WATER AND GROWTH IN THE WEST[1]

Doing More With Less: Remaining Opportunities for "Tuning the System"

THE POTENTIAL FOR CENTRAL VALLEY SYSTEM-WIDE CONJUNCTIVE WATER MANAGEMENT

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Preface

Like over-subscribed water systems throughout the American West, the Central Valley of California must now expand the benefits of a fixed endowment of water and the infrastructure to store and deliver it. This integrated water system encompasses virtually the entire state, less the drainages east of the Sierra and west of the coastal ranges. Functionally, it runs from Trinity, Shasta and Plumas Counties in the north to the Mexican border in the south. It is dominated by the federal Central Valley Project and the California State Water Project and their 330 odd contracting water districts, which together comprise the largest complex of dams, pumps and canals in the world. Altogether, 85% of the states' publicly and privately developed water supply is devoted to agriculture, but the greatest increases in demand will be urban growth and environmental restoration.

This Central Valley system provides a useful laboratory for solutions to a broad array of water management challenges not because all the answers are to be found here, but because many of the problems of global concern in water resource management have been encountered and addressed here earlier than elsewhere. The Central Valley of California is one of the most transformed landscapes on the planet. And that history is revealed in the manipulation of its waters. The challenge now is to return some semblance of natural processes and functions to a waterscape that has been fundamentally transformed by:

- Construction of 1,000 dams and reservoirs and 1100 mile of canals
- Depletion of 50% of the historic flows into the delta
- "Reclamation" of 97% of its wetlands into farmlands
- Conversion of the vast marshlands of the delta into a complex of islands that have subsided below sea level behind a labyrinth of earthen dikes that are extremely

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vulnerable to seismic failure and which convey water to export pumps capable of diverting 15,000 cubic feet per second

- A massive burden of silt from the Sierra from the hydraulic mining era of 150 years ago which continues to clog waterways and fill the estuary
- Accumulation of some 3 million tons of salts per year in the prime agricultural lands of San Joaquin valley and in the river itself
- Depletion and contamination of groundwater to the point where it is coming unavailable for irrigation and unsuitable for drinking water

The consequences of this transformation include:

- 5 species of salmon and native resident fishes on the brink of extinction
- The water supply for 20 million Californians and a $14 billion per year agricultural industry in imminent peril of catastrophic loss due to the seismic vulnerability of the delta levee system
- Extirpation of the salmon fishery of the San Joaquin River
- Loss of up to 500,000 of agricultural land to salinization
- Periodic flooding of communities along the tributaries to the Sacramento and San Joaquin Rivers

The era of intensive infrastructure development to meet unmet needs is now behind us, as witness the hopefully final defeat of the two decades-long effort to build the Auburn Dam for water supply and flood control. There is no longer the financial, political or environmental capital for such projects. The trend today is to arrest and reverse past damage.

To this end, California has harnessed and now largely exhausted a suite of regulatory and planning devices. The Central Valley is on the verge of completing the most intensive water resource planning effort of all time, the federal-state CALFED Bay Delta Program. Yet, the result of this 5-year, multi-agency, multi-stakeholder effort will be merely roadmap written in broad-brush strokes and the potential for substantial funds to implement it. Today, operation of the Central Valley water supply system is "governed" to a considerable extent by the requisites of the federal and state endangered species protection acts. Any significant alteration of the status quo (for good or for ill) must be preceded by an elaborate environmental review process. All new facilities require an array of permits. The federal and state Clean Water Acts have limited flow depletions as a water quality parameter.

Though indispensable for preventing and mitigating environmental damage from water development, these regulatory tools look backward, not forward to the brave new world of environmental restoration, on which the best hope for a livable planet rests. Repairing damaged natural systems will require a different tool: the acquisition of rights in water, storage system and delivery systems. The interests in water, storage and conveyance facilities, and aquifers needed to provide water for environmental restoration, and for the unmet consumptive users, has not yet been characterized well enough to launch the necessary consensual transactions.

This paper focuses on one such opportunity to "tune the system": integrating groundwater banking into the existing surface water storage and delivery system through a series of voluntary, compensated water transfer arrangements. That technique is called "system-wide conjunctive water management", which is to be distinguished from the more conventional practice of groundwater development for purely local benefits.

System-Wide Conjunctive Water Management Defined

A system-wide approach to conjunctive water management involves integrating groundwater banking into the existing surface water storage and delivery system of the Central Valley to enhance the ability to capture flood flows and carry this water over to years of lower than average run-off to enhance dry year supply reliability. It treats groundwater banking just like the construction of additional surface storage reservoirs: as a means of providing additional supplies for the entire system, not just for the adjacent or overlying water users, water districts or landowners. It involves reoperation of the ten existing terminal reservoirs of the Central Valley tributaries, which are owned and operated by the U.S. Bureau of Reclamation, the California Department of Water Resources, the U.S. Army Corps of Engineers, and several municipal and agricultural water districts. These reservoirs would be reoperated to provide the source water for actively recharging the groundwater banks with water that would otherwise spill for flood control, moving this water to groundwater basins with unutilized storage capacity (because they feature cones of depression from previous or contemporary groundwater exploitation) chosen for their hydrogeological suitability, geographic advantages, and local acceptability. This recharge water would be recovered and reintegrated into the existing (or enhanced) water delivery system to provide supply benefits throughout the system and to all sectors. The main advantage of system-wide conjunctive water management is the large yield potential and system-wide benefits. This approach fulfills the mandate of the Central Valley Project Improvement Act to the Bureau of Reclamation to study reservoir reoperation, conjunctive use and other techniques to supplement and replace the water dedicated to fish and wildlife restoration under that 1992 Act.

This approach is to be distinguished from local groundwater development projects for local benefit, which are commonplace in California and which will proliferate of their own accord. These do not typically involve transfer arrangements with reservoirs owned by other entities. Historically, conjunctive use has meant many things to many stakeholders. To illustrate, we can distinguish seven permutations of conjunctive use arrangements in theory or in practice in California:

1) Local benefit projects utilizing full aquifers where storage space has to be created by extracting groundwater first, and then replenishing through natural recharge. These are sometimes called groundwater substitution projects. Examples include the project that the Glen Colusa Irrigation District is investigating. However, there are no currently operating projects of this type outside of adjudicated basins (such as the Raymond basin, the San Gabriel basin and the Orange County Water District). We

want to understand how such projects could be designed to work in non-adjudicated, non-overdrafted basins.

2) Groundwater export projects utilizing full aquifers where storage space has to be created by extracting groundwater first, and then replenishing through natural recharge and then exporting the water. These are another type of groundwater substitution project. The DWR Drought Water Bank, and the DWR Supplemental Water Purchase Program are the only two examples we are aware of. In the future, such projects can be envisioned at the Stony Creek fan, the Butte Basin and the Conaway Ranch area—all in the Sacramento Valley.

3) Groundwater export projects utilizing full aquifers where storage space has to be created by extracting groundwater first, and then replenishing through artificial recharge with water imported from a reservoir or surface stream in an "area of origin" that is hydrologically disconnected from the recharge zone. Connectivity may be a matter of degree—i.e., it might be a function of the transmissivity of the aquifer and the distance from the source water area to the recharge area. There are no case examples of this type of project. Yet, this is the type of project that could have significant yield benefits in the Stony Creek fan, the Butte Basin and the Conaway Ranch area.

4) Local benefit projects where recharge from native water sources occurs before recovery. The Merced ID/City of Merced project, the Clovis/Fresno project, and the Bakersfield emergency banking project are all of this type.

5) Local benefit projects where recharge from imported water sources occurs before recovery. Projects of this type include the Kern Water Bank, SNAGMA, Arvin Edison Water Storage District, Semi-tropic's groundwater banking program, Berenda-Mesa's groundwater banking program, and the project of the Mojave Water Agency.

6) Groundwater export projects where recharge from imported water sources occurs before recovery. Projects of this type include Madera Ranch, San Joaquin County—EBMUD, Arvin Edison-MWD, and the Semi-tropic project.

7) Local benefit projects where recharge is accomplished with recyled or reclaimed water before recovery. The water quality issues predominate in these projects.

