NATURAL RESOURCES JOURNAL

Volume 41
Issue 3 *Summer 2001*

Summer 2001

Institutions and Conjunctive Water Management among Three Western States

William Blomquist

Tanya Heikkila

Edella Schlager

WILLIAM BLOMQUIST, TANYA HEIKKILA & EDELLA SCHLAGER*

Institutions and Conjunctive Water Management among Three Western States

ABSTRACT

Conjunctive water management involves the coordinated use of ground and surface water supplies. It aims to enhance overall water supplies and guard against drought. In this article, we consider how water governance institutions affect the implementation of conjunctive management. To explain this connection, we present data from a study of conjunctive management in Arizona, California, and Colorado. We discuss how the institutional arrangements across these three states impact the transaction costs and other factors associated with conjunctive management and suggest how different institutional arrangements facilitate or impede conjunctive management.

INTRODUCTION

The development, distribution, and protection of water resources are among the most important political and public policy issues in the western United States. A long-standing and frequently stated recommendation for improved watershed use and protection is the coordinated use of surface and underground water resources, also known as conjunctive management.[1] Conjunctive management has been promoted

---

* William Blomquist is an Associate Professor of Political Science in the Department of Political Science at Indiana University, Indianapolis. Tanya Heikkila is a Post-Doctoral Fellow at Indiana University, Bloomington. Edella Schlager is an Associate Professor of Public Administration and Policy at The University of Arizona.

1. *See generally* Harold Conkling, *Utilization of Ground-Water Storage in Stream System Development*, 111 TRANSACTIONS AM. SOC'Y CIV. ENGINEERS 275 (1946); 1 PRESIDENT'S WATER RESOURCES POLICY COMMISSION, A WATER POLICY FOR THE AMERICAN PEOPLE (1950); Harvey O. Banks, *Utilization of Underground Storage Reservoirs*, 118 TRANSACTIONS AM. SOC'Y CIV. ENGINEERS 220 (1953); Victor E. Gleason, *Water Projects Go Underground*, 5 ECOLOGY L.Q. 625 (1976); Norman W. Thorson, *Storing Water Underground: What's the Aqui-fer?* 57 NEB. L. REV. 581 (1978); Frank J. Trelease, *Conjunctive Use of Groundwater and Surface Water*, 27B ROCKY MTN. MIN. L. INST.1853 (1982); U.S. ADVISORY COMMISSION ON INTERGOVERNMENTAL RELATIONS, COORDINATING WATER RESOURCES IN THE FEDERAL SYSTEM: THE GROUNDWATER-SURFACE WATER CONNECTION (1990); David Keith Todd & Iris Priestaf, *Role of Conjunctive Use in Groundwater Management*, PROC. AM. WATER RESOURCES ASS'N CONF.139 (1997); AGWA NGT Conjunctive Use Workshop Committee, *Conjunctive Use Issue Paper*, *in* NATIONAL WATER RESEARCH INST., CONJUNCTIVE USE WATER MANAGEMENT PROGRAM WORKSHOP REPORT 1 (1998).

as a promising approach—for some, the *most* promising approach—for achieving multiple water resource policy objectives under natural and regulatory constraints.

Institutions—laws and regulations, governmental and nongovernmental organizations—shape both the extent and the manner of implementation of conjunctive management. Our goal in this article is to illustrate and explain that connection by comparing the conjunctive management experiences of three western states with differing water institutions: Arizona, California, and Colorado. These comparisons are based primarily on original research we conducted in those states from 1997 through 1999.[2] In this article, we first describe conjunctive water management, including its promise and its limitations. We then explain why institutional arrangements are critical factors facilitating or discouraging conjunctive management programs. Finally, we describe our findings from Arizona, California, and Colorado; compare their different institutional arrangements and conjunctive management experiences; and discuss the relationships between institutions and conjunctive water management suggested by those differences.

I. CONJUNCTIVE WATER MANAGEMENT

The purposes of conjunctive management are to coordinate water resource use in ways that reduce exposure to drought, to maximize water availability, to protect water quality, and to sustain ecological needs and aesthetic and recreational values.[3] Other potential benefits are improved security of water supplies, reduced reliance on costly and environmentally disruptive surface water impoundment and distribution systems, and enhanced protection of aquatic life and habitat.[4]

Conjunctive management achieves these purposes by capturing surplus precipitation and streamflow, controlling releases from surface water storage facilities, and storing surface supplies underground in aquifers.[5] The stored groundwater serves as a non-evaporating "bank" that can be tapped during subsequent dry periods to sustain consumptive uses

---

2. Because many of the findings are distilled from dozens of interviews and site visits we conducted in Arizona, California, and Colorado during that period, they may not conform to all citation conventions of the law review literature. We gratefully acknowledge the funding support of the National Science Foundation and U.S. Environmental Protection Agency, Grant Number R824781. Neither funding agency is responsible for the findings or conclusions reported herein.

3. *See generally* U.S. ADVISORY COMMISSION ON INTERGOVERNMENTAL RELATIONS, *supra* note 1.

4. *Id.*

5. *Id.*

or supplement stream flows. The aquifer thus provides a regulatory storage medium that helps to smooth out the greater variability of water demands and surface water supplies. Overall, surface water and aboveground storage facilities are operated together with groundwater supplies and underground storage as components of a single system (*i.e.*, operated "conjunctively"). Multiple water needs are met by shifting mixes of surface and groundwater supplies determined by their relative availability.[6]

Conjunctive water management can be implemented by different methods. One method is known as direct recharge, transferring surface water to an underground aquifer for storage.[7] Direct recharge occurs naturally when precipitation and stream flow passes through surface and subsurface soils to reach aquifers. Direct recharge can also be encouraged artificially. Artificial recharge may be accomplished by constructing percolating basins, where water is spread onto permeable soil and allowed to sink underground, or by injection wells that force the water into the ground. The choice of means of artificial recharge depends upon the physical characteristics of the aquifer and overlying soils and other factors. Relevant physical characteristics include the depth of the aquifer, the permeability of the soil materials between the land surface and the aquifer, and the rate at which water moves through them.[8] Other relevant factors include land availability (percolating basins require more space than injection wells) and financial resources (injection wells are more expensive to install and maintain).[9]

"In lieu" recharge programs involve the exchange of surface water for groundwater.[10] When surface water is plentiful, water users rely upon it instead of groundwater. This allows groundwater that otherwise would have been extracted to accumulate underground, supplemented by any natural recharge occurring over the same period. The unused groundwater is therefore "banked" and can be drawn upon later when surface water is scarce.

Calls for greater implementation of conjunctive management, especially in the western United States, have increased over the past half-century. Three factors account for most of this increase:

---

6. *Id.* at 27-28.

7. *Id. See also* ASS'N OF GROUND WATER AGENCIES, GROUNDWATER AND SURFACE WATER IN SOUTHERN CALIFORNIA: A GUIDE TO CONJUNCTIVE USE 5 (2000).

8. AGWA NGT Conjunctive Use Workshop Committee, *supra* note 1, at 4-5.

9. Carl J. Hauge, *The Importance of Ground Water in California*, *in* CHANGING PRACTICES IN GROUND WATER MANAGEMENT—THE PROS AND CONS OF REGULATION 15, 25-28 (1992).

10. AGWA NGT Conjunctive Use Workshop Committee, *supra* note 1, at 2; *See also* Sue McClurg, *Maximizing Groundwater Supplies*, W. WATER, May/June 1996, at 4, 4.

- Population growth and migration have increased demand on water supplies in the West, and the Southwest in particular.[11] Meeting those demands has required not only greater, but also more reliable, water supply sources.
- Water demands are out of phase in space and time with the availability of water supplies. Water supplies in the Southwest are most plentiful during the comparatively cooler winter months, but peak demands for irrigation, cooling, and drinking water, as well as water for recreation and waste disposal, occur in the heat of late summer. This divergence underscores the importance of storing water when available for recapture.[12]
- The twentieth century tools most often used to meet demands for increased water storage and distribution capacity in the West—damming, diverting, and channeling surface streams—have become less viable.[13] Some of this change owes to emerging social values for aesthetic, recreational, and ecological values served by streamflows.[14] The change has also occurred because rising costs of building surface water storage facilities collided in the 1970s and 1980s with strained federal and state government budgets.[15] Both trends contributed to the search for new ways to meet rising water demands in the West.

