



**DESCHUTES RIVER CONSERVANCY**  
**RIVER PAPERS**

**Auctions and the Reallocation of Water  
Rights in Central Oregon**

**Ray Hartwell  
Bruce Aylward**

**April 2007**

**OUR MISSION** To restore streamflow and improve water quality in the Deschutes Basin.

# **Auctions and the Reallocation of Water Rights in Central Oregon**

**Ray Hartwell**

**Bruce Aylward**

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**DESCHUTES RIVER CONSERVANCY**

**River Paper Series No. 1**

## **Deschutes River Conservancy**

In November of 1996, Environmental Defense, local irrigation districts, and the Confederated Tribes of Warm Springs founded the Deschutes River Conservancy (DRC) in response to the growing need for a consensus building organization to address concerns about water quantity and quality in the Deschutes River Basin. The DRC is governed by a 22-member board of directors with twelve representatives from private interests and ten from public interests that represent the major agencies and stakeholder groups in the basin. Through market-based approaches, the DRC is engaging in projects and transactions that manage Deschutes Basin water resources in a manner that supports growing communities, fosters healthy habitat for fish and wildlife while maintaining the quality of life that has brought us all to this region. The DRC is nationally recognized as a leader in river restoration.

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### **Information for Authors**

For any questions about the eligibility of a paper and information on submission requirements interested authors should contact the DRC's Program Analyst at [brett@deschutesrc.org](mailto:brett@deschutesrc.org).

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## **1. Introduction**

Water supplies in much of the West are insufficient to meet all demand under current allocation schemes. In this context, pressure to balance the emerging needs of development and environmental restoration necessarily requires reallocation of water rights away from agriculture and other traditional uses. Market-based mechanisms are widely advocated as a means of accomplishing this on efficiency and political grounds. These mechanisms are attractive politically because they are voluntary and obviate the need for government takings or exercise of eminent domain

Posted-offer procurement and negotiated individual transactions have been prominent market-based approaches to water reallocation, though their success has been hindered by a dearth of information on appropriate pricing. Auctions present an alternative approach that is attractive on theoretical grounds because of the potential to minimize costs of water right acquisition in information-poor environments. Despite this, relatively few real world water right auctions have been implemented, much less studied.

This paper presents an analysis of three water right auctions in two different contexts in Oregon's Deschutes River Basin. The experience with auctions in the Deschutes Basin is examined in the context of other efforts to use auction mechanisms in water management and other natural resources contexts. A concise theoretical overview frames the discussion.

The 2003 and 2004 auctions to lease water rights for instream flow augmentation from Ochoco Irrigation District patrons are used to highlight aspects of learning in a repeated auction process. Discriminatory pricing and a single-round sealed bid procurement approach characterize these auctions. Results are contrasted with previous efforts to lease water for instream use under a fixed price scheme. The improvement in the information environment is discussed.

Discussion of a 2004 auction of water development offset credits ("mitigation credits") provides insight into the demand side of the emerging market for water rights in Central Oregon. This effort was an ascending-bid "English" auction in which bids were posted online.

Finally, the two types of auctions discussed serve as a point of departure for discussion of a possible two-sided sealed bid allocation mechanism, whereby market transactions directly between holders of agricultural water rights and conservation buyers, developers, and those in need of mitigation credits could be effectuated. Potential advantages and disadvantages of this approach are discussed, both in theory and in practice.

## **2. Theoretical Background and Literature Review**

### **2.1 Market-Based Natural Resource Allocation**

There is extensive economic literature on the advantages of market-based environmental management approaches as compared to administrative procedures. Economists have long held that the use of "market-based" or "economic-incentive" instruments, principally pollution taxes and systems of tradable permits, to address environmental problems, rather than so-called

“command-and-control” instruments will yield efficient allocations of these resources (Stavins 1998). Colby (2000) points out that even in the best-case context of effective governments and rule of law, public administration of rights to use natural resources are notoriously inefficient. In contrast, markets create an opportunity cost of resource use and thus encourage efficiency. Stoneham et al. (2002) point out that in making resource use decisions, property right holders only can perceive values for actions that are priced in some market.

For all that recommends market based natural resource allocation, logistical and political difficulties often serve as barriers to systems of free trade. Indeed, a casual examination of the attributes of many of the goods in question illustrates why the development of functioning markets tends to lag in the natural resource sector relative to other areas of capitalist economies. In short, many of the basic preconditions of market failure are present in natural resource management. In this context, implementation of market incentives is a question of politics and administrative craft more than of simple will; even once there is consensus on the merits of market based management, devising an actual system to facilitate trade can be a daunting challenge.