System-wide conjunctive use is described by type # 6 above throughout the Central Valley, and possibly by type # 3 in the Sacramento Valley with more politically difficult institutional arrangements. Getting the institutional structures right is the *sine qua non* for successful projects of both types. What the system-wide and local benefit approaches share is the reality that conjunctive water management will require the cooperation of local groundwater users and landowners at the banking sites. "Local control" of groundwater banking is axiomatic under the existing legal framework governing groundwater rights, which treats groundwater as a common property resource, subject to correlative rights and obligations. Any perceived tension between these approaches is likely to be resolved by close examination of the specific institutional arrangements requisite to a successful program. Thus, institutional design is an exercise in defining **who** controls **what** and **how**, that is, by detailing the mechanisms for local control. As with all common property resources, the challenge is to share benefits without permitting tactical vetoes. We believe this should be markedly easier where the local groundwater users do not have pre-existing rights to the recovered groundwater because it has been imported into the basin—the system-wide conjunctive management approach—compared to the case where local groundwater is developed for export—the local benefit approach. These issues are revisited in the section of this paper on legal and institutional constraints.

The Potential Benefits of Conjunctive Water Management

System-wide conjunctive water management could have profound implications for expanding the beneficial use of water and its infrastructure in two ways. First, coupling water transfers to storage is a way to harness market incentives to improve the efficiency of water use in agriculture. We define efficiency as the ratio of agricultural profit (not necessarily product) to the water applied (not necessarily consumed). Today, California farmers are about as efficient as is economically justified, given the artificially low prices they pay for water. To improve efficiencies, the economics of water would have to be changed to make it worthwhile (and economically rational) for farmers (and their districts) to invest more in efficiency measures and technologies. In theory, this could be done by raising the cost of water, but that would not be acceptable to the farmers. The alternative is to raise the value of water in agriculture without raising the cost. That is what water markets can do. If the market value of water is higher than its irrigation value (which is the case where water is applied inefficiently or on low-value crops), it is worthwhile for the farmer (or district) to invest more in water conservation or crop shifting. This incentive is greatly increased if the conserved water can be stored for use during years of relative scarcity.

Today, there is not much incentive to make investments that could save water but that would pay off only over several years, because the market for conserved water is intermittent. In years when there is a lot of water available, the incentives to conserve are low because the market value of the water is relatively low. Conversely, there is not much potential for water savings in dry years because it is needed for present consumption. If water that is conserved in all years can be stored for resale during drier years, when prices are high, multi-year investments become worthwhile and the value of conserved water is maximized. System-wide conjunctive water management is a way to provide such inter-annual storage.

Second, system-wide conjunctive water management is a way to actually increase the yield of the developed water system without constructing additional surface storage reservoirs. There will be no peace in the California water wars, or prospect of restoring damaged aquatic ecosystems, unless additional water can be generated in dry years to meet unmet needs in all sectors—without displacing already-vested water uses. As this paper will show, the dry-year yield potential from system-wide conjunctive water management is surprisingly large—theoretically as large as the capacity of the California State Water Project. Conjunctive use is also likely to be faster, less expensive and more environmentally acceptable than surface storage alternatives. This is important for all water using sectors, including the environment. Indeed, the environmental benefits could be three-fold:

- Conjunctive use could provide the water that will be needed for environmental restoration purposes, both instream and out of stream. Some 300-500 thousand acre-feet per year are being discussed within the CALFED program.
- Conjunctive use provides a benign alternative to meet the future projected needs of the urban and agricultural sectors
- Reoperation of reservoirs for conjunctive use could be accomplished in a manner that would restore downstream fluvial processes and provide the associated habitat benefits.

Primer on System-Wide Conjunctive Water Management

Conceptual discourse on conjunctive use and groundwater banking has been taking place in California for many years. Groundwater banking has become part of the standard litany of water management strategies for California, and is often held up as a win-win alternative for the state's disparate stakeholders. When an attempt is made, however, to translate the conceptual model into actual yield enhancing projects, promise and expectation often give way to concern and uncertainty. Focusing attention on the conjunctive management of specific rivers and groundwater basins consistently raises "red flags" for those whose livelihoods depend on these resources. The research we have conducted to date responds to many of the regularly waved red flags. NHI's **Feasibility Study of a Maximal Program of Groundwater Banking in California** (assessable from the NHI web page at www.n-h-i.org reports that:

- Re-operation of the terminal reservoirs on each of the major rivers between the Lake Shasta and Millerton Lake as part of a system-wide groundwater banking program, in coordination with reservoirs located upstream, could generate approximately 1 million acre-feet of average annual yield and increase the overall performance of the surface water infrastructure.
- An inventory of potential aquifer storage sites discovered over 10 million acre-feet of available storage at various places around the Central Valley, much of which could be accessed by re-operating and/or modifying conveyance infrastructure.
- By increasing yield on the San Joaquin River, aquifer storage at Gravelly Ford could allow for downstream releases of approximately 144 thousand acre feet to restore the anadromous fishery while largely preserving the important agricultural economy in the southern San Joaquin Valley, which currently diverts nearly the entire flow of the river.

- The proximity of a significant aquifer storage resource to the east of the Delta in San Joaquin County could increase the reliability of water supply south of the Delta, relieve chronic groundwater overdraft conditions and allow for enhanced Delta outflow when integrated with enhanced Delta conveyance infrastructure.
- At a cost which is generally less than $300 per acre-foot, groundwater banking projects similar to the examples cited above are much more affordable that surface water development projects, which can cost up to $3000 per acre-foot.
- Under existing law, there is no proscription against importing surface water for storage in a groundwater basin and eventual recovery for use off site.

We recognize that the task of fulfilling the promise of actual groundwater banking opportunities will only come from site-specific analysis that sufficiently resolves local details to allay the concerns of local actors and regional water managers alike. Our next phase of analysis will involve extending preliminary operational analysis to the most promising groundwater banking sites.

The Problem: Imbalance Between Existing Stocks and Anticipated Flows

In the parlance of systems analysis, system reliability is a function of stock and flow characteristics. Systems where the desired flows are a large fraction of available stocks are vulnerable to disruption. A system of reservoirs which just covers demand under average hydrologic conditions will have difficulty providing adequate water supplies during times of drought. Municipal supply organizations have long understood the importance of system reliability. A survey conducted for the California Urban Water Agencies estimated the statewide value of water supply reliability to urban consumers at more than one billion dollars annually (Barakat & Chamberlin 1994).

Historically, the response to increased "flows" (i.e. demand) in the California water system has been to increase stocks by constructing massive surface reservoirs. This approach, however, has fallen out of favor due to its high economic and environmental costs. Relative to the construction of surface water reservoirs, enlarging the stock via groundwater banking, the storage of excess wet year supplies in subsurface aquifers is a less controversial, lower cost, more environmental benign approach. Groundwater banking has numerous economic and environmental advantages compared to surface water storage: it reduces losses from evaporation; it allows long-term storage; it allows for greater regulation of natural inflows, without the construction of a huge new network of reservoirs; and it is generally less expensive than surface storage. As with all water storage systems, however, the main purpose of groundwater banking is to convert a fluctuating input of water from precipitation and snowmelt, into a steady supply stream which responds to a water demand pattern which differs from the input stream. Also in keeping with other forms of storage, groundwater banking occurs when water is plentiful, and produces stocks to tap when water is scarce.

Based on this operational definition, the natural hydrologic system is the preeminent practitioner of groundwater banking. During wet years, excess precipitation and elevated stream flows result in high levels of infiltration. As a result, aquifer recharge exceeds pumping, which has been suppressed by well-endowed surface water supplies, and there is a net inflow into the aquifer. Groundwater has been banked. When dry hydrologic conditions return, suppressing both infiltration and surface water supplies, pumping by those overlying the aquifer will exceed recharge and the bank will be tapped. Natural groundwater banking, which cycles volumes of water which are orders of magnitude larger than those contemplated here, is not the focus of the system-wide program of groundwater banking. Nor will the program rely on shaving the peaks off of the relatively infrequent and limited duration large flow events which already occur below California's surface water reservoirs during wet years.

In order to increase the available stock, the system-wide program of groundwater banking will start by intentionally transferring water from surface water storage to a groundwater bank during the late spring and summer. As this is the period of time when storage in California's reservoirs is generally highest, the transfers can be aggressive and sustained. They can be accomplished either directly, through percolation at spreading basins, or through "in lieu" surface water deliveries in areas which rely heavily on groundwater pumping. The result of several months of intentional transfer will be an increment of additional storage in an aquifer and the equal increment of potential storage space in the surface water reservoir. Final augmentation of the available stock in the system will be accomplished during subsequent winter storms and early spring runoff when the extra available reservoir space enable flood control operations that capture an increased volume of the reservoir inflow. Should a reservoir emerge from the wet season full, then the increment of water in the groundwater bank represents yield that would have otherwise gone unrealized. With these additional supplies in place, when the next dry year inevitably comes, economic demand for water may be satisfied from the groundwater bank, leaving the available surface water to be used to respond to the critical environmental need for enhanced stream flow.

