Memorandum

To:	Water Supply Advisory Committee members
From:	Jennifer Peers and Robert Raucher, Stratus Consulting Inc.; Bill Faisst and colleagues, Brown and Caldwell; and Robert Marks and Michael Burke, Pueblo Water Resources, Inc.
Date:	6/1/2015
Subject:	Aquifer Storage and Recovery

1. Introduction

This memorandum provides a summary of information on Aquifer Storage and Recovery (ASR) developed by Pueblo Water Resources, Inc. (with significant input from others, including Bill Faisst and Erin Mackey from Brown and Caldwell).

2. Overview of Technology

ASR is a technology that involves "banking" of water in an aquifer when excess water is available, and subsequent recovery of the water from the aquifer when needed. ASR uses the same wells for injection and recovery. Regulatory requirements in California include using water that meets potable standards for injection, and then treating the extracted water as necessary to potable standards before distribution to customers for drinking water and other purposes.

3. History of Application

ASR projects have been operating worldwide for several decades. ASR use has been increasing in recent years – currently over 25 operating ASR facilities operate in the United States and over 50 other projects are in the development stages. A relevant example of a nearby existing ASR project is the Monterey Peninsula ASR Project. This project involves diversion of excess winter and spring flows from the Carmel River system to the Seaside Groundwater Basin after treatment. The Monterey Peninsula ASR Project uses 4 total wells with a combined average annual yield of approximately 625 million gallons per year (mgy). Table 1 summarizes additional examples of successful and problematic ASR projects; and we discuss a pilot project in the Everglades in Section 4.3.

Table 1. Examples of ASR projects in the United States

Project	Status and year initiated	Capacity in storage	Issues and comments
Northwest Hillsborough County Reclaimed Water ASR Project; Southwest Florida Water Management District; Hillsborough County, FL	Abandoned	N/A	Source: Reclaimed water Treatment type: Tertiary Purpose: Drinking water Reported issues: Water quality concerns
Southern Nevada Groundwater Bank; Southern Nevada Water Authority/Las Vegas Valley Water District; Las Vegas, NV	Active 1987	> ~ 104,000 mg	Source: Surface water Treatment type: Drinking water Reported issues: None
City of Roseville ASR Program; City of Roseville; Roseville, CA	Active 2004	~ 3,270 mgy	Source: Surface water Treatment type: Drinking water Purpose: Drinking water Reported issues: Initial concern about water losses
Groundwater Replenishment System; Orange County Water District/Orange County Sanitation District; Orange County, CA	Active 2008 (initial program in 1950s)	~ 31,000 mgy (future likely ~ 36,500 to ~ 51,000 mgy)	Source: Purified recycled water Current treatment type: Membranes and advanced disinfection (MF/RO/UV + H_2O_2) Purpose: Drinking water through groundwater augmentation Reported issues: Primary purposes are control of seawater intrusion. Currently water districts are ramping up from 85 mgd to 100 mgd and are studying possible increase to 135 to 140 mgd. This project started in the 1950s as an injection barrier project, to control seawater intrusion into the overdrafted local aquifers, with part of the injected water available as drinking water after it mixed with local groundwater.
Monterey Peninsula ASR Project; Monterey Peninsula Water Management District and California American Water; Monterey County, CA	Active 2001	625 mgy	Source: Surface water Treatment type: Drinking water Purpose: Primarily seasonal storage, with secondary provisions for carryover storage for drought reserve Reported issues: Well plugging, DBP formation

Table 1. Examples of ASR projects in the United States (cont.)

Project	Status and year initiated	Capacity in storage	Issues and comments
City of Tracy ASR Project; City of Tracy; Tracy, CA	Active 2011	325 mgy	Source: Surface water Treatment type: Drinking water Purpose: Primarily seasonal storage, with secondary provisions for carryover storage for drought reserve Reported Issues: None
Goleta Water District ASR Program; Goleta Water District; Goleta, CA	Active 1978	150 mgy	Source: Surface water Treatment type: Drinking water Purpose: Seasonal storage, with secondary provisions for restoring aquifer water level/ storage conditions Reported Issues: None
Las Posas Basin ASR Project; Calleguas Municipal Water District and Funding from Metropolitan Water District of Southern California; Ventura County, CA	Initiated in 1993; now marginally operational	100 billion gallons with projected withdrawal rate up to 30 billion gallons per year; less than 10 billion gallons achieved	Source: Surface water Treatment type: Drinking water Purpose: Multi-year storage for emergency and/or drought reserve Reported issues: Geologic faulting created unanticipated impacts during recovery of stored water – substantial quantities of injected water are apparently unrecoverable. Unable to pump for more than a few days. After most of the project was constructed at a total expenditure of $150 million, Metropolitan Water District withdrew from the project and was refunded $54 million because the project failed to deliver water as contracted.

DBP: disinfection byproduct; H_2O_2: hydrogen peroxide; MF: microfiltration; mg: million gallons; mgd: million gallons per day; RO: reverse osmosis; UV: ultraviolet.

4. ASR/Indirect Potable Reuse (IPR) for Santa Cruz

4.1 Requirements

A successful Santa Cruz ASR project would require four basic project components, as described below, with an explanation of how they might be met for a Santa Cruz project.

