Aquifer Storage and Recovery Case Study

Site: St. Michael, Minnesota

Highlights

"The Joint Powers Water Board constructed what is referred to as an Aquifer Storage and Recovery (ASR) system, which is the first such system in the state of Minnesota… This system results in a tremendous cost savings to our customers."

-Joint Powers Water Board Website

- The ASR dual-purpose injection and recovery well located in St. Michael, Wright County, Minnesota serves the residents of St. Michael, Albertville, and Hanover, which are the member-cities of the Joint Powers Water Board.
- Operating at full-scale since 2012, this ASR project was the first of its kind in Minnesota, and remains the only ASR project ever operated at full-scale in the state.

Summary

In the early 2000s, the Joint Powers Water Board (JPWB) of Albertville, Hanover, and St. Michael was faced with increasing water demand from their combined population of 27,000. Their drinking water treatment plant was reaching its maximum capacity in the summer months due to seasonal elevations in water use. In 2006 the JPWB began investigating the feasibility of ASR instead of opting to expand the capacity of the facility. Subsequently, in early 2009 the JPWB constructed an ASR facility in the town of St. Michael. The JPWB operates eight groundwater production wells and this ASR well was the ninth well constructed by the board. Therefore, it is referred to by the JPWB as "Well #9". Two pilot studies, overseen by the Minnesota Department of Health (MDH), were conducted in February and March of 2009 involving the injection and later recovery of 300,000 and 6,000,000 gallons of water respectively. A third pilot study was conducted from June 2010 to February 2011 consisting of the injection of 60 million gallons and subsequent recovery of 50 million gallons of water. Analysis of these three pilot cycles suggested that full scale operation consisting of the injection of 100 million gallons and the subsequent recovery of 90 million gallons of water could be initiated the following year. From 2012 to the present day, eight ASR cycles have been conducted with no perceivable adverse effects on water quality.

The U.S. Environmental Protection Agency (US EPA) permits ASR at Well #9 through the Underground Injection Control Program, treating it as a Class V Well. The current permit is effective from September 24th, 2019 to September 24th, 2029. The permit will also remain in effect upon delegation of primary enforcement responsibility to the state of Minnesota if Minnesota chooses to adopt this permit as a State permit. MDH has also issued a variance to the JPWB to conduct full-scale operations. This variance is required as Minnesota Rules, Chapter 4725 states that a well or boring must not be used for disposal of surface water, groundwater, or any other liquid, gas, or chemical. MDH is notified when the JPWB commences injection and recovery at Well #9, as well as ahead of each sampling event.

The source water for injection at Well #9 consists of treated water from the drinking water treatment plant located in St. Michael, Minnesota. The drinking water treatment plant currently draws from seven of the eight available production wells meaning that groundwater is the sole source for recharge. These seven wells draw from a combination of glacial (unconfined), the Mt. Simon, and the Hinckley aquifers. The treatment plant has a capacity of 10 million gallons per day (MGD) and treats groundwater high in iron and manganese with chemical oxidation and subsequent rapid sand pressure filtration. The source water is treated to potable standards and is distributed directly through the drinking water distribution system or diverted to Well #9 during periods of recharge. The JPWB is permitted to inject up to 100 million gallons and recover 90% of the injection volume from the proceeding injection period. The extra 10% is left in the ground to act as a buffer for future cycles.

Water is injected at Well #9 by a dual-purpose well. The injection is simply done using gravity by pumping through a 3-inch pipe turned down into the well borehole. The rate of injection is approximately 300 gpm. Injection generally begins in November, and runs until the end of June. There is then at least a week-long buffer period before recovery begins. They typically pump 30,000 - 50,000 gallons at the beginning of recovery which they do not send into the distribution system. This is to make sure that they're pumping everything out of the well casing as well as to provide sufficient time for tests results on turbidity, chlorine, and phosphate to come back. Recovery then runs from July to September or October at a constant rate of 1000 gpm (Figure 1).

