AQUIFER STORAGE RECOVERY OF TREATED DRINKING WATER pdf

1: Aquifer Storage & Recovery - Joint Water Commission

Aquifer Storage and Recovery, or ASR, is the injection of treated drinking water into an aquifer for later recovery and use. An aquifer is an underground layer of sand, gravel or rock through which water can pass and is stored.

Final Position on ASR Aquifer Storage Recovery ASR is the storage of water in a well during times when water is available, and recovery of the water from the same well during times when it is needed. Large water volumes are stored deep underground, reducing or eliminating the need to construct large and expensive surface reservoirs. In many cases, the storage zones are aquifers that have experienced long term declines in water levels due to heavy pumping to meet increasing urban and agricultural water needs. Groundwater levels can then be restored if adequate water is recharged. The main driving force behind the current rapid implementation of ASR technology around the world is water supply economics. ASR systems can usually meet water management needs at less than half the capital cost of other water supply alternatives. A second important driving force has been the increased recognition of this technology as being good for the environment, aquatic and terrestrial ecosystems. By reducing or eliminating the need for construction of dams, and by providing reliable water supplies through diversions of flood flows instead of low flows, ASR systems are usually considered to be environmentally friendly. Storage zones range in depth from as shallow as about 75 m ft. Groundwater levels in the storage zones range from as much as 10 m 30 ft. Most sites have one or more natural water quality constituents that are unsuitable for direct potable use except following treatment. At one site, not currently in operation, ASR was shown to be feasible and highly cost-effective storing drinking water in an aquifer containing seawater. For most of these sites, it is first necessary to properly develop the storage zone around the well, after which it is possible to recover the same volume as that stored. At a few, more challenging sites water quality, hydraulic or geochemical constraints may limit recovery to somewhat less than the volume stored. Water is stored deep underground in water-bearing geologic formations, or "aquifers" that may be in sand, clayey sand, sandstone, gravel, limestone, dolomite, glacial drift, basalt and other types of geologic settings. Stored water displaces the water naturally present in the aquifer, creating a very large bubble around the well. The bubble is usually confined by overlying and underlying geologic formations that do not produce water, however at several sites the aquifer is unconfined. Storage volumes in these bubbles range from as small as about 50 Ml 13 million gallons in individual ASR wells, to as much as 10, Ml 2. ASR Applications Most ASR systems provide seasonal water storage, storing water during the wet season and recovering it during the following dry season. Many also use ASR for water banking, storing water during wet years and recovering it years laterduring extended droughts. Increasingly many water managers are constructing ASR systems to ensure reliability during emergencies, whether severe floods, earthquakes, contamination incidents, pipeline breaks, or potential damage due to warfare or sabotage. Actually there are at least 22 ASR applications, and others will undoubtedly follow. Most operating ASR sites are storing treated drinking water. When recovered from storage, this water usually requires only disinfection before being sent out to the water distribution system. In recent years other applications of ASR technology have also begun. In the Tampa Bay area of Florida, which is an area with tremendous growth in water demand and limited a vailable supplies, treated wastewater is reclaimed and piped to golf courses, parks, gardens and other areas requiring irrigation to reduce the demand for potable water. When the rains begin and irrigation demand ceases, reclaimed water is stored in ASR wells in deep brackish aquifers, from which it is recovered when needed to meet irrigation demands during dry periods. Several sites are storing untreated groundwater pumped from overlying or underlying aquifers, or from wellfieldslocated at great distances from the ASR site. When needed, this water is recovered from the storage zone and combined with whatever flows are then available from the primary water sources, to help meet peak or emergency water demands. In coastal areas subject to salt water intrusion, or other areas subject to contamination or overpumping, ASR is being used to achieve the full water supply benefits of local aquifers, which are then used for water storage more than for water production. The newest ASR application is for storage of partially-treated surface water. Prior to recharge, water is treated sufficiently to ensure that the aquifer does not plug with particulates or organic material, and to ensure that the aquifer is not contaminated. Generally it is anticipated that the level of treatment will be less than that required for production of drinking water. Stored water is recovered to help meet peak demands for supplemental untreated water, whether for urban needs, ecosystem protection, low streamflow maintenance, agricultural irrigation, industrial water requirements, power plant cooling make-up water, or other needs. ASR is a unique technology, different than for production wells or injection wells. Understanding ASR technology ensures success in almost all situations, whereas failure to understand the unique aspects of this technology can lead to failure, lost investment and disappointment. For anyone who may be interested, I coined the term "aquifer storage recovery" in when the first ASR system at Manatee county, Florida, began successful operation. Development of this system had been underway since