Overcoming the Barriers

System-wide conjunctive water management requires reoperating the 10 terminal reservoirs in the Central Valley system to generate the "source water" that would be banked in the 10-12 most promising groundwater banking sites arrayed up and down the Valley. This includes reservoirs and banking sites in both the Sacramento and San Joaquin Valleys. This type of groundwater banking has not developed in the Central Valley. That is in part because of the perception by local groundwater users that groundwater should be developed to serve purely local water needs. And, the dependence of anadromous fish in the Central Valley on cold-water releases from the major foothill reservoirs has forestalled consideration of aggressive reservoir re-operation.

In the San Joaquin Valley, the potential for groundwater banking is massive. Past dependence on groundwater has produced areas where the water table is depressed, creating opportunities for storage. Moreover, heavy groundwater development has catalyzed a number of detailed hydrogeologic studies and information on aquifer characteristics is widely available. In the Sacramento Valley there are fewer areas of long-term overdraft, as there exists a high degree of interaction between rivers and groundwater. Thus, groundwater elevations tend to recover relatively quickly during wet period following dry years when heavy pumping occurs. While this natural interaction between river and groundwater is useful for local water users, it complicates efforts to use Sacramento Valley aquifers as a storage medium for non-local beneficiaries. While areas do exist within the Sacramento Valley where groundwater levels have been permanently depressed by pumping, there is less local incentive to pursue intentional groundwater storage north of the Delta. As a result, the hydrogeology of the Sacramento basin remains poorly documented and accounting for the water stored can be a significant problem. In both the Sacramento and San Joaquin Valleys, however, detailed inventories of potential groundwater banking sites need to be elaborated and presented. Of particular interest should be the degree to which integration of a particular groundwater basin into the Central Valley water system facilitates the efforts of overlying water managers as compared with strictly local water management initiatives.

Even with this inventory in hand, however, developing an operational strategy to capitalized on specific groundwater banking opportunities will remain problematic. Surplus surface water for groundwater banking is most commonly available in the Sacramento Valley. The Mokelumne River, and the San Joaquin tributaries, while endowed with excess surface waters, have less substantial hydrologic potential. Hydrogeologically, however, many of the most promising storage sites lie in the San Joaquin Valley. Moving excess Sacramento Valley surface water to these sites may involve transit through the Delta, from which exports are increasingly constrained.

In addition to operational considerations, economic obstacles to the realization of a maximal program of groundwater banking must be identified and overcome. As both the physical and institutional arrangements for aquifer storage differ from surface storage, so to must the financial considerations. In terms of planning and construction costs, aquifer storage and recovery is significantly less expensive than dam construction. However, some of the ancillary benefits of surface storage, such as hydroelectric power generation, flood control and recreation, which have been used to offset these costs, may compete with reoperation of the reservoir for groundwater banking.

Surface Water Supply

On average, California is not short of water. Annual runoff averages roughly 71 million-acre feet (MAF), or 78 MAF when supplies originating out of state are included. In 1990, a relatively dry year, uncontrolled flows accounted for 24 MAF, irrigated agriculture for 24 MAF, urban use for 6 MAF, and "other uses" for 1 MAF. Roughly 30 MAF of the 1990 total was accounted for as "other outflow" -- e.g. not allocated to any specific use (DWR 1994).[3] These long-term averages, however, mask the variability that characterizes California hydrology. Consider that:

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[3] It is important to recognize that this "other outflow" probably generates environmental benefits and should not be viewed entirely as surplus. The outflow is simply excess to minimum environmental flow standards that have been established for various streams and wetlands

- Extended droughts are common. Over the six year periods from 1929-34 and 1987-92, cumulative runoff in the Sacramento and San Joaquin Rivers was slightly above half the long-term average. Runoff in 1976-77 was only 33% of the long-term average for the two rivers.
- Much year-to-year variability exists. In the period between 1906 and 1993, 27 years were dry to critical while 34 were wet.
- Runoff in California is highly seasonal. Much of the flow occurs during a few months when snowmelt and rainfall coincide.
- Surface water supplies are spatially non-uniform. Roughly 75% of the natural runoff is north of Sacramento while 75% of the demand is south (DWR 1994).

The existing storage and conveyance infrastructure is designed to "even out" this variability in surface water supply.

Groundwater Supplies

Under current working assumptions one method of covering the anticipated shortfall will be an increased reliance on groundwater. Already, during dry years such as 1990, increased pumping results in a statewide groundwater overdraft of roughly 1.3 MAF. But future increases in demand cannot be met through continued high levels of groundwater overdraft. Under historic conditions, the Central Valley rivers recharged the aquifers below the valley floor during periods of high flow and the groundwater sustained the low flow stage in rivers. By comparison, recharge via direct precipitation on the valley floor was a relatively minor component of the historic water balance (± 1.5 MAF/year according to Williamson et al 1989). The regulation of high flows in the rivers of the Central Valley, combined with extensive groundwater pumping, substantially altered this annual cycle. In many parts of the Central Valley, groundwater no longer contributes to low stage stream flow, which is now comprised primarily of agricultural return flows. Across the region, current groundwater flow patterns are linked to the confounding alterations of the natural system that have accompanied decades of groundwater extraction and the hydraulic manipulation of surface water. In the western San Joaquin Valley, for example, the arrival of imported surface water from the Sacramento Valley raised the water table by as much as 170 feet. Further south in the Tulare Basin, where groundwater remains the primary source of irrigation water, the free surface has fallen as much as 400 feet.

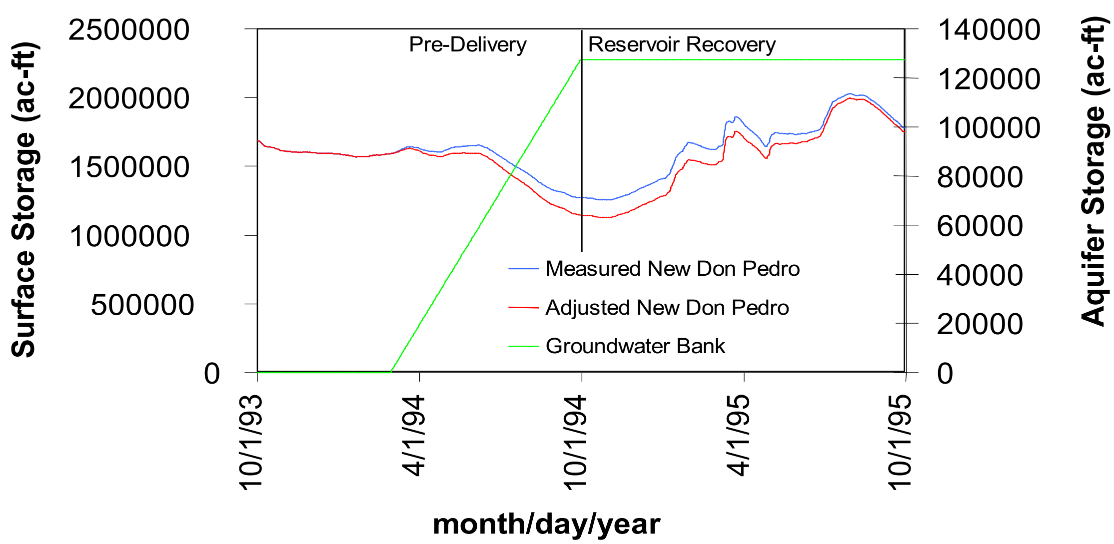
This is not a system that can sustain the practice of satisfying increases in demand in the coming decades with a steadily increasing reliance on groundwater pumping. Such a strategy would likely return the system to the period of rapidly falling water tables, increased pumping cost, and land subsidence which plagued the first epoch of groundwater dis-equilibrium. There must be some consideration given to the need to increase storage in order to avoid a potentially destabilizing increase in groundwater pumping.

Storage Opportunities

The ability to store additional water and further "even out" natural variability would ease the predicted water availability shortfalls. Although California has a network of some 1400 major reservoirs, total storage in these reservoirs is approximately 42 MAF – only 60% of the average annual runoff (DWR 1994). The creation of sufficient additional surface storage to substantially even out variability is unrealistic. For example, proposals to build Auburn dam, a facility capable of storing 2.3 MAF, have been so controversial that funding has been blocked since Congress initially authorized the project in 1965. Even if Auburn dam were constructed, it would only increase the total system storage from 60 to 62.5% of annual runoff. Construction of all the new proposed surface storage facilities would increase the total capture of the system to 71% of annual runoff – and at an unacceptably high financial and environmental cost.