As Colby (2000) points out, rights to natural resources are frequently hard to measure, over allocated, or both. Further, these rights may be inchoate, untested, or otherwise legally ambiguous. Common good characteristics and the presence of externalities in many resource contexts cast doubt upon the superior efficiency that arguably is created through trade. Enforcement of any use limits can be intrinsically difficult and property rights can be hard to define. Finally, physical and geographic restrictions can impose boundaries on the feasible marketplace in the form of transaction costs.

In the context of water rights, conveyance costs necessarily limit the geographic scope of a given market. Although upstream to downstream transfers can be costless in certain basins, physical limitations often impede transactions. In particular, the capital costs associated with canal development, coupled with electricity costs of pumping water over long distances, can combine to limit the physical scope of trade. As a result, the volume of trade and numbers of participants in water markets is expected to be low (Colby 2000), even absent political and other administrative restrictions on trade. Water administration is conducted under state law in the western United States (Colby 2000), and transfers of water rights between states are generally not legal. Additionally, in many states including Oregon, intra-basin transfers are not permitted, further limiting the potential trade in water rights. Also, irrigation district interests in maintaining district integrity can make trade between districts hard to effectuate.

Other challenges to establishing functioning water markets include measuring water, defining rights to water, enforcing rights to water, and investing in conveyances. Equity and social concerns add another level of complication, including the sale of rights by cash-poor farmers and externalization of social and environmental costs (Dinar et al. 1997). Further, statutory protection of third party users from injury associated with water right transfers creates de facto tertiary interests in property rights to water. Administrative transfer procedures aimed at safeguarding common good aspects of water use often provide avenues for challenges to water reallocation, introducing an additional element of cost and risk into transactions. Infrequent transactions introduce additional uncertainty into the process. As Colby (2000: 643) states, “transactions, when they first begin to occur in a new area, resemble complex diplomatic

negotiations rather than commodity exchanges.” The characterization aptly describes some of the initial market transaction efforts in the Deschutes, where in many cases years passed before the transfers we fully completed.

Despite these limitations, high marginal costs of developing new supplies coupled with growing demand has led to increased interest in reallocation of water rights through trade. A priori, the low marginal benefit of water use in agriculture seems to promise extensive gains from trade. In this context, water market activity has been on the rise in recent years; though by a broader standard efficient commodity markets for water remain rare. In the context of this market development, auctions have been ballyhooed as a means for individual buyers or sellers to reap some of the gains from trade even in the absence of a fully functioning market.

## **2.2 Auctions**

In the context of market-based allocation of water resources, auction mechanisms are attractive for their ability to facilitate resource distribution in a manner that maximizes social efficiency and is privately cost-effective. In the case of a single buyer (such as a water administrator or conservation group), competitive auctions allow for the lowest total expenditure cost for each given quantity of water acquired. Crucially, these objectives can be met without knowledge of the private values that others place on the resource (Chan et al. 2003).

Auction designs vary widely in terms of bidding protocol, the price paid by winners, and the number of items available for sale (see Chan, et al. 2003 for a comprehensive overview). In addition, auctions can be used to either sell or buy items. For the sake of simplicity, the following section describes the traditional auction where the auctioneer seeks to sell an item or items. However, all of the forms described can be used in reverse “procurement” auctions where the auctioneer seeks to purchase some good. These two forms are symmetric, and analysis is applicable across both approaches. An understanding of the aspects of different designs is essential to crafting successful auctions, as the wrong design applied to a situation can have disastrous results (Chan et al. 2003; Klemperer 2002).

An English, or ascending bid, auction uses a bidding process of serial public bids, each higher than the last, until bidding stops. The item at auction is sold to the highest bidder. In contrast, Dutch auctions feature a decreasing announcement of bid levels, with the winning bid being the first to accept the falling transaction price. In a sealed-bid auction, participants submit confidential bids and the highest bidder wins the auction.

Under a sealed bid approach, a separate question is what price the winning bidder should pay. One approach is to have the winner pay the value of the winning bid in a so called first-price auction. Alternatively, a Vickrey or second-price auction has the winner pay an amount equal to the highest losing bid. This approach was first proposed by Vickrey (1961), and is designed to prevent strategic under-bidding. If there are multiple winners, then additional considerations enter into the scenario. In a discriminatory auction, each winner pays the value of his bid. Uniform auctions differ in that bid values are ranked in order to determine bid acceptance, but all accepted bids pay the same amount. Note that a variation of the Vickrey auction can be used in this multi-unit uniform price scenario by having all winners pay an amount equal to the highest losing bid.

