CONJUNCTIVE WATER MANAGEMENT: WHAT IS IT? WHY CONSIDER IT? WHAT ARE THE CHALLENGES?

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INTRODUCTION

In previous articles of this informational series on groundwater and water wells, incentives for groundwater management, possible approaches to groundwater management, and groundwater level monitoring were discussed in detail. Copies of these articles can be downloaded at http://www.glenncountywater.org (select water education, bottom left menu). This article will build upon these topics by discussing conjunctive management of groundwater and surface water supplies.

USING GROUNDWATER AND SURFACE WATER TOGETHER

Surface water and groundwater typically have a natural hydrologic connection. Conjunctive water use is an approach that recognizes this connection and tries to utilize it to use the overall water supply more efficiently. Some view groundwater use by individuals to supplement limited surface water supplies as conjunctive water use. Others envision conjunctive water use as large, elaborate regional water management programs that store large volumes of surface water below ground during normal and high rainfall years and then pump large volumes of groundwater from storage during drought years. Fundamentally, both examples illustrate conjunctive water use even though they differ in scope, scale, and the degree of coordination required among water users. Both are using surface water and groundwater together to improve the overall availability and reliability of water. Both may share common purposes for using surface water and groundwater in combination such as managing diminishing surface water supplies, convenience, economics, and using water reasonably and beneficially.

DISTINGUISHING CONJUNCTIVE WATER USE FROM CONJUNCTIVE WATER MANAGEMENT

Conjunctive water use primarily changes the timing in the flow of existing water sources by shifting when and where it is stored and does not result in new sources of water. Conjunctive use is often incidental as water users intuitively shift between surface water and groundwater sources to cope with changes and shortages. While conjunctive use may prove successful for an individual or group of water users to manage an immediate situation, it is also possible for conjunctive use to unintentionally harm the groundwater basin and other groundwater users who are not involved in conjunctive use but are reliant on the same groundwater basin.

An alternative to conjunctive water use is conjunctive water management. The difference between the two is more than semantics. Conjunctive water management engages the principles of conjunctive water use, where surface water and groundwater are used in combination to improve water availability and reliability. But, it also includes important components of groundwater management such as monitoring, evaluation of monitoring data to develop local management objectives, and use of monitoring data to establish and enforce local management policies. Scientific studies are needed to support conjunctive water management. They provide important data to understand the geology of aquifer systems, how and where surface water replenishes the groundwater, and flow directions and gradients of groundwater.

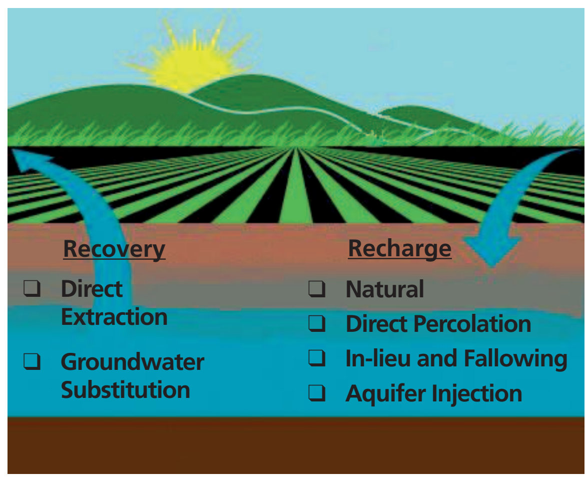

Figure 1. Recovery and recharge, two principle operational components of conjuctive water management.

COMPONENTS OF CONJUNCTIVE WATER MANAGEMENT

Figure 1 illustrates that conjunctive water management has two principal components, irrespective of whether it is practiced by individuals or implemented by a group of individuals as a coordinated program. These components are commonly referred to as:

- ❑ **Recharge**
- ❑ **Recovery**

Recharge Methods

Aquifer recharge is dependent on many factors such as the required recharge rate and recharge volume which is related to water demand, the area available for recharge, the surface and subsurface geologic conditions in the groundwater basin, the availability of surface water for recharge, and the ability to distribute a surface water supply over the groundwater basin to accomplish recharge.

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Natural recharge is the simplest method of replenishing groundwater in almost all basins. Water percolates into the aquifer system from some combination of surface water sources such as streams, rivers, lakes, surface water conveyance facilities, precipitation, and applied irrigation water. Natural recharge may also occur from subsurface inflow from other parts of the groundwater basin. This recharge method requires no infrastructure or surface water supply other than what already exists through natural conditions. Natural recharge is typically the slowest method of replenishing the aquifer system and is relatively unmanaged.

