slightly deficient for existing demands. If no additional storage is constructed, PHD is recommended to be considered for future demand projections, or a reduction in service pressures will occur in the system during PHD events.

Potable System Capacity

The City's existing potable water system has an approximate total capacity of 22,800 gpm (32.8 MGD). The existing potable water system has an existing firm capacity of 20,700 gpm (29.8 MGD), if the high service pump or a membrane train in the West Pasco Water Treatment Plan (WPWTP) is out of service.

The City currently is designing improvements at the WPWTP to provide a total capacity of 18 MGD and a firm capacity of 12 to 15 MGD. The City is also currently implementing improvements at the Butterfield Water Treatment Plan (WTP), which may increase capacity by 1 MGD to 3 MGD. For the purposes of the analyses presented herein, a combined increase in source capacity of 15 MGD between the WPWTP and the Butterfield WTP are assumed.

With the completion of these improvements at the City's existing WTPs, the City's potable water system is projected to have a slight source capacity deficiency in 2036 of approximately 145 gpm (0.2 MGD) based on the system's total capacity, and a capacity deficiency of approximately 2,245 gpm (3.2 MGD) based on the system's firm capacity, as shown in **Table 8**. The City's projected year 2036 potable water system demands are based on the City's *Water System Plan* (WSP) Table 6-2 and are assumed to include both infill demands and the demands projected in the City's UGA expansion area. However, the City's WSP presents a population increase by the year 2036 that is approximately 10,000 people less than the City's 2020 draft *Comprehensive Plan*. If the City's WSP is underestimating the projected 2036 water service population by approximately 10,000 people, approximately 3.2 MGD (2,222 gpm) of additional source capacity will be required. For the purposes of this analysis, the additional 10,000 people are assumed to be added to the year 2036 demands, as shown in **Table 8**.

Table 8

Potable Water System Supply Capacity Evaluation

2036 Capacity (Peak Season)

Description	Total Capacity (gpm)	Firm Capacity (gpm)
Source Capacity		
Existing Source Capacity	22,800	20,700
Additional WPWTP Capacity	8,333	8,333
Total Source Capacity	**31,133**	**29,033**
Demands		
MDD	29,056	29,056
UGA Expansion Area MDD	2,222	2,222
Total Demands	**31,278**	**31,278**
Surplus (or Deficient) Source Capacity		
Surplus (or Deficient) Source Capacity	**(145)**	**(2,245)**

(1) Existing system storage is slightly deficient for existing demands. If no additional storage is constructed, PHD is recommended to be considered for future demand projections, or a reduction in service pressures will occur in the system during PHD events.

(2) Total capacity of existing sources:
Butterfield WTP 18,633 gpm (26.8 MGD)
WPWTP 4,167 gpm (6 MGD)

Combined Irrigation and Potable System Firm Capacity

The combined capacity of the City's irrigation and potable water systems in peak, shoulder, and off seasons is shown in **Table 9**, based on the ***firm*** capacity of each water system. Demands during the peak season are based on MDD, demands during the shoulder season are based on average day demand (ADD), and demands during the offseason are zero for the irrigation system and are estimated to be approximately half of the ADD for the potable water system.

Table 9

Combined Water Systems 2036 Supply Capacity Evaluation

Description	Peak Season (May - Sept)	Shoulder Season[1] (Apr, Oct)	Off Season[2] (Jan, Feb, Mar, Nov, Dec)
Source Capacity (gpm)			
Irrigation Sources	20,750	20,750	0
Potable Sources	29,033	29,033	29,033
Total Source Capacity	**49,783**	**49,783**	**29,033**
Demands (gpm)			
Irrigation Demand	29,298	17,336	0
Potable Demand	31,278	14,894	7,447
Total Demand	**60,577**	**32,231**	**7,447**
Surplus (or Deficient) Source Capacity			
Surplus (or Deficient) Source Capacity (gpm)	**(10,793)**	**17,553**	**21,586**
Surplus (or Deficient) Source Capacity (MGD)	**(15.54)**	**25.28**	**31.08**

(1) Assumes ADD.

(2) No demand for irrigation system. Assumes 0.5*ADD for potable system, consistent with historical City demand patterns.

The results of the combined systems evaluation indicates that the systems will have an approximate 10,793 gpm (15.54 MGD) capacity deficiency during the peak season, an approximate 17,553 gpm (25.3 MGD) surplus during the shoulder season, and an approximate 21,586 gpm (31.1 MGD) surplus during the off season.

Peak Season Firm Capacity

The City's combined irrigation and potable systems are projected to have an approximate 15.5 MGD deficiency during the peak season on a firm capacity basis, prior to consideration of any M&I supply, as shown in **Table 9**. Based on approximately 153 days within the peak season, this equates to 1.04 billion gallons (3,200 acre-feet) of deficient supply volume, as shown in **Table 10**. For the entirety of the peak season, the City's irrigation and potable system demands are assumed to be 90 percent of each system's MDD to account for consumption variability throughout the peak season.

Table 10

Combined Water Systems 2036 Peak Season Volume Capacity Evaluation

***Without* M&I Supply**

Description	Peak Season[1] (May - Sept)
Number of Days	
Number of Days	**153**
Source Capacity Volume (billion gallons)	
Irrigation Sources	4.57
Potable Sources	6.40
Total Source Capacity Volume	**10.97**
Demand Volume (billion gallons)	
Irrigation Demand	5.81
Potable Demand	6.20
Total Demand Volume	**12.01**
Surplus (or Deficient) Source Volume	
Surplus (or Deficient) Source Volume (BG)	**(1.04)**
Surplus (or Deficient) Source Volume (acre-feet)	**(3,200.5)**

(1) Assumes 90 percent of MDD for entirety of peak season.

If the City is successful in coordinating an M&I water agreement with SCBID and Reclamation for 20 cfs (9,000 gpm) and 2,500 afy, the calculated 2036 capacity shortfall during the peak season is shown in **Table 11**.

Table 11

Combined Water Systems 2036 Peak Season Capacity Evaluation

***With* M&I Supply**

Description	Peak Season Flowrate Basis (May - Sept)	Peak Season Volume Basis[1] (May - Sept)
Description	**Source Capacity (gpm)**	**Source Capacity Volume (billion gallons)**
City Irrigation Sources	20,750	4.57
M&I Source	9,000	0.82
City Potable Sources	29,033	6.40
Total Source Capacity Volume	**58,783**	**11.78**
Description	**Demand Rate (gpm)**	**Demand Volume (billion gallons)**
Irrigation Demand	29,298	5.81
Potable Demand	31,278	6.20
Total Demand Volume	**60,577**	**12.01**
Description	**Surplus (or Deficient) Source Rate (gpm)**	**Surplus (or Deficient) Source Volume (billion gallons)**
Surplus (or Deficient) Source Capacity	**(1,793)**	**(0.23)**
Surplus (or Deficient) Source Volume (acre-feet)	**---**	**(700.5)**

(1) Assumes 90 percent of MDD for entirety of peak season.

Off Season Firm Capacity

The City's firm capacity surplus in the off season may be available for aquifer recharge in the future. Supply capacity in the off season can come from both the irrigation and potable water systems. If the City uses the irrigation system's Columbia River intake and the USBR/Harris Road Booster Pump Station (BPS) that is in series with the Columbia River intake (and downstream of the intake within the physical irrigation system) to pump to a future aquifer recharge location, approximately 2.8 MGD of supply from the irrigation system can be attained. The Columbia River intake has more capacity than the USBR/Harris Road BPS; therefore, the USBR/Harris Road BPS capacity is more limiting than the Columbia River intake and was used to calculate the irrigation system source capacity in the off season.

The City's potable water system is capable of providing off season supply from both the WPWTP and the Butterfield WTP. However, the Butterfield WTP is distant from the City's irrigation system and from most future growth and demand in the water system. As such, the City's WPWTP surplus firm capacity of approximately 8.4 MGD is assumed to be available for future aquifer recharge. The WPWTP future firm capacity is assumed to be 15 MGD, and the demand served by the WPWTP is currently approximately 25 percent of the City's wintertime demand (1.8 MGD), plus a conservative estimate of all future growth-related demand (4.8 MGD), resulting in a year 2036 demand of approximately 6.6 MGD. Based on approximately 151 days within the off season, this equates to 1.69 billion gallons (5,191 acre-feet) of additional supply volume, as shown in **Table 12**.

Table 12

Combined Water Systems 2036 Off Season Volume Capacity Evaluation

2036 Firm Capacity

Description	Off Season (Jan, Feb, Mar, Nov, Dec)
Number of Days	
Number of Days	**151**
Source Capacity Volume (billion gallons)	
Irrigation: USBR/Harris Road BPS	0.42
Potable: West Pasco WTP[1]	2.27
Total Source Capacity Volume	**2.69**
Demand Volume (billion gallons)	
Irrigation Demand	0.00
Potable Demand[2]	1.00
Total Demand Volume	**1.00**
Surplus (or Deficient) Source Volume	
Surplus (or Deficient) Source Volume (BG)	**1.69**
Surplus (or Deficient) Source Volume (acre-feet)	**5,191.4**

(1) West Pasco WTP firm capacity 10,433 gpm (15.0 MGD).

(2) Demand supplied by the WPWTP, excluding demand supplied by the Butterfield WTP.

Shoulder Season Firm Capacity

The City's firm capacity volume surplus in the shoulder season is approximately 1.54 billion gallons through the 61-day period of April and October. For conservatism, this surplus volume was assumed to not be available to the system in the future.

Off Season Capacity Constraints

Physical Capacity Constraints

The City's off season physical source capacity is described in the **Off Season Firm Capacity** section of this technical memorandum, and is based on approximately 2.81 MGD of supply from the irrigation system and approximately 8.40 MGD of supply from the WPWTP, for a total of approximately 11.2 MGD of physical source capacity, as shown in **Table 13**.

Table 13
Physical Capacity Evaluation

Description	Surplus Source/Pumping Capacity (MGD)	Surplus Transmission Capacity[1] (MGD)	Limiting Capacity (MGD)
Irrigation System	2.81	2.54	2.54
Potable System	8.40	8.50	8.40
Total	**11.21**	**11.03**	**10.94**

(1) Based on maximum velocities of 5 feet per second.

The transmission main downstream of these sources provides a slight reduction in physical capacity. Based on maximum velocities of 5 feet per second (fps), the irrigation system is only capable of conveying 2.54 MGD between the USBR/Harris Road BPS and the candidate ASR recharge/recovery areas, limited by the 12-inch-diameter water main in Broadmoor Boulevard. Based on the same 5 fps velocity constraint, the proposed 24-inch-diameter Zone 3 transmission main north of I-182 in Broadmoor Boulevard has conveyance capacity for approximately 8.50 MGD of ASR recharge supply. This 8.50 MGD capacity is based on the proposed 24-inch-diameter transmission main having a 10.15 MGD capacity at 5 fps and reductions based on year 2036 domestic supply requirements within this transmission main. These off season supply requirements are based on assumptions that half of the year, 6.6 MGD of 2036 WPWTP domestic flow is conveyed to Zone 1 via a separate transmission main, leaving 3.3 MGD requiring to be conveyed to Zone 3. Of the remaining Zone 3 domestic conveyance, it is assumed that half of the supply is conveyed into Zone 3 via other transmission routes, resulting in approximately 1.65 MGD to be conveyed via the Broadmoor Boulevard 24-inch-diameter transmission main that also will provide conveyance to the ASR recharge/recovery areas. The resulting capacity available for ASR recharge is 10.15 MGD – 1.65 MGD = 8.50 MGD, as shown in **Table 13**.

The City's 2036 off season physical capacity limitation is the irrigation system transmission capacity, and the potable system source capacity, resulting in approximately 10.94 MGD of physical capacity available for ASR recharge, as shown in **Table 13**. Velocities in excess of 5.0 fps can be achieved in the system, but are not considered as part of this analysis for conservatism.

Legal Capacity Constraints

Any water diverted or withdrawn for ASR supply will need to be under the limitations of an existing water right. Water rights can have limitations on instantaneous rate, annual volume, point of diversion or withdrawal, place of use, and period of use. Additionally, water rights can be subject to minimum instream flows, such as the Quad Cities water right.

Water Rights Self-Assessment

This section is intended to compare the existing water rights for the potable and irrigation systems against the currently installed pumping capacity and water use.

Water rights for the uninterruptible potable system (**Table 1**) currently exceed the demand from both an instantaneous and annual basis. However, there is a calculated potable water shortfall in annual volume of 2,713 afy (0.88 BG) in the year 2036 (**Figure 4**). Therefore, there is no annual volume available under the existing uninterruptible potable water rights for storage in an ASR project.

However, there is water available for use under the interruptible portion of the Quad Cities water right, which can be diverted from the West Pasco or Butterfield intakes when flow provisions are met that is equal to a maximum of 42 cfs (18,850 gpm; 27.14 MGD) and 12,348 afy (4.02 BG).

Use of water from the irrigation system (**Table 2**) currently exceeds the water right limit for the instantaneous rate and annual volume (**Table 14**). **Table 14** compares the current irrigation system water rights to the actual pumping rate of the irrigation sources and volume pumped during the 2020 irrigation season, which is the highest historical demand season.

Table 14

Irrigation System Comparison of Water Rights with Water Use

Instantaneous			Annual		
Water Rights (gpm)	2020 Use (gpm)	Difference (gpm)	Water Rights (afy)	2020 Use (afy)	Difference (afy)
17,608	17,750	(142)	7,216.7	9,768.4	(2,551.7)

However, the period of use authorized under the various irrigation system water rights (**Table 3**) limits when those water rights can be used to provide water to an ASR project. Also, projections of irrigation system demand in 2036 show that irrigation demand will exceed the irrigation system's current water rights by approximately 3,000 afy; therefore, there is no available water under the existing irrigation system water rights.

A comparison of the standalone system water rights against water use was beyond the scope of this analysis, but it is possible that those water rights could be used to meet future demand directly or provide water that could be used for ASR.

Future Groundwater Sources in Hydraulic Continuity with Columbia River Surface Water

Future source capacity for ASR recharge may include additional City surface water supply or City groundwater supply, as presented in **Table 13**, as well as surface water in the form of M&I supply from SCBID and Reclamation. An additional form of future supply for the City may include groundwater sources in hydraulic continuity with Columbia River surface water, such as a wellfield consisting of conventional vertical wells or a Ranney well collector system.

It should be feasible to add one or multiple collector wells or conventional wellfields as points of withdrawal to the Quad Cities water right, through the water right change application process, if desired by the City and agreed to by the other Quad Cities, based on the following two points.

- RCW 90.03.570(2)(c) authorizes the proposed water right change to an unperfected surface water permit, since the water right currently is subject to minimum instream flow requirements and would continue to be after the change.
- The City of Kennewick is already authorized to use collector wells under the water right.

In order to have a wellfield or collector well approved as a point of withdrawal under the interruptible portion of the Quad City water right, the City will have to prove to Ecology, through aquifer characterization and testing, that the impacts due to pumping the wells can be considered the same as a direct surface water diversion. If groundwater pumping from a well leads to long lags in impact to the Columbia River, then that well is not a good candidate to be used under an interruptible water right because its pumping and associated impacts will not be able to be managed on a daily basis and impairment of the minimum flows will occur after pumping has ceased, but while the impact remains.

