Water Banks: A Tool for Enhancing Water Supply Reliability

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This guidebook is part of an ongoing series intended to assist public agencies, non-profit organizations, and the private sector with design and implementation of water acquisition programs to improve water supply reliability during drought and under climate change. Other titles in this guidebook series include: *Water Auction Design for Supply Reliability: Design, Implementation and Evaluation*, which explains both the theory and practical aspects of water auctions, and *Dry-year Water Supply Reliability Contracts: A Tool for Water Managers*, which chronicles a variety of trigger-induced contingent contracts and how to implement them. All the guidebooks may be retrieved at http://www.azwaterinstitute.org/ewsrpublications.html.

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The purpose of this guidebook is to provide an overview of the roles and functions that a water bank can serve and the steps needed to create an effective water acquisition program to enhance supply reliability using a water bank. We also provide a concise menu of decision and evaluation criteria and examine design and implementation factors, as well as potential shortcomings and challenges in water bank design and operations.

Water Banking Background

Water supply availability is highly variable across seasons and years in many regions and may become even more difficult to predict as climate change progresses (Garrick and Jacobs 2006; Williams 2007). There are many approaches to address the challenges posed by supply variability. A water bank is one approach for smoothing out the effects of variability in water supplies. A water bank is an institutional mechanism designed to facilitate transfers of water on a temporary, intermittent or permanent basis through voluntary exchange.[1] Specifically, water banks are generally established to accomplish one (or more) of the following: a) create a more reliable water supply during dry years through voluntary trading; b) ensure a future water supply for various water needs; c) promote water conservation by encouraging water users to conserve and deposit conserved water into the bank; d) facilitate more active water market activity; e) resolve issues between groundwater and surface-water users; and f) ensure compliance with intrastate agreements regarding instream flows and with interstate compacts (Clifford, et al. 2004). Water banks range in geographic scale from involving local water users in a specific urban area or a county to offering services across broad regions, sometimes including several states (the Arizona Water Bank, for instance, also serves Nevada and California).

Several types of arrangements can be used to bank water. Here we discuss four key ways water banks operate to make water available for future use: surface storage in a reservoir, underground storage in an aquifer, facilitating transactions among entitlement holders, and institutional banking (i.e. water trusts).

Surface storage banking includes the storage of physical water to be used later in the year if the need arises (Clifford, et al. 2004). Because the water is physically stored, and can be accounted for, a great level of security is obtained. This may be accomplished through actual entitlement diversions to a reservoir or through "top water banking,"

[1] In any arrangement transferring water, the buyer and seller should proceed with caution. State and federal laws may limit whether a transfer may occur, the volume of a proposed transfer, or the location of transfer. Local laws should also be consulted. Further, if water is transferred interstate, a state or federal agency may be required to administer the bank.

where an annual allocation of surface water is not diverted but left in a reservoir storage for future use. However, because the water must be moved to the storage location and stored there, a fair amount of capital investment may be required in conveyance and storage infrastructure or in paying for access to existing infrastructure. Additionally, there will be transmission losses of the banked water due to percolation into the groundwater basin or evaporation into the atmosphere.

Groundwater banking and/or aquifer storage and recovery is a process of using available aquifer space to store surface water in years of surplus water availability which can then be pumped in years where water is in shortage (Semitropic 2004). Groundwater banking generally occurs in one of two ways: in-lieu (or indirect) recharge and direct recharge. With in-lieu recharge, groundwater is allowed to remain in the aquifer by substituting surface water for groundwater that would normally have been pumped. With direct recharge, water is stored in a defined recharge basin and allowed to percolate directly into the groundwater basin (Semitropic 2004). Rather than allowing excess water to passively percolate into an underlying aquifer, it is also possible to directly inject water into the aquifer, as is often done in an aquifer storage recovery program (Washington Department of Water Resources 2009).[2] An advantage to groundwater banking is that the water is physically stored with relatively low capital investment, as the aquifer is naturally occurring.[3] Additionally, by allowing the water to percolate (or be injected) into the groundwater basin, the likelihood of land subsidence is reduced.

The main limitation of groundwater banking is that groundwater rights are often poorly defined and absent legislative or judicial intervention, the "rule of capture" is often used as the means and measure of groundwater ownership (Lueck 1998). That is, because it is difficult to assign property rights in groundwater and because it is often difficult to exclude potential pumpers or limit pumping, groundwater is often managed as an open access resource. Under this arrangement, individual groundwater pumpers tend to pump "too much and too soon" (i.e. use groundwater sub-optimally). As a result, the resource tends to become depleted in a manner consistent with the so called "tragedy of the commons" (Hardin 1968).[4] In order to combat this tendency, states and water districts

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[2] Rather than storing water in a cavernous aquifer, it may be possible to store water into locally occurring sands during times of surplus and extract that water in times of shortage (Eckhardt 2009).

[3] However, sometimes the capital investment may be large. For example, the Central Arizona Water Conservation District (CAWCD) recently spent $19 million to construct its Tonopah Desert Recharge Project.

[4] As groundwater pumpers draw down the water table, the cost of pumping tends to increase with higher energy demands and in some cases wells have to be deepened or new ones drilled. Therefore, it becomes more likely that pumpers will race to capture the resource in an effort to minimize the costs associated with pumping from greater depths.

have adopted groundwater use regulations of various types with varying degrees of success in maintaining groundwater levels and minimizing drawdown. The security of water banked in an aquifer depends on the regulatory framework in place to protect banked water so that it will be available for recovery, and to prevent water contamination and excessive drawdown.[5] One practical example of such a regulatory framework is the Arizona long-term storage credit system. Depending on a particular set of criteria, underground storers of water have a right to pump the water back out of the ground (Arizona Revised Statutes 45-852.01).