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2: Aquifer Storage Recovery Forum (ASR) Water Resourcing

Artificial recharge (AR) and aquifer aquiferAn aquifer is a geological formation or group of formations or part of a formation that is capable of yielding a significant amount of water to a drinking water well or spring. storage and recovery (ASR) are processes that convey water underground. These.

Among the rolling ranchlands of southern Bexar County, San Antonio Water System operates one of the largest reservoirs of its kind anywhere in the U. Let Sarah take you on the 90 second tour. ASR technology is relatively new. SAWS stores excess Edwards Aquifer drinking water during rainy times in a large-scale underground water storage facility in south Bexar County for use during our dry South Texas summers or prolonged droughts. Environmentally friendly method of storing Edwards Aquifer drinking water in the Carrizo Aquifer. Water stored during the year can be used during dry, hot periods. Maximizes use of pumpage allocations from the Edwards throughout the year. Underground storage means no evaporation. Less vulnerable to contamination than surface storage. Most land directly above the underground reservoir can continue its prior use. ASR technology is a proven method of storing water underground. The concept is simple. Water is pumped from the Edwards Aquifer throughout the year and stored in the Carrizo Aquifer in southern Bexar County. Later, during the hot, dry periods, the drinking water is pumped back into the existing distribution system to help meet demand. If water is not required to be recovered during the current year, it can remain in storage until required in a future year. As of February , more than , acre-feet of water was stored underground. During wet periods, there was no method to store allocations that were not used. There is no carry over or credit for pumping rights not used in a given year. This means "use it or lose it. We strive to be environmentally sensitive leaving our job sites â€” like this one near the ASR project â€” preserved in their natural splendor. The water is withdrawn during dry periods recovery mode to help maintain spring flows in New Braunfels and San Marcos, ensuring the protection of endangered species. This also lessens the effect of drought on the Edwards Aquifer. While not required by state law, a mitigation program has been implemented to assist area well owners that may be impacted by draw down during the recovery phase. Approximately 60 million gallons per day mgd well field capacity. Water stored during the year can be used during dry, hot months. Underground storage means less evaporation.

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3: NCDEQ - Aquifer Storage and Recovery

The State Water Resources Control Board (State Water Board) adopted general waste discharge requirements for aquifer storage and recovery (ASR) projects that recharge groundwater with treated drinking water (General Order) on September 19,