Hydrologic Potential of System-Wide Conjunctive Water Management

A system-wide program of groundwater banking seeks to divert surplus surface water to storage in suitable groundwater basins. This diversion would permit immediate storage and eventual recovery of water that would otherwise flow out to sea. This could be done by installing massive pumps and diversion canals to capture water during peak winter and spring flow events. The important thing to note about this approach is that it involves manipulation of the hydrograph in the river while the storage in the reservoir upstream remains unaltered.



An alternate, and potentially complementary, strategy for groundwater banking involves the pre-delivery of water from surface water reservoirs to groundwater banking sites. Under this arrangement, water would be released from storage in California's major foothill reservoirs for transfer to aquifer storage during the summer and fall. This transfer could be accomplished directly through percolation at spreading basins or indirectly through *in lieu* deliveries to farms which would otherwise rely on groundwater for irrigation. Instead of directly altering downstream hydrographs during peak flow events, pre-delivery results in a decline in upstream reservoir storage levels. The increase in aquifer storage creates additional storage capacity in the reservoir. The magnitude of the "new water" is measured by the quantity of water flood flows that can be retained rather than released for flood control purposes during the next water year. In effect, the excess available flood control capacity in the reservoir allows for the eventual recovery of surface storage back to the historic reservoir levels. Once storage in the reservoir recovers back to historic levels, the water stored in the groundwater bank becomes yield that would have otherwise been released during the peak flow events.

The re-operation of surface reservoirs is a more intentional and approach to groundwater banking than the periodic capture of peak flows as it does not require the installation of large diversion capacity which will only be used during short time windows. By "evening-out" the transfer of surface water to aquifer storage, pre-delivery allows for continual benefit to be derived from the physical and operational changes associated with groundwater banking.

Conjunctive Use Potential

To estimate the hydrologic potential of the pre-delivery of surface water to groundwater banking in the Central Valley watershed, NHI developed the Conjunctive Use Potential model. It is based on liberal assumptions about: (1) the existence of infrastructure; (2) a limited scale investment in the direct diversion of high flows to aquifer storage; and (3) the availability of suitable groundwater banking sites. On the other hand, CUP adopts a very conservative posture towards the need to preserve adequate cold water in the major foothill reservoirs. This cold-water resource is needed to maintain suitable temperatures in the spawning and rearing reaches downstream of the reservoirs in Table 1. The conservative posture should help allay concerns over impacts to hydropower production targets or lake recreation opportunities, although these uses of surface reservoirs are not specifically considered in the CUP analysis. The most important lesson to derive from Table 1 is that in six of the ten important rivers in the Central Valley, annual flows exceed the available storage and the improved flood control flexibility made possible through pre-delivery can help capture "new" water without imperiling anadromous fish below the dam.

CUP Model Methodology

1. Compare ***historic daily reservoir releases*** to minimum ***required economic and environmental flows***. Historic releases in excess of required flows are considered "surplus", while smaller historic releases create a "deficit". Accumulate daily differences over the entire year to determine whether the year is wet or dry.
2. When environmental requirements create a deficit, adjust September 30 reservoir storage levels by this increment. Should the adjusted storage falls below a ***minimum carryover storage target*** set to preserve adequate cold water for anadromous fish below the dam, a shortage equal to the amount needed to meet the minimum carryover is applied to economic uses.
3. When a net surplus exists, the adjusted storage from Step 2 is compared to the ***target carryover storage***. If adjusted storage exceeds this parameter, water is pre-delivered to aquifer storage at a rate dictated by user defined ***transfer and storage constraints***. Surface storage is reduced by the same amount. Pre-delivered water is initially "provisional" storage as it can be recalled if needed.
4. Subsequent surplus flows will be held in surface storage until the Step 2 storage trace has been regained, transforming a similar amount of "provisional" storage to banked groundwater. If sufficient surpluses exist to transform all "provisional" storage to banked groundwater, additional surpluses can be transferred into the provisional groundwater account, provided that space is available in the bank.
5. Subsequent deficits which result in adjusted storage below target carryover initiate a search for replacement water and, if necessary, the recall of "provisional" storage at a rate dictated by ***user defined recovery constraints***. A shortage is declared when reservoir storage remains below the minimum target.

Table 1: Details of the Major Foothill Reservoirs in the Central Valley

River	Reservoir/Dam	Operator	Storage (TAF)[4]	Mean 1921–1983 Unimpaired Flow[5]
American	Folsom	USBR/CVP	974	2,660
Calaveras	New Hogan	USBR	317	163
Feather	Oroville	DWR/SWP	3,538	4,441
Merced	New Exchequer	MeID	1,025	967
Mokelumne	Camanche	EBMUD	417	730
Sacramento	Shasta	USBR/CVP	4,552	8,303
San Joaquin	Millerton Lake	USBR/CVP	520	1,740
Stanislaus	New Melones	USBR/CVP	2,420	1,131
Tuolumne	New Don Pedro	MoID/TIDD	2,030	1,841
Yuba	New Bullards Bar	YCWA	966	2,333

Simulations

Four different scenarios were simulated using CUP. These are summarized in the matrix shown in Table 2. The base case represents the case where instream flow standards are set to the highest possible level, carryover standards set in the AFRP are used where available to define the carryover target parameter, and 20% of the upstream storage can be tapped to make up any deficit relative to the minimum carryover. The other three simulations are departures from this base case. Scenarios 2 through 4 are designed to evaluate the sensitivity of the estimated average annual yield to various management strategies. Scenario 2 in particular merits some explanation. In this simulation the AFRP prescribed carryover targets are set aside in favor of the more aggressive targets derived from the application of the equations (1) and (2) to Shasta, New Hogan, and Camanche Reservoirs. Under each of these scenarios, a small simulated capacity to capture flow during peak winter and spring flow events was included. It is important to keep in mind, however, that this approach is considered secondary to reservoir re-operation in CUP.

Results

The estimated average annual yield in the base case simulation is 894.4 TAF, a significant quantity of water that could contribute mightily to the quest for consensus in California's water sector. In addition, the alternative management strategies described in scenarios 2 through 4 improve the performance of the groundwater-banking program.

Table 2: Average Annual Yield Estimates from Revised CUP Model (in TAF)

(CU: conjunctive use re-operation; HP: capture of hydrograph peak)

	Base Case			Set Aside AFRP			Relax Standards			Full Upstream		
River	CU	HP	Total	CU	HP	Total	CU	HP	Total	CU	HP	Total

[4]Draft of the California Water Plan Update, Department of Water Resources, California Water Commission, November 1993.
[5]California Central Valley Unimpaired Flow Data, 2nd Edition, California Department of Water Resources, Division of Planning, February 1987

American	64.8	15.6	80.4	64.8	15.6	80.4	72.9	17.4	90.3	137.1	15.2	152.3
Calaveras	12.8	12.6	25.4	15.9	11.5	27.4	14.7	13.2	27.9	12.7	12.6	25.3
Feather	107.3	19.6	126.9	107.3	19.6	126.9	122.8	21.7	144.5	117.1	19.6	136.7
Merced	92.9	15.2	108.1	92.9	15.2	108.1	134.7	22.4	157.1	93.0	15.2	108.2
Mokelumne	53.7	15.7	69.4	51.6	15.7	67.3	77.6	23.3	100.9	59.6	15.0	74.6
Sacramento	170.8	26.0	196.8	184.5	26.0	210.5	195.3	31.2	226.5	170.8	26.0	196.8
Stanislaus	51.6	13.4	65.0	51.6	13.4	65.0	79.5	26.4	105.9	58.3	13.4	71.7
Tuolumne	65.3	12.6	77.9	65.3	12.6	77.9	116.4	24.8	141.2	72.1	12.4	84.5
Yuba	117.5	27.0	144.5	117.5	27.0	144.5	157.8	31.3	189.1	122.6	27.1	149.7
Total			894.4			908.0			1183.4			999.8

Relative to the base case, the most dramatic improvements come from reducing the simulated instream flow standards from high to medium. Even without relaxing the instream flow standards, however, the performance of the system can be improved by taking full advantage of the opportunity to release water from storage in upstream reservoirs when it is needed to re-establish the minimum carryover level on October 1st. Table 3 details the pattern of reliance on upstream storage that emerges from this simulation. Although the use of this water affords extra benefit to the ground water banking program, any advantage gained must certainly be weighed against power generation potential that might be lost in the process. This analysis suggests, however, that the notion of integrating storage upstream of the major foothill reservoirs into the maximal statewide groundwater-banking program is certainly worth pursuing. This type of integration, however, would involved a wide array of actors running from the electric utilities which operate the upstream reservoirs, the water agencies which operate the major foothill reservoirs and their customers, and the land owners overlying the potential aquifer storage sites. The complexity of negotiating arrangements acceptable to all these parties will require a keen eye towards the legal and institutional nuances governing groundwater in California. Given the enormous potential payoff, however, there should be ample incentive to address any potential problems.