In a single-unit auction, a single item is being bought or sold, while multi-unit auctions sell multiple like items. As discussed later in the paper, the requirement that goods at sale in a multi-unit auction be homogeneous has important implications for the design of water right auctions. The often heterogeneous nature of water rights poses challenges in ranking bids if diverse rights are included in the same auction process

## **2.3 Evaluation of Auction Performance**

### **2.3.1 Bidding Behavior**

While it has been shown that in a controlled environment, the English, Dutch, Sealed-bid, and Vickrey auctions produce on average the same revenue, this result does not imply that choice of auction design is unimportant (Chan et al. 2003). Rather, given real world variation in auction environments, attention to auction design is crucial to auction success. Indeed, Klemperer (2002: 170) mentions that while the bulk of the literature on auctions focuses on results under assumptions of large numbers of participants and perfect competition, practical auction design is in contrast “mostly good elementary economics.”

The central question is how and to what extent different auction designs induce bidders to truthfully reveal their resource valuations through their bids. A key concept in the analysis of this aspect of auction design is the ‘private value’ that the participant places on the item. In theory, a bidder will realize a net utility gain if he is able to acquire the item for any amount up to this true value of the item in his private use. Of course, to the extent that a bidder can obtain the item for less than this value, he will accrue rents and obtain some of the surplus that would go to the producer (auctioneer) if the trade had occurred at a higher price. In this situation, a profit-maximizing auctioneer will attempt to craft an auction that will not provide opportunities for bidding significantly below one’s private resource value. This ‘bid shading’ by participants trying to reap excess rents is a threat to efficient auction outcomes; as a result, design modifications seek to eliminate profitable bid shading opportunities. In this context, selected design choices and their implications are described below.

### **2.3.2 Evaluation Criteria**

Auction performance can be measured on several parameters. From the perspective of successful design, two considerations are paramount: efficiency and revenue generation. Other design choices are of importance primarily for how they affect these two measures.

An auction outcome is efficient if goods are allocated to their highest value uses. Under this allocation, the social utility of the good is maximized, and all potential gains from trade through reallocation are exploited. Provided that all costs are internalized so that social and private costs and benefits are aligned, allocation of goods to those with the highest private resource values will be efficient. If an auction induces bidders to bid their private resource values, then the good will be allocated efficiently.

While efficiency of auction outcomes is in the clear interest of society, it is generally a secondary concern relative to revenue generation for the auctioneer (or his client). An auctioneer seeks to fully capitalize an asset in a traditional auction by generating maximum revenue from its sale. Similarly, in procurement, the auctioneer’s goal is to acquire the good at the lowest possible cost.

Importantly, these two objectives for auction success are often jointly realizable in efficient markets. In a competitive market without market failure, a sale to the highest bidder will simultaneously maximize revenue and efficiency, because the highest bidder will by definition be the one who has the highest private resource value, which will be aligned with the social resource value because there are no externalities. However, in cases where markets are not competitive, externalities are present, or other market failures exist, joint maximization of these two parameters may be impossible. In this case, the success of a given auction outcome will be a function of one's perspective. Tradeoffs between social efficiency and revenue maximization are discussed in the evaluation of each auction.

## **2.4 Auction Design**

### **2.4.1 Discriminatory vs. Uniform Price**

The central issue in evaluating the choice of discriminatory or uniform auction is bidding behavior. While it is obvious that discriminatory auctions maximize revenue holding bid behavior constant, the question is whether such a structure creates an incentive to alter bids from one's private resource value. Hailu and Thoyer (2005) find that discriminatory auctions underperform other formats based on experimental models, and that over-bidding to sell items was common under such formats. Hailu and Thoyer's model features bidders submitting a function of how much water they would be willing to forego using for different prices; as such, their results may not be generalizable to situations where only the number of acres irrigated can be curtailed, rather than the amount of water per acre (this is the case in Oregon and the Deschutes basin).

These disadvantages were found to be particularly acute when number of participants is low. To illustrate with an example of a single-unit reverse auction to buy water rights, if a given irrigator places a true value of  $A$  on his water use, he should be willing to forego that use for any amount over  $A$ . However, under a discriminatory auction, he may increase his bid to sell significantly above  $A$  to  $A'$  (especially if  $A$  is on the lower end of the spectrum of demand) in hopes of reaping economic rents. In a Vickrey auction, the same irrigator might be willing to bid his true value of  $A$ , knowing that he is guaranteed to get  $B$ , the value of the losing bid above  $A$  in the event that  $A$  is the lowest (winning) bid. In this case, if  $B$  is less than  $A'$ , then the uniform Vickrey auction will be more cost effective than the discriminatory auction because the auctioneer will pay less for the item purchased, even though he pays more than the winning bid value. At the same time, discriminatory auctions are easily understood and offer the possibility of winning with an inflated bid to sell an item, which is attractive to participants.