A water bank may also be involved in facilitating arrangements that secure water for future use, such as water transaction or brokerage activities. A bank may operate primarily to bring together buyers and sellers, lessors and lessees, and to facilitate trades. This may be achieved by either providing a venue for buyers and sellers to exchange information such as an electronic forum where water quantities and prices may be placed for sale (or lease) and where buyers may purchase (or lease) entitlements.[6] The immediate purpose of this framework is to reduce the costs associated with water transactions (Howe and Weiner 2002). In order for this to occur, the process must be streamlined; that is, trades must be relatively easy to consummate and the process should be open to a variety of participants (irrigation districts, cities, individual irrigators, etc.).

Another water banking format is "institutional banking." Institutional banking refers to the transfer of legal documents that represent access to a specific water quantity during a specific time period (Clifford, et al. 2004). In general, institutional banking refers to holding and management of water entitlements in trust for either a predetermined amount of time or indefinitely, usually for the purposes of augmenting instream flow. Because the water is not required to be physically stored at a particular location, the large capital investment requirement characteristic of the surface storage banking format is unnecessary; however, because the water is not physically stored, the

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[5] Several[0] solutions have been proposed to combat excessive drawdown: yield stock rights, unitization, proportional rights. With yield-stock rights, individual water users in the aquifer are given property rights for a share of the groundwater. Each right has two components: 1) claim to a percentage of the annual recharge into the aquifer, and 2) claim to a percentage of the aquifer's storage or stock. The initial allocation of the water right is based on an individual's historic water use during a specific time period (Clifford, et al. 2004). Unitization, which was originally developed as a tool for managing oil reservoirs but may be extended to groundwater management, means an aquifer is operated or managed by a single firm or entity. Individual landowners within the aquifer elect a manager and the manager's objective is to ensure efficient yield production from the aquifer by regulating the spacing of wells and applying an extraction rate that maximizes long term benefits (Wiggins and Libecap 1985).[5][0] The proportional rights approach develops a market for groundwater rights that is based on a proportion of the aquifer's annual safe yield. The principal objective of this proposal is to ensure that the aquifer maintains a minimum level (Clifford et al. 2004).

[6] Another way to describe this scenario is a bulletin board system where sellers supply information to the bulletin board and purchasers may read the board and make purchase offers to sellers.

water availability is not as secure. Nevertheless, institutional banking may be attractive when the cost of capital investment is extremely high or when the main purpose is stream flow augmentation (Burke et al. 2004).

Water Banking Creation and Operation

Management and Operation

An important aspect of the water bank is the determination of who should run and operate the water bank. Generally, ownership and administration of a water bank may take one of four forms: public organization, private-nonprofit organization, private-for-profit corporation, or public-private partnership (Clifford, et al. 2004). The type of organization chosen can have a direct impact on the level of acceptance and trust that water users have. For instance, in a location where the potential water bank participants have had negative experiences with a specific federal or state agency, it would be imprudent to organize a water bank managed by that agency.[7] In some regions, there may be a widespread resistance to for-profit enterprises overseeing water matters and so a private enterprise water bank may not gain acceptance and participation. In the western United States, there exist water banks managed by federal agencies, by state agencies, by water districts, by non-profit organizations and by private firms. Examples are provided in a subsequent section of this paper. As a component of encouraging participant trust, it is important for the water bank to encourage general community acceptance. To encourage acceptance, a water bank may provide community outreach and education opportunities. Additionally the water bank should attempt to be as transparent as possible and attempt to explain the economic, environmental, and legal costs and benefits of water banking to the community. This process may be achieved through a variety of means including literature distribution, community meetings, open houses, telephone hotlines, internet websites, or any viable mechanism of information dissemination. Included in this discussion should be an explanation of whether participants risk losing their water rights by participating in the water bank under a state “use-it-or-lose-it” provision.[8] If the particular state does have a use-it-or-lose-it provision, it may be appropriate for the water bank to encourage legislation that allows participation in the water bank without the fear of forfeiting entitlements.[9]

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[7] An example of this is the Yakima Basin in Washington. In that basin, water appropriators reportedly distrust government, particularly when it is engaging in water transactions (Rux 2008).

[8] A use-it-or-lose-it provision refers to the notion that it is possible for an individual to forfeit a water entitlement simply by not using the entitlement for a period of time.

[9] It is important point is that if the participant’s water entitlement is a federal contract, the state law might not determine whether a use-it-or-lose-it provision applies; rather federal law is likely to control.

To encourage political consistency, local and state agencies may choose to promote the water bank and the benefits that are to be realized by its operation. Finally, key community members and representatives of stakeholders should be included on the board or advisory committee (Clifford, et al. 2004). This serves at least three purposes. First, by including key community members and representatives of stakeholders, the water bank appears more transparent, and thus more likely to be perceived as fair by the community. Second, the water bank will appear to the community as more legitimate, as the individuals within the community will be aware that some of the decision makers will also be impacted by the creation of the water bank. Third, information dissemination to community members is more likely to occur, trickling down from the key community members to the rest of the community.

Encourage Irrigator Participation

Because much of the banked water is likely to be supplied by the agricultural community, it is important to encourage the agriculture community to participate.[10] One way to encourage agricultural participation is for irrigation districts to promote water banking activities to their members or for the district itself to become involved by becoming buyers or sellers within the water bank (Clifford, et al. 2004). By involving entire irrigation districts, the supply (or demand) of water may become consolidated such that larger volumes of water are available (or purchased). If the bank provides temporary transfers, and assuming that a use-it-or-lose-it provision does not apply, then a mechanism for meeting new water demands without water permanently leaving the agricultural sector will become available. This alternative may be more favorably perceived than agricultural water being permanently purchased away from agricultural use because water entitlements are retained by the agricultural landowner. However, if the bank provides for permanent transfers, then market trades can be used to gauge the value of the water. Finally, it may be true that the agricultural community may benefit as a demander, because the bank may be used to provide a source of water for growers seeking water to expand operations (Clifford, et al. 2004; Howe and Weiner 2002), or provide an alternative water source during supply shortfalls. This intra-farm component is pivotal to improving relationships and encouraging trust with the agricultural community because it indicates a willingness of the water bank to sell water to the highest value use, whether that use is agricultural or dry-year municipal supply.

