Flying A Holdings

Aquifer Storage Recovery (ASR)

Water Supply System & Water Quality Testing

Water Policy Interim Committee
August 16, 2007

WATER POLICY INTERIM COMM.
AUGUST 16-17, 2007
EXHIBIT 12

Water Use for Growth Under Montana Water Law

Overview

- Aquifer Storage Recovery (ASR) allows for change in use of existing surface water rights from irrigation to domestic.
- Monitoring and assessment are required to ensure water quality and water quantity balance.

Problem Definition

Water storage must be used to enhance water availability by extending the period of use of existing surface water rights.

ASR – An Effective Solution

- Closed basins with limited water availability can continue to grow by storing water with ASR.
- Growth can be accomplished using existing surface water rights.
- Surface water rights can be changed within existing Montana water law.

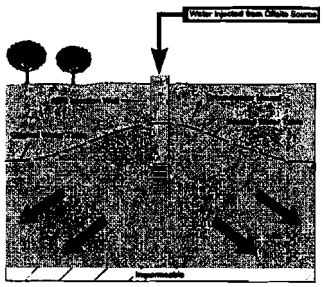
ASR – An Effective Solution

The ASR concept is simple: store water underground when river levels are high, then pump the stored water out when it's needed.

ASR – An Effective Solution

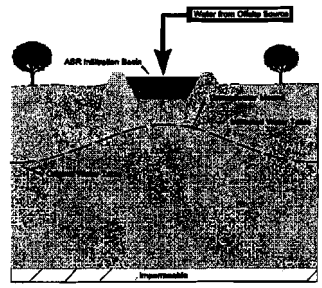
River water can be stored in an aquifer by injecting it in wells or infiltrating it through basins.

Water injected to an aquifer through a well causes the water table to rise.



The result is a groundwater mound.

Water infiltration through an unlined basin also results in a groundwater mound.



When needed, the water in the mound can be pumped out, resulting in no net depression of the water table.

ASR Success Defined As:

- No depletion of base stream flows and protection of senior water rights
- No groundwater contamination – ensures water quality
- No groundwater depletion

Requirements for ASR Success:

- Characterization by qualified professionals
- Long-term monitoring to ensure water quality and a balance in water quantity.

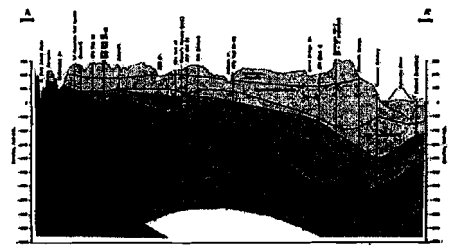
Characterization

Project proponents should study impacts to all surface waters.

The studies must be completed to assure the protection of senior water rights.

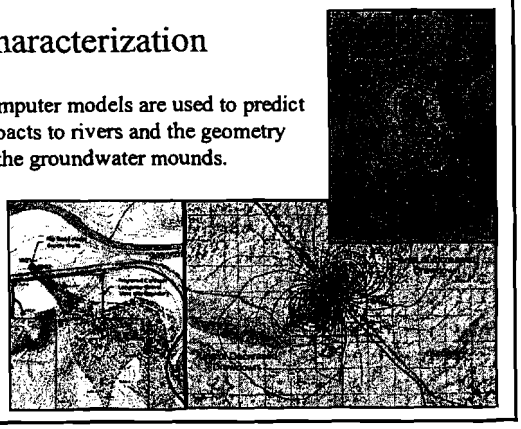
Characterization

Groundwater may occur in highly complex hydrogeologic environments.



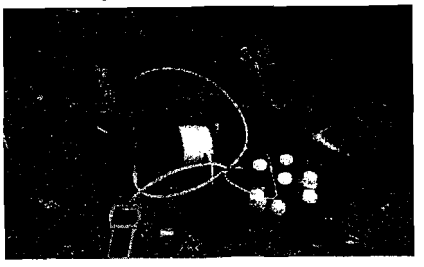
Characterization

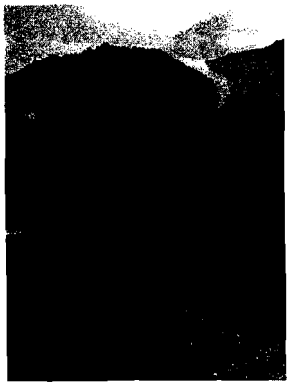
Computer models are used to predict impacts to rivers and the geometry of the groundwater mounds.



