Groundwater Banking and the Conjunctive Management of Groundwater and Surface Water in the Upper Snake River Basin of Idaho

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Chapter 1: INTRODUCTION

Purpose

This project was designed as an exploratory project to consider concepts, issues, and potential benefits of groundwater banking in the Upper Snake River Basin of Idaho. An important motivation of the project was to explore ways that the existence of a groundwater banking program could increase the quantity and reliability of water available for US Bureau of Reclamation (Reclamation) to enhance ecological flows in the Snake River. As an exploratory project, it did not have the intent to design, promote, or instigate ground-water banking. Instead, the intent was to provide background information for administrative agencies to consider if implementation of ground-water banking were contemplated.

As an exploratory project, this project did not have the intent to design, promote, or instigate groundwater banking. Instead, the intent was to provide background information for administrative agencies to consider in the event that implementation of groundwater banking was considered. A project requirement was to develop demonstration software, but this was not intended to dictate working practice to entities that may contemplate adoption of banking.

If groundwater banking were to be contemplated or adopted, rules and procedures would need to be carefully thought out and explicitly communicated. There is danger that users would "game the system" and use groundwater banking in inequitable ways, for instance to avoid providing necessary mitigation.

Content of Report

This report describes water banking in general, and how groundwater banking in the upper Snake River basin of Idaho fits with Reclamation's goals and mission. It briefly describes water banking in the western United States, the economics of water banking, and institutional issues of groundwater banking in Idaho. Demonstration software for accounting of banked groundwater. Stakeholder input is summarized. The report does not summarize the project Website; it is self-explanatory and may be viewed at http://www.if.uidaho.edu/%7Ejohnson/hydroweb/index.html.

The report also responds to specific requirements applied by Reclamation at the beginning of the project:

1. Describe banking concepts which increase availability of surface reservoir storage for maintenance of fisheries habitat during dry years.
2. Describe banking concepts which provide a market mechanism for trading and/or buying and selling of credits by both private and public entities.
3. Describe banking concepts which support the optimal use of both aquifer storage and surface reservoir storage for irrigators and fisheries in the Snake River basin.

Finally, the report discusses the applicability and possible next steps for groundwater banking in the upper Snake River basin, and will discuss extrapolation of findings to other Reclamation regions. Appendices contain the text of journal articles published or submitted in connection with this project and economics background information.

Acknowledgements

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A participants' group of stakeholder representatives provided insight and review of the project and project products. The participants were placed in the awkward position of being associated with a project whose outcome was beyond their control. Participants recognized and accepted the hazard that the reported findings of the project may be contrary to their own views or the positions of the organizations that participants represent. Nevertheless, all the participants considered the ideas presented, offered insight, and allowed their participation to be known. The project is much stronger due to their valuable contributions. Participants include:

Vince Alberdi	Twin Falls Canal Company
David Blew	Idaho Department of Water Resources
Jon Bowling	Idaho Power Company
Charles E. Brockway	Brockway Engineering
Ron Carlson	Water District 01
Jerry Gregg	U.S. Bureau of Reclamation

Chris Jansen-Lute	U.S. Bureau of Reclamation
Bryan Kenworthy	U.S. Fish and Wildlife Service
Randy MacMillan	Clear Springs Foods
Chris Meyer	Givens Pursley LLC
Tony Olenichak	Water District 01
Bill Quinn	Idaho Department of Water Resources
Cindy Robertson	Idaho Department of Fish and Game
Walt Pool	Idaho Department of Fish and Game
Norm Semanko	Idaho Water Users Association
Garth Taylor	University of Idaho Agricultural Economics
Lynn Tominaga	Idaho Groundwater Appropriators
Dave Tuthill	Idaho Department of Water Resources
Will Whelan	The Nature Conservancy

All participants were invited to submit counter-point opinion documents in response to this draft report, to be included without editing in the appendix of the final report. None were received, but this should not be construed as endorsement by the participants.

Disclaimer

The findings in this paper are not necessarily the opinions of Reclamation, the University of Idaho, nor of the participants. Findings are not presented as recommendations, but as input for decision makers to consider.

Chapter 2: OVERVIEW OF WATER BANKING

The Multiple Dimensions of Water Banking

The term "water banking" interacts with prior appropriation water allocation in many dimensions: 1) Physical source of water (ground water, surface water, or spring discharge[1]); 2) Single quantity (i.e. given volume of storage) vs. stream of benefits (i.e. ongoing authorization to divert at a given rate and/or annual volume); 3) Assignment of ownership vs. facilitation of transactions. One can envision a three-dimensional matrix, with some elements addressed by prior appropriation, some by water banking, and some by both. Each element in the matrix includes physical and administrative components. Figure OV-1 is an illustration of this conceptual three-dimensional matrix. Table OV-1 lists the elements of this matrix and describes how each may be addressed within prior appropriation and/or water banking.

[1] Spring discharges are treated separately because their physical source is ground water but in many jurisdictions they are legally treated as surface water.

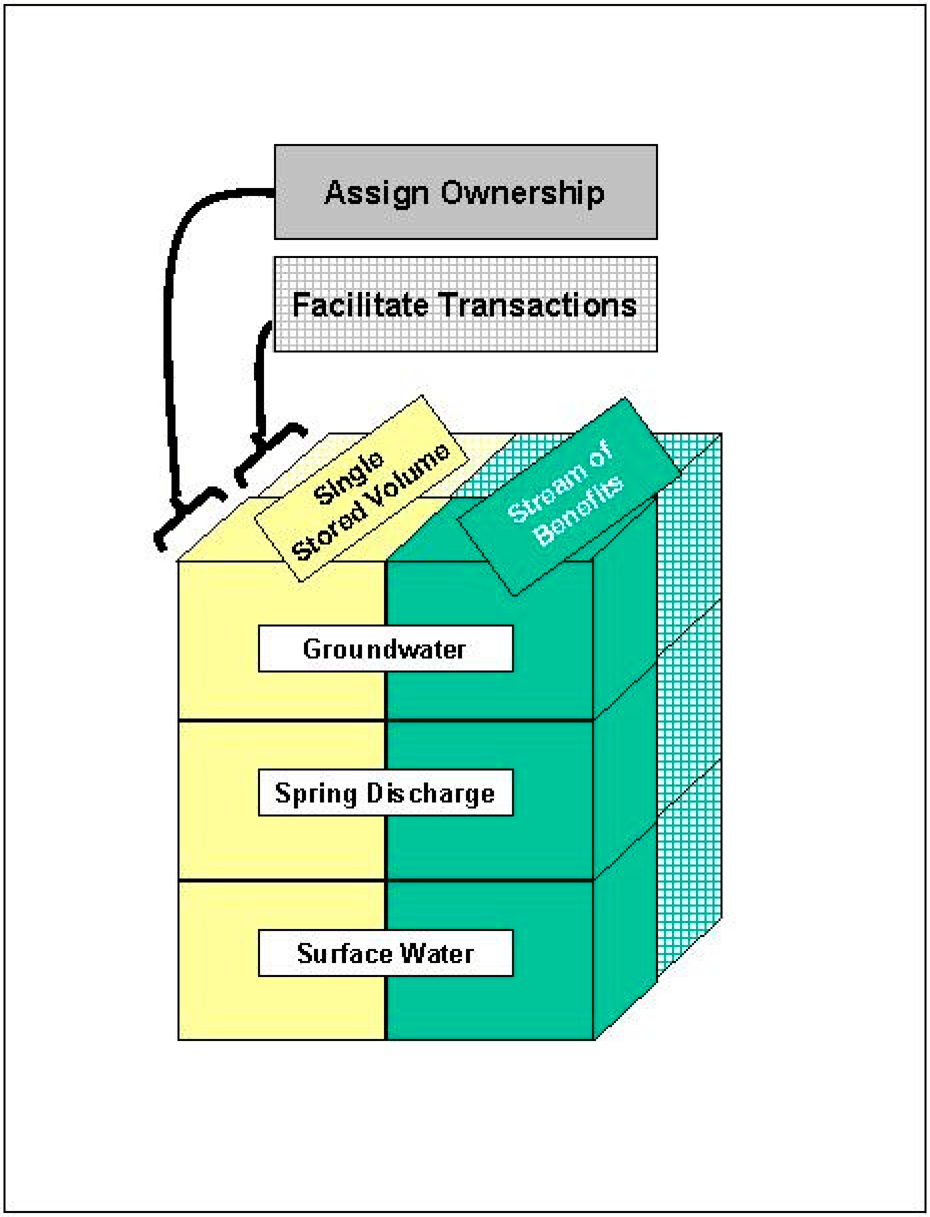

Figure OV-1. Conceptual matrix illustrating three possible dimensions of water banking and prior appropriation administration.

Table OV-1.
Description of Elements of Three-dimensional
Array of Water Banking and Prior Appropriation.

Ownership/ Transactions[2]	**Stored Vol/ Stream of Ben.**	**Nominal Water-right Source**	**Prior Approp.**	**Water Banking**	**Example/ Comments**
Assign Ownership	Stored Vol	Ground Water		X	Arizona water banks
Assign Ownership	Stored Vol	Spring Discharge			(not physically possible)[3]
Assign Ownership	Stored Vol	Surface Water	X		Storage water rights
Assign Ownership	Stream of Benefits	Ground Water	X		Diversion water rights
Assign Ownership	Stream of Benefits	Spring Discharge	X		Diversion water rights
Assign Ownership	Stream of Benefits	Surface Water	X		Diversion water rights
Facilitate Transactions	Stored Vol	Ground Water		X	Possible but not practiced under Idaho statutes. Some California ground-water banks.
Facilitate Transactions	Stored Vol	Spring Discharge			(not physically possible)
Facilitate Transactions	Stored Vol	Surface Water	X	X	Permanent water-rights transfer
Facilitate Transactions	Stored Vol	Surface Water		X	Idaho Water District 01 Rental Pool
Facilitate Transactions	Stream of Benefits	Ground Water	X		Permanent water-rights transfer

[2] The traditional transaction mechanism of purchasing the real property of the place of use with its appurtenant prior-appropriation water rights is omitted from Table OV-1.

[3] There is no practical technological means to stop the flow of springs in order to store spring water. If spring water is conveyed to a surface reservoir for storage it becomes surface water storage; if it is re-injected into the aquifer for storage it becomes ground water storage.

Ownership/ Transactions[2]	**Stored Vol/ Stream of Ben.**	**Nominal Water-right Source**	**Prior Approp.**	**Water Banking**	**Example/ Comments**
Facilitate Transactions	Stream of Benefits	Ground Water		X	Idaho Water-Supply Bank.
Facilitate Transactions	Stream of Benefits	Spring Discharge			(limited practical ability)[4]
Facilitate Transactions	Stream of Benefits	Surface Water	X		Permanent water-rights transfer
Facilitate Transactions	Stream of Benefits	Surface Water		X	Idaho Lemhi Rental Pool. Idaho Water-Supply Bank

[4] Transactions in ownership of authorization to divert spring water are generally limited to sales of the real property of the place of use along with appurtenant water rights, unless conveyance infrastructure are constructed to carry water to a new place of use.

Current Idaho Water Banking

Idaho has existing statutes (Idaho Code 42-1761, 2009) which authorize water banking under the direction of the Idaho Water Resource Board (IWRB). Current water-banking activity in Idaho can be categorized as follows:

1. Reservoir-storage Rental Pools quantify and assign ownership to stored volumes of surface water. Marketing and exchange are facilitated with administratively-determined prices and use preferences. See Idaho Water Resource Board (2009).
2. The Lemhi Rental Pool (IWRB, 2009) allows water-right holders to offer temporary use of surface-water flow rights to the Pool at a bid price. If accepted, the right is said to be "leased" to the Pool and the bidder foregoes use. Prospective users may contract with the Pool to use a right ("rent" from the pool) at the bid price, or may conduct written negotiations with the lessor for a change in price. The intent of creating the pool and its primary use has been to obtain irrigation water to sustain stream flows for fisheries requirements.
3. The Wood River Basin Enhancement Water Supply Bank (IWRB, 2009) was created to accept temporary donations of surface-water flow rights in order to dedicate flows to maintain stream flows, with protection from junior appropriators and from forfeiture.
4. The Water Supply Bank is authorized to deal with temporary exchange of surface-water flows not discussed above, as well as ground-water and spring flow rights. (IWRB, 2009). The banked and exchanged units are authorizations to divert from natural-flow runoff and not particular quantities of stored water.

   Currently there are about 520 ground-water rights enrolled in the Water Supply Bank (Case 2008). Sixty of these represent reallocations of water rights to new uses and/or places of use. The remaining 460 appear to be enrolled primarily to protect the water rights from legal forfeiture.

   One of the stated goals of the Water Supply Bank is to provide "a source of adequate water supplies to benefit new and supplemental water uses" and encourage "the highest beneficial use of water" (IWRB 2009). It appears that for ground water the Water Supply Bank is not as effective in these goals as it could be (see Appendix 2).

Ground-water Banking Considered in this Project

There is a wide range of possibilities of future ground-water banking that could be applied in the upper Snake River basin, considering all the combinations and permutations of the dimensions of water banking described above. This project focused on mechanisms that account for, assign ownership to, and facilitate exchange of physical quantities of water stored in the aquifer.

This array of possibilities creates levels of potential complexity and compatibility with existing statutes and procedures. Increasing complexity typically would require larger adjustments to Idaho statute and policy. The following discussion illustrates a progression of complexity and modification that might be required. These, especially the final level, are presented as conceptual discussions and not in any way as recommendations or proposals.

Level I: No change in statute. It appears that existing statutes would authorize the IWRB to institute ground-water banking that assigns ownership and facilitates transactions for stored volumes of ground water, with the following characteristics:

1. Supervision and Operation:
    a. The bank could be operated directly by the Idaho Water Resource Board, as is the current Idaho Water Supply Bank.
    b. The Idaho Water Resource Board could issue a charter to an operating authority, as is done in the current Idaho Rental Pools.

2. Deposit Mechanisms: Any combination of the following activities could be authorized as deposit mechanisms:
    a. Intentional infiltration of surface water expressly for the purpose of aquifer recharge.
    b. Incidental recharge from irrigation or other surface-water use.[5]
    c. Permanent retirement of ground-water rights. The consumptive use that would otherwise have occurred from in-priority pumping is the recorded deposit volume.
    d. Temporary cessation of pumping of ground-water rights. The in-priority consumptive use that would otherwise have occurred is recorded as a deposit.
    e. Provision of surface water to offset ground-water pumping, sometimes known as in-lieu supplies, or in Idaho as ground-water conversions. The in-priority consumptive use that would have occurred from ground water, plus any incidental recharge of surface water that would not have otherwise occurred is recorded as a deposit.
        i. Permanent conversion from ground-water to surface-water supplies (Contor et al 2008).
        ii. Supplying surface water to offset ground-water irrigation at times when canal capacity and water availability allow. Typically, additional surface water will be supplied in the springtime and occasionally in the fall, but during the peak irrigation season ground water will still be relied upon .

[5] This is an example of a potential activity that would require careful consideration; such a credit may be construed to encourage waste. As with all the possibilities presented here, this is a description of an option and not a recommendation.

f. Net reduction in consumptive use from changing to lower-evapotranspiration crops on ground-water irrigated lands (Contor and Pelot 2008).[6]
g. Net increase in incidental recharge from changing to lower-evapotranspiration crops on surface-water irrigated lands. The credit amount would be the reduction in consumptive use, discounted by any reductions in surface-water diversions associated with the cropping change (Contor and Pelot 2008).[7]
h. Excess mitigation created as part of a mitigation plan required by Idaho Department of Water Resources (Johnson et al 2004). This condition arises when mitigation is required for the protection of a particular river or spring reach, but the proposed mitigation also generates benefits for reaches for which mitigation is not required.

3. Withdrawal Mechanism: The only withdrawal mechanism practical without changes in Idaho statutes or policy appears to be to surrender credits to document satisfaction of mitigation requirements for ground-water pumping that otherwise would be deemed out-of-priority:
   a. Mitigation required by a water-rights transfer.
   b. Mitigation required as a condition for a new ground-water right.
   c. Mitigation requirements issued in response to a water-right delivery call.
   d. Mitigation for additional pumping of existing supplemental ground-water rights, over and above the historical usage or the usage contemplated in the water right.

4. Marketing, Exchange and Reallocation: It appears that any one of several marketing, exchange and allocation options could be adopted under current Idaho law:
   a. Credits issued to individuals:
      i. No exchange allowed; only the depositor may make withdrawals.
      ii. Free exchange allowed, with no market facilitation, supervision, or intervention by the operating authority. Any exchange or marketing occurs in private transactions, or potentially through the operation of entrepreneurs who use their own resources to set up trading mechanisms or to purchase and resell certificates.
      iii. Exchange allowed, with market facilitation and supervision by the operating authority.
         1. Physical or electronic bulletin boards or trading floors.
         2. Auctions operated by the operating authority (see Appendix 5).

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[6] This is another example of a potential activity that would require careful consideration. Such a provision might provide opportunities to "game the system" and harm other users.
[7] This activity would also require careful consideration.

3. First-come-first-serve voluntary acceptance of credits into a pool, and re-sale of credits for withdrawal, at prices set by the operating authority.

b. No credits issued to individuals:
In this category of exchange and marketing, any authorized deposit is immediately valued at a price set by the operating authority. The depositor receives only cash or a share of ownership in the revenue stream that will be generated by the bank; no credits for actual water or holdings in the bank are ever issued. All withdrawals must be based upon purchase of authorization from the operating authority, at a set price. Users who wished to make deposits for their own use would essentially submit simultaneous deposit and withdrawal applications.

5. Documentation of Ownership: There are two primary options for documenting ownership of credit in the banking system. The first could be called the currency model and the second could be called the property-deed model.
   a. In the currency model, individual physical certificate documents would be issued corresponding to the credits earned by a deposit activity. These would be similar to individual pieces of legal-tender cash currency. Possession of the physical document constitutes ownership. The ground-water operating authority would make no effort to track ownership or exchanges of physical documents. For a withdrawal activity to be authorized, the authority would accept and retain physical certificates tendered by individuals proposing a withdrawal.
   b. In the property-deed model, the operating authority maintains a database of ownership of credits. Individual physical certificates may still be issued, but in the case of loss, destruction, or presentation of competing certificates, the authority's record would be binding. In this model, all transactions would need to be recorded with the authority, similar to the recording of exchanges of real property or motor vehicles. This requires an accounting system that can quantify physical quantities of water placed into storage, depletion of those quantities, and withdrawals. Simultaneously, it must assign ownership to all the physical water stored in the banking system.

6. Ground-water Banking and Prior Appropriation: A draft report (Contor et al 2005) discusses the prior-appropriation considerations and options for ground-water banking. The most workable paradigm seems to be an exact parallel to the priority treatment of surface-water reservoirs: Priority is considered in determining whether water is available to store. Once stored, it is deliverable to the storage holder independently of the current

deliverable priority date.

7. Reclamation's Participation in Ground-water Banking: Under ground-water banking that could be established under current statute, Reclamation could acquire aquifer credits by directly performing any deposit activities that are authorized. For instance, managed aquifer recharge would likely be adopted as an authorized deposit mechanism. Reclamation could build recharge facilities, purchase storage water in the Idaho Rental Pool, deliver it to the recharge sites and manage the aquifer recharge, in order to obtain credits. Reclamation could also earn credits by participating cooperatively in any authorized deposit activities: For instance,, if a private group constructed a recharge site and purchased storage water, Reclamation could provide conveyance through its canals and thereby earn a pre-negotiated percentage of the credits generated. Another alternative might be for Reclamation to provide in-kind services to quantify, manage and validate reductions in consumptive use, and again earn a pre-negotiated percentage of credits. Finally, if the adopted ground-water banking system included provision for marketing and exchange of credits, Reclamation could purchase aquifer credits.

   Under current statute, it appears that there are three main opportunities for Reclamation to use credits:

   a. Use credits to mitigate for otherwise out-of-priority irrigation wells that are part of Reclamation projects, such as the A and B Irrigation District.
   b. Use credits to mitigate for otherwise out-of-priority pumping of wells that pump into the Snake River or its tributaries (exchange wells), in a program where the water injected to the stream is protected instream for ecological purposes. The exchange-well water right authorizes the diversion and the ground-water banking credits mitigate for any impact the pumping would have upon other water rights. Existing flow-augmentation agreements provide the mechanism to protect the water from re-diversion by junior users on the Snake River and allow its delivery downstream for species protection.
   c. Negotiate private agreements with irrigators whereby the irrigators would use their own wells to divert the water represented by Reclamation's credits, and the storage water the irrigators would otherwise have used is applied to existing flow-augmentation agreements.

   In each case, withdrawal could occur from existing wells under existing water rights. Additional water rights could potentially be obtained and additional wells constructed. It is likely that any new water rights would include explicit mitigation requirements as conditions of the water right.

If ground-water banking organized under existing statutes included marketing or exchange provisions, Reclamation or other users desiring to support spring discharges and river gains for ecological purposes could purchase credits and hold them out of circulation. Retained credits would not be available as mitigation for pumping, so total pumping would be reduced. Aquifer water levels, river gains and spring discharges would be maintained at higher levels than otherwise would have occurred.

Level II: Moderate change in Idaho Policy. A second level of ground-water banking could be contemplated that required linking ground-water banking accounting to the surface-water-irrigation system. This would allow gains to the Snake River that are created by a deposit activity to be claimed and utilized by the depositor. The separate accounting of exchange-well[8] water in Idaho Water District 01 is an example of the ability to separately identify and protect individual streams of water according to their source characteristics (Contor et al 2005). Another example is the operation of the Lemhi Rental Pool in Idaho. The general water-law principles of foreign waters (Getches 1990) and separate delivery of storage water provide additional illustrations of the workability of this concept.

With this modification, Reclamation could directly dedicate to existing flow-augmentation agreements the river flows that its credits represent, without the physical pumping, re-delivery and exchange activities described above.

All other the other options for ground-water banking under current statute and policy would remain available for consideration in this level of ground-water banking.

Level III: Changes in minimum streamflow statutes. A modification of Idaho Code that has the potential to apply private resources to protection of environmental services provided by rivers is to allow other entities besides the IWRB to hold water rights for uses in the stream channel. Another modification would be to allow transfer of senior-priority water rights to use in the stream channel with preservation of priority. In connection with the administrative linkage of ground-water banking and surface-water administration, these statutory changes could allow private or non-governmental parties to assist Reclamation in providing flows for ecological or species-preservation purposes. They could also allow Reclamation to provide ecological flows outside of existing flow-augmentation agreements.

As with other concepts in this report, these possibilities are described because they do exist. Inclusion in the report is not a recommendation, nor is it a

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[8] This is water pumped from the aquifer under a diversion right and injected into the river to compensate for withdrawals from the river that otherwise would have been unauthorized or out-of-priority. It is delivered to the point of rediversion in accordance with injections to the river and independently of the priority hierarchy of other deliveries from the river.

complete discussion of the implications that would have to be considered if such changes were contemplated.

Level IV: Fully integrated surface-water and ground-water banking and administration. While the social, legal and administrative hurdles to adoption would be significant, there is a radical concept of conjunctive management, administration and water banking that can be instructive to contemplate. It has the potential to maximize the economic efficiency of allocation of water resources and the equity of the distribution of benefits, and minimize conflict. Like any major change, it also would be subject to hazards of errors, blunders and political manipulation in the process of adoption. It is not presented here with the expectation that its adoption could be realistic, but to illustrate concepts of allocation that aid in considering ground-water banking.

The basic concept has been described over the years by Ron Carlson, former water master of Idaho Water District 01. It is that the operating authority has the discretion to use all infrastructure, water rights and water sources to distribute water to users in the way that makes the most sense physically. The authority has the duty and obligation to manage the system in a manner to maximize distribution of water to the most users possible while honoring prior-appropriation seniority in times of shortage.

The idea can be introduced by considering a small hypothetical basin with surface-water and ground-water interaction. We assume that there are no obligations to downstream surface-water users, and that society has chosen to maximize irrigation. Society also has a strong desire to sustain minimum stream flows in late summer.[9] Details of these targets are not important; they are presented only to give structure to the illustration of operation.

The administrative authority is given the power to divert and deliver water wherever needed to achieve the objectives of maximum irrigation and sustained stream flows in late summer. This power includes the ability to deliver surface water to lands with ground-water rights and ground water to lands with surface-water rights and to construct new infrastructure, including managed-recharge facilities.

The important hydrologic and water-right relationships are:

1. When surface water is delivered to irrigation, incidental recharge occurs and builds storage in the aquifer.
2. Surface-water that passes out of the basin is no longer available for use.
3. Base flow in the stream, and irrigation from the stream, is sustained by gains to the river from the aquifer.
4. Aquifer underflow out of the basin is minimal.
5. Ground-water pumping within the basin depletes base flow in the stream.

[9] It is acknowledged that protecting species and habitat is actually more complex than just providing a minimum flow in late summer.

6. There is a temporal delay and attenuation of effects so that recharge that occurs in the spring replenishes the river in late summer, and pumping that occurs in late summer depletes the river after the end of the irrigation season.
7. Surface-water rights are senior to ground-water rights.
8. There are no surface-water rights that would be considered flood rights, ordinarily deliverable only for a brief period in wet years, even if there were no ground-water pumping in the basin.

With these physical and water-right conditions, in this paradigm the operating authority would deliver as much water as possible to irrigated lands and recharge sites during springtime periods of high flow. Deliveries of surface water for irrigation would be targeted to farms with highest conveyance loss and opportunities for incidental recharge. Any needed ground water pumping would be targeted to locations where the primary impacts to the stream would occur before or after, but not during, the critical late-summer low-flow period.

During mid- to late-summer periods of low flow, the operating authority would deliver as much surface-water as possible while maintaining the desired minimum stream flow. Additional irrigation demands would be satisfied by ground-water pumping. Spatial distribution of ground-water pumping and surface-water irrigation would be selected to minimize depletion and maximize gains to the river during the critical period. Surface water would be targeted to parcels with lowest conveyance losses.

Relative to status-quo water administration, this system would increase storage in the aquifer in the springtime and increase withdrawals from the aquifer in late summer. The total amount of water leaving the basin would be reduced and therefore the total amount available within the basin would be increased.

Expanding this concept of management to the upper Snake River valley introduces additional complexity. The timing of impacts to surface water from incidental recharge or pumping varies from a few days to decades, depending on location. The hydrograph of impacts is attenuated by storage in the aquifer; an event that provides high intensity of recharge for a few days will provide a lower intensity of increased reach gains for a much longer period. The use of aquifer response functions in ground-water banking accounting, described in a later section (Chapter 7), provides tools to address these issues.

Another difference between the hypothetical case and the upper Snake River valley is the existence of surface-water rights that are essentially flood-water or high-water rights. Had ground-water development never occurred, these rights would be in priority only for a few weeks of the year, and possibly not at all in dry years. It would be unjust and economically inefficient[10] to construct

[10] It would be economically inefficient because it would result in an imbalance between the marginal revenue/marginal cost relationships between users.

an administrative system to guarantee these rights full delivery, at the expense of nominally-junior ground-water rights.

A just and equitable solution probably lies in partitioning each surface-water right into a fraction satisfied from base flow and a fraction satisfied from surface-water inflows into the basin. The fraction satisfied from base flow depends on the integrated effect of aquifer recharge and discharge over the past years and decades. It is this portion that is impacted by ground-water pumping and benefited by recharge, retirement of water rights, in-lieu supplies of surface water to offset ground water, reduction of consumptive use, and mitigation benefits to non-target reaches.

Decisions about the priority and deliverability of ground-water rights should be based on the aquifer water budget and the base-flow-supplied portion of surface-water rights. To confound delivery decisions for ground-water rights with considerations of the runoff-supplied fraction of surface-water rights would result in the counter-productive practice of reducing ground-water pumping in dry periods and increasing it in wet periods. One can consider the aquifer as a very large reservoir, and explore its management by considering the rational operation of surface-water reservoirs. With this paradigm, it is easy to see that maximum utilization of total water resources would be obtained by reducing ground-water extraction during wet periods and increasing it in dry periods.

The aquifer accounting tools and methods described later in this report provide the technical ability to perform this type of administration. All the deposit, withdrawal, marketing and exchange options described in this report would be applicable to this hypothetical integrated restructuring of water-right administration and delivery. This level of legal and policy modification is not presented as a proposal for change; it is simply to illustrate principles of efficient utilization of resources that may be enhanced by properly-constructed ground-water banking policies.

Chapter 3: GROUNDWATER BANKING AND RECLAMATION'S NEEDS AND MISSION

Reclamation Criteria

One of the intermediate products of the project was a draft report entitled "Groundwater Banking in the Eastern Snake Plain: Potential Conflicts and Opportunities for Reclamation" (Contor et al 2005). It listed seven criteria from Schmidt et al (2005) that would be important to Reclamation in evaluating a groundwater banking plan. Along with an eighth criterion suggested by later Reclamation reviewers, these are:

1. A suitable banking authority oversees groundwater credit and debit accounting in the Eastern Snake Plain.
2. Banking credits are earned by reductions in groundwater irrigated land as well as managed aquifer recharge.
3. Managed aquifer recharge water comes mainly from retirement of surface-water irrigated lands.
4. An open and fair market for earning and trading groundwater banking credits exists, in which Reclamation can participate.
5. Hydrologic monitoring is adequate to verify aquifer conditions, including recharge activities, spring discharge, and aquifer storage.
6. The enhanced ESPA model has demonstrated its validity as a groundwater accounting tool, by reliably forecasting groundwater levels and spring discharges.
7. Reclamation is able to achieve some of its own policy objectives by participating in groundwater banking activities.
8. Changes in allocation are monitored to ensure that downstream effects do not jeopardize Reclamation project operations.