Strategic Policy

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[10] In the western United Stated, irrigators account for approximately 80% of freshwater withdrawals (USGS 2009).

A water bank needs a long-term strategic policy and established policies and standards for daily operations (Håkansson and Snehota 2006). The strategic policy should reflect the underlying goals and vision of the water bank. As a practical consideration, the bank must determine whether it will buy, sell and hold water itself, whether it will operate as more of a brokering service or whether it will operate in a more institutional manner (i.e. more like a water trust). This focus assists in setting the bounds of what the bank is capable of doing and may have an impact on the manner in which the bank's internal funds are distributed. To minimize the potential costs associated with potential disputes, a mechanism of dispute resolution should be created and clearly defined so that disputes can be quickly, equitably, and efficiently resolved.

Unless taxes or state appropriations support operations, as may be the case for a state funded water bank, a fee-for-service structure needs to be developed and implemented. Depending on the services that the water bank is providing, the types of transactions that are likely to take place and the particular market structure utilized, the fee structure may vary. For instance, the type of fee structure utilized by a bank engaged in physical storage may be different than the fee structure that is appropriate for a water bank engaged in brokering transactions.

Geographic Area and Eligibility

The bank ought to consider the geographic area(s) for which participants are eligible to participate in the bank. The bank should include an area large enough such that participation, and the consequent procurement of enough water to rationalize the creation of the bank, is likely. But the area should not be so large that water bank administration and resource transportation costs are overly burdensome. Additionally, it may become necessary to determine which (types) of water entitlements are eligible for participation.[11] For instance, it may be important to determine whether a particular seniority date is required in order to participate. This particular decision may turn on the type of water bank used. If the water is physically transferred and stored, the seniority date of the water entitlement may not be important so long as the storage arrangements are secure, i.e. not susceptible to being lost in flood releases. However, some water banks will want to specify an acceptable range of seniority dates given that junior entitlements may not have a reliable yield for the bank during drought.

Operational Policy and Market Creation

[11] For the purposes of this guidebook, the term "water entitlement" is a generic term referring to any type of transferrable water entitlement; including water rights defined by state law, contractual rights to water from a federal project, etc.

In order to ensure that administrative red tape is kept to a minimum, the bank should strive to provide a relatively simple method for market-based transfers, particularly for relatively short-term transfers. This is for two main reasons: first, in a relatively short-term transfer situation, the water demanded is often needed nearly immediately. Red tape and the prospect of complex transfer processes make engaging in a short-term transfer less attractive because there is a possibility that the demander will not obtain the desired water when the demander requires the water (Howe and Weiner 2002). Second, because complex transfer processes generally take longer than relatively less complex processes, the price agreed upon upfront may not accurately reflect the current market price and therefore may provide the market with skewed information. Longer transfers, of course, may require more extensive approval but may be streamlined to encourage the transfer of resources from lower- to higher-valued uses. In order to facilitate transfers, it may be prudent to establish a method of verifying bankable quantity, type of entitlement, and transfer capability of water entitlements which includes requiring evidence that shows the water right ownership is valid and in good-standing (Clifford, et al. 2004). A system of pre-approved enrollment may be developed for those who have previously participated, so long as the water entitlements are the same. Pre-approval of water rights is also essential before listing permanent transactions.

A water bank must also determine what type of market (or pricing) structure to use in order to transfer the water from willing seller to willing buyer. In order to ensure that the water market pricing mechanism is structured correctly, a set of principles should be developed that reflect the goals of the water bank (Clifford, et al. 2004). First, the market pricing structure should be developed such that the net benefits are maximized and equity among affected parties is considered. The pricing structure should encourage competitive bidding and discourage misrepresentation of values (O'Donnell and Colby 2009a). The market risks to all of the parties should be considered and the costs and risk should be spread among the bank, buyer, and seller to encourage participation (O'Donnell and Colby 2009b).

Several market structures exist that may be utilized to assist in market price determination. One market structure that a water bank may utilize is a clearing house structure (Clifford, et al 2004). Under this framework, the water bank operates as a bulletin board service that lists individually submitted water supplies available for transfer. Water demanders access the bulletin board and attempt to find a water volume (and potentially priority date and location) that they deem satisfactory. The buyer and the seller communicate via the water bank, and a transaction may or may not occur. With this method, the overall cost to run the water bank is relatively low; however, its applicability is limited by at least two factors. First, for this approach to be effective the volume of water supplied by a particular water supplier must be equal to the volume of water demanded by a particular water demander. The supplier and demander will have very little latitude to negotiate because the water bank will be reluctant to release personal supplier information to the demander (or vice versa). This leads to the second limitation: if the water bank provides enough information to the parties such that they are able to communicate with one another, then they may attempt to transact outside of the water bank. Thus, depending on how the water bank is organized, it may not receive a payment for pairing the supplier and demander.

Another structure that a water bank may use is a fixed price structure (Clifford, et al. 2004). Under this structure, the water bank sets the price of the water at the maximum price it believes it can set and still clear the market. This structure is limited in practice because the price that is set is not the market price; rather, it is merely conjecture. Additionally, because not all water entitlements carry the same value (because of seniority date) it may be necessary to have a tier of prices that reflect the relative value of rights. Therefore, the bank will be required to guess the market prices of several heterogeneous entitlements. Additionally, the price setting function of the bank may actually influence, and consequently bias, the market by establishing a price for transfers.

The water bank may use an auction market structure (O'Donnell and Colby 2009a). This can take two forms: a procurement auction form and a conventional auction form. A procurement auction, in this case, refers to the water bank obtaining volumes of water from willing sellers (bidders). The water bank's goal is to obtain a target volume of water at the lowest possible price. The information that the bidders submit includes two key pieces of information: the volume of water being offered and the price per volume of water. The auctioneer water bank either accepts or rejects bids based upon a series of predetermined criteria. The process is complicated because water and water rights are heterogeneous. For instance, there may be water quality or seniority differences that may make comparing various bids difficult. To mitigate this heterogeneity problem, it may be appropriate to have minimum standards of water quality and have a priority cut-off date.[12] Under this structure, water is supplied to the water bank, and when needed, the bank/auctioneer, commences an auction. Under a conventional auction format, the water bank is already in possession of the water (or the entitlement to the water) and auctions the water off to willing purchasers. This ensures that the highest and best economic use is achieved and it also ensures that there is a continual updating of market values

[12] For a full discussion of creating a water procurement auction, *see* O'Donnell and Colby 2009a.