Meeting the ever-increasing need for reliable water supplies, which necessarily includes adequate storage and conveyance capacity, *without* additional surface storage and distribution capacity, has fed the interest in conjunctive management options. The Natural Heritage Institute heralded conjunctive management as a form of "environmentally benign water development," and recommended "using groundwater storage to make sure that both the environment and the economy have the water they need in dry years."[16]

---

11. *See generally* MARC REISNER & SARAH BATES, OVERTAPPED OASIS: REFORM OR REVOLUTION FOR WESTERN WATER (1990).

12. *See* ASS'N OF GROUND WATER AGENCIES, *supra* note 7, at 11.

13. *See generally* Marc P. Reisner, *Deconstruction in the Arid West: Close of the Age of Dams*, 1 HASTINGS W.-NW. J. ENVTL. L. & POL'Y 1 (1994).

14. *See* REISNER & BATES, *supra* note 11, at 35-36. *See also generally* SARAH BATES ET AL., SEARCHING OUT THE HEADWATERS: CHANGE AND REDISCOVERY IN WESTERN WATER POLICY (1993).

15. *See* U.S. ADVISORY COMMISSION ON INTERGOVERNMENTAL RELATIONS, *supra* note 1, at 28.

16. *See* Natural Heritage Inst., Feasibility Study of a Maximal Groundwater Banking Program for California: Working Draft 2 (May 8, 1997) (unpublished report, on file with author). *See also* Long's Peak Working Group on National Water Policy, *America's Waters: A New Era of Sustainability*, 24 ENVTL. L. 125, 138 (1994).

Storing water underground is also seen as a financially attractive alternative to dams and reservoirs. The value of a groundwater basin can be measured partly in terms of the avoided costs of an equivalent quantity of surface storage capacity. It is especially valuable to have groundwater storage that avoids the costs of surface storage capacity that would be used only occasionally to meet peak or emergency demands.[17] Recent studies for two major urban water districts in California, the East Bay Municipal Utility District and the Metropolitan Water District of Southern California, concluded that conjunctive management was a less expensive means of securing additional water supplies or improving the reliability of water supplies, compared with construction of additional surface water storage capacity.[18] A similar finding resulted from a study done around the same time for a large Bay Area water agency—the East Bay Municipal Utility District.[19]

II. PHYSICAL AND INSTITUTIONAL FACTORS OF CONJUNCTIVE MANAGEMENT

Physical and institutional factors critically affect the existence, type, structure, and purpose of conjunctive management projects.[20] Physical requirements include the availability of groundwater basins suitable for replenishment, storage, and extraction, located in settings where water demands are increasing relative to supplies. Suitability of a groundwater basin is a composite of aquifer characteristics including the following:[21]

- available storage capacity;
- soil characteristics that determine whether and how rapidly surface water can move into the aquifer;
- existing groundwater quality, since poor-quality groundwater will degrade the quality of surface water that is mixed with it; and

17. *See, e.g.*, WILLIAM BLOMQUIST, DIVIDING THE WATERS: GOVERNING GROUNDWATER IN SOUTHERN CALIFORNIA 18 (1992).

18. *See generally* Anthony Fisher et al., *Alternatives for Managing Drought: A Comparative Cost Analysis*, 29 J. ENVTL. ECON. & MGMNT. 304 (1995); METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA, SOUTHERN CALIFORNIA'S INTEGRATED WATER RESOURCES PLAN (1996) at E-11.

19. *See* METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA, *supra* note 18, at 304.

20. Financial factors also affect conjunctive management projects. We do not, however, address such factors in this article.

21. Hauge, *supra* note 9, at 25-26.

- the aquifer's depth from the land surface, which affects the distance that stored water must be lifted to be recovered for use.

Conjunctive management also requires at least occasional surpluses of surface water that can be stored or exchanged for groundwater. Water conveyance mechanisms—such as pipes, ditches, or streambeds—must also be available to transport water between storage and usage locations.[22] The logistics of capturing surplus surface supplies, storing them underground until needed, and retrieving and delivering them when and where needed affect the implementation of a conjunctive management program.

In addition to physical factors, institutional arrangements—rules and organizations—are key elements of water management.[23] Rules governing water use, such as laws defining water rights, are critical to conjunctive water management. Western states have devised diverse systems of property rights in groundwater. Under the "prior appropriation" doctrine that governs surface water in most western states, individuals are granted fairly well-defined and transferable rights. Most western states also apply the prior appropriation doctrine toward some or all of the groundwater within the state, providing individuals with relatively secure rights to the use of specified amounts of groundwater.[24] Other states follow variations of the "beneficial use" doctrine, allowing overlying landowners to pump unspecified amounts of groundwater as long as they do not engage in wasteful uses or interfere with the rights of other overlying owners.[25] Because this doctrine does not authorize individuals to control specific

22. *Id.*

23. We define institutional arrangements as the rules individuals create, use, revise, and even violate when behaving in relation to one another and the physical world. *See* Elinor Ostrom, *An Agenda for the Study of Institutions*, 48 PUB. CHOICE 3, 5-7 (1986). For good discussions on the relationship between institutions and water resource management, see Helen M. Ingram et al., *Guidelines for Improved Institutional Analysis in Water Resources Planning*, 20 WATER RESOURCES RES. 323 (1984); William B. Lord, *Institutions and Technology: Keys to Better Water Management*, 20 WATER RESOURCES BULL. 651 (1984).

24. Western states using prior appropriation to govern groundwater use include Alaska, Colorado, Idaho, Kansas, Montana, Nevada, New Mexico, North Dakota, Oregon, South Dakota, Utah, Washington, and Wyoming. *See* ZACHARY A. SMITH, GROUNDWATER IN THE WEST (1989).

25. *Id.* at 9-11. California and Oklahoma apply the beneficial use doctrine in combination with a "correlative rights" doctrine that explicitly recognizes the equal priority of every overlying owner to a proportionate share of the yield of the groundwater basin. Arizona, Hawaii, and Nebraska follow the beneficial use doctrine outside designated management areas but issue restricted pumping permits within those areas. Texas has followed a rule of absolute ownership, i.e., allowing overlying landowners to pump the water beneath their land without restriction. *Id. passim.*

amounts, groundwater is more nearly an open-access resource for overlying landowners.

Water rights affect incentives to engage in conjunctive management. Well-defined rights in surface and groundwater help assure individuals and organizations that they will maintain control and thus recover benefits from the water they commit to a conjunctive management project. Allocating rights to use and to store specific amounts of ground and surface water makes it easier for individuals and organizations to decide in times of surplus to store water to meet future shortfalls.[26]

With less well-defined property rights, individuals and organizations cannot be sure they will be able to recover stored water. Before committing to a conjunctive management project, they will need to address this uncertainty. Reducing that uncertainty may mean securing commitments of cooperation from all or most other water users in a basin, assuring anyone who stores water underground that others who have access to the basin will not withdraw and use it. Such a requirement substantially increases a conjunctive management project's "transaction costs"—the resources required to identify, negotiate with, and reach and enforce agreements among the parties to an exchange or an enterprise.[27] All other things being equal, we would expect higher transaction costs to be associated with a lower frequency of successful conjunctive management, and vice versa.

Other types of institutional arrangements affecting conjunctive management are organizational. Because conjunctive management projects can involve acquiring, transporting, and storing different types of water across different delivery and storage facilities, there can be organizational complexity. Often, more than one public or private organization is involved in a conjunctive management project. All other things being equal, the more organizations that are involved in a conjunctive management project, the higher the transaction costs attending their coordination. Again, we would anticipate that high transaction costs inhibit the successful development and implementation of conjunctive management.

Mechanisms such as water banks, water districts, or special authorities can lower the transaction costs associated with conjunctive management by reducing searching, bargaining, and monitoring costs, and pooling risks. Each water user need not identify and reach agreements with all others if instead it can contract with or become a member of a bank, district, or authority that pools activities across large numbers of participants.

---

26. U.S. ADVISORY COMMISSION ON INTERGOVERNMENTAL RELATIONS, *supra* note 1, at 27-53.

27. *See generally* Michael Taylor & Sara Singleton, *The Communal Resource: Transaction Costs and the Solution of Collective Action Problems*, 21 POL. & SOC'Y 195 (1993).

Physical conditions may determine the feasibility of conjunctive management, but the barriers to its wider application are increasingly understood to be institutional.[28] The coordinated actions necessary for implementation of a conjunctive management program are more likely to occur if rules and organizational arrangements (a) protect those who invest in facilities, or who store water now for recapture later, and (b) promote coordination of actions necessary to divert, impound, recharge, store, protect, and extract water.