Table 1-1
Full Scale ASR Cycles

Year	Injection Time Period	Recovery Time Period	Injection Volume (Gallons)	Recovery Volume (Gallons)	Buffer Volume (Gallons)
2012	4/25/2012 - 8/26/2012	8/30/2012 - 10/5/2012	50,427,000	40,590,000	9,837,000
2013	1/23/2013 - 5/31/2013	6/18/2013 - 8/1/2013	57,566,000	47,453,000	10,113,000
2014	12/9/2013 - 7/14/2014	7/22/2014 - 9/27/2014	94,628,000	85,966,000	8,662,000
2015	2/9/2015-7/15/2015	7/22/2015-9/9/2015	69,829,000	61,882,000	7,947,000
2016	11/17/2015-6/28/2016	7/8/2016-9/13/2016	100,791,000	95,326,000	5,465,000
2017	11/1/2016-7/7/2017	7/14/2017-9/18/2017	107,015,000	94,933,000	12,082,000
2018	12/11/2017-7/1/2018	7/14/2018-9/10/2018	93,200,000	81,462,000	11,738,000

Figure 1: ASR cycle detail from 2012-2018 [3]. *Source:* 2018 ASR Summary Report by the JPWB

Water is stored in the Mt. Simon Sandstone aquifer between the depths of 403 and 504 feet below the ground surface. The Mt. Simon aquifer is a poorly to moderately cemented coarse- to fine-grained sandstone. It is confined in the area around the injection site by the overlying Eau Claire Formation. This reduces the chance of contamination of the Mt. Simon Sandstone by surface activities. The Eau Claire Formation is a 75-foot-thick shale layer in the vicinity of Well #9. Three miles north of the ASR site, the Eau Claire Formation is not present, meaning that the Mt. Simon aquifer can exhibit semi-confined characteristics, and may not be separated from the overlying glacial aquifer by the one or more bedrock unit(s) that are typically present.

Stored water is subsequently recovered using the same dual-purpose well with a 150 hp submersible pump which sits at a depth of 260 feet below ground surface and pumps 1000 gpm to a 10-inch column pipe at 400 feet of total dynamic head. The recovered water can spend anywhere from one week to nine months in the aquifer. Because all injected water is drinking water quality and originates from groundwater, pathogen attenuation through travel time is not a concern.

There is a nested set of 3 monitoring wells on the property of the well house for Well #9. One of these monitoring wells is drilled into the Mt. Simon aquifer, while the other two are in shallow and deep glacial sediment respectively. There is also another nested set of 3 monitoring wells about 500 feet away from Well house #9 to the northwest. One of these wells is drilled into the Mt. Simon aquifer, and their permit specifies that at least one background sample must be collected from this test well before injection prior to the beginning of each cycle. This is ultimately to establish a baseline that is used to determine what effect the operations at Well #9 are having on the water quality in the Mt. Simon aquifer. This test well is also sampled at the end of the recovery stage for comparison. There are two other monitoring wells accompanying this one, which are drilled into the deep glacial aquifer and the Franconia-Ironton-Galesville aquifer, respectively (Figure 2).

Table 3-2 Geologic & Hydrogeologic Classification - Well No.9

Formation	Lithology	Classification	Thickness	Depth		Elevation	
				Top	Bottom	Top	Bottom
Drift	Sand & clay units	Aquifer	165	0	165	1011.5	846.5
Franconia	Fine sandstone	Aquifer	103	165	268	846.5	743.5
Ironton and Galesville	Sandstone	Aquifer	57	268	325	743.5	686.5
Eau Claire	Clay	Confining Unit	78	325	403	686.5	608.5
Mt. Simon	Sandstone	Aquifer	102	403	505	361.5	506.5

(1) Classification based on ASR Well #9 (Unique No. 740991).

Figure 2: Geological strata underlying the area around the injection point (2018 ASR Summary Report by the JPWB).

Some mixing may occur between native groundwater and injected water. These interactions may result in the occurrence of deleterious (geo)chemical interactions, which may cause contamination to arise in either the injected water or native groundwater. The native Mt. Simon water has elevated concentrations of iron, manganese, and radionuclides. Iron and manganese are only subject to secondary standards, but recovered water in the 2018 cycle exhibited concentrations of iron and manganese that were far below the secondary drinking water standard as set by the EPA. As for the radionuclides, the combined radium-226/228 concentrations in the recovered water were well below the maximum contaminant limit (MCL) of 5 pCi/L, and adjusted gross alpha activities in the recovered water were well below their MCL of 15 pCi/L. There is not a concern about either chloride or nitrate contamination of the aquifer as the recharged water contains chloride and nitrate concentrations that are well below the federal drinking water standard and only slightly higher than the background concentrations in native Mt. Simon water.