(O'Donnell and Colby 2009a).[13] Finally, the water bank may use a contingent contract structure, also known as a dry-year water supply reliability contract ("reliability contract"). A reliability contract is an arrangement to transfer water that is made in advance between parties (usually an irrigation district and a large municipal water supplier), that is triggered by pre-specified low supply conditions (O'Donnell and Colby 2009b). This structure requires that individual contracts be consummated on either the irrigator or irrigation district level and as such may be prone to high transaction costs. However, because water is only transferred when it is needed, the probability of unnecessary transfers is minimized.[14]

Environmental and Third Party Impacts

Because environmental objectives are likely to be important, water banks may be required to ensure that bank exchanges do not inadvertently impact existing stream flow levels – particularly when there are federally or state set minimum stream flow levels (Burke et al. 2004). In order to facilitate this, it is important that instream flows be legally classified by applicable state or federal law as a beneficial use so that the water will not be subject to forfeiture. Additionally, the water bank should allow open participation in the bank by third parties that would like to acquire water for instream use. Also, it may be necessary to consider not only stream-flow levels, but also other potential environmental impacts of transferring water to the bank. For instance, there may be negative environmental impacts resulting from agricultural fallowing where the runoff from irrigation supported riparian habitat. In order to combat this potential issue, a mitigation fund may be developed to compensate for negative impacts from water transfers. Information should be made available to individuals that may be impacted by the water bank concerning the presence and operation of this mitigation fund.

Water bank operations may not only have environmental impacts but also third party impacts. For instance, if water is banked in lieu of agricultural production, there may be localized economic consequences. These may include a reduction of the number of individuals in the workforce in a particular community[15] which, in turn, may have a negative impact on the local economy. It is important to consider whether these impacts are likely to occur and whether it is appropriate to implement a mitigation fund to alleviate these impacts.

Costs of Administration and Monitoring

[13] It may be possible to combine both the procurement and conventional auction into what is called a double-sided auction (Hartwell and Aylward 2007).

[14] For a full discussion of dry-year water supply reliability contracts, *see* O'Donnell and Colby 2009b.

[15] For example, it has been reported that 450 jobs were lost in Yolo County, California as a result of California's 1991 Drought Water Bank (McClurg 1992).

It is important to consider what administrative costs will be incurred by the bank and determine whether the benefits attributable to the water bank exceed the operational and administrative costs. In each case, there will be costs associated with developing the appropriate structure and operating framework (Clifford, et al. 2004). There will be costs associated with the process of implementation and analysis. Because education and outreach is an important component to the creation of a successful water bank, it may be necessary to fund a public awareness campaign. This may be as relatively costless as recruiting and training volunteers to go door-to-door or as costly as creating a workable webpage; regardless of the methods chosen, there are likely costs associated with the campaign. Additionally, there will be costs associated with record keeping and reporting. This will include costs associated with record keeping of deposits, updating databases of potential buyers and completed transactions and also reporting to stakeholders.

Examples of Water Banks

The following section provides brief descriptions of a variety of water banks that have been implemented, are currently operating, or have been proposed. This section highlights key aspects of water bank design and implementation and illustrates an array of types of banks.

Arizona Water Bank

The state of Arizona conducts water banking operations through the Arizona Water Banking Authority (AWBA) in order to store water (underground) and utilize the state's entire 2.8 million acre-foot entitlement of Colorado River water (Guenther 2008). Created in 1996, the AWBA stores Arizona's unused Colorado River water entitlement to meet future needs for: 1) Firming (to secure) adequate water supply for municipal and industrial users in the Central Arizona Project (CAP) service area and along the Colorado River in times of shortages; 2) Meeting the management plan objectives of the Arizona Groundwater Code; 3) Meeting the State's obligation pursuant to Indian water rights settlements; 4) Assisting the Colorado River fourth priority municipal and industrial users in developing credits that could be used to increase their future supplies for firming; and 5) Assisting Nevada and California through interstate water banking (Guenther 2008).

The Arizona Water Banking Authority (AWBA) operates not as a market mechanism or a facilitator of transfers between buyers and sellers; rather, it operates as a system of storage facilities. The AWBA purchases excess CAP water or effluent and the price that AWBA pays is set annually by the Central Arizona Water Conservation

District (CAWCD) (Clifford et al. 2004).[16] AWBA can not own, develop, operate or construct storage facilities but has obtained permits to reserve storage capacity in all state facilities (Clifford et al. 2004). Stored water refers to the amount of accrued long-term storage credits. These credits will equal the purchased quantity minus delivery conveyance losses and the statutory five percent contribution to the aquifer for maintaining the long-term health of the ground water system (Clifford et al. 2004). AWBA cannot be the entity which recovers the water. Instead, the storage credits are transferred to either the Arizona Department of Water Resources or the Central Arizona Groundwater Replenishment District CAGRD. The Arizona Department of Water Resources could acquire these storage rights and extinguish them whereby leaving the water permanently in the aquifer as a water management tool. CAGRD would acquire the storage credits during dry years and recover the water to meet the water demands of the CAP subcontractors (Clifford et al. 2004).