Additional discussion of these criteria is available in the 2005 draft report and in Schmidt et al (2005). The first two criteria are easily achievable. The third, relating to the source of recharge water, depends on the structure of groundwater banking. Managed recharge is but one of many deposit mechanisms. Under one paradigm of groundwater banking, the banking system would primarily address quantification, assignment of ownership, and exchange of water stored in the aquifer. Management of individual deposit activities such as managed recharge would be handled by existing organizations, under existing jurisdictions. In this framework, if Reclamation wished to influence the source of water used for managed recharge, it would negotiate that in the recharge forum rather than the groundwater banking forum. Under another paradigm, however, the groundwater banking authority would become an umbrella organization that superceded existing jurisdictions in order to manage all deposit activities. In that case, discussion of the source of water for recharge would be a component of groundwater banking negotiations.

The fourth Reclamation criterion is that the banking system should incorporate an open and fair trading mechanism in which Reclamation may participate. Facilitating marketing and exchange is an option that could be incorporated into groundwater banking. Even if Reclamation were not allowed to participate in the new supplies, the existence of additional supply could increase Reclamation's access to water by satisfying some other demands for water, reducing the effective aggregate demand for existing supplies.

The fifth and sixth criteria are discussed in later sections of this report.

The seventh criterion, the ability of groundwater banking to assist Reclamation in achieving its goals, is the subject of this section of the report. The discussion that follows relies heavily on the 2005 draft report, without further citation.

The eighth criterion discusses the effects of allocation decisions on downstream flows, and the impacts these could have on Reclamation's ability to fulfill contract obligations. These concerns would automatically be addressed by prior-appropriation water law, if the banking system were structured so that all diversions of surface water associated with groundwater banking would be made within the priority hierarchy.

Groundwater Banking and Reclamation Goals

The project Website includes a draft document on Groundwater Banking and Reclamation (Contor et al 2005), which provides the basis for this section of the report. Groundwater banking may encourage or facilitate a number of activities which relate to Reclamation's interests:

1. Managed aquifer recharge. Early in the project, undue attention was focused on managed aquifer recharge, under the apparent misconception that managed recharge and groundwater banking were essentially synonymous. Managed recharge is simply the process of physically placing water into the aquifer, explicitly and intentionally to increase aquifer storage.[11]

   Despite the fact that managed aquifer recharge is only a deposit mechanism within the larger concept of groundwater banking, it received significant attention and discussion during the project and is of particular interest to Reclamation. Congress has directed Reclamation to study and participate in managed recharge (USC Title 43, Chapter 12, Sections 390g-1 through 390g-8). In Idaho, Reclamation was one of the early proponents and investigators of managed recharge (US Bureau of Reclamation 1962). However, current local perception seems to be that

[11] In Arizona, the term "managed recharge" applies when water is intentionally percolated through the bed of natural structures such as dry stream beds, and "constructed recharge" occurs in human-built facilities (Swieczkowski 2003). Both concepts are referred to as "managed recharge" in this report.

Reclamation in practice opposes managed recharge, though official statements indicate conceptual willingness to consider it under certain conditions. Managed recharge presents several concerns for Reclamation (Keyes 2004a):

a. Recharge may violate Palisades Reservoir winter savings agreements.
b. Recharge may interfere with Reclamation's water rights that are relied upon to fill reservoirs.
c. Conveyance of recharge water in Reclamation canals may not be a federally-authorized use of facilities (Keyes circa 1997).

The issue of the winter savings agreements applies only to winter-time delivery of water to recharge, and only in canals subject to the agreements. Further, it can potentially be addressed by mechanisms discussed later in the report under "Modification of Reclamation Policy."

If the surface-water-storage paradigm of priority is adopted, Reclamation's water rights would be protected. Water would only be made available for deposit activities, including managed recharge, within the priority hierarchy. Reclamation's rights will be fully protected in their place within priority.

The issue of federally-authorized purposes applies only to recharge water delivered via Reclamation canals or supplied by storage from Reclamation facilities. It is also further discussed later in the report.

2. Non-recharge deposit activities. As described above, there are several additional deposit mechanisms that could be considered in groundwater banking.

The concept of granting credit for incidental recharge has significant implications that will be discussed later in this report.

Retirement or temporary idling of groundwater rights, as well as reducing consumptive use by changing cropping patterns, satisfies the Reclamation criterion of earning credits by reducing groundwater irrigation. It also may help achieve the Reclamation objective of alleviating "recurring problems of surplus crops and low commodity prices" (USC Title 43, Chapter 12, Section 1a, 390vv).

Supplying surface water in lieu of groundwater pumping may help achieve the Reclamation objective of "improving the management of the West's water resources (McDonald 2001) but may also compete for surface-water supplies that Reclamation may seek for other purposes.

Accepting excess mitigation as a banking deposit affects

Reclamation goals by improving the economic efficiency of water use.

3. Mitigation for groundwater transfers and new groundwater rights. Mitigation sustains aquifer water levels, protecting Reclamation's interests in the A and B Irrigation District. It also sustains spring discharges and river gains, and therefore increases flow available for species protection in the Snake River.

4. Temporary or permanent reallocation of water to new uses. These uses include environmental uses and domestic, commercial, municipal and industrial (DCMI) uses. By providing a source and mechanism for mitigation, groundwater banking may facilitate reallocation that otherwise would not have occurred. This supports Reclamation's policy of "facilitating transfers of non-project water and water-rights from willing sellers to willing buyers" (US BOR 2004, Policy B4, item 4B) as well as its policy of being "supportive of voluntary transfers and conversions of project water... to new uses (McDonald 2001)." Reclamation reviewers suggest that the current policy is not to encourage reallocation to new uses other than ESA flow augmentation.

5. Market transactions to facilitate reallocation. Market transactions have the potential to reduce conflict and to allow prices to signal the uses that are most desired by today's society. Allowing and facilitating a form of groundwater banking that included marketing and exchange provisions would fulfill Reclamation's role to "seek to encourage all parties to reduce transaction costs" (McDonald 2000, Tab B Principle B2). This aids Reclamation in its goal of "improving the management of the West's water resources" (McDonald 2001). Allowing environmental interests (including Reclamation) to obtain instream-flow water through market mechanisms may reduce attempts to obtain water by litigation or legislation. This would reduce conflict and costs for all water users.

6. Reclamation participation in groundwater banking. As described above, Reclamation could earn or purchase credits in the banking system. These could be applied to obtain flow augmentation water. This would protect Reclamation's ability to meet contractual obligations to irrigators and others (Rigby 2004).

7. Participation in groundwater banking by non-Reclamation entities. To the extent that non-Reclamation participation improves the economic efficiency and management of water resources and facilitates reallocation of water to new uses, it is compatible with Reclamation goals. However, if groundwater banking enables other entities to better compete for limited water supplies that Reclamation desires, it could have a negative impact on Reclamation's objectives.

8. Delay of construction of surface-water storage. By providing additional supplies of water, facilitating storage of water in the aquifer delays the need for federal expenditures to enlarge or construct additional surface-water storage. The avoidance of future federal expenditures is considered an indication that an activity "will help the Bureau of Reclamation achieve management objectives" (McDonald 2000, Tab F).

Potential Conflicts

Some potential conflicts between groundwater banking and Reclamation objectives have been discussed above. A more complete list includes the following, with some repetition:

1. Competition. Activities facilitated by groundwater banking could increase competition for water sought by Reclamation. However, the very essence of the evolution of prior-appropriation water law is the implicit fact that demand will far exceed supply in the arid west. The requirement that Reclamation abide by state water law (MacDonnell and others 1991) and the existence of prior-appropriation water law in Idaho could be construed to indicate that competition is not a valid reason for Reclamation to oppose water banking, since competition already exists and is already addressed. Another potential response to concerns about competition would be to incorporate preference rules within the banking structure. However, the social and political process of achieving adoption of such rules could be challenging. Instigating a preference discussion could work against Reclamation's interest, if the final selection is dominated by preferences not favorable to Reclamation's preferred uses of banked water.

2. Authorized use. Reclamation participates in flow augmentation, even though it is not an authorized purpose for the facilities used. It is seen as a necessary activity to protect Reclamation contractual delivery agreements (Keyes 2004a, Rigby 2004). Since contractual delivery agreements are an authorized purpose, by extension flow augmentation to protect contractual agreements is also deemed authorized.

   This logic could be applied to Reclamation's direct participation in any groundwater banking deposit activity, including managed recharge. It could also be extended to Reclamation participation in the deposit activities of others. For instance, Reclamation could negotiate with entities performing managed recharge to obtain a percentage of the banking credits obtained, in exchange for using Reclamation facilities to convey water to the recharge site. Reclamation would then be able to use these credits to fill contract obligations, or as described above to aid flow augmentation and protect Reclamation's ability to fulfill obligations. Such activity would be compatible with Reclamation's directive to make "excess capacity available... to assist in improving management" of water (McDonald 2001).

If explicit authorization is needed, multiple mechanisms exist and have been successfully used in the past. Case histories include successful application of the Warren Act, the 1920 Act, the 1939 Act and new legislation to justify changes in authorized purposes (MacDonnell and others 1991). For managed recharge, precedent has already been set in Idaho for simply invoking the 1902 Reclamation Act as authorization (US Bureau of Reclamation 1962).

3. Disincentive to active management. Managed recharge may create a false sense of security and forestall water management (Keyes circa 1997). To the extent that groundwater banking could facilitate managed recharge, this criticism might also apply to groundwater banking. However, the act of adopting groundwater banking would be a deliberate movement in the direction of active management. By participating in groundwater banking and managed recharge, Reclamation may generate good will required for it to influence other water management activity in Idaho.

4. Reclamation transfers. In the context of Idaho water law, groundwater banking would likely be operated under existing water-banking statutes. These state that water banking may be considered a substitute for state water-law transfers (Idaho Code 42-1764). If use of water banking is also considered a type of Reclamation transfer, it must be compatible with Reclamation transfer policies. A 1997 policy memo addresses Reclamation transfers to DCMI purposes (McDonald 2000) but policy for Reclamation transfers to environmental purposes is less well defined.

   Third party effects must be considered in evaluating Reclamation transfers, and Reclamation guidance indicates that third-party and public-trust questions should be answered with the context of state water law (McDonald 2000, Tab F). The accounting procedure described later in this report explicitly addresses third-party effects, as does Idaho water law. If the groundwater bank were chartered under Idaho statutes, these provisions should satisfy Reclamation's obligation.

5. Cooperative agreements. The mechanisms described for Reclamation to obtain and use banking credits include entering agreements with other entities and water users. Reclamation would need to determine whether authority exists to enter agreements, and what formal process is required to finalize agreements. Agreements would be needed for:
   a. Joint deposit activities where Reclamation earns credits by actively participating with others in managed recharge, retirement of groundwater pumping or other deposit activities.

b. Facilitation activities where Reclamation earns credits by passively allowing the use of Reclamation canals to convey water to managed recharge sites.
c. Withdrawal activities where Reclamation authorizes irrigators to extract Reclamation groundwater credits in exchange for the irrigators' surface supplies being dedicated to flow augmentation or other Reclamation purposes.

6. Anadromous fisheries. Instream flow for anadromous fisheries may not be defined by Reclamation as reimbursable, where water for irrigation is reimbursable. Transfers that change reimbursibility require special consideration to be certain that the financial position of Reclamation is not harmed by the transfer (McDonald 2000, Tab F). Reclamation's participation in the surface-water Rental Pools to obtain water for flow augmentation sets a precedent that should allow it to use groundwater banking for similar purposes.

7. Crop surpluses. If groundwater banking allows irrigation to proceed which otherwise would have been curtailed, it may be construed to interfere with Reclamation's directive to help alleviate crop surpluses (USC Title 43, Chapter 12, Section 1a, 390vv).

In summary, groundwater banking offers many potential enhancements to Reclamation goals and a few potential conflicts. Reclamation may find it desirable to actively promote and encourage groundwater banking, to tacitly accept groundwater banking instigated by other jurisdictions, or to oppose it.

There appear to be mechanisms for Reclamation to take any of these paths. Reclamation has set precedents by acquiescing to surface-water banking (Idaho Rental Pools) using Reclamation facilities, and by participating in flow augmentation despite lack of explicit authorization. It appears that these precedents combined with the opportunities to change purposes identified by MacDonnel et al (1991) would allow Reclamation to accept and participate in groundwater banking in Idaho if it chose. On the other hand, the authorized-purpose arguments could be adopted as sufficient justification for Reclamation to decline to participate in groundwater banking, if it perceived banking as unfavorable.

Reclamation as Operator of the Bank

Reclamation could potentially be the operator of a groundwater bank in the upper Snake River basin by receiving a charter from the Idaho Water Resource Board under state law. If Reclamation were thoroughly convinced that groundwater banking was desirable, it is theoretically possible that it could operate a unilateral banking system independent of the Idaho Water Resource Board. Reclamation would apply to the Idaho Department of Water Resources for a state-law storage water right, with the aquifer designated as the reservoir, and operate its own groundwater banking activities.

In either case, if Reclamation were the operator of the bank, it is possible that adoption of the bank would require full review under various federal statutes such as the Endangered Species Act, Clean Water Act, National Environmental Policy Act, and so forth. These are discussed further in Chapter 6. The review alone may be enough burden to stop the adoption of groundwater banking. However, a precedent has been set for Reclamation's participation in surface-water banking operated by other entities under State charter. This indicates that it is likely that Reclamation could participate in groundwater banking operated by other entities, without triggering burdensome review provisions.

Chapter 4: ECONOMICS OF GROUND-WATER BANKING

In the broadest sense, economics is the study of how we allocate resources and how we pay the factors of production of goods and services. Because ground-water banking is a change in allocation mechanisms, economics must be considered. Much of the following discussion relies upon Contor and Schmidt (2006), contained in Appendix 4. See also Appendix 5 for additional economics discussion.

A fundamental assumption of the ground-water banking project is that an allocation mechanism is good if it is economically efficient and equitable.

Economic efficiency is obtained when resources are allocated in such a way that society as a whole obtains the maximum benefit from its limited resource base. It turns out that maximum efficiency is obtained when each user of a commodity pays a marginal cost equal to that users' marginal benefit, and commodities are allocated to maximize the total payments from users.

Equity is defined here in terms of "that part of the legal system built around the principles of natural justice and fair conduct, [and] specifically designed to deal with those cases where formal law would result in an unfair outcome" (Green 2003). Important components of equity are:

1. Uniform access to goods or services by all segments of society. Any preferences, barriers or differential pricing that exist have a rational basis tied to the overall needs and desires of society.
2. Exchange or trade is voluntary.

Markets and Water Allocation

Markets (when properly functioning) are seen as an allocation mechanism that achieves both efficiency and equity. Appendix 5 discusses some basin market principles. Since ground-water banking is seen as a potential mechanism to improve water allocation by bringing some market characteristics into prior appropriation, in this project banking was examined in market terms. The economics page of the project Website (http://www.if.uidaho.edu/%7Ejohnson/hydroweb/economics.html) listed four general market-economics topics that may affect ground-water banking:

1. Market Failures
    a. Externalities
    b. Public-goods Issues (described as “Tragedy of the Commons” on the Website)
2. Transaction Costs
3. Induced Behaviors
4. Pricing Mechanisms

These four points, along with the market requirement of a homogeneous commodity (see Appendix 5), will be discussed in further detail.

Externalities. Externalities occur when some positive or negative effect of an economic activity is not considered by the party making decisions regarding the activity. The effect is *external* to the decision. In terms of economic efficiency, the marginal cost that the decision maker equates with marginal benefit is the wrong marginal cost, because it omits costs and benefits borne or enjoyed by other members of society. The result, from the viewpoint of society as a whole, is that too many activities with negative externalities, and too few with positive externalities, are undertaken. A water-resources externality occurs when there is a hydrologic condition which creates rivalry of use, combined with a failure of a property-rights condition (Slaughter and Wiener 2007).

Not all negative impacts are externalities. When a junior user is curtailed in order to protect a senior water right, this is not an externality; it is simply the operation of an allocation mechanism for scarce resources. In making the decision to divert, the senior user is implicitly deciding to forego the potential revenue of selling the water right to other users (assuming an adequate reallocation mechanism is available); the junior's demand for the water is therefore internal to the decision. However, in Idaho, because there is no provision in the law for conversion of senior water rights to instream purposes with preservation of priority, the senior use's impact on species and the environment *is* an externality: Society's desire for ecological services is not part of the opportunity cost considered by the senior user.

Taxes or subsidies are one possible policy response to externalities. Taxing an activity that produces a negative externality[12] increases the marginal cost faced by the decision maker. If the tax level is appropriate, the marginal cost is approximately equal to the marginal cost to society as a whole and the decision maker will engage in the socially-optimum level of activity. Similarly, a subsidy increases the marginal benefit seen by the decision maker, inducing an increase in production to the socially optimum level. The taxation/subsidy response requires that the optimal tax or subsidy level can be calculated, and that political processes can set taxes and subsidies to the optimum level. It is not at all certain that either is true.

Another general policy response to externalities is to adjust property rights so that exclusion is aligned with rivalry. The creation of Conjunctive Management Rules in Idaho is an example. The negative externality that ground-water pumping imposed on spring uses and river gains was addressed by applying an existing exclusion mechanism (the prior-appropriation delivery call) to ground-water users. This assigned to the spring and river users

[12] Sometimes called a Pigovian tax.

ownership of the portion of pumped ground-water that was injurious to senior water rights.[13]

Public-goods Issues. The market mechanisms described in Appendix 5 work for private goods that are rival in use and for which exclusive property rights are available and enforceable (Randall 1983; see also Appendix 3). Market requirements are substantially satisfied and the allocation of goods is equitable and economically efficient.

However, not all uses of water are rival. For instance, instream flows for ecological purposes can be non-rival with instream flows for recreation and non-rival with hydropower generation. Compounding the problem is the fact that many non-rival uses are also non-exclusive. A power company could expend resources to increase instream flows, but without an exclusion mechanism, it would be difficult to compel recreational users to participate in the cost, and even harder to attract contributions from all the members of society who benefit from varied and dispersed ecological services that result from sustained river flows.

A typical response to non-rival and non-exclusive water uses is to provide these by public funding. Reclamation's funding of surface-water-banking withdrawals to support flow augmentation is an example. However, for such funding to be socially optimal, "the tax taken [to fund the public purpose] must be equal to the efficient level…. Tax levels are unlikely to be set either in this manner or with this effect" (Green 2003).

Homogeneous Commodity. Market transactions achieve economic efficiency and equity because prices implicitly contain all necessary information about society's use preferences and the costs of providing the commodity. This allows each user to equate his/her marginal benefit with the marginal cost to society. However, this only works if the commodity is homogenous; the cost of provision reflected in an asking price must be for the same sort of water contemplated by a potential purchaser or user. An important consideration for ground-water banking is that water is generally not a homogeneous commodity:

1. Its use value is highly sensitive to *location* because it is a bulk commodity with high transportation costs relative to its value. Further, these costs are anisotropic; down-gradient transport is orders of magnitude less costly than up-gradient transport (Taylor 2008).
2. The marginal benefit of water use is highly sensitive to *time* of use.
3. Most uses of water are sensitive to the *form* of the water, including temperature, dissolved minerals and chemicals, sediment loading and biological constituents.
4. Administrative responses to the difference in propagation of effects from different locations can introduce heterogeneity. This point is important in ground-water banking. In applying the no-harm rule to ground-water-right transfers, Idaho Department of Water Resources uses aquifer response

[13] Idaho is still learning how to apply the conjunctive management rules, and some users likely feel that externalities still exist.

functions to express the impact of pumping at the new and old locations as time series of effects at various spring reaches or river reaches. If the timing or magnitude to any reach is substantially different between the "new" and "old" transfer locations, the water uses are deemed to be different enough that a transfer cannot be approved without significant mitigation. This essentially makes ground-water pumping at each location a unique commodity different from pumping at all other locations, rendering reallocation extremely difficult and hindering market transactions.

There can never be a single homogeneous commodity class that comprises all water, from all sources and for all purposes. However, there can be sub-markets of water of different classes that can each be reasonably homogeneous, with economically-efficient allocation within each class. Ice cold potable water, in plastic bottles and available at a filling station, can be sold for the equivalent of hundreds of thousands of dollars per acre foot. Surrounding the filling station might be an alfalfa field where process waste water is applied at a marginal cost of nearly zero. These uses are not homogeneous and cannot efficiently participate in the same market, but each could exist within its own relatively homogenous class where marketing and allocation were efficient.

<u>Market Barriers and Transaction Costs.</u> All exchange activities impose some cost on the traders, even if it is only the time that it takes to engage in negotiations. For trade to efficiently allocate resources, transaction costs must be small relative to the potential gains of trade. Water transactions often have high transaction costs due to the extensive analyses needed to satisfy the prior-appropriation no-harm rule.[14] High transaction costs can prevent the movement of resources to their highest-value use to society, reducing economic efficiency.

Market barriers have the same effect as high transaction costs; they restrict reallocation of resources. Important market barriers in Idaho include:

1. Use-category preferences in surface-water rental pools.
2. Prohibition on senior priority for instream uses, even via water-rights transfer of existing senior rights.
3. Restrictions on who may hold rights for instream use.
4. Restrictive parameters of flow-augmentation agreements.

One hazard of market barriers is that a barrier does not remove the demand for the good. Those unable to obtain water for desired purposes in the market or allocation method are more likely to pursue litigation or legislation, generating conflict. The other hazard is economic inefficiency. Figure E-1a illustrates the construction of an aggregate demand curve[15] for two users of a hypothetical commodity. At any given price, the aggregate demand is the

[14] See discussion in Appendix 4. The no-harm rule is sometimes seen as market hostile but actually evolved to address other market deficiencies in water reallocation.
[15] Please see Appendix 5 for clarification on the construction and meaning of this type of figure.

horizontal summation of User A's demand and User B's. For instance, at a price of $15/unit, User A is not willing to purchase any of the commodity, and the aggregate demand comprises only User B's demand of approximately 2.5 units. At a price of $5/unit, User A is willing to purchase 3.5 units. Her/his demand added to User B's demand of 4.5 units gives the aggregate demand of eight units at a price of $5/unit.

Figure E-1b adds the supply curve to this aggregate demand chart. The supply curve is upward sloping to the right, indicating that suppliers are willing and able to deliver more of the commodity at higher prices. The equilibrium price is P2 (approximately $6.25/unit). At that price, the quantity suppliers are willing to provide equals the quantity that users (in aggregate) are willing to purchase. This quantity is Q2, approximately seven units.

Figure E-1c shows how User A and User B make allocation decisions relative to the equilibrium price. For clarity, the aggregate demand and supply curves have been removed, leaving only the market price and the two users' individual demand curves. The market price intersects User A's demand curve at quantity A and User B's curve at quantity B; User A is willing to purchase quantity A (about one third of total demand) and User B purchases the remainder (quantity B). Because market conditions prevail, this market allocation is economically efficient, meaning that society's benefit from allocation of this resource is maximized. There are two reasons for this result:

1. Both users are paying a marginal cost equal to their marginal enjoyment (as defined by their individual demand curves).
2. Allocation decisions are based upon the actual marginal cost of providing the commodity (implicit in the supply curve).

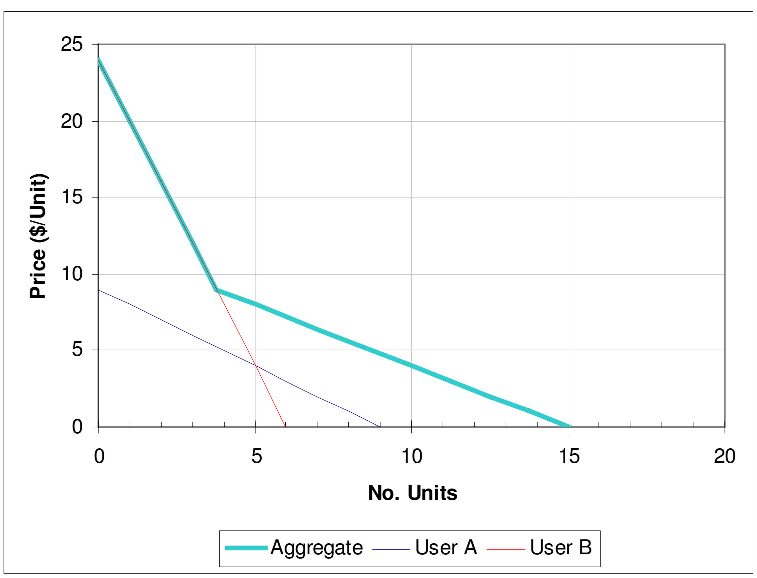

Figure E-1a. Construction of aggregate demand curve for two users of a hypothetical commodity.

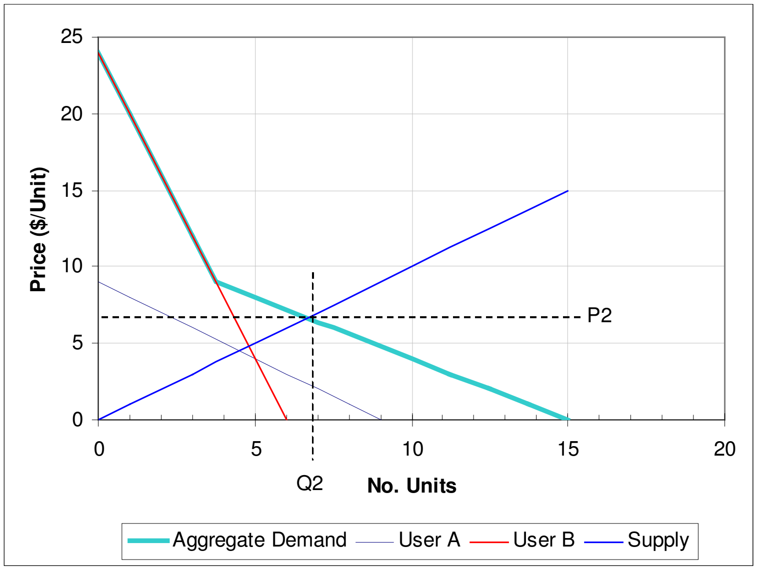

Figure E-1b. Supply curve intersecting the aggregate demand curve.

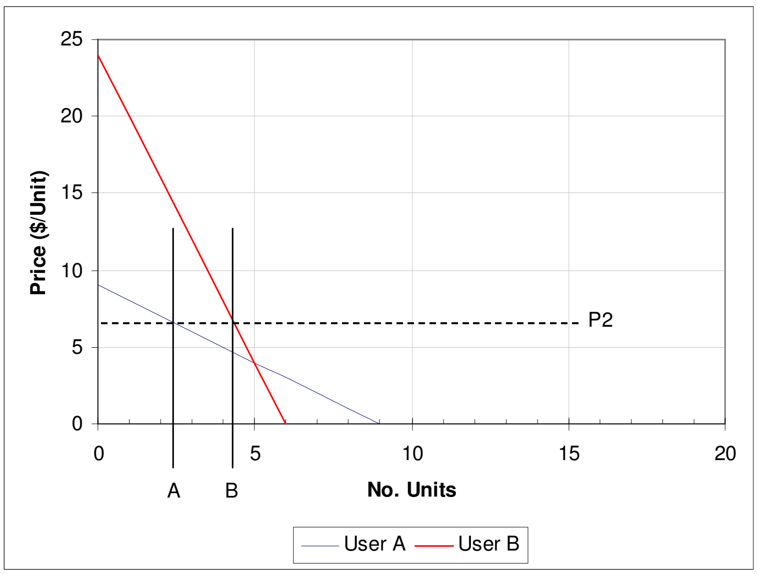

Figure E-1c. Equilibrium price (P2) interacting with individual demand functions for User A and User B.

Next, consider how market barriers and high transaction costs distort the economically efficient allocation. In Figure E-2, a market barrier prevents User B's demand from being considered in allocation decisions. Supply conditions are unchanged from Figure E-1. The aggregate demand seen by the market only reflects User A's demand, and the market clears at less than $5.00. User A commands quantity A', almost twice the economically-efficient quantity observed in Figure E-1c. Suppliers are faced with lower prices and lower sales than the efficient level.

Figure also E-2 illustrates a paradox of market barriers: At the economically efficient price, User B would demand about 4.5 units. The artificial price induced by the market barrier increases User B's willingness to purchase to purchase five units. The result is that User B's perception of injury is not 4.5 units, but five units. User B's total willingness to pay is $20 (five units at four dollars). If User B is predisposed to conflict, this defines the litigation budget that he/she perceives. Note that this exceeds User A's total expenditures for the commodity.

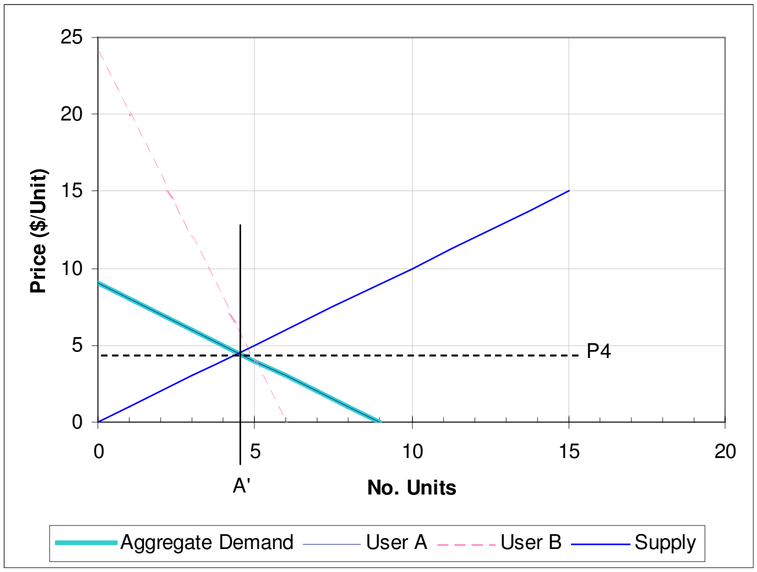

Figure E-2. Hypothetical market condition with barriers preventing entry by User B.

<u>Induced Behaviors.</u> One of the hazards of water administration and water allocation decisions is that policies may induce behaviors different than those intended or desired. An example is that the prior-appropriation provision for forfeiture due to non-use can induce wasteful usage of water specifically to avoid forfeiture, when it could be more beneficial to society if the water were used elsewhere. Current Idaho water banking statutes provide protection against forfeiture and allows water to be temporarily applied to other uses.