III. CONJUNCTIVE WATER MANAGEMENT IN ARIZONA, CALIFORNIA, AND COLORADO

The effects of physical characteristics and institutional arrangements on the adoption and development of conjunctive water management become clear through an examination of three western states. Arizona, California, and Colorado share several physical and socioeconomic characteristics:

- All three states are located in the relatively arid West. Average annual rainfall in the most populated regions of each state ranges from 8 to 12 inches in Arizona, to 12 to 20 inches in southern California and eastern Colorado.[29]
- All three states are experiencing significant pressures of growth and development. Arizona experienced 40 percent population growth in the last decade, California 13.6 percent, and Colorado 30.6 percent.[30]
- All three states experience significant water supply-demand maldistribution. Their areas of greatest water demand are located far from their areas of greatest supply.[31] All three states have attempted to address this maldistribution by tapping the Colorado River but may soon encounter stricter limits on its use.[32]

---

28. At a 1998 Workshop on Conjunctive Use convened by the National Water Research Institute and sponsored by the Association of Ground Water Agencies and the Metropolitan Water District of Southern California, participants from local, regional, and state agencies as well as the academic and consulting communities ranked "impediments to implementing a cost-effective conjunctive use water management program in California." Every one of the ten most significant barriers they identified had to do with the assignment of rights, risks, and responsibilities; the distribution of costs and benefits; and the opportunities and disincentives for inter-organizational cooperation and coordination of activities. *See* NATIONAL WATER RESEARCH INSTITUTE, *supra* note 1, at 5-39.

29. *See* Western Regional Climate Center, *Precipitation Maps of the Western U.S., at* http://www.wrcc.dri.edu/pcpn/.

30. *See* U.S. Census Bureau, *State and County Quick Facts,* http://quickfacts.census.gov.

31. *Id. See also* Western Regional Climate Center, *supra* note 29.

32. *See generally* Reisner & Bates, *supra* note 11.

All three states wrestle with increasing water demand in relatively arid environments, but some of their critical institutional and physical features differ. For example, they have different legal doctrines governing groundwater and use different types of state and local organizations for governing and managing water. That variation allows for an exploration of the effects of institutional arrangements on conjunctive water management.

A. Arizona

Conjunctive management emerged in Arizona with major changes to the state's groundwater laws in the 1980s and the arrival of Colorado River water via the Central Arizona Project (CAP) in the early 1990s.[33] Prior to 1980, when the state legislature passed the Arizona Groundwater Management Act,[34] groundwater was governed by the beneficial use doctrine.[35] Prior to the 1980s, therefore, no institutional mechanism existed to secure the rights and interests of individuals or parties who might put forth the expense and effort to store surface water underground.

The 1980 Groundwater Management Act served to quantify groundwater rights in areas of the state that have the highest agricultural and urban groundwater demands.[36] In these areas, known as Active Management Areas (AMAs), the amount of groundwater available to municipal, industrial, and agricultural users is limited based on historic use. Those limits become stricter over time in order to encourage water conservation and limit total water demand.

In 1986, the Arizona legislature explicitly encouraged conjunctive management by passing the Groundwater Storage and Recovery Projects Act, since revised as the Underground Water Storage, Savings and Replenishment Act.[37] The act authorizes private individuals and public agencies to develop projects to store water in underground aquifers through direct or in-lieu recharge.[38] The act charged the Arizona Department of Water Resources (ADWR) with developing application,

---

33. *See* Wallace A. Ambrose & Pat Lynn, *Groundwater Recharge: Enhancing Arizona's Aquifers*, J. AWWA, Oct. 1986, at 85.

34. ARIZ. REV. STAT. §§ 45-561 through 45-581 (1994 & Supp. 2000).

35. John D. Leshy & James Belanger, *Arizona Law: Where Ground and Surface Water Meet*, 20 ARIZ. ST. L.J. 657 (1988).

36. *See* ARIZ. REV. STAT. §§ 45-411 through 45-637 (1994 & Supp. 2000).

37. Originally ARIZ. REV. STAT. § 45-651; *superseded by* ARIZ. REV. STAT. § 45-801 (1994 & Supp. 2000). After the Arizona legislature had added provisions for other specific underground water storage programs between 1986 and 1993, it consolidated the programs under the 1994 Underground Water Storage, Savings and Replenishment Act. ARIZ. REV. STAT. §§ 45-801 through 45-895 (1994 & Supp. 2000).

38. ARIZ. REV. STAT. §§ 45-811.01 through 45-812.01 (Supp. 2000).

approval, and monitoring processes for these recharge projects.[39] The act also authorized private individuals and public agencies to apply to the ADWR for water storage permits in order to store specific amounts of water in their own or others' underground storage projects.[40]

The ADWR has developed and implemented the application processes to approve underground water storage projects and permits. Applicants for direct recharge projects must (1) demonstrate the hydrologic and technical feasibility of the recharge facility, (2) describe the proposed facility and its potential impacts, (3) include monitoring and contingency plans, and (4) demonstrate compliance with water quality laws.[41] Permit applications for in-lieu projects must demonstrate that a particular groundwater user will reduce pumping by an amount equal to the replacement surface water provided.[42] The parties engaging in storage or supplying water for indirect groundwater savings receive credits from the state for future recovery of that water, and those permits are transferable within the project's AMA.[43]

Arizona water users began to take advantage of the opportunity to develop water storage projects in the 1990s, after the ADWR began developing assured water supply rules pursuant to the 1980 Groundwater Management Act.[44] The rules require all non-agricultural water retailers (*i.e.*, primarily municipal water utilities and private water companies serving urban areas) to demonstrate a 100-year supply of water sufficient to cover all new and existing uses.[45] The 100-year water supply, however, cannot consist of mined groundwater.[46] This requirement spurred the interest of large urban water suppliers in developing water storage projects and permits they could use to show an assured future water supply. Table 1 shows a rapid increase in the amount of water stored underground in Arizona after the assured water supply rules were published in 1992.

---

39. *Id.*

40. ARIZ. REV. STAT. § 45-831.01 & § 45-871.01 (Supp. 2000).

41. *See* ARIZ. REV. STAT. § 45-811.01 (Supp. 2000); ARIZ. DEP'T OF WATER RES., APPLICATION PACKET FOR UNDERGROUND STORAGE, SAVINGS AND REPLENISHMENT PROJECTS (1997) [hereinafter APPLICATION PACKET].

42. *See* ARIZ. REV. STAT. § 45-812.01 (Supp. 2000); APPLICATION PACKET, *supra* note 41.

43. *See* ARIZ. REV. STAT. §§ 45-831.01 through 45-832.01 (Supp. 2000); APPLICATION PACKET, *supra* note 41.

44. ARIZ. REV. STAT. §§ 45-401 through 45-704 (1994).

45. ARIZ. REV. STAT. § 45-576 (2000).

46. ARIZ. REV. STAT. § 45-561 (2000). "Mined groundwater" is groundwater extracted in greater amounts than will be replenished naturally or artificially.

TABLE 1. Total Groundwater Recharge in Arizona by Active Management Area 1989-1997 (in Acre-Feet)

	Active Management Area				
	Phoenix	Pinal	Tucson	Prescott	Statewide Totals
1989	775.43	175.00			950.43
1990	2,038.35	105.00	2,316.80	2,131.00	6,591.15
1991	1,838.83	190.00	2,500.00	2,128.00	6,656.83
1992	80,960.10	155,377.00	2,408.00	2,559.00	241,304.10
1993	123,640.08	215,206.00	2,618.00	2,272.00	343,736.08
1994	71,431.09	33.00	3,464.60	531.00	75,459.69
1995	132,548.14	43,625.00	13,160.00	875.00	190,208.14
1996	161,680.32	55,947.00	22,129.30	1,329.00	241,085.62
1997	314,256.61	145,438.00	34,812.40	1,510.00	496,017.01
Total	889,168.95	616,096.00	83,409.10	13,335.00	1,602,009.05
Recovery to Date	(33,086.00)	(325.00)	(20,809.70)	-----	-54,220.70
Net Recharge	856,082.95	615,771.00	62,599.40	13,335.00	1,547,788.35

To assist smaller entities, such as residential housing developers and small water companies, in meeting the assured water supply rules, the legislature authorized the creation of the Central Arizona Groundwater Replenishment District in 1993 as a subdivision of the Central Arizona Water Conservation District, which manages the CAP.[47] The conservation district develops stored water credits through conjunctive management projects, and smaller entities that do not have their own storage projects can acquire stored water credits by contract with the district.[48]

In 1996, the state encouraged additional underground water storage by creating the Arizona Water Banking Authority.[49] The state legislature formed the Authority—sometimes called the "state water bank"—to store Arizona's currently unused Colorado River allotment being delivered by the CAP.[50] The water bank is authorized to use CAP water in direct and in-lieu recharge projects.[51]

---

47. *See* ARIZ. REV. STAT. §§ 48-4401 through 4404 (2000).