A preliminary review of possible sites for a wellfield or collector well system includes five candidate sites within the City. These sites are shown in **Figure 5**, and a description of each site is as follows.

1. Adjacent to Butterfield WTP Intake
    a. Pros:
        i. City owns land and controls waterfront.
    b. Cons:
        i. More than 5 miles from closest point of irrigation system.
        ii. Distant from future City growth areas.
        iii. More than 9 miles from candidate ASR recharge/recovery areas A, B, and C.
        iv. Proximity to Butterfield WTP would limit contribution from collector well system without additional dedicated transmission if water from the collector well system was to be used for direct potable supply in addition to ASR recharge.
2. Wade Park (south end of Road 54)
    a. Pros:
        i. City owns land.
    b. Cons:
        i. More than 3 miles from closest point of irrigation system.
        ii. Distant from future City growth areas.
        iii. More than 7 miles from candidate ASR recharge/recovery areas A, B, and C.
3. Chiawana Park
    a. Pros:
        i. City owns land.
    b. Cons:
        i. More than 2 miles from closest point of irrigation system.
        ii. More than 4 miles from candidate ASR recharge/recovery areas A, B, and C.
4. Adjacent to WPWTP Intake
    a. Pros:
        i. City owns land.
        ii. Adjacent riverfront land is available.
        iii. Proximity to candidate ASR recharge/recovery areas A, B, and C and future City growth areas.
    b. Cons:
        i. Significant utility congestion in Court Street.

5. Adjacent to Harris Road or Shoreline Road
    a. Pros:
        i. Closest location to candidate ASR recharge/recovery areas A, B, and C.
        ii. Proximity to future City growth areas.
    b. Cons:
        i. Property acquisition.
        ii. Difficult construction in some locations due to steep bank.
        iii. Although closest location to candidate ASR recharge/recovery areas and anticipated growth, more than 2 miles of dedicated transmission required between wellfield/ collector well system and potential ASR development sites.

Preliminary review and consideration of these five possible groundwater development sites suggest that Location Nos. 4 and 5 are favorable if a wellfield or collector well system is considered as an alternative ASR supply source option and pursued in future planning efforts. Advantages of a dedicated wellfield or collector well system and transmission main to the candidate ASR recharge/recovery areas is that the water would not have to be treated to full drinking water standards, as would be required when utilizing the existing potable water system, and the physical capacity of the system for delivering water for recharge would not fluctuate throughout the year based on demands on the potable system. Significant capital expenditures however, are anticipated to construct a wellfield or collector well system and the multiple miles of transmission main necessary to convey the water to the candidate ASR recharge/recovery areas.

ASR Capital Improvement Requirements

This section describes the planning-level improvements required to supply water to, convey water from, and store water at ASR recharge/recovery areas and sites. For the purposes of this technical memorandum, three potential ASR recharge/recovery sites were identified for evaluation, as shown in **Figure 6**. It is assumed that ASR recharge/recovery sites will be constructed at two of these three locations, which are located within Recharge/Recovery Areas A, B, and C. No ASR recharge/recovery sites are proposed within Recharge/Recovery Area D. The capital improvement requirements described in this technical memorandum will be based on the three combinations of ASR recharge/recovery sites, as follows.

1. ASR Recharge/Recovery Site Nos. 1 and 2
2. ASR Recharge/Recovery Site Nos. 2 and 3
3. ASR Recharge/Recovery Site Nos. 1 and 3

The water main segments shown in **Figure 6** are proposed to connect the existing irrigation and potable systems with the candidate ASR recharge/recovery sites. These segments are approximately consistent with future potable Zone 3 transmission main identified in the *West Pasco WTP Expansion Proposed Improvements and Design Criteria Technical Memorandum* (RH2, 2020) that are necessary for future transmission between the WPWTP and the Zone 3 distribution system, as well as a future Zone 3 tank site along Road 68 approximately between Powerline Road and Kau Trail. As such, the water main Segments A through D shown in **Figure 6** are long-term transmission main projects for the City, and the construction of these water main segments for ASR recharge/recovery purposes is anticipated to serve multiple purposes for the City's water system. Water main Segments E and F shown in

Figure 6 are proposed irrigation main to extend irrigation transmission north of Sandifur Parkway to ASR Recharge/Recovery Site Nos. 1 and/or 2 if irrigation supply is desired for recharge and recovery.

A summary of the improvements necessary for each of the three combinations of ASR recharge/recovery sites is included in the subsequent sections.

ASR Recharge/Recovery Site Nos. 1 and 2

If ASR Recharge/Recovery Site Nos. 1 and 2 are selected for implementation, it is recommended that a "2x2" wellhouse be constructed at each site, with one well at each site completed in the Umatilla Member of the Saddle Mountains Formation, and the other well at the same site completed in the Frenchman Springs Member of the Wanapum Basalt. Each well is assumed to be capable of recharge at 1,500 gpm and recovery at 2,000 gpm to resolve the projected year 2036 deficiencies of the City's potable and irrigation systems during recovery periods, and to utilize the off season capacity in each of the potable and irrigation systems during recharging periods. The "2x2" wellhouse configuration and assumed recharge and recovery rates are consistent with the *Task 2 – Hydrogeologic Feasibility Assessment.*

Water main segments A, B, C, and E, as shown in **Figure 6**, are necessary to be completed to connect the existing potable and irrigation systems with the ASR recharge/recovery sites. With ASR Recharge/Recovery Site Nos. 1 and 2 implemented, it is recommended that Site No. 1 be designed for recharge from both the City's irrigation system and the City's potable water system, and Site No. 2 designed for recharge from only the City's potable water system. The use of the City's USBR/Harris Road BPS in the off season will provide approximately 1,750 gpm, with consideration for a 5 fps velocity limitation, which is viable to approximately recharge one ASR well and is recommended to be the City's dedicated ASR irrigation well. With two ASR wells proposed to be constructed at each site, and the treatment requirements associated with using irrigation supply as ASR recharge (as described in the **Recharge and Recovery Treatment** section of this technical memorandum), it is unlikely that irrigation supply will be available to be conveyed beyond Site No. 1; therefore, no additional dedicated irrigation transmission to Site No. 2 is recommended.

Water recovered from storage at Site Nos. 1 and 2 is recommended to be predominantly for the City's potable water system, with three of the four ASR wells utilized for potable water recharge and recovery. Treatment of the recovered water, as well as treatment of the recharge water, is described in the **Recharge and Recovery Treatment** section of this technical memorandum.

A summary of the improvements recommended if candidate ASR Recharge/Recovery Site Nos. 1 and 2 are selected is as follows. Planning-level, order-of-magnitude costs for these recommended improvements are shown in **Table 15**. Treatment-related improvements in **Table 15** are based on irrigation supply being used for recharge and recovery at one ASR well, and potable supply being treated for recharge and recovery at three ASR wells. Costs associated with treating irrigation supply for potable water recharge and recovery are not included in **Table 15**.

- Potable Water Main Segments A, B, and C
- Irrigation Water Main Segment E
- Two wells drilled and developed in the Umatilla Member of the Saddle Mountains Formation
- Two wells drilled and developed in the Frenchman Springs Member of the Wanapum Basalt

- "2x2" wellhouse at ASR Recharge/Recovery Site Nos. 1 and 2

Table 15

ASR and Transmission Main Planning-Level Cost Estimates

Improvement	Description	Quantity	Unit Cost	ASR Recharge/Recovery Sites		
				Site Nos. 1 and 2	Site Nos. 2 and 3	Site Nos. 1 and 3
			Water Main Segments			
Segment A (Potable)[1]	30-inch	2,600 LF	$700 per LF	$0	$0	$0
Segment A (Potable)[1]	24-inch	7,200 LF	$575 per LF	$0	$0	$0
Segment B (Potable)	24-inch	4,500 LF	$575 per LF	$2,587,500	$2,587,500	$2,587,500
Segment C (Potable)	24-inch	9,300 LF	$575 per LF	$5,347,500	$5,347,500	$5,347,500
Segment D (Potable)	24-inch	9,500 LF	$575 per LF	---	$5,462,500	$5,462,500
Segment E (Irrigation)	12-inch	4,500 LF	$350 per LF	$1,575,000	$1,575,000	$1,575,000
Segment F (Irrigation)	12-inch	7,800 LF	$350 per LF	---	$2,730,000	---
Water Main Totals				**$9,510,000**	**$17,702,500**	**$14,972,500**
			ASR Wells			
Umatilla Drilling and Developing	950 feet BGS	2	$1,200 per foot	$2,280,000	$2,280,000	$2,280,000
Frenchman Springs Drilling and Developing	1,750 feet BGS	2	$1,200 per foot	$4,200,000	$4,200,000	$4,200,000
Equip ASR Wells (Pump, Motor, Column Pipe)	2,000 gpm pump	4	$400,000 per well	$1,600,000	$1,600,000	$1,600,000
2x2 Wellhouse Mechanical, Structural, Treatment, Electrical, Controls, Site Work	50-foot by 50-foot wellhouse	2	$2,000,000 per 2x2 site	$4,000,000	$4,000,000	$4,000,000
ASR Well Totals				**$12,080,000**	**$12,080,000**	**$12,080,000**
Combined Totals				**$21,590,000**	**$29,782,500**	**$27,052,500**

(1) The 24- and 30-inch proposed water main comprising Segment A is required to be constructed as part of the City's capacity upgrades at the West Pasco WTP; therefore, it is not shown as an additive cost specific to future ASR wells. Segments B, C, and D are also planned as long-term transmission projects by the City within Zone 3, but are included in this table.

ASR Recharge/Recovery Site Nos. 2 and 3

If ASR Recharge/Recovery Site Nos. 2 and 3 are selected for implementation, it is recommended that a "2x2" wellhouse be constructed at each site, with one well at each site completed in the Umatilla Member of the Saddle Mountains Formation, and the other well at the same site completed in the Frenchman Springs Member of the Wanapum Basalt. Each well is assumed to be capable of recharge at 1,500 gpm and recovery at 2,000 gpm to resolve the projected year 2036 deficiencies of the City's potable and irrigation systems during recovery periods, and to utilize the off-season capacity in each of the potable and irrigation systems during recharging periods. The "2x2" wellhouse configuration and assumed recharge and recovery rates are consistent with the *Task 2 – Hydrogeologic Feasibility Assessment.*

Water main segments A, B, C, D, E, and F, as shown in **Figure 6**, are necessary to be completed to connect the existing potable and irrigation systems with the ASR recharge/recovery sites. With ASR Recharge/Recovery Site Nos. 2 and 3 implemented, it is recommended that Site No. 2 be designed for recharge from both the City's irrigation system and the City's potable water system, and Site No. 3 be designed for recharge from only the City's potable water system. The use of the City's USBR/Harris Road BPS in the off season will provide approximately 1,750 gpm, with consideration for a 5 fps velocity limitation, which is viable to approximately recharge one ASR well and is recommended to be the City's dedicated ASR irrigation well. With two ASR wells proposed to be constructed at each site, and the treatment requirements associated with using irrigation supply as ASR recharge (as described in the **Recharge and Recovery Treatment** section of this technical memorandum), it is unlikely that irrigation supply will be available to be conveyed beyond Site No. 2; therefore, no additional dedicated irrigation transmission to Site No. 3 is recommended.

Recovery water from Site Nos. 2 and 3 is recommended to be predominantly for the City's potable water system, with three of the four ASR wells utilized for potable water recharge and recovery. Treatment of the recovery water, as well as treatment of the recharge water, is described in the **Recharge and Recovery Treatment** section of this technical memorandum.

A summary of the improvements recommended if ASR Recharge/Recovery Site Nos. 2 and 3 are selected is as follows. Planning-level, order-of-magnitude costs for these recommended improvements are shown in **Table 15**.

- Potable Water Main Segments A, B, C, and D
- Irrigation Water Main Segments E and F
- Two wells drilled and developed in the Umatilla Member of the Saddle Mountains Formation
- Two wells drilled and developed in the Frenchman Springs Member of the Wanapum Basalt
- "2x2" wellhouse at ASR Recharge/Recovery Site Nos. 2 and 3

ASR Recharge/Recovery Site Nos. 1 and 3

If ASR Recharge/Recovery Site Nos. 1 and 3 are selected for implementation, it is recommended that a "2x2" wellhouse be constructed at each site, with one well at each site completed in the Umatilla Member of the Saddle Mountains Formation, and the other well at the same site completed in the Frenchman Springs Member of the Wanapum Basalt. Each well is assumed to be capable of recharge at 1,500 gpm and recovery at 2,000 gpm to resolve the projected year 2036 deficiencies of the City's potable and irrigation systems during recovery periods, and to utilize the off season capacity in each of the potable and irrigation systems during recharging periods. The "2x2" wellhouse configuration and assumed recharge and recovery rates are consistent with the *Task 2 – Hydrogeologic Feasibility Assessment.*

Water main segments A, B, C, D, and E, as shown in **Figure 6**, are necessary to be completed to connect the existing potable and irrigation systems with the ASR recharge/recovery sites. With ASR Recharge/Recovery Site Nos. 1 and 3 implemented, it is recommended that Site No. 1 be designed for recharge from both the City's irrigation system and the City's potable water system, and Site No. 3 be designed for recharge from only the City's potable water system. The use of the City's USBR/Harris Road BPS in the off season will provide approximately 1,750 gpm, with consideration for a 5 fps velocity limitation, which is viable to approximately recharge one ASR well and is recommended to be the City's dedicated ASR irrigation well. With two ASR wells proposed to be constructed at each site, and the treatment requirements associated with using irrigation supply as ASR recharge (as described in the **Recharge and Recovery Treatment** section of this technical memorandum), it is unlikely that irrigation supply will be available to be conveyed beyond Site No. 1; therefore, no additional dedicated irrigation transmission to Site No. 3 is recommended.

Recovery water from Site Nos. 1 and 3 is recommended to be predominantly for the City's potable water system, with three of the four ASR wells utilized for potable water recharge and recovery. Treatment of the recovery water, as well as treatment of the recharge water, is described in the **Recharge and Recovery Treatment** section of this technical memorandum.

A summary of the improvements recommended if ASR Recharge/Recovery Site Nos. 1 and 3 are selected is as follows. Planning-level, order-of-magnitude costs for these recommended improvements are shown in **Table 15**.

- Potable Water Main Segments A, B, C, and D
- Irrigation Water Main Segment E
- Two wells drilled and developed in the Umatilla Member of the Saddle Mountains Formation
- Two wells drilled and developed in the Frenchman Springs Member of the Wanapum Basalt
- "2x2" wellhouse at ASR Recharge/Recovery Site Nos. 1 and 2

ASR Recharge/Recovery Site Acquisition

Each "2x2" wellhouse is anticipated to require approximately a 1 acre site for the wellhouse, miscellaneous site improvements, and a 100-foot sanitary control radius for each well. Property acquisition is not anticipated to be onerous within any of the ASR Recharge/Recovery Site Nos. 1, 2, or 3.

The vicinity of Site No. 1 includes agricultural and undeveloped acreage, with platting of portions of this land beginning in 2020, and development in this location anticipated to begin as early as 2021. Opportunities for the City to purchase the land necessary for a "2x2" wellhouse in the vicinity of Site No. 1 are likely available in 2021 and should remain available for a number of years.