The Ground-water Banking Project did not identify other significant status-quo concerns with induced behaviors.

<u>Pricing Mechanisms</u>. When market conditions are met, market-derived prices convey all relevant supply and demand information to all participants, and invite individual users to automatically select the level of consumption that equilibrates marginal cost with marginal benefit. Inadequate numbers of market participants, transaction costs or barriers, and high costs of obtaining information can distort market prices and result in less-than-optimum allocation.

Four pricing issues affect water resource allocation and should be considered in terms of ground-water banking:

1. Administratively-determined pricing.
2. Marginal cost of zero faced by the water user.
3. Water charges are for delivery only.

4. Barriers and Pricing.

Administratively-determined pricing. Administrators may perceive a need to set prices in order to cope with price distortions due to lack of market requirements. As illustrated in Appendix 5, unless the administrative authority happens to accidentally set a price near the economically-efficient price, administratively-determined prices will result in either shortages or surpluses. Users will respond not to a marginal cost of water that represents its cost to society, but to the artificially-determined price. They will match their marginal benefit with the wrong marginal cost, and economically-inefficient quantities will be used.

If the conditions that distort prices are related to numbers of traders or high costs of obtaining information, administrators can use auction mechanisms such as multi-stage or compulsory-bid auctions (see Appendix 5) to bring information to the market place and induce participants to reveal their true preferences. These tools can powerfully and quickly move prices to market equilibrium.

Marginal cost of zero faced by the water user. In the short run, the important price for decision making is the marginal cost, because it is only the marginal cost that can be avoided by changing the amount of water used. In many canal companies, irrigation districts or water districts, the charge is a flat per-acre or per-share charge based on a pro-rata share of expenses. Once the decision is made to irrigate, the annual cost is fixed and is independent of the quantity of water used.[16] Because rational producers will continue adding a production input until the increased value of production (the marginal value product or MVP) equals the marginal cost, this pricing induces irrigators to apply copious quantities of water. In Figure E-3, zero marginal cost invites the rational producer to use three feet of water to produce five tons of crop (point C). That is, the user applies water until the last drop of water produces no additional yield, so that the marginal revenue (zero) matches his/her marginal cost.

This is optimum for society as a whole only if the marginal value of water to the rest of society is also zero. If water has some value to the rest of society, significant reallocation of water from this irrigation activity could be accomplished with surprisingly small impacts on crop yields: Reducing water use by one third reduces crop yield by only eight percent (point B), and cutting water use in half reduces yield less than 20 percent (point A).

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[16] In some companies, the assessment must be paid whether or not water is even used; otherwise the company will retire or auction the shares. This makes even the long-run marginal cost zero.

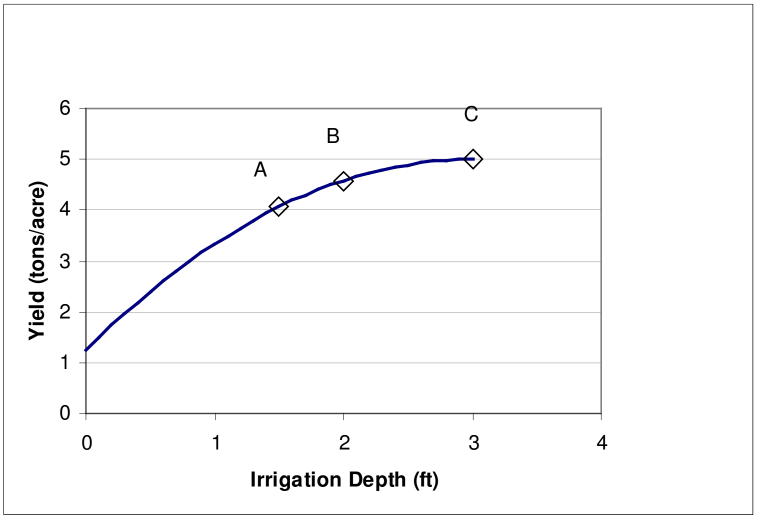

Figure E-3. Typical water production function showing zero-marginal-cost production (point C) and reduced-water use production (A and B). The shape of the curve depends on initial irrigation efficiency; 50% was used here.

Water charges are for delivery only. In some cases the decision price for the irrigator is truly a marginal cost. One example is the energy costs for ground-water irrigation; every acre foot of water pumped increases the energy bill for the season. However, in Idaho there is no charge for the water itself and so the even if the irrigator faces a marginal cost, it includes no indication of the value the water has to society. The marginal cost implicit in the irrigator's decision is not the right price and so the quantity of water used is not the right quantity for maximum social benefit.

Barriers and Pricing. As discussed above and illustrated in Figure E-2, barriers cause part of society's preferences for water use to not be reflected in the price, distorting water-use decisions and introducing economic inefficiency. High transaction costs can have the same effect, such as the high transaction costs of water-rights transfers.

Markets and Ground-water Banking

Ground-water banking can address some of these market concerns and conditions, facilitating the movement of water to uses desired by society and improving the economic efficiency of water use. Some of issues can only be partly addressed by ground-water banking, however.

<u>Externalities</u>. Current externalities in the upper Snake River basin are described in a memo on the project Website (Contor 2005). That memo lists a table of approximate magnitudes and describes the methods of estimation of magnitude of existing externalities. A more complete list is presented in Table E-1, including the potential deposit mechanisms, which would be positive externalities if currently implemented:

Table E-1
Summary of Hydrologic Externalities
in the Upper Snake River Basin

Externality	**Positive/ Negative**	**Impact to:**	**Approximate Current Magnitude (KAF/year)**
1. Snake-river diversions (net)	Negative	Snake River	7,200
2. Recharge incidental to surface-water irrigation	Positive	Aquifer[17]	4,700
3. Net Ground-water Pumping[18]	Negative	Aquifer	1,140
4. Managed Recharge	Positive	Aquifer	(small)
5. Retirement of Ground-water Rights	Positive	Aquifer	(small)[19]
6. Temporary Cessation of Ground-water Pumping	Positive	Aquifer	(zero)
7. Provision of In-lieu Supplies	Positive	Aquifer	(small)
8. Excess Mitigation	Positive	Aquifer	(small)
9. Conversion to less-consumptive crops	Positive	Aquifer	(zero)

The potential deposit activities described earlier in this report are currently positive externalities, because there is no mechanism to assign ownership for the benefits created. Benefits accrue to whomever they will, usually spring users, surface-water users who depend on reach gains and ground-water pumpers. The cost of providing the benefits would be external to the decision processes of users and the potential value to the users would be external to the decision process of providers.

Note that all the positive externalities except for incidental recharge currently occur at very low levels. This observation and history confirm the economic theory that positive externalities are generally provided at less-than-optimum levels: As early as 1962 Reclamation demonstrated the practical ability to perform managed recharge and determined that its potential value to water users (in 1960s dollars) was approximately $700,000 per year (US Bureau of Reclamation 1962). However, there has been very little meaningful managed recharge accomplished in the nearly 50 years since Reclamation's pioneering work. In its report, Reclamation noted the lack of mechanisms to assign

[17] Impacts to the aquifer include secondary impacts to springs and hydraulically-connected river reaches.
[18] This is only an externality if Conjunctive Management Rules are not providing adequate relief.
[19] CREP program (long-term but not necessarily permanent retirement).

ownership and collect revenues for the benefits created by managed recharge and predicted that this would be a significant obstacle to implementation.

Ground-water banking can internalize the benefits of all the listed deposit mechanisms by creating useable, tradable credits issued to depositors. For new activities (that is, activities that presently occur only at low levels), it is straightforward to determine who should receive ownership: The party or entity that causes storage in the aquifer to be greater than it would have been otherwise owns the benefit. This is sound by both the economic efficiency and equity criteria.

Assignment of ownership can also internalize existing externalities, but it raises questions of equity. In Idaho, the Conjunctive Management Rules (Idaho Department of Administration 1994) were adopted to address the externality imposed by ground-water pumpers upon spring users and surface-water users dependent on reach gains. The rules internalized the pumpers' impacts on seniors by creating an exclusionary mechanism (making pumpers subject to prior-appropriation delivery calls) that assigned ownership to senior users of spring discharges and river gains. While the action has internalized the externality by aligning property rights with hydrologic effects, it has also had an equity impact on the wealth of ground-water pumpers. These individuals invested in irrigation infrastructure or irrigated lands in good faith, in accordance with water law that existed at the time. With the adoption of the Rules, they found the value of their water rights suddenly impacted by a new and profound uncertainty of supply.

With other existing externalities, it is not even clear to whom ownership should be assigned. The positive externality of recharge incidental to surface-water irrigation is larger than the externality addressed by Conjunctive Management Rules. Assigning ownership would internalize this benefit, but there are multiple legitimate claimants, as explained in Appendix 4. Regardless of to whom ownership was assigned, there would be significant transfer of wealth and equity issues to wrestle with.

The largest-volume current externality is the burden that surface-water irrigation imposes on species and river ecology. It would not be straightforward to determine who should receive ownership, and there would also be equity issues. Additionally, it is affected by public-goods issues due to the non-rival and non-exclusive nature of ecological, species-protection and recreational uses of river flows.

Four different levels of potential ground-water banking were described in the Overview, ranging from banking compatible with existing statutes and policies (Level I) to a radical, hypothetical banking system incorporating significant changes to statute, policy and allocation practice (Level IV). An important motivation for ground-water banking is to improve economic efficiency (i.e.

maximize the benefit received by society from allocation of water resources). Table E-2 provides insight to the potential value of ground-water banking by describing the ability of ground-water banking to address upper Snake River basin externalities. It also lists other economic factors affecting each particular externality.

Table E-2
Addressing Hydrologic Externalities
in the Upper Snake River Basin Using Ground-water Banking

Externality	**Level of GW Banking Required**	**Degree of Internalization**	**Other Factors**
1. Snake-river diversions (net) impact to ecological services	Level IV	Moderate	Rivalry and exclusion
2. Recharge incidental to surface-water irrigation	Any	High	Equity issues
3. Net Ground-water Pumping	Level IV	High	Conjunctive Mgt. Rules
4. Managed Recharge	Any	Full	
5. Retirement of Ground-water Rights	Any	Full	
6. Temporary Cessation of Ground-water Pumping	Any	Full	
7. Provision of In-lieu Supplies	Any	Full	
8. Excess Mitigation	Any	Full	
9. Conversion to less-consumptive crops	Any	Full	

Public-goods Issues. Ground-water banking can assist in resolution of the public-goods issues by providing another forum where water can be sought for flow augmentation, ecological services and species needs. In general, any activity that increases the overall supply of water benefits all water uses by shifting the aggregate supply curve outward. This can even benefit a water use that is given lower preference or limited access, as discussed later in the report in the section that addresses specific project requirements.

Level II and Level III ground-water banking concepts provide significantly better opportunities than Level I for making water available for public purposes. They expand mechanisms to use banked credits and expand the legal ability to use water in stream.

The issues of rivalry, exclusion and setting an economically-efficient funding rate still remain and are not addressed by ground-water banking itself, at any level.

Homogeneous Commodity. One of the greatest advantages of ground-water banking can be its ability to make water a more homogeneous commodity, thereby facilitating its marketing. Under the current administrative structure in Idaho, it may be hypothetically possible that an entity could agree to engage in one of the described deposit activities, in behalf of another party who needed mitigation. An individual hydrologic evaluation of the impacts of the deposit and the activity requiring mitigation would be prepared and presented to Idaho Department of Water Resources. Unless the two activities were identical in place and time,[20] the time series of hydrologic effects would differ (e.g. mitigation requirements would not match hydrologic benefit) and some additional mitigation or adjustment would be required. Currently, each transaction is treated as a unique and isolated incident; almost no homogeneity exists in mitigation requirements or plans.

In current administrative practice the mitigation requirement is seen as a monolithic unit that has specific requirements such as "10 units of A, 20 units of B,10 units of C, 25 units of D," where each letter represents impact to a particular reach at a particular time. The user is under the obligation to provide some monolithic mitigation activity (or a combination of a few activities) that at a minimum generates the requirements. Perhaps a mitigation plan is found which generates the benefit "25 A, 25 B, 25 C, 25 D." It is accepted, with 15 units of A, 5 of B and 15 of C becoming unreimbursed excess mitigation.

The technological innovation of linking aquifer response functions to double-entry accounting (see Appendix 1 and Appendix 2) creates homogeneity in ground-water transactions with two essential mechanisms:

1. All events are distilled into their effects on individual spring reaches or river reaches, at specific time periods. Benefits are homogeneously described in terms of time series at individual reaches, as are mitigation requirements.
2. Marketing provisions create a pool of generated benefits to which all users have access. Excess benefits are made available to later users, and any user can access the market to supplement mitigation activities. The effect is that monolithic mitigation requirements, and monolithic mitigation plans, are broken down in to exchangeable components represented in the homogeneous descriptions provided by the accounting method.

With this realization of ground-water banking, the user may find that five units of B and ten of D can be purchased reasonably. The mitigation plan is scaled back to the level 15 A, 15 B, 15 C, 15 D. Five excess units of A and five of C are banked and become available in the market to subsequent users.

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[20] If this were the case the water supply for the deposit could simply be dedicated to the new activity; ground-water mitigation and banking would not even be needed.

This process greatly homogenizes deposits and mitigation requirements. Banked ground water is still not a perfectly homogeneous commodity; a two-month injection of 100 acre feet in Arco can never be hydrologically equivalent to a one-day withdrawal of 100 acre feet in Jerome. But the process reduces an infinite number of monolithic deposit activities and monolithic mitigation requirements to a finite series of discrete components something like: "Year-2009 impacts to Henrys Fork; Year-2010 impacts to Henrys Fork;... Year-2159 impacts to Bliss Reach...."

The expected outcome if this realization of ground-water banking is adopted is that credits in reaches most affected by desired new uses will develop a premium marketability and market value. This will invite and induce private investment in deposit activities that provide benefits specifically to those reaches. These activities will necessarily generate some benefits to non-target reaches. The operation of market forces will reduce the price of credits in those reaches, sending signals to potential new users that invite them to develop uses which capture social benefit from these excess mitigation benefits. Appendix 5 discusses the role that investors may place in facilitating reallocation of water.

In summary, operation of ground-water banking can introduce homogeneity, allowing marketing that aligns marginal benefit with marginal cost and moves allocation towards the economically efficient condition.

<u>Market Barriers and Transaction Costs.</u> Ground-water banking itself does not necessarily remove market-access barriers, but removal can be part of the negotiations around the implementation of a ground-water bank. This is essentially the difference between the Level I, Level II and Level III concepts of ground-water banking presented earlier in the report. Level I does not formally address any barriers but provides additional mechanisms for non-preferred uses (such as Reclamation's need for flow augmentation) to seek access to water. Level II and Level III begin to directly address barriers. Pricing mechanisms can also be seen as a kind of market barrier; these are discussed below.

Transaction costs could be significantly reduced under all levels of ground-water banking. The linkage of response functions to double-entry accounting that automatically distills events into homogeneous descriptions of impacts over time to reaches eliminates the need for individual analysis for each proposed transaction. Currently, not only must each applicant spend significant resources to retain qualified individuals to perform analyses, the administrative agency must hand-check and verify each unique analysis. By distilling all events into effects at the river and eliminating the practice of treating each as a unique monolithic event, banking removes the need for these costly and time-consuming individual analyses. Ground-water banking could also reduce the transaction costs of identifying, contacting and negotiating with potential buyers and sellers of water rights for transfer or mitigation purposes.

Induced Behaviors. Participants repeatedly expressed concerns that users would somehow "game the system" if ground-water banking were adopted, though concrete examples of potential abuses were never provided. It is likely that certain provisions of individual classes of allowable deposits and allowable withdrawals could invite counter-productive behavior. However, the project failed to identify specific provisions that must be avoided or included. Additional work would be advised if an administrative agency contemplated implementing ground-water banking.

Pricing Mechanisms. Adoption of ground-water banking provides an opportunity to consider and reconsider pricing mechanisms. Implications of various pricing mechanisms and concerns are described below.

Administratively-determined prices. Any of the levels of ground-water banking can use administratively-determined pricing or market prices. Any could be constructed with pricing preferences or tiered pricing. As described above, administratively-determined prices are likely to result in either surpluses or shortages, and allocation of water at economically-inefficient levels. Preferential prices or tiered pricing greatly limit the ability for all users to select the level of consumption that equates marginal benefit of use with marginal cost. The ability to achieve economic efficiency is hindered.

Figure E-4 provides a hypothetical example of the allocation of supply under the following conditions of administratively-determined, preferential prices:

1. User A has first access to the water supply, at a very low administratively - determined price. The supply curve seen by A is horizontal and terminates at system capacity.
2. User B has access to the remainder, at a higher administratively-determined price.
3. Both users have typical production-based demand curves, sloping down to the right. User B places higher value on obtaining water, but has smaller total requirements than User A.

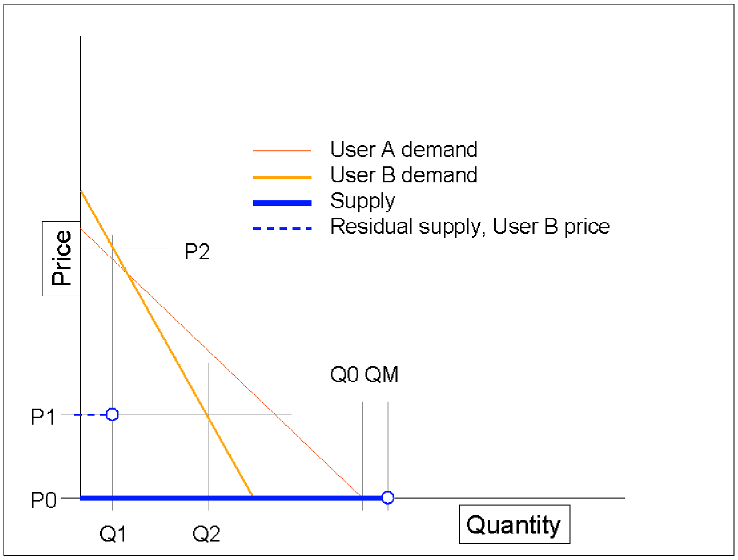

Figure E-4. Fixed-price, preferential pricing mechanism with two hypothetical users.

User A's demand intersects the supply curve at Q0, which is the quantity A uses. Q1 (total supply minus the amount used by A) is available to User B at administratively-determined price P1. At that price, User B desires Q2 and experiences a shortage equal to (Q2 - Q1). User B would have been willing to pay as much as P2 for quantity Q1.

Since the demand curve is defined by the enjoyment derived from using the commodity, the integrated area under the demand curve, up to the quantity used, is a measure of the total enjoyment received from use of the resource. Figure E-5 and Figure E-6 illustrate the benefits enjoyed by User A and User B, respectively.

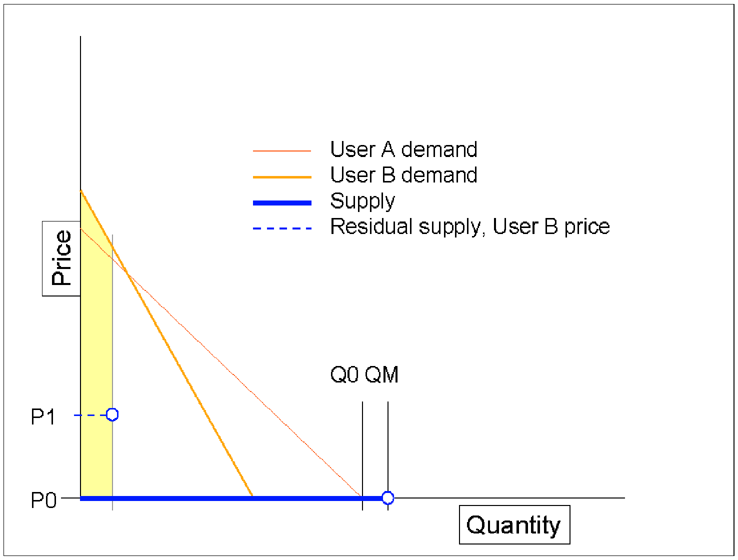

Figure E-5. Benefit enjoyed by User A (shaded area).

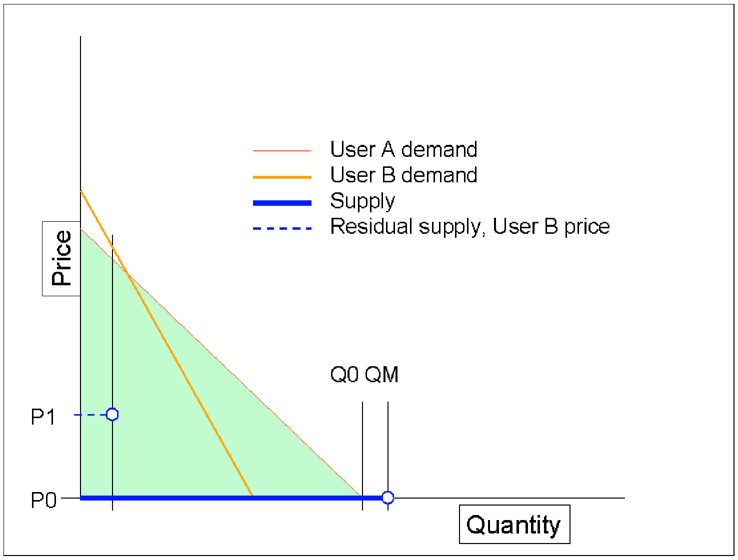

Figure E-6. Benefit enjoyed by User B (shaded area)

Total enjoyment and therefore economic efficiency could be improved by allowing market prices to allocate distribution between User A and User B. User A's preference could be preserved in equity by initially allocating all the water to A but allowing A to sell water to B at negotiated prices. This internalizes B's demand to User A's decision process; in deciding to use water, User A implicitly decides to forego the price that User B would have paid. Since trade is voluntary, User A cannot be worse off; he/she could always refuse to trade and remain at the initial condition. However, whenever User A was using water at a quantity that caused his/her own marginal benefit to be less than B's willingness to pay, A could improve his/her position by selling water to B. With negotiation, the parties could arrive at an allocation similar to that shown in Figure E-7.[21] User A utilizes Q3 and sells Q4 (equal to QM - Q3) to User B at a price of P3.

[21] This is not necessarily the optimum solution. It is a possible solution that is superior to the administratively-determined pricing allocation.

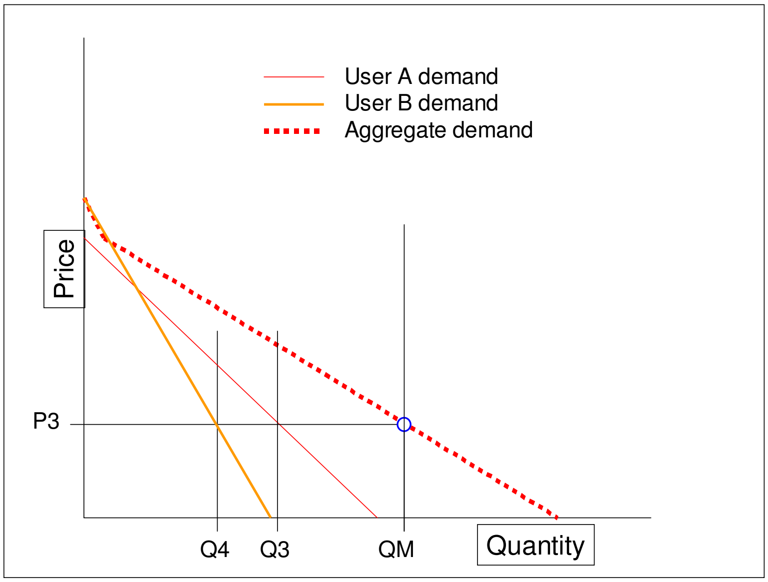

Figure E-7. Allocation with negotiated sales of water from User A to User B.

Figures E-8a and E8-b show the benefits enjoyed by User A. All the blue shaded area in Figure E-8a is the benefit derived from use of water, while the area with dots is in E-8b is the benefit of the revenue received from marketing water to User B. Total benefit to User A is the sum of the two blue areas. The diagonal-striped area is the enjoyment lost by not having the use of the marketed water. It is obvious that A is better off, because the revenue from trade (dotted area) exceeds the lost enjoyment (striped area).

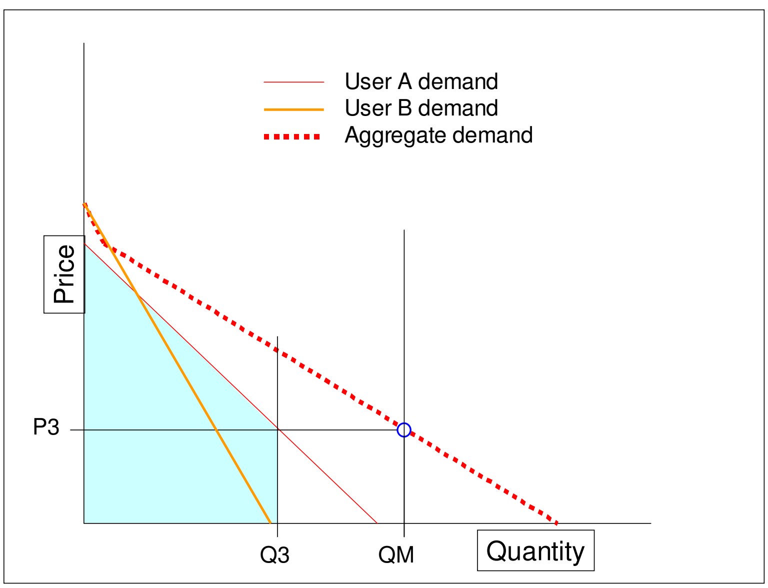

Figure E-8a. Benefits of water use enjoyed by User A after trade with User B.

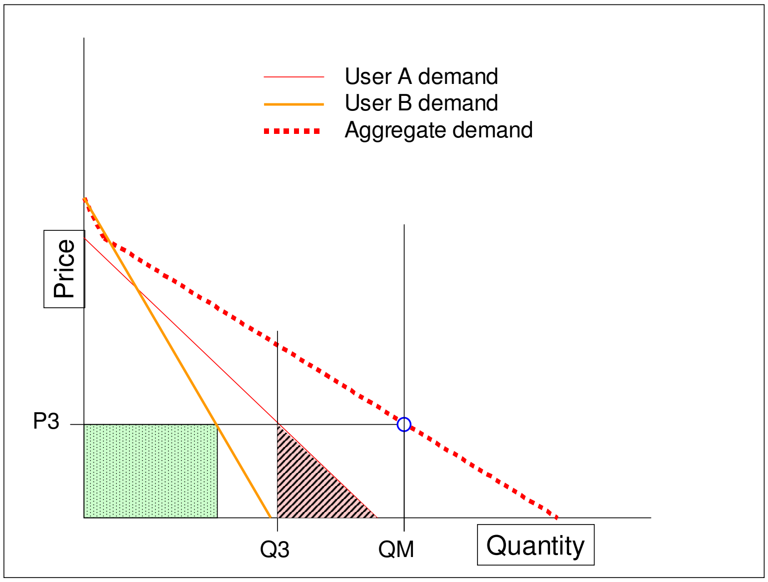

Figure E-8b. Revenue earned by A from sale of water (dotted portion). Note that it exceeds the value of lost enjoyment of the water conveyed (striped portion). User A's total enjoyment is equal to the blue shaded area in Figure E-8a plus the blue dotted area in E-8b.

Figure E-9 shows User B's enjoyment. Comparing Figure E-5 to Figure E-9 shows that User B is also clearly better off; total enjoyment (area under the curve) is greater, and no shortage is experienced.

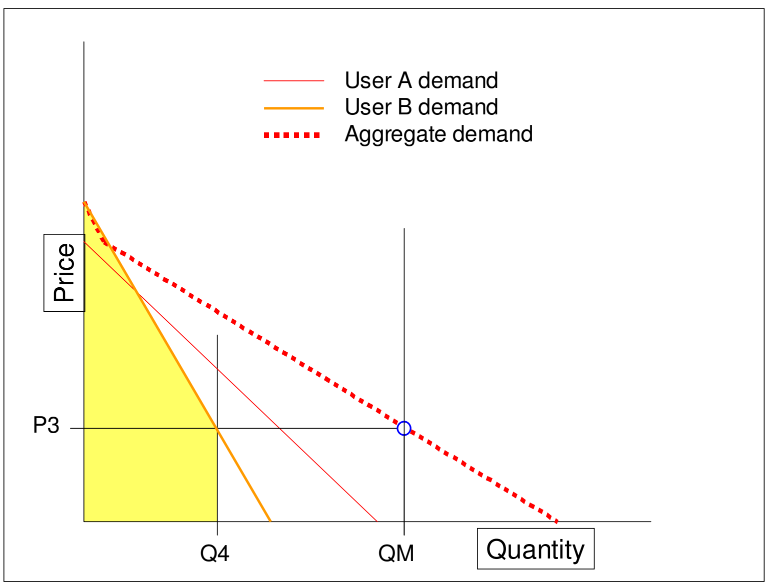

Figure E-9. Benefit enjoyed by User B after trade (shaded area).

Marginal cost of zero faced by the water user. In addition to illustrating principles of administratively-determined pricing, the example above shows how marketing provisions can internalize the demand of other users into the marginal decision cost for water users. It also shows how the wealth of preferred water users can be preserved by assigning revenues of trade back to the preferred users, preserving to them the benefit of the original zero-marginal-cost provision.

Water charges are for delivery only. Ground-water banking can cause the actual value of water to society to be included as part of the marginal cost for decisions. Two components are required; authorized deposit mechanisms must include foregone pumping of ground water, and marketing provisions must be included in the banking program.

Barriers and Pricing. Price-related barriers could be addressed in the negotiations surrounding ground-water banking. Any that exist could be retained or removed, at the choice of the adopters of ground-water banking.