1. **A supply of water for injection**. For Santa Cruz, ASR might involve the diversion of “excess” winter and spring flows from the San Lorenzo River.

2. **A system for the diversion, treatment, and conveyance of water between the source and storage basin**. Water could be diverted through the Tait Street Diversion facility, treated at the Graham Hill Water Treatment Plant (GHWTP), and conveyed through existing water distribution systems (or through new pipeline interties).

3. **A suitable groundwater basin with available storage space**. Water could be stored in the Soquel-Aptos Groundwater Basin [which underlies the Santa Cruz Water Department (SCWD) service area and the Soquel Creek Water District (SqCWD)] and/or the Santa Margarita Groundwater Basin [which underlies the Scotts Valley Water District (SVWD)].

4. **Wells to inject and recover the stored water.** Existing and new wells in the Purisima Aquifer and/or Scotts Valley Subarea.

4.2 Key Findings

Pueblo Water Resources, Inc. (2015) found that ASR is potentially feasible for Santa Cruz.[1] Pueblo Water Resources, Inc. used an estimate of approximately 558 mgy as potentially available for storage based on some earlier studies that considered existing water rights, some in-stream flow requirements, and existing demands. The potential storage capacity in the Purisima Aquifer and Scotts Valley Subarea is estimated at about 5 billion gallons, more than the 3 billion gallons estimated for meeting the projected needs of Santa Cruz (see April/May Packet Item 8a.1). However, some of that aquifer storage capacity may be required for recharge efforts by Scotts Valley and Soquel Creek.

The primary existing constraint on the potential water available for injection is the excess winter-time capacity of the GHWTP which, based on analyses by Kennedy/Jenks, is currently limited to 2 mgd (above that required to meet Santa Cruz’s winter time daily demand of about 8 mgd). The 10 mgd GHWTP winter capacity limit is based on higher turbidities experienced during the winter months that make the water more challenging to treat as well as capacity constraints resulting from maintenance activities conducted during the non-peak season.

Based on previous studies by Kennedy/Jenks and others, Pueblo Water Resources, Inc. noted that with infrastructure improvements and expansion at GHWTP, the capacity for injection could

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1. These findings also apply to IPR in which the aquifers serve as the required “environmental buffer.” However, because the source water for IPR is highly purified recycled water, under current regulations the same well cannot be used for both injection and recovery, and the injection wells must be located at a set distance from existing or new drinking water supply wells (to guarantee a minimum travel time is met within the groundwater system before the injected water is extracted).

potentially be increased to 8 mgd. It is also possible that water might be diverted from Felton and, if treated to meet potable quality standards, used for injection.

Pueblo Water Resources, Inc. (2015) note that a preliminary planning-level estimate of the capital costs for a 2 mgd recharge project would be on the order of $40 million. Expanding to a scale of 8 mgd adds an additional estimated capital cost of $200 million (for a total capital cost of $240 million). The 8 mgd-scale ASR program would produce an estimated annual project supply of approximately 500 mgy.

Additional significant unknowns that have the potential to present a serious constraint for an ASR program include:

1. Potential for adverse geochemical interactions among source waters, native groundwater, and aquifer mineral matrices. Pueblo Water Resources, Inc. believes it is unlikely that such conditions will present a fatal flaw in the Santa Cruz region (though it has been an issue in some other locations), but recommends that geochemical interaction modeling be performed to confirm.

2. Potential for significant hydraulic losses from the groundwater storage basins. These losses are likely to be smaller for small-scale ASR projects than larger ones. This means that it may be challenging to accomplish large-scale storage and retrieval at the levels needed to meet anticipated needs. This issue may be heightened by the efforts of overlying water districts (SVWD and SqCWD) concurrently seeking to recharge the same aquifers. For the Purisima aquifer under SCWD and SqCWD, some percentage of recharged waters could flow underground into Monterey Bay.

3. Because the potential ASR locations for larger-scale ASR (e.g., 8 mgd injection capacity) are predominantly within the jurisdictional boundaries of other water agencies (SVWD and SqCWD), Santa Cruz will need to forge several institutional agreements to enable storage and retrieval by the city, and to provide a mechanism for equitable cost-sharing (and water-sharing) with the neighboring water districts (which will benefit from the aquifer recharge). It may be possible to implement small-scale ASR (e.g., 2 mgd injection capacity) within SCWD boundaries (i.e., in the Live Oak well field).

4.3 Next Steps/Potential Constraints

The reconnaissance-level evaluation (based primarily on previous research) completed by Pueblo Water Resources, Inc. (2015) suggests that ASR has the potential to be a useful water management tool for Santa Cruz. However, moving from potential to actually implementing ASR requires additional evaluation. ASR is not as simple as storing water in a bathtub – as the examples discussed above indicate, some projects have been successful at meeting anticipated goals, whereas others prove marginal or wholly unsuccessful at different stages in the planning process and even after implementation. For example, after implementing the Las Posas Basin

ASR project (presented in Table 1) and finding that it was not operating as expected, the Calleguas Water District eventually found that “many of the geological assumptions and groundwater modeling criteria related to the [ASR] facility’s operation were in error” (Calleguas, 2011).