48. *See* ARIZ. REV. STAT. § 48-4462 (2000).

49. *See* ARIZ. REV. STAT. § 45-2401 (Supp. 2000).

50. *See id.*

51. *See id.* The Authority is also authorized to store water underground for entities in California and Nevada. ARIZ. REV. STAT. § 45-2471 (Supp. 2000). The logic for these provisions is as follows: These three states share the lower Colorado River as their borders, and have

The creation of the Central Arizona Water Conservation District and the Arizona Water Banking Authority appears to have had the intended effect. Table 2 shows that the two agencies combined had accumulated more than one million acre-feet of water storage credits through 1997.

TABLE 2. Arizona's 1997 Long Term Storage Credits by Provider Type, in Acre-Feet (AF)

Entity Type	Long Term Storage Credits (AF)	Percent of Total Credits
State Special Districts (AWBA & CAWCD)	1,065,763	70 percent
Municipal	405,033	27 percent
Irrig/Water/Utility Districts	29,150	2 percent
Private Corp/Individuals	12,442	1 percent
Total	1,512,388	100 percent

As of 1998, the ADWR has issued permits for 42 groundwater recharge projects.[52] More than half of those projects have been in operation for less than five years. The remaining projects have operated for five to ten years. Because they are relatively new, nearly 40 percent of the projects have only stored a few hundred acre-feet of water.

All of Arizona's projects are located within the state's AMAs. Table 1 shows the amount of groundwater recharged and recovered across each of the AMAs over the past decade. The AMAs are the only basins in Arizona where groundwater rights have been quantified. Thirty of the 42 projects are located in the Phoenix AMA, which encompasses the East and West Salt River groundwater basins that underlie the Phoenix metropolitan area. Seven other projects are in the Tucson AMA, four in the largely agricultural Pinal County AMA, and one in the Prescott AMA in northern Arizona.

In-lieu projects represented just under half (40 percent) of the number of underground storage or savings projects, but accounted for nearly 70

allocations of Colorado River water that are governed by interstate compact. Neither California nor Nevada have as much underground storage capacity close to the river as Arizona does, but if all three states could capture and store surplus Colorado flows underground in Arizona during wet years, they would be able in future dry years to recover the stored underground water and exchange it for different allocations of diminished Colorado River flows. Both the Metropolitan Water District of Southern California and the Southern Nevada Water Authority have been negotiating the terms of such arrangements with the Arizona Water Banking Authority, but to date no water has been stored pursuant to this provision.

52. Data on the number of permitted projects, length of permits, and permitted capacity was compiled from the ARIZ. DEP'T OF WATER RES., Q. STATUS REP. UNDERGROUND WATER STORAGE, SAVINGS, AND REPLENISHMENT PROGRAM, SECOND QUARTER (1998). The number of permitted projects is subject to change each quarter as permits expire and new projects are permitted.

percent of the storage capacity for conjunctive management projects in the state.[53] The in-lieu projects in Arizona account for this disproportionately large share for two reasons. First, nearly all of the in-lieu projects are in agricultural areas, and irrigated agriculture represents most of Arizona's water use.[54] Second, CAP water represents most of the surplus surface water available in Arizona, and agricultural users have been more willing than municipal and industrial users to use CAP water.[55]

In 1998, the most recent year for which complete data were available, 31 organizations held permits issued by the ADWR to participate in 42 conjunctive management projects.[56] These organizations include the Central Arizona Water Conservation District, the Arizona Water Banking Authority, municipalities, irrigation districts, and private companies. Through 1997, more than 1.5 million acre-feet of long-term groundwater storage credits were developed by these various organizations. With its CAP supplies, the state water bank provides water to more projects than any other organization in the state. Table 2 shows that as of 1997, the Central Arizona Water Conservation District, which manages the CAP, and the Arizona Water Banking Authority combined held 70 percent of the credits in Arizona for long-term storage of water underground.

The majority of Arizona's conjunctive management projects are managed by cities or water districts with access to project water supplies, primarily the CAP and the Salt River Project's Salt and Verde River supplies. In fact, over 60 percent of the permitted projects in 1998 were for storage or use of CAP water.[57] Treated effluent was the only other main source of water for conjunctive management projects in the state.

Given the limited surface water supplies in the state, the potential for continued conjunctive use over the next 20 to 30 years appears largely dependent on the state's ability to store unused Colorado River allocations conveyed by the CAP. For the year 2000, the Arizona Water Banking Authority planned to bank approximately 290,000 acre-feet of Arizona's surplus Colorado River water.[58] Over the next 20 years, the Authority may be able to store at least eight million acre-feet of excess Colorado River

---

53. *See* Tanya Heikkila, *The Role of Boundaries and Coordination in Conjunctive Management: A Cross State Comparison*, *in* MANAGING COMMON POOL RESOURCES IN A PUBLIC SERVICE INDUSTRY: THE CASE OF CONJUNCTIVE WATER MANAGEMENT (2001).

54. According to the ADWR, water demand in 1995 across the four AMAs totaled over 3 million acre-feet. Among the agricultural, municipal, industrial, and Indian sectors, agriculture was the highest water use, consuming 62 percent of the total AMA demand. Ariz. Dept. of Water Res., *Overview of AMAs*, http://water.az.gov (2000).

55. Lower Colorado River water (CAP water) is notoriously high in minerals and salts that have made it less attractive to urban users.

56. *See* Heikkila, *supra* note 53.

57. *See id.*

58. *See* ARIZ. WATER BANKING AUTH., ANNUAL REPORT 1999, at 12 (2000).

water to meet Arizona's future needs. Until the state's CAP allotments are fully utilized, most of these credits will remain in long-term storage accounts.[59]

After that, the prospects for large-scale water storage are less clear. Water demand forecasts for the next 50 years would indicate shortages of CAP water beginning around 2025.[60] Once shortages begin, the Arizona Water Banking Authority is obligated to transfer its credits to the Central Arizona Water Conservation District to meet demands of CAP contractors. The state has considered additional options such as establishing a credit loan program to municipal and industrial users or creating a credit pool that could be used when lower priority CAP allocations become unavailable.[61]

It is also possible that conjunctive management efforts in Arizona will be re-focused in the future on seasonal storage and recovery programs. Seasonal or cyclical storage and recovery may be the area where future institutional changes could be targeted in order to prevent the state from becoming reliant on groundwater mining once Colorado River allotments are fully used. The state's ability to manage its ground and surface supplies efficiently in the future also will depend on how the state addresses water demand factors such as urban growth.

B. California

While conjunctive management in Arizona is relatively new and state-driven, conjunctive management has a much longer and more decentralized history in California. Water providers in the Los Angeles area, for example, started experimenting with artificial groundwater recharge in the 1920s.[62] Since these early efforts, California's conjunctive management programs have used a wide variety of techniques, including injection well recharge, basin and streambed recharge, water banking, and in-lieu exchanges.[63]

Conjunctive management programs in California operate within a complex system of institutional arrangements governing surface and groundwater resources. California water law contains separate systems for surface water rights and groundwater rights. Recognized surface water

59. *See id.* at 16. It is also possible that some stored water could be exchanged with California or Nevada if water conditions on the Colorado River warrant. *See* ARIZ. REV. STAT. § 45-2471 (2000).

60. *See* Frank Metzler & Tom Carr, *CAP Supply for the 21st Century: Taking Our Droughts to the Bank, in* WATER AT THE CONFLUENCE OF SCIENCE, LAW, AND PUBLIC POLICY: PROCEEDINGS OF THE ELEVENTH ANNUAL SYMPOSIUM, ARIZONA HYDROLOGICAL SOCIETY 240, 240 (1998).

61. *See* ARIZ. WATER BANKING AUTH., *supra* note 58, at 17.

62. *See* Blomquist *supra* note 17, at 73.