Auction Mechanism and Administrative Prices. One of the reasons that administratively-determined prices are adopted is that water markets, especially new water markets, can have small numbers of traders and little information. This violates market requirements. Participants are reluctant to reveal their true preferences, in hopes of obtaining water at far less than their actual willingness to pay, or providing it at far more than their actual willingness to sell. Without an established market price, users may not even know where to begin in assessing their own true marginal value for water.

Auctions are a useful and time-honored mechanism for discovering market information and extracting true preferences from participants. The modifications of compulsory-bid mechanisms (Heany et al 2006, Young and McColl 2003) and multi-stage auctions (Hartwell and Aylward 2006) further strengthen the ability to induce players to participate at or near their true willingness to pay or willingness to provide. Additional information is found in Appendix 5.

Summary

The economics of ground-water banking and water allocation can be described in terms of equity and of economic efficiency. When market conditions are in place, market allocation satisfies both these criteria. However, water allocation suffers from market deficiencies in terms of economic externalities, public-goods considerations, homogeneous commodity requirements, and market barriers. Additional concerns include induced behaviors and pricing mechanisms.

Ground-water banking can provide significant relief in internalizing externalities and in rendering banked ground water a more homogeneous commodity. It can incorporate any pricing mechanism, including those most likely to produce efficient and equitable allocation.

Ground-water banking would be less successful in addressing the public-goods aspects of in-river uses for recreation and ecological services, though it can be structured to make additional water available for these purposes.

Adoption of a ground-water banking system would require careful consideration of possibly undesirable behaviors that could be induced. The project was not successful in identifying what these might be; additional work is warranted.

Appendix 5 contains economic background material, including discussion of basic supply and demand concepts, and elaboration on auction methods. The chapter on specific reporting requirements also includes significant discussion and illustrations of the economic factors that influence the ability of ground-water banking to make water available to Reclamation for species-preservation purposes and to irrigators.

Chapter 5: WATER BANKING IN OTHER WESTERN STATES

The Overview (Chapter 2) described water banking in Idaho, including the operating surface-water rental pools. Other western states have various realizations of the concept of water banking, applied to both ground-water and to surface water. There are water banks that only deal with physical storage and release of water, and there are water banks that deal only with authorizations to divert. Primary purposes of water banking can be for environmental purposes, irrigation, or DCMI (domestic, commercial, municipal and industrial) purposes. Marketing provisions include banks that only release water to the depositor, banks that allow trading at administrtatively-determined prices, and banks that function as a trading floor or electronic auction board.

A very good summary of water banking in the western US has been compiled by the State of Washington Department of Ecology and is available at http://www.ecy.wa.gov/biblio/0411011.html. Additional information is available at http://www.if.uidaho.edu/%7Ejohnson/hydroweb/Hydroweb_data/OtherStatesGWBanking_200507.pdf, which is a summary presentation prepared by IWRRI staff member Jennifer Griger. The project website "reports and links" page includes both these references, along with the following links to other states' Internet resources:

- Arizona Water Bank Authority (Arizona)
- Central Arizona Project (Arizona)
- CalFed Home Page (California)
- Metropolitan Water District (California)
- Orange County Water District (California)
- Kern Water Bank (California)
- Southeastern Colorado Waer Conservation District (Colorado)
- Colorado Water Conservation District (Colorado)
- Southern Nevada Water Authority (Nevada)
- Truckee Meadows Water Authority (Nevada)
- Pecos River Basin Water Bank (New Mexico)
- Deschutes Resources Conservancy (Oregon)
- Edwards Aquifer Authority (Texas)

The Arizona Water Bank Authority example of a working ground-water bank. This bank quantifies and accounts for ownership of volumes of water delivered to and stored in the aquifer. The bank utilizes a discount for uncertainty, with a larger discount applied when the water source is treated effluent than when it is diverted surface water. The rationalle is that treated effluent, if not applied to aquifer recharge, would likely have been handled in a fashion that would have resulted in some incidental recharge. Administrative distinctions are also made regarding the type of site or location used for recharge. In Arizona parlance, "managed recharge" takes place when recharge water is delivered to dry natural water channel or river bed, while "constructed recharge" occurs when water is delivered to a human-made facility. Arizona's ground water bank does not facilitate ownership transactions; stored water is made available only to the depositor. An interesting feature of this ground-water bank is that recharged water retains some of the legal characteristics of the source water; for instance, if water from the Arizona Central Project is recharged, upon withdrawal it is only eligible for uses authorized for project water. Only hydraulically-closed aquifers, with no discharge to surface-water systems, are eligible to contain banked water.

Chapter 6: INSTITUTIONAL ISSUES

Bureau of Reclamation institutional issues are discussed in Chapter 3, and State of Idaho issues are discussed in Chapter 2. This chapter considers other jurisdictions whose influence may be important in ground-water banking.

1. Tribal Concerns
2. Non-Reclamation Federal Policy
    a. Endangered Species Act
    b. Clean Water Act
    c. National Environmental Policy Act

Tribal Concerns

In the upper Snake River valley, the Shoshone-Bannock Nation has lands that overlie the aquifer that would be the subject of ground-water banking, and has water rights in the same surface-water sources that others may use for deposit activities. The Tribal Water Resources Council agreed to discuss how ground-water banking might affect Tribal interests, and provided access to consultants and personnel working with Tribal water resources issues. This process revealed the following important points in the context of ground-water banking:

1. Snake River Basin Adjudication settlements between the Tribe, the United States and the State of Idaho appear to prohibit the Tribe from marketing its ground water to others. Therefore, a ground-water bank would not be particularly useful as a revenue mechanism for the Tribe.
2. Tribal water rights appear to be adequate for the present time, so it is not likely that the Tribe would benefit from purchasing or withdrawing water from a ground-water bank.
3. Ground-water banking concepts may be useful for the Tribe in its own water management policies.
4. If a ground-water bank were developed which operated in areas surrounding Tribal jurisdiction, it could increase Tribal exposure to potential negative factors:
    a. Aquifer depletion due to mismanagement of the bank.
    b. Additional competition for surface-water supplies, if other users seek surface water for banking deposits.
    c. Water quality issues, if ground-water banking facilitates additional growth or industrial development near Tribal lands.

While banking offers potential hazards, the Tribe would benefit from the same secondary benefits that all other water users would benefit from (see "Obstacles" section of report, Chapter 10):

1. To the extent that ground-water banking facilitates better management of the aquifer, all users will benefit.

2. If ground-water banking causes overall aquifer storage to be greater than it otherwise would have been, water levels and spring discharges on Tribal Lands will benefit.
    a. The retained allowance for uncertainty accrues to the benefit of the aquifer and therefore will increase spring discharges.
    b. Any deposits that are not fully utilized by withdrawals will increase water levels and spring discharges.
3. If ground-water banking reduces conflict and confrontation, all water users are less vulnerable to unfavorable legislation or administrative decisions.
4. Tribal members as individual citizens will benefit indirectly from regional economic activity sustained and facilitated by ground-water banking.

It is possible that ground-water banking would offer more hazards than benefits to the Shoshone-Bannock Nation. Tribal leaders and water-resources staff were very willing to cooperate with this project and would likely welcome the opportunity to provide input and assistance, if the process of actually establishing ground-water banking were contemplated in eastern Idaho.

Non-Reclamation Federal Policy

Two reports on the project website (Moore 2008a, Moore 2008b) describe the basic purposes and requirements of the Endangered Species Act, the Clean Water Act, and the National Environmental Policy Act. As discussed in Chapter 3, these laws and policies would likely come into full play if Reclamation attempted to establish and operate ground-water banking on its own. They may also apply if Reclamation received a charter to operate ground-water banking through the Idaho Water Resource Board.

Historical operation of Idaho Rental Pools has included water stored in some Reclamation facilities. Reclamation has a history of using Rental Pools to obtain flow augmentation water, without full review under these various Federal laws and programs. These precedents may allow Reclamation to participate in ground-water banking that was chartered and operated by other jurisdictions.

Summary

State of Idaho law and policy is discussed in Chapter 2, and Reclamation policy is discussed in Chapter 3. The Shoshone-Bannock Nation is an important regional stakeholder for whom ground-water banking may hold more danger than promise. Environmental reviews may be triggered under non-Reclamation federal law and policy if Reclamation were to implement or operate ground-water banking. If other entities operated ground-water banking, Reclamation may be able to participate without full federal review, as it has in existing surface-water banking activity.

Chapter 7: HYDROLOGIC METHODS AND DEMONSTRATION SOFTWARE

Task 8 of the original work plan was to explore hydrologic methods for accounting for banked ground water and to construct demonstration proof-of-concept software for hydrologic accounting. This chapter of the final report relies heavily upon the draft report "Ground-water Banking in the Eastern Snake Plain: Hydrologic Methods for Accounting and Demonstration Software Tool" (Contor and Johnson 2005), found upon the project Website. There are two basic hydrologic quantification tasks that must be addressed: Quantification of deposits and withdrawals, and quantification of water in storage within the banking system.

Quantification of Deposits and Withdrawals

The report Overview Section (Chapter 2) lists several potential deposit and withdrawal mechanisms that might be considered in adopting a ground-water banking system. Idaho Department of Water Resources practice in transfers of ground-water rights suggests two options for quantification of deposits and withdrawals: When a transfer is from like-use to like-use (for instance, from irrigation in one location to irrigation in another), the quantification is based upon the nominal volume limit of the water right. When a water-rights transfer involves a change in use (for instance, from irrigation to industrial use), the right is quantified in terms of recent historical actual diversion volume. A third option is to quantify deposits and withdrawals in terms of the net effect upon the aquifer.

If credits were issued in terms of nominal water-right volume or of actual diversion volume, a user of credits would have to research the record of credits to determine what was quantified when the credits were issued. If not, injury could result. For instance, 1,000 acre feet of credit could be earned by foregoing flood irrigation of 200 acres of land at a historical diversion depth of five feet. However, the benefit to the aquifer from foregoing this use would only have been the 400 acre feet of net consumptive use (diversion volume minus percolation volume) that would have occurred had irrigation continued. If the credits were then redeemed for 1,000 acre feet of 100% consumptive industrial use, the effect upon the aquifer and therefore upon other users would be an increase in net extraction of 600 acre feet. Because the applicability of credits to proposed withdrawal activities would depend upon the analysis of the deposit mechanism vs. the proposed withdrawal mechanism, negotiating exchange of credits, and the establishment of a market price for credits, would be impaired. Banked credits would not meet the market requirement of homogeneity (see Economics section of report, Chapter 4).

Because of these considerations, the draft report proposed that all credits be quantified in terms of net impact upon the aquifer. Transaction costs can be reduced by agreeing on set net consumptive rates for each use category. While these will not be precisely accurate for any given transaction, they can be correct on average. This is the practice in the Deschutes, Oregon ground-water bank (Aylward 2006). Once accepted as deposits, all credits have equal standing and are homogeneous.

Quantification of Water Stored Within the Banking System

Hydrology of Deposits and Withdrawals. Hydrologically the first impact of a recharge event is to create a mound of water in the aquifer directly beneath the recharge site. The first impact of well extraction is to create a cone of depression directly around the well. The first impact of foregone extraction is that a cone of depression that would have existed in fact does not exist. The common thread is that the first hydrologic impact of any deposit or withdrawal activity is an impact upon aquifer storage. In a simple, hydraulically-closed aquifer, accounting for the volume of change in storage is adequate. Over time, the mound or cone of depression will equilibrate to a uniform change of water level in the aquifer, but its total volume will remain equal to the deposited or withdrawn volume. It is this simplicity of accounting that has confined nearly all current ground-water banking activities to hydraulically closed aquifers (Sweitzcowski 2003, Bonesteel 2003).

When the aquifer is connected to surface-water bodies, the mound or cone of depression propagate outward until they reach a connected water body. Hydraulically-connected surface water bodies will have an existing relationship with the aquifer depending on the relative head in the aquifer and in the surface-water body. Figure H-1 illustrates four possible relationships.

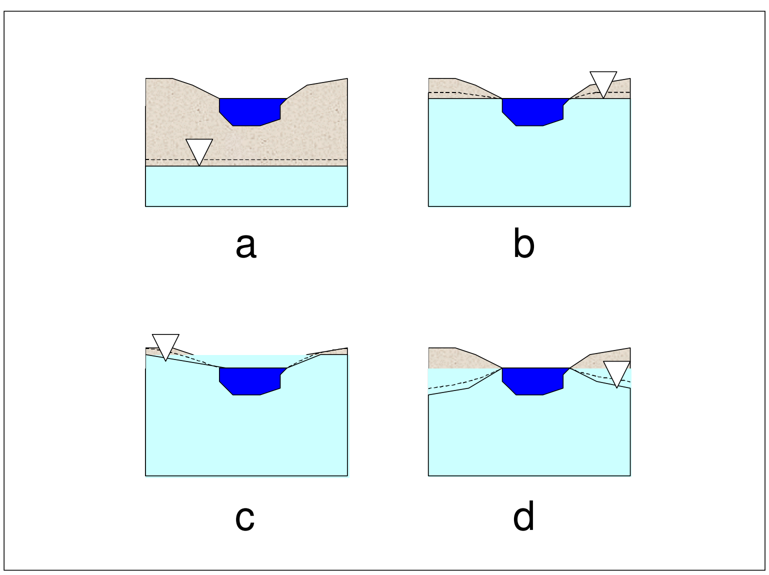

Figure H-1. Four possible hydraulic connection conditions.

Perched streams (a) are usually losing streams, with the rate of loss is governed entirely by conditions in the stream. If recharge were to raise the water table (dashed line), the rate of loss would not change in response. If a stream is hydraulically connected with the aquifer but aquifer head is exactly the same as head in the stream (b), there is no flow. Recharge would raise the water table and cause the stream to become a gaining stream. When aquifer head is higher than head in the stream (c), the stream is gaining. An increase in aquifer head will cause the stream to gain more. If the stream is hydraulically connected to the aquifer and aquifer head is lower than the stream (d), the stream is also a losing stream, with rate of loss sensitive to aquifer head. Recharge would increase the head in the aquifer and reduce the rate of loss from the stream.

In the case of a perched stream, the hydrologic effect of recharge remains within the aquifer unless heads rise so high that the aquifer intercepts the saturated stream-bed materials and the stream becomes no longer perched. In the other three cases, when the mound or cone of depression reaches the stream, the hydrologic effect is that some of the deposit or withdrawal effect is propagated *from storage in the aquifer* to *a change in flow in the stream.* A concept that is difficult to grasp is that the *quantity effect upon the stream* of the aquifer deposit or withdrawal depends only upon the hydraulic properties of the stream bed and adjacent aquifer, and the change in aquifer head induced by the deposit or withdrawal. If recharge is applied in Figure H-1d, molecules of water still leave the stream and enter the aquifer. However, the rate of loss is reduced so that the water-quantity effect on the stream is exactly as if a pipeline were delivering water to the stream.

From a water-quantity-accounting standpoint, cases (b), (c) and (d) are identical. The first consequence of recharge is an increase of storage in the aquifer, causing a change in head. As this change in head propagates outward it intercepts a hydraulically-connected stream and changes flow between the stream and aquifer. The change in flow persists over a period of time until exactly the volume that was recharged has appeared in the stream as increased flows, either through physical movement of molecules into the stream (case (b) and (c)), or through reduced movement of molecules out of the stream (case (d)). When the entire recharge volume has been depleted, heads and flows between the stream and aquifer return to what they would have been without the recharge event. The same concept applies to a withdrawal, except that the effect upon the stream (either an increase in loss, or a reduction in gain) persists until the cone of depression has been replenished and heads and flows return to what they would have been without the withdrawal activity.

Springs are also hydraulically connected to the aquifer, and in Idaho water law are classified as surface water. Recharge also increases spring discharge, by increasing aquifer head near the spring and thereby increasing the driving gradient that controls the discharge rate of the spring. This is illustrated in Figure H-2.

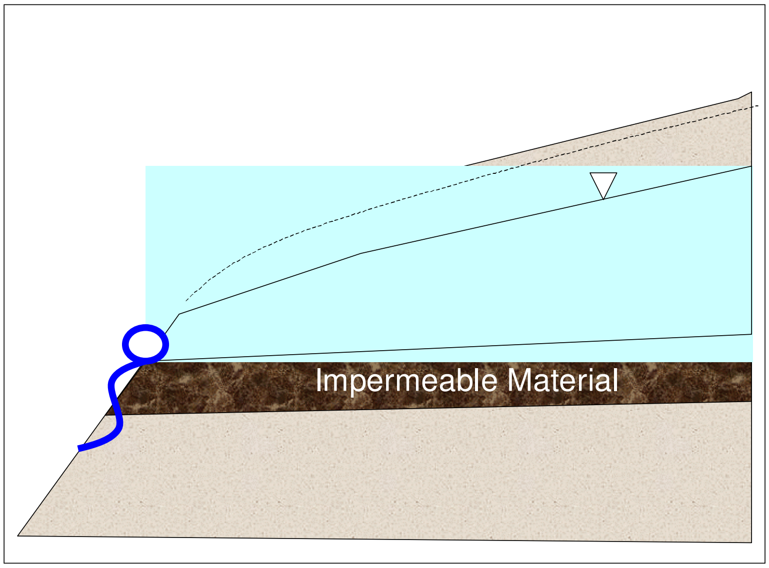

Figure H-2. Conceptual illustration of spring discharge.

Superposition and Response Functions. The hydrologic concept of superposition (Reilly et al 1987) describes how the impact of a deposit or withdrawal event can be analyzed independently of underlying aquifer conditons, so long as the aquifer and surface-water are hydraulically connected. This allows the use of aquifer response functions (Barlow and Moench 1998, Bostock 1971, Cosgrove et al 2008, Cosgrove 2005, Cosgrove and Johnson 2004, Cosgrove 2001, Glover and Balmer 1954, Johnson and Cosgrove 1999, Maddock 1974, Maddock 1972, Miller et al 2007, Olsthoorn 2007, Sun et al 2004). A draft report (Contor and Johnson 2005) and Appendix 1 discuss these concepts further, including application of response functions to non-linear systems.

Accounting Requirments. The main point of ground-water banking is to store water in the aquifer for use at a different time or place. An obvious requirement for accounting is to be able to appropriately represent migration to hydraulically-connected surface water, so that a withdrawal is not made based upon a deposit event that has already been propagated into the stream and no longer is stored in the aquifer.

Storage Credits and Mitigation Credits. Early in the project we considered the concept of "storage credits" to describe water that was still within the aquifer, and "mitigation credits" to describe fluxes (actually *changes in flux,* as described above) that were currently being felt at surface-water bodies. The accounting process would periodically adjust storage credits and mitigation credits to reflect the migration discussed above. When withdrawals were made from the aquifer, the part of the withdrawal that came from aquifer storage would be offset with storage credits, and the part that immediately affected surface-water bodies (including springs) would be offset with mitigation credits. Figure H-3 illustrates a conceptual difficulty with this method.

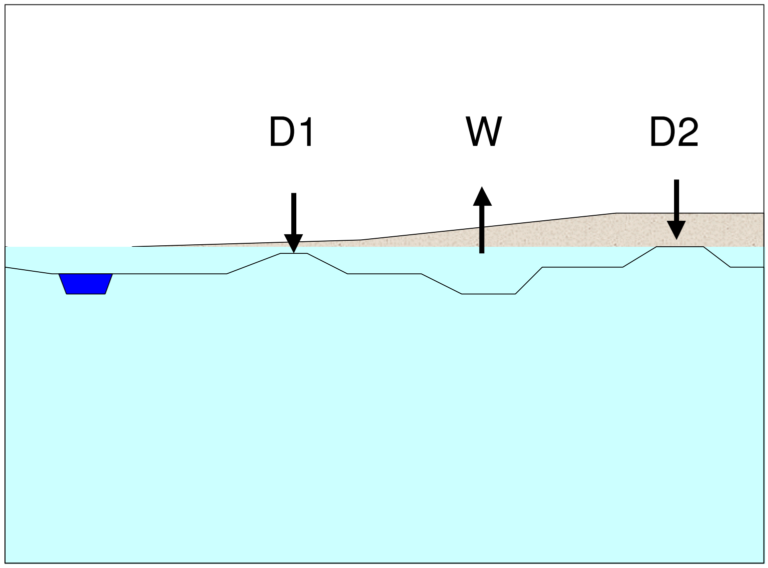

Figure H-3. Deposits and withdrawals in different locations, distant from surface-water bodies.

In a large aquifer such as in the upper Snake River valley, two different deposits distant from the aquifer could both be represented almost entirely by storage credits for many years. However, their benefits may not necessarily be equivalent in terms of mitigating for impact to surface water bodies. Intuitively one can see that the benefits of deposit *D1* might be substantially depleted before the impact of withdrawal *W* reaches the river. Similarly, the benefits of deposit *D2* might arrive too late to offset all of the impact of withdrawal *W*. One possible response is illustrated in Figure H-4: The aquifer could be divided into compartments, and storage credits would be further described by the compartment in which they resided.

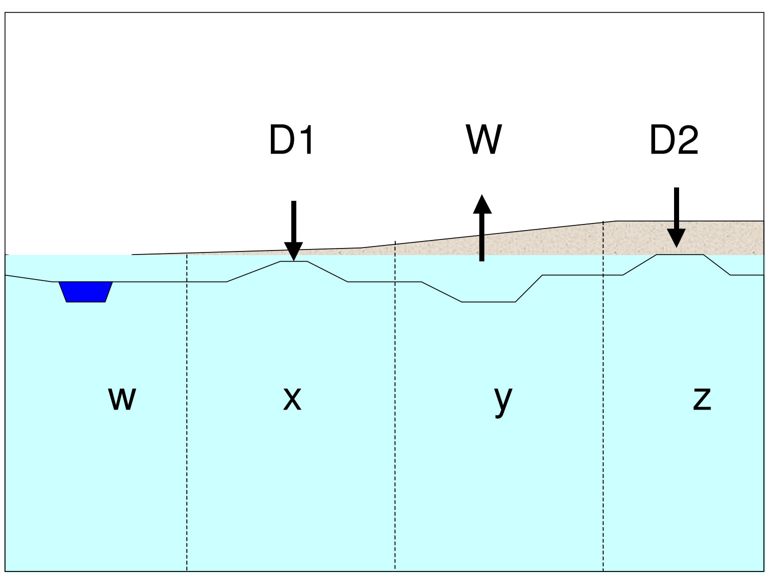

Figure H-4. Aquifer divided into compartments *w, x, y* and *z* for describing storage credits spatially.

In addition to describing storage credits, mitigation credits, and the conversion of storage credits into mitigation credits, the accounting process would also have to describe storage credits spatially and account for migration of storage from one compartment to the other. The difficulty of this is compounded by the fact that Figure H-4 is really only a slice through the aquifer. One could picture compartments *w', x', y'* and *z'* coming out of the paper towards the reader, and compartments *w*, x*, y** and *z** behind the figure. Not only would storage in compartment *z* migrate to *x*, but also to *z** and *z,'* and thence to *x', x*, z'', z**,* etc. This fact greatly increases the complexity of the accounting task.

Credits Described in Terms of Reach Impacts. One of the three significant findings of the project was the realization that all storage and mitigation credits could be collapsed into descriptions of their time series of effects at the surface-water bodies, without loss of information. The amount of flux to surface water bodies, the volume of water remaining in storage, and the remaining time required for storage water to find its way to the surface water are all implicitly contained within the time series of impacts at the surface-water body, contained within the aquifer response functions for impacts at the location of the deposit or withdrawal.

Figure H-5 is a cartoon of response functions that might be representative of the activities in Figure H-3 and Figure H-4. Figure H-6 shows the sum of deposits *D1* and *D2* as a heavy line, with the remainder (after mitigating for withdrawal *W*) as a thin line. The remainder would be available to mitigate for other withdrawals, perhaps in combination with other deposits.

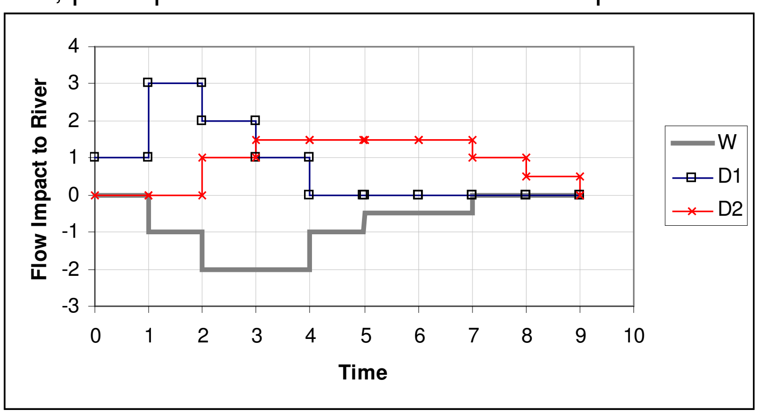

Figure H-5. Response functions for activities shown in Figure H-3 and Figure H-4.

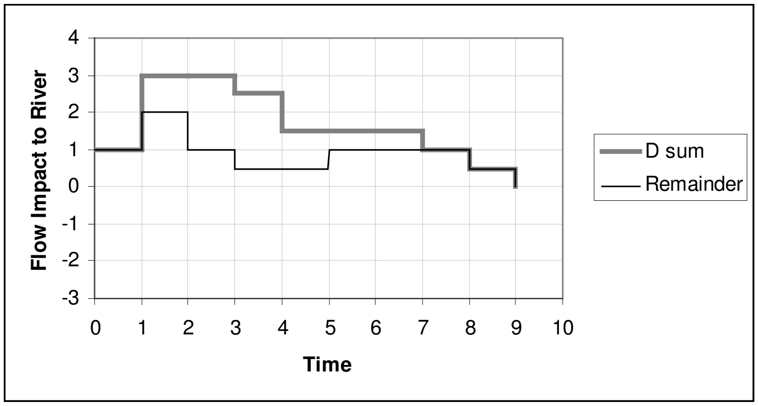

Figure H-6. Combined effect of deposits, and remainder after mitigating for withdrawal.

The expression of banked quantities of water in terms of the time series of impacts at hydraulically-connected surface-water bodies has two important results. First, accounting is greatly simplified. Second, great homogeneity is introduced into ground-water banking. Many different deposit and withdrawal activities in many different locations, at many different times, can be uniformly described as time series of impacts to surface water. As discussed in Chapter 4, homogeneity is an important market requirement needed for economically-efficient market allocation of commodities.

Assignment of Ownership of Banked Water

Once the effects and impacts of withdrawals and deposits are quantified, a system is needed to record and assign ownership to them. If transactions and exchange are to be allowed, the system must accommodate changes in ownership. Financial double-entry accounting (Stevenson and Budd 1959) was selected for the demonstration software for the following reasons:

1. It is a mature technology described as early as 1494 (Macve 1996).
2. Robust commercial accounting software applications are available that incorporate the ability to handle tens of thousands of account holders and hundreds of thousands of transactions, with appropriate security measures.
3. Double-entry accounting simultaneously tracks quantities of water in the banking system and all the ownership claims upon banked quantities of water.
4. By requiring that all withdrawals be offset by existing balances before being approved, double-entry accounting automatically satisfies the prior-appropriation no-harm rule that no reallocation of water can leave any other user worse off than before.
5. In addition to quantities of stored water and ownership claims, at all times the accounting records provide:
    a. Cumulative impacts to surface water since the start of banking.
    b. A history of transactions by each participant.

c. The future impacts that will occur based on transactions that have already taken place.

Appendix 1, the draft report (Contor and Johnson 2005) and many textbooks are available to describe the operation of double-entry accounting.

Demonstration Software

Demonstration software prepared as a proof-of-concept may be downloaded from http://www.if.uidaho.edu/%7Ejohnson/hydroweb/reports.html. The download includes executable files, source-code files, text listings of source code, and sample data. Its operation is described in the draft report.

The demonstration includes the ability to designate part of each deposit as an irrevocable allowance for uncertainty, to be retained by the banking authority. This allowance accrues to the benefit of the aquifer, providing protection to imprecision in the quantification of response functions. Note, however, that imprecisions will be somewhat offsetting since the same response functions will be applied to both deposit and withdrawal activities.

Conclusion

Ground-water banking requires methods to quantify:

1. Deposits.
2. Withdrawals.
3. Water in storage.
4. Hydrologic impact upon surface-water bodies.
5. Ownership claims and changes in ownership.

One of the most important outcomes of the project has been the realization that aquifer response functions can distill all impacts into representation as time series of effects at surface-water bodies. If this is combined with quantification of deposits and withdrawals that expresses all events in terms of net impact to the aquifer, using aquifer response functions to describe all events has the economically-important effect of creating homogeneity.

Financial double-entry accounting tracks quantities of banked water and ownership claims, as well as facilitating accounting for trade, marketing and change in ownership.

Demonstration software serves as proof-of-concept of the ability to link these two technologies in an important innovation that allows ground-water banking in aquifers that are hydraulically connected with surface water.

Chapter 8: STAKEHOLDER INPUT

Stakeholder input was received by inviting a number of participants to meet, discuss, share viewpoints and review intermediate products. A panel discussion was held at the January 2007 annual meeting of the Idaho Water Users' Association, featuring the following panelists:

1. Dave Tuthill, IDWR
2. Jerry Gregg, Reclamation
3. Lynn Tominaga, Idaho Ground Water Appropriators
4. Vince Alberdi, Twin Falls Canal Company
5. Randy MacMillan, Clear Springs Foods
6. Bruce Aylward, Deschutes River Conservancy (Oregon)
7. Kim Goodman, Trout Unlimited.