Native Mt. Simon water is in a reduced state and has elevated concentrations of iron, manganese, and radionuclides. Recharge water, on the other hand, has a high oxidation potential, contains supplemental fluoride, chlorine, and polyphosphate, as well as has had iron and manganese removed, all from the drinking water treatment process. The interaction of the injected water with the native Mt. Simon water could cause dissolved ferrous iron (Fe(II)) in the native Mt. Simon water to become oxidized to ferric iron (Fe(III)). This ferric iron will precipitate out of solution as ferric hydroxides or by bonding to another anion such as phosphate or arsenic. In addition, the introduction of oxidized water into reduced native groundwater could cause oxidative dissolution of arsenic-bearing sulfide minerals such as arsenopyrite (FeAsS). Mobilized Fe(II) could be oxidized and hydrolyzed to form ferric iron hydroxides, which could attenuate arsenic mobility, however presence of dissolved organic matter in the injected water could inhibit this process. Arsenic concentrations in the recovery water were slightly higher than background or recharge concentrations, suggesting that some mobilization of arsenic may be occurring. However, the injection water contains negligible total organic carbon, and recovery water contains arsenic concentrations well below the federal drinking water standard of 10 micrograms/liter. In summary, the recovered water consistently meets the requirements set forth in the National Primary Drinking Water Standards, and requires no further treatment upon recovery prior to distribution.

Policy Connections

This is the first ASR project in Minnesota, therefore the State is not the primary enforcement or regulatory body; instead the JPWB uses the EPA as their permitting authority and sends the EPA their water quality sample reports. JPWB is also required to send water quality sample reports to MDH. MDH handles most drinking water well permitting in Minnesota, but for this project bringing in the EPA was seen as prudent due to this being the first project of its kind in Minnesota. If more ASR projects are deemed feasible in Minnesota, it would likely be advisable that the permitting and regulatory authority be shifted to a state agency, such as California has done. The ASR project would still be required to meet federal regulations for drinking water standards and Class V injection well operation, but through an agency such as the MPCA or

MDH, the State would be able to regulate more stringently if they so desired, for the further protection of public health.

Economic Considerations

This ASR project in St. Michael, Minnesota allowed the JPWB to avoid a very expensive upgrade to their drinking water treatment plant which in turn saved their customers a significant amount of money. It seems that this scenario of a municipality growing and exceeding the demand of their water treatment plant is not unique to the cities of the JPWB. ASR seems to be a sustainable application to avoid a capital-intensive expansion, and is well-suited to communities with variable seasonal demand.

Future Projections

So far there have not been any major concerns with the ASR process in St. Michael and the other municipalities that are served by the JPWB. There is some concern about the formation of the disinfection byproducts in the categories of total trihalomethanes (TTHM) and the five most common haloacetic acids (HAA5) during storage of the injected water, but concentrations upon recovery in 2019 were well below their respective MCLs. In addition, measurement of the water levels in the drift and Ironton- Galesville aquifer during 2018 ASR operations suggest that no leakage occurs into or from the Mt. Simon aquifer, reaffirming its good performance as a target aquifer for ASR. It will be interesting to observe whether concentrations of chemicals at the monitoring well 500 feet away (TW-6) from background measurements will increase appreciably in the coming years, as the injected "buffer" water horizontally displaces more native groundwater.

References

1. Site Visit to Joint Powers Water Board Facilities and Conversation with Andy Ahles
2. USEPA Permit for Operation of Well #9 by the JPWB Issued in 2019
3. 2018 ASR Summary Report by the JPWB Available online at *(https://jointpowerswater.com/aquifer-storage-and-recovery-asr/)*
4. Wu, X., Bowers, B., Kim, D., Lee, B., & Jun, Y.-S. (2019). Dissolved Organic Matter Affects Arsenic Mobility and Iron(III) (hydr)oxides Formation: Implications for Managed Aquifer Recharge. Environmental Science & Technology, (Iii). https://doi.org/10.1021/acs.est.9b04873
5. Dickoff, Meghan Elizabeth. "Modeling Flow and Arsenic Contamination During Aquifer Storage and Recovery Pilot Tests in Green Bay, WI." *University of Wisconsin - Madison*, 2010