Table 3: Simulated Transfers from Upstream Storage to the Major Foothill Reservoirs under the Full Upstream Scenario (transfers in ac-ft)

River	No. of Transfers	Average Transfer
American	10	182,649
Calaveras	0	0
Feather	7	182,764
Merced	5	9195
Mokelumne	9	55,427
Sacramento	6	106,904
Stanislaus	3	87,343
Tuolumne	8	131,810
Yuba	3	53,935

Groundwater Banking Site Analysis

The hydrologic potential analysis assumed the ability to convey surface water and to store it in a suitable groundwater banking site. 17 potential groundwater storage sites were identified by the CALFED Bay-Delta Program. The active recharge storage estimates, which total over 10 MAF are shown in Table 4.

Table 4: CALFED Estimates of Active Groundwater Storage Capacity

North of Delta Storage	Potential Storage	South of Delta Storage	Potential Storage
Butte Basin	470 TAF	Folsom S. Canal (east S.J. County)	860 TAF
Cache Creek Fan (Cache-Putah)	450 TAF	Kern River Fan	930 TAF
Colusa County	320 TAF	Gravelly Ford/Madera Ranch	350 TAF
Eastern Sutter County	470 TAF	Mendota Pool (Westside)	900 TAF
Sacramento County	260 TAF	Mojave River	200 TAF
Stony Creek Fan	640 TAF	Semitropic WSD	1000 TAF
Sutter County	1180 TAF	Tuolumne/Merced Basin	1250 TAF
Thomes Creek Fan	220 TAF		
Yuba County	540 TAF		
Total North of Delta	**4,550 TAF**	**Total South of Delta**	**5,490 TAF**

When compared with the hydrologic potential of the rivers considered in CUP, the first observation one makes is that while most of the yield associated with reservoir re-operation will be generated in the Sacramento Valley, much of the potential storage is located south of the Delta. This raises the issue of how best to convey water across that keystone of the California water system. What is required is operational analysis of specific groundwater banking opportunities that can explore the full implications of various assumptions about the existence and operation of conveyance infrastructure. This sort of operational analysis has been completed for two of the potential sites, Cache Creek-Putah Basin and the Gravelly Ford site.

To provide CALFED with a more refined and conservative estimate of groundwater banking capacities for a system-wide program, NHI teamed with other technical experts from CH2Mhill, the Bureau of Reclamation and Saracino and Kirby to screen and estimate the storage capacity of potential conjunctive use/groundwater banking sites to the north and to the south of the Sacramento-San Joaquin Delta and the recharge and recovery rates associated with each potential site. These two parameters are needed to estimate the yield associated with conjunctive use. We also considered the relative "implementability" of a potential project, assessed primarily on the basis of whether local agencies in a basin had begun to formulate their own plans for conjunctive use. When passed through the aforementioned screens the following set of potential sites emerged.

- Stony Creek Fan
- Butte Basin

- Cache-Putah Basin (Conaway Ranch)
- Sacramento North Area
- South Sacramento County
- San Joaquin County
- Madera Ranch
- Kings River Alluvial Fan
- Kern Water Bank

From this set, the working group generated an operational scenario matrix reflecting the full range of physically possible permutation of the ways these sites could be brought into operation. While in theory any conjunctive use site could be associated with any surface water supply, the working group used it best professional judgment to develop these scenarios by combining the following basic project elements:

- The groundwater basin.
- Associated surface water resources.
- Existing or reasonable new facilities for tapping the surface water resource.
- Existing or reasonable new facilities for conveying the stored groundwater to potential project beneficiaries.

Any of the possible permutations also included the possibility of implementing *in lieu* arrangements. Potential configurations constrained either by inadequate supply (e.g. the relatively small Stony Creek) or operational uncertainly (e.g. the Shasta-Trinity system in light of pending Trinity River flow recommendations) were either removed or flagged.

Ideally, estimating the operational capacity of a conjunctive use project should rely upon transient analysis of recharge and recovery of project operations. This type of analysis would allow for consideration of:

- The impact of storage and recovery operations on the other components of the water balance for a groundwater basin (e.g. surface water groundwater interactions).
- The impact of storage and recovery operations on existing groundwater users in the basin.
- The potential to manage the overall basin response to storage and recovery operations by raising groundwater levels beyond the limits of existing draw down features.
- Any losses that might be associated with storage and recovery operations.

The best way to consider these issues is through the development and operation of appropriate groundwater models. Instead, the following estimation of the potential storage capacity of the potential projects was based on static geometric analysis of existing draw down features. Working from DWR water level elevation maps for fall 1992, the total unsaturated volume was adjusted by an estimate of the specific yield extracted from databases for the Central Valley Groundwater/Surface Water Model (CVGSM). The result was an estimate of the available water storage capacity. By it very nature this approach is extremely conservative. Essentially existing draw down features were treated as "tanks" of fixed dimensions within which water could be stored. No assessment was made of the potential to increase the capacity of a tank by raising the water level around a depression.

The results of passing the selected projects through this analytical filter are contained in Table 5.

Table 5

Storage Site	Unsaturated Volume (ac-ft)	Assume S_y[2.] = 0.1 Potential Storage (ac-ft)	Assume S_y = 0.2 Potential Storage (ac-ft)
Stoney Creek[1.]		200000	200000
Butte Basin[1.]		200000	200000
Conway Ranch[1.]		200000	200000
Sacramento North Area	1855040	185504	371008
S. Sacramento Co./Elk Grove	3884160	388416	776832
S. Sacramento Co./Galt	2315520	231552	463104
San Joaquin County	2326720	232672	465344
Madera Ranch	2867200	286720	573440
Kings River Fan	4346784	434678	869357
Kern Water Bank[3.]		1200000	1200000
Total Storage		2959542	4719085

[1.] The potential storage for these sites is assumed to equal 200 TAF after the native groundwater has been developed.

[2.] The CVGSM model assumes that specific yield ranges from 0.08 and 0.12 over several large parametric elements. In keeping with this data, the first column assumes that Sy equals 0.1 while the second column assumes that in areas suitable for groundwater banking the value may increase to 0.2.

[3.] Data for the Kern Water Bank was developed by the Kern County Water Agency

Estimate Appropriate Recharge and Recovery Rates for the Projects

For the purposes of this analysis, appropriate recharge and recovery rates was developed using a proxy derived from analysis carried out for the Madera Ranch groundwater banking project. Preliminary engineering analysis suggested that water could be recharged to the site at a rate of 400 cfs (Navigant Consultants, 1998). Dividing this rate by the total available storage capacity at the site, we arrived at recharge and recovery proxy of 0.004 ac-ft per day/ac-ft of storage. This factor was adjusted for the other sites based on the ratio of the hydraulic conductivity at the site (as extracted from CVGSM databases) to the hydraulic conductivity at Madera Ranch (as determined during an on-site aquifer test). Table 6 contains estimates of appropriate recharge and recovery rates based on the application of this proxy to the suite of potential projects.

Table 6: Estimates of Appropriate Recharge and Recovery Rates at Selected Conjunctive Use Project Sites in the Central Valley

Storage Site	CVGSM Hydraulic Conductivity (ft/day)	Assume S_y = 0.1 Potential Storage (ac-ft)	Recharge/ Recovery[1.] (ac-ft/day)	Assume S_y = 0.2 Potential Storage (ac-ft)	Recharge/ Recovery (ac-ft/day)
Stoney Creek	60	200000	960	200000	960
Butte Basin	30	200000	480	200000	480
Conway Ranch	38	200000	608	200000	608
Sacramento North Area	28	185504	416	371008	831
S. Sacramento Co./Elk Grove	28	388416	870	776832	1740
S. Sacramento Co./Galt	28	231552	519	463104	1037
San Joaquin County	120	232672	2234	465344	4467
Madera Ranch[2.]	50	286720	1147	573440	2294
Kings River Fan	50	434678	1739	869357	3477
Kern Water Bank[3.]	50	800000	3200	800000	3200
Total Storage		2559542		4319085	

[1.] Assumes that recharge occurs at a rate of 0.004 ac-ft/day/ac-ft of storage at Madera Ranch with the rate being adjusted at other sites based on the ratio of the CVGSM hydraulic conductivity at that site to the hydraulic conductivity at Madera Ranch

[2.] Pump test conducted at Madera Ranch found that the hydraulic conductivity ranged from 50-95 ft/day

[3.] Data for the Kern Water Bank was developed by the Kern County Water Agency

To arrive at an ultra-conservatives estimate of storage potential, potential projects at Stony Creek, Butte Basin, and the Cache-Putah Basin (Conaway Ranch) were eliminated because groundwater tables are currently so high that aquifer storage space would need to be created by first extracting water and then replenishing that water through active recharge of water from reservoirs or though passive recharge through precipitation. These may prove to be attractive projects with due consideration of ways in which adverse impacts on groundwater pumpers could be ameliorated. The Sacramento North Area was also eliminated based on the supposition the Sacramento North Area Groundwater Management Agency would fully exploit the storage potential at this site.