Questionnaires were distributed to the audience, as well as provided on the project Website (http://www.if.uidaho.edu/%7Ejohnson/hydroweb/index.html). Thirteen questionnaires were returned at the water users' meeting, and two additional were returned by mail shortly after the meeting. The following summary is extracted from the project Website:

1. About me:
   a. Legal residence
      i. North Idaho 0
      ii. South Idaho 15
      iii. Other USA 0
      iv. Outside USA 0
   b. Age
      i. Under 20 years 0
      ii. 20 yrs or over 15
   c. Primary Interest in GW Accounting[22]
      i. Environmental 1
      ii. Recreation 0
      iii. Aquaculture 0
      iv. Crop ag. 12
      v. Livestock ag. 4
      vi. Comm. & Muni. 2
   d. I own an Idaho water right
      i. Yes 14
      ii. No 1

2. What I think Ground-water Accounting will do
   a. Move water out of Idaho
      i. Agree 0
      ii. Disagree 14

[22] Some respondents checked more than one primary interest.

      iii. Neutral 4
   b. Increase pumping
      i. Agree 3
      ii. Disagree 10
      iii. Neutral 2
   c. Increase recharge
      i. Agree 11
      ii. Disagree 3
      iii. Neutral 1
   d. Provide water for environmental uses and recreation
      i. Agree 5
      ii. Disagree 7
      iii. Neutral 3
   e. Provide water for economic growth
      i. Agree 11
      ii. Disagree 3
      iii. Neutral 1
   f. Concentrate water in the hands of the wealthy
      i. Agree 5
      ii. Disagree 9
      iii. Neutral 1
   g. Reduce Conflict
      i. Agree 7
      ii. Disagree 5
      iii. Neutral 3
   h. Overall I think GW accounting will be[23]
      i. Good 8
      ii. Neutral 6
      iii. Bad 2

3. What I think about the project
   a. More emphasis needed for
      i. Policy and environment 6
      ii. Economics 7
      iii. Hydrology 10
      iv. Admin & Operation 12

4. Source of responses
   a. IWUA meeting January 2007 13
   b. US Mail[24] 2
   c. E-mail 0

5. Summary of written responses. (Written responses were given to specific questions and to a general "comments" area on the questionnaire):

[23] One participant checked both "neutral" and "bad."
[24] Both US mail responses were received shortly following the IWUA meeting.

a. Other viewpoints of what GW accounting will accomplish:
    i. Uphold prior appropriation doctrine - agree
b. My biggest fear for GW accounting:
    i. Will be incomplete, bias modeling, incomplete modeling
    ii. Inaccurate accounting.
    iii. May result in legislation that will be adverse to existing uses.
    iv. That the accounting will go forward with the use of flawed models and data with false outcome.
    v. Environmentalists will demand more water.
    vi. Movement of water is unknown - does it move through the aquifer quickly or slowly?
    vii. Change in aquifer content may be difficult to monitor.
c. My greatest hope for GW accounting:
    i. Management of aquifer
    ii. Management of both surface and ground water
    iii. That those gathering information will approach all surface water users (canals) for more personal input. Process needs more time with water users face to face.
    iv. That we will be able to see an account balance of ground water.
    v. Early water rights will be protected better.
    vi. To put to rest that the aquifer is not overappropriated.
    vii. It has possibilities but I'm skeptical
d. Additional topics that should be considered:
    i. Water accounting should be about water hydrology and accounting only. The administration and operation is for state and owner of water rights.
    ii. Different levels of aquifer and sources, historical snowpacks and their affect on aquifer recharge, snowpacks that don't run off to the river.
    iii. Water could be put in the gravel pit at Blackfoot for recharge. City of Blackfoot would buy the water and it would leach into the aquifer.
    iv. Reduce GW pumping, too bad the state has put so many at risk, but reality is what it is. This is not, and should not become a burden to Idaho tax payers.
    v. Recharge aquifers all over state on high water years.
    vi. Priority doctrine.
    vii. State of Idaho's responsibility for where we are today.
    viii. Rental pool fees should be considered for junior pumpers on a declining aquifer.
e. Additional input should be sought from:
    i. Fish and wildlife interests, domestic users (individual)
    ii. Canal companies should each have better input, or those users who have worked and lived in the affected area and have personal observation and historical input.

iii. All canals in the SWRB.
iv. State of Idaho law
v. The users
vi. Ground water needs to step forward more
vii. Other river basins that may be capable of providing alternate flow to allow in basin.

f. Comments:
   i. Is this concept being explored just to pacify current litigation between the surface and ground water users.
   ii. Recharge? A Sacred Cow! Bureau of Reclamation could step forward and contribute i.e. winter water savings contract.
   iii. I don't think any one person should have the power to shut down any one use of our water or any resource we have.
   iv. I think we should wait and see what the Water Resource Board Framework looks like and then decide what additional input is needed.
   v. The sooner we reduce GW pumping the better off the state will be. We all must recognize that use is exceeding supply and GW pumpers need to stop wasting valued dollars in trying to skirt state laws and the fact the aquifer is overappropriated.
   vi. Maintain "first in right" throughout procedures to maintain order in irrigation.
   vii. I believe GW accounting is the only method to make progress towards solving the recharge dilemma.

With the participants' group, one-on-one meetings were conducted as well as a few group meetings. The introduction of this report identified the participants and discussed their role as follows:

> "A participants' group of stakeholder representatives provided insight and review of the project and project products. The participants were placed in the awkward position of being associated with a project whose outcome was beyond their control. Participants recognized and accepted the hazard that the reported findings of the project may be contrary to their own views or the positions of the organizations that participants represent. Nevertheless, all the participants considered the ideas presented, offered insight, and allowed their participation to be known. The project is much stronger due to their valuable contributions. Participants include:

Vince Alberdi	Twin Falls Canal Company
David Blew	Idaho Department of Water Resources
Jon Bowling	Idaho Power Company
Charles E. Brockway	Brockway Engineering
Ron Carlson	Water District 01

Jerry Gregg	U.S. Bureau of Reclamation
Chris Jansen-Lute	U.S. Bureau of Reclamation
Bryan Kenworthy	U.S. Fish and Wildlife Service
Randy MacMillan	Clear Springs Foods
Chris Meyer	Givens Pursley LLC
Tony Olenichak	Water District 01
Bill Quinn	Idaho Department of Water Resources
Cindy Robertson	Idaho Department of Fish and Game
Walt Pool	Idaho Department of Fish and Game
Norm Semanko	Idaho Water Users Association
Garth Taylor	University of Idaho Agricultural Economics
Lynn Tominaga	Idaho Ground Water Appropriators
Dave Tuthill	Idaho Department of Water Resources
Will Whelan	The Nature Conservancy

All participants were invited to submit counter-point opinion documents in response to this draft report, to be included without editing in the appendix of the final report. None were received, but this should not be construed as endorsement by the participants."

The participants' page on the project website includes the following summary of input received.

"From the participants we have learned:

- Verification of the hydrologic tools is important. A banking system requires confidence that water actually does what the tools say it will.
- Verification and enforcement of user commitments is vital. Deposits must actually occur and withdrawals must be within authorized limits.
- Opinions about market mechanisms range from "market mechanisms are vital" to "any market-based approach will be a deal-breaker".
- Potential users worry about the complexity of accounting and administration that ground-water banking may create.
- Potential users have a high level of concern about the implications of accommodating new uses while protecting existing uses.
- Existing surface-water rental pools can provide a model for some concepts of ground-water banking. For instance, in a surface-water reservoir the water is delivered *to storage* under the priority system (only delivered when seniors are satisfied). Once stored, the water is the "property" of its owner, deliverable upon demand (within operating rules of the pool). One of these operating rules is a shrinkage adjustment for evaporation and seepage; this could be a model for dealing with the "leaky vault" condition in a ground-water bank."

The final item is an important finding of the project and came originally from participants. Participants also provided valuable input on the Agent Based Modeling described later in the report, at a meeting where intermediate results were displayed and the model was demonstrated. Participants also helped the project researchers understand the concepts that are described in the discussion on obstacles, later in the report.

Summary

Stakeholders, as represented by both the participants' group and a very small number of questionnaires received from other individuals, in general seem cautious and skeptical of ground-water banking. This is underscored by the tone of the written comments: Even though the responses to individual questions (such as whether responders believed ground-water banking would reduce conflict) tended to be positive, the written comments tended to be cautious and doubtful.

Chapter 9: AGENT-BASED MODELING

The ground-water banking project greatly benefited from the participation of Mr. Beaudry Kock of the USGS/ Massachusetts Institute of Technology MUSIC program. Kock plans a submission to the Journal of the American Water Resources Association describing his work with ground-water banking in the upper Snake River basin.

Agent-based modeling is a powerful computer-modeling technique that allows researchers to model individual decision-making agents (in our case, farmers, canal companies, power companies, and administrative agencies). It incorporates artificial intelligence to allow learning and adaptive behavior, and it includes the opportunity to introduce stochastic perturbations that would be unforeseeable to the agents. Agents learn from one another and from their experiences, but have the ability to sometimes forget what they have learned and to take actions that do not necessarily maximize their economic utility. Further realism is introduced by limiting information available, so that just as in life, agents must sometimes make decisions with only partial availability of relevant facts.

The value of agent-based modeling is primarily that researchers can test modifications in administration, physical systems or social relationships, in a safe environment where the consequences of failure do not affect real people, environmental systems or economic values. Second, by forcing the rigorous specification of social (economic, political, legal) mechanisms, researchers can better explore their own assumptions about how these mechanisms and systems work. Third, by using a bottom-up approach, unexpected results may be seen at the macro scale that could not otherwise be predicted with a top-down analysis.

Based on interviews with stakeholders and discussions with other researchers, Kock simulated the both the physical systems and the decision-makers and players, for ground-water and surface-water irrigation and hydropower generation on the Snake River in the upper Snake River basin. The Eastern Snake Plain Aquifer Model (Cosgrove 2005) provided the basis of the ground-water hydrology, and a simple cellular automata river system provided for the surface water simulation. Ground-water banking utilized the concepts incorporated in the demonstration software described in this report. Kock's realization of ground-water banking was designed in a way that tested the impact of imprecision and uncertainty in aquifer response functions. He allowed the simulation to operate without ground-water banking, and then applied two different potential realizations of ground-water banking; one with, and one without administratively-determined pricing.[25]

[25] There may have been some anomalies in the setup of the market-price simulation; price behavior was unexpected, though agent response to prices was exactly as economic theory would predict.

Agent-based modeling is still an emerging science, and like any modeling, results are dependent on the assumptions and calibration of the model. With those qualifications, however, we report that agent-based modeling confirmed economic theory that increased access to water through voluntary market mechanisms would reduce stress and conflict in a community. The modeling did not produce large changes in the supply of water available. This may be a result of the model setup (agents had no access to water that currently is released for flood control, for instance), but it confirms at least the subjective expectations of the author of this report. Kock's draft final paragraph is quoted below:

"In this modeling project we sought to apply integrated socio-hydrologic modeling to the task of exploring what effects a ground water banking institution would have on levels of water conflict within an over-allocated artificial hydrologic system, and how the banking institution would perform in terms of transaction volumes and other measures. We have shown that the introduction of a banking institution to a conflicted system can have the effect of reducing conflict even without providing additional water in the short term, due to the various cognitive benefits of having additional options to manage conflict, and the effects of social networks in propagating perceptions of conflict and stress. We have demonstrated that a banking system in this setting would perform relatively well in terms of administrative efficiency, but would not necessarily generate great physical benefits or costs in the short term. We have provided a simple and functional recipe for a ground-water bank, the component rules of which appear to work well in facilitating operation of the bank for a large and complex conjunctive use system. Finally, we have demonstrated that the choice of pricing mechanism for a ground water bank can have powerful implications for the relative and absolute volumes of lease and deposit transactions made through the bank, and that designers of ground water banking systems would do well to consider how much regulatory control they wish to maintain over the pricing of water in the bank."

Chapter 10: OBSTACLES IN GROUND-WATER BANKING

Public Acceptance of Banking. One of the obvious obstacles in ground-water banking is gaining public acceptance and achieving implementation. The participant group in general seemed more skeptical than enthusiastic. Professional facilitation would greatly improve the likelihood of incorporating all stakeholders' concerns and achieving implementation of a workable banking plan.

The Idaho Water Resource Board experience with the Comprehensive Aquifer Management Plan (CAMP) for the eastern Snake River plain (Idaho Water Resource Board 2009 (2)) provides a pattern. It was conducted with a broad base of stakeholder participants (including Reclamation) and facilitated by professional mediators. It has been successful in conducting difficult negotiations and achieving broad-based support of a management plan, which has not happened in decades of prior work without professional facilitators.

Public-goods Issues. As described in the economics and Reclamation sections of the report, ground-water banking can provide additional access to water for public purposes such as flow augmentation. However, banking alone cannot overcome the rivalry, exclusion and public-funding issues that make it difficult to achieve the economically-efficient level of expenditures for public purposes.

Technical Limitations of Response Functions. All the available technical tools for generation of response functions offer approximations of complex and imperfectly understood natural systems. Some of them can be very good; the Eastern Snake Plain Aquifer Model (Cosgrove 2005) was calibrated to thousands of individual observations and did an admirable job of matching observations. In a post-calibration application it did a reasonable job of simulating a drought outside the calibration period, even using estimated data . Nevertheless, all technical tools will have limitations and uncertainties.

The section of the report on demonstration software includes provision for a retained allowance for uncertainty, designed to protect the aquifer system and other users from imprecision in the tools. Other factors also limit exposure:

1. Unless Level IV banking is adopted (see discusssion of levels of banking in the Overview section of the report, Chapter 2), the impact of banking is likely to be small relative to overall hydrologic inputs, outputs and flow through the system. There will be significant buffering ability in the system.
2. Banking activity is likely to begin slowly. Adoption of banking can even include a trial period with a sunset clause, or a limit on annual volume of participation for the first few years. There will be time to observe and correct for any unforeseen results of banking.

3. The same hydrologic tools will be used to quantify deposits and withdrawals. If the tool chronically mis-estimates the magnitude or timing of impacts to a particular reach, it will include the same biases in its estimates of the impact of banking deposits and withdrawals. The imprecisions will largely be self-canceling.
4. Scientific investigation of physical systems, and methods for representing them, will continue to improve. Improved knowledge can be used to refine response functions used in banking accounting as time goes on.

Public Perception of Response Functions. The size and complexity of most aquifers that are connected with surface-water bodies precludes the ability to verify response functions with physical experiments. This is certainly true in the upper Snake River valley. Users are placed in the difficult position of having to accept scientific assessments of the reliability of the response function. The assessments will be performed by technical personnel who will not be comfortable making the kinds of broad endorsements that users will look for, even when the tools used to generate response functions may be worthy.

Discussions with the participant group indicate that acceptance of the technical tools will be a significant factor in negotiating implementation of ground-water banking. It can almost appear that a technical tool is accepted when it supports a favored outcome (perhaps administrative action against another water user) but challenged when it supports an unfavored outcome (such as a mitigation plan offered in response to the administrative action).

The technical complexity of response functions and the methods used to generate them can also be a barrier to acceptance. The linkage of response functions with double-entry accounting increases the complexity; even hydrologists knowledgeable about response functions can struggle with the accounting concepts. After detailed presentation of the linkage, and discussion of the ability it provides to conduct banking in aquifers connected to surface-water bodies, one of the participants still stated emphatically in a public meeting that he felt ground-water banking was only appropriate for hydraulically-closed aquifers like those used for ground-water banking in Arizona and Nevada.

These are social issues best approached by social scientists, rather than hydrologists or engineers. They must be dealt with by any jurisdiction contemplating adoption of a banking system.

Hydrologic and Administrative Peculiarities of Spring Use. The primary hydrologic challenge of incorporating springs into ground-water banking is that human control of the discharge rate of individual springs is technologically difficult. A spring user could conceptually agree to forego use of his/her water right, but this could not be used as a banking deposit because there is no technological method to stop the discharge and cause aquifer storage to increase.[26]

There is an adminstrative difficulty arising out of this hydrologic fact that is larger than ground-water banking but affects it. Senior and junior spring users have mixed geographical distribution throughout the areas of spring discharge. Actions designed to benefit senior spring users also benefit juniors, who are often junior even to the ground-water users who have funded the mitigation. The junior spring users have neither legal nor equitable entitlement to enjoy the benefits, but even so these benefits would occur. There would be no hydrologic benefit to aquifer water users if junior spring users were blocked from their use of these benefits. There is currently no mechanism to require participation in providing the benefits or to prevent free-rider use, though Level IV banking could include mechanisms to address the issue. However, this would require adoption and use of uncomfortable and unpopular enforcement capabilities.

A related hydrologic challenge is that human abiltiy to target benefits to particular springs is also limited. A spring user could conceptually purchase and retire credits in order to secure increased spring discharges, but there is no technological method to steer the benefits to his/her individual spring;[27] benefits would accrue to all springs in the affected spring reach.[28] The collective group could band together to purchase and retire credits, but they would face exclusion and free-rider issues.

The important result is that it is unlikely that ground-water banking can be designed in a way that spring users can meaningfully participate as depositors or purchasers of credits. The advantages to spring users from ground-water banking will be secondary benefits, similar to the secondary benefits to Native American interests discussed earlier in the report:

5. To the extent that ground-water banking facilitates better management of the aquifer, spring users will benefit.
6. If ground-water banking causes overall aquifer storage to be greater than it otherwise would have been, spring discharges will increase.
    a. The retained allowance for uncertainty accrues to the benefit of the aquifer and therefore will increase spring discharges.

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[26] A spring user could also negotiate to accept some kind of compensation rather than pursuing a priority call. This may be a good conflict-resolution strategy but it is not included in the concepts of ground-water banking considered here because it does not increase aquifer storage.
[27] Conceptually, the spring user could construct a well with which to withdraw purchased credits. Low marginal revenue per diverted volume, combined with the technological risk of pump failure and aquaculture's requirement for constant flow, generally make this impractical for aquaculture users.
[28] The problem is not as severe for users of gains to river reaches because water can flow down channel from the location where gains are improved, or can be used in exchange for upstream uses. The ability in surface-water administration to protect from intervening juniors already exists; this is currently sometimes done with storage water or injected foreign waters such as exchange-well water.

   b. Any deposits that are not fully utilized by withdrawals will increase spring discharges.

7. If ground-water banking reduces conflict and confrontation, spring users are less vulnerable to unfavorable legislation or administrative decisions.
8. Spring users as individual citizens will benefit indirectly from regional economic activity sustained and facilitated by ground-water banking.

Chapter 11: SPECIFIC REQUIREMENTS OF WORK PLAN

The project work plan originally presented by Reclamation required three specific responses related to Reclamation's goals and interest. This section of the report addresses these required topics:

1. Describe banking concepts which increase availability of surface reservoir storage for maintenance of fisheries habitat during dry years.
2. Describe banking concepts which provide a market mechanism for trading and/or buying and selling of credits by both private and public entities.
3. Describe banking concepts which support the optimal use of both aquifer storage and surface reservoir storage for irrigators and fisheries in the Snake River basin.

Groundwater banking can help achieve these goals in three general ways:

1. Any activity that increases storage within the basin will increase water availability to all water users and for all purposes.
2. To the extent that water banking facilitates economic efficiency, it will promote optimal use of all water resources, including aquifer storage and surface reservoir storage.
3. A particular groundwater banking system could include negotiated rules and preferences to support these goals.

Increasing Storage to Increase Water Availability to All Users

Increasing storage obviously increases water availability to all users in a functioning market environment. One can sketch new supply curves in Figures E-1a through E-1c to verify this. Even in the presence of market barriers or preferences the simple availability of additional storage (for instance, groundwater stored in an aquifer under a water-banking program) can benefit all water users. Figure E-4 illustrated allocation of water in a situation where there were preferences and a two-tiered pricing system. Figure SR-1 expands this illustration to include new supply. It shows the original supply conditions as QM (total supply made available to the preferred user at a very low price) and Q1 (residual supply made available to the non-preferred user at price P1). QM_a is the increased supply in the basin. The preferred user still uses quantity Q0, with $Q1_a$ being the residual supply available to the non-preferred user. The preferred user is benefited by having a larger buffer for uncertainty, and the non-preferred benefits from access to a greater supply.

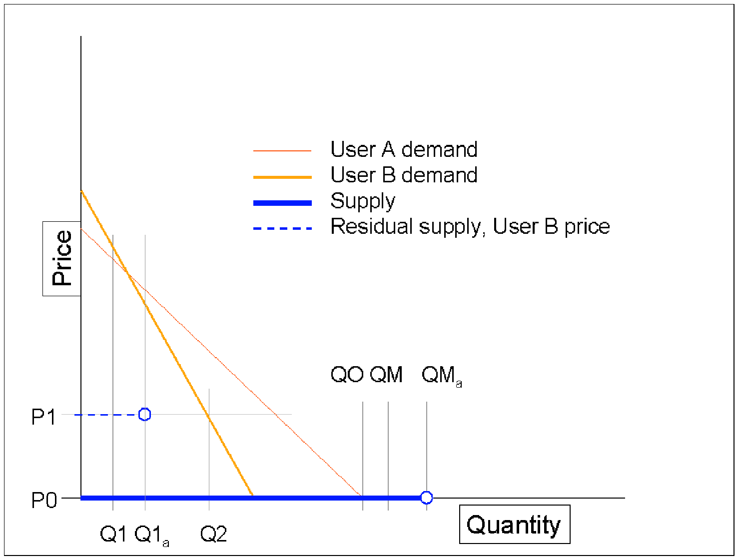

Figure SR-1. Increased supply under conditions of preferential pricing. See Figure E-4.

Figure E-7 showed how allowing the preferred user to resell to the non-preferred user at a market-determined price improved the position of both. Increased supply in the basin benefits all users under these conditions also, as shown in Figure SR-2. The original condition was for preferred users to utilize quantity Q3, selling the remainder (Q4 = QM - Q3) to non-preferred users at price P3. Under conditions of increased supply (QM_a), preferred users retain $Q3_a$ for their own use and sell $Q4_a$ to the non-preferred users. Both groups of users enjoy larger quantities of water.[29] Note that as in the Figure E-7 illustration, preferred users retain the advantage of the preference: Since trade is voluntary, they can never be worse off; they always have the option to not participate in the market and enjoy a status equal to the no-market condition.[30]

[29] As with Figure E-7, Figure SR-2 does not necessarily illustrate an optimum solution; it illustrates one solution where increased supply improves availability to all users.

[30] The Economics section (Chapter 4) of the report discusses how participation *will* improve their condition, by moving them toward the optimum position of equating marginal benefit with marginal decision price.

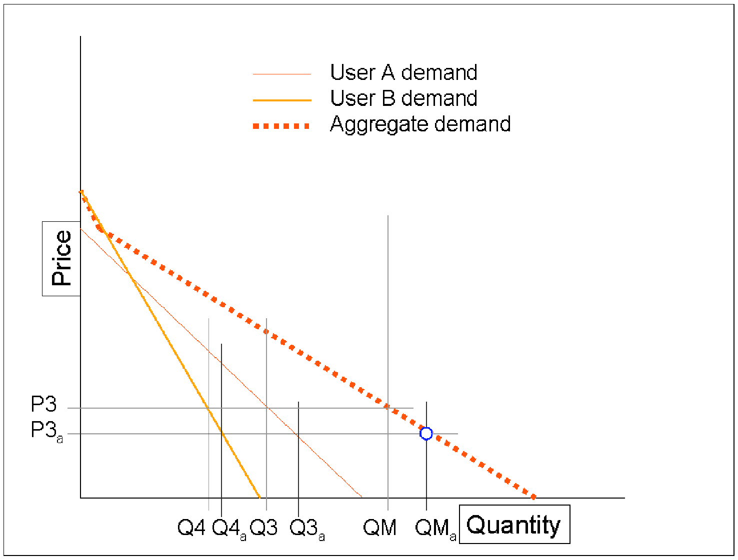

Figure SR-2. Benefit of increased supply when preferred users have the option to resell to non-preferred users. See Figure E-7.

Increased Economic Efficiency

The second point is essentially a circular argument: Since economic efficiency is the measure of the total benefit society receives from its limited basket of resources, improving economic efficiency by definition "support[s] optimal use" of resources. Groundwater banking can improve economic efficiency by facilitating transactions, allowing for market-driven prices, and allowing investors to participate in the banking system. Groundwater banking can also improve economic efficiency by addressing externalities. These mechanisms are discussed in detail in the Economics section of the report.

Rules and Procedures to Achieve Goals

In addition to these inherent effects of groundwater banking and marketing, explicit rules could be adopted to facilitate the three target outcomes. For instance, availability of surface reservoir storage and the mix of use between surface reservoir and aquifer supplies could be controlled by rules that forbade using surface water for groundwater-banking deposits when surface-water supplies were low, or adjusted the discount for uncertainty to influence timing of use of surface water. Rules could discourage withdrawals from groundwater storage when surface-water supplies were high, perhaps by requiring documentation of the reason that surface water could not be used for the requested withdrawal purpose.

Other Reclamation criteria[31] identified by Schmidt et al (2005) and later reviewers include:

[31] See Reclamation section (Chapter 3) of report.

9. A suitable banking authority oversees groundwater credit and debit accounting in the Eastern Snake Plain.
10. Banking credits are earned by reductions in groundwater irrigated land as well as managed aquifer recharge.
11. Managed aquifer recharge water comes mainly from retirement of surface-water irrigated lands.
12. An open and fair market for earning and trading groundwater banking credits exists, in which Reclamation can participate.
13. Hydrologic monitoring is adequate to verify aquifer conditions, including recharge activities, spring discharge, and aquifer storage.
14. The enhanced ESPA model has demonstrated its validity as a groundwater accounting tool, by reliably forecasting groundwater levels and spring discharges.
15. Reclamation is able to achieve some of its own policy objectives by participating in groundwater banking activities.
16. Changes in allocation are monitored to ensure that downstream effects do not jeopardize Reclamation project operations.

These criteria could also be influenced by specific rules within groundwater banking, or negotiated in connection with its adoption. For instance, encouraging foregone groundwater use as a deposit mechanism could be accomplished by absolute prohibitions on managed recharge at certain times or locations, or by rewarding foregone extraction with a lower discount for uncertainty than used for other deposit mechanisms.

In considering adoption of specific rules, the following cautions should be considered:

1. As with administratively-determined prices, the most likely outcome for artificially determining something that can naturally arise from economic forces is that the wrong price, wrong participation level, etc., will be implemented.
2. Rule adoption will be a political process. Opening the door to negotiation of special rules may be counter productive, if it finally results in adoption of rules hostile to Reclamation interests.

Summary

The creation of additional supplies via groundwater banking, the creation of access by incorporating marketing provisions and improvement of economic efficiency by addressing externalities all tend to benefit the three purposes called out by the specific project requirements. Additional support for these purposes could be created by negotiating particular restrictions and preferences within groundwater banking, but there are potential hazards associated with the negotiation process.

Chapter 12: NEXT STEPS FOR GROUNDWATER BANKING

There are three possible arenas for next steps in investigation of ground-water banking in the upper Snake River basin. These can be categorized as *Hydrologic/Economic/Accounting, Implementation* and *Social Science* activities.

Hydrologic/Economic/Accounting

The hydrology of the Eastern Snake Plain aquifer are reasonably well understood, though obviously not perfectly. Work is ongoing by the State of Idaho and others to continually improve hydrologic knowledge. The methods used to derive aquifer response functions are well known, established and accepted within the hydrologic science community. Double-entry financial accounting is an even more mature, established and accepted technology. This project has demonstrated that response functions and double-entry accounting can be functionally linked.

Though the current state of knowledge in this category is adequate for functional ground-water banking, there are three avenues where additional work could be beneficial:

1. Refine linked accounting methodology to include provisions available in commercial financial-accounting software to deal with security issues and very large numbers of transactions.
2. Using the work of Cosgrove et al (2008) as a guide, explore objective methods to determine the appropriate allowance for uncertainty that should be withheld from banking deposits.
3. Continue to explore methods to adapt response functions (strictly defined for confined aquifers) to unconfined aquifers. Current work by Dr. Gary Johnson with non-linearity and response functions in the Spokane-Valley/Rathdrum Prairie Aquifer can provide a starting point for this work.

Implementation

Though ground-water banking cannot solve all water allocation problems in the upper Snake River basin, it has great potential to benefit irrigators, domestic, commercial, municipal and industrial users, and Reclamation. While it offers few direct benefits to spring users, all its secondary effects on spring users are positive. Level I ground-water banking could be adopted within current Idaho statutes and could achieve many of the potential benefits of ground-water banking. Needed hydrologic, economic and accounting methods and concepts are in place and have been demonstrated in proof-of-concept software.

The Eastern Snake Plain Aquifer CAMP process (Idaho Water Resource Board 2009 (2)) has determined a need for large aquifer-budget adjustments.

Anecdotal evidence indicates high willingness-to-pay on the part of private parties with financial resources, if they could invest in ways that secured ownership to tangible benefits.[32] This project has demonstrated that assignment of credit for benefits is a valid and effective mechanism to internalize and therefore increase the magnitude of implementation of activities that are now positive externalities. Ground-water banking can be configured to perform this function.

With adequate hydrologic and accounting methods in place, and faced with great need and opportunity, it appears that the most pressing current need for ground-water banking is to proceed with pilot-project implementation.

Social Science

The ground-water banking project was received with a high degree of skepticism. Proposals for pilot ground-water banking projects have similarly been received without enthusiasm. Nearly 50 years ago Reclamation demonstrated the practicality and effectiveness of managed aquifer recharge (US Bureau of Reclamation 1962), yet almost no recharge has been implemented since.

It appears that there is a fundamental need for social science research into better ways to engage the public and governmental jurisdictions in considering new concepts. This need outweighs the current need for physical science and economics work. It may be a necessary first step before pilot implementation of ground-water banking can be considered.

Summary

The preliminary economic, hydrologic, accounting and policy background work for ground-water banking has been completed. The next logical step in exploration of ground-water banking should be pilot implementation, but it may be that more basic social science work must be done before this can be attempted.

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[32] One of the author's acquaintances was prepared a few years ago to invest $400,000 to $500,000 on water rights and infrastructure in order to secure a supply of 700 acre feet per year. If this were scalable to the CAMP proposed adjustments (and it may not be), this would suggest nearly half a billion dollars of private resources that could be tapped with proper policies.