63. *See* STEVE BACHMAN ET AL., CALIFORNIA GROUNDWATER MANAGEMENT 65 (1997).

rights include riparian rights of landowners adjacent to a stream and appropriative rights to divert water for use on non-adjacent land.[64] Appropriative rights to surface water use are determined by the state through a permit process administered by the California Water Resources Control Board.[65]

Groundwater rights are recognized and allocated by a multi-faceted, and sometimes overlapping, set of rules. Together, they present something like a body of "common law," made and enforced primarily in the courts, with little or no statutory guidance. Because different court-decreed allocations of groundwater have been issued in different circumstances, all of the following possibilities for acquiring and defending rights of groundwater use exist and may apply in California:[66]

- Overlying landowners enjoy non-quantified, correlative rights to pump groundwater for beneficial use on their overlying land.[67]
- If overlying owners' uses do not exhaust the aquifer's sustainable yield, there remains some amount of "surplus" groundwater left for capture by others. They may appropriate this surplus groundwater by pumping it and delivering it to non-overlying lands or to lands they do not own (municipalities or agencies supplying water to their residents are typical appropriators). Decreases in the surplus result in elimination of appropriators in reverse order of seniority, and ultimately in the elimination of all appropriators in order to assure supplies for overlying owners.[68]
- Overlying owners and senior appropriators cannot sleep on their rights, because a taking of non-surplus groundwater notoriously and continuously for several years may ripen into a superior prescriptive right.[69]
- In a few locations in California, even overlying, appropriative, and prescriptive rights must yield to the special case of pueblo water rights that trace back to the time of Spanish occupation.[70]

---

64. *See* CAL. WATER RES. CONTROL BD., THE WATER RIGHTS PROCESS (1994).

65. *Id.*

66. *See* ARTHUR L. LITTLEWORTH & ERIC L. GARNER, CALIFORNIA WATER (1995); *See also* WILLIAM BLOMQUIST, PH.D., WATER SECURITY AND FUTURE DEVELOPMENT IN THE SAN JUAN BASIN: THE ROLE OF THE SAN JUAN BASIN AUTHORITY (1998).

67. *See* Tehachapi-Cummings County Water Dist. v. Armstrong, 122 Cal. Rptr. 918, 924 (Ct. App.1975).

68. *See* Corona Foothill Lemon Co. v. Lillibridge, 66 P.2d 443, 446-48 (Cal.1937); Cal. Water Service Co. v. Edward Sidebotham & Son, Inc., 37 Cal. Rptr. 1, 7 (Ct. App. 1964).

69. *See* City of Pasadena v. City of Alhambra, 207 P.2d 17, 29-30 (Cal. 1949).

70. *See* City of Los Angeles v. City of San Fernando, 123 Cal. Rptr. 1, 22-42 (1975).

- Any individual or organization that imports water into a watershed for use upon the land also has a right to pump and use the return flows of their imports.[71]
- Pumping rights (based on any of the above theories) have also been secured by adjudication. These quantified rights may derive from a stipulation among the parties, or from a determination by the court.[72]

Since most types of conjunctive management operations involve or require some control of stored groundwater, California's groundwater governance can hamper conjunctive management programs. In many basins, overlying landowners and appropriators have insufficient assurance that water they place in storage will be available later for pumping and delivery.

California's governance of groundwater occurs almost entirely through local public and private entities. In keeping with the state's strong tradition of local home rule, groundwater management has been established and organized (where it exists at all) through locally-created arrangements such as water users' associations, local special districts, and joint-powers agreements among other local governments.[73] There is no comprehensive network of state or local governments responsible for managing groundwater supplies or protecting groundwater quality, so there are many groundwater basins in the state for which no organization has yet been created to serve those purposes.[74] Where such organizations have been established, water users have done so in response to particular local conditions and needs. As a result, groundwater management entities in California exhibit a variety of forms.

These institutional conditions regarding water rights and groundwater organizations in California help to explain why conjunctive management has not been implemented in many actively used groundwater basins, even where it would be physically feasible and arguably desirable.[75] In our research, we selected a sample of 70 groundwater basins in California[76] and

71. *See id.* at 13-14.
72. Blomquist, *supra* note 17, at 75 *et seq.*
73. *Id.* at 5.
74. *See* BACHMAN ET AL., *supra* note 63, at 97.
75. *See generally* Natural Heritage Institute, *supra* note 16.
76. We conducted a cluster sample of California's population of 450 groundwater basins, identifying 30 percent of the basins in each of the state's hydrologic regions. We excluded from the population some hydrologic areas where conjunctive management was physically not feasible due to aquifer characteristics. The initial sample resulted in 70 basins. From this sample, we identified basins where conjunctive management was occurring and not occurring.

found only 12 containing conjunctive management projects.[77] Within those 12 basins were 34 active projects on which we collected information. Through secondary sources, conjunctive management programs were found in three more basins in our sample, but we do not have data on the projects in those basins.[78] Table 3 summarizes the conjunctive management projects occurring in our California sample, including (a) the number of basins sampled in each hydrologic region, (b) the number of sample basins with conjunctive management projects, (c) the number of projects operating in the sample basins, and (d) the average number of acre-feet of water per year going into the projects.

Notably, each of the twelve basins where we collected data on conjunctive management projects has some form of locally-initiated basin-wide governance institution such as a special water district or a basin adjudication. We found no conjunctive management projects in basins that lacked basin-scale arrangements for governing groundwater use.

Of the 34 conjunctive water management projects in these twelve basins, 19 were operated by a single organization, 13 involved two to four organizations, and the remaining two involved five or more organizations. This finding is consistent with the expectation that the involvement of larger numbers of organizations raises the transaction costs of designing and operating a conjunctive management project and, all other things being equal, makes such projects less likely to develop.

On the other hand, the number of participants in a conjunctive water management project was weakly related to the amount of water stored in the project. In other words, the larger the conjunctive management project, the more likely it was to have multiple participating organizations. Projects annually storing less than 10,000 acre-feet of water average 1.6 participants.

77. The twelve basins in our sample with conjunctive management programs were Antelope Valley basin (Los Angeles County), Carmichael portion of Sacramento River basin (Sacramento County), Lower Mojave River basin (San Bernardino County), Modesto basin (Stanislaus County), Orange County Coastal Plain (Orange County), Salinas Valley basin (Monterey County), Santa Margarita River basin (San Diego and Riverside counties), Santa Maria Valley basin (Santa Barbara County), Suisun-Fairfield Valley basin (Solano County), Tulare Lake basin (Kings County), and Ventura Central basin (Ventura County).

78. Our number of basins with active projects may underestimate the extent of conjunctive management in California. Because we sampled randomly, our sample of 70 basins included at least 15 that are undeveloped in remote regions of the Sierra Nevada Mountains and the Mojave Desert and are far from urban or agricultural centers.

TABLE 3: Conjunctive Water Management Activities in Sample of 70 California Groundwater Basins, by Region

Hydrologic Region (& Counties)	# of Basins in Sample	# of Sample Basins With CWM Projects	# of CWM Projects Identified in Sample	Estimated Acre-Feet of Water per Year in CWM Projects
San Francisco Area	8	1	1	5,500 AF
Central Coast	8	2	4	164,050 AF
South Coast (LA, Ventura, Orange, SD)	13	5	17	613,900 AF
Sacramento Area	10	1	1	9,600 AF
San Joaquin Valley/Tulare Lake	10	3	9	468,500 AF
South Lahontan (Mojave, Mono, San Bernardino)	13	2	1	0 AF (new project)
Colorado Desert (San Bernardino, Riverside, Imperial)	8	1	1	3,700 AF
Totals	70	15	34	1,265,250AF*

* Data missing on projects in 3 basins.

Projects annually storing more than 10,000 acre-feet of water average 2.2 participants.

Relying solely on local institutions for governing groundwater and for organizing conjunctive management projects may have limited the number of locations with conjunctive management programs in California. Nevertheless, our data show that local arrangements are capable of producing extensive and enduring conjunctive management programs. To put it another way, California's basin-by-basin decentralized approach may make it harder to initiate conjunctive management projects, but it does not inhibit the size or longevity of those that emerge. Illustrating this point, the total quantity of water used for conjunctive management just in the California basins in our sample nearly matched the entire amount stored in Arizona's more comprehensive state-directed program, and our California sample does not include all of the basins in the state with conjunctive management programs.[79]

TABLE 4: California Conjunctive Management Projects by Type and Water Use, in Acre-Feet (AF)			
Project Type	**Frequency**	**percent of Total Projects**	**Av. Volume of Water per Year**
In-Lieu Groundwater Savings	14	41 percent	479,250 AF*
Direct Recharge (Spreading Basins or Injection Wells)	12	35 percent	400,400 AF
Return Flow Recharge (Excess Irrigation or Controlled Dam Releases)	5	15 percent	377,100 AF
Draw-Down of Groundwater Table to Allow for Surface Water Irrigation	2	6 percent	5,500+ AF**
Groundwater Pumping for Surface Water Supplements	1	3 percent	3,000 AF
Sample Basin Totals	34	100 percent	1,265,250 AF

* Missing data on 2 projects
**Missing data on 1 project

Conjunctive management methods in California are diverse, addressing the different types of water supply problems faced by water users. Table 4 summarizes the methods used in the 34 projects that are operated in the basins in our sample. As in Arizona, in-lieu projects were common, especially in agricultural areas. These projects can be less expensive to start and maintain, since they do not require as many physical facilities as direct recharge projects (*e.g.*, percolation ponds and injection wells).