We also assumed a recharge rate in the Sacramento Valley of 0.5 feet/day spread over 1 square mile, increasing 250 cfs during the growing season to account for *in lieu* possibilities. Assuming 1 well per 10 acres at the project site pumping at 1500 gpm, the recovery rate in South Sacramento County was set at 200 cfs. Projects in the San Joaquin Valley were considered to be less constrained by competing land-use considerations. These assumptions led to the following values for storage, recharge and retrieval:

Table 7: Aggregate Conjunctive Use "Projects" and Associated Sites

Project	Storage	Recharge Oct-Apr	Recharge May-Sept	Retrieval

North of Delta				
So. Sacramento County	500 TAF	150 cfs	250 cfs	200 cfs
South of Delta				
San Joaquin County	500 TAF	250 cfs	350 cfs	200 cfs
Madera Ranch	300 TAF	400 cfs	400 cfs	200 cfs
Kings River Fan	500 TAF	250 cfs	350 cfs	200 cfs
Kern Water Bank	500 TAF	250 cfs	350 cfs	200 cfs

Aggregating the remaining potential projects increases the potential conjunctive use program to 1.8 MAF south of the Delta and 500 TAF north of the

Legal and Institutional Analysis

Realizing the hydrologic potential of system-wide conjunctive water management requires that legal and institutional barriers be identified and surmounted.

Basic Premise

Basically, the incentives for a system-wide program of groundwater banking would be as follows, landowners overlying the storage site would agree to store the water as part of the program in exchange for a portion of the "new" water, or for a cash payment. Water will be regarded as "new" water if it would otherwise have been released for flood control purposes and flowed out to sea. Well monitoring may be necessary in selected areas to prevent increased pumping by overlying and adjacent landowners in storage areas, who could be tempted to irrigate new lands, avoid higher surface water costs, and/or to compensate for unrelated market transfers of surface water rights. Opportunities may exist to incorporate storage entities as a part of AB 3030 groundwater management plans for districts throughout the state, indeed in the case of *in lieu* storage this may be the preferred approach. Potential beneficiaries of the groundwater banking program would be invited to participate in the arrangement under agreements that would give them access to purchase a specified amount of the banked groundwater. The funds collected from the beneficiaries would be used to defray the costs of the program, which are expected to include the construction of new infrastructure and electricity for pumping the stored water.

Basic Approach

A preliminary analysis of California groundwater law has been conducted to explore how a groundwater banking program could be set up so that the rights to the program water stored in groundwater basins could be protected against claimants that are not participating in the program. In pursuing this legal research two program designs were considered: (1) groundwater banking through active recharge and (2) groundwater banking through *in lieu* arrangements. Both designs would tap flood control releases that otherwise escape beneficial use. Thereafter the program designs diverge somewhat as they are predicated on different legal entitlements to extract and use the stored groundwater. The details of this legal research are included in an August, 1994 NHI document entitled *Analysis of Preferences in Rights to Groundwater Under California Law & Implications for Design of Conjunctive Water Use Programs*.

In this analysis NHI defined a number of distinct "types" of groundwater. While from a hydrologic perspective, a molecule of groundwater in a basin is not physically distinguishable from any other molecule, our analysis suggests that from a strictly legal perspective there are multiple groundwater types in the State. Our conception of a system-wide groundwater banking program will focus on the situation where the organizer of a groundwater banking program would seek to obtain rights to groundwater that was imported from outside the groundwater basin, which has not become the underflow of a surface stream nor an underground stream, and which will be put to beneficial use at a location physically removed from the land overlying the basin. This type of groundwater offers several important protections to the organizers of a groundwater banking program. The most salient details of the legal analysis on the active and *in lieu* program designs are framed as responses to pertinent questions.

Legal and Institution Questions

The questions posed below go right to the heart of perceptions that the benefit of water stored in an aquifer is the sole possession of overlying landowners. The responses assert that for groundwater of the type described above, this perception is generally not valid. Having established this conclusion, questions related to how to best capitalize on potential storage opportunities can be posed.

Could parties with potential claims on groundwater hamper the eventual recovery of stored groundwater?

In the Case of Active Recharge

Prescriptive right holders, overlying users, and importers of aquifer recharge water cannot assert a superior claim to the water banked under a system-wide conjunctive management program, provided that the organizer of the groundwater banking program is a public entity, as described below, and the water is ultimately used reasonably and beneficially. The only colorable claim of overlying groundwater users would result if the importer abandoned the imported water once it was in the ground. Spreading does not constitute such abandonment.[6] Other importers can claim only rights to a quantity of water attributable to their own imports--a situation that does not threaten the operation of a groundwater banking program. Thus, a public importer of water of this type need only be concerned about being displaced by appropriators.

Appropriators have a superior claim to water of this type only if the importer fails to require the water for reasonable beneficial use--that is, if the water is considered "surplus." The burden of proof would be on the would-be appropriator to show that such

[6] City of Los Angeles v. City of Glendale, 142 P.2d 289, ___, 23 Cal.2d at 76-78 (Cal. 1943).

water was, in fact, surplus.[7] Storage of groundwater for domestic, irrigation, and municipal purposes is typically considered a reasonable beneficial use.[8] Storage of groundwater is a beneficial use if the water is later applied to the beneficial purposes for which the water was first appropriated on the surface.[9] Thus, it is important that, in addition to manifesting an intent to recapture imported waters stored in the ground, the organizer of the groundwater banking program demonstrate that such waters are being stored for later application to reasonable beneficial uses. In this way, the storage itself will be considered beneficial.

Thus, if the organizer of the groundwater banking program holds rights to groundwater of the type described above, the program should be able to deposit water in the ground and, by right, withdraw it again.

In the Case of *In Lieu* Arrangements

Under an in lieu system, the program would enter into arrangements with overlying landowners who already have access to groundwater. During periods when the program desires to recharge groundwater, the landowners would forego pumping and accept a substitute surface delivery from the program instead. In the case where the landowner has access to surface water, when the program desires to withdraw groundwater, the landowner would curtail its surface water use and substitute groundwater pumping. When the landowner has no independent claim to surface water, recovery by the program would rely on the physical extraction of stored groundwater.

The basic problem with such an arrangement is that the program will not be withdrawing groundwater that it has physically put into the aquifer through an active recharge program. Instead, it will require groundwater rights holders to forego pumping water that they are otherwise legally entitled to extract in some years and to offset that forbearance by drawing more heavily on the aquifer in other years. The problem is that the contracting landowners have no better right to the underlying groundwater than do all of the other landowners overlying that same aquifer. The rights are "correlative", that is, of equal stature and limited by the principle of mutual avoidance of harm. Thus, in years of forbearance, the other pumpers would be entitled to extract the water that the program intended to store. In years of extraction, the contracting landowner's rates of withdrawal may impair the rights of the correlative pumpers.

Recognizing in the organizer a superior right to groundwater stored when surface water is used in lieu, could involve upsetting an established set of property rights and investment-backed expectations, something courts are typically loathe to do. Fortunately the only colorable claim of overlying groundwater users to water of the type described above would result if the importer abandoned the imported water once it was in the

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[7]Miller v. Bay Cities Water Co., 107 P. 115, ___ (Cal. 1910); Allen v. California Water & Tel. Co., 176 P.2d 8, ___ (Cal. 1947) (burden on appropriator to show existence of surplus); Monolith Portland Cement Co. v. Mojave Public Utilities Dist., 316 P.2d 713, ___ (Cal. Ct. App. 1957) (burden on off-tract user to show existence of surplus); 62 Cal. Jur. 3d, Water § 410 (1981).
[8]Rank v. Krug, 142 F.Supp. 1, 111-12, 113-14 (S.D. Cal. 1956), *affirmed in part and reversed in part*, California v. Rank, 293 F.2d 340 (9th Cir. 1961), *modified upon rehearing*, 307 F.2d 96 (9th Cir. 1962), *affirmed in part*, City of Fresno v. California, 372 U.S. 627 (1963), *overruled*, California v. FERC, 495 U.S. 490 (1990).
[9]CAL. WATER CODE § 1242 (West 1971).

ground. Delivery for surface use does not constitute such abandonment.[10] The important point when imported water is used is that the mass balance in the groundwater basin will be the same whether the water is actively recharged or delivered *in lieu* of groundwater pumping. In both cases during years or storage, more water is contained within the basin than would have been stored absent the program.