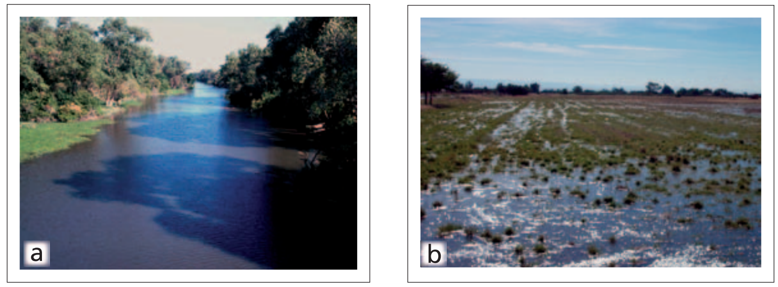


Figure 2. Two examples of natural recharge: a) percolation from natural watercourses; and b) infiltration of applied irrigation water.

Direct percolation recharge is accomplished by ponding water in percolation basins where it infiltrates downward into the aquifer system. Percolation basins constructed on highly permeable geologic materials can result in a rapid, efficient, and economical way to recharge the aquifer. This recharge method usually requires large dedicated areas for recharge and, unfortunately, such surface and subsurface geologic conditions are not common in many areas. Percolation basins require a means of conveying water into the ponds on a regular basis and usually require annual maintenance to sustain soils at high percolation rates, to control aquatic weeds, and to maintain basin structures, all of which represent a continuing expense for conjunctive water management.

Figure 3. Man-made infiltration basins are an example of direct recharge.

In-lieu recharge is a variation of natural recharge. This recharge method is accomplished by providing surface water to areas that customarily use groundwater. The aquifer system partially recharges from the application of surface irrigation water and seepage of surface water from conveyance facilities. At the same time, it reduces demands on the aquifer system from groundwater extraction and leaves more groundwater in aquifer storage for later use. Unlike direct recharge, in-lieu recharge can be implemented under virtually any soil and geologic conditions. However, in-lieu recharge can be very complex and expensive to implement if attempted in an area where surface water is not readily available or if surface water conveyance facilities must be constructed to provide surface water into areas that have historically relied upon groundwater. Regulations on where water can legally be conveyed and concerns about environmental impacts from new surface water facilities can be important factors affecting the feasibility of in-lieu recharge.

Figure 4. Fallowing annual cropland is a form of in-lieu recharge. After harvest of a crop, the crop residue may be incorporated into the soil. This improves infiltration of rainfall and reduces water use by vegetation. The land is left idle for a season to reduce demand on groundwater.

Fallowing is an alternate and less effective form of in-lieu recharge that is accomplished by choosing to not plant an annual crop for a season. This recharge method removes demands on the aquifer system in areas that rely on groundwater to irrigate and leaves this water in the aquifer system for later use. This form of recharge, if practiced over a large enough area, may create third party economic impacts on rural communities and local governments. Somewhat related, Regulated Deficit Irrigation (RDI), is another form of in-lieu recharge that may be practiced in permanent orchard and vine crops and in perennial alfalfa crops to lessen demands on the aquifer system. When RDI is practiced in perennial crops, irrigation is reduced in controlled amounts at specific stages of crop development to benefit the crop or to minimize the risk of crop injury as a result of withholding water. The potential for in-lieu recharge from RDI is site specific because deficit irrigation may already knowingly or unknowingly be in practice. Fallowing and RDI are not as productive at recharge as in-lieu recharge because there is no deep percolation of applied surface irrigation water to the aquifer system.

Aquifer injection is another method of recharge. Water is injected into the aquifer system by operating a well backwards. It has the advantage of working in almost all geologic conditions and in relatively small areas where other recharge techniques are less suitable. Aquifer injection is relatively expensive when used on a large scale that requires a number of injection wells. The usual costs for well construction, pump operation, and mechanical maintenance exist with aquifer injection plus additional costs are necessary to treat the water prior to injection. The water for injection must be free of turbidity, bio-matter, bacteria, and viruses and the water chemistry must be compatible with the water quality in the aquifer system, otherwise, concerns with water quality, clogging of well screens, or clogging of the pore space within the aquifer system surrounding the injection well may arise.