Long-Term Monitoring

Water quality monitoring is necessary to avoid potential contamination of groundwater and surface water.





Long-Term Monitoring

Monitoring stage and flow is required to assure water diverted from the river is replaced 100%

Conclusions

- Through a change of use in existing surface water rights, ASR allows economic development to continue under existing Montana water law.
- ASR can mitigate surface water diversions 100% and ensure the protection of senior water right holders.
- Detailed studies and long-term monitoring are required to maintain water quality and a balance in water quantity.

http://www.asrforum.com/fatestudy/

What is 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. ASR provides a cost-effective solution to many of the world's water management needs, storing water during times of flood or when water quality is good, and recovering it later during emergencies or times of water shortage, or when water quality from the source may be poor. 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. When compared to alternatives requiring construction of water treatment plants and surface reservoirs to meet increasing peak demands, potential cost savings have been known to exceed 90 percent. 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 (200 ft) to as deep as 900 m (2,700 ft). Groundwater levels in the storage zones range from as much as 10 m (30 ft) above land surface to more than 300 m (900 ft) below land surface (bls). Natural water quality in the storage zone ranges from fresh, suitable for drinking without treatment, to brackish, including total dissolved solids (TDS) concentrations up to about 5,000 mg/l. Most sites have one or more natural water quality constituents that are unsuitable for direct potable use except following treatment. Such constituents may include iron, manganese, fluoride, hydrogen sulfide, sulfate, chloride, radium (224/226 /228), gross alpha radioactivity, and other elements that are typically displaced by the stored water

as the bubble is formed underground. At two sites, one of which is 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 10,000 Ml (2.5 BG) or more in large ASR wellfields.

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 later during 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. ASR is being increasingly considered for development of strategic water reserves to provide water supply security from terrorism or warfare. In fact, 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 available 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. Reclaimed water ASR is therefore beginning to be a booming application of the ASR technology.

Several sites are storing untreated groundwater pumped from overlying or underlying aquifers, or from well fields located 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. Groundwater ASR is increasingly viewed as a desirable application of ASR technology.

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. 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 makeup 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.

Where is ASR?

Systems are known to be operating in the United States, United Kingdom, Canada, Australia and Israel (click on each country name to view more details). ASR systems are also known to be operating in India and Namibia. ASR development programs are underway in several other countries, including the Netherlands, New Zealand, Thailand and Taiwan. Operating systems are defined as those for which construction is completed, facilities are fully permitted and in operation.

In the United States, the U.S. Geological Survey conducted small tests of well recharge systems beginning in the late 1940s, but none of these test sites were placed into operation. The first ASR well began operation at Wildwood, New Jersey, in 1969, and this system is still in operation, having been expanded to four wells. Most subsequent ASR wells have been constructed since 1983, when the Manatee County, Florida, ASR system began operation. Currently, about 56 ASR sites are in operation around the United States, ranging from a single well to 30 wells, with recovery capacities ranging from 2 Ml/d (0.5 MGD) from single wells to 400 Ml/d (100 MGD) from wellfields. In the early stages of planning and implementation is a very large ASR program for south Florida to restore the Everglades. At such time as this program is completed, it is expected to have over 300 ASR wells storing and recovering water at combined rates of up to 8,000 Ml/d (2 BGD).

If you know of other ASR systems in development or operation, or changes needed to the sites shown above, Contact David Pyne and provide the needed information so that the lists and maps can be updated.

Flying A Holdings
Investigations To Satisfy HB 831, Section 15. Hydrogeologic Assessment
(paraphrased below, see grey highlighting)

Project Background

- Points Of Diversion (POD)
  - Farmers Canal head gate on the West Gallatin River will remain the same.
  - The secondary POD (Farmers Canal Lateral) will move down stream to property.
  - New points of diversion for the Aquifer Storage and Recovery (ASR) wells.
- Place of Use
  - Remain the same for early phases
- Expand as the water distribution system expands
- Artificial recharge through upgradient well – Recovery from subsurface storage using downgradient well
  - Not traditional ASR which recovers from injection well.
  - Better arrangement for protecting streamflow and senior water rights

(1) (a) Hydrogeologic Assessment

- Geology and the Hydrogeologic Environment:
  - Main aquifer is the regional unconfined aquifer:
    - occupies Quaternary alluvium
    - is in direct hydraulic continuity with the W. Gallatin River, local creeks, and some reaches of local irrigation ditches.
  - The underlying confined aquifer, in Tertiary sediments, will not be tapped or recharged
    - is important as a regional water source and hydrogeologic unit
    - hydraulic properties such that it will have little long-term influence on the project.