AWBA also participates in an interstate water management function for the benefit of the state of Nevada. In this arrangement, Arizona stores available Colorado River water (up to 1.25 million acre feet) apportioned to Nevada in an underground aquifer. Nevada then receives credits for the water stored underground. When Nevada needs to recover some of this banked water, it uses its storage credits and withdraws a portion of Arizona's Colorado River water directly from Lake Mead. Arizona then withdraws the same amount of water from its groundwater aquifer (Southern Nevada 2009). Per the terms of the agreement, Nevada paid Arizona $100 million in 2005, and will make 10 annual installments of $23 million beginning in 2009 until the entire 1.25 million acre-feet is exhausted (Southern Nevada 2009).[17]

The Arizona definition of beneficial use facilitates transfers to the AWBA because forfeiture of rights does not result if the water rights are stored in a groundwater bank for future beneficial use or if surface and groundwater are exchanged.[18] Additionally, subject to approval by the Arizona Department of Water Resources, a water right may be severed from the appurtenant place of use and transferred to another place without loss of priority of right.[19]

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[16] Three primary sources of funding are utilized: 1) the state general fund; 2) groundwater withdrawal fees collected within the Phoenix, Pinal and Tucson Active Management Areas (AMA); 3) 4 cent ad valorem property tax charged in the CAWCD three county service area (Clifford et al. 2004).

[17] In 2007 and 2008 the Southern Nevada Water Authority (SNWA) could withdraw 20,000 acre-feet of water, in 2009 and 2010, 30,000 acre-feet. Beginning in 2011, the SNWA has a maximum recovery rate of 40,000 acre-feet per year until the bank reserves are fully exhausted (Southern Nevada 2009).

[18] Under nearly any other circumstances, the water entitlement may be forfeited if not beneficially used for five years. Arizona Revised Statutes §45-141.

[19] The type of use may also be changed. Arizona Revised Statutes §45-172.

California's Drought Water Bank

California's Drought Water Bank, operational in the years 1991, 1992, and 1994, was a clearinghouse that pooled water and allocated supplies to critical demands in the state (Clifford et al. 2004; Howitt and Lund 1999). The purpose of the drought bank was to move drought water supplies from the northern part of the state to the southern part of the state through a market-based approach. The California Department of Water Resources (DWR) negotiated water supply contracts with individual suppliers at varying prices (Clifford et al. 2004). The seller could be an owner of appropriative water rights or an individual who held entitlements to delivery for irrigation (Clifford et al. 2004). In 1991, three main methods were utilized: 1) fallowing contracts, whereby the surface irrigation water was sold in lieu of irrigating; 2) groundwater contracts, where groundwater would be used instead of surface water and the surface water would be sold; 3) stored water contracts for releasing water from reservoirs. The bank also obtained special riparian rights. All potential buyers were required to quantify their "critical needs" for the current year remaining after maximum utilization of normal sources including surface water allocations, groundwater, reclaimed water, and other water transfers (Clifford et al. 2004). Extreme critical needs were given priority and included water for drinking, health, sanitation, fire protection, and agricultural critical needs (Clifford et al. 2004).[20]

The 1992 bank was similar to the 1991 bank with some modifications. First, a water seller was found only after a buyer had been identified and a purchase contract signed. This was done to limit the cost carry-over associated with storage of excess water (Clifford et al 2004). Second, the water supplies were divided into six separate pools of water which could have different pricing mechanisms. However, all six pools established the same purchase price and selling price (Clifford et al. 2004). Third, fallowing contracts were eliminated resulting in less concentrated impacts (Clifford et al. 2004). Finally, buyers could store purchased water as long as its use occurred prior to December 1995 (Clifford et al. 2004). The 1994 bank operated under similar rules as the 1992 bank. A precautionary bank was developed in 1995, but the bank design switched to the use of option contracts.[21] Due to a relatively wet year, the 1995 bank was never operational.

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[20] "A seller had representation on the "Water Purchase Committee" which set the purchase price. Water was sold at $175 [per acre foot] reflecting all the acquiring costs including the purchase contracts, transport through the Delta, and administration of the bank. The water was delivered at the Harvey O. Banks Delta Pumping Plant, and a buyer was responsible for transportation costs beyond the pumping station. The DWR sold 396,000 acre-feet to 12 purchasers. The remaining 264,000 acre-feet was purchased by the state at $45 million to increase carryover storage which was delivered to [The State Water Project] SWP contractors in 1992" (Clifford et al. 2004; Water Education Foundation 1996).

[21] For a full explain of option contracts, *see* O'Donnell and Colby 2009b.

The data from the 1991, 1992 and 1994 banks indicates significant price responsiveness (or, to use the economist's term, price elasticity) (Howitt and Lund 1999). That is, when price changes, water suppliers (primarily agricultural water users foregoing use of their water) were willing and able to provide more water to the bank at relatively higher prices, while water demanders were more willing to demand significantly more water at relatively lower prices. This natural adjustment of supply and demand in response to price signals is one advantage of allowing a market pricing mechanism to reallocate water resources rather than an administratively fixed price (Howitt and Lund 1999).[22] In the 1991 water bank, it was identified that 499,000 acre-feet was the minimum volume of water that would be required to meet critical needs. However, after the price was set at $175/acre-foot, only 389,000 acre-feet were actually purchased (Howitt and Lund 1999). "Critical needs" was calculated partially as a function of the volume that cities and agricultural districts indicated they critically needed. However, when the price was set, the volume of water purchased was 22% lower than what the demanders indicated was critically needed. A market pricing mechanism that adjusts in response to changing demand and supply conditions can avoid the problems with setting a fixed price and then encountering excess demand or supply of water offered by a bank.

A thorough analysis of the third party impacts of the 1991 Bank found that net jobs were created and that it had a net positive impact on the state economy because low-value water uses were exchanged for relatively higher-value uses. However, water exporting regions suffered an income loss while importing agricultural regions experienced an income gain (Howitt 1994).[23]

California's Dry-Year Purchasing Program

California's Dry-Year purchasing Program, established in 2001, features a one-year leasing program intended to create a more reliable water supply through voluntary trading. Water is supplied to the bank by irrigation districts in the northern part of the state and demanded by irrigation districts in the southern part of the state (Clifford 2004). The dry-year purchasing program operates in a similar manner to the prior drought water banks and features two different contract structures: 1) dry-year option contracts[24] and 2)

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[22] Howitt enumerates, however, that in some public water projects it may be appropriate for the water bank to engage in price setting because private valuation of water entitlements may undervalue the resource vis-à-vis public valuation.