The vicinity of Site No. 2 includes agricultural and undeveloped acreage, as well as a number of single-family homes on ½- and 1.0-acre lots. The City is believed to be evaluating site acquisition in this vicinity for a future Zone 3 tank site in the coming years, and it is anticipated that a "2x2" ASR wellhouse can be located at the same site as the future tank. Opportunities for the City to purchase the land necessary for a "2x2" wellhouse in the vicinity of Site No. 2 are likely available in 2021 and should remain available for a number of years.

The vicinity of Site No. 3 includes agricultural acreage. Developers representing these property owners have been in contact with the City regarding utility service for future development of this land. This site is currently outside of the City's urban growth boundary, but is anticipated to be within the City's future urban growth boundary as shown in the City's draft *Comprehensive Plan* update, which is anticipated to be adopted and approved in 2021. As such, development is expected within the vicinity of Site No. 3 within the next 10 years, and opportunities for the City to purchase the land necessary for a "2x2" wellhouse in this location likely will be available as early as 2022 or 2023.

Recharge and Recovery Treatment

In order to preserve water quality and protect existing and beneficial uses of groundwater, an ASR project must comply with the Antidegradation Policy stated in WAC 173-200-030. All contaminants proposed for discharge into groundwaters shall be provided with all known, available, and reasonable methods of prevention, control, and treatment (AKART).

If an ASR site is recharged with potable surface water it would likely need to be treated to remove arsenic and silver, as identified in the March 8, 2021 Task 3 Technical Memorandum by Golder Associates Inc. (Golder) attached as **Appendix A**. When this water is withdrawn in the future, it would need to be re-chlorinated and possibly re-fluoridated to match distribution water. Disinfection byproducts (DBPs) are not likely to be an issue since other municipal ASR systems which store treated drinking water in basalt-hosted aquifers have demonstrated DBP attenuation in the subsurface. Chlorine compounds lower than 1 mg/L can actually help control biological growth in the wellbore and prevent clogging of the well screen and liner or aquifer formation. Inorganic and volatile organic chemical samples should be collected to verify background groundwater quality. The dechlorination and chlorination chemicals can be stored in a chemical storage tank within a new building with metering pumps to flow pace to the withdrawal rate. This infrastructure may cost on the order of $100,000 for the chemical tanks, metering pumps, chemical injection piping, and facility structure. If DBPs continue to form and become an issue, then a granulated activated carbon, reverse osmosis, or aeration system can be implemented to reduce these contaminants. Further alternatives analyses would be required to estimate the costs and effectiveness of these technologies, but they would be at least an order-of-magnitude higher than a dechlorination and chlorination facility. If arsenic in the ASR source water is higher than the groundwater, then arsenic treatment will be required prior to recharge to the aquifer. This likely would be in the form of pyrolusite or GreensandPlus media filtration, and a pilot study would need to be conducted to verify treatment effectiveness and estimate capital costs.

If an ASR site is recharged with treated irrigation water, it can either be withdrawn and reused for irrigation or treated further for potable use. If the site will be used for irrigation water, then the City does not have to modify or further condition this water and can reuse it for irrigation as needed. However, before the recharged irrigation water can be used for potable applications, AKART and anti-degradation standards would require turbidity removal and chlorination. Turbidity removal should occur prior to recharge to avoid clogging the wellbore and negative impacts to the well and aquifer performance. Chlorination can occur before recharge to meet antidegradation standards to inactivate bacteria and viruses, but this may contribute to the formation of DBPs. The disinfection process will be further refined at a later stage of this project. Fluoride also would need to be added to match distribution water. A 2.8 MGD treatment facility for turbidity removal and chemical feed may cost on the order of $3 million. An alternative would be a wellfield or collector well to provide natural filtration requiring no specialized treatment or waste disposal costs, which may be on the order of $4 to 5 million. Samples will be collected of the source and aquifer waters to verify water quality and determine if other treatment is required to comply with anti-degradation standards.

ASR Recharge/Recovery Site Recommendations

If each of ASR Recharge/Recovery Site Nos. 1, 2, and 3 remain viable from a hydrogeologic perspective, ASR Recharge/Recovery Site Nos. 1 and 2 are recommended for implementation, with one ASR well identified as the City's irrigation ASR well, and three ASR wells reserved for potable water. The purpose of designating one of the ASR wells as an irrigation ASR well is partially based upon eliminating the need for treating all of the recovered water and partially based upon still being able to use the recovered water if the ASR water quality was less desirable drinking water due to secondary contaminants or aesthetic concerns (taste, odor, temperature). Benefits of Site Nos. 1 and 2 compared to the other configurations include the following.

- Least cost configuration, as shown in **Table 15**.
- Proximity of sites to future City growth areas.
- The “2x2” wellhouse at ASR Recharge/Recovery Site No. 2 can share a site with the City’s future Zone 3 tank along Road 68.

The recommendations provided herein are based relying on the firm capacity surplus of the City’s WPWTP during the off season for ASR recharge at three ASR wells at a rate of approximately 1,500 gpm (2.2 MGD) per well. The fourth ASR well can be recharged with the City’s irrigation USBR/Harris Road BPS to recharge a dedicated irrigation ASR well at approximately 1,500 gpm (2.2 MGD). If a dedicated irrigation ASR well is not desired by the City, the City would have capacity in year 2036 to recharge four potable water ASR wells based on the future maximum capacity (18 MGD) of the WPWTP in the off season. Relying on the WPWTP to operate at its future maximum capacity (18 MGD) for extended periods of time or year-round is not recommended due to the lack of redundancy and stress that this operating condition would place on the facility’s infrastructure; therefore, three potable water ASR wells and one irrigation water ASR well are recommended. The Columbia River Intake is recommended to be used for the irrigation portion of the ASR supplies to avoid operating the WPWTP at maximum capacity for both reliability and redundancy purposes.

Data Gaps and Uncertainties

The period of use of the irrigation system water rights are variable and some are unspecified or general in nature (i.e., “seasonal”). Consequently, it is not clear how much irrigation water may be available for ASR recharge during the off season, particularly from the two surface water diversions (Columbia River Intake and Butterfield Intake).

Based on previous irrigation water usage data, it appears the City is using all of its available instantaneous rate and annual volume from the irrigation wells to meet demands (no surplus). From **Table 3**, it appears there are no water rights available from the two surface intakes because of apparent period-of-use constraints.

Projected future demands on the potable water system in the Water System Plan (Murraysmith, 2019) suggest that the City does not have enough uninterruptible water right annual volume associated with its potable system to meet future demand, let alone to provide water for ASR. The irrigation system is believed to be in the same situation, leaving no excess water to provide for ASR.

Taking into consideration the minimum instream flow provision, operating procedures will have to be developed to allow the City to successfully manage the diversion of water for ASR under the interruptible portion of the Quad Cities water right.

If the City wants to install and operate a wellfield or collector well for ASR supply using the interruptible portion of the Quad Cities water right, it will have to demonstrate that pumping impacts can be regulated the same as a direct surface water diversion and that there will be no impairment of the provisioned minimum instream flows due to its operation.

Future Work Considerations

Incorporate the results of the pending water right change application decisions once they have been made by Ecology. These decisions should provide clarity on which water rights can be withdrawn from which sources and the authorized purposes of use.

Analyze the source metering data not only from the irrigation system, but also the standalone systems that are proposed to be changed to evaluate how much water from these systems might be currently unused and available for meeting future demands and/or ASR recharge.

File and have processed a water right change application on the Quad Cities water right requesting to add one or multiple wellfield or collector well locations as points of withdrawal.

References

GSI Water Solutions (2020). *Hydrogeologic Feasibility Assessment, Aquifer Storage and Recovery Feasibility Study, City of Pasco, Washington.* December 2020.

Golder Associates (2021), *Pasco Aquifer Storage and Recovery Feasibility Assessment – Task 3 Source Water Quality*.

Murraysmith (2019). *Comprehensive Water System Plan*, City of Pasco. January 2019.

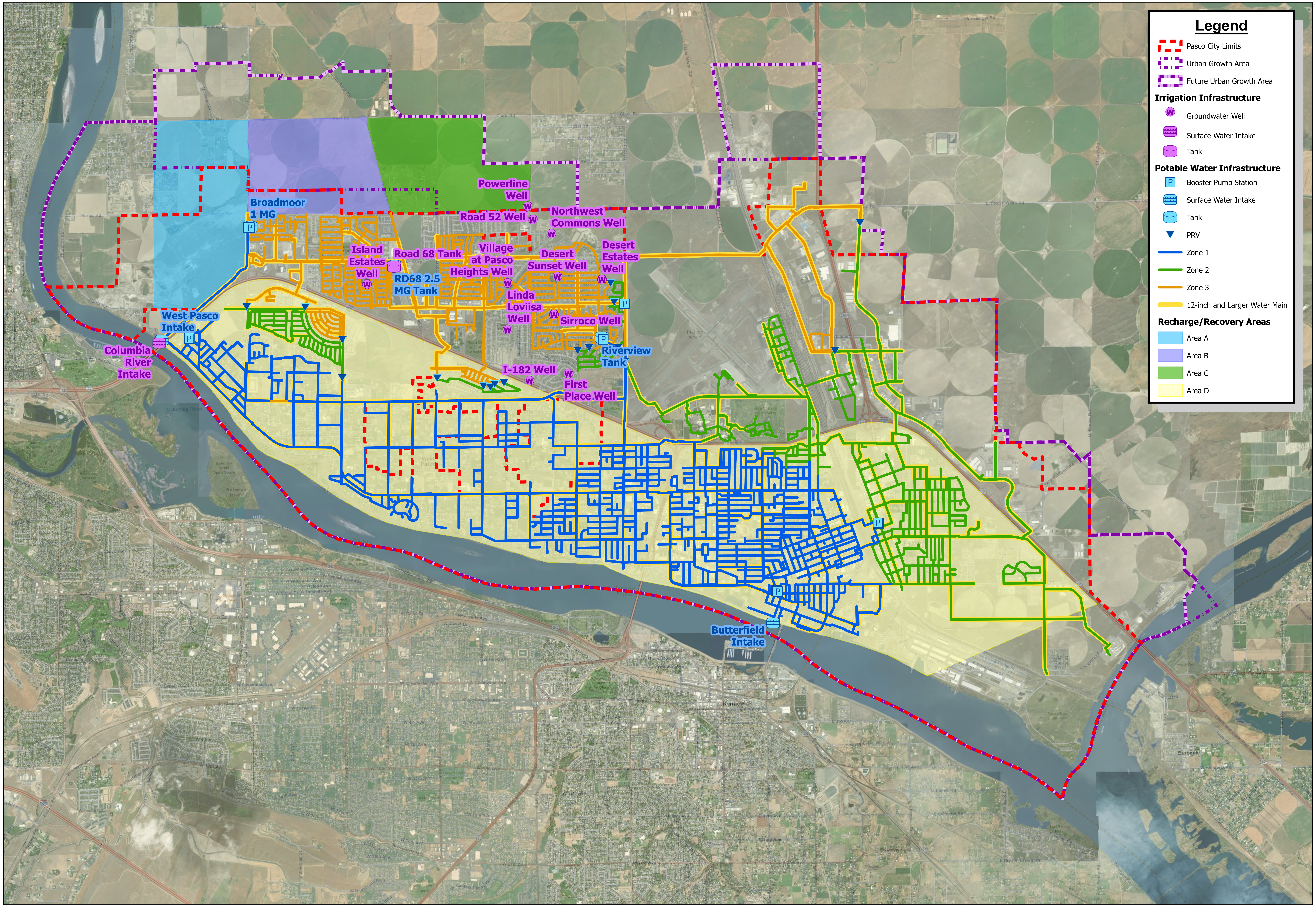
RH2 Engineering, Inc. (2020) *West Pasco WTP Expansion Proposed Improvements*.

RH2 Engineering, Inc. (August 29, 2019). *Future Irrigation System Supply Technical Memorandum*.

RH2 Engineering, Inc. (October 31, 2018). *Irrigation System Capacity Analysis Technical Memorandum*.

RH2 Engineering, Inc. (2016). *Regional Water Forecast and Conservation Plan*, City of Kennewick, City of Pasco, City of Richland, City of West Richland.

Figures



This map is a graphic representation derived from various Geographic Information Systems. It was designed and intended for City of Pasco staff use only; it is not guaranteed to survey accuracy. This map is based on the best information available on the date shown on this map.

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Vicinity Map

Figure 1
Existing Potable Water and Irrigation System Infrastructure

City of Pasco
Aquifer Storage & Recovery Feas. Study

PRELIMINARY

1 inch : 2,500 Feet

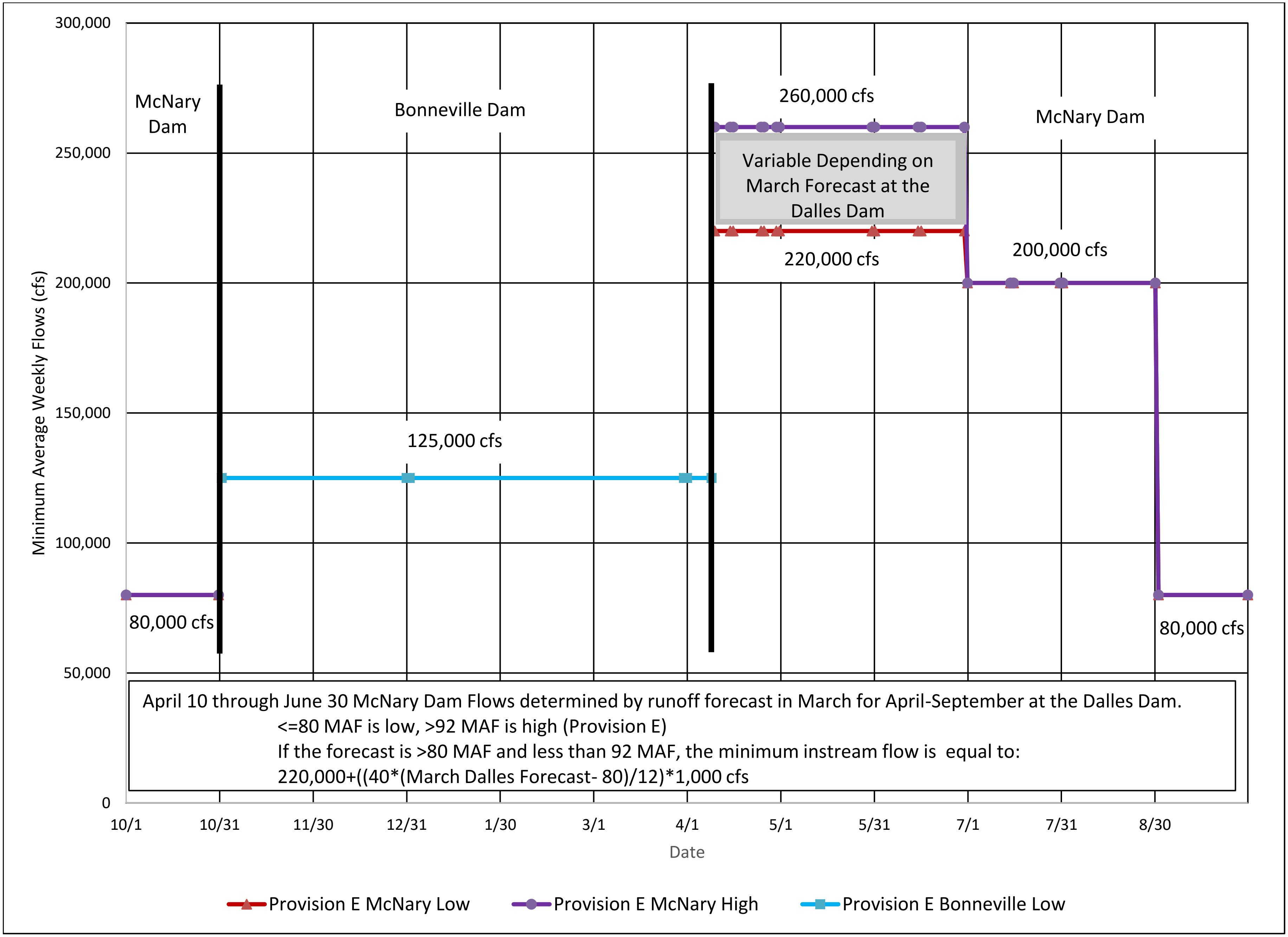
0 1,250 2,500 5,000 Feet

DRAWING IS FULL SCALE WHEN BAR MEASURES 2"