Chapter 13: EXTRAPOLATION TO OTHER RECLAMATION REGIONS

The question of extrapolation to other Reclamation Regions can be distilled into a question of what regional differences are important in the context of ground-water banking. A starting point may be to list components or concepts of ground-water banking that will be constant in any location:

1. Hydrologic science of ground-water/surface-water interactions.
2. Economics of water allocation and reallocation.
3. Validity of demonstration software.
4. Requirements for a ground-water banking system.
5. Reclamation policy, roles and goals.
6. Legal requirements for Reclamation's adherence to state water law.
7. Interactions with US Federal law.
8. Benefits and challenges of ground-water banking.
    a. Potential benefits of ground-water banking to facilitate movement of water to higher economic uses.
    b. Opportunities for ground-water banking to give Reclamation access to water for public purposes.
    c. Potential benefits to irrigators and DCMI users.
    d. Difficulty in providing direct benefits to spring users.
    e. Difficulty of obtaining the economically-efficient level of public expenditure for public purposes.

Some components of ground-water banking are dependent on local conditions. As Reclamation contemplates ground-water banking in other jurisdictions, even within Reclamation's Pacific Northwest Regions, these must be considered on a case-by-case basis. They include:

1. Presence or absence of significant hydrologic non-linearities that could affect the applicability of response functions:
    a. Large areas of phreatophytes whose evapotranspiration is an important part of the water budget, which may transition in and out of hydraulic connection with the aquifer as water levels change.
    b. Very thin aquifers whose transmissivity varies substantially within the range of water-level changes that normally occur or might be induced by ground-water banking.
    c. Surface-water bodies whose extent of hydraulic connection with the aquifer changes significantly within the range of expected water-level changes.

2. The degree of knowledge of local hydrologic conditions. In the upper Snake River basin, a calibrated aquifer model exists which has been accepted by the court for water administration. In other locations, less detailed hydrologic knowledge may be available. However, Leake et all

(2008) (in cooperation with Reclamation) have demonstrated methodology for quickly and inexpensively generating response functions using uncalibrated or semi-calibrated aquifer models based upon those data that are available.

3. The particulars of local jurisdiction and the status of governing statutes. Idaho has a ground-water banking statute that clearly assigns jurisdiction over ground-water banking and explicitly authorizes ground-water banking. In other states (see Chapter 5), there may be no clear assignment of jurisdiction; jurisdiction may be assigned to county or local authorities, or jurisdiction may vary regionally.

4. Individual social relationships and alliances between Reclamation, Native American Nations, state and local governments, and various water-user communities will vary from locality to locality.

The general concepts, practices, benefits and challenges of ground-water banking seem to apply universally. Specifics of a particular implementation will depend on unique local conditions. This is particularly true of the social aspects of implementation, which are the aspects for which this project provided the least information.

Chapter 14: SUMMARY

Water banking in general is a concept that has the ability to improve economic efficiency and reduce conflict by facilitating storage and exchange of water supplies. Ground-water banking is an attractive water banking mechanism because it uses aquifers as storage vessels. Aquifers have vast capacity, low construction costs, and offer protection from evaporation and to some extent from contamination.

The ground-water banking project has explored issues and solicited input on ground-water banking issues and concerns. A project Website includes links to intermediate products and to materials from other entities inside and outside of Idaho.

The project findings indicate that ground-water banking has the potential to reduce conflict and improve allocation of scarce water resources. However, stakeholders appear to be more skeptical than enthusiastic about ground-water banking, and proposals for pilot ground-water banking projects associated with managed recharge experiments have twice been unsuccessful.

Key accomplishments and findings of the project include the following:

1. The project has achieved a technical innovation linking aquifer response functions with double-entry accounting, which makes ground-water banking practical in aquifers hydraulically connected to surface-water bodies. Previous methods were applicable only to hydraulically-closed aquifers. Demonstration software has been constructed as a proof-of-concept. This linkage is the subject of a submitted journal article.
2. Agent Based Modeling has confirmed economic theory and user responses suggesting that ground-water banking would reduce stress and conflict. This work was done primarily by Reclamation's Science and Technology program and the USGS/MIT MUSIC program, with collaboration of the ground-water banking project. This work is the subject of a soon-to-be submitted journal article.
3. The logical next step for ground-water banking in Idaho is a pilot project. Stakeholder and agency trepidation is high enough that this will likely require professional facilitation, and may need preliminary social science work to inform the process.
4. In addition to the articles on the accounting method and Agent Based Modeling, an additional journal article has been published and another submitted in connection with the project.

Ground-water banking may offer more hazard than benefit to the Shoshone-Bannock Nation. Its potential benefits to spring users are secondary effects associated with reduced conflict and additional aquifer storage. For irrigators and domestic, commercial, municipal and industrial users, it is a concept that has the potential to reduce conflict, increase economic efficiency, facilitate transactions and improve access to water. Ground-water banking offers Reclamation improved access to water for flow augmentation purposes and an opportunity to assist in improving water management and water allocation. It offers the State of Idaho the potential of improved management and reduced conflict in the basin.

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APPENDIX 1: Revision 1 of Submission to the Journal of the American Water Resources Association (*.pdf of proof document from JAWRA)

Groundwater Banking in Aquifers that Interact with Surface Water

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Groundwater Banking in Aquifers that Interact with Surface Water

Bryce A. Contor

ABSTRACT

Increasing worldwide demands for water call for mechanisms to facilitate storage of seasonal supplies and mechanisms to facilitate reallocation of water. Markets are economically efficient reallocation and incentive mechanisms when market conditions prevail, but special hydrologic and administrative conditions of water use and allocation interfere with required market conditions.

Water banking in general can bring market forces to bear on water storage and reallocation, improving economic efficiency and therefore the welfare of society as a whole. Groundwater banking can utilize advantages of aquifers as storage vessels with vast capacity, low construction cost, and protection of stored water.

For groundwater banking in aquifers that interact with surface water, an accounting system is needed that addresses the depletion of stored volumes of water as water migrates to surface water. Constructing such a system requires integration of hydrologic, economic and legal principles with principles of financial accounting. Simple mass balance accounting, even with allowances for depletion, is not adequate in these aquifers.

Aquifer response functions are mathematical descriptions of the impact that aquifer pumping or recharge events have upon hydraulically connected surface water bodies. Double entry accounting is a financial accounting methodology for tracking asset inventories and ownership claims upon assets.

The powerful innovation of linking aquifer response functions with double entry accounting technologies allows application of groundwater banking to aquifers where deposits can be depleted by migration to hydraulically connected surface water. It honors the

hydrologic realities of groundwater/surface water interaction, the legal requirements of prior appropriation water law, and the economic requirements for equitable and efficient allocation of resources.

Key terms: Water resource economics, surface water/groundwater interactions, water allocation, groundwater banking, aquifer response functions.

1. INTRODUCTION

1.1 Reallocation, Markets, and Prior Appropriation.

In many areas worldwide, most sources of water have been fully appropriated (at least seasonally) and put to use. New water needs must primarily be met by reallocation from existing uses or by new storage of seasonal flows. To economists, the prime criterion for judging resource allocation mechanisms is economic efficiency, measured by the benefit society as a whole receives from its limited basket of available resources. Maximum benefit is achieved when the marginal value of resource use is equal to the marginal cost for every use and every user. When required market conditions prevail, market allocation allows this happy result to be obtained by voluntary exchange (Matthews 2004). Unfortunately, as described later, the hydrologic and institutional factors of water use and allocation do not always meet market requirements. Addressing these deficiencies underpins the no-harm rule of prior appropriation transfer law, which is sometimes seen as market hostile and a barrier to full economic use of water (Brewer et al 2008, Jones 2001, Getches 1990). An old but enlightening discussion by Gould (1988) shows how the no-harm rule arises precisely out of the deviation of water from an ideal rival and exclusive (Randall 1983) market commodity. The rule precludes harm that would otherwise arise from external costs imposed by transactions, but in the process inadvertently violates market requirements of access and lack of barriers (Contor 2008).

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1.2 Water Banking as a Reallocation Mechanism

Water banking in general can be seen as a reallocation enhancement within prior appropriation (Slaughter and Wiener 2007) and must be compatible with prior appropriation law in those jurisdictions. It offers an opportunity to use market-like mechanisms to move water quickly to alternate uses, increasing the economic benefit that society receives from its limited water resources. Banking can also create incentives to individuals or organizations to capture and store water whose value is limited due to the time or place that it occurs naturally, for higher-valued use later or at different places. Incentives invite private investment to increase storage of water. If reallocation mechanisms operate adequately, this allows all users access to greater quantities of water at lower marginal cost.

1.3 Groundwater Banking

Water banking usually includes the concept of storage of water, and it is that paradigm of banking considered in this paper. Aquifers are attractive storage vessels due to low construction costs, vast potential capacity, protection of stored water from evaporation, and some protection from contamination. Many aquifers have additional capacity that could be utilized by appropriate human management. Groundwater banking can provide a mechanism to administer and account for storage of water in aquifers. It can provide a mechanism for reallocation of scarce water resources and an incentive for additional storage activity. Groundwater banking could be seen as an umbrella activity that organizes, quantifies, assigns ownership and facilitates transactions for quantities of water stored or utilized via a variety of activities.

1.4 Groundwater Banking and Aquifer Characteristics

Some individual activities (i.e. Aquifer Storage and Recovery, or ASR) currently take place in aquifers connected with surface water. However, from literature review and discussions with water bank officials it appears that groundwater banking as an umbrella activity has generally been confined to the hydrologically simple case of storage of water in aquifers closed to surface water interaction. In these aquifers, simple in-and-out mass balance accounting (such as that used for surface water reservoirs) meets market requirements and can provide market mechanisms and market advantages. However, ordinary mass balance accounting is not adequate for groundwater banking in aquifers hydraulically connected with surface water. As described below, use of mass balance accounting alone can cause injury to surface water users due to differences between the timing and location of deposit accretions and withdrawal depletions.

1.5 Innovation for Accounting in Groundwater Banking

This paper describes an innovation that links the hydrologic concept of aquifer response functions (Leake et al 2008, Maddock 1972, Glover and Balmer 1954) with the financial accounting concept of double entry accounting (Stevenson and Budd 1959). This allows economic market requirements to be met and water law requirements to be honored in aquifers hydraulically connected with surface water bodies, greatly increasing the pool of candidate aquifers for groundwater banking.

2. ECONOMICS OF GROUNDWATER BANKING

2.1 Market Requirements

Market requirements include having a homogeneous commodity, a large number of traders with access to information and to the market, and a property rights system where exclusion is aligned with rivalry (Randall 1983) in such a manner that costs and benefits are internal to the trading parties. Under these conditions, market based prices implicitly convey all needed information to trading parties. Individual maximization of objectives leads participants to trade, exchange and adjust the quantities they use, until all users have equated their own marginal costs and benefits. When market requirements are fully met, this guarantees the economically efficient apportionment of resources to competing uses and invites investment to increase storage of water, if needed.

2.1.1 Homogeneity. Unfortunately, water as a commodity is often deficient in one or more market requirements. First, water is generally not a homogeneous commodity: a) Its use value is highly sensitive to ***location*** because it is a bulk commodity with high transportation costs relative to its value (though in some locations the relative value of water is increasing). Further, these costs are anisotropic; down gradient transport is orders of magnitude less costly than up gradient transport. b) Because many agricultural or industrial processes require water at specific times, the ***time*** of water availability strongly influences its value. c) Most uses of water are sensitive to the ***form*** of the water, including temperature, dissolved minerals and chemicals, sediment loading and biological constituents. d) Administration of groundwater transactions can introduce heterogeneity in banked quantities of groundwater.

2.1.2 Rivalry. Second, not all water uses are rival. Markets function best for rival goods, where enjoyment by one user precludes enjoyment by another. Instream uses for recreation, ecological services and power generation can be non-rival. Delay in return flows can benefit late-season irrigation further downstream and create antirival dependency. Groundwater pumping can be congestible with other groundwater pumping; that is, at lower levels of development, one user's pumping has no practical effect upon other users and uses are non-rival, but as development increases, pumping interference becomes non-trivial and rivalry occurs.

2.1.3 Exclusiveness. Third, exclusive use of water cannot always be enforced. Technologically it is difficult to restrain the flow of water to springs or to exclude non-payers from enjoying ecological services that arise from the presence of water in streams and wetlands. In Idaho, an instream flow use cannot acquire senior priority, even through purchase and transfer, and therefore has an institutional exclusion disadvantage. In jurisdictions where groundwater is administered separately from surface water, senior surface users have an institutional exclusion disadvantage relative to junior groundwater pumpers.

2.2 Groundwater Banking and Market Requirements

Obviously, groundwater banking cannot solve all the homogeneity, rivalry and exclusion issues described above, for all classes and uses of water. The concept of groundwater banking in this paper aligns rivalry and exclusion between surface water and groundwater, and creates homogeneity for volumes of water stored in aquifers. It does this in a manner compatible with prior appropriation law, substantially satisfies economic market requirements (Contor 2008), and honors the hydrologic realities of aquifers connected with surface water bodies.

3. WATER LAW OF GROUNDWATER BANKING

3.1 Groundwater Banking and Prior Appropriation

This paper describes a mechanism for accounting for volumes of water that are physically stored in an aquifer directly as a result of human activity. The water law paradigm of surface water storage provides a legal framework for the priority treatment of groundwater storage. In surface water reservoirs, water is delivered to storage when water is available to the storing party, within the priority hierarchy. Once stored it is subject to depletion charges such as evaporation but deliverable to the owner upon demand. The reasoning is that the stored water would not be there but for the actions of the party that stored it, and therefore it is legitimate to treat the stored water essentially as simple private property (Getches 1990). The accounting system described here for groundwater banking could work with the same paradigm of in-priority delivery to storage and on-demand withdrawal.

3.2 Groundwater Banking and Reallocation of Water

If water banking contemplates marketing or exchange of water, it is a reallocation mechanism. A basic tenet of prior appropriation law is the no-harm rule of reallocation: "Changes... must not cause material harm to the uses of other appropriators.... The possibility of harm and not a certainty [is sufficient to block a change]" (Getches 1990, see also Johnson et al 1981). In or out of prior appropriation jurisdictions, equity and property rights considerations require that groundwater banking include exclusion provisions equivalent to the no-harm rule.

3.3 Requirements of Groundwater Banking Accounting

In order to meet these legal requirements and satisfy economic conditions for market allocation of resources, accounting for groundwater banking must perform five vital functions: 1) quantify and assign ownership to deposits; 2) quantify and assign ownership to withdrawals; 3) quantify and assign ownership to stored volumes of water; 4) address depletion of stored volumes that occurs as effects propagate to surface water bodies; 5) facilitate transactions.

4. HYDROLOGY OF GROUNDWATER BANKING

4.1 Groundwater Banking and Groundwater/Surface Water Interaction

Aquifer hydrology affects the mechanisms needed to meet banking requirements. The hydrology of groundwater banking can be considered by looking at increasingly complex hypothetical aquifers. The important factor for groundwater banking is the relationship between aquifer deposit and withdrawal activities and impacts that propagate to surface water bodies.

<u>4.1.1 Aquifer not connected to surface water</u>. This is the simplest hydrologic case; an

aquifer bounded by an essentially impermeable geologic structure and with no communication with surface water. Recharge either raises the water table (unconfined aquifer) or the potentiometric surface (confined aquifer) and creates a volume of stored water that remains available for extraction.

4.1.2 Aquifer connected to one surface water body. If the aquifer is hydraulically connected to a stream or other surface water body, the depletion of stored water by migration to surface water must be considered. Recharge creates a volume of stored water in the aquifer, but also generates time-varying flux to the surface water body. There are two important hydrologic characteristics of recharge to such a system; all recharge eventually will migrate to the surface water body (unless first extracted), and the timing of migration is governed by distance, aquifer characteristics and characteristics of the interconnection with surface water (Jenkins 1968).

4.1.3 Aquifer connected to more than one surface water body. The additional complexity of another hydraulically connected water body introduces the need to apportion between surface water bodies the time-varying flux created by the deposit. The proportioning of effect depends on the geometry of the aquifer and surface water bodies, the location of the deposit or withdrawal, the nature of the connections between surface water and the aquifer, and all aquifer characteristics except storage coefficient (a measure of the aquifer's ability to store water). Timing of effects depends on these factors as well as aquifer storage coefficient and therefore can respond differently to deposit location than does partitioning of effects.

Though additional complexities could be introduced, this case incorporates all the effects of hydrologic complexity that must be addressed in groundwater banking: 1) Pumping or recharge can impact more than one surface water body; 2) The partitioning of volume impacts to different surface water bodies is dependent on the location of the pumping or

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recharge as well as aquifer and surface water connection characteristics; 3) The timing of impacts also varies by surface water body and with location of the deposit/withdrawal, but it can vary in a different manner than the partitioning of total volume.

4.2 Special Characteristics of Groundwater/Surface Water Interaction

An important hydrologic concept is that recharge or pumping can affect both gaining and losing hydraulically connected streams. A recharge event may cause a gaining stream to gain more, or a losing stream to lose less. In either case, total flow in the stream is larger than it would have been and that is the important concept for water quantity administration. Another important concept is that recharge (deposit) or extraction (withdrawal) events propagate in the same manner in time and space; only the sign of the impact on surface water changes (Jenkins 1968). A final effect, one that is counter intuitive and difficult for lay audiences to accept, is that lateral propagation of effects is independent of existing gradient or flow direction as long as all groundwater/surface water connections are maintained. The mechanism presented here relies upon these essential components of the principle of superposition (Olsthoorn 2007, Reilly et al 1987).

4.3 Accounting Requirements and Hydrology

In the simple aquifer (no connection to surface water), in-and-out mass balance calculations provide adequate quantification. This is parallel to typical surface water reservoir accounting. However, the hydrology of the more complex cases renders simple mass balance accounting inadequate. This is true even if a mass balance depletion adjustment (similar to evaporation charges in surface water storage) is made, because of the differences in timing caused by transit through the aquifer. A user could make a deposit distant from the surface water body, which would express itself to surface water as benefits that commenced at a particular time and continued in a time series characteristic of the location of the deposit.

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Simple mass balance accounting could allow a withdrawal at a different location, one that depleted the surface water body at different times or depleted a different surface water body. At some times or locations, depletions to surface water would not be balanced by accretions from the deposit activity, violating the economic requirement of internalized costs and the legal requirement of no harm.

5. GROUNDWATER BANKING USING LINKED RESPONSE FUNCTIONS AND DOUBLE ENTRY ACCOUNTING

5.1 Aquifer Response Functions and Groundwater Banking

5.1.1 Description of response functions. Aquifer response functions (Leake et al 2008), also known as algebraic technical functions (Maddock 1972), are mathematical descriptions of the timing and magnitude that a pumping or recharge event will have upon a surface water body. They can address the timing and depletion issues for which simple mass balance accounting is inadequate.

Though they rely upon numerical superposition (Olsthoorn 2007, Reilly et al 1987) and therefore are formally defined for confined aquifers, in many cases aquifer response functions may be used in unconfined systems (Cosgrove and Johnson 2004, Maddock 1974, Jenkins 1968). Response functions may be obtained by analytical methods (Miller et al 2007, Jenkins 1968), from operation of calibrated or uncalibrated numerical models (Leake et al 2008), or by statistical analysis (Olsthoorn 2007, USDA 2000).

5.1.2 Economic and legal implications of use of response functions. Use of aquifer response functions in accounting for groundwater banking aligns the hydrologic realities discussed above with the economic requirements of internalization, or equivalently, the legal requirements of the no-harm rule. By distilling all pumping and recharge events into the common currency of time series of hydrologic impacts, response functions also perform the

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important economic function of rendering banked groundwater a homogeneous commodity, making it more suitable for efficient market allocation.

5.2 Double Entry Accounting

5.2.1 Description of double entry accounting. Double entry financial accounting was described by Luca Pacioli in 1494 (Macve 1996) and is a mature methodology. It is "double entry" in two senses: every transaction is recorded as both a debit entry and a credit entry, and at all times the accounting system tracks both ***inventory*** in asset accounts and ***claims*** to inventory in ownership accounts (Stevenson and Budd 1959). Financial accounting further divides ownership accounts but this refinement is not needed here.

Representing transactions with debit and credit entries is of interest perhaps only to bookkeepers, but it results in the simultaneous tracking of inventory and ownership. This offers great power for management of groundwater banking and automatically enforces the legal no harm rule by ensuring that all withdrawals are supported by prior deposits.

5.2.2 Basic application of double entry accounting in groundwater banking. When a groundwater banking deposit or withdrawal is made, the first half of the double entry records the quantity of water (inventory effect) and the second half records claims (ownership effect). Because of the double entry process, the method at all times maintains a list of accounted assets and ownership claims, a record of the transactions that have changed assets and claims over time, and a record of the cumulative impact of groundwater banking upon each affected surface water body.

5.3 Linkage Between Aquifer Response Functions and Double Entry Accounting

A detailed description of the linkage is not necessary, and space does not permit its inclusion here. It is described in a draft report available from http://www.if.uidaho.edu/~johnson/hydroweb/reports.html, along with demonstration software

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that confirms the technical ability to link the technologies. With this linkage, aquifer response functions quantify storage volumes while double entry accounting assigns ownership and facilitates transactions.

5.4 Deposits and Withdrawals

5.4.1 Deposit activities. Hydrologically and economically, any activity could rationally be considered a deposit that causes more water to be held in storage than would have been otherwise. This could include the following:

1. Physically placing water into the aquifer with the original and primary intent to increase storage, as is done with managed recharge or the storage phase of ASR projects.
2. Providing recharge incidental to other human water use activity, such as leakage from canals or percolation from surface water irrigated fields.
3. Implementing temporary or permanent cessation of groundwater pumping that otherwise would have been authorized (i.e. in priority).
4. Provision of surface water supplies in lieu of groundwater pumping that otherwise would have been authorized.
5. Altering of cropping patterns so that total consumptive use from groundwater irrigation is reduced.
6. Altering cropping patterns so that total consumptive use from surface water is reduced while maintaining existing surface water diversions and return flows.
7. In an aquifer connected to more than one surface water body, a mitigation plan that compensates for depletion to one surface water body may generate excess benefits to another. These excess benefits could be treated as deposits in a groundwater banking system, improving economic efficiency by assigning

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ownership to the benefits which mitigation plan participants have created.

8. Flow augmentation (defined here as water delivered to a surface-water body as mitigation for depletions from groundwater pumping) could conceivably be treated as a deposit, by using an appropriate (i.e. immediate) response function.

Quantities of aquifer storage resulting from any of these deposit mechanisms are hydrologically and economically equivalent. However, each mechanism has special considerations beyond the scope of this paper. For example, see Glennon (2002) regarding in lieu provision of surface water or Contor and Schmidt (2006) regarding recharge incidental to irrigation.

<u>5.4.2 Withdrawal activities.</u> Rational candidates for allowable withdrawals in a banking system include:

1. Direct extraction from the aquifer, including the recovery phase of ASR.
2. Application of credits as an offset to existing pumping that would otherwise be unauthorized (i.e. out of priority).
3. Application of credits to satisfy administratively required mitigation for a prior appropriation delivery call.
4. Direct extraction from hydraulically connected surface water.

As with deposit mechanisms, each of these has considerations and implications beyond the scope of this paper.

5.5 Details of Linkage Operation.

Linking response functions to double entry accounting allows the quantification of stored water to be described in terms of time series of effects upon surface water bodies. This greatly simplifies accounting and has the important economic effect of making banked quantities of water homogeneous. These aspects of the linkage are novel and powerful,

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along with the applicability to aquifers connected with surface water.

The linked system's approach to the five required functions of groundwater banking are described below:

5.5.1a Quantification of deposits: The actual volume of the deposit depends on the nature of the deposit event (aquifer recharge, storage component of ASR cycle, foregone extraction, etc.) and requirements determined by the banking authority. In groundwater banking accounting, the volume of water would be converted to time series of impacts to surface water bodies by applying the response functions appropriate to the location of the deposit activity. The result would be one time series of benefits for each connected surface water body. Each series would be divided into appropriate temporal components, as determined by the banking authority. Table 1 illustrates the hypothetical partition of a 100-unit deposit event.

In double entry accounting, each combination of stream (or other surface water body) and time period in Table 1 would be represented by an asset account. The first half of the double entry for a deposit would be to increase the balance of each asset account by the volume of water shown by the appropriate entry in Table 1.

5.5.1b Assignment of ownership to deposits: Each account holder in the bank would have corresponding ownership accounts (initially with zero balances). The second half of the double entry would be to increase the appropriate stream/period ownership accounts of the depositor.

TABLE 1 NEAR HERE

5.5.2 Quantification and assignment of ownership for withdrawals: The banking authority would specify accepted withdrawal mechanisms and volume calculation methods. Once the volume of a proposed withdrawal was determined, the banking authority would

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apply response functions to determine the time series of effects that the withdrawal would have upon surface water. The authority would compare these effects to the applicant's ownership balances, and if the applicant owned adequate volume for each affected stream and time period, the withdrawal would be authorized. The first half of the double entry would decrease the appropriate asset accounts and the second half would decrease the applicant's corresponding ownership accounts.

5.5.3 Quantification and assignment of ownership to stored volumes: The accounting of deposits and withdrawals described above implicitly includes an accounting of stored volumes. This is part of the simplification and power of the linked approach. At any time, the total volume of banked water in the system is the sum of volumes for asset accounts representing time periods that are not yet expired. The volume owned by any one claimant is the sum of his/her ownership accounts for non-expired time periods.

5.5.4 Accounting for depletion by migration to surface water bodies: Because all volumes of water are recorded in accounts by affected surface water body and time period, the expiration of time period accounts as time progresses automatically adjusts both the recorded volume of stored water and the ownership claims upon it.

5.5.5 Facilitation of transactions: The double entry for an exchange transaction would include an entry to reduce the seller's ownership accounts and a corresponding entry to increase the buyer's. Asset accounts would not be adjusted because the exchange itself would not remove nor add stored water.

5.6 Challenges to the Linked Accounting Method

5.6.1 User acceptance. The primary challenge to use of linked aquifer response functions and double entry accounting is likely to be user acceptance. All of the described methods for obtaining response functions are accepted scientifically, within bounds inherent to the methods. However, the validity of response functions is generally difficult to verify with simple stress/response physical demonstrations; an experiment large enough to generate an unambiguous signal distinct from background events would nearly always be impractical. Acceptance therefore depends on technical assessment by experts, who may use methods such as models, end member function analysis, tracers (natural and artificial) and verification with analytical calculations. These do not provide the concrete and intuitive results that a physical demonstration would, leaving lay users in a less than satisfying position.

5.6.2 Technical limitations. All hydrologic methods, including response functions, include some degree of imprecision and uncertainty. A second challenge is the danger that imprecision in response functions may allow injury to the resource, if authorized withdrawals cause depletions that are not balanced by the effect of deposits. An Arizona response to the general concept of uncertainty and imprecision is to discount groundwater banking deposits by some percentage, so that the earned credit is smaller than the deposited volume. In double entry accounting, the full (pre discount) deposit volume would be recorded in appropriate asset accounts. To balance the asset entry, ownership entries would include increases to retained uncertainty accounts owned by the public for the discount fraction as well as increases in the depositor's ownership accounts for the remainder. The retained uncertainty accounts would provide a record of the cumulative benefit to surface water bodies from the operation of the discount. Table 2 illustrates the retained uncertainty accounting of the hypothetical deposit volumes of Table 1.

TABLE 2 NEAR HERE

The important principle for the discount mechanism is to set the allowance high enough to accommodate uncertainty in predicted outcomes, but low enough that transaction costs are not prohibitive. Cosgrove et al (2008) provide some guidance in assessing uncertainty, but further work is needed in the specific application to groundwater banking. One compensating factor is that any imprecision in response functions will be applied to both deposits and withdrawals, providing some self-canceling effect.

6. SUMMARY

The combination of aquifer response functions and double entry financial accounting principles provides an accounting method for groundwater banking. This mechanism accounts for physical quantities of stored water and ownership claims upon it. Aquifer response functions quantify the storage by collapsing all events into time series of effects at hydraulically connected surface water bodies. They provide the ability to represent and account for depletion of banked water by leakage to surface water. Double entry accounting provides the ability to know at all times the amount of banked water in storage, the ownership claims upon it, and the history of accrued impact to surface water bodies. In combination, the two technologies enforce the operation of the prior appropriation no harm rule, guaranteeing that the net effect of groundwater banking upon surface water bodies is always positive.

The ability to account for stored water and its depletion, migration, and ownership claims is an essential component of groundwater banking for aquifers that are hydraulically connected to surface water bodies. Simple mass balance accounting requires a closed aquifer; the adaptation presented here makes groundwater banking also applicable to non-closed aquifers in communication with surface water, greatly expanding its potential.

With the capabilities provided by this linkage, groundwater banking can improve utilization of water resources by facilitating additional storage in times of surplus, internalizing costs and benefits, providing market information and a market forum, creating a homogeneous commodity of trade, and allowing market prices to guide the optimum allocation of water between existing and new uses.

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Table 1
Response-function Partitioning of Hypothetical 100-unit Groundwater-banking Deposit Event

Year	Volume Impact, Stream 1	Volume Impact, Stream 2
2010	50	0
2011	35	0
2012	7	1
2013	3	3
2014	0	1

Table 2
Accounting of Hypothetical Deposit Event Shown In Table 1, with Discount for Uncertainty

Changes to Asset Accounts		
Year	**Stream 1**	**Stream 2**
2010	50	0
2011	35	0
2012	7	1
2013	3	3
2014	0	1
Changes to Ownership Accounts: Retained Uncertainty		
Year	**Stream 1**	**Stream 2**
2010	5.0	0
2011	3.5	0
2012	0.7	0.1
2013	0.3	0.3
2014	0	0.1
Changes to Ownership Accounts: Depositor		
Year	**Stream 1**	**Stream 2**
2010	45.0	0
2011	31.5	0
2012	6.3	0.9
2013	2.7	2.7
2014	0	0.9

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APPENDIX 2

Appendix 2 contains the text submitted to the Journal of Contemporary Water Research and Education in December 2008. This submission was invited by the journal.