Index to all pages: Aquifer Storage and Recovery Unlike the Edwards Aquifer with its high transmission rates, water in a sand aquifer tends stay in place or move very slowly. Water injected into unconfined sand forms a stationary dome, and if there are confining layers then water spreads out horizontally. Either way, it is possible to store water in sand and come back years later and extract the exact same water. When there is extra Edwards water around, it can be injected into locally occurring sands and extracted during times of shortage. Water from other sources can also be transported and stored in the sands for later use. ASR offers several big advantage. Storing water underground in sand instead of a reservoir means that no water evaporates and it is protected from contamination. In the background is a water management facility with pumps and storage tanks. One of the 29 ASR wellheads is at right, where water is injected and recovered from the underlying sands. The rest of the image is the water storage area, where cows continue to roam and life for the previous landowners goes on mostly unchanged. ASR technology has been in use for many years on the east coast, in Florida, and in California. When source water is available, it is injected into the Carrizo sand aquifer. The same wells are later used to extract the water and distribute it to users. The water retrieved is the exact same water that was injected, and there is no evaporation. The land overlying the wellfield can also continue to be used for other purposes such as agriculture or grazing. The study included looking at availability of water for storage, whether the source waters were compatible with water in the destination aquifers, and the quality and movement of water in each aquifer. The Carrizo-Wilcox is composed mainly of sand interbedded with gravel, silt, clay, and lignite. In some places the water has a high iron content, and hydrogen sulfide and methane also occur. Carrizo water is easily treated by conventional methods, and lots of people currently use it without treatment. In September the San Antonio Water System purchased a acre farm over the Carrizo-Wilcox near the Atascosa-Bexar county line, and added two more large adjacent tracts in February for a total of over 3, acres 6, 7. SAWS developed an aggressive project timetable to have the facility online and producing water in late or early , and plans included leaving the farms in agricultural production. Engineers began preparing plans for a facility capable of producing about 30, acre-feet of water per year, enough for about 60, families. As initially envisioned, the project was mainly a Carrizo production facility, with less emphasis on storage and recovery. Engineers estimated it could produce 30 million gallons per day of local Carrizo water for about 50 years. Regulations require that water has to be treated to drinking water quality before it can be injected into the ground and stored for later use. The Twin Oaks are on the right. During an initial site visit by architects, engineers, and SAWS water treatment experts, the late-morning heat drove the group to seek shade under this tree. One of those in attendance dubbed the facility being envisioned the "Twin Oaks plant", and the name stuck. OK I admit it, it was me. A small portion of the Carrizo-Wilcox aquifer in Bexar county is not within any groundwater district and therefore not regulated. SAWS officials appealed to the Board to delay calling for an election, asking for time to explore a joint management agreement that could provide more protection than regulation. The utility proposed a contract with the District that would provide for mitigation and paying to remedy any problems caused by declining aquifer levels. SAWS would also fund a well monitoring program so that impacts could be measured. Meanwhile, in November of , the utility received a permit from the Texas Natural Resource and Conservation Commission to construct and operate the system On January 16 the election scheduled for February 2 was halted by a federal judge after a community group filed a lawsuit alleging the election would violate the federal Voting Rights Act because there would be only one voting site The election was cancelled and re-scheduled for May 4 Observers noted that even if voters decided to include the area in the Evergreen Underground Water District, it would not necessarily mean the end of the project. Area residents who opposed the project were worried that pumping of large volumes by SAWS would cause their own wells to decline, and they were also worried about possible chemical reactions from the introduction of Edwards water. SAWS officials conceded that drawdown of wells in the vicinity of the project will occur 9 , but they promised that mitigation would include lowering of pumps, deepening of wells or drilling new ones, or the provision of access to potable-water service from a local purveyor. Tests conducted on the feasibility of mixing Carrizo and Edwards water did not reveal any problems or adverse chemical reactions. In April SAWS revised its policy to say it would draw no more than 28, acre-feet over the two years of and 17 , and that total withdrawals for the five year period from to would be no more than 32, acre-feet. After , SAWS agreed to an annual Carrizo withdrawal limit of 6, acre-feet, or 2 acre-feet per acre of land owned, which is the same limitation typically imposed by groundwater conservation districts on all landowners within their jurisdiction. On May 4, south Bexar county voters rejected annexation into the Evergreen Underground Water District by a vote of to Supporters of annexation had argued that inclusion in the District would safeguard their water supply, while opponents countered that inclusion would mean additional regulation and taxes without any benefit. County Commissioner Robert Tejeda said "I think the people that were for the annexation will still be protected. A groundbreaking ceremony was held on July 31, construction began on August 1, and the facility opened in June of By the end of , over 20, acre-feet had been stored for later use. This water came in very handy during the drought later that