Recovery of Groundwater

The recovery component of conjunctive water management removes water from aquifer storage during times when it is needed. Recovery is primarily accomplished by extracting groundwater from wells. However, in less common situations natural recovery of shallow groundwater occurs when it discharges into surface water sources such as streams, rivers, and lakes. Depending upon the historical source of surface and groundwater used in a basin, groundwater extraction from wells can be categorized into two types:

- ❑ **Direct extraction recovery**
- ❑ **Groundwater substitution recovery**

Direct extraction recovery is when wells are used to extract groundwater in areas that have historically used groundwater and the water is then used directly on the overlying lands. Direct extraction also includes water that is extracted from the aquifer and conveyed to other areas for use.

Groundwater substitution also relies upon wells to remove water from aquifer storage but in this case groundwater is substituted for surface water that would have customarily been used on the overlying lands. This leaves the surface water in the watercourse for utilization elsewhere.

CONJUNCTIVE WATER MANAGEMENT OPERATIONS

Challenges

With conjunctive water management, recharge and recovery are cycled over a period of time to balance them. Conjunctive management can and typically does, cause larger than normal declines in local groundwater levels during more intensive periods of recovery and may pose problems for other groundwater users in the basin who may not be part of the conjunctive management effort. Conversely, during periods of recharge groundwater levels may become higher than normal and lead to problems for other water users. Effective groundwater level monitoring and basin management objectives are the primary tools to assure that operational approaches to conjunctive management are sustainable in the long term and to avoid unwanted problems for other water users.

Figure 5. Proper conjunctive water management operations balance recharge and recovery over an appropriate period of time.

Operational Approaches

The length of the recharge and recovery cycle is a critical operational consideration in conjunctive water management. Cycle length can broadly be categorized into three modes of operation:

- ❑ **Short Cycle**
- ❑ **Annual Cycle**
- ❑ **Long Cycle**

Short cycle conjunctive water management recharges water and then recovers that water over a course of days, weeks, or perhaps months. An example of short cycle conjunctive water management might involve using aquifer injection for recharge and then within days or weeks that same water is recovered by direct extraction. The same well is used for injection and extraction. This short cycle approach has been used to service peak daily and maximum monthly water demands in some areas. This is a relatively expensive operational approach but it is not cost prohibitive in some instances.

Annual cycle operational approaches are similar to those used to manage surface water reservoirs. Water is recharged in months when surface water supplies become available and then recovered during periods of peak demand. Recharge and recovery are typically done within the same year to sustain a balance. The cost and complexity of this type of conjunctive water management approach can vary because a variety of recharge methods may be considered. This type of operational approach may or may not be coupled with re-operation of surface water reservoirs.

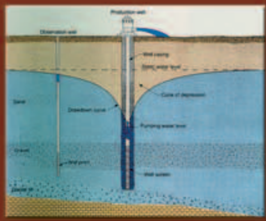
Long cycle conjunctive water management is commonly referred to as “water banking projects”. The aquifer system is typically recharged during years of abundant surface water availability and recovery is done in a year or consecutive years of drought when there is a surface water shortage. Any combination of recharge and recovery methods can be implemented. Usually the operation of surface reservoirs is closely coordinated with long cycle conjunctive water management to transfer water from short-term reservoir storage to long-term groundwater storage.

Several technical factors will determine the appropriate cycle length. The distance between the primary recovery area and any unintentional surface water recharge or discharge areas such as streams, rivers, or lakes is important. Also, the permeability and storage capacity of the aquifer system will influence the operational approach. Long cycle operations are more efficient and productive when the primary recovery area and unintentional recharge or discharge areas are further apart and for aquifer systems with higher permeability. Short cycle and possibly annual cycle operations are more appropriate when areas of recharge and recovery are in proximity and for less permeable aquifer systems.

CONJUNCTIVE WATER MANAGEMENT – A CREATIVE PROCESS

Conjunctive management can involve a variety of water management components and different operational approaches that may cross political or institutional boundaries. There clearly is no “one-size-fits-all” approach to conjunctive water management. It requires balancing recharge with recovery and monitoring to validate the conjunctive water management. Management should occur at local levels where the unique set of conditions is well understood and where interested water users can participate and remain informed. Institutional constraints, environmental concerns, economic considerations, and the political climate are also important when implementing conjunctive water management.

This article is the second in a series of five to be published in 2005-06 discussing topics related to groundwater and water wells in the northern Sacramento Valley.



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