Status of Ground-water Banking in Idaho

Bryce A. Contor
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In the arid western United States, water systems are fully allocated or nearly so. Where new infrastructure (such as storage dams) might allow utilization of the few remaining unallocated flows, the financial and ecological cost of these is increasingly prohibitive. Therefore, water for new uses must usually be obtained through reallocation of water that has already been claimed and assigned within prior appropriation system. The water-rights transfer is the traditional reallocation mechanism. However, economists tend to prefer market solutions because, when they work well, they provide an economically efficient allocation of goods and resources. Further, they are seen as equitable because they achieve this through voluntary exchange. Some economists criticize prior appropriation as being hostile to water markets and failing to allocate water to the highest value uses. It is even quipped that that an economist is a person who "doesn't see anything special about water" (Gould, 1988). Water banking is touted as a potential mechanism to bring some market characteristics and advantages into prior appropriation.

For a market to function, several basic factors must be substantially present:

1. Property rights
    a. fully specified
    b. exclusive
    c. enforceable and enforced
    d. transferable
2. Costs and benefits internal to the players
3. Adherence to moral norms
4. Adequate numbers of buyers and sellers
5. Access to information
6. Lack of market barriers
    a. Regulatory or market-access barriers
    b. Transaction costs
7. Homogeneous commodity

When one or more of these required attributes is missing or inadequate, economists say that a market failure has occurred. In that case, markets are not necessarily efficient or equitable. In asserting that market allocation of water is desirable, or that there is nothing special about water, one asserts that these market requirements are substantially present; that is, that no market failure has or will occur.

Market Requirements, Rivalry and Exclusion

Much has been written about water-rights transfers and water reallocation (an incomplete listing includes Brewer *et al* 2008; Johnson *et al* 2008; Kryloff 2007; Slaughter and Wiener 2007; Heaney *et al* 2006; Wilkins-Wells *et al* 2006; Draper 2005; Johnson *et al* 2004; Matthews 2004; Gardner 2003; Young and McColl 2003; Howe and Goemans 2003; Yoskowitz 2001; Waterstone and Burt 1988; Grant 1987; Anderson and Johnson 1986; Johnson *et al* 1981). An old but enlightening discussion (Gould, 1988) explains some of the characteristics of water that have resulted in the adoption of prior appropriation and its transfer requirements. Gould shows that many of the prior-appropriations transfer requirements seen as market-hostile turn out to be efforts to address the lack of one or more market requirements in water allocation and distribution. The concepts presented by Gould are discussed more generally by Randall (1983) and may be used to examine whether there is something special about water. Traditional discussions of market failure explore issues of public goods, common-pool resources, natural monopoly, and externality. Randall asserts that these terms are more confusing than enlightening, and proposes a system where instead goods and services are described in terms of Rivalry and Exclusion.

Rivalry is related to the physical characteristics of the good and the nature of uses that are made of it. Randall classifies goods as rival, nonrival, or congestible. Congestible goods are nonrival up to some capacity constraint, then become rival. In water resources, one must also consider antirival relationships, where one use provides a benefit to another.

Randall's other criterion is exclusion, which is a function of institutional and technological factors. Exclusion and nonexclusion are important in water resources, though Randall also discusses the theoretical concept of hyperexclusion.

Whether one uses traditional market-failure nomenclature or Randall's classifications, the concepts are useful to consider in assessing reallocation mechanisms. The important economic implication is that market requirements are met, and the prized advantages of markets are realized, only for goods that are both rival and exclusive. Many aspects of water use are nonrival, congestible, or antirival. Some uses are technologically nonexclusive (flowing springs are difficult to shut off) and some are institutionally nonexclusive (Idaho minimum streamflow rights cannot acquire senior priority even by purchase and transfer). There is indeed something special about water.

Water Banking in Idaho

There are two main categories of water banking in Idaho, Rental Pools and the Water Supply Bank. Space permits only discussion of the application of the Water Supply Bank to ground-water reallocation. Useful discussions of Rental Pools and surface-water banking are provided by Briand *et al* (2008) and Slaughter and Wiener (2007). As applied to ground-water rights, Idaho's Water Supply Bank is essentially a clearing house for trading of authorization to divert. It does not manage the physical storage or exchange of volumes of water stored in the aquifer, though such would appear possible within existing statutes.

<u>Historical Water-right Activity Levels</u>

The goal of water-banking legislation was clearly to facilitate reallocation. Its success can be measured in part by considering levels of activity. One can use pre-moratorium activity levels to estimate the amount of activity that would be expected with an adequate reallocation process.

Figures 1 through 3 show the number of ground water rights in Idaho for each year of priority, for various water-use categories. Priority date approximates the development date of a water right. These categories comprise about 95% of ground-water use, either by water-right count or total diversion rate.

Figures near here

The large increase in irrigation rights starting about 1950 is consistent with the historical timing of improved pump technology and availability of rural three-phase electric power in Idaho. There may be a slight declining trend in number of new rights per year between 1950 and 1985, which is consistent with Gould's hypothesis that the best lands would have been developed first. As development costs increase and revenue potentials decline, reduction in activity is an expected outcome. The steeper decline between 1985 and 1990 could reflect increased protest activity that may have preceded the moratoriums. The pattern since 1990 is consistent with imposition of a moratorium followed by continued development of some previously-permitted rights that had received priority advancements for various reasons.

The time series of domestic, municipal and stockwater rights appear to be consistent with a steadily increasing population, except for the 1970-1980 spike and the declines discussed above. These data are harder to interpret because there is only a partial record of *de minimus* rights, which mostly are single-family domestic water rights and small stockwater rights. Recording of these is not currently required, though many were voluntarily recorded as part of the Snake River Basin Adjudication.

<u>Expectations for Reallocation Activity</u>

One could assume that the number of reallocations to irrigation would be relatively few, since the best lands would have been the first to be irrigated and there would be little economic justification to move water to less-productive land. A first estimate is that an adequate reallocation mechanism would allow tens to perhaps a few hundred transactions per year, in either case just a fraction of the 1,000 to 1,500 annual allocations that occurred prior to moratoriums.

The long-term domestic/municipal trend could be extended linearly into the future. Based on the historical data, it is estimated that annually 1,000 to 3,000 reallocations to domestic/municipal uses would occur with an adequate mechanism.

Two different interpretations could be applied to stockwater rights. The first is that since all pastureable land is likely already in use and presumably has adequate stockwater, there should be little need for reallocation of additional water to stockwater use. The other interpretation is that the dairy industry in south central Idaho could be expected to grow and will require continued reallocation. A broad-brush expectation for an adequate mechanism ranges from tens to hundreds of reallocations to stockwater per year.

Combining these expectations, it is estimated that an adequate reallocation mechanism should be expected to accommodate approximately 1,000 to 4,000 transactions per year.

Observed Reallocation Levels

Though the legislature intended that water banking serve as a "substitute for... transfer proceedings" (Idaho Code 42-1764), the primary reallocation mechanism is still the water-rights transfer. The overall effectiveness of reallocation should be examined by considering both banking reallocations and transfers. The effectiveness of banking itself can be considered by comparing its annual activity with total numbers of reallocations.

In recent years, Idaho Department of Water Resources has generally processed around 200 to 250 water transfers per year (Keen 2008). Many of these involve ground-water rights, though the current database configuration does not allow precise delineation by source. Data provided by IDWR (Case 2008) show that there are about 520 ground-water rights currently enrolled in the Idaho Water Supply Bank. Of these, 60 are rented from the bank and represent active reallocation activity. The remaining 460 are static and appear to be placed in the bank primarily as protection against water-right forfeiture. Combining transfers and Water Supply Bank transactions, the total number of actual ground-water reallocations appears to be in the range of 125 to 300 transactions per year. Between 20 percent and 50 percent of these are facilitated by the Water Supply Bank.

Assessment of Ground-water Banking in Idaho

Current reallocation transactions in Idaho constitute about three to 30 percent of the number of transactions that would be expected in an adequate reallocation mechanism. It appears that the current mechanisms are not fully "providing a source of adequate water supplies to benefit new and supplemental water uses" nor fully encouraging "the highest beneficial use of water" (see Idaho Water Resource Board overview of water banking at http://www.idwr.idaho.gov/waterboard/water%20bank/Documents/BankOverviewFAQ.pdf). If the lower estimate is correct, the need for reallocations in Idaho exceeds the current level by an order of magnitude. Even if one were to assert that overall reallocation approaches adequacy, the bank itself does not appear to be meeting its stated purpose, since its reallocations are fewer than those accomplished by water-rights transfers.

Potential for Ground-water Banking

There is an opportunity in Idaho to improve the benefit society receives from a limited pool of water resources by allowing additional reallocation of water to higher-value uses. Modifications to ground-water banking can be used to facilitate exchange while appropriately aligning exclusion and rivalry and satisfying market requirements.

Costs and benefits of trade must be internal to the players in a transaction. This requires the ability of exclusion. The prior-appropriation no-harm transfer rule is essentially a particular form of exclusion. However, it tends to generate excessive transaction costs and constitutes a market barrier. Exploring rivalry issues of reallocation of ground water will aid understanding of appropriate exclusion mechanisms for ground-water banking.

The ground-water-to-ground-water relationship of reallocation is theoretically rival; a gallon of water consumptively used from one well is unavailable to be pumped from another. However, at current levels of development in the highly transmissive and productive Eastern Snake River Plain Aquifer, wells are independent in practical effect (though not nonrival by Randall's definition). Since reallocation by definition requires cessation of the former use, this practical independence can be expected to continue.

The ground-water-to-surface-water relationship of reallocation is more complex. For surface-water bodies not hydraulically connected to the aquifer, surface water is independent of ground water. When the surface-water body is connected to the aquifer, ground-water pumping is rival to surface-water use. The Eastern Snake River Plain Aquifer in southern Idaho is hydraulically connected to some reaches of the Snake River and to springs tributary to the river. These springs are legally classified as surface water. Surface-water allocation along the Snake is administered by reach, based on the hydrology and interaction of natural-flow runoff, storage releases, and gains and losses to the aquifer. The degree of rivalry that the pumping has with a particular river or spring reach depends on its location. The aquifer is large enough that there are significant differences in timing of effects to surface water. Some wells affect some reaches within weeks or months, while impacts from other wells may not affect the river or springs until river decades after the time of pumping. A reallocation that moves the point of diversion changes the rivalry relationships.

To its credit, the Idaho Department of Water Resources has recognized these potential changes in rivalry, and has understood that unfettered reallocation of ground-water rights would violate the market requirement of costs being internal to the players in a transaction. This explains the cumbersome analyses required for ground-water-rights transfers, and probably explains the lack of utilization of the Water Supply Bank as a substitute for transfer proceedings. However, while addressing the market requirement of internalized costs these procedures have violated the low-transaction-cost requirement and have rendered ground-water rights a non-homogeneous commodity. Further, typical mitigation plans have produced un-reimbursed gains to non-target surface water bodies, violating the requirement of internalized benefits.

To meet market requirements and properly align rivalry and exclusion, a system of quantifying physical rivalry relationships must be incorporated with a system of tracking ownership claims. Aquifer response functions (Cosgrove and Johnson 2004), also known as algebraic technical functions (Maddock 1972), provide the mechanism for physical quantification. They have the important capability of distilling all recharge, discharge and exchange activities into time series of effects at defined surface-water reaches that are hydraulically connected to the aquifer. This assures that rivalry and exclusion can be satisfied, and renders banked ground water homogeneous. Principles of double-entry financial accounting provide the capability for tracking ownership. The linkage between these two technologies is demonstrated by proof-of-concept software available at
http://www.if.uidaho.edu/%7Ejohnson/hydroweb/reports.html.

With this accounting of water quantities and ownership, a ground-water bank could be established where the units banked were the impacts realized at surface-water bodies. This appears to be compatible with existing Idaho law. Activities that could be considered deposits include:

1. Temporary cessation of pumping or permanent retirement of a ground-water right. The in-priority consumptive use that otherwise would have been supported is banked as a deposit.
2. Reduction due to intentional changes in crop mix of consumptive use that otherwise would have been supported by in-priority groundwater pumping (see http://boise.uidaho.edu/documents/IWRRI_2008-001_ChangeInCropMix_20080125.pdf?pid=105706&doc=1).

3. Supplying in-lieu surface-water supplies to replace ground-water pumping that otherwise would have occurred. In-priority consumptive that would otherwise have been supported by ground water, along with incidental recharge from surface water delivery which would not have otherwise occurred, are bankable deposits.
4. Intentional aquifer recharge, or the storage phase of aquifer storage and recovery.
5. Excess benefits created by mitigation plans.

As a hedge against technical uncertainty, a percentage of the deposited water could be deemed an uncertainty allowance, held irrevocably by the State and accruing to the benefit of the aquifer. The demonstration software includes this functionality.

Under current Idaho statutes, it appears that direct diversion of water from the aquifer could be allowed as withdrawal from the bank, along with application of credits as mitigation for otherwise out-of-priority use of ground water. As with deposits, aquifer response functions would be used to quantify the effects of a proposed withdrawal, which would be distilled into time series of effects at river reaches through the use of aquifer response functions. This restores the important market requirement of homogenous goods. Double-entry accounting and the structure of accounts automatically aligns the timing and location of impacts of withdrawals with the benefits of deposits, satisfying the prior-appropriation no-harm rule and internalizing all hydrologic impacts of the transaction.

Credit owners may also choose to retire credits without extraction, specifically to ensure a benefit to the aquifer and interconnected surface-water bodies. Environmental interests and holders of water rights in springs may have such a preference. With additional legislation, credit owners could perhaps also use their credits to offset direct diversion from surface-water bodies.

Prices could be set administratively as has been done in Idaho Rental Pools. Alternately, market prices could be allowed to operate, better meeting the market requirements of information and lack of barriers. This would allow banking to more closely approach the market benefits of economic efficiency and equity.

The effectiveness of such a banking system can be assessed by reviewing its ability to satisfy market requirements. Table 1 provides a summary.

Table 1 near here

Conclusion

Prior appropriation is criticized for reallocation restrictions that appear to be market-hostile but in reality are attempts to address the lack of fundamental market requirements. This lack is due to the rivalry characteristics of water that arise from physical characteristics and the nature of use, along with exclusion characteristics that arise from technological abilities and institutional decisions. Water banking can be a mechanism to introduce some market mechanisms into prior appropriation by better aligning rivalry and exclusion, in order to better secure the market advantages of economic efficiency and equity.

Ground-water banking in Idaho supplies only part of the annual reallocation of ground water to new uses, with the balance being supplied by traditional prior-appropriation water-right transfers. Total reallocation activity appears to be significantly lower than the expected adequate level, based on pre-moratorium rates of issuance of new allocations. This indicates that water is not being reallocated to highest and best uses, and consequently that society as a whole is not receiving maximum benefit from the limited water resources that exist.

Activity in reallocation could be increased if the satisfaction of market requirements and the prior-appropriation no-harm rule were automatic and low cost. This could be achieved by modifying ground-water banking to use aquifer response functions to address rivalry issues and double-entry accounting to address exclusion and ownership. Actual volumes of water stored in the aquifer could be banked, and market prices could be allowed to convey the information needed to secure the market efficiencies desired. Most market requirements could be fully met by this arrangement and all could at least be partially met. The linkage of the two technologies has been demonstrated in proof-of-concept form.

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Tables

Table 1
Assessment of Ability of Described Ground-water Banking
to Meet Market Requirements

Requirement	Met?	Comment
Property rights		
Fully specified	Yes	
Exclusive	Partially	Technologically, migration of stored ground-water to springs and rivers cannot be excluded. Banking credits that expire unused create unpriced antirival benefits.
Enforceable and enforced	Yes	Structurally possible, though some users may assert that current enforcement is inadequate.
Transferable	Yes	
Costs and benefits internal to players	Partially	See exclusion comment.
Adherence to moral norms	Yes	This is the subject of debate but is structurally possible.
Adequate numbers of buyers and sellers	Yes	
Access to information	Yes	If market prices are allowed.
Lack of market barriers		
Low regulatory barriers	Possibly	Depends on implementation details; requires market prices.
Low transaction costs	Possibly	Depends on cost of operation and level of participation.
Homogeneous commodity	Yes	This is a consequence of using aquifer response functions to distill all transactions into time series of effects at river or spring reaches.

Figures

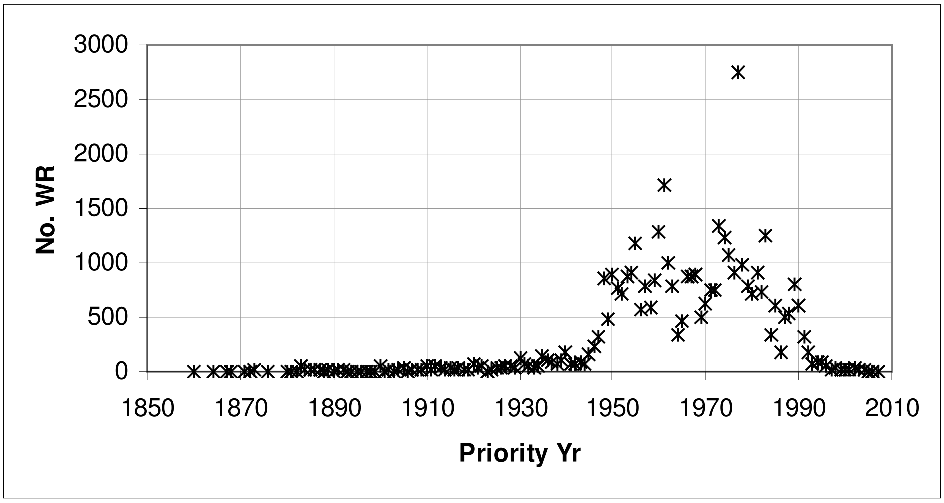


Figure 1. Number of ground-water irrigation rights in Idaho by priority year.

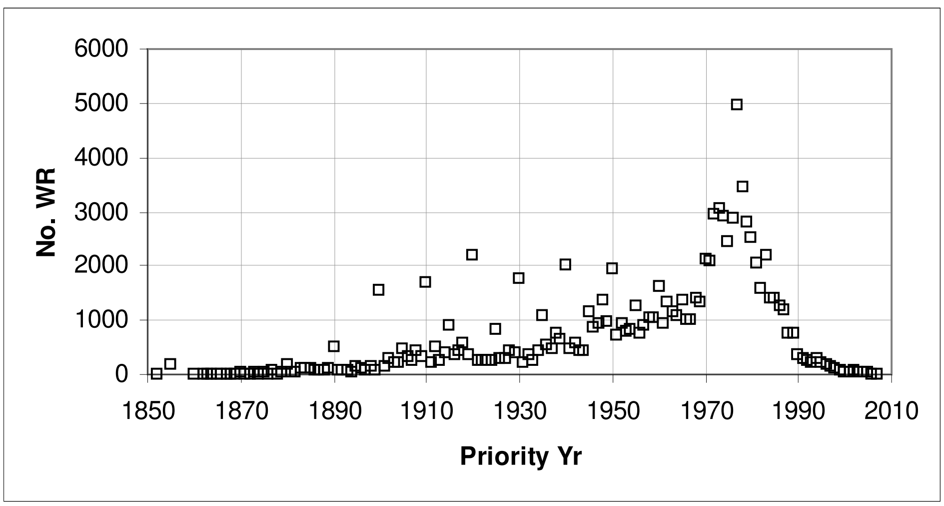


Figure 2. Number of ground-water domestic and municipal rights in Idaho by priority year.

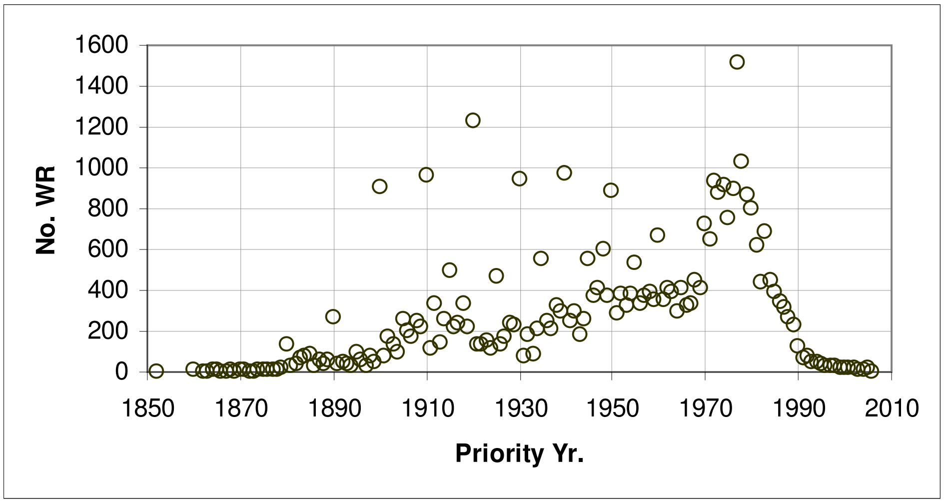
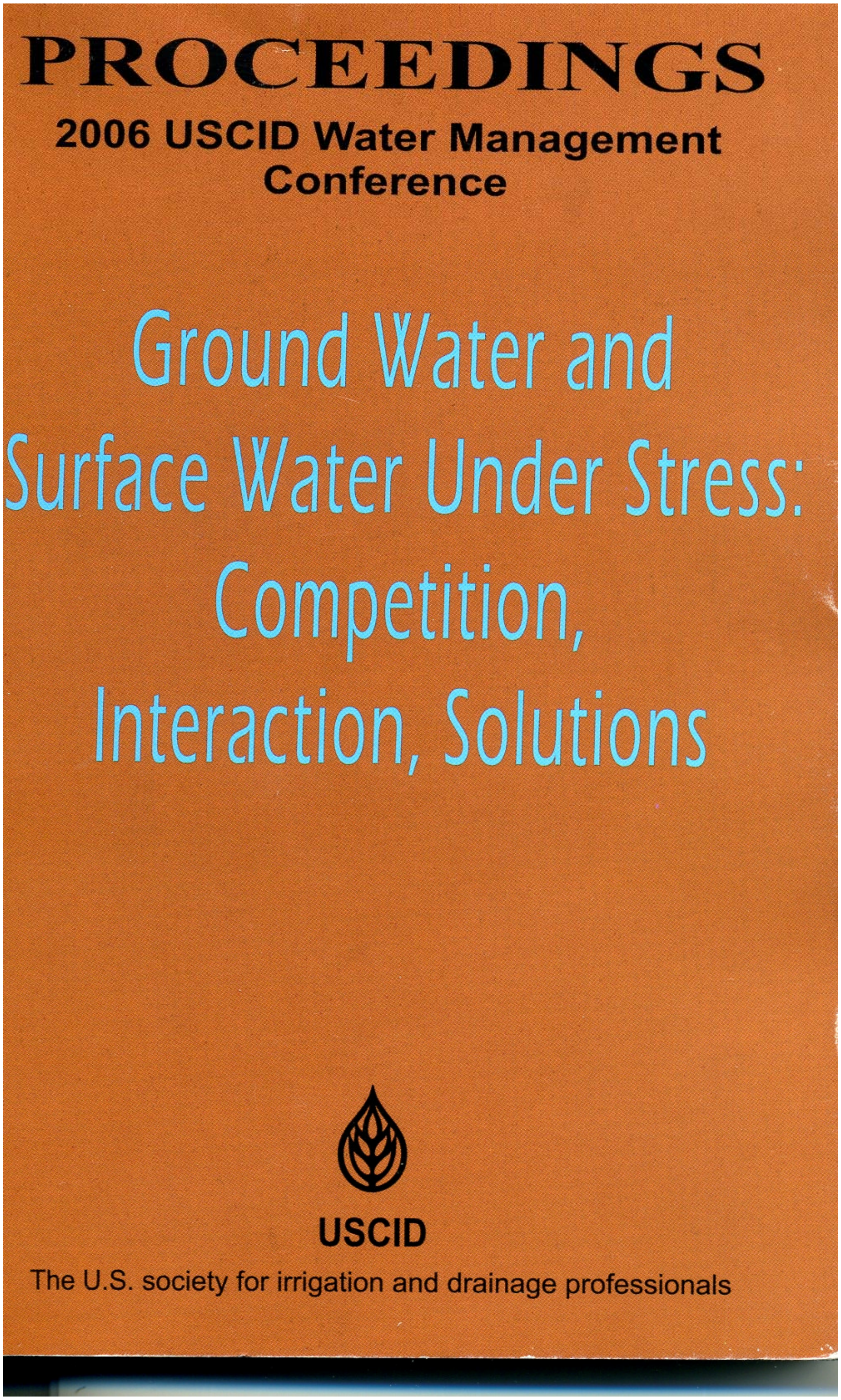


Figure 3. Number of ground-water stockwater rights in Idaho by priority year.

APPENDIX 3: USCID Publication 2006



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GROUND-WATER BANKING IN THE EASTERN SNAKE PLAIN AQUIFER

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R.D. Schmidt[2]

ABSTRACT

All societies must make resource allocation decisions, assigning resources to the production of goods and services. Decisions must be made regarding how to utilize resources in production, what to produce, how much to produce, for whom to produce, and how to pay the factors of production (Medema, 1993). In Idaho and much of the western United States, the prior appropriation doctrine has been selected as the mechanism to allocate water. Most other resources are allocated by the market system, and some market mechanisms operate within prior appropriation.

Water banking is a tool that may expand the operation of market mechanisms within prior appropriation, helping to address current problems of conflict, waste, environmental harm and impeded economic growth. In other words, banking can be helpful in allocating scare water resources to the maximum benefit of society as a whole. In order to consider the possibility that a ground-water banking system in Idaho's Eastern Snake Plain Aquifer could improve efficiency, reduce conflict and supply water to ecological needs while protecting existing uses, the US Bureau of Reclamation (Reclamation) has funded a ground-water banking study with the Idaho Water Resources Research Institute (IWRRI). This is an investigative study designed to identify and explore issues, rather than to actually propose or construct a ground-water banking system.

Work to date suggests that instances of conflict, waste, ecological harm or impeded economic development associated with water use can be traced back to a deficiency in one or more market or property-right requirements. This premise is explored by considering hydrologic, economic and administrative considerations of externalities, and by considering public-goods characteristics of instream-flows for recreational and ecological purposes.

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BACKGROUND

Eastern Snake Plain Aquifer/River Interaction

Physical Description. The Eastern Snake Plain Aquifer occupies approximately 10,000 square miles in the southeastern part of the state, extending from Ashton, Idaho in the northeast to King Hill, Idaho in the southwest. The largest source of recharge is percolation incident to irrigation from the Snake River. The primary discharge is to the Snake River, via tributary springs and direct river gains. Ground-water pumping for agricultural irrigation is a large secondary discharge from the aquifer. The average net discharge from the aquifer to the Snake River is approximately 5,350,000 acre feet/year (Cosgrove et al, 2005). Especially in the summer months, the bulk of the flow in the Snake River at King Hill is derived from spring discharges. The Snake River is an important tributary to the Columbia River and an important migratory pathway for Pacific steelhead and salmon. In the vicinity of the springs, the Snake River is also habitat for sturgeon.

Administrative Concerns. Idaho's surface-water allocation process and ground-water allocation process were developed on parallel tracks that failed to acknowledge the hydraulic connections that can exist between surface water and ground water. In 1993, this failure was challenged by a user who relied on spring discharges and held senior water rights (Raines, 2004). One result of this challenge, known as the "Musser Case," was the implementation of conjunctive management rules for the Eastern Snake Plain Aquifer (Idaho Department of Administration, 1994). The rules officially link ground-water and surface-water administration, wherever a hydrologic connection exists. Idaho's implementation of the rules is evolving, with implications extending to ground-water transfers (Johnson et al, 2004) and surface-water delivery calls (Idaho Department of Water Resources, 2006).

Environmental Concerns - Mid-Snake. Summer-time water-quality concerns in the reach immediately adjacent to the springs include temperature, dissolved oxygen, sediment loading and nutrient loading. These are all affected by the quantity of cool, clean water entering from the springs.

Environmental Concerns - Pacific Steelhead and Salmon. The Snake River is an important tributary to the Columbia River and an important fish migration pathway. Reclamation participates in providing flow augmentation water to aid Pacific species by purchasing water from Idaho surface-water rental pools, in an arrangement authorized by Idaho legislation (State of Idaho, 2006). The connection between aquifer/surface interaction and Pacific species is two-fold; not only do springs from the aquifer provide a large fraction of the summertime flows in the Snake River, but storage in the aquifer is a potential source of water to meet water needs in dry periods, including ecological needs.

Allocation, Markets and Prior Appropriation

Some economists assert that the prior appropriation system "does not facilitate the emergence of water markets" and that, therefore, "water is often not allocated to the highest value uses" (Hamilton et al, 2000). Others suggest that since water rights can be bought and sold, water *is* allocated by the market; in this view prior appropriation is not an alternate method of allocation but an alternate *property-right description mechanism* within a market allocation system (Slaughter, 2006). In the context of ground-water banking it is probably not important which viewpoint is correct; what is important is to understand that water isn't bought and sold in the ways we are used buying and selling other commodities. In Idaho, what is generally exchanged and marketed is not water itself but *the right to the use of water*, if and when it is physically and administratively available.

Markets. A simple definition of a market is "a place where many sellers display and sell their goods... a region or outlet for successful trading" (Lexicon, 1992). More formally, a functioning market includes (though perhaps imperfectly) the following characteristics (Medema, 1993):

- property rights
  - fully specified
  - exclusive
  - enforceable
  - transferable
- costs and benefits *internal* to the players
- adherence to moral norms
- adequate numbers of buyers and sellers
- no barriers to exchange
- adequate information
- homogeneous commodity

Preliminary work in the Ground-water Banking Project suggests that instances of conflict, waste, ecological harm or impeded economic development associated with water use can be traced back to a deficiency in one or more of these market or property-right requirements. Many of these deficiencies may be discussed in terms of *externalities* and *public goods.*

Externalities. An "externality" or "third-party effect" occurs when a cost (or benefit) of a transaction is borne (or enjoyed) by a group or individual not a party to the transaction. The core of the definition is that the cost or benefit is *external* to the decision process of the party undertaking the activity from which the cost or benefit flows. To economists, externalities are a problem in terms of equity (by the simple definition that it is unfair to either bear the costs or enjoy the benefits of others' economic activity) and efficiency (since the full cost or benefit is not considered in the decision, the decision cannot be optimum for society as a whole).