year, when more than 6, acre-feet of stored water was produced, deferring Edwards pumping and protecting springflows and endangered species. When the rains returned, the facility went back into recharge mode and began storing excess Edwards waters throughout the very rainy year of In , drought returned, and the facility was again a key component in maintaining the J index well and springflows. In the graphic below, drought restrictions were declared when the day average of the J reached , and Twin Oaks went into action, recovering about 20 cubic feet per second of stored Edwards water. Over the next two weeks, the J rose more than 10 feet. It was a hot summer, and when demand began to increase again in mid-Juy, the J began to drop again and SAWS contemplated increasing the Twin Oaks withdrawal rate. That proved to be unnecessary when Hurrican Dolly soaked the region on July The J remained above the trigger level for drought restrictions for the rest of the year and Twin Oaks returned to recharge mode. The several weeks of operation where the facility helped meet demand in a critical period barely put a dent in the total stored volume, which was about 45, acre-feet at that time. While Twin Oaks has already proven its usefulness in deferring Edwards pumping to protect springflows, in the facility became an even greater component of regional plans to protect federally-listed endangered species that depend on the Edwards Aquifer. In , regional stakeholders began working toward a legislative deadline to produce a management plan under a process known as the Edwards Aquifer Recovery Implementation Program EARIP. In the stakeholders reached a consensus about the elements and financing of the plan. One of the main elements is use of Twin Oaks to store excess water for regional partners and hold it for retrieval during droughts. The facility was used again in , when the worst one-year drought on record occurred. Although rainfall in was above average, Aquifer levels did not really recover from the previous year, so water was withdrawn from storage during the summer to help maintain springflows. Recharge resumed in the fall and by the end of , there was almost 95, acre-feet in storage. Although rainfall in was about average in San Antonio, much less fell in Edwards Aquifer recharge areas to the west, so Aquifer levels remained relatively low and the Twin Oaks plant saw its longest production run since the facility opened. By June of , with the drought continuing, production resumed and continued until December, when the facility began storing water leased by the Edwards Aquifer Authority as part of the regional Habitat Conservation Plan for the protection of springflows and endangered species. At the end of there was 73, acre-feet in storage. The drought finally ended in and a lot of unused Edwards water was available to SAWS, so by the end of there was 88, acre-feet in storage. Their pumping has the capability and really quite the certainty of moving that bubble of Edwards water over into the Staggs Ranch area where it can be pumped out by Bexar Met. A year later, in August in , the Bexar Met board voted to downsize their plans to 2. In , SAWS completed an additional seven wells for the exclusive purpose of gaining access to the 6, acre-feet per year of local Carrizo water covered in the agreement with the Evergeen District. The Carrizo wells were placed upgradient from the stored Edwards water in order to reduce the hydrostatic pressure on the Edwards bubble and help to keep it from migrating downgradient and away from the recovery wells. But the latest draft of the plan released in November only suggests that SAWS might consider another project. At this time, no one has any plans for a second ASR facility, mainly because the storage capacity at Twin Oaks has turned out to be much greater than first thought. Initial estimates were that about 22, acre-feet of water could be stored. In a SAWS staffer discovered that consulting engineers had made a rather serious error in their mathematical computations. Their calculated storage volume was incorrect by an order of magnitude. It will produce brackish water from a formation that is deeper than the Carrizo sands, leaving the stored Edwards intact. See the desalination page for a graphic showing the relation of the two formations to the ASR and desalination wells. In , the city of Buda approved a feasibility study to examine the possibility of storing Edwards water in the Trinity Aquifer. Buda water specialist Brian Lillibridge said "Drought resiliency is one of the huge benefits that ASR can add to an existing water supply. The ability to store a large volume of water to offset pumping reductions is invaluable Phase II added an additional 17 wells. In June of , civic leaders and water utility officials gathered to witness the first flow of water down the Twin Oaks cascade aerators. The Treatment Process When Edwards water is recovered, it does not require treatment before distribution. The treatment plant portion of the Twin Oaks facility is designed to make native Carrizo Aquifer water compatible with Edwards Aquifer supplies. Carrizo water is typically high in iron and manganese and has lower hardness and pH than Edwards water. Cascade aerator First, carbon dioxide and lime are added to the raw Carrizo water to increase pH, hardness, and carbonate alkalinity. A step-feed aeration process right removes any excess carbon dioxide, provides oxidation of the iron and hydrogen sulfide, and increases the dissolved oxygen concentration. Solids contactor Polymer is added to the aerated water to assist coagulation of suspended solids into large, settleable particles. Potassium permanganate is then added to the water to oxidize manganese into an insoluble form that can be removed by sedimentation and filtration. Solids contact clarifiers right are designed to remove the settleable particles in the water. Dual media filter Dual media filters right remove any remaining solid particles. Three recycle pumps and a filter backwash waste clarifier accommodate the backwashing of the filters. Materials used to prepare this section: Lose the pound gorilla" Wilson County News, September 26,

