Chapter 12 Aquifer Storage and Recovery

12.1 Introduction

Aquifer storage and recovery (ASR) is a means of enhancing water recharge to underground aquifers through either pumping or gravity feed. Stored water can then be pumped from below ground during dry periods for subsequent reuse and can therefore be a low cost alternative to large surface storages. In the stormwater context, it may also be used as a method to store excess water produced from urbanisation during wet periods (e.g. winter) and which can then harvested during long dry periods to reduce reliance on mains supply for uses such as irrigation.

Both stormwater and treated wastewater are potential sources for an ASR system. This chapter focuses on stormwater ASR systems, although many of the concepts are the same for both systems. Stormwater ASR systems are designed to harvest increased flows attributed to urbanisation. Harvesting urban runoff and diverting it into underground groundwater systems also requires that the quality of the injected water is sufficient not to degrade the existing and potential future beneficial uses of the groundwater supplies. The level of treatment is dependent on the quality of the groundwater. In most instances, the range of management measures described in this manual will provide sufficient treatment prior to injection.

The viability of an ASR scheme is highly dependent on the underlying geology of an area and the presence and nature of the aquifers. There are a range of possible aquifers that can accommodate an ASR scheme including fracture unconfined rock and confined sand and gravel aquifers. Detailed geological investigations are required to establish the feasibility of any ASR scheme. This Chapter provides an overview of the main elements of an ASR system and directs readers to more specific guidance documents.

Broad requirements of ASR systems include:

- protecting or improving groundwater quality where ASR is practiced
- ensure that the quality of recovered water is fit for its intended use
- protecting aquifers and aquitards (fractured rock) from being damaged by depletion or excessive pressure (from over-injection)
- avoiding problems such as clogging or excessive extraction of aquifer sediments
- ensuring reduced volumes of surface water downstream of the harvesting point are acceptable and consistent with a catchment management strategy.

In addition to the physical requirements of an ASR system, they also require permits to divert water, to install treatment measures, to inject into groundwater as well as extraction for the intended use. A thorough investigation of the required permits should be undertaken. The Victorian Smart Water fund plans to develop Best Practice

Guidelines for ASR in Victoria, commencing in 2004. Further information on this project can be found at www.smartwater.com.au.

The following material has been reproduced from the Code of Practice for Aquifer Storage and recovery (SA EPA, 2004) with the permission of the author, to provide an overview of the main components of an ASR system.

12.2Components of an ASR system

An ASR scheme that harvests stormwater typically contains the following structural elements (see Figure 12.1):

- a diversion structure from a stream or drain
- a control unit to stop diversions when flows are outside an acceptable range of flows or quality
- some form of treatment for stormwater prior to injection
- a wetland, detention pond, dam or tank, part or all of which acts as a temporary storage measure (and which may also be used as a buffer storage during recovery and reuse)
- a spill or overflow structure incorporated in wetland or detention storage
- well(s) into which the water is injected (may require extraction equipment for periodic purging)
- an equipped well to recover water from the aquifer (injection and recovery may occur in the same well)
- a treatment system for recovered water (depending on its intended use)
- systems to monitor water levels, and volumes injected and extracted
- systems to monitor the quality of injectant, groundwater and recovered water
- sampling ports on injection and recovery lines
- a control system to shut down recharge in the event of unfavourable conditions.

Figure 12.1 presents a schematic of the major elements of an ASR scheme.