Direct recharge methods are used in about 35 percent of the projects on which we gathered data. They were somewhat more common in heavily urbanized areas; most are in southern California's metropolitan areas and coastal communities. Our interviews with project managers and water users indicated that direct recharge allowed local water providers the opportunity to store water for times of drought or to avert seawater intrusion in coastal basins. This method also allows municipalities or water districts to use

79. For example, our sample did not include a number of basins along the central and southern California coast with long-standing conjunctive management programs, or some large-scale programs in the Central Valley such as the Kern Water Bank.

treated effluent as a source of recharge water, which promotes water reuse and conserves native and imported supplies.

A third conjunctive management technique that comprises about 15 percent of the projects in the sample of California's groundwater basins is "return flow" recharge. Irrigation districts or large-scale surface suppliers are the most common types of organizations that use this technique. The benefit of return flow recharge is that it requires little or no additional infrastructure to store water underground where it is feasible to use. Return flow projects take advantage of the portion of water diversions or reservoir releases that, after being used for irrigation, returns naturally underground through the soil. Irrigators or water agencies using this method then recover percolated water through pumping when surface flows are scarce.[80]

The diversity of conjunctive management methods at work in California reflects a tailoring to local circumstances, which is consistent with the state's basin-by-basin decentralized approach. It also reflects a diverse array of recharge water supplies. A variety of sources of water were used for groundwater recharge in the 34 conjunctive management projects in our California sample. Five of the projects combined multiple sources of water for basin recharge.

Fifteen projects use imported water from one of the state's major water projects, including the Metropolitan Water District of Southern California's Colorado River aqueduct, the State Water Project operated by the California Department of Water Resources, and the Central Valley Project managed by the U.S. Bureau of Reclamation. Water from these three projects represents the largest recharge water source in our data, about 41 percent of all the water used for conjunctive management. Fourteen projects use water from local rivers and streams that are native to project basins. Five projects also use treated effluent or storm water. Four projects rely primarily on groundwater for supplemental pumping or conservation.

Although major surface water projects provide the bulk of recharge water in the California projects we studied, the agencies that manage these facilities—Metropolitan Water District, California Department of Water Resources, and the U.S. Bureau of Reclamation—generally do not operate the conjunctive management projects. They are involved directly in only three of the 34 projects on which we collected data. More often, these big suppliers sell water to local agencies that use it for conjunctive management.[81]

---

80. This is also referred to as "passive recharge." *See* Todd & Priestaf, *supra* note 1, at 140.

81. A supplemental observation is appropriate for Metropolitan Water District of Southern California, since it has facilitated local conjunctive management projects by providing replenishment water at a discounted rate and by constructing or financing some of the facilities (especially pipelines) used by local agencies for their conjunctive management projects. *See* METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA, *supra* note 18, at E-14.

California's locally-driven conjunctive management projects are highly basin-specific, with few or no cross-locality arrangements for storing or sharing water supplies. The state's basin-by-basin approach has probably contributed to the state's under-realized conjunctive management potential.[82]

As we have noted throughout this discussion, California's approach raises the costs of putting conjunctive management endeavors together. California's approach also virtually assures that conjunctive management is developed only in locations where the benefits from conjunctive management appear to be large enough to offset the substantial costs of assembling and maintaining the inter-organizational coordination needed to accomplish conjunctive management. These include locations where groundwater overdrafting has been severe and sustained enough to yield harmful effects such as drying up of wells, subsidence of overlying lands, or intrusion of seawater in coastal aquifers.

Finally, conjunctive management projects in California are typically designed to provide protection of multiple interests. In the absence of a state-directed conjunctive management policy, such as the one in Arizona, conjunctive management programs are likely to emerge only when those who share access to and rights in the groundwater resource can reach agreement on how to use it for storage and recovery. California's approach therefore virtually assures that no basin-wide groundwater management programs, including conjunctive management, will be implemented unless multiple interests have been accommodated. A substantial benefit of this approach, on the other hand, is the noteworthy long-term stability for conjunctive water management programs that have been implemented in the state.

C. Colorado

In Colorado, conjunctive management emerged in the 1960s as a means of resolving intense conflict between surface water and groundwater rights holders in the watersheds of the South Platte and Arkansas rivers. These are the major rivers in the eastern half of Colorado, and both are hydrologically connected to groundwater. The South Platte River is connected to a groundwater aquifer estimated to contain approximately eight million acre-

---

82. *See, e.g.*, Natural Heritage Institute, *supra* note 16.

feet of water.[83] The Arkansas River is connected to an aquifer estimated to contain approximately two million acre-feet of water.[84]

Colorado's prior appropriation doctrine allocates water rights on the basis of seniority for both surface water and tributary groundwater.[85] Since surface water was developed first, most surface water users are senior to most tributary groundwater rights holders. This has rendered much of the tributary groundwater in the South Platte and Arkansas River basins inaccessible, due to the interaction between the seniority system of Colorado law and the hydrologic connection between surface and groundwater in these watersheds. As such, pumping tributary groundwater along the rivers lowers surface water flows and can even dry up the stream, thus invading the senior rights of surface water users. In Colorado, the tradeoff between groundwater and surface water is clear. Protecting surface water rights holders forecloses access to much of the groundwater in the aquifer because intensive groundwater pumping injures the rights of surface water appropriators.

This tradeoff between surface water and groundwater became apparent in the 1950s when Colorado suffered a sustained drought. The problem became acute in the 1960s. During the drought, farmers who had not previously relied on groundwater drilled wells and began pumping.[86] This trend continued through the 1960s. From 1940 to 1972, the number of irrigation wells in the Arkansas River basin alone skyrocketed from 40 to 1,477.[87] The effect on surface water flows was evident by the 1960s, and surface water rights holders began to demand protection of their senior rights.

In the summer of 1966, the Colorado State Engineer ordered 39 wells in the Arkansas River Valley shut down in order to satisfy senior rights holders.[88] This action triggered intense conflict, which the Colorado legislature partially tried to resolve by incorporating tributary groundwater use into the state's prior appropriation system.[89] The theory behind this legislation was that an integrated system of water rights would clarify the relative priority of all surface and groundwater users within the same watershed, conferring appropriative rights upon groundwater pumpers

83. *See* Lawrence J. MacDonnell, *Colorado's Law of "Underground Water": A Look at the South Platte Basin and Beyond*, 59 U. COLO. L. REV. 579, 585 (1988).

84. *See* David L. Harrison & Gustave Sandstrom, Jr., *The Groundwater–Surface Water Conflict and Recent Colorado Water Legislation*, 43 U. COLO. L. REV. 1, 14, n.45 (1971).

85. *See* Smith, *supra* note 24, at 75-78.

86. *See* MacDonnell, *supra* note 83, at 582.

87. *Id.* at 592, n.9.

88. *See* G.E. RADOSOVICH ET AL., EVOLUTION AND ADMINISTRATION OF COLORADO WATER LAW: 1876-1976, at 139 (1976).

89. *See* Harrison & Sandstrom, *supra* note 84, at 20-22.

while still protecting senior surface water users. Of course, the historical development of water use in eastern Colorado still guaranteed the senior position and, thus, legal priority of surface water use.[90]

The interviews we conducted and the data we collected in Colorado found that conjunctive management has become the means by which junior appropriators, mostly well pumpers, continue to use water while satisfying the rights of senior appropriators. We found that conjunctive management in Colorado is employed almost exclusively to supplement the flows of surface streams. Our interviews also found that, by volume, the dominant type of conjunctive management in Colorado is in-lieu as opposed to direct recharge. Pumpers of tributary groundwater offset their diminution of surface water flows by acquiring additional surface water and placing it under the control of the State Engineer, who releases it in the stream at the time and place that senior surface water appropriators require it. This practice is called "stream augmentation" or "replacement."