- Water Quality:
    - Ongoing monitored to decide what treatment is required.
    - Expect to pre-treat with chlorine & maintain a chlorine residual in water injected into the aquifer.

(b) (i) Net Depletion of Surface Water

- Net Depletion Prediction and Timing - estimated by detailed 2-dimensional groundwater flow modeling.

(c) (i) Amount (Historically) Diverted;

- Reviewed Gallatin County Water Resources Survey of 1952, original water right claims, and DNRC General Abstract for each right.
- Currently documenting farm consumption and diversions during 2006-07:
    - Amount diverted for irrigation with hourly stage recording in diversion flume.
    - Amount water not consumed with hourly stage recording of stage in flume at downstream edge of property.
    - Power consumption records for irrigation diversion pump
    - Affidavits from the farm's lessee for 2006 and 2007
    - Aerial photography records from NRCS showing farm historically operated according to current operations.

(ii) Conveyance Losses

- Includes evaporation and percolation to aquifer
- Flow and stage measurements along Farmers Canal and its diversion structures at 4-locations, from Canal / S. Cottonwood confluence to downstream edge of property.
- Flow and stage measurements along Elk Grove Ditch (on-farm conveyance channel) at 3 locations document portion of the diverted water is used for irrigation..
- Flow measurement locations positioned to:
    - Measure losses between diversions.

- Measure losses according to native soil types.
- Measure losses between the upstream and downstream edge of the property.

- Evaporation losses from Farmers Canal and Elk Grove Ditch estimated according to published standards.

(ii) Return Flow (to aquifer) including treated wastewater

- Return flow of applied irrigation water occurs by percolation down beyond the rooting zone - be estimated as difference between published crop requirements and the estimated volume applied.

(2) (a) Hydrogeologic Assessment to predict net depletion of surface water;

- 2 groundwater flow models (using MODFLOW 2000 program by USGS) developed & used to predict net depletion regionally, then locally. from:
  - West Gallatin River,
  - South Cottonwood Creek,
  - Elk Grove Ditch,
  - Lehrkind Ditch,
  - Hyalite creek.
- Regional model checks geographic extent of pre-stream capture
- Local model details pre-stream capture, artificial recharge, and net depletion
- Simulates long-term (multi-year) effects with a 2-week time step, rather than monthly, in order to show greater detail in the timing of pre-stream capture effects and to simulate a shortened irrigation season.
- Simulations indicate no net depletion, because pre-stream capture completely compensated by injecting surface water into the unconfined aquifer upgradient of the withdrawal wells.

(a) Geology and Parameters of the Aquifer System

- Geologic setting interpreted from published reports and on-site test wells
- On-Site Testing:
  - Two 72-hour constant rate tests at different parts of the property to estimate aquifer parameters.
  - Aquifer parameter estimates from neighboring projects, including Utility Solutions and Day Ranch, and published values.
- On-Site Groundwater Monitoring: two test wells and 5 observation wells that fully penetrate the Quaternary Alluvium.
  - 5 shallow observation wells (less than 20 feet deep) near surface water features to investigate the interaction between ground water and surface water.
  - Hourly water level data from representative set of these wells since August of 2005, and from three off-site wells and MSU's monitoring network
- Monitoring locations, including MSU's nearby locations, surveyed and referenced to common grid system, to interpret hydraulic gradient and groundwater flow directions.

(c) Evidence of Water Availability

- A detailed legal availability study was conducted water rights on the West Gallatin, Gallatin, and upper Missouri (to Canyon Ferry Lake) Rivers - concluded that the project's West Gallatin water rights have been available 100% of the time.
- On-site pumping tests, neighboring pumping tests, and the groundwater flow model show that the water will be physically available.