NORTH

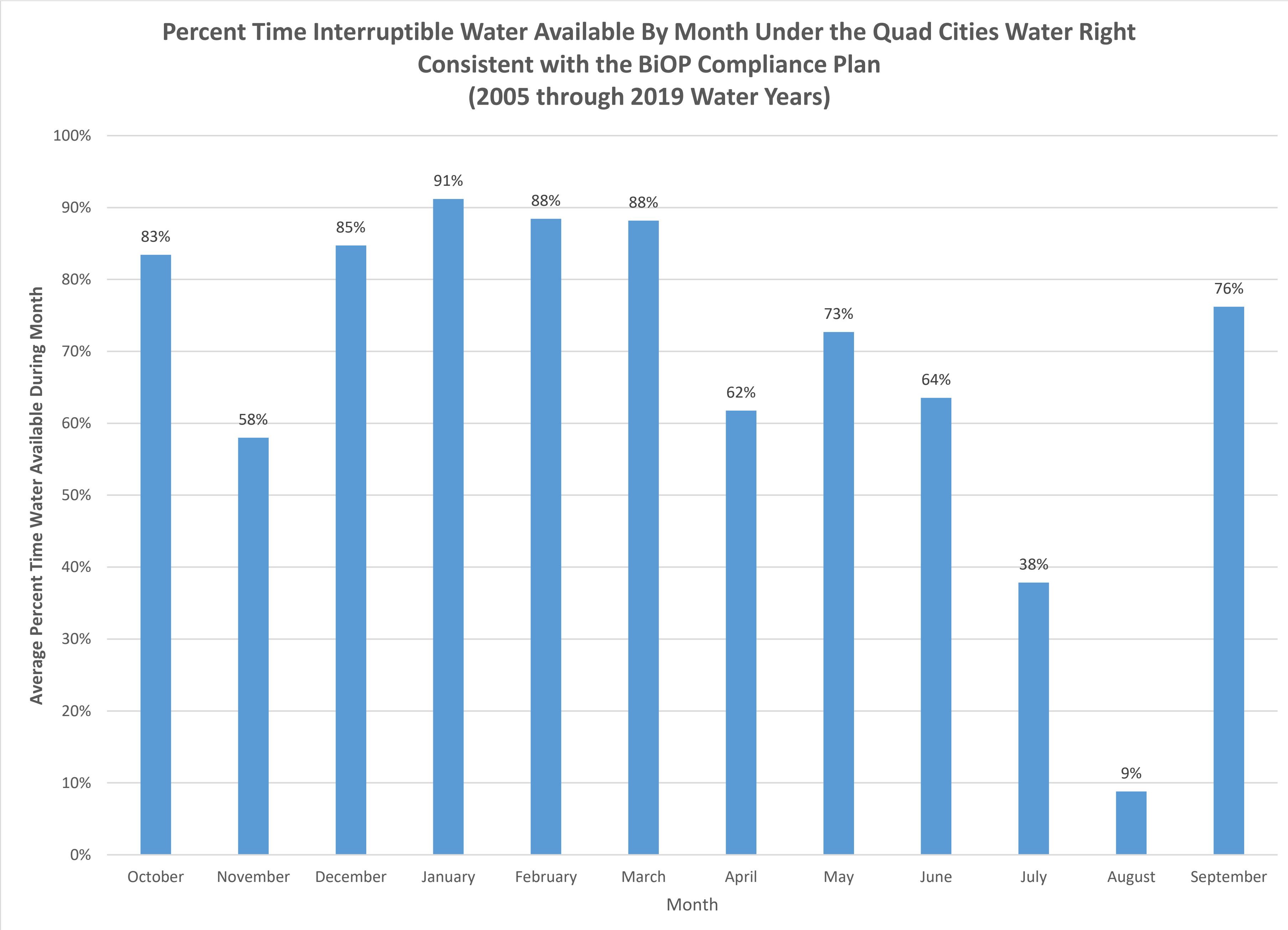
J:\DATA\GSI\20-0142\GIS\PSC ASRFS PROJECT\PSC ASRFS.APRX BY: TCORNELIUS PLOT DATE: JAN 15, 2021 COORDINATE SYSTEM: NAD 1983 HARN STATEPLANE WASHINGTON SOUTH FIPS 4602 FEET

Figure 2



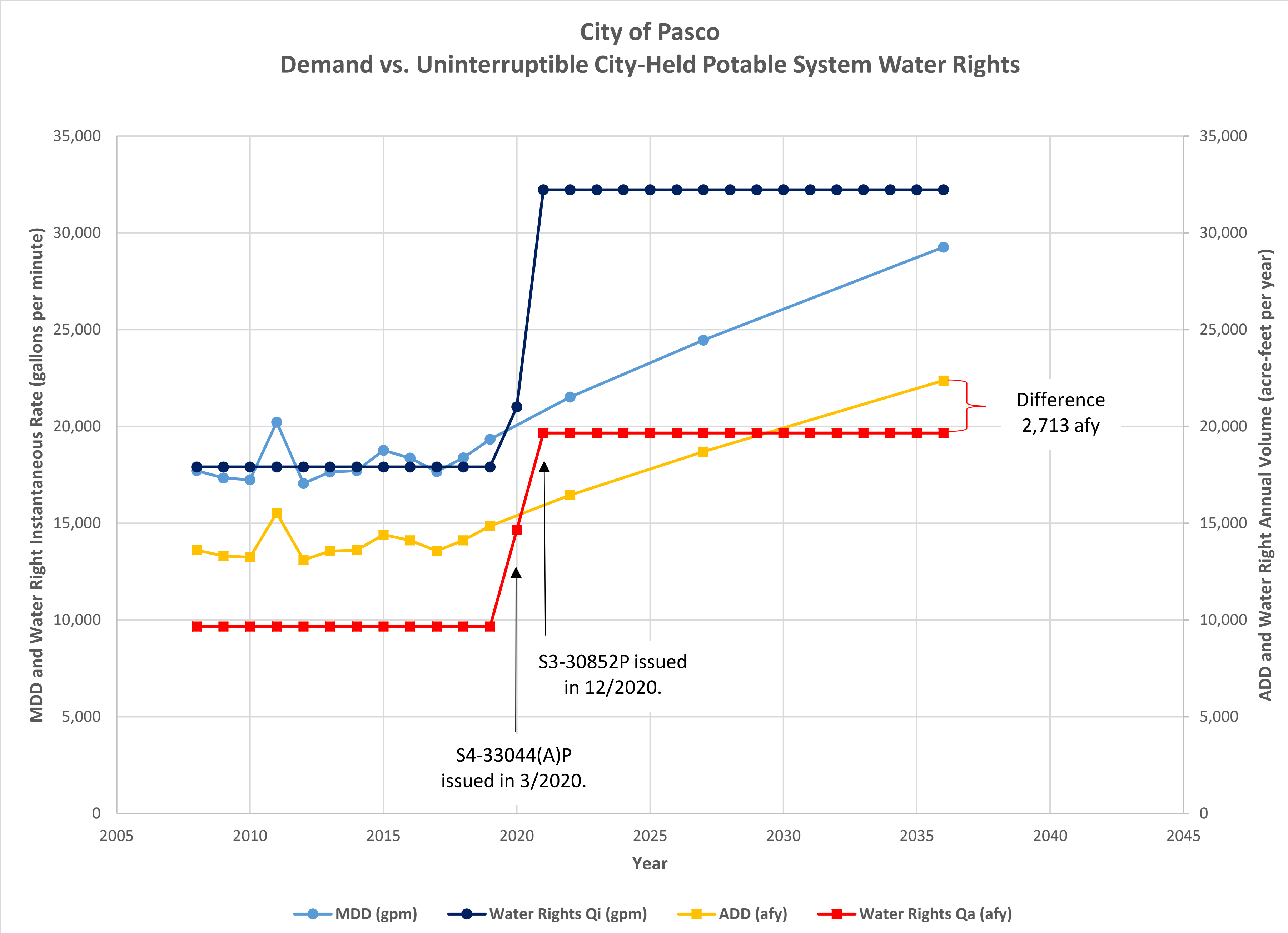
300,000
250,000
200,000
150,000
100,000
50,000
0
Minimum Average Weekly Flows (cfs)
McNary Dam
Bonneville Dam
260,000 cfs
McNary Dam
Variable Depending on March Forecast at the Dalles Dam
220,000 cfs
200,000 cfs
125,000 cfs
80,000 cfs
80,000 cfs
April 10 through June 30 McNary Dam Flows determined by runoff forecast in March for April-September at the Dalles Dam.
<=80 MAF is low, >92 MAF is high (Provision E)
If the forecast is >80 MAF and less than 92 MAF, the minimum instream flow is equal to:
220,000+((40*(March Dalles Forecast- 80)/12)*1,000 cfs
10/1
10/31
11/30
12/31
1/30
3/1
4/1
5/1
5/31
7/1
7/31
8/30
Date
Provision E McNary Low
Provision E McNary High
Provision E Bonneville Low

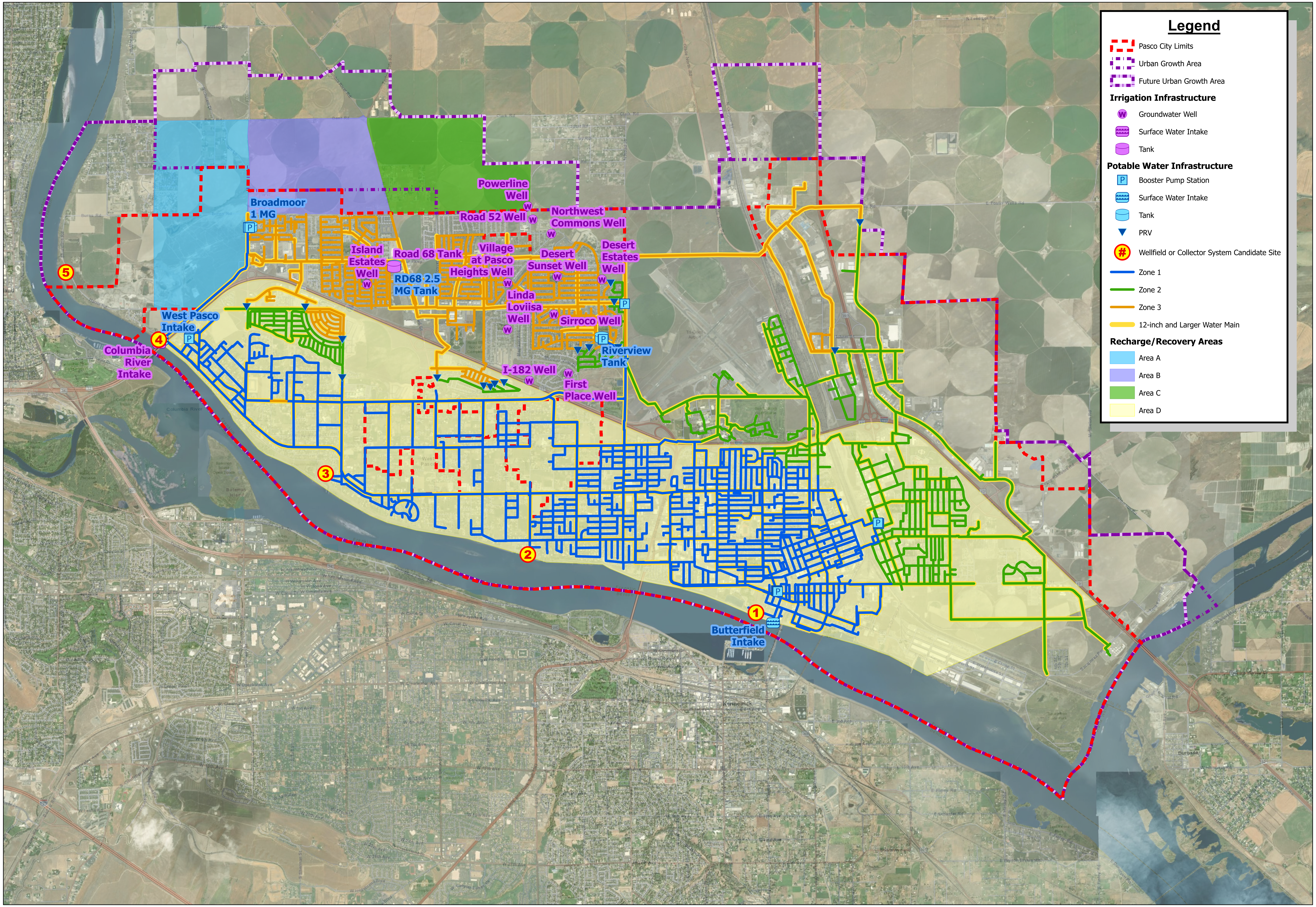
Figure 3



Percent Time Interruptible Water Available By Month Under the Quad Cities Water Right
Consistent with the BiOP Compliance Plan
(2005 through 2019 Water Years)
Average Percent Time Water Available During Month
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
83%
58%
85%
91%
88%
88%
62%
73%
64%
38%
9%
76%
October
November
December
January
February
March
April
May
June
July
August
September
Month

Figure 4


City of Pasco
Demand vs. Uninterruptible City-Held Potable System Water Rights
MDD and Water Right Instantaneous Rate (gallons per minute)
ADD and Water Right Annual Volume (acre-feet per year)
0
5,000
10,000
15,000
20,000
25,000
30,000
35,000
2005
2010
2015
2020
2025
2030
2035
2040
2045
Year
Difference
2,713 afy
S3-30852P issued
in 12/2020.
S4-33044(A)P
issued in 3/2020.
MDD (gpm)
Water Rights Qi (gpm)
ADD (afy)
Water Rights Qa (afy)