To limit risks, a phased implementation process is recommended (Johnson et al., 2014). In the first phase, the involved parties define and agree on the objectives. For example, the Florida Everglades ASR Project (see box at right) focused on storing water for recovery during seasonal or longer-term dry periods, as well as restoring the quality, quantity, timing, and distribution of water flows in the Everglades ecosystem. The site location is selected based on its potential to meet those objectives. As part of phase one, the parties also conduct a detailed evaluation of the environmental, regulatory, and water rights issues associated with the project as well as an economic analysis to compare the cost effectiveness of the proposed project in comparison with other alternatives. As discussed in the Everglades memorandum (Stratus Consulting, 2015), the lack of information on the costs and feasibility of other alternatives poses a potential hurdle for seeking funding for that ASR project. In phase one the parties also identify the water source, the aquifer characteristics, and the aquifer geochemistry (see Stratus Consulting, 2015, for a detailed example of a phase one study). If no fatal flaws are identified, the parties move on to phase two: field testing. In phase two, ASR implementation is tested at increasing scales to evaluate changes over time. If no fatal flaws are identified, the project can be expanded to multiple wells and move toward full implementation.

Florida Everglades ASR Planning Process

The U.S. Army Corps of Engineers and the South Florida Water Management District conducted a $25 million, 11-year study to evaluate the feasibility of implementing a large-scale regional ASR project. This project was envisioned as including over 330 ASR wells to store up to an estimated 1.7 billion gallons per day. The study focused on questions about water quality, hydrogeology, recharge and recovery, costs, and energy use. Although the study identified no fatal flaws, it suggested that ASR is feasible for only a small subset of the original well sites (131 wells) and the potential project has numerous remaining uncertainties.

See also memorandum re: Aquifer Storage and Recovery, Lessons Learned from the Florida Everglades (Stratus Consulting, 2015).

Source: National Research Council of the National Acadamies, 2015.

To summarize, Table 2 presents a summary of next steps and associated potential fatal flaws associated with implementing ASR. Note that these steps are not listed in chronological order, and many steps are iterative.

Table 2. Overview of ASR planning steps and potential fatal flaws

Step	Potential Constraint(s)
Refine estimates of available water under alternative futures ▸ Refine projected models ▸ Check water rights and environmental requirements for limits	Not enough potable quality water available to store
Understand suitability of aquifers for ASR ▸ First via modeling ▸ Next via pilot testing ▸ Third via preliminary implementation	Rock fracturing or other undesirable characteristics or changes in the aquifer Losses to ocean, local surface water bodies, or other aquifers that limit ability to retrieve water
Evaluate geochemistry ▸ First via modeling ▸ Next via pilot testing	Adverse geochemical reactions that could negatively affect water quality
Evaluate feasibility of expanding capacity of system to divert and treat water (currently the limiting factor)	Potential for smaller project Insufficient capacity of diversion and treatment to meet future water needs Competition for storage space by overlying water districts
Obtain permits for underground injection	Failure to obtain a permit (unlikely)
Develop agreements with SqCWD and SVWD and landowners	Failure to reach acceptable agreements for rights of way, well placement and operation, cost-sharing, water sharing, and other critical project aspects

References

Calleguas. 2011. Preliminary Draft: Las Posas Basin-Specific Groundwater Management Plan. September 14. Available: http://www.calleguas.com/images/docs-water-resources-and-quality/drafts-for-discussion/DRAFT-Las-Posas-BSMP_rollout_LPUG_091411.pdf. Accessed May 28, 2015.

Johnson, C., A. Tancreto, J. Miller, T. Linkfield, and C. Brown. 2014. Preliminary Development of an Adaptive Assessment Program for Operating Aquifer Storage and Recovery (ASR) Sites. 10th Internal Hydrogeological Congress of Greece. Available: http://www.researchgate.net/profile/Christopher_Brown17/publication/267097426_PRELIMINARY_DEVELOPMENT_OF_AN_ADAPTIVE_ASSESSMENT_PROGRAM_FOR_OPERATING_AQUIFER_STORAGE_AND_RECOVERY_%28ASR%29_SITES/links/54454bad0cf22b3c14dde2be.pdf. Accessed May 5, 2015.

National Research Council of the National Acadamies. 2015. *Review of the Everglades Aquifer Storage and Recovery Regional Study*. Prepared by the Committee to Review the Florida Aquifer

Storage and Recovery Regional Study Technical Data Report Water Science and Technology Board Division on Earth and Life Studies.

Pueblo Water Resources, Inc. 2015. Technical Memorandum re: City of Santa Cruz WSAC; Reconnaissance-Level Evaluation of ASR and IPR. From Robert C. Marks to Robert S. Raucher. Pueblo Water Resources, Inc. May 15.

Stratus Consulting. 2015. Memorandum re: Aquifer Storage and Recovery, Lessons Learned from the Florida Everglades. To Water Supply Advisory Committee members from Allison Ebbets and Karen Raucher. Stratus Consulting Inc., Boulder, CO. June 1.