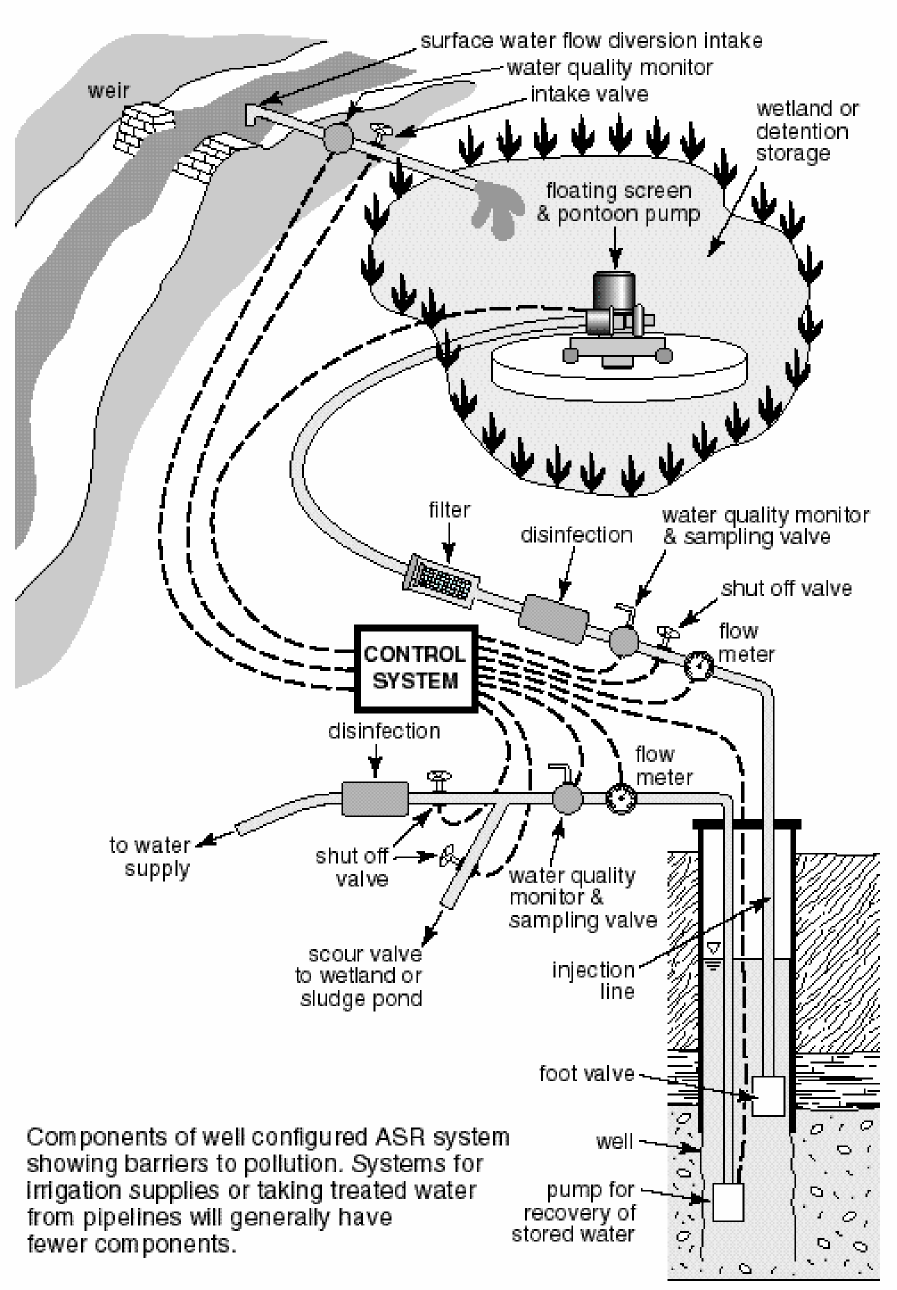

Figure 12.1 Components of a well-configured ASR system (diagram CSIRO Land and Water)

12.3Treatment and pollution control

For stormwater ASR systems, water quality treatment will be required prior to injection into groundwater. The level of treatment depends on the quality of the groundwater (beneficial uses) and local regulation should be checked. Many of the treatments described in earlier chapters will provide sufficient treatment for an ASR system. These systems also have the added benefit of reducing the risk of ‘clogging’ the ASR injection well because of efficient fine sediment removal.

12.3.1 Knowledge of pollutant sources in the catchment upstream

Each ASR scheme must identify potential pollution sources within a catchment and plan risk management strategies, including pollution contingency plans. For urban stormwater harvesting, treatment measures described in this manual are considered a minimum requirement.

Comparisons with native groundwater quality and its environmental values will indicate the requirements for treatment of water detained for injection. An evaluation of the pollutants that may be present within the injectant water needs to be carried out on a catchment basis. Pollutants will vary according to whether the catchment drains urban residential, urban industrial, rural or a combination of any of these catchment types.

The concentrations of pollutants typically have seasonal or within-event patterns, and heavy pollutant loadings can be avoided by being selective in the timing of diversions. Knowledge of the potential pollutant profile helps to define water quality sampling and analysis costs when determining the viability of the ASR project.

12.3.2 Aquifer Selection

The quality of water to be injected must be no worse than the quality of water already in the aquifer, and better if possible. As discussed earlier, the aquifer may already be providing beneficial uses to others and the quality and flow requirements of these users needs to be considered in the aquifer selection. This may exclude using aquifers containing high quality groundwater for ASR schemes.

Factors to consider when choosing a suitable aquifer include:

- environmental values of the aquifer (beneficial uses)
- sufficient permeability of the receiving aquifer
- salinity of aquifer water greater than injection water
- possible damage to confining layers due to pressure increases
- adverse effects of reduced pressure on other groundwater users
- higher recovery efficiencies of porous media aquifers
- impacts on other aquifer users
- aquifer mineral dissolution, if any, and potential for well aquitard collapse.

12.3.3 Pretreatment prior to injection

Many of the treatment measures describe in earlier chapters of the Manual are suitable as pretreatments for ASR schemes. In general, methods that have long detention times are advantageous to reduce pathogenic microorganisms in addition to other pollutants.

An advantage of using treatment with large storages (e.g. wetlands) is the dilution effect should an isolated pollution event occur, thus reducing the risk of aquifer contamination.

12.3.4 Injection Shutdown System

Controls should be incorporated to shut down an injection pump or valve if any of the following exceed the criteria for the environmental values of the aquifer:

- standing water level in the well
- injection pressure
- electrical conductivity (salinity)
- turbidity
- temperature
- pH
- dissolved oxygen concentrations
- volatile organics
- other pollutants likely to be present in injectant water that can be monitored in real time.