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Vicinity Map

Figure 5
Wellfield or Collector System Candidate Sites

PRELIMINARY

City of Pasco
Aquifer Storage & Recovery Feas. Study

City of Pasco Washington

1 inch : 2,500 Feet

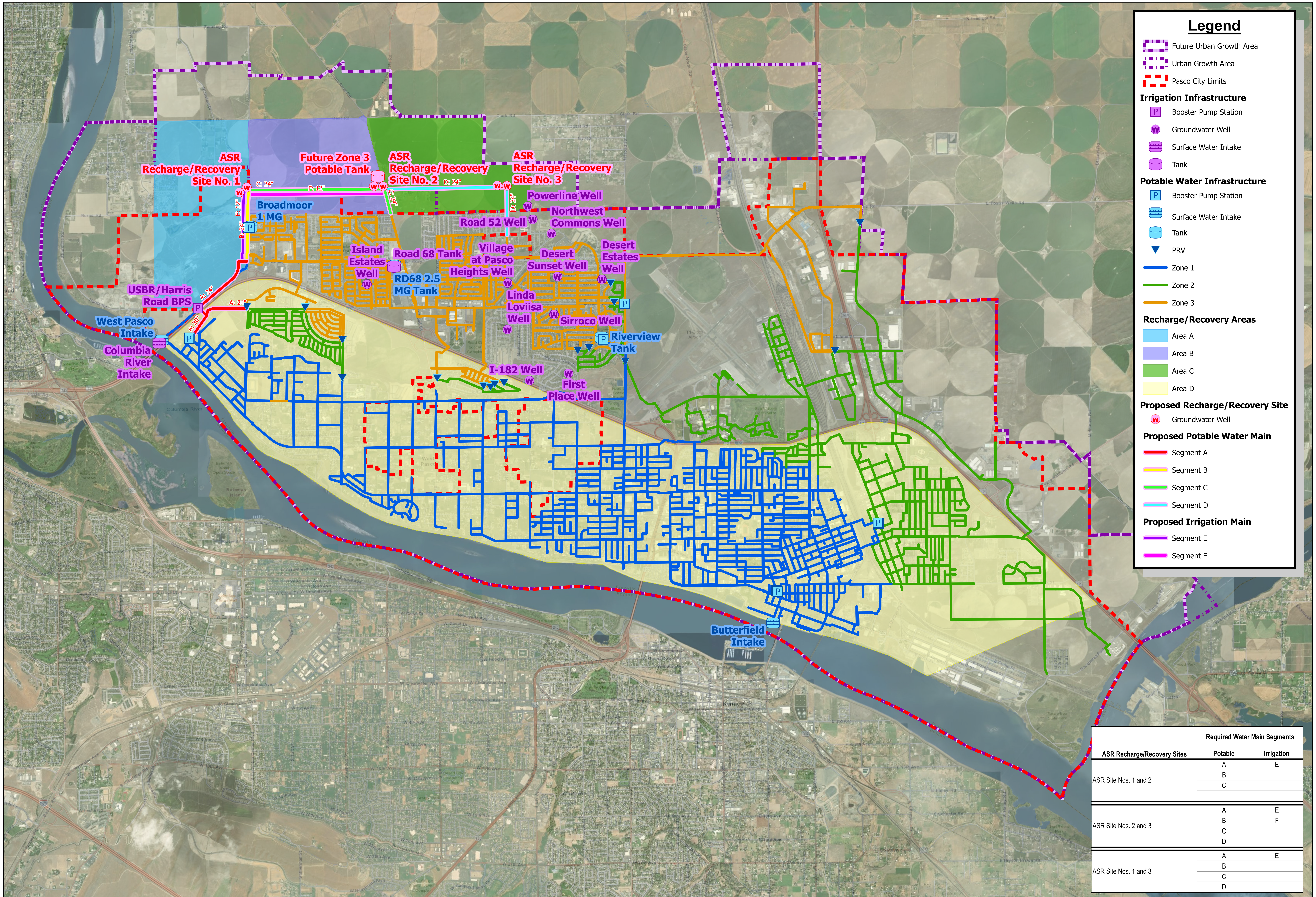
0 1,250 2,500 5,000 Feet

DRAWING IS FULL SCALE WHEN BAR MEASURES 2"

RH2

NORTH

J:\DATA\GS\20-0142\GIS\PSC ASR\FS PROJECT\PSC ASRFS.APRX BY: TCORNELIUS PLOT DATE: FEB 8, 2021 COORDINATE SYSTEM: NAD 1983 HARN STATEPLANE WASHINGTON SOUTH FIPS 4602 FEET



ASR Recharge/Recovery Sites	Required Water Main Segments: Potable	Required Water Main Segments: Irrigation
ASR Site Nos. 1 and 2	A	E
	B	
	C	
ASR Site Nos. 2 and 3	A	E
	B	F
	C	
	D	
ASR Site Nos. 1 and 3	A	E
	B	
	C	
	D	

J:\DATA\GIS\20-0142\GIS\PSC ASRFS PROJECT\PSC ASRFS.APRX BY: TCORNELIUS PLOT DATE: MAR 8, 2021 COORDINATE SYSTEM: NAD 1983 HARN STATEPLANE WASHINGTON SOUTH FIPS 4602 FEET

Vicinity Map

Figure 6
Proposed ASR Improvements and Infrastructure
City of Pasco Aquifer Storage & Recovery Feas. Study

PRELIMINARY

City of Pasco Washington

1 inch : 2,500 Feet

0 1,250 2,500 5,000 Feet

DRAWING IS FULL SCALE WHEN BAR MEASURES 2"

RH2

NORTH

Appendices

TECHNICAL MEMORANDUM

DATE March 8, 2021 **Project No.** 20147623

TO Kenny Janssen, LG
GSI Water Solutions Inc.

FROM Michael Klisch, LHG (WA), Derek Holom, LHG (WA), and Cheryl Ross, LHG (WA) **EMAIL** dholom@golder.com

PASCO AQUIFER STORAGE AND RECOVERY FEASIBILITY ASSESSMENT – TASK 3 SOURCE WATER QUALITY

This technical memorandum prepared by Golder Associates Inc. (Golder) provides a summary of water quality characteristics relevant to the operation of an Aquifer Storage and Recovery (ASR) system for the City of Pasco (City) based on available water quality data and published reports. This technical memorandum is not a stand-alone document but instead, was prepared for inclusion as an Appendix in GSI Water Solutions Inc.'s (GSI) Pasco ASR Feasibility Study report, which provides additional project details and context.

1.0 SOURCE WATER QUALITY

Potential source waters for ASR operations include: 1) one of the City Water Treatment Plants (WTPs) that treats surface water from the Columbia River (Butterfield WTP or West Pasco WTP); 2) shallow groundwater from the City's irrigation wells; or 3) untreated surface water from the City's Columbia River Intake used as an irrigation supply source.

This section presents water quality characteristics for source water based on review of local and regional water quality data and the reports described below:

- Regional Columbia River water quality obtained from published studies by the United States Geological Survey (USGS) (Fuhrer and others 1996) and a Hanford Site report (CH2M Hill 2019) and regional shallow groundwater quality obtained from the USGS (Elbert and others 1995). It is notable that the USGS data sources are approximately 25 years old.
- City of Pasco Irrigation System Master Plan (Murray, Smith & Associates 2013).
- Source water quality data from the City WTPs and source water quality assessment for City of Kennewick's ASR feasibility studies (Golder 2012a and 2012b; HDR Engineering Inc. 2012).
- Groundwater quality data for the Pasco Gravels (i.e. Hanford Formation) from the Pasco Bulk Fuel Terminal Site (Washington State Department of Ecology [Ecology] Site ID# 579).

1.1 Water Quality Characteristics of Untreated (Raw) Columbia River Water

1.1.1 Pasco Water Treatment Plants (Butterfield and West Pasco)

The City operates two WTPs (Butterfield and West Pasco) that treat Columbia River water prior to distribution to their potable system. The City also uses untreated and unfiltered Columbia River water via their Columbia River Intake (located at the West Pasco WTP) as a supply source for their irrigation system. Water quality data from the City's WTPs were downloaded from the Washington State Department of Health (DOH) Sentry Database by GSI and provided to Golder (DOH 2020). The data obtained from DOH includes results for analyses of both raw (pre-treatment) and finished (post-treatment) water for the period from January 2010 to September 2020. Raw water results are discussed in this section and the finished water results are discussed in Section 1.2.1. The raw water quality results are assumed to be representative of the water quality conditions expected from the City's Columbia River Intake.

The raw water quality data set includes results for analysis of fluoride, nitrate and total organic carbon (TOC). Results are summarized as follows:

- Fluoride concentrations ranged from 0.07 to 0.11 milligrams per liter (mg/L) (12 samples collected between 2016 and 2020)
- Nitrate concentrations ranged from 0.3 to 0.7 milligrams per liter as nitrogen (mg/L-N) (two samples, one from each WTP collected in 2010 and 2013)
- TOC concentrations ranged from 0.6 to 2.5 mg/L with a mean concentration of approximately 1.3 mg/L (86 samples collected between 2010 and 2020)

1.1.2 Kennewick WTP

Water quality data from DOH for the Kennewick WTP were previously compiled and evaluated by Golder for the Phase II ASR Feasibility Study (Golder 2012a). The 2012 data set includes water quality data for raw, finished, and "unknown" samples types collected between 1994 and 2012. This report presents results for raw and finished water quality separately (unknown sample types have been excluded from this review). Raw water results are discussed in this section and the finished water results are discussed in Section 1.2.2.

The raw water data set includes results for analysis of total metals, nutrients, major ions and total dissolved solids (TDS) for two samples collected in 1994 and 2010 (Table 1). With the exception of turbidity, results indicate compliance with Washington Drinking Water Criteria (WAC 246-290-310) for all analyzed constituents. Selected results are discussed below:

- TDS was approximately 200 mg/L. Alkalinity was the dominant anion and calcium was the dominant cation.
- Alkalinity ranged from approximately 30 to 90 mg/L as calcium carbonate ($CaCO_3$).
- Nitrate concentrations were less than 1 mg/L.
- Sulfate concentrations were approximately 10 mg/L.
- Sodium concentrations were less than 5 mg/L (i.e. below the drinking water advisory level of 20 mg/L).
- Total iron and manganese concentrations were low (less than 0.1 mg/L for iron and less than 0.05 mg/L for manganese).

Raw water also meets the Washington Groundwater Anti-Degradation Criteria (WAC 173-200-040) for all analyzed inorganic constituents, with the exception of arsenic and silver, for which compliance with anti-degradation criteria could not be assessed. Both arsenic and silver were reported as below detection; however, their respective analytical reporting limits were higher than the anti-degradation criteria (for one sample a lower reporting limit was achieved for silver and result indicated compliance with anti-degradation criterion).

1.1.3 Regional Data

Lower Columbia River (below the Bonneville Dam) water is classified as calcium-magnesium-bicarbonate type (Fuhrer and others 1996). Columbia River water in the Hanford area is also classified as a calcium-magnesium-bicarbonate type (CH2M Hill 2019).

Based on data presented in Fuhrer and others (1996), Lower Columbia River water quality at the Warrendale Station below the Bonneville Dam (the furthest upstream station evaluated by Fuhrer and others[1] - the station closest to Pasco) is characterized as follows:

- River pH values indicate circum-neutral to alkaline conditions (reported pH values ranged from approximately 7.5 to 8.7).
- Dissolved oxygen measurements collected from 1974 to 1994 were high (i.e. ranging from about 80 to 140 percent of saturation) and exhibited minimal variability. High concentrations of dissolved oxygen below the Bonneville Dam are attributed to the effects of water spilling over the dam.
- Specific conductance ranged from approximately 130 to 180 microSiemens per centimeter (μS/cm).
- Nitrate concentrations ranged from <0.05 to 0.4 mg/L-N. Results for a single sample (0.3 mg/L-N) reported by CH2M Hill (2019) for a Columbia River sample collected near Hanford is within the range reported by the USGS.
- Dissolved iron (0.002 to 0.025 mg/L) and dissolved manganese (<0.001 to 0.002) concentrations were low.

1.2 Water Quality Characteristics of Treated Columbia River Water

1.2.1 Pasco Water Treatment Plants (Butterfield and West Pasco)

Water quality data for the post-treatment (finished) water at the Butterfield and West Pasco WTPs are summarized in Table 2 (period of record from 2010 to 2020). According to the City's Comprehensive Water System Plan (Murraysmith 2019), water treatment at both WTPs includes the addition of coagulants (alum) and chlorine. The West Pasco WTP water is then strained, filtered, and fluoridated before storage and distribution. The Butterfield WTP includes flocculation basins, sedimentation basins, a mixed-media filter, and a second addition of coagulants and chlorine before storage and distribution. The DOH finished water quality data set includes results for parameters regulated in drinking water including TDS, metals[2], nutrients, cyanide, radionuclides, disinfection by-products (DBPs), and volatile and synthetic organic compounds (VOCs and SOCs) (DOH 2020). All VOCs and SOCs were consistently reported as below detection and therefore are not included in Table 2. Radionuclide concentrations were either below detection or detected at concentrations below drinking water criteria. Notable data gaps in the finished water quality data set include some major ions (e.g., alkalinity), dissolved oxygen, and pH. Water quality results are similar for the two WTPs. Notable differences between the two WTPs include generally higher DBP concentrations and lower sulfate concentrations reported for West Pasco compared to Butterfield; however, observed differences may be attributed to the timing of sample collection and analysis as well as the number of samples collected (i.e. fewer measurements generally available for Butterfield compared to West Pasco).

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[1] Water quality data for the Columbia River farther downstream near Portland and below are available; however, these data were not evaluated because of the potential influences of urbanization and mixing with the Willamette River.

[2] Metals in this memorandum refers to both metals and metalloids. DOH data source does not indicate fraction of metals analyzed (i.e. total or dissolved).

Treated Columbia River water meets Washington Drinking Water Criteria (WAC 246-290-310) for all analyzed constituents. Treated water also meets the Washington Groundwater Anti-Degradation Criteria (WAC 173-200-040) for all analyzed inorganic constituents, with the exception of arsenic and silver, for which compliance with anti-degradation criteria could not be assessed. Both arsenic and silver were reported as below detection; however, their respective analytical reporting limits were higher than the anti-degradation criteria:

- Arsenic was not detected (<0.003 to <0.001 mg/L); the anti-degradation criterion is 0.00005 mg/L.
- Silver was not detected (<0.1 mg/L); the anti-degradation criterion is 0.05 mg/L.

Results for selected parameters are summarized as follows:

- Nitrate concentrations ranged from 0.3 to 1 mg/L-N.
- Iron concentrations were consistently below detection (<0.1 mg/L) and manganese concentrations were low (<0.01 mg/L).
- TOC concentrations ranged from 0.6 to 1.8 mg/L.
- Most measured metals were consistently below detection.

DBP data from the WTPs indicate the treated water meets drinking water criteria for chloroform, dibromochloromethane, and total trihalomethanes (TTHMs). However, bromodichloromethane exceeded the anti-degradation criterion of 0.3 micrograms per liter (μg/L) at both WTPs (2.5 μg/L at Butterfield WTP during a single sampling event and 1.9 to 2.9 μg/L at West Pasco WTP during six sampling events). Chloroform also exceeded the anti-degradation criteria of 7 μg/L at the West Pasco WTP (14 to 52 μg/L for six samples). Bromoform and dibromochloromethane concentrations were below the anti-degradation criteria for both WTPs.