[23] Howitt also indicates that short-run and long-run effects of a water bank ought to be considered. For instance, with periodic reductions in economic activity, capital and labor remain in a particular district but are at times under-employed. Under permanent shifts, however, capital and labor must make other arrangements for the future (Howitt 1994).

[24] "Under the dry-year option contract, the buyer submitted an option request to DWR by November 30 of previous year. This request specified the quantity, maximum price, and delivery terms. At the time of the

direct purchase contracts.[25] After contract terms were arranged, potential sellers were then contacted to supply the buyers. Buyers with similar terms were incorporated into a purchase pool (Clifford et al. 2004). Under both contract types, the buyer was responsible for conveyance costs beyond the point of delivery.

Colorado's Arkansas River Basin Bank

The Arkansas River Basin Bank was established in 2001 as a pilot program to study the viability of water banking in the Arkansas River Basin.[26] The bank was designed to provide a clearinghouse to facilitate short-term (one year) bilateral trades between willing buyers (urban users) and willing sellers (agricultural users) through an online bulletin board listing service and was administered by the Southeastern Colorado Water Conservancy District (SCWCD) (Howe and Weiner 2002). The water bank was contentious primarily because it allowed some out-of-basin permits but also because irrigators may have been averse to some of the potential effects of transferring water out of a particular area, including local economic impacts and environmental impacts (Howe and Weiner 2002).

The bank functioned primarily through the online registry and webpage. Depositors and bidders are required to register through the website and the web page provides detailed information on depositors and bidders (Clifford et al 2004). The deposit information lists the name of the depositor, the quantity of water approved by the Division Engineer, the minimum asking price, the source of the water, as well as other location information (Clifford et al. 2004). The website also provides a listing of individuals seeking water, including contact name, requested quantity, and phone number (Clifford et al. 2004).

The prices set were based upon market-based negotiations between buyer and seller; however, no transactions were completed through the water bank. At least four reasons for the lack of transactions have been advanced. First, the price-per-acre-foot required by the seller was higher than the going market price of short-term leases

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option request submittal, the buyer paid a non-refundable agreement preparation payment of $2,500 in 2002 to offset the cost incurred by DWR in preparing the Memo of Understanding (MOU) for the current year. In addition, the buyer paid an option deposit fee of $10 per acre-foot requested. The DWR charged $5 for an administrative fee, and the remaining $5 was applied to the option exercise payment" (Clifford et al. 2004).

[25] "A buyer submitted a purchase water request specifying the quantity, maximum price and delivery terms. All requests were submitted by March 31st. At the time of request, the potential buyer submitted the agreement preparation payment and a purchase deposit of $25 per acre-foot requested. This fee consisted of a $5 administrative fee retained by the DWR and a $20 fee applied to the purchase component" (Clifford et al. 2004).

[26] The bank became active in 2003 with a sunset provision of five years so that the bank's viability could be examined.

(Clifford et al. 2004).[27] As a result, buyers were able to acquire the desired water in the lease market at a lower price. Second, although the process was designed to be streamlined, the administrative process and associated waiting periods were prohibitive.[28] The approval process was lengthy; the process was expected to require a minimum of two months and average three months[29] (Clifford et al. 2004). This was deemed to be unwieldy for a single-year lease. Third, the bank provided seller names and contact information on its website. As a result, buyers could circumvent the water bank by perusing the website, finding names and contact information of potential sellers and contacting them directly.[30] Fourth, irrigators are sometimes cautious when agreeing to sell or lease their water entitlements. This is particularly true when leasing their entitlement requires them to fallow their land, as was the case in this instance, because the local community internalizes many of the costs associated with fallowing (Simpson 2005).

Colorado West Slope Bank

A bank that is under consideration by the Colorado River Water Conservation District is the proposed Colorado West Slope Bank. This bank is designed to manage the threat of a potential interstate compact call on the Colorado River. Because the West

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[27] The range that the sellers requested was between $500 and $1000 per acre-foot per year.

[28] The Arkansas River Bank lists the steps required to consummate a transaction (Arkansas Basin River Bank):

- Water owners wishing to temporarily lease their water shall fill out an application, gather all pertinent information and submit the documents to the Southeastern Water Activity Enterprise office along with an application fee of $15.00.
- The completed application will be reviewed by the Division 2 Engineer's office to assure that the water is available to be leased.
- The staff will then post the offering on the water bank website.
- Qualified bidders may then post their bids on the water.
- Bids are a binding offer to pay such amount.
- On the 11th business day after posting the offering, staff will review the in-basin bids. The highest bid(s) meeting the minimum acceptable bid required by the lessor will then be submitted to the lessor for acceptance.
- The lessor may then accept any out-of-basin bid as they are posted. Upon acceptance, a lease is prepared and posted as under contract for the thirty-day public review. The proposed lease will also be mailed to those on the notification list. After the thirty-day review, the Division Engineer has 5 days to consider comments and will provide the terms and conditions for the transaction.
- Quantification of the available water is based on historical consumptive use.
- Once all parties involved in the transaction accept the Terms & Conditions, then an agreement is signed and a transaction fee is paid to the bank.
- The water bank will notify the Division Engineer's office, the reservoir operator where the water is stored, and those on the notification list.
- The lessee must notify the Division Engineer 24 hours in advance of when they need the water released.

[29] This is the case even though the bank provided simple pre-written contacts on its website in an effort to expedite the process.

[30] In at least one case, a seller withdrew a volume of water from the bank and sold the water privately (Clifford et al. 2004).

Slope's water consumption is mostly agricultural and because its priority is generally senior to the 1922 Colorado Compact, it is feared that junior municipalities and users with critical needs (i.e. fire districts) will either condemn or purchase the water rights and move them out of the West Slope should a curtailment occur (Water Information Program 2009). Therefore, the purpose of the program is to ensure a future water supply for various water needs.