(b) Water Quality Report

- Inventory
- Public Water Supply (PWS-6) Source Water Protection assessment
- Water quality testing of source water (West Gallatin Water via the Farmers Canal) and groundwater ongoing since 2006
- Excellent quality water

(iii) Water Treatment Method for Injection Into Aquifer

- comply with sections 18 and 19 and the water quality laws under Title 75, chapter 5:
  - Pre-treatment likely by chlorination
  - Temporary diversion into a storage pond may be included to manage early season high turbidity water.
  - The storage pond may be constructed to also provide additional water storage for injection after the ditches are dry. te the net depletion

Aquifer Storage and Recovery

Aquifer Storage and Recovery (ASR) involves injecting water into an aquifer through wells or by surface spreading and infiltration and then pumping it out when needed. The aquifer essentially functions as a water bank. Deposits are made in times of surplus, typically during the rainy season, and withdrawals occur when available water falls short of demand.

Aquifer Storage and Recovery Rule

Background

In the 2000 session, the Washington State Legislature passed Engrossed Second Substitute House Bill 2867, which expanded the definition of "reservoir" in RCW 90.03.370 ("Reservoir permits...") to include, "any naturally occurring underground geological formation where water is collected and stored for subsequent use as part of an underground artificial storage and recovery project".

This legislation allows to Ecology to issue reservoir permits to authorize ASR projects. Previously, reservoir permits were only for surface water impoundment projects.

The rule, Chapter 173-157 WAC - Underground Artificial Storage and Recovery, establishes standards for review of ASR proposals and mitigation of any adverse impacts in the following areas:

- Aquifer vulnerability and hydraulic continuity
- Potential impairment of existing water rights
- Geotechnical impacts and aquifer boundaries and characteristics
- Chemical compatibility of surface and ground waters
- Recharge and recovery treatment requirements System operation
- Water rights and ownership of water stored for recovery Environmental impacts

ASR Benefits

Some recognized benefits of Aquifer Storage and Recovery are:

- Substantial amounts of water can be stored deep underground. This may reduce the need to construct large and expensive surface reservoirs.
- ASR systems are considered to be more environmentally friendly than surface reservoirs. They also offer more protection from tampering.
- ASR may restore and expand the function of an aquifer that has experienced long-term declines in water levels due to heavy pumping necessary to meet growing urban and agricultural water needs.

ASR Application Process

In the 2002 legislative session, Engrossed House Bill 2993 simplified the application process for an ASR project by specifying that Ecology "may accept for processing a single application form covering both a proposed reservoir and a proposed secondary permit or permits for use of water from that reservoir."

Following are the basic steps involved in permitting an ASR project:

1. Prior to applying, assess potential issues and impacts to the hydrogeologic system and the environment. If the general setting and conditions cannot be described in sufficient detail for the application, then a more detailed feasibility study must be performed. The feasibility study should reduce uncertainty with respect to project issues and impacts, as well as better quantify the available storage within the aquifer.
2. Schedule a pre-application meeting with Ecology to discuss the project plan and likely requirements for monitoring and mitigation.
3. Submit an application for an ASR project that contains at a minimum:

    a. Water rights for the source waters for the proposed ASR project.
    b. A general description of the physical design of the hydrogeologic system prepared by an engineer or geologist registered in the state of Washington.
    c. A general description of the operational design of the hydrogeologic system prepared by an engineer or geologist registered in the state of Washington.
    d. A project plan.
    e. A data monitoring plan.

An environmental assessment and analysis of any potential adverse conditions or potential impacts to the surrounding environment, limited to storage and subsequent use of stored water, that might result from the project.

Water Quality Issues

Water to be stored in an aquifer as part of an ASR project must meet water quality standards for ground waters of the state of Washington (Ch. 173-200 WAC). Additionally, injection wells for an ASR project must be registered with Ecology in accordance with the provisions of Chapter 90.48 RCW (Water Pollution Control Act) and Chapter 173-218 WAC (Underground Injection Control Program). For more information on the Underground Injection Control program, please see the UIC Web site.

Current Projects in Washington

- City of Yakima (1305 KB PDF)
- Lakehaven Utility District (Federal Way) (357 KB PDF)
- Summary of Projects (Appendix to ASR 2001 Report to the Legislature) (133 KB PDF)

Links

- ASR Concise Explanatory Statement - for rule adoption
- Artificial Storage and Recovery of Ground Water - 2001
- Report to the Legislature Appendix to ASR 2001
- ASR Forum Web site (ASR Systems, Florida) - A lot of great information on ASR - includes an interactive forum.
- ASR Animation (ASR Systems, Florida) - See how ASR works! (Flash Animation)
- Washington Water Storage Task Force - Read about other water storage issues in Washington
- Water Storage Grants