Not all unpleasant consequences of water allocation are externalities, though there is a tendency to call them such (Taylor, 2005). The reality of allocation of scarce resources to infinite wants, failure of enforcement, failure of adherence to social norms and market barriers can all be mistaken for externalities. The key element of an externality is that part of the cost or benefit of an activity is *external* to the decision process of the party engaging in the activity.

Public Goods. Public goods are goods that 1) can be enjoyed by one person without diminishing the enjoyment by another, and 2) that lack the property-right characteristic of exclusion. Typically in a market these goods do not attract resources commensurate with their value to society, because it is not rational for any individual to expend resources towards those goods, when others will continue to extract enjoyment and cannot be excluded (Medema, 1993).

EXTERNALITIES AND GROUND-WATER/SURFACE-WATER INTERACTIONS

Addressing externalities requires an understanding of their origins. In the context of ground-water/surface-water interactions, a necessary but not sufficient condition for an externality to exist is a hydrologic connection. A second necessary condition is for the hydrologic connection to *not* be recognized in the allocation system. Thus, Slaughter and Weiner (2006) identify the separate management of ground water and surface water (in jurisdictions that ignore the hydrologic reality of interconnection) as an "important failure to specify property rights." In Idaho prior to the Musser Case, any material harm that junior ground-water pumping caused to holders of senior spring rights was an externality. Today in Idaho, with the existence of conjunctive management rules, any such harm would be a failure of adherence to social norms, or a failure of the enforcement mechanism. Impacts of *senior* pumping are the result of our society's allocation decision and *not* externalities. They are not externalities because part of the opportunity cost considered by the senior pumpers is the market price the rights would command if sold. This implicitly includes the demand of holders of junior rights; their demand is therefore *internal* to the decision process.

Idaho's conjunctive management rules attempt to address one hydrologic externality, the potential negative impact of ground-water pumping on springs and river gains. Other hydrologic externalities still are unaddressed in Idaho. These include:

1. The positive impact to the aquifer of incidental recharge from surface-water irrigation. In total annual volume this far exceeds the externality that current conjunctive management rules address. Further, changes in surface-water practices have reduced this incidental recharge, with an

impact to springs of the same order of magnitude as the ground-water pumping that is addressed by the rules (Cosgrove et al, 2005).

2. The ecological cost to the river ecosystem of surface-water irrigation diversions. It may be argued that this is simply a result of our social decision to prefer irrigation to instream flows (an allocation decision). However, because current Idaho legal barriers largely prevent purchasing senior water for instream flow, the potential demand of environmental interests is not part of the opportunity cost considered by irrigators and the ecological cost is external to irrigators' decisions.
3. The excess benefit to one or more river reaches that is often generated as part of a transfer mitigation plan. This is small in volume relative to other externalities, but important in the context of economic growth since transfer of existing rights is virtually the only source of water now available for economic growth in southern Idaho.
4. Managed[3] recharge.
5. Retirement of existing ground-water pumping.
6. Providing surface water during times of plenty as an in-lieu supply to lands that otherwise would be irrigated with ground water.

These all are externalities because hydrologic connections exist but the property allocation system does not allow the costs or benefits to be internal to the decisions of those initiating the activities. The last three activities would cause the quantity of water stored in the aquifer to be greater than it otherwise would have been. They are currently externalities because there is no mechanism to assign ownership of the benefits. As expected for a case of positive externality, these activities currently take place at very low levels, if at all. Because of lack of specification of a property right, the market fails to properly signal the value they could have to all water users.

EXTERNALITIES AND GROUND-WATER BANKING

Ground-water banking can address externalities by quantifying and assigning ownership to hydrologic impacts. Reclamation and IWRRI have incorporated response functions (Cosgrove and Johnson, 2004) and basic financial accounting principles (double-entry accounting) in a "proof of concept" computer program that illustrates how a ground-water banking system could perform these functions. Incorporation of hydrologic tools allows adjustment for the hydrologic reality of migration and dissipation of impacts over space and time. Incorporation of a standard financial accounting method tracks ownership and prevents withdrawals

[3] The Idaho definition of managed recharge is physically placing water in the aquifer with the primary intent to increase storage, no matter the nature of the structure or location of recharge. This differs from the Arizona definition that managed recharge is intentional recharge that takes place in a natural (vs. human-made) channel or structure (Swieczkowski, 2003).

from ever exceeding the residual balance of past deposits. Effects are *internalized* by the assignment of a property right (ownership of banking chits or credits).

For new activities such as managed recharge or retirement of senior ground-water pumping, the assignment of ownership is straightforward. The proposed activity has not yet occurred, and the water it will cause to be stored in the aquifer will not have been there, but for the proposed activity. No obstacles exist to assigning ownership of chits to the person or entity who will cause that water to be stored.

On the other hand, incidental recharge has existed as an externality for decades. Any attempt to address the externality by assigning ownership to the incidental recharge will have an impact on property rights that were perfected in the presence of the externality. Great care is warranted. At least three potential owners could be identified:

1. The public as custodian of the environment. Those who believe that the environment was the first user of the water (and that irrigators were second in time) consider suggestions that environmentalists should buy water as "bizarre" (Green, 2003). An argument can be made that society as a whole bears the cost of reduction in ecological services due to removing this water from the river, and that therefore the public as custodian of the environment should own the incidental-recharge chits.
2. Senior surface-water irrigators whose diversions supply the incidental recharge. These users can logically assert ownership of the chits because their predecessors expended the resources to create the distribution systems, and they themselves own the water rights under which the diversion is authorized.
3. Ground-water users and downstream surface-water users (spring users and river users who rely upon river gains). These users may also assert ownership because they have expended resources to perfect water rights in the resulting aquifer storage, river gains and spring discharges. They undertook this activity in good faith, in accordance with the water-law environment that prevailed at the time. Further, communities have sprung up dependent upon the farm economy sustained by these water uses. Current Idaho law allows perfection of a water right in a waste stream but forbids the user to compel the waste to continue. However, Idaho's constitution (State of Idaho, 2003) authorizes the legislature to modify

prior appropriation. An equity[4] and public-interest argument could be made that the property-right specification of rights in waste water should be changed; assigning chits to spring users would essentially be this kind of change.

In order that the assignment of chits may perform its economic function of sending signals to guide water-use decisions, water users who are not assigned chits must be required to purchase them in some manner. While the Coase Theorem of economics suggests that the distribution of water to canal leakage, aquifer use and instream-flows would equilibrate to the same point regardless of who owned the chits (Taylor, 2005), there are very real issues of equity (in the broader definition) and transfer of wealth to consider. Note, however, that *any* correction of an imperfect property specification potentially involves a transfer of wealth, because current patterns of ownership and prices of assets have equilibrated to the current condition with its externalities. For example, the conjunctive management rules, as they become fully implemented, are reducing the value of junior ground-water rights and are precipitating a transfer of wealth from those who are currently invested in junior ground water. On the other hand, leaving the externality unaddressed would have perpetuated what has been essentially a transfer of wealth from spring users and users of reach gains.

In summary, ground-water banking can potentially address current externalities as well as externalities of potential future beneficial activities. Using ground-water banking to internalize benefits of beneficial future activities, thereby promoting flexibility and economic opportunity, is relatively straightforward and could be implemented in the first step of an incrementally-developed ground-water banking plan. Using ground-water banking to address existing externalities will require considerable care and deliberation and might best be approached in a later step.

BARRIERS AND GROUND-WATER BANKING

Ground-water banking may help overcome the frustration environmental interests feel in the current inability to move senior water rights to instream-flow purposes. One mechanism (potentially available under current statute and policy) would be for Reclamation to acquire ground-water chits through providing in-lieu supplies in wet years, retiring ground-water rights, managed recharge or purchase. In dry years, Reclamation could negotiate with holders of water in surface-water rental

[4] In this context, equity is defined more broadly as "that part of the legal system built around the principles of natural justice and fair conduct, [and] specifically designed to deal with those cases where formal law would result in an unfair outcome" (Green, 2003). The economic problem of externalities is both an equity problem and an efficiency problem, thus both equity and efficiency arguments are appropriate in considering how to address externalities.

pools to use Reclamation's ground-water chits by irrigating with ground water instead of rental-pool water. In exchange, the surface-rental-pool water would be made available for flow augmentation.

Providing market access to water for all purposes, including ecological purposes, would provide procedural equity. It would also certainly reduce conflict; if a market mechanism existed for environmental groups to purchase water for instream flow, there would be little justification to pursue water via litigation.

PUBLIC GOODS AND GROUND-WATER BANKING

Many ecological and recreational uses of water include characteristics of public-goods; one person can enjoy the resource without diminishing the enjoyment of another, and additional participants cannot be excluded or compelled to pay. The market fails to capture all of the potential demand and therefore the price signal is an incorrect representation of the desires of society as a whole. Therefore, even with the provisions described above, ground-water banking might still not result in the optimum level of instream flows for society as a whole; as a public good, instream flows may not attract resources commensurate with their true value to society. In the case of individuals, "economic value may diverge markedly from willingness to pay" (Green, 2003). In the case of potential purchasers who are public institutions (such as Reclamation), willingness to pay is tied closely to the resources available from taxation. However, "for the efficient level of public investment to be achieved, the tax taken... must be equal to the efficient level.... Tax levels are unlikely to be set either in this manner or with this effect" (Green, 2003).

CONCLUSION

Instances of conflict, waste, ecological harm or stifled economic growth suggest flaws in an allocation system. Economic principles and the requirements of markets and property right systems may be used to examine problems with water allocation.

The economic concept of externalities can be used to explain allocation issues associated with surface-water irrigation, pumping of ground water, and enjoyment of spring discharges and river gains associated with the aquifer. Ground-water banking can be a tool to internalize some of these effects. If the effects are internalized, the signals sent to water users will promote decisions that more closely align the utilization of resources with the needs of society as a whole. Because current patterns of ownership have equilibrated to existing externalities and conditions, there is a need to proceed with great care and deliberation in ground-water banking policies that assign ownership to existing effects (such as incidental recharge from surface-water irrigation). Assigning ownership to the effects of future activities (such as retirement of ground-water pumping, providing in-lieu supplies, or managed recharge) is more straightforward because no one yet has developed a claim to ownership of the benefits.

Ground-water banking can also be a tool to facilitate the movement of water to ecological purposes. It certainly would promote equity of process, reduce the potential for conflict and move some water to ecological uses. However, the public-goods characteristics of water for recreation and ecological purposes may still prevent ground-water banking from facilitating the optimum allocation between recreational, ecological and other water uses.

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APPENDIX 4:

Background Economics Information

Market Basics

Markets are allocation mechanisms where individuals negotiate the exchange of commodities, goods and services. Basic concepts of markets are demand, supply, and prices.

Figure A5-1 illustrates an individual's hypothetical demand function. The downward slope of the curve indicates the principal of declining marginal satisfaction with increased consumption: The first unit provides a great deal of satisfaction, but as more and more are consumed, each successive unit brings less satisfaction. Demand is willingness to pay. This individual would pay eight dollars for the first unit, because it would deliver eight dollars worth of satisfaction. However, if he/she already had six units, the price would have to drop to two dollars in order to induce purchase of a seventh, since it only brings two dollars of satisfaction.

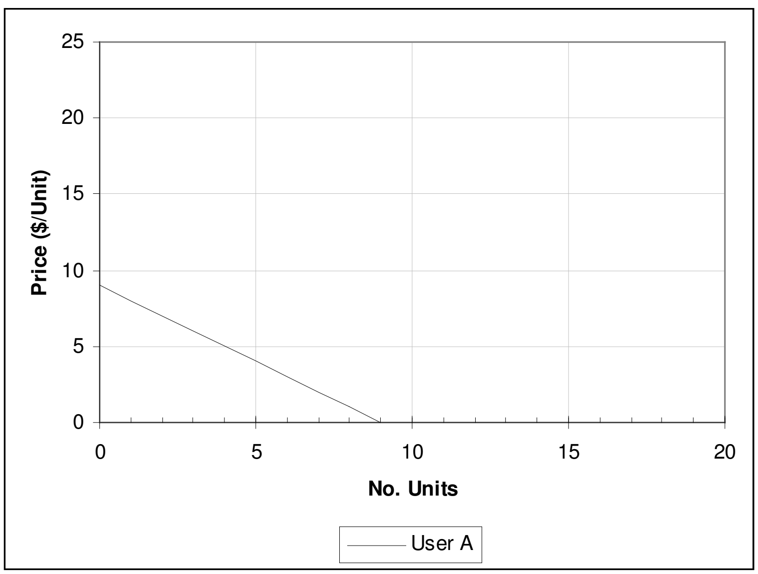

Figure A5-1. Single-user demand curve. Note that quantity is on the horizontal axis and price on the vertical axis, even though we normally talk about quantity as a function of price.

Aggregate demand for a market is obtained by horizontal summation of individual demand functions. In Figure A5-2, at a price of eight dollars User A is willing to purchase one unit and User B will purchase four, for total demand of five units.

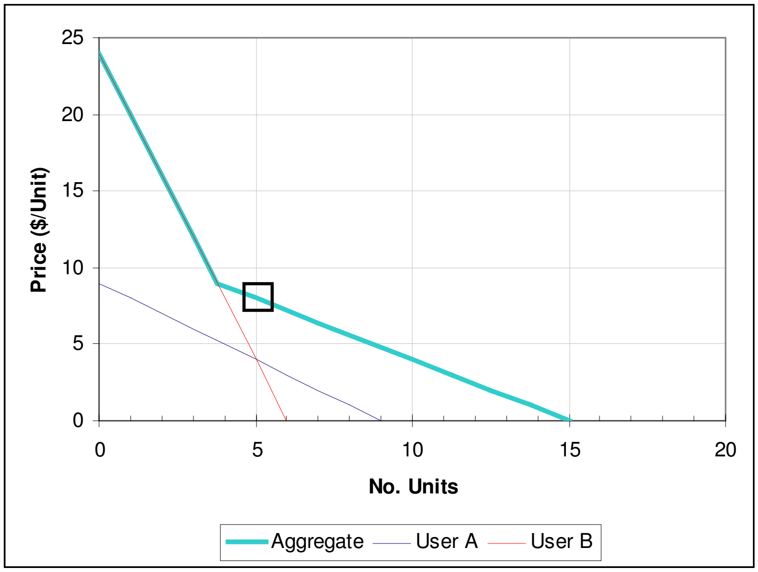

Figure A5-2. Aggregate demand for two users. The rectangle shows the aggregate demand of five units at a price of eight dollars.

Aggregate supply functions are generally illustrated as upward sloping. If a good is more valuable per unit, suppliers are generally willing and able to supply a larger total quantity. Figure A5-3 shows an intersection of the aggregate demand curve with a hypothetical aggregate supply curve, at three different potential prices.

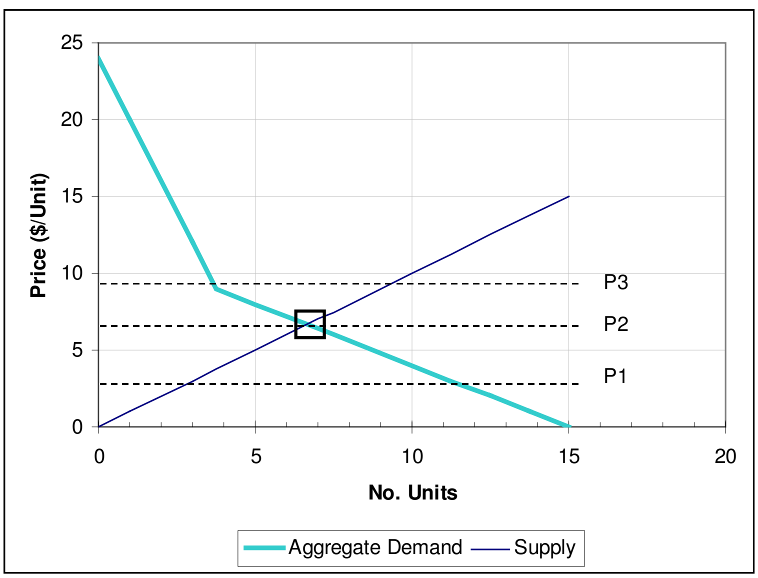

Figure A5-3. Aggregate demand and supply with three possible prices.

Price P1 would result in a shortage if artificially maintained. At that price, consumers would demand 12 units but only three would be produced. An artificially-maintained price of P3 would produce unsustainable surpluses; nine units would be produced, but only four purchased. If market pricing were allowed (and market conditions substantially satisfied), prices would equilibrate to the boxed intersection of P2, $6.40, with a willingness to provide and a willingness to purchase of seven units.

Once the equilibrium price was established, User A and User B would each respond based on their individual demand functions, as illustrated in Figure A5-4. At $6.40 per unit, User A would be willing to pay for 2.6 units and User B would be willing to pay for 4.4, giving the total aggregate demand of seven units.

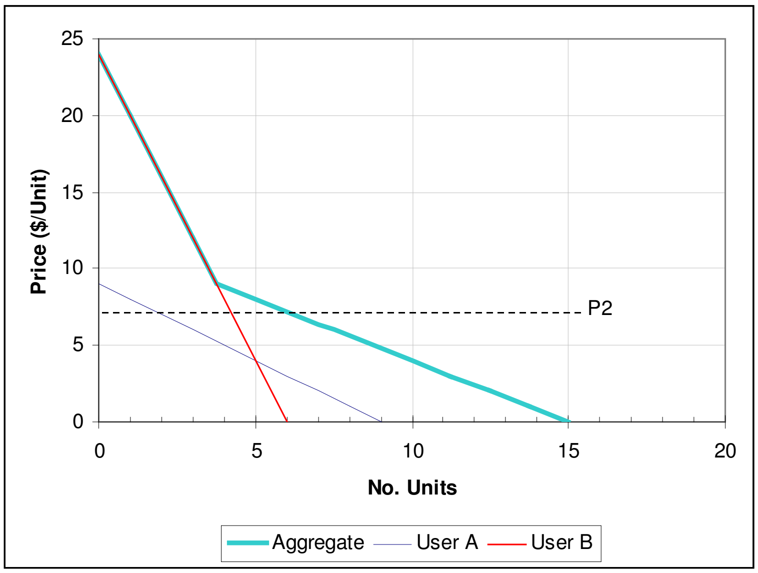

Figure A5-4. Response of User A and User B to market price P2.

Because each has full access to the market and engages in voluntary trade, each has equated his/her marginal satisfaction with the market price. This is a general result when markets function properly; equilibrium prices result in each user choosing a consumption level which automatically equates marginal cost with marginal benefit, guaranteeing economic efficiency.

Happily, the conditions required for market functioning also guarantee the components of equity described in the body of the report. These market conditions are:

8. Property rights
    a. fully specified
    b. exclusive
    c. enforceable and enforced
    d. transferable
9. Costs and benefits internal to the players
10. Adherence to moral norms
11. Adequate numbers of buyers and sellers
12. Access to information
13. Lack of market barriers
    a. Regulatory or market-access barriers

   b. Transaction costs
14. Homogeneous commodity

When one or more of these required attributes is missing or inadequate, economists say that a "market failure" has occurred. In that case, markets are not necessarily efficient or equitable. In asserting that market allocation of water is desirable, or that there is nothing special about water, one asserts that these market requirements are substantially present; that is, that no market failure has or will occur.

Market Requirements, Rivalry and Exclusion

An old but enlightening discussion of water marketing, prior appropriation and third party effects (Gould, 1988) explains some of the characteristics of water that have resulted in the adoption of prior appropriation and its transfer requirements. Gould shows that many of the prior-appropriations transfer requirements seen as market-hostile turn out to be efforts to address the lack of one or more market requirements in water allocation and distribution. The concepts presented by Gould are discussed more generally by Randall (1983) and may be used to examine how there is, indeed, something special about water. Traditional discussions of market failure discuss issues of public goods, common-pool resources, natural monopoly, and externality. Randall asserts that these terms are more confusing than enlightening, and proposes a system where instead goods and services are described in terms of Rivalry and Exclusion

Rivalry is related to the physical characteristic of the good and the nature of uses that are made of it. If use of the good by one person precludes its use by another, the goods are rival. A restaurant meal is an example of a rival good. Nonrival goods or services are those where enjoyment by one user does not preclude or interfere with use by another. National defense and scenic beauty are sometimes given as examples. An important rivalry concept identified by Randall is congestibility. Congestible goods are nonrival up to a threshold of use, beyond which they become rival. A theater show is congestible. A concept not discussed by Randall, but hinted at in Gould's writing, is a fourth class of rivalry that could be called antirival uses. A restaurant located near a theater enjoys an antirival relationship with the theater; the more viewers the theater attracts, the more customers the restaurant is likely to serve. A closely related concept might be called antirival congestible uses. These are uses that are antirival up to a point, then transition through nonrival to rival status.

Randall's other criterion is exclusion. This is a function of institutional and technological factors. In the case of the theater, a building that blocks sight and sound is the technological factor that allows exclusion. The theater's policy of charging admission, and the legal framework that permits this, are the institutional factors. Non-exclusive goods are obviously those where no individual can be excluded from use. An example might be the gathering of coal spilled along a railway, in a setting where neither a fence (technological barrier) nor enforcement (institutional barrier) prevent it. Exclusive goods are obviously those where access can be controlled. Construction of a fence and posting of a security guard would transform coal-gathering to an exclusive activity. A more difficult concept is hyperexclusiveness. Hyperexclusive goods would be those where technological and institutional factors allow each user to be charged a unique price that exactly matched his/her willingness to pay. The old country doctor who accepted a chicken at one home and charged a gold coin at the next may have approached hyperexclusion.

There is no *a priori* requirement of linkage between rivalry and exclusiveness classifications. The coal example (without fences or enforcement) is a case of rivalry without exclusion. Subscription satellite radio is an example of exclusion without rivalry. Hamburgers are both rival and exclusive. Sunsets are neither.

Whether one uses traditional market-failure nomenclature or Randall's classifications, the concepts are useful to consider in assessing reallocation mechanisms. The important economic implication is that market mechanisms do not result in the optimum allocation of resources under all combinations of rivalry and exclusion. Market requirements are met, and the prized advantages of markets are realized, only for goods that are both rival and exclusive.

Other Special Characteristics of Water

Gould hints at but does not explicitly discuss an important special characteristic of water that was not addressed by Randall's generic discussion: It is a low-value bulk commodity with high transportation costs (Taylor, 2008). Further, because water can move by gravity in natural or human-made channels, the transportation costs are highly anisotropic. Moving water downstream is virtually costless or may even generate hydropower revenue. Moving water upstream is expensive due to both infrastructure and energy constraints. Similarly, trans-basin transfers are physically possible only under favorable geographic configurations. There are three consequences of this unique characteristic of water:

1. There is often asymmetry in the nature of rivalry and exclusion between pairs or groups of water users. A downstream use that benefits from the delay of return flows has an antirival dependence on the upstream use, but the upstream use has no antirival dependence on the downstream use.
2. Some uses of water in practical effect are independent, though the categories of use would otherwise be rival. Irrigation on the Columbia River and on the Missouri River are not rival, but neither are they nonrival

in the sense that Randall describes. These will be labeled independent uses in this report.

3. Water often fails to meet the *homogeneous commodity* market requirement.

In the western United States, water use and water supply are highly variable in time and space. Rivalry conditions between uses and users can change frequently and rapidly. For instance, hydroelectric generators in Idaho have generally opposed diversion of water for managed aquifer recharge, seeing it as rival to power production. At times of the year, it can indeed be rival. In the spring, however, when all plants are operating at capacity and runoff is being spilled, diversion to managed recharge is nonrival. Paradoxically, one consequence of recharge is increased reach gains and spring discharges to the river in late summer when flows are low and hydropower demand is high. This fraction of the recharge use is an antirival benefit to power generation. Depending on the relative magnitudes of the rival, nonrival and antirival fractions, opposition to recharge may or may not be rational. In 1961 Reclamation concluded that managed recharge offers a net benefit to hydropower generation (US BOR 1961).

Auction Mechanisms

One of the reasons that administratively-determined prices are adopted is that water markets, especially new water markets, can have small numbers of traders and little information. This violates market requirements. Participants are reluctant to reveal their true preferences, in hopes of obtaining water at far less than their actual willingness to pay, or providing it at far more than their actual willingness to sell. Without an existing market price or past sales precedence, users may not even know where to begin in assessing their own true marginal value for water.

Auctions are a useful and time-honored mechanism for extracting actual preferences from participants and discovering market information. With the modifications of compulsory-bid mechanisms (citation: Australia) and multi-stage auctions (citation: Oregon), participants can better be induced to participate near their true willingness to pay or willingness to provide. The following description is designed to illustrate concepts and not prescribe a bidding process; construction of an actual bidding mechanism would require additional research and careful consideration.

The compulsory-bid process is a mechanism designed to induce participants to consider and face their own marginal benefit from water use, and to consider becoming a supplier in the market place. While all participants are required to bid, no restriction is placed on bid price. A user determined not to provide water simply posts a very high "sell" bid.

If temporary foregone ground-water pumping were a deposit mechanism in a ground-water banking system, all holders of ground-water rights could be required to post compulsory sell bids (legislation may be required to accomplish this). Similarly, all holders of existing credits could be required to post bids. Participation could be ensured by assigning a low but approximately reasonable default offer price for all cases where bids are not received. Simultaneously, all prospective buyers would be invited to participate. In the first round, many right holders would be expected to post very high sell bids in order to exclude themselves from marketing. However, in the posted results of first-round bidding, these users would note "buy" bids that actually exceed their own marginal value of water. This would invite serious contemplation of participating in the market; they would see (as User A did in the example in the report) the opportunity to improve their condition by reducing water use and marketing some water.

The multiple-bid process is important in order to introduce bidders to the range of possibilities that exist for both supplying and purchasing banked water. In the first round, many potential sellers would be expected to over-price, and many potential buyers would be expected to under-price their offerings. Viewing their bids in comparison with all other bids allows them to consider their standing in relationship to all other bidders. It will invite them to consider re-bidding closer to their own actual marginal value, knowing that a sale at a reasonable price is better than a no-sale at an extravagant price.

A possible structure for the first time the sale was conducted could be a three-stage auction. All participants would place first-round bids with no restrictions on bid amounts. The bids would be posted (anonymously, or with names attached as the banking authority determined) and distributed for full inspection. The distribution could include a list of how the buy and sell bids would have matched, as described below. After a set review period, all participants would place second-round bids, again with no restrictions. Participants would be notified, however, that their third-round bids, which will be final and binding, cannot differ from second-round by more than a fixed percentage. This invites all participants to approximately reveal their true preferences but still provides opportunity for learning and discovery. After a few auctions, the first round could probably be eliminated, but unless auctions were held as often as monthly, there would probably be value in at least a two-stage mechanism.

It is highly unlikely that the sell bids and the buy bids will exactly match in quantity and price. Allocation could proceed according to the "choice" mechanism used in auctions of lots or batches of items: The high bidder chooses as many of the lot as he/she wishes, paying the bid price for each item. If items remain, the second is offered choice at his/her bid, etc. In the case of a water auction, bidders would have specified a volume of water, a "buy" or "sell" price, and if the accounting mechanisms described in the report are followed, an affected river reach and time of impact. The auction authority would line up "buy" and "sell" bids from high to low and select combinations from the "sell" column to satisfy the "buy" bids, honoring all bid prices. Prior to the auction, the authority would decide and announce whether transactions would be finalized at the "buy" price, the "sell" price, or an average. Table E-3 lists some hypothetical bids and Table E-4 shows the disposition, assuming finalization at an average price.

Table E-3
Hypothetical Bid Prices for Reach X, Time Period Y

Bid Number	Buy or Sell	Quantity (acre feet)	Price ($/acre foot)
B1	Buy	100	50.00
B2	Buy	1000	25.00
B3	Buy	15	20.00
B4	Buy	5000	15.00
B5	Buy	200	4.50
S1	Sell	200	250.00
S2	Sell	50	40.00
S3	Sell	800	22.50
S4	Sell	2500	12.50
S5	Sell	1000	10.00

Table E-4
Hypothetical Disposition of Bids from Table E-3

Settlement Number	Buyer	Acre Feet	Price	Seller
1	(no sale)	200	-	S1
2	B1	50	$45.00	S2
3	B1	50	$36.25	S3
4	B2	750	$23.75	S3
5	B2	250	$18.75	S4
6	B3	15	$16.25	S4
7	B4	2235	$13.75	S4
8	B4	1000	$12.50	S5
9	B4	1765	-	(no sale)
10	B5	200	-	(no sale)

The reader can confirm that every completed transaction was at a price lower than the buyer's bid and higher than the seller's bid.

Restrictions on Market Participation

Part of the history of prior appropriation is a healthy resistance to the concept of speculation. This arose from the physical geography of the arid west and the ability to appropriate water with very little effort; in most jurisdictions users had but to scratch out some semblance of a ditch and perhaps post a notice. However, this only initiated the process of perfecting a water right. Without the anti-speculative provisions of prior appropriation, an early-arriving entrepreneur could have made a nominal appropriation of large quantities of water at little effort. This would have unjustly granted control of vast tracts of real estate without making improvements or investments that built community and capacity.

This danger does not exist in the currently-contemplated water banking system, because deposit activities require real effort and financial investment. However, those who need water for new uses do not always control the physical infrastructure, water rights, or geographic locations suitable for making deposits. Those who have the ability to make deposits may not need the benefits that a deposit would generate, and may not have the resources to wait for eventual sale of credits. Allowing investors to participate in the bank could bridge the gap between these parties and facilitate allocation of water to the uses most beneficial to society as a whole.

A perceptive investor might anticipate a future need for credits in a particular reach of the river to support expected development or industrial activity. In years of low agricultural commodity prices, he/she could contract for temporary foregone ground-water pumping with irrigators in locations where the credits generated would be active at the time and place of anticipated need. The irrigator would receive immediate cash income and reduction in operating costs, the investor would acquire aquifer credits, and in the future, developers needing mitigation credits would find a ready source. By foreseeing the need, funding the initial deposit and assuming risk, the investor would facilitate economic activity and perform a valuable function.