In this bank, water users with pre-1922 rights would be compensated for entering into an agreement to offer their senior water rights that are exempt from compact administration[31] to junior users who would otherwise be called out by compact delivery requirements; temporary use of senior rights would only be permitted if a compact call was imminent or in effect (Water Information Program 2009). Junior entitlement holders would be permitted to subscribe to the bank as a sort of insurance policy (Water Information Program 2009). The bank would serve as the administrator and clearing house for those with senior, pre-1992 water rights and those with junior rights needing an alternative source of water (Water Information Program 2009). A potential hurdle of this program is that it is unclear which junior users would be allowed to participate if a compact call was eminent or whether priority would be given to particular users. It is also unclear which needs are truly critical and should therefore be validated.

Truckee Meadows Groundwater Bank

The Truckee Meadows Groundwater Bank operates as a recharge program through aquifer storage and recovery for the purposes of ensuring future water supply and to resolve potential surface and groundwater tensions. Surface water is recharged using wells to enhance the water resource, improve the water quality at well sites, and may be drawn upon in times of drought (Truckee 2009). During this recharge season, more than four million gallons per day are injected into different well sites across the Truckee Meadows and 19,000 acre-feet of water has been banked since 1993 (Truckee 2009).

The Truckee Meadows Groundwater Bank does not facilitate the sale of water; it is accounts for the groundwater credits and withdrawals in the Truckee Meadows basin. The administrative process is as follows: the total long-term average that can be withdrawn from the basin is 15,950 acre-feet per year. This baseline determines the credits and debits of the water accounting system. Credits are realized during years when withdrawals are less than 15,950 acre-feet, and debits are created during years when withdrawals exceed 15,950 acre-feet (Clifford et al. 2004).

New Mexico's Pecos River Basin Water Bank

[31] Article VIII of the Colorado Compact states that "[p]resent perfect rights to the beneficial use of waters of the Colorado River System are unimpaired by this [1922] compact."

Water banking in New Mexico has been limited, as the state does not have a comprehensive water banking program. However, as a result of state legislation in 2002, the water banks in the lower Pecos River Basin were permitted to develop. All transfers must be consistent with the Pecos River Compact and the water must remain within the basin. Specifically, all transfers must be used as "temporary replacement water" to augment flow in the lower Pecos River. The replacement water will augment stream depletions caused by continued (but temporary) use of water rights junior to the Compact Administration Date, primarily for the purpose of augmenting flows for a federally protected species, the bluntnose shiner (Clifford et al. 2004).

Any bank instituted is to be designed to act as a broker between the depositor of rights and the buyer. As of 2004, no applications for bank charters had been submitted. Hence, there has been no trading activity and a market price could not be determined. It in unclear why no water banks have been developed to specifically market water in the Pecos River Basin; however, it may be because of the development of the website "www.waterbank.com/."

Waterbank.com and other private sector banks

Waterbank.com operates as a privately owned water bank and utilizes a bulletin board service for the purchase and sale of water resources in New Mexico (including the Pecos River Basin), other locations within the United States, and internationally. The site also offers to provide other services such as ranch sales and water valuation. Other privately held water banks can be found on the internet, typically specializing in a particular region.

Waterbank.com is not a unique instance of for-profit water banks; rather, they are becoming more commonplace. For example, watercolorado.com is a private broker of regional water rights in Colorado. Additionally, watercolorado.com engages in leasing operations of water entitlements. Additionally, private for-profit water banks (or entities engaging in water trading) are beginning to develop internationally.[32]

Pecos River Acquisition Program

The Pecos River Acquisition, beginning in 1992 and administered by the Interstate Stream Commission (ISC), operates on the lower Pecos River as a clearinghouse to facilitate bilateral trades of permanent purchases and temporary leases (Clifford et al. 2004). The ISC negotiates with the Carlsbad Irrigation District to purchase water in order to meet a flow compact with Texas.

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[32] For instance, Archards Irrigation (http://www.archards.com.au/?watertrade) is a for-profit company based in Australia that, among other things, engages in water trading. Another example is Percat Water (http://www.percatwater.com.au/frameset.html).

Oregon-California Klamath River Basin Pilot Water Bank

In 2001, the US Bureau of Reclamation instituted the Klamath River Basin Pilot Water Bank (KWB) for the purpose of augmenting federally mandated minimum stream flow levels in the Klamath Basin for a threatened salmon population (GAO 2005). The KWB manages stream flow levels by utilizing at least two water supply reliability tools. The first tool is a groundwater substitution program where irrigators receive consideration for switching from surface-water to groundwater at the request of KWB. Second, KWB may ask irrigators to store a minimum volume of water in exchange for consideration. The stored water may then be called by KWB by a particular date, and released into the river (BOR 2009).

Oregon's Deschutes River Conservancy

The Deschutes River Conservancy[33] operates mainly in the capacity of a brokerage or exchange between willing sellers and buyers[34] and primarily for the purpose of groundwater mitigation activities. Because surface water is generally oversubscribed, and groundwater is the only source of new water entitlements, Oregon often requires mitigation credits to drill and extract groundwater. The Deschutes Groundwater Mitigation Bank offers mitigation credits for this purpose. The credits mitigate for the effects of new water use on streamflow in the lower Deschutes River (Deschutes 2009). Credits can be leased on a yearly basis or permanently.[35]

Additionally, The Conservancy also operates The Deschutes Water Alliance Bank, which is explicitly designed to "improve streamflows and water quality in the Deschutes Basin, secure and maintain a reliable and affordable supply of water to sustain agriculture, and secure a safe, affordable and high quality water supply for urban communities" (Deschutes 2009).[36] Under the auspices of this bank, the Conservancy manages an in-stream leasing program which may be utilized until the more costly permanent groundwater mitigation credits are available. It also participates in the market by purchasing water entitlements for the purposes of stramflow restoration.

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33 The Deschutes River Conservancy is a non-profit corporation founded by the Environmental Defense Fund, the Confederated Tribes of the Warm Springs Reservation, and local irrigation districts (Deschutes 2009).