1.2.2 Kennewick WTP

As described in Section 1.1.2, Golder conducted a source water assessment of water from Kennewick's WTP as part of the Phase II ASR Feasibility Study (Golder 2012a; HDR 2012). Kennewick water treatment includes membrane filtration followed by sodium hypochlorite injection before distribution to the water system (RH2 2017). Finished water quality results are presented in Table 3. Water quality results indicate compliance with Washington Drinking Water Criteria (WAC 246-290-310) for all analyzed constituents (Table 3). Selected results are listed below:

- TDS concentrations ranged from approximately 70 to 280 mg/L.
- Alkalinity concentrations ranged from approximately 50 to 70 mg/L as $CaCO_3$.
- Nitrate concentrations ranged from 0.14 to 2.7 mg/L-N.
- Sulfate concentrations ranged from approximately 6 mg/L to 26 mg/L[3].
- Sodium concentrations were less than 10 mg/L.
- Iron concentrations ranged from <0.01 mg/L to 0.2 mg/L.

[3] One sample was reported at less than 50 mg/L.

- TOC concentrations ranged from 0.9 to 3.8 mg/L.

Treated water is classified as calcium-magnesium-bicarbonate type (HDR 2012). The DOH database did not include pH data. WTP pH data provided by the City of Kennewick for the period 2010 to 2012 indicated pH values ranging from approximately 7.8 to 8.4; Golder 2012a)[4].

Laboratory results from samples collected between 1993 and 2012 indicate that concentrations exceed the groundwater anti-degradation criteria (WAC 173-200-040) for the following DBPs and arsenic (Table 3):

- Bromodichloromethane ranged from 0.7 to 12 μg/L (anti-degradation criterion is 0.3 μg/L).
- Bromoform was 22 μg/L in one sample collected in 1993 (anti-degradation criterion is 5 μg/L).
- Chloroform was detected in 21 samples above the anti-degradation criterion of 7 μg/L with a maximum concentration of 43 μg/L.
- Dibromochloromethane was detected in 16 samples above the anti-degradation criterion of 0.5 μg/L with a maximum concentration of 6 μg/L
- Arsenic was detected at 0.0029 mg/L in one sample in 2009 (anti-degradation criteria is 0.00005 mg/L). The remaining samples were non-detect (<0.002 to <0.005 mg/L)

1.3 Water Quality Characteristics of the Hanford Formation (Shallow Groundwater)

The uppermost (suprabasalt) groundwater encountered in the project area primarily occurs within the Pasco Gravels of the Hanford Formation (Golder 2012a; INTERA 2020). The Hanford Formation thickness ranges from about 40 to more than 300 feet in the greater Pasco Basin and is primarily composed of unconsolidated deposits of silt, sand, and gravel that was deposited by several cataclysmic events associated with the Missoula Floods (INTERA 2020). The water quality review provided in this section is primarily focused on available groundwater quality data that are interpreted to represent the Hanford Formation. The Ringold Formation typically underlies the Hanford Formation and is composed of semi-indurated to indurated, fluvial and lacustrine deposits. In the Pasco Basin, the thickness of the Ringold Formation is highly variable, ranging from absent to more than 400 feet thick. Aquifers occur within the Ringold Formation but are significantly less permeable than the Hanford Formation sediments (INTERA 2020).

1.3.1 Regional Information

Information on regional shallow groundwater quality was obtained by GSI from the Ecology Environmental Information Management (EIM) Database. Information in the EIM database includes groundwater quality from regional Ecology groundwater quality studies and groundwater quality data from contaminated sites. Completion details and lithologies of the wells were not included. The EIM data supplied by GSI were filtered to remove data collected at contaminated sites where native groundwater quality may have been affected by site activities. The inorganic groundwater quality data from the EIM database are summarized in Table 4 and includes groundwater quality data collected as part of the following Ecology studies[5]:

[4] Unknown if reported pH values were taken before or after treatment.

[5] Database does not provide references for these studies.

- Central Columbia Basin Groundwater Monitoring Area - Nitrate Characterization Study (September to November 1998).
- Columbia Basin Crop and Water Quality Monitoring Study (April 2000 to May 2006).
- Irrigated AG Technical Assistance (April 2000 to May 2006).
- Washington State Agricultural Chemicals Pilot Study (September 1988 to May 1989).

The groundwater quality data summarized in Table 4 include the largest data record for nitrate or nitrate plus nitrite analyses. The samples collected as part of the Washington State Agricultural Chemicals Pilot Study included additional inorganic constituents for three samples. Results are summarized as follows:

- Nitrate (and nitrate plus nitrite) concentrations based on 346 samples ranged from non-detect (<0.01 mg/L-N) to approximately 40 mg/L-N. Nitrate concentrations were higher than the drinking water and anti-degradation criteria of 10 mg/L-N in 140 of the samples (i.e. approximately 40% of samples).
- Iron and manganese (total recoverable fraction) were analyzed during two sampling events for the Agricultural Pilot Study. Iron concentrations ranged from 0.02 to 13 mg/L and manganese concentrations ranged from 0.01 to 0.7 mg/L.
- TOC concentrations ranged from 3 to 30 mg/L (15 samples).

For the two samples for which complete major ion analysis is available, one sample has a major ion composition classified as a magnesium-bicarbonate type and the other is classified as a bicarbonate-type with no dominant cation. The presence of elevated nitrate concentrations in some wells suggests oxidized groundwater conditions. Metals data are limited to a few samples. The available dataset, albeit limited, indicates the potential for exceedances of drinking water and/or groundwater anti-degradation criteria in shallow groundwater (e.g., arsenic, lead, iron and manganese). At some wells, groundwater TDS concentrations exceed the secondary drinking water maximum contaminant level (SMCL) of 500 mg/L.

Additional information on nitrate in shallow groundwater units (Pasco Gravels and underlying Ringold Formation) in the Pasco Basin (Benton and Franklin Counties) is summarized in Elbert and others (1995). In Franklin County, nitrate concentrations in the Pasco Gravels ranged from about 1 to over 20 mg/L-N; the lower range of nitrate concentrations are typically observed in wells that are deeper than 300 feet and/or in close proximity to irrigation canals. Elbert and others (1995) noted that nitrate concentrations in groundwater increased by as much as two orders of magnitude between the 1950s and the mid-1990s at some locations in Franklin County.

Elbert and others (1995) also present data for fluoride and pesticides. Groundwater samples for fluoride analysis were collected from 142 wells completed in both shallow groundwater units and deeper basalt units in Benton and Franklin Counties. Fluoride concentrations in the Pasco Gravels wells were less than 1 mg/L. Groundwater samples were collected from 10 wells completed in sediments (no differentiation between Pasco Gravels or Ringold Formation) and analyzed for a suite of commonly-used pesticides. Dicamba was detected in two wells at concentrations of 0.01 μg/L and picloram was detected at a concentration of 0.03 μg/L in one of the wells with a dicamba detection. There is no drinking water criterion for dicamba and the drinking water criterion for picloram is 500 μg/L.

1.3.2 Local Information

1.3.2.1 City of Pasco Shallow Groundwater Wells

Groundwater quality data from the City's former supply wells completed in the Hanford Formation were downloaded from the DOH Sentry Database by GSI and provided to Golder. The dataset includes several samples collected between 1988 and 2003 from pre-treatment, post-treatment, and "unknown" sample types. Data were provided for five sources:

- Source 02: Wells 1A & 1B
- Source 03: WP Well 2
- Source 04: WP Well 3
- Source 05: Dradie St. Well (decommissioned in 2017)
- Source 06: WP Wellfield which includes Source 03, 04, 07, and 08 (WP Well 2, WP Well 3, WP Well 1A, and WP Well 1B, respectively)

Table 5 provides a summary of all the analyses included in the DOH dataset for the City's former supply wells. No alkalinity, dissolved oxygen, or pH data were available for review. Water quality results indicate compliance with Washington Drinking Water Criteria (WAC 246-290-310) with the following exceptions:

- Nitrate (14 to 17 mg/L-N) in six samples collected between 1993 and 1994 (MCL of 10 mg/L-N)
- Single conductivity (760 µmhos/cm) exceedance of the SMCL in 1993 (SMCL of 700 µmhos/cm)
- Single iron (0.34 mg/L) exceedance of the SMCL in 1993 (SMCL of 0.3 mg/L)
- Single manganese (0.06 mg/L) exceedance of the SMCL in 1993 (SMCL of 0.05 mg/L)
- Single TDS (510 mg/L) exceedance of the SMCL in 1993 (SMCL is 500 mg/L)
- Sodium (28 to 47 mg/L) in all six samples collected between 1988 and 1997 exceeded the advisory limit of 20 mg/L

DBPs were detected in one sample of post-treated water at the following concentrations (Table 5):

- Bromoform was measured at 2.9 µg/L, below the anti-degradation criterion of 5 µg/L.
- Bromodichloromethane was measured at 1.4 µg/L, above anti-degradation criterion of 0.3 µg/L.
- Dibromochloromethane was measured at 3.6 µg/L, above anti-degradation criterion of 0.5 µg/L.
- Chloroform was non-detect (<0.5 µg/L).

Arsenic was also detected in one post-treated sample collected in 2002 at a concentration of 0.003 mg/L; this is below the drinking water criterion of 0.01 mg/L, but above the groundwater anti-degradation criterion of 0.00005 mg/L. Arsenic concentrations in the remaining five "unknown" type samples were all non-detect (less than 0.01 mg/L).

1.3.2.2 City of Pasco Irrigation Wells

The City of Pasco Irrigation System Master Plan (Murray, Smith & Associates 2013) includes DBP data for four samples from a source identified as "92" in Appendix A of their report; it is uncertain if this is Source 02 or another source. It is assumed that the data are for finished water. The DBPs were all below their respective drinking water criteria, but above the groundwater anti-degradation criteria (except for TTHM), as summarized below:

- Chloroform ranged from 20 to 39 μg/L (anti-degradation criterion is 7 μg/L)
- Bromodichloromethane ranged from 1.9 to 5.3 μg/L (anti-degradation criterion is 0.3 μg/L)
- Dibromochloromethane was measured in one sample at 0.5 μg/L (anti-degradation criterion is 0.5 μg/L)
- TTHMs ranged from 23 to 45 μg/L

1.3.3 Pasco Bulk Fuel Site

Table 6 is a summary of the water quality of the Pasco Gravels based on samples collected from five wells at the Pasco Bulk Fuels Site (Ecology site ID# 579). The wells are completed at depths of 25.5 to 40 feet below ground surface and are interpreted to be representative of background groundwater quality in the Pasco Gravels. Groundwater quality data are from sampling events in 2006, 2008, and 2010 were compiled for pH, major ions, nutrients, metals, and organic constituents. Arsenic data were available for two additional sampling events in 2012 and 2014. Water quality results indicate compliance with Washington Drinking Water Criteria (WAC 246-290-310). Based on field parameter measurements associated with the 2006, 2008, and 2010 sampling events, pH is circum-neutral (7.0 to 7.7), specific conductance ranges from approximately 120 to 700 µS/cm, and dissolved oxygen is variable (ranges from 0.1 to 9.2 mg/L, with a mean value of 3.6 mg/L). The major ion composition of Pasco Gravels groundwater is classified as calcium-magnesium-bicarbonate type with moderate to moderately high alkalinity (ranges from approximately 90 to 190 mg/L as $CaCO_3$). Results for selected parameters are summarized below (total metal concentrations are discussed below):

- The typical analytical reporting limit for arsenic ranges from 0.002 to 0.005 mg/L. Arsenic was not detected in 14 of the 23 samples. Lower analytical reporting limits have been achieved for some samples. When detected, arsenic concentrations have ranged from 0.0009 to 0.005 mg/L.
- The typical analytical reporting limit for iron is 0.2 mg/L. Iron was typically below detection (i.e. <0.2 in 13 of 15 samples). Iron was detected at low concentrations (up to 0.18 mg/L) during two sampling events for which a lower analytical reporting limit was achieved.
- For most wells, nitrate[6] concentrations exceed the drinking water criteria of 10 mg/L-N. Nitrate concentrations were consistently below the analytical reporting limit (<0.01 to <0.07 mg/L-N) in one well and consistently below the drinking water criterion in a second well, ranging from 3.2 to 9.4 mg/L-N. In the remaining three wells, nitrate concentrations ranged from 13 to 18 mg/L-N.
- The average sodium concentration of 29 mg/L exceeded the drinking water advisory level of 20 mg/L; sodium concentrations ranged from 4.9 to 54 mg/L. The average TDS concentration was 375 mg/L, but some samples reported concentrations higher than the drinking water and anti-degradation criteria of 500 mg/L.

[6] Nitrate refers to nitrate+nitrite results.

1.3.4 City of Kennewick Source Water (Ranney Collector Wells)

Kennewick operates two Ranney collector wells (RC4 and RC5) as part of their source water for their ASR system (Golder 2012b; HDR 2012). Information on the water quality characteristics of the City of Kennewick source water is detailed in the Phase 2 ASR Feasibility report (Golder 2012a). The Ranney collector wells are installed in shallow gravels adjacent to the Columbia River and are interpreted to collect shallow groundwater that discharges to the river (HDR 2012). Table 7 summarizes the water quality data for RC4 and RC5 presented in Golder (2012b) for the period 2002 to 2012. With the exception of isolated iron measurements, water quality results indicate compliance with Washington Drinking Water Criteria (WAC 246-290-310). Water from the Ranney collector wells is characterized as a calcium-magnesium-bicarbonate type water. Groundwater pH values were circum-neutral (7.5 to 7.8) and specific conductance ranged from approximately 290 to 580 µmhos/cm (Golder 2012b). Selected results for the Ranney collector wells are listed below:

- Alkalinity concentrations were variable, ranging from 1 to 257 mg/L as $CaCO_3$.
- Nitrate ranged from 0.15 to 4.3 mg/L-N.
- Sulfate ranged from 20 to 42 mg/L.
- Sodium ranged from 15 to 25 mg/L.
- Iron ranged from <0.01 mg/L to 0.44 mg/L. There has been only one exceedance of the iron drinking water secondary maximum contaminant level (SMCL) of 0.3 mg/L reported at both RC4 and RC5 over the period of record (sample date of June 19, 2007 for both sources).
- Arsenic generally ranged from 0.001 to 0.005 mg/L with one sample measured at the drinking water limit (0.01 mg/L) on a single occasion at RC5. Arsenic concentrations therefore have exceeded the anti-degradation criterion of 0.00005 mg/L.

2.0 SUMMARY OF FINDINGS

Based on review of the data sources identified in this memorandum, the characteristics of Columbia River and City shallow groundwater quality are summarized in this section.

Columbia River water is classified as a calcium-magnesium-bicarbonate type water with circum-neutral to alkaline pH and moderate alkalinity concentrations. Nitrate, iron, and manganese concentrations are relatively low in Columbia River water and all reported parameters meet drinking water criteria per WAC 246-290-310 (based on the data sets reviewed for this evaluation). DBPs were detected below drinking water criteria but above the groundwater anti-degradation criteria (WAC 173-200-040) in treated Columbia River water from the Pasco and Kennewick WTPs. Total suspended solids (TSS) data were not available for raw or treated Columbia River water. Based on the design of the City WTPs, it is assumed that raw Columbia River water likely contains TSS. Elevated TSS in ASR source water may affect well performance.