Temporary plans of augmentation and replacement plans are the institutional arrangements through which Colorado's form of conjunctive management is implemented.[91] Temporary plans of augmentation are allowed in the South Platte basin.[92] A pumper who wishes to continue or increase pumping, but would risk invading senior rights, submits an augmentation plan to the State Engineer's office for approval. If the plan is approved, the pumper must annually provide the State Engineer with estimates of the amount of water to be pumped and the amount of water that it will make available to the division engineer for the South Platte basin to be placed in the river to satisfy senior appropriators.[93] When temporary augmentation plans were first created in the 1970s, the State Engineer required augmenting five percent of pumped tributary groundwater.[94] That is, a pumper with an approved augmentation plan would have to provide the State Engineer with a volume of water equal to five percent of the amount pumped. Currently, about 30 percent of the water pumped must be augmented.[95]

---

90. In both the Arkansas and South Platte basins, individuals with surface water rights dating to the mid-1880s or earlier are generally assured that at least a portion of their right will be satisfied even during peak summer demands. Groundwater use was not widespread until the 1950s.

91. *See* GEORGE VRANESH, COLORADO WATER LAW 407 (1987); *see generally* COLORADO STATE ENGINEER, AMENDED RULES AND REGULATIONS GOVERNING THE DIVERSION AND USE OF TRIBUTARY GROUNDWATER IN THE ARKANSAS RIVER BASIN (1996).

92. *See* MacDonnell, *supra* note 83, at 589-90.

93. *Id.* at 597-98.

94. Interview with Jim Hall, Colorado State Engineer's Office, in Loveland, Colo. (Oct. 1998).

95. *Id.*

In the Arkansas River basin, replacement plans are used to accomplish similar purposes.[96] Entities operating under replacement plans must acquire and make available to the water engineer of the Arkansas basin a specific volume of water that is equal to a specific portion of the water pumped by each well.[97] The percentage of water that must be replaced for each well depends on the use of the well. If the well is used to supplement surface water, 30 percent of the water pumped must be replaced to the Arkansas River; if the well is the sole source of supply, 50 percent of the water pumped must be replaced; and if the well is used for sprinkler irrigation, 75 percent of the water pumped must be replaced.[98] All wells are metered, and each month the water engineer tallies the amount pumped from each well and the amount that must be replaced.

The replacement plans in the Arkansas River more accurately replace the amount of water that well pumpers take out of priority; whereas the temporary plans of augmentation in the South Platte basin provide just enough water to quiet the complaints of senior appropriators about the water used by junior well pumpers.[99] As seen from table 5, due to the larger scale of water use in the South Platte basin, more water is provided for conjunctive management purposes there than in the Arkansas basin.

In both basins, large-scale organizations have emerged to ease the burden of administrative compliance with the conjunctive management system on small irrigators. Two organizations in the South Platte basin—the Central Colorado Water Conservation District (CCWCD) and the Groundwater Appropriators of the South Platte (GASP)—cover thousands of wells under temporary plans of augmentation. Several thousand wells in the South Platte River Basin, primarily between Greeley, Colorado, and the border with Nebraska, are covered by GASP alone. To become a member, a well owner must purchase one membership for each 100 acre-feet or portion thereof that is pumped. The owner must also pay a fee equal to the cumulative annual fees charged by GASP since its inception in 1972. In addition, members pay an annual fee based on the amount they expect to pump during the year. From 1972 to 1992, the unit fee rose from $15 to approximately $120.[100]

96. *See generally* COLORADO STATE ENGINEER, *supra* note 91.

97. *See id.* at 3-4.

98. *See id.* at 5-6.

99. *See* MacDonnell, *supra* note 83, at 593.

100. *See id.* at 592; *See also* Groundwater Appropriators of the South Platte River Basin, Inc. (Introductory brochure, no title or date) (on file with author).

TABLE 5. Augmentation & Recharge Deliveries in Colorado's South Platte & Arkansas River Basins, 1994-1998,[a] in Acre-Feet

	South Platte Basin	Arkansas Basin	State Total[b]
1994			
Augmentation	95,042	8,317	108,500
Recharge	68,997	0	80,762
1995			
Augmentation	85,235	1,675	98,054
Recharge	90,141	0	105,031
1996			
Augmentation	101,864	1,865	108,712
Recharge	98,783	1,484	129,492
1997			
Augmentation	51,563	18,374	79,591
Recharge	104,672	2,128	134,801
1998	66,924	2,892	74,283
Augmentation			
Recharge	104,656	2,638	114,503
Totals	**867,877**	**39,373**	**1,033,729**

[a]Data from STATE OF COLORADO DIVISION OF WATER RESOURCES, 1998 CUMULATIVE YEARLY STATISTICS OF THE DIVISION OF WATER RESOURCES

[b]State Total includes quantities from Divisions 3, 4, and 7, which are not represented in this chart. No recharge or augmentation deliveries occur in Divisions 5 and 6.

In the Arkansas River basin, three water user associations have devised replacement plans covering a combined total of more than 2,000 wells. The Arkansas Groundwater Users Association (AGUA) and the Colorado Water Protection and Development Association (CWPDA) cover 1,819 wells located between Pueblo, Colorado, and the John Martin Reservoir west of Lamar, Colorado.[101] Depending on annual rainfall, the two associations combined make available between 33,000 and 51,000 acre-feet of water to the water engineer to replace pumping that would otherwise injure senior

101. Interview with Dale Baker, Director, Colorado Water Protection and Development Association, and Jeanette Bryan, Director, Arkansas Groundwater Users Association, in Pueblo, Colo. (Oct.1998).

rights holders.[102] Most of the replacement water is leased and comes from surface water storage and distribution projects developed by the cities of Pueblo and Colorado Springs, the Southeastern Colorado Water Conservancy District, and the U.S. Bureau of Reclamation.[103] A third organization, the Lower Arkansas Water Management Association (LAWMA), covers 640 wells located between the John Martin Reservoir and the Kansas state line. The association owns all of its replacement water, equaling about 14,000 acre-feet.[104]

These South Platte and Arkansas basin organizations substantially reduce transaction costs for junior water users and the State Engineer's office. Without them, each well owner would have to search for and negotiate agreements for surplus water and make it available to the State Engineer, who in turn would have thousands more plans to keep track of and well owners to monitor. This would be especially burdensome for the small-scale pumpers, of whom there are many; for instance, of the 173 entities that ordered replacement water from AGUA in 1998, 161 required less than 10 acre-feet of water.[105]

We found that some conjunctive management in Colorado is accomplished using direct recharge, but for the same purpose as the in-lieu program—supplementing stream flows.[106] Direct recharge occurs mostly in the South Platte River basin through decreed augmentation and recharge plans. To obtain a decree, the entity files a proposed augmentation plan with a water judge. The plan includes a listing of wells to be covered and augmentation structures to be used to recharge water to the aquifer, the methods for measuring well depletions and augmentation accretions to the South Platte River, a request for a decreed right to a portion of South Platte River water to be used for augmentation purposes, and actions the entity will take if its augmentation practices fail to fully cover its pumping in any given year.[107] If the judge finds that the plan accords with Colorado's policies of promoting the beneficial use of water while protecting the rights of senior users, he then issues a decree recognizing the augmentation plan and granting the water right for augmentation purposes.[108]

---

102. *Id.*

103. *Id.*

104. Interview with Don Higbee, Director, Lower Arkansas Water Management Association, in Lamar, Colo. (Oct. 1998).

105. Arkansas Groundwater Users Association, AGUA pumping and orders by Farm Unit (1998) (unpublished document, on file with author).

106. *See generally* JAMES W. WARNER ET AL., RECHARGE AS AUGMENTATION IN THE SOUTH PLATTE RIVER BASIN (1994).

107. *Id.* at 1.

108. *Id.* at 4.