4: SAWS: Twin Oaks - Aquifer Storage & Recovery

Aquifer Storage and Recovery Aquifer Storage and Recovery (ASR) is the process of injecting water into the ground for storage and later recovering that water for use. One common use of ASR is for management of peak demand and raw water supply in public drinking water systems.

The primary function of these wells is to supply potable water to a community. The secondary purpose is to allow treated water, meeting local and state regulations for potable water, to be injected back into the aquifer for extraction at a later date. Groundwater is replenished in times of suplus supply to allow for extraction at a later date. Sometimes groundwater quality exceeds allowable limits for saline, arsenic and other components that cause a utility to pull a well out of production, or requires additional treatment above ground to bring the water into compliance for drinking water standards. Injected water can form a higher quality bubble in wells such as these to allow this higher quality water to then be extracted at a later date to eliminate the more expensive surface treatment options later. Typically injection and extraction points differ in these applications so there is retention in the aquifer for a period of time before extraction, so that there is not a direct, immediate link to the extracted water coming immediately from the injection point. Brine Disposal During desalination of water through reverse osmosis, there is a brine waste stream that must be disposed of. A brine disposal well injects this high saline content water into deeper aquifers or other brackish water aquifers that are not use for drinking water supply. Groundwater Remediation Contaminated groundwater is extracted from an identified plume and delivered for a specific treatment process based on the contaminates that need to be removed. Generally the extraction wells are located on the most hydraulically down-gradient boundary of the contaminant plume. The injection wells are typically separate wells, located on the most hydraulically up-gradient boundary of the plume. Most of these wells are equipped with submersible pumps to allow for backlashing of the injection well after a pre-determined length of time to remove any clogging mechanisms that can degrade the injection performance of the wells. Most often, the extracted backflush water is delivered back into the treatment system in a closed loop process. This vadose zone is located above the aquifer and extends all the way up to the surface. The vadose zone affects the natural percolation of water from the land surface to the aquifer during natural recharge through rainfall. The most common use of the vadose zone for artificial recharge is through infiltration basins and typically involves the use of storm-water or treated effluent flows. These basins, however take up a good amount of surface area to achieve the necessary infiltration rates. Vadose Zone recharge wells require much less land surface for installation than infiltration basins. In these applications, the effluent is treated to injection permit requirements and pumped to these recharge wells from an adjacent wastewater treatment plant. The injected treated effluent is then subject to soil aquifer treatment and improved quality as it percolates down to the saturated zone to replenish the groundwater. Although vadose zone wells are typically considerably less expensive to install, they can also experience clogging events that are more difficult to correct. Since vadose zone wells do not have backwash pumps installed, protecting the well against clogging becomes critically important. Injection flow rates are typically less than those of similar size saturated zone injection wells. Although located in the non-saturated zone, the same clogging mechanisms can exist in vadose zone wells as in saturated zone wells. ATES is applied to provide heating and cooling to buildings or other industrial facilities such as power generation or manufacturing plants. The technology was developed in Europe over 25 years ago, with installations exceeding 1, location in Netherlands and Scandinavia, but has only recently started seeing acceptance and use in the US. But with ATES, an aquifer is used to store energy rather than only extracting energy from it. Through the by extraction and injection of groundwater from aquifers, recovery of thermal energy is achieved using groundwater wells. ATES requires a suitable aquifer subsurface geology , into which at least two separate thermal wells are installed, a cold well and a warm well. ATES systems will usually operate on a seasonal basis. The cool groundwater that is extracted in summer, is passed through a heat exchanger for cooling by transferring heat from the building to the groundwater. During the process, the heated groundwater is injected back into the aquifer for storage of heated groundwater. The flow direction is reversed during the winter allowing the heated groundwater to be extracted and used for heating through a heat pump. The customized injection ports on the valve allow for precise control to maintain consistent, repeatable set points for optimal flow rates.