Groundwater quality of the shallow unconfined aquifers in the Hanford Formation (predominately in the Pasco Gravels) is characterized as a magnesium-bicarbonate type water to bicarbonate type water with no dominant cation. Groundwater quality meets primary drinking water criteria with the exception of nitrate (based on the data sets reviewed for this evaluation). Nitrate concentrations are typically higher than Columbia River water, with concentrations ranging from below detection to 30 mg/L-N. Based on the groundwater quality data available for review, iron and manganese concentrations within the shallow aquifer within the Hanford Formation are variable and often higher than concentrations in the Columbia River and both iron and manganese have been measured above their SMCLs of 0.3 and 0.05 mg/L, respectively. The available metals data indicate a potential for arsenic to be present at low concentrations (i.e. part per billion levels). Baseline shallow groundwater arsenic concentrations may therefore exceed the anti-degradation criterion of 0.00005 mg/L. Concentrations of major ions and metals are generally higher in the shallow groundwater compared to the Columbia River.

A summary of the water quality characteristics for Columbia River water and shallow groundwater in the Hanford Formation is provided in the following below.

Attribute	Columbia River	Notes	Shallow Groundwater	Notes
Description	Review included data for treated and untreated samples		Shallow unconfined aquifers in the Hanford formation (predominantly the Pasco Gravels)	
Primary Data Sources (local)	City WTPs - Butterfield and West Pasco (DOH) **(Table 2)**	Two City WTPs report similar finished water quality	City's former supply wells **(Table 5)**; Pasco Bulk Fuel Terminal **(Table 6)**; Kennewick's Ranney collector wells **(Table 7)**	
Primary Data Sources (regional)	USGS (Fuhrer et al. 1996); Kennewick ASR Feasibility Study (Golder 2012a) **(Tables 1 and 3)**	Water quality data sets >10 years old and may not be representative of current conditions	Ecology's EIM Database **(Table 4)**; USGS (Elbert et al 1995)	USGS data set >10 years old and may not be representative of current conditions
Water Type (based on major ion chemistry)	calcium-magnesium-bicarbonate		magnesium-bicarbonate to bicarbonate with no dominant cation	
pH	Circum-neutral to alkaline (Kennewick WTP and USGS)	DOH WTP data set does not include pH	Circum-neutral	Based on Kennewick Ranney collector wells and Pasco Bulk Fuel Terminal
Alkalinity	30 to 90 mg/L as $CaCO_3$ (Kennewick WTP)	DOH WTP data set does not include alkalinity	Typically moderate to moderately high (60 to 250 mg/L as $CaCO_3$)	
TDS	~100 mg/L (City WTP) ~100 to 300 mg/L (Kennewick WTP)		~60 to 650 mg/L	Groundwater TDS exhibits more variability than Columbia River (based on datasets reviewed)
TSS	No data	Assumed that City WTPs designed to target removal of TSS (potential for ASR well clogging if a raw water source used)	No data – not typically analyzed in groundwater samples	

Attribute	Columbia River	Notes	Shallow Groundwater	Notes
Nitrate	Generally low (<1 mg/L-N)	Kennewick WTP data indicate concentrations up to a few mg/L are possible	Variable ranging from <0.01 mg/L-N to 30 mg/L-N	Temporal and seasonal variations in nitrate concentrations were not evaluated
Iron (Fe) and Manganese (Mn)*	Low (<0.2 mg/L)		Variable (Fe ranges <0.01 to more than 13 mg/L; Mn ranges 0.02 to 0.7 mg/L)	The highest concentrations of Fe and Mn were reported in the EIM database (Table 4).
Metals	Low		Generally low but relatively higher than the Columbia River	
TOC	~1 to 4 mg/L		3 to 30 mg/L	Reported in the EIM database (Table 4)
DBPs	Present in treated water		Not present in untreated groundwater	
Drinking Water Quality Criteria (WAC 246-290-310)	DOH treated water data set for City WTPs indicates compliance for all monitored parameters	DOH data set includes limited information for raw water samples (i.e. nitrate, fluoride and TOC)	Meets all primary drinking water criteria. Occasional exceedances for secondary standards (Fe, Mn, TDS, and conductivity). Sodium is generally exceeded (20 mg/L advisory level) with a range of ~2 to 60 mg/L	
Anti-Degradation Groundwater Quality Criteria (WAC 173-200-040)	Potential for DBP exceedances. City WTP arsenic and silver results were non-detect but at reporting limits above their respective groundwater criteria. Single low-level arsenic detection for Kennewick WTP indicates potential for arsenic to exceed groundwater criteria.	DBP exceedances reported in City WTP and Kennewick WTP data sets	Arsenic has been measured above the groundwater criterion of 0.00005 mg/L. Most non-detect results were to a reporting limit of 0.01 mg/L.	

* Fraction analyzed in samples (total versus dissolved) not reported in all datasets.

3.0 DATA GAPS AND UNCERTAINTIES

Evaluation of ASR feasibility requires a current and comprehensive analysis of source water quality. Some of the datasets evaluated are more than a decade old and therefore may not be representative of current water quality conditions. The available datasets are also insufficient to evaluate temporal trends in water quality. Both surface water and shallow groundwater, in particular if there is communication between shallow groundwater and surface water, may exhibit seasonal variation in water quality. The available groundwater quality data indicate some variability in groundwater quality; however, the available datasets were insufficient to draw conclusions regarding current spatial trends in groundwater quality (e.g., areas of higher and lower nitrate concentrations).

The primary data gaps are listed below:

- **Columbia River** – Comprehensive analyses of untreated water from the City Columbia River Intake (irrigation supply) and untreated and treated Columbia River from Pasco's WTPs were not available for review; this should include major ions, pH, reduction-oxidation potential (redox), dissolved oxygen, trace metals (total and dissolved), nutrients, TOC, TSS, TDS, and possibly redox-dependent species. Collection and analysis of samples over time should be conducted to evaluate seasonal trends.
- **Shallow Groundwater** – There are insufficient groundwater quality data to fully characterize shallow groundwater. The water quality data available for the City's former shallow supply wells were limited to regulated constituents. Similarly, water quality data for the City's irrigation wells are limited to nitrate and a few DBP samples from an uncertain source. A comprehensive analysis of water quality parameters is necessary to characterize groundwater from the suprabasalt aquifer system as a potential source of water for future geochemical modeling (i.e. evaluate mixing with native groundwater and recharge water-aquifer matrix interactions). The available data are also insufficient to characterize spatial trends in groundwater quality needed to inform a decision on the location of a possible suprabasalt groundwater source.

The recommended analytical suite for surface water and groundwater quality analyses would be determined following additional project evaluations. Selection of analytical methods to achieve analytical reporting limits below all applicable standards, in particular groundwater anti-degradation standards, should be considered during the planning stages of an analytical program.

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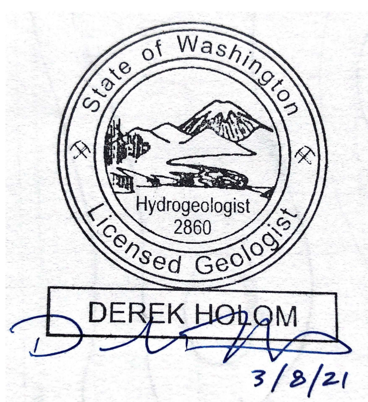

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MK/DH/CR/

https://golderassociates.sharepoint.com/sites/130627/project files/6 deliverables/task 3 - source water quality/final/20147623-tm-rev0-pasco asr task 3 source water quality-030521.docx

List of Tables

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Tables

Table 1. Kennewick WTP Untreated Water Quality - DOH 1994 to 2010

Analyte	Units	Drinking Water MCL/SMCL (WAC 246-290-310)	Groundwater Criteria (WAC 173-200-040)	Raw		
				Maximum	Minimum	No. of Samples
Alkalinity as $CaCO_3$	mg/L			94	26.4	15
Antimony	mg/L	0.006		<0.006	<0.005	2
Arsenic	mg/L	0.01	0.00005	<0.01	<0.003	2
Barium	mg/L	2	1	<0.1	0.0231	2
Beryllium	mg/L	0.004		<0.003	<0.0008	2
Cadmium	mg/L	0.005	0.01	<0.002	<0.002	2
Calcium	mg/L			16.4	16.4	1
Chloride	mg/L	250	250	<20	1.59	2
Chromium	mg/L	0.1	0.05	<0.02	<0.01	2
Color	Color Units	15	15	15	<15	2
Conductivity	µmhos/cm	700 (SMCL)		140	140	2
Copper	mg/L	1.3	1	<0.2	0.0023	2
Cyanide	mg/L	0.2		<0.05	<0.01	2
Fluoride	mg/L	4 (MCL) / 2 (SMCL)	4	<0.5	<0.2	2
Hardness	mg/L			66	57.7	2
Iron	mg/L	0.3	0.3	<0.1	0.0353	2
Lead	mg/L	0.015	0.05	<0.002	<0.001	2
Magnesium	mg/L			4.06	4.06	1
Manganese	mg/L	0.05	0.05	0.0352	<0.01	2
Mercury	mg/L	0.002	0.002	<0.0005	<0.0004	2
Nickel	mg/L	0.1		<0.1	<0.04	2
Nitrate (as N)	mg/L-N	10	10	0.7	0.144	4
Nitrite (as N)	mg/L-N	1		<0.5	<0.2	2
Selenium	mg/L	0.05	0.01	<0.01	<0.005	2
Silver	mg/L	0.1	0.05	<0.1	<0.01	2
Sodium	mg/L	20 (advisory level)**		<5	2.9	2
Sulfate	mg/L	250 (SMCL)	250	10	9	2
Total Dissolved Solids	mg/L	500 (SMCL)	500	199	100	2
Thallium	mg/L	0.002		<0.002	<0.002	2
Turbidity	NTU	1		2.86	0.5	2
Zinc	mg/L	5	5	0.0027	0.0027	2

shown are "action levels" set by the EPA and referenced in WAC 246-290-310
--- indicates not analyzed, measured, or defined
< indicates non-detect below value
C.U. color units
mg/L - milligrams per liter
µg/L - micrograms per liter
µmhos/cm - micromhos per centimeter
MCL - maximum contaminant level
MCLG - maximum contaminant level goal
N - nitrogen
NTU - Nepthelometric turbidity units
SMCL - secondary maximum contaminant level

Table 2: Treated Water Quality Data from City of Pasco Water Treatment Plants

Analyte	Units	Drinking Water MCL/SMCL (WAC 246-290-310)	Groundwater Criteria (WAC 173-200-040)	Butterfield WTP				West Pasco WTP			
				Maximum	Minimum	Mean	No. of samples	Maximum	Minimum	Mean	No. of samples
Conductivity	µmhos/cm	700 (SMCL)		187	178	183	2	218	168	181	5
Color	C.U.		15	<15	<15	---	2	<15	<15	---	5
Turbidity	NTU			0.13	<0.1	0.12	2	0.21	<0.1	---	5
Total Dissolved Solids	mg/L	500 (SMCL)	500	110	107	109	2	105	104	105	2
Sodium	mg/L	20 (advisory level)**		5.8	4.7	5.2	2	5.94	3.9	4.9	5
Hardness	mg/L			85	80	82	2	87.9	69.2	77	5
Sulfate	mg/L	250 (SMCL)	250	22	20.6	21.3	2	17	11	13	5
Chloride	mg/L	250	250	4.7	4.0	4.4	2	7.6	2.7	4.3	5
Fluoride	mg/L	4 (MCL) / 2 (SMCL)	4	0.86	0.65	0.76	2	0.88	0.43	0.67	5
Nitrate-N	mg/L-N	10	10	1.0	0.3	0.6	8	0.8	0.34	0.5	9
Nitrite-N	mg/L-N	1		<0.2	<0.1	---	2	<0.2	<0.1	---	5
Antimony	mg/L	0.006		<0.006	<0.003	---	2	<0.006	<0.003	---	5
Arsenic	mg/L	0.01	0.00005	<0.003	<0.001	---	2	<0.003	<0.001	---	5
Barium	mg/L	2	1	0.032	0.031	0.031	2	0.034	0.025	0.029	5
Beryllium	mg/L	0.004		<0.0008	<0.0003	---	2	<0.0008	<0.0003	---	5
Cadmium	mg/L	0.005	0.01	<0.002	<0.001	---	2	<0.002	<0.001	---	5
Chromium	mg/L	0.1	0.05	<0.02	<0.007	---	2	<0.02	<0.007	---	5
Copper	mg/L	1.3**	1	<0.02	<0.02	---	2	<0.02	<0.02	---	5
Cyanide	mg/L	0.2		<0.05	<0.01	---	2	<0.05	<0.01	---	5
Iron	mg/L	0.3 (SMCL)	0.3	<0.1	<0.1	---	2	<0.1	<0.1	---	5
Lead	mg/L	0.015**	0.05	<0.001	<0.001	---	2	<0.001	<0.001	---	5
Manganese	mg/L	0.05 (SMCL)	0.05	<0.01	0.0022	---	2	<0.01	0.0035	---	5
Mercury	mg/L	0.002	0.002	<0.0004	<0.0002	---	2	<0.0004	<0.0002	---	5
Nickel	mg/L	0.1		<0.1	0.0015	---	2	<0.1	<0.005	---	5
Selenium	mg/L	0.05		<0.01	<0.002	---	2	<0.01	<0.002	---	5
Silver	mg/L	0.1 (SMCL)	0.05	<0.1	<0.1	---	2	<0.1	<0.1	---	5
Thallium	mg/L	0.002		<0.002	<0.001	---	2	<0.002	<0.001	---	5
Zinc	mg/L	5	5	<0.2	0.002	---	2	<0.2	<0.2	---	5
TOC	mg/L			1.76	0.55	0.91	46	1.55	0.62	0.99	20
Chloroform	µg/L	70 (MCLG)	7	6.9	6.9	6.9	1	51.8	13.6	28.6	6
Bromodichloromethane	µg/L	See TTHM	0.3	2.5	2.5	2.5	1	2.9	1.9	2.4	6
Dibromochloromethane	µg/L	60 (MCLG)	0.5	<0.5	<0.5	---	1	<0.5	<0.5	---	6
Bromoform	µg/L	See TTHM	5	<0.5	<0.5	---	1	<0.5	<0.5	---	6
Total Trihalomethane (TTHM)	µg/L	80		9.4	9.4	9.4	1	54.6	15.5	31	6

Notes:
** - indicates analytes not regulated by the Washington State Board of Health, but acknowledged to have public health significance. Levels shown are "action levels" set by the EPA and referenced in WAC 246-290-310
Non-detect values assumed equal to reporting limit in calculation of mean concentrations
--- indicates not analyzed, measured, or defined
< indicates non-detect below value
C.U. color units
mg/L - milligrams per liter
µg/L - micrograms per liter
µmhos/cm - micromhos per centimeter
MCL - maximum contaminant level
MCLG - maximum contaminant level goal
N - nitrogen
NTU - Nepthelometric turbidity units
SMCL - secondary maximum contaminant level