Decreed plans of augmentation and of recharge are becoming more prevalent among irrigation districts and farmers in the South Platte River basin. For instance, we found that every irrigation district in Water District One, a subdivision of the State Engineer's office located near the town of Fort Morgan, Colorado, either already has a decreed augmentation or recharge plan or is developing one. Under a typical plan, the irrigation district diverts water from the South Platte River in the fall and spring when its right to augmentation water is in priority. The water is diverted into irrigation ditches and recharge ponds, which often are natural depressions located next to irrigation ditches. The water in the ditches and ponds then percolates into the aquifer and slowly migrates back to the river. The ponds are located and managed in such a manner that the bulk of the stored augmentation water returns to the river during the peak summer demand period to cover out-of-priority well pumping that would otherwise be shut down.[109] From 1980 through 1997, the six irrigation districts with augmentation or recharge plans have placed approximately 385,000 acre-feet of water into ditches and ponds.[110]

Conjunctive water management is going to play a central role in a number of water conflicts currently simmering in Colorado, particularly in the South Platte River basin. First, because they do not completely cover out-of-priority pumping, temporary plans of augmentation operated by the CCWCD and GASP are coming under increasing scrutiny as demand for water in the South Platte basin mounts.[111] Both organizations and the State Engineer's office are responding to pressure from senior water rights holders to increase stream augmentation. Currently, GASP, for instance, is working with irrigation districts to develop additional recharge ponds.[112]

Second, in order to protect endangered species on the Platte River in Nebraska and comply with the relatively new Platte River Cooperative Agreement between Colorado, Nebraska, and Wyoming, [113] Colorado will have to enhance South Platte River flows so more water reaches Nebraska. The state and a number of major Colorado water providers and users have

109. Interview with Bart Woodward, Director, Riverside Irrigation Company, in Fort Morgan, Colo. (Oct. 1998).

110. *See* Division One, Colorado State Engineer's Office, Diversion Summary in Acre Feet for Individual Classes of Water [All Years], Water District 1 (Jan. 1999) (unpublished document, on file with author).

111. *See* MacDonnell, *supra* note 83, at 613.

112. Interview with Jon Altenhofen, Northern Colorado Water Conservancy District, in Loveland, Colo. (July 1999).

113. Cooperative Agreement for Platte River Research and Other Efforts Relating to Endangered Species Habitat Along the Central Platte River, July 1, 1997, U.S.-Wyo.-Colo.-Neb.

collaborated on a recharge facility approximately 50 miles from the Nebraska border. Additional facilities are in the planning stages.[114]

Third, some of the fast growing Front Range cities in and adjacent to the Denver metropolitan area are beginning to experiment with the California/Arizona style of conjunctive water management that features groundwater storage. They intend to capture surplus surface water when available and store it in the deep aquifers underlying the area.[115] This approach has been less common along the Front Range, not only because water from the mountains sufficed to meet past growth in water demands, but because the Denver region aquifers are sandstone formations and harder to recharge than the sandy alluvial basins found in Arizona and California.

IV. COMPARING THE THREE STATES

The extent and types of conjunctive management activities clearly differ across Arizona, California, and Colorado. In all three states, conjunctive water management is occurring in areas of increasing water demand and limited water supplies. In Arizona, for instance, conjunctive management is occurring in the central and southern portions of the state encompassing the Phoenix and Tucson metropolitan areas and the major agricultural area between them. In California, conjunctive management is seen primarily in urbanized Southern California and the agricultural areas of the Central Valley. And in Colorado, conjunctive management occurs in the eastern half of the state, home to most of its urban population and agricultural production.

The portions of the three states where conjunctive management is most common are also best suited to it by their physical characteristics. These areas feature extensive groundwater basins, large surface water projects, and the pumps, canals, and ditches necessary to transport and deliver water over long distances. The basic physical ingredients for conjunctive water management are all in place in the areas of greatest water demand in each state.

In Arizona, the Central Arizona Project and the Salt River Project provide the primary source of water and the infrastructure necessary for conjunctive management. In California the Colorado River Aqueduct, State Water Project, and Central Valley Project and their associated facilities support conjunctive water management. Conjunctive management in

114. Interview with Jon Altenhofen, Northern Colorado Water Conservancy District, in Loveland, Colo. (July 1999).

115. *See* Denver Basin Artificial Recharge Extraction Rules, 2 Colo. Code Regs. § 402-11 (1995), http://water.state.co.us/.

Colorado's South Platte River basin incorporates the Colorado-Big Thompson Project and numerous projects developed by the Denver Water Board, while the Arkansas River basin employs the Fryingpan-Arkansas Project and numerous projects developed by the cities of Pueblo and Colorado Springs.

Although each state's physical circumstances support the development of conjunctive water management, their institutional settings—and the interactions between their physical and institutional settings—are sufficiently different to generate diverse forms of conjunctive water management. Two key comparisons indicate how the interaction of institutional arrangements and physical circumstances may aid or impede conjunctive management.

A. Purposes of and Approach to Conjunctive Management

Compared with Colorado, water users in Arizona and California are much more reliant on groundwater and surface project water than they are on local streams and rivers. Arizona and California water users also have access to large, productive groundwater basins with substantial storage capacities. Consequently, conjunctive management in Arizona and California primarily emphasizes the long-term underground storage of surplus surface project water, especially imported water. Each year in those two states, water users place hundreds of thousands of acre-feet of water underground. Nevertheless, the type and size of projects differ substantially between the two states due to the different institutional arrangements governing groundwater.

Conjunctive water management in Colorado is pursued for different reasons than in Arizona or California. Consequently, conjunctive management projects there take on distinctly different forms. For instance, in Colorado, conjunctive management is used to help protect senior surface water rights holders by providing junior rights holders access to additional groundwater pumping without diminishing the surface flows to which the senior users' rights apply. Because junior pumpers must keep their extractions from diminishing supplies that rightfully belong to senior surface water appropriators, well owners use conjunctive management to supplement stream flows, not for long-term underground water storage.

B. Water Storage and Replenishment Rights and Organizations

Compared with California, rights to groundwater in Arizona and Colorado are relatively well defined. Groundwater rights in Arizona are quantified in the most heavily used basins and include rights to store and retrieve water from underground and even to transfer stored water.

Any person or organization may acquire a recharge permit from the ADWR, recharge water into a basin, and recover that water later without fear that other basin users will claim and use that water. Consequently, projects in Arizona tend toward one or two participants who jointly fund and develop the project. Only a handful of projects are relatively large and involve multiple participants.

Furthermore, in Arizona the state-created Central Arizona Groundwater Replenishment District and Arizona Water Banking Authority acquire surplus surface water and store it underground. Individuals or organizations in need of access to stored water can contract with either state agency instead of having to devise and implement a water storage program of their own.

In Colorado, it is also possible for individual water rights holders to engage in conjunctive management with the full expectation that they will receive the benefits from it. In the South Platte River basin, mutual ditch companies, irrigation districts, and farmers have individually developed direct recharge projects to replace the water to the river taken by well pumping. These entities receive credits for the water that the recharge projects place in the river. Any credits in excess of what is needed to cover well pumping may be sold. Also, conjunctive water management in Colorado is facilitated by organizations that were formed to coordinate actions among and on behalf of numerous water appropriators. These organizations were not formed to gain control of a basin and conduct conjunctive management activities themselves, as is the case in California. Rather, these organizations were formed to lower the transaction costs of engaging in conjunctive management, thus making conjunctive management affordable for many "small" water users.

California is the reverse. The multiple property rights systems governing groundwater in California—and especially the lack of clear rights to store and recapture specified amounts of groundwater—discourage individual entities from engaging in conjunctive water management. Coordination at the basin level is necessary for entities in California to realize the benefits of conjunctive management. In most cases, this has meant that major water users in a California basin must participate in creating a basin-wide governance structure in order to provide the necessary security needed for conjunctive management plans. Only then can appropriators rest assured that they will capture the benefits of conjunctive management.

V. CONCLUSION

Conjunctive water management is a tool for enhancing water supply reliability in water-scarce areas by taking advantage of the storage capacity of groundwater basins and the cyclical availability of surface flows to maximize overall supplies. It has both economic and environmental advantages over more traditional water supply management techniques, but its use is affected by physical, financial, organizational, and institutional variables. Physical and institutional settings directly affect the extent and type of conjunctive water management in Arizona, California, and Colorado.

In closing, we emphasize a key point of comparison among the states' institutions. Institutional arrangements affect the transaction costs associated with the creation, operation, and maintenance of a project, and in so doing are likely to affect the existence and type of projects occurring. Compared with California, Arizona and Colorado have more deliberately and effectively reduced the transaction costs of engaging in conjunctive water management. Providing a system of well-defined, quantified water rights substantially reduces the costs of conjunctive water management. Entities are more nearly certain that they can capture the benefits of water placed in underground storage or of surface water–groundwater exchanges. Arizona and Colorado also have reduced transaction costs of conjunctive water management by creating and recognizing entities that pool water across multiple water appropriators, making conjunctive management available to even the very small water appropriator. California is beginning to recognize and reduce transaction costs of assembling conjunctive water management projects by reducing the need to create separate organizations for managing groundwater basins. In all three states, the use of conjunctive management as a means of meeting future water needs will continue to expand.