5: Valve Applications | Aquifer Storage and Recovery

Drinking/Potable Water The term Aquifer Storage and Recovery, or ASR, predominantly applies to municipal production wells that are set up for dual purpose, injection and pumping operation. The primary function of these wells is to supply potable water to a community.

Impacts on underground sources of drinking water Aquifer recharge AR and aquifer storage and recovery ASR are manmade processes or natural processes enhanced by humans that convey water underground. The processes replenish ground water stored in aquifers for beneficial purposes. Although AR and ASR are often used interchangeably, they are separate processes with distinct objectives. AR is used solely to replenish water in aquifers. ASR is used to store water, which is later recovered for use. Background Projects for AR and ASR are increasing in number nationwide, especially in areas with potential for water shortages. AR and ASR projects are frequently found in areas of the United States that have high population density, proximity to intensive agriculture, dependence and increasing demand on ground water for drinking water and agriculture, and limited ground or surface water availability. Northeastern and midwestern states with relatively abundant water supplies may not have used AR and ASR widely. However, in many southeast, southwest, and western states, AR and ASR are popular options to provide a reliable water supply. The objective of AR is to replenish water in an aquifer. Injecting water into AR wells can prevent salt water intrusion into freshwater aquifers and control land subsidence. In contrast, ASR wells are used to store water in the ground and recover the stored water for drinking water supplies, irrigation, industrial needs, or ecosystem restoration projects. The stored water may be recovered from the same well used for injection or from nearby injection or recovery wells. Several methods of introducing water into an aquifer exist including: The UIC program does not regulate the recovery of the stored water. Construction of injection wells for AR and ASR varies depending upon site-specific conditions and project objectives. The well is typically authorized by rule if both the owner or operator submits the well information and the well injection does not endanger a USDW. The regulating agency may require an individual permit if additional operating requirements are needed to ensure USDW protection. As of , nine states require water used for AR and ASR injection be potable or treated to national or state standards. Potable water is defined differently in each state. Drinking water from a public water treatment system Untreated ground water and surface water Treated effluent Reclaimed or recycled water Some states allow additional types of water to be injected for AR and ASR. The water sources are subject to state regulations or state water criteria. The following examples illustrate potential concerns. Pathogens may enter aquifers if water is not disinfected prior to injection. Some states allow injection of raw water and treated effluent. In these states, the fate of microbes and viruses in an aquifer is relevant. Disinfection byproducts can form in the aquifer if water is disinfected prior to injection. Soluble organic carbon should be removed from the injectate before disinfection. If not, chlorinated disinfectants may react with the carbon to form contaminating compounds. Contaminants include trihalomethanes and haloacetic acids. Metals and radionuclides may be mobilized from the rock depending on the chemistries of the injected water and the aquifer. Differences in pH and reduction-oxidation potential between the injected water and aquifer may cause arsenic, iron, manganese, or radionuclides that are present in the rock to dissolve into the USDW. Carbonate precipitation in carbonate aquifers can clog wells when the injectate is not sufficiently acidic. Recharge into aquifers of poor quality water has, in some cases, improved ambient water quality. Contact Us to ask a question, provide feedback, or report a problem.

6: Aquifer storage and recovery - Wikipedia

Aquifer storage and recovery (ASR) is a way of storing drinking water underground, then pumping it out when it is needed. During the winter and spring, Beaverton injects treated drinking water from the Joint Water Commission (JWC) Opens a New Window.

AQUIFER STORAGE RECOVERY OF TREATED DRINKING WATER pdf

7: Tualatin Valley Water District : Water Sources

Note: Citations are based on reference standards. However, formatting rules can vary widely between applications and fields of interest or study. The specific requirements or preferences of your reviewing publisher, classroom teacher, institution or organization should be applied.

8: Aquifer Storage and Recovery

The Authority has 21 aquifer storage and recovery (ASR) wells at the Peace River Facility. Fully treated drinking water is injected for storage into these wellfields, and recovered back to the raw water reservoirs when needed to meet Authority Customer demands in dry periods.

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