Table 3. Kennewick WTP Finished Water Quality - DOH 1995 to 2012

Analyte	Units	Drinking Water MCL/SMCL (WAC 246-290-310)	Groundwater Criteria (WAC 173-200-040)	Finished		
				Maximum	Minimum	No. of Samples
Alkalinity as $CaCO_3$	mg/L			71	54	8
Antimony	mg/L	0.006		<0.006	<0.003	15
Arsenic	mg/L	0.01	0.00005	0.0029	<0.002	15
Barium	mg/L	2	1	0.039	<0.01	15
Beryllium	mg/L	0.004		<0.003	<0.0008	15
Cadmium	mg/L	0.005	0.01	<0.002	<0.002	15
Calcium	mg/L			15.7	4	3
Chloride	mg/L	250	250	6.75	4	15
Chromium	mg/L	0.1	0.05	0.02	0.0015	15
Color	Color Units	15	15	5	5	15
Conductivity	µmhos/cm	700 (SMCL)		277	118	15
Copper	mg/L	1.3	1	0.003	0.0013	15
Cyanide	mg/L	0.2		<0.01	<0.005	15
Fluoride	mg/L	4 (MCL) / 2 (SMCL)	4	0.255	0.057	15
Hardness	mg/L			212	49.2	15
Iron	mg/L	0.3	0.3	0.2	<0.01	15
Lead	mg/L	0.015	0.05	<0.002	<0.001	15
Magnesium	mg/L			15.1	3.57	3
Manganese	mg/L	0.05	0.05	0.0318	0.002	15
Mercury	mg/L	0.002	0.002	<0.0005	<0.0002	15
Nickel	mg/L	0.1		<0.1	<0.03	15
Nitrate (as N)	mg/L-N	10	10	2.73	0.139	15
Nitrite (as N)	mg/L-N	1		<0.5	<0.2	15
Orthophosphate as P	mg/L			<0.1	<0.1	2
Selenium	mg/L	0.05	0.01	0.0015	0.0015	15
Silica	mg/L			3	3	2
Silver	mg/L	0.1	0.05	<0.1	<0.01	15
Sodium	mg/L	20 (advisory level)**		6.74	2.5	15
Sulfate	mg/L	250 (SMCL)	250	25.6	6.17	15
Total Dissolved Solids	mg/L	500 (SMCL)	500	275	74	14
Thallium	mg/L	0.002		<0.002	<0.002	15
Total Nitrate/Nitrite (as N)	mg/L-N	10		2.73	0.139	14
Turbidity	NTU	1		2.31	<0.1	15
Zinc	mg/L	5	5	0.009	0.0011	15
Total Organic Carbon	mg/L			3.81	0.88	33
Bromate	mg/L	0.01		<0.005	<0.005	12
Bromochloroacetic Acid	µg/L			2.8	<1	11
HAA(5)	µg/L	60	--	21.4	1.14	11
Dibromoacetic Acid**	µg/L	See HAA(5)		2.76	<1	11
Dichloroacetic Acid**	µg/L	See HAA(5)	--	10.3	<1	11
Monobromoacetic Acid**	µg/L	See HAA(5)	--	<1	<1	11
Monochloroacetic Acid**	µg/L	See HAA(5)	--	<2	<2	11
Trichloroacetic Acid**	µg/L	See HAA(5)	--	11.1	1.14	11
Total Trihalomethane (TTHM)	µg/L	80	--	58.2	7.3	24
Bromodichloromethane	µg/L	See TTHM	0.3	11.9	0.69	24
Bromoform	µg/L	See TTHM	5	22	0.3	23
Chloroform	µg/L	70 (MCLG)	7	43.2	1.6	24
Dibromochloromethane	µg/L	60 (MCLG)	0.5	6	<0.5	23

Notes:
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--- indicates not analyzed, measured, or defined
< indicates non-detect below value
C.U. color units
mg/L - milligrams per liter
µg/L - micrograms per liter
µmhos/cm - micromhos per centimeter
MCL - maximum contaminant level
MCLG - maximum contaminant level goal
N - nitrogen
NTU - Nepthelometric turbidity units
SMCL - secondary maximum contaminant level

Table 4: Shallow Groundwater Quality Data from EIM Database for the Pasco Basin

Analyte	Units	Drinking Water MCL/SMCL (WAC 246-290-310)	Groundwater Criteria (WAC 173-200-040)	Maximum	Minimum	Mean	No. of Samples
Alkalinity, Bicarbonate as $CaCO_3$	mg/L			246	160	217	3
Alkalinity, Carbonate as $CaCO_3$	mg/L			1	1	1	2
Arsenic	mg/L	0.01	0.00005	0.007	0.0047	0.006	3
Cadmium	mg/L	0.005	0.01	0.0004	0.0002	0.0003	2
Calcium	mg/L			60.7	48.2	56.3	3
Chloride	mg/L	250	250	48	29	35	3
Chromium	mg/L	0.1	0.05	0.0219	0.005	0.011	3
Copper	mg/L	1.3**	1	0.005	0.005	0.005	2
Iron	mg/L	0.3 (SMCL)	0.3	13.1	0.02	4.38	3
Lead	mg/L	0.015**	0.05	0.072	0.0022	0.017	6
Magnesium	mg/L			29	24.3	25.9	3
Manganese	mg/L	0.015**	0.05	0.71	0.01	0.24	3
Mercury	mg/L	0.002	0.002	0.00016	0.0001	0.0001	3
Nickel	mg/L	0.1		0.026	0.01	0.02	3
Nitrate	mg/L-N	10	10	37.9	0.1	13	290
Nitrate + Nitrite	mg/L-N			30.3	<0.01	10.6	56
Phosphorus	mg/L			1.82	0.026	0.66	3
Potassium	mg/L			5.6	0.65	3.3	16
Selenium	mg/L	0.05	0.01	0.007	0.001	0.004	3
Sodium	mg/L	20 (advisory level)**		60	2.5	29	6
Sulfate	mg/L	250 (SMCL)	250	88	81	85	3
Total Dissolved Solids	mg/L	500 (SMCL)	500	670	220	425	18
Total Organic Carbon	mg/L			30.2	3	11	15
Total Phosphorus	mg/L			0.21	0.004	0.026	15
Zinc	mg/L	5	5	0.052	0.030	0.043	3

Notes:
** Indicates analytes not regulated by the Washington State Board of Health, but acknowledged to have public health significance.
mg/L - milligrams per liter
N - nitrogen
MCL - maximum contaminant level
SMCL - secondary maximum contaminant level
$CaCO_3$ - calcium carbonate
< indicates less than value

Table 5: Summary of Groundwater Quality Data from Pasco's Former Shallow Supply Wells

Analyte	Units	Drinking Water MCL/SMCL (WAC 246-290-310)	Groundwater Criteria (WAC 173-200-040)	All Sources*		
				Maximum	Minimum	No. of Samples
Antimony	mg/L	0.006		<0.005	<0.005	2
Arsenic	mg/L	0.01	0.00005	0.003	0.003	7***
Barium	mg/L	2	1	<0.1	<0.25	6
Beryllium	mg/L	0.004		<0.003	<0.003	2
Cadmium	mg/L	0.005	0.01	<0.002	<0.002	6
Chloride	mg/L	250	250	50	10	6
Chromium	mg/L	0.1	0.05	<0.01	<0.01	6
Color	CU		15	5	<5	6
Conductivity	umhos/cm	700 (SMCL)		760	370	6
Copper	mg/L	1.3**	1	<0.2	<0.2	5
Cyanide	mg/L	0.2		<0.05	<0.05	1
Fluoride	mg/L	4 (MCL) / 2 (SMCL)	4	0.6	<0.2	6
Hardness	mg/L			258	122	6
Iron	mg/L	0.3 (SMCL)	0.3	0.34	<0.1	6
Lead	mg/L	0.015**	0.05	<0.002	<0.01	6
Manganese	mg/L	0.05 (SMCL)	0.05	0.056	<0.01	6
Mercury	mg/L	0.002	0.002	<0.0005	<0.0005	6
Nickel	mg/L	0.1		<0.04	<0.04	2
Nitrate-N	mg/L as N	10	10	17	<0.5	23
Nitrite-N	mg/L as N	1		0.3	0.05	3
Selenium	mg/L	0.05		<0.005	<0.005	6
Silver	mg/L	0.1 (SMCL)	0.05	<0.01	<0.01	6
Sodium	mg/L	20 (advisory level)**		47	28	6
Sulfate	mg/L	250 (SMCL)	250	102	56	2
Thallium	mg/L	0.002		<0.002	<0.002	2
Total Dissolved Solids	mg/L	500 (SMCL)	500	510	<150	2
Turbidity	NTU			0.7	0.1	6
Zinc	mg/L	5	5	<0.2	<0.2	5
Bromodichloromethane	mg/L	See TTHM	0.3	1.4	<0.5	8
Bromoform	mg/L	See TTHM	5	2.9	<0.5	8
Chloroform	mg/L	70 (MCLG)	7	<0.5	<0.5	8
Dibromochloromethane	mg/L	60 (MCLG)	0.5	3.6	<0.5	8

Notes:

* All sources include: Source 02 (Well 1A & 1 B); Source 3 (WP Well 2); Source 04 (WP Well 3); Source 05 (Dradie St. Well); and Source 06 (WP Wellfield)

** - indicates analytes not regulated by the Washington State Board of Health, but acknowledged to have public health significance. Levels shown are "action levels" set by the EPA and referenced in WAC 246-290-310

***Six of seven results for arsenic were <0.01 mg/L (0.003 represents maximum and minimum value measured).

--- indicates not analyzed, measured, or defined
< indicates non-detect below value
CU color units
mg/L - milligrams per liter
µg/L - micrograms per liter
µmhos/cm - micromhos per centimeter
MCL - maximum contaminant level
MCLG - maximum contaminant level goal
N - nitrogen
NTU - Nephelometric turbidity units
SMCL - secondary maximum contaminant level

Table 6: Summary of Groundwater Quality Data from Pasco Bulk Fuel Terminal Wells

Analyte	Units	Drinking Water MCL/SMCL (WAC 246-290-310)	Groundwater Criteria (WAC 173-200-040)	Maximum	Minimum	No. of Samples
Alkalinity	mg/L			190	89	15
Bicarbonate Alkalinity as $CaCO_3$	mg/L			190	89	10
Carbonate Alkalinity as $CaCO_3$	mg/L			<5	<5	10
Arsenic	mg/L	0.01	0.00005	0.005	0.00088	23
Calcium	mg/L			92	31	15
Chloride	mg/L	250	250	45	4.6	15
Chloroform	µg/L	70 (MCLG)	7	5	0.13	23
Fluoride	mg/L	2 (MCL) / 4 (SMCL)	4	0.36	0.086	15
Iron	mg/L	0.3 (SMCL)	0.3	0.18	0.032	15
Lead	mg/L	0.015**	0.05	0.002	0.00016	23
Magnesium	mg/L			25	6.4	15
Nitrate + Nitrite	mg/L-N	10	10	18.2	<0.7	15
Orthophosphate as P	mg/L			0.3	0.22	15
Potassium	mg/L			11	3.4	15
Sodium	mg/L	20 (advisory level)**		54	4.9	15
Sulfate	mg/L	250 (SMCL)	250	82	7.7	15
Total Dissolved Solids	mg/L	500 (SMCL)	500	660	58	15
Field Parameters						
pH	s.u.		6.5-8.5	7.7	7.0	15
Specific Conductance	µS/cm	700 (SMCL)		704	120	15
Dissolved Oxygen	mg/L			9.2	0.1	15

Notes:

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< indicates non-detect below value

mg/L - milligrams per liter

µg/L - micrograms per liter

µS/cm - microSiemens per centimeter

MCL - maximum contaminant level

MCLG - maximum contaminant level goal

N - nitrogen

NTU - Nephelometric turbidity units

SMCL - secondary maximum contaminant level

s.u. - standard units of pH

Table 7: Kennewick Source Water Quality (2002 to 2012) - Ranney Collector Wells

Analyte	Units	Drinking Water MCL/SMCL (WAC 246-290-310)	Groundwater Criteria (WAC 173-200-040)	Ranney Collector Well 4			Ranney Collector Well 5		
				Maximum	Minimum	No. of Samples	Maximum	Minimum	No. of Samples
pH[a]	s.u.	6.5 to 8.5	6.5 to 8.5	7.5	7.8	6	7.5	7.8	6
Alkalinity as $CaCO_3$	mg/L			211	59.3	31	257	1	29
Antimony	mg/L	0.006		<0.006	<0.003	9	<0.006	<0.003	9
Arsenic	mg/L	0.01	0.00005	0.0037	0.0015	9	0.01	<0.002	8
Barium	mg/L	2	1	<0.4	0.01	9	<0.4	<0.01	9
Beryllium	mg/L	0.004		<0.004	<0.0008	9	<0.004	<0.0008	9
Cadmium	mg/L	0.005	0.01	<0.004	<0.002	9	<0.002	<0.002	9
Calcium	mg/L			49	38	3	43	39	3
Chloride	mg/L	250	250	20	7.9	9	<20	10.0	9
Chromium	mg/L	0.1	0.05	0.02	0.001	9	0.0038	0.0038	9
Color	CU	15	15	<15	5	9	<15	5	9
Conductivity	µmhos/cm	700		582	357	9	531	294	9
Copper	mg/L	1.3**	1	0.02	0.0014	9	<0.2	0.0012	9
Cyanide	mg/L	0.2		<0.05	<0.005	9	<0.05	<0.005	9
Fluoride	mg/L	4 (MCL) / 2 (SMCL)	4	<0.5	0.14	9	<0.5	0.13	9
Hardness	mg/L			214	140	9	191	141	9
Iron	mg/L	0.3 (SMCL)	0.3	0.44	<0.01	9	0.38	<0.01	9
Lead	mg/L	0.015**	0.05	<0.002	<0.001	9	<0.002	<0.001	9
Magnesium	mg/L			20	15	3	15	14	3
Manganese	mg/L	0.05 (SMCL)	0.05	0.034	0.002	9	0.0024	0.0022	9
Mercury	mg/L	0.002	0.002	<0.0005	<0.0004	9	0.0005	<0.0004	9
Nickel	mg/L	0.1		<0.1	<0.03	9	<0.1	0.0012	9
Nitrate	mg/L-N	10	10	4.3	1.19	12	3.21	0.149	12
Nitrate + Nitrite	mg/L-N	10		4.3	1.19	11	3.21	0.149	11
Nitrite	mg/L-N	1		<0.5	<0.05	11	<0.5	<0.2	11
Orthophosphate	mg/L			0.2	0.2	1	0.1	0.1	1
Selenium	mg/L	0.05	0.01	<0.01	0.002	9	<0.01	0.0012	9
Silver	mg/L	0.1 (SMCL)	0.05	<0.1	<0.01	9	<0.1	<0.01	9
Sodium	mg/L	20 (advisory level)**		27	14	9	26	16	9
Sulfate	mg/L	250 (SMCL)	250	42	20	9	32	6.7	9
Thallium	mg/L	0.002		<0.002	<0.002	9	<0.002	<0.002	9
Total Dissolved Solids	mg/L	500 (SMCL)	500	422	209	9	394	218	9
Turbidity	NTU	1		0.99	0.06	9	0.54	0.03	9
Zinc	mg/L	5	5	<0.2	<0.01	9	<0.2	0.0017	9

Notes:

a. pH data are for Ranney Collector Wells 4 and 5 combined

** - indicates analytes not regulated by the Washington State Board of Health, but acknowledged to have public health significance. Levels shown are "action levels" set by the EPA and referenced in WAC 246-290-310

< indicates non-detect below value

CU - color units

mg/L - milligrams per liter

µg/L - micrograms per liter

µmhos/cm - micromhos per centimeter

MCL - maximum contaminant level

N - nitrogen

NTU - Nephelometric turbidity units

SMCL - secondary maximum contaminant level

Appendix A