Of course, the problem associated with *in lieu* recharge may be avoided where groundwater basins have been adjudicated such that the particular extraction rights have been quantified. This is the situation with a number of groundwater basins in Southern California. A potential shortcoming of adjudication, other than the time and cost associated with the process, is that the final judgments in Southern California often proscribe out of basin transfers of groundwater. This may hinder the ability to recover groundwater of the type described. .

The technique of in lieu storage can be also used outside adjudicated groundwater basins, but special arrangements will be necessary. There are several potential approaches:

- The correlative rights problem can be avoided by bringing all of the correlative rights holders into the contractual arrangement, or mitigated by bringing most of them into it. The ability of any one rights holder to upset the program by withholding consent remains, however. This is where incorporation of storage entities as part of AB 3030 management plans could prove particularly beneficial.

- The program could be operated in a manner that would presumptively avoid injury to correlative rights holders by foregoing pumping for a period sufficient to assure that when accelerated pumping occurred, it would not disadvantage the correlative rights holders compared to the status quo. That might mean designing the program so that the number of sequential years of accelerated pumping was limited.

- Special legislation might be enacted to preclude suits against the program by non-contracting landowners where the groundwater that the program causes to be extracted in any one year was limited to amounts that could have been extracted in any previous year but for the forbearance imposed by the program. This would be a legislative interpretation of the "no harm" rule as applied in the narrow context of an in lieu groundwater banking program. While a general groundwater management regime may be beyond reasonable legislative expectations, a modest enactment of this sort may be realistic.

What sort of entity should operate the program?

[10] City of Los Angeles v. City of Glendale, 142 P.2d 289, ___, 23 Cal.2d at 76-78 (Cal. 1943).

The organizer of the groundwater banking program will enjoy the best legal position to recover the groundwater that it has stored if it is a public agency managing groundwater. Under these circumstances, the right to extract the stored groundwater enjoys a high priority. Such a right prevails over all rights except in the following circumstances:

> (1) It is inferior to the state-held public trust interest of the people of California, as are all usufructory rights;
>
> (2) It is of equal priority with pueblo rights, but, since pueblo rights apply only to native water, disputes between the two results in apportionment to the importer of the quantity of groundwater attributable to imports;[11]
>
> (3) It is of equal priority with other public and private importers in the watershed of destination and use, but disputes between these parties are also resolved by apportioning to each importer "the amounts attributable to the import deliveries of each."[12]

An importer's right to recapture imported recharge water is established by manifesting such intent prior to importation.[13] A groundwater banking program is predicated upon such an intent.

The advantage of the program organizer being a public entity is that that status precludes the potential for adverse rights attaching to the program's stored groundwater through prescription. While CAL. CIVIL CODE § 1007 (West 1982) literally protects "any public entity" from prescription, the courts have been reluctant to afford the statute its broadest application[14] and may try to limit the definition of "public entity" to exclude some marginal parties. Therefore, care should be exercised in choosing or establishing the program organizer. Further research is needed regarding the outer bounds of the "public entity" definition. For instance, it would be useful to know whether a groundwater banking program organizer that was the creature of a memorandum of understanding between the state and federal government might qualify.

Where should the program store the imported water?

In the most general sense, in order to simplify the legal situation, the target groundwater storage basin should be composed of percolating strata and be isolated from surface waters, such as streams or the underflow of streams. This would minimize the interplay of various legal doctrines, avoid factual disputes, and make the legal outcomes more predictable. As a result, the participants in the program will feel more secure about their rights and about the investments required to implement active recharge.

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[11] City of Los Angeles v. City of San Fernando, 537 P.2d 1250, ____, 14 Cal.3d at 288 (Cal. 1975).
[12] City of Los Angeles v. City of San Fernando, 537 P.2d 1250, ____, 14 Cal.3d at 260-62 (Cal. 1975).
[13] City of Los Angeles v. City of Glendale, 142 P.2d 289, ___, 23 Cal.2d at 78 (Cal. 1943); City of Los Angeles v. City of San Fernando, 537 P.2d 1250, ____, 14 Cal.3d at 257-58 (Cal.1975).
[14] *See* City of Los Angeles v. City of San Fernando, 537 P.2d 1250, ____, 14 Cal.3d at 272, 274, 276 (Cal. 1975).

Under the groundwater banking arrangements explored here, however, water might be introduced into a groundwater basin at one location and extracted at another some distance away. This raises the question of the hydrologic interconnections that must be maintained between the imported recharge water and the extracted water in order to preserve the importer's preference right. "Imported water" is "foreign water imported from a different watershed."[15] The advantage of obtaining the rights of an importer is that California law gives high priority to these rights in order "to credit the importer with the fruits of his expenditures and endeavors in bringing into the basin water that would not otherwise be there."[16] Under this rationale, it would appear that the area of recharge must be hydrologically connected to the area of discharge such that the program is pumping groundwater that "would not otherwise be there" but for the recharge. In other words, the two areas much be sufficiently proximate and interconnected so that the recharge water would be expected to replenish the area of discharge within the timeframe of the two events.[17]

Establishing proximity and interconnectedness is very important. Many California cases determining groundwater rights turn on geohydrologic characteristics of the groundwater aquifers. In addition to locating a storage site that is factually simple, it would be useful to locate one that is scientifically well studied; ideally, one where the pertinent scientific facts have been determined in prior judgments. Such prior judicial fact finding may not be binding on parties to any future suit but would at least serve as an advance indicator of what the program might expect from future litigation.

From what source(s) should the program obtain surface water for storage?

One consideration in selecting a source of program water is the fixed capital requirements of the program. If the program requires appreciable new physical infrastructure, as will likely be the case for a maximal program of groundwater banking, the costs of those capital investments will presumably have to amortized by the project itself over a period of time. In that circumstance, the program will require a reliable source of water over that same time horizon. If, by contrast, the program requires only limited capital investment, the program water can be intermittent or less reliable. Therefore, an early question to be resolved is whether the program can be based on an interruptible source of water, or does it require a durable source? The hydrologic distinction between capturing peak floods (intermittent) and re-operating reservoirs (reliable) will certainly bear on the appropriate response to this question.

What parties should be involved?

The program organizer should seek contractual arrangements with parties owning land overlying groundwater since they may possess both spreading grounds and a right to

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[15] City of Los Angeles v. City of San Fernando, 537 P.2d 1250, ____, 14 Cal.3d at 261 n.55 (Cal. 1975).
[16] City of Los Angeles v. City of San Fernando, 537 P.2d 1250, ____, 14 Cal.3d at 261 (Cal. 1975).
[17] One of the cases holds that it is possible to establish a right to imported water by making deliveries and withdrawals within one's own reservoir and alleging in a complaint that one intended to capture return flow from waters imported into the basin. City of Los Angeles v. City of Glendale, 142 P.2d 289, ___, 23 Cal.2d at 78 (Cal. 1943); City of Los Angeles v. City of San Fernando, 537 P.2d 1250, ____, 14 Cal.3d at 257-58 (Cal.1975). The issue, then, is whether the conjunctive use program would be viewed as delivering and withdrawing water from within the same underground reservoir.

extract groundwater. Their participation and cooperation may be secured by sharing the benefits of the program with them, either in terms of new water or monetary compensation. The presumption in this case is that the sharing of benefits made available to the overlying landowners will be sufficient to surpass the water management opportunities afforded by strictly local opportunities.

Distilling The Lessons On Designing Successful Institutional Arrangements From Case Studies

As an early step in designing a workable system-wide conjunctive management arrangement, NHI and the Bureau of Reclamation are studying nine historic conjunctive use projects—some successful and some not. The purpose of the case studies is to distill the variables in the design and execution of conjunctive use projects that militate in favor of success or failure. We are primarily interested in the institutional frameworks, but want to also be alert to hydrologic or economic or geographic features that appear to correlate strongly with success. The term "institutional factors" means the mechanisms for:

⇒ Creating and protecting the legal rights of the conjunctive water manager to obtain water from the surface reservoir or stream, convey it to the groundwater banking site, recharge the groundwater, extract the stored water and reconvey it to points of end use.

⇒ Avoiding, minimizing, mitigating or compensating adverse impacts on other interests, including those with rights to the source water, those with rights to the conveyance system, those with rights to pump from the same aquifer, those with rights to use of the land areas in which recharge and recovery facilities are constructed.