12.3.5 Maintenance and Contingency Plans

Protection of the treatment and detention system from contamination is a necessary part of the design in ASR systems. This includes constructing treatment systems away from flood-prone land, taking care with or avoiding the use of herbicides and pesticides within the surrounding catchment, planting non-deciduous vegetation, and preventing mosquitoes and other pests breeding in the storage pond.

Contingency plans should be developed to cater for the possibility of contaminated water being inadvertently injected into the aquifer. These include how to determine the duration of recovery pumping (to extract contaminated water), what sampling intervals are needed and how to manage recovered water.

12.3.6 Recovered Water Post-treatment

For drinking water supplies, recovered water may need to be treated, e.g. using ultraviolet disinfection. For some other forms of supply, such as irrigation via drippers, it may be necessary to insert a cartridge filter.

12.3.7 Discharge of Well Development/Redevelopment Water

In the development of wells for use in an ASR system, the well needs to be “developed”, that is, it needs to be purged for a period of time to remove poor quality water that may have been created as part of the construction of the well. Usually this water is high in fine sediment and as such must not be disposed of to a water body or a watercourse unless it is of suitable quality. It may be used on site, possibly for irrigation, discharged to the sewer (with the approval of the relevant authority), or returned to a treatment system.

12.3.8 Groundwater Attenuation Zones

In some cases the impact of certain ground water pollutants can be diminished over time due to natural processes within the aquifer. Chemical, physical and microbiological processes can occur to ameliorate the harm or potential harm caused by these pollutants.

12.4 Quality of water for injection and recovery

The selection of a storage aquifer and the quality of water that can be injected will be determined by a Water Quality Policy if the relevant agency (e.g. EPA, water authorities).

Designated environmental values of the recovered water, such as raw water for drinking, stock water, irrigation, ecosystem support and groundwater ecology are determined from:

- ambient groundwater quality, with reference to the National Water Quality Management Strategy (Australian Drinking Water Guidelines 1996, NHMRC & ARMCANZ; Australia & New Zealand Guidelines for Fresh and Marine Water Quality 2000, ANZECC & ARMCANZ)
- local historical and continuing uses of those aquifers

Artificial recharge should improve or at least maintain groundwater quality.

12.5 Domestic scale ASR

It is also possible to install an ASR scheme at the domestic scale. Generally they are subject to the same considerations as larger scale design, however being smaller systems they are likely to be shallower and therefore additional considerations are required.

It is recommended that domestic scale ASR in shallow aquifers not be undertaken in locations where water tables are already shallow (less than 5 m) or in areas where:

- saline groundwater ingress to sewers occurs
- water tables could rise to within 5 m of the soil surface as a result of ASR in areas of expansive clay soils
- other structures such as cellars or basements could be adversely impacted by rising water tables

- dryland salinity is an issue in the local catchment

The water recharged must be of the highest possible quality, equivalent to roof runoff after first flush bypass, such as overflow from a rainwater tank, and must be filtered to prevent entry of leaves, pine needles and other gross pollutants into a well.

Runoff from paved areas must not be admitted, unless this has first passed through a treatment measure (as described in previous chapters) to reach the required quality for injection.

An inventory should be made of other potential pollutants in the well's catchment and strategies devised to ensure these are excluded from the well, or are treated and removed before water enters the well.

The aquifer pressure must at all times be below ground level. To achieve this, injection should be by gravity drainage into the well, rather than by using a pressurised injection system, and there should be an overflow facility, e.g. to a garden area where excess water discharges to or to the urban stormwater drainage system.

12.6 Additional information

This chapter provides a brief introduction into ASR and the considerations required to assess feasibility. Considerably more investigations and consultation are required to determine the functional details of a possible ASR system.

There are some Australian guidelines available for ASR systems (particularly from South Australia where there is considerable experience with these systems) as well a Victorian Guideline for ASR being developed as part of the Smart water fund. Some relevant guides and websites for further information are listed below.

- Environment Protection Authority (South Australia), 2004, Code of Practice for Aquifer Storage and Recovery (www.environment.sa.gov.au/epa/pdfs/cop_aquifer.pdf)
- Dillon, PJ & Pavelic, P 1996, 'Guidelines on the quality of stormwater and treated wastewater for injection into aquifers for storage and reuse', *Research Report No 109*, Urban Water Research Association of Australia.

12.7 Web sites

Aquifer Storage Recovery
www.asrforum.com

International Association of Hydrogeologists—Managing Aquifer Recharge (IAH-MAR)
www.iah.org/recharge/

CSIRO water reclamation project in Australia
www.clw.csiro.au/research/catchment/reclamation/

Smart water fund

www.smartwater.com.au

Environment Protection and Heritage Council (EPHC)
www.ephc.gov.au/index.html

Department of Water, Land and Biodiversity Conservation (regarding licensing requirements)
www.dwlbc.sa.gov.au