[34] The buyers must be "qualified" according to predetermined standards set by the Deschutes River Conservancy. This reflects the Conservancy's desire to minimize speculation in the market and allows it to have a greater degree of control over the market activities.

[35] Mitigation credits may be purchased from private brokers, in addition to the Deschutes River Conservancy.

[36] In addition to the activities that the Deschutes River Conservancy characterizes as water banking, it is also engaged in other streamflow augmentation activities such as leasing programs, conserved water programs (i.e. ditch lining and the like), and transfer programs.

Idaho Rental Pools Water Bank(s)[37]

The state of Idaho has been engaging in water banking from as early as the 1930s and continues its water banking operations to this day (Idaho 2009). The main purpose of the rental pools water banks is to physically store water for the purposes of creating greater supply reliability within the state of Idaho; however, in recent years, water has also been leased by the U.S. Bureau of Reclamation for the purpose of streamflow augmentation for salmon recovery operations.

Texas Water Bank

The Texas Water Bank, established in 1993, is managed by the Texas Water Development board, which facilitates marketing and transfer of water rights in the state of Texas (Texas Water Bank 2009). The Bank acts as a clearinghouse of water marketing information and maintains registries of water bank deposits, sellers, and buyers, and negotiates acceptable sale price and terms (Clifford 2004). A fee system is utilized to offset the cost of operating the bank; however, the bank must be subsidized by state tax dollars as the fees collected are not sufficient to cover the operational costs (Clifford 2004).

The Bank may participate in the market by purchasing and transferring water rights in its own name (Texas Water Bank 2009). Additionally, under state law, transfers are reportedly allowed outside of the state (Clifford 2004). Therefore the Bank is capable of assisting in the development of regional water banks. The regional water banks would follow the same procedures as the statewide bank (Clifford 2004).

Australia

Water banking has been used rather extensively in Australia mainly in the Murray Darling Basin through an online bulletin board approach (Water Find 2009; Murray 2009), but the Northern Victorian Water Exchange has also utilized auction methods to reallocate water resources (Bjornlund 2003). A main purpose of this water banking design is to provide an opportunity for buyers and sellers to be responsive to changing conditions. Price evidence suggests water traders are indeed responsive to changing conditions while participating in these water banks (Bjornlund 2003). That is, price does react to changing market conditions. Additionally, the banks are designed to make water resources available to those individuals that are in immediate need (Bjournlund 2003). As a result, the process is generally streamlined to facilitate a relatively quick turnaround.

Summary

[37] There are several rental pool water banks within Idaho; here I discuss the banks in general. For a complete description of each of the banks please *see,* Idaho 2009 and Clifford 2004.

Water banks can be a valuable tool to enhance water supply reliability, where legal frameworks and institutions governing water rights and water use allow for water banking activities. As the examples provided in this guidebook demonstrate, existing water banks display great variety in their geographic coverage, their objectives, the services they provide and the legal authorizations under which they operate.

In this guidebook, we presented an overview of the roles and functions that a water bank can serve, as well as summarizing the steps needed to create an effective water acquisition program. Additionally, following the references section, we provide a concise checklist of important issues to consider in the creation and operation of a water bank. This guidebook is part of an ongoing series intended to assist public agencies, non-profit organizations and the private sector with design and implementation of water acquisition programs to improve water supply reliability during drought and under climate change. Other titles in this guidebook series include: *Water Auction Design for Supply Reliability: Design, Implementation and Evaluation*, which explains both the theory and practical aspects of water auctions, and *Dry-year Water Supply Reliability Contracts: A Tool for Water Managers*, which chronicles a variety of trigger-induced contingent contracts and how to implement them. All the guidebooks may be retrieved at http://www.azwaterinstitute.org/ewsrpublications.html.

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Water Banking Creation and Operation Checklist
Below is a checklist of major issues to consider when creating a water bank.

Management and Operation

- ☐ Determine appropriate entity to manage/operate the bank:
  - Public organization
  - Private non-profit organization
  - Private for-profit organization
  - Public-private partnership
- ☐ Create a system of education and outreach.
  - Public awareness campaign created?
  - Is there a manner in which individuals may conduct water bank inquiries?
- ☐ Include key community members in the decision-making and/or management processes.

Strategic Policy

- ☐ Develop long term strategic policy.
- ☐ Should the bank be designed to store water in a physical location?
  - If yes, should the bank utilize reservoir storage or underground storage?
  - If no, should the bank be designed to accommodate brokerage services or institutional (trust) services?
- ☐ Should the bank have the ability to purchase water entitlements on its own, or should the bank operate in a more administrative capacity?
- ☐ Set a fee for service structure.
  - Set flat participation fee?
  - Charge a fee per transaction?
  - Set different fees depending on the types of transactions or transaction volumes?
- ☐ Set an equitable and efficient dispute resolution mechanism.

Geographic Area and Participant Eligibility

- ☐ From what area should participation be allowed?
  - Large enough are to encourage robust participation, but not so large make administration and transportation costs overly burdensome.
- ☐ Which entitlements should be allowed to participate?

Operational Policy and Market Creation

- ☐ Establish a method of verifying bankable quantity, type of entitlement, and transfer capability of water entitlements.
- ☐ Determine what type of market (or pricing) structure to utilize:
  - Unilaterally set prices per volume of water?
  - Utilize a bulletin board method for pricing?
  - Utilize an auction method?
    - Single sided or double sided?
  - Allow a contingent contract (option contract) structure?

Encourage Irrigator Participation

- ☐ Utilize outreach activities to target irrigators and irrigation districts.
- ☐ Explain that irrigators may directly benefit from both the purchase and sale of entitlements.

Environmental and Third Party Impacts

- ☐ Has instream flows been legally classified as a beneficial use?
- ☐ Will water banking create negative environmental or third party impacts?
  - Should a mitigation fund be developed to compensate for negative environmental or third party impacts?

Cost of Administration and Monitoring

- ☐ Design a system of record-keeping and reporting.
- ☐ Implement a system of monitoring and enforcing fallowing agreements