In tracking these features and variables, the case studies need to be conscious of the differences in projects with respect to the sequence of recharge/recovery, passive vs. active recharge, and imported vs. native waters. These variables define the seven different types of conjunctive use projects that are theoretically possible, described earlier in this paper.

<u>The Cases to be Studied:</u>

Ideally, we would want to examine at least one case illustrating each of these seven options. However, we have found no cases involving options # 1, 3 or 7. For these, we will have to extrapolate from the other options. For options where there are illustrative successes and failures, we will want to do at least one of each. Thus, the following cases will be studied:

1) The DWR Drought Water Bank (type # 2 project)
2) The DWR Supplemental Water Purchase Program (type # 2 project)
3) Kings River Conservation District (type # 4 project)

4) Kern Water Bank (type # 5 project)
5) SNAGMA and American River Cooperating Agencies project (type # 5 project)
6) Semi-tropic water bank (type # 5 project)
7) Madera Ranch (type # 6 project)
8) San Joaquin County/EBMUD (type # 6 project)
9) Arvin Edison/MWD arrangement (type # 6 project)

Each of the cases studies will evaluate how the project has succeeded or failed in:

1) Dealing with the hydrogeologic risks associated with groundwater banking. These are of several types:

   A) The risk of losing stored water because it "leaks" out of the aquifer and cannot be recovered without adverse impacts on other groundwater users in that aquifer.

   B) The risk of losing stored water because it is not possible to increase the pumping rate at times of extraction without adversely affecting other groundwater pumpers in that aquifer.

   C) The risk that raising the groundwater table will reduce natural infiltration and thereby deprive other groundwater users of natural recharge water.

   D The risk that raising the groundwater table will invade the root zone of permanent crops or create phreatophytic vegetation that is subject to regulation as a wetland.

2) Dealing with the legal risks associated with the potential for litigation or actions before the State Water Board with respect to the foregoing hydrologic risks?

3) Dealing with the political risks associated with adverse community reactions in light of real or perceived risks of the foregoing variety?

4) Dealing with the need for reservoir reoperation where that is the source of the banked water?

5) Dealing with the competing water rights where direct diversion of surface flows comprises the source of the water?

6) Dealing with the competing groundwater rights where extraction precedes recharge?

7) Protecting its banked groundwater from extraction by other groundwater pumpers?

8) Procuring conveyance capacity for both the put and take operations?

9) Dealing with land use conflicts for both the put and take and conveyance features?

10) Dealing with potential damages to structures or crops associated with manipulating groundwater levels?

11) Dealing with water quality consequences of groundwater banking (e.g. leaching of soil contaminants into the stored water, incompatibility of existing and banked groundwater chemistry)?

12) Dealing with any other third party impact problems and community relations in general) e.g., local participation in the design and execution of the project, transparency and access to information, conduct of technical studies, public hearings and/or consensus building processes, etc.)?

13) Dealing with environmental issues not already enumerated above?

14) Securing adequate financing for its infrastructure and operations?

For all of these considerations, the case studies must assess how successful the project has been, and how it could have been better designed to deal with them more successfully.

Forming a Consortium of Central Valley Water Interests To Complete the Technical Investigation of a System-Wide Conjunctive Water Management Program

So far, the work described in this paper has been undertaken by the Natural Heritage Institute in part under a grant from the Ford Foundation, in part under a partnership with the U.S. Bureau of Reclamation, and in part under contract with the CALFED Bay-Delta Program. It would now be advantageous to broaden the consortium to include all "indispensable parties" and other reservoirs of expertise and Central Valley stakeholders. That is desirable because the success of this enterprise will ultimately require larger resources—both financial and intellectual--and the full cooperation of the agencies whose voluntary participation is necessary to the implementation of a system-wide conjunctive water management program. This program represents the best opportunities to improve water supply reliability in a way that will benefit all sectors. The U.S. Bureau of Reclamation has an obligation under the Central Valley Project Improvement Act to study reservoir reoperation, conjunctive use and other techniques to supplement and replace the water dedicated to fish and wildlife restoration. NHI and the environmental community are interested in environmentally benign water management innovations such as conjunctive use. All water users within the Central Valley water system have a stake in reducing the conflicts over dry year water in this over-subscribed system.

The objective of a consortium effort is **not** to provide another forum for policy debates or a vehicle to pursue special interests. Rather, it is a joint effort to conduct the highest quality technical work on the design of a program that can provide maximal system-wide benefits for all water users in the Central Valley system, including the environment. It is intended to be an altruistic and public-spirited endeavor to meet the future water needs of the Central Valley and the State of California, not an effort to seek special advantages at the expense of competitors. We intend to begin operating as a consortium when a critical mass of participants and resources has come together, with the expectation that others may choose to join later.

We want to bring together into the design phase the entities whose participation will ultimately be necessary to implement a system-wide conjunctive water management program. Thus, we envision the following membership, functions, organizational structure and products. Ideally, the consortium will eventually include:

- Local water agencies and/or other associations of landowners and water users that overlie the 10-12 potential groundwater banking sites
- The counties within which the potential groundwater banking sites are found
- The owners and operators of the terminal reservoirs on the Central Valley tributaries
- The potential end users of the banked water including agricultural, urban and environmental requirements
- Agencies with specialized expertise and data

Ultimately, the functions and structure of a conjunctive use consortium will be determined by its members. The initial partners suggest that the members not conduct the technical studies themselves. Rather, we envision that the consortium members would pool resources (financial and informational) to enable an expert study team to be assembled to conduct the investigation. The objectivity and scientific integrity of the study team would be guaranteed by divorcing support of the project from management of the study. A technical oversight committee would be formed, consisting of technically qualified representatives of the consortium members (and perhaps others by invitation). This committee would exercise oversight of the project manager and study team. The project manager would be selected and operate at the pleasure of the consortium.

Support and funding for the investigation will come from the pooled resources of the consortium, so the price for participation is a specific and substantial contribution of **funds, data**, and/or **expertise**, or some combination of these. The use of the funds, data and expertise will be determined by the consortium as a whole, based solely on considerations of making the study as technically credible as possible.

In sum, the rights and duties of the consortium members would be to:

- Pool resources
- Approve a charter for the consortium that will, among other things, specify the roles and contributions of the members
- Develop and approve a study plan and budget
- Select a study manager that will then assemble and direct an interdisciplinary study team comprised of experts chosen for their skill and objectivity

- Review and approve the final workproducts. Any consortium member reserves the right to dissent from any aspect of the report or its findings or conclusions.

The end product will be a technically sound, stakeholder-neutral and implementable plan for establishing a groundwater banking program which can operate in combination with a broader mix of water supply reliability options. The aim is system-wide yield augmentation, without prejudging how that yield may be distributed among sectors or regions, while avoiding or mitigating all adverse impacts on the environment or existing ground and surface water users. The products of the study would not be owned or controlled by the consortium or any individual members thereof. Rather, the report would be made generally available to CALFED, the implementing agencies, and the public at large.

The final report will describe at an operational level of detail how a system-wide, maximal scale conjunctive water management program can be structured and operated that will meet the following constraints and design specifications:

- The program will operate on the basis of voluntary, compensated contractual arrangements among operator owners, land and water rights holders in the groundwater banking sites, conveyance operators and end users to ensure local control

- It will cause no uncompensated adverse impacts on other groundwater or surface water rights holders

- It will cause no unmitigated environmental impacts

- It will be operated in an economically optimal fashion (i.e. the volumes of water and scale of operations will be limited by the marginal cost of substitute supplies)

- No new surface water storage will be assumed (although the analysis may describe how additional temporary surface storage capacity and enhanced water conveyance capacity might affect potential yield and operations)

- No new public subsidies (i.e., unamortized or concessionary public investment) will be assumed. That is to say, the project will be assumed to be self-financing.

- No changes in existing laws will be assumed, although the final report may identify legal reforms or measures to clarify existing law that would facilitate the program.

Conclusion

In California, as elsewhere in the American West, management of a fixed endowment of water resources will be a daunting challenge at the "next meridian", to borrow the term coined by Professor Charles Wilkinson, particularly as we move from prevention to restoration and from regulation to consensual transactions. Yet, to borrow another phase from Roger Patterson, the former Regional Director of the Mid-Pacific Office of the Bureau of Reclamation, we are blessed with more solutions than problems. It is increasing clear that the limiting factor in successful innovation is not physical constraints but institutional rigidity. At NHI we believe that the path of least resistance is to ask first how it is possible to reoperate the existing physical system to expand beneficial uses, then to ask what changes in the economic incentive structure would be necessary to induce those reoperations, and then, but only then, ask how the existing legal and institutional structures might be improved to enable those incentives. System-wide conjunctive water management is only one of many such opportunities to "tune the system".

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