### **2.4.2 Iterative vs. Single-Round Auctions**

Another important aspect of auction design is whether to conduct multiple rounds of bidding. In a traditional auction, a single round of bidding is conducted to determine which bids are accepted. This approach is inexpensive and straightforward, but there can be significant uncertainty as to outcomes, especially if informational asymmetries exist. Information asymmetry exists when auction participants and auctioneers have different levels of information about resource values. Under these conditions, expectations as to likely bid values and auction results may not comport with reality, and opportunities for gains from trade can be missed.

Uncertainty regarding potential outcomes can be mitigated by conducting an iterative auction with multiple rounds of bidding and revision of bids permitted between rounds. Generally, provisional acceptance of bids is disclosed after each round. Cummings et al. (2004) explain that this provisional disclosure is crucial to bidder learning. In every subsequent round, rejected bidders may lower their bids (in the case of a reverse auction) in order to make their offers more attractive. Accepted bidders may raise or lower their bids in order to either obtain resource rents or safeguard their bids against competition. The decision as to how to revise bids will in part be a function of how close the bidder believes their bid is to the threshold for acceptance. Empirical simulations of an iterative auction designed to inform the Georgia Irrigation auctions suggests that auctioneer outcomes are maximized by disclosing whether a bid is accepted in a given round, but that disclosing the actual acceptance threshold leads to bid shading. Cummings et al. (2004) point out that if there is opportunity for participants to share information between rounds, they will be able to reach a good estimate of the threshold nonetheless.

Two important effects result from the use of iterative bidding. First, the outcome of the auction is more predictable, because preliminary rounds of bidding allow for the establishment of a more stable market clearing price through the adjustment of bids described above. This can be an important consideration in the context of contentious public programs, where political embarrassment could result from an imperfect result (Cummings et al. 2004). Second, the cost-effectiveness of the auction may differ from that of an equivalent single-round auction. The direction of that change will depend on individual bidding behavior, but some laboratory research suggests that average costs may decline (Cummings et al. 2004).

While the multi-round format permits learning from tentative outcomes of previous rounds of bidding, it can also facilitate coordination among participants in efforts to collude to keep prices low. This is a particular risk if there is little competition in the auction and this becomes apparent through the intermediate round bid outcomes (Klemperer 2002). Such efforts to collude are perhaps a larger risk in formats where bidder identities are known. It is also noteworthy that a series of similar single round auctions can provide similar opportunities for tacit collusion among bidders that hinders auction results (Klemperer 2002).

### **2.4.3 Constraints**

A third area of variation in auction design revolves around the constraints or objectives of the auctioneer buyer or seller. In this section, it is assumed that the auctioneer is a party to the transaction, rather than simply an impartial broker of transactions. As such, the auctioneer has the incentive to maximize revenues (or minimize costs in a procurement). If the buyer or seller of goods at auction is not the auctioneer, then additional questions about the appropriate role of the auctioneer are raised. That is, to what extent should the auctioneer's design prioritize client interests versus those of auction participants or society at large.

If constraints exist, there is a separate consideration of whether they should be disclosed. In the short run, withholding information can thwart efforts by bidders to extract information rents from the auction. However, in the long run, improvements in the information environment can provide signal to the market that may result in more efficient long-term resource allocation decisions (Stoneham et al. 2002).

Budget constraints typically take one of several forms. In a multi-unit auction, an overall budget cap in a reverse auction designates the total amount to be spent on purchases of winning bids. A reserve price is used to ensure a minimum or maximum price for the sale or purchase of a unit in an auction. Stoneham et al. (2002) point out that in the presence of a severe budget constraint, a reserve price may not be necessary. Unit targets for purchase or sale levels in an auction are another form of cap. These constraints serve the primary goal of guarding against undesirable auction outcomes. In so doing, they necessarily affect the auction results, and can thus affect bidding strategy as well.

### **Budget Caps**

An overall budget cap in a multi-unit reverse auction specifies the total amount to be spent on acquisitions. Under discriminatory pricing, this implies that all bids (below any reserve price) will be accepted in order from the lowest to the highest until the budget cap is met. If the budget constraint is known, participants may alter their bidding to maximize private outcomes in ways that drive up procurement costs. On the one hand, bidders may have an incentive to lower bids to ensure that they will not be rejected due to exceeding the cap. On the other hand, in an auction with few participants, absent a reserve price, disclosure of a budget constraint could encourage bidders to inflate their bids in order to exploit limited supply and large fixed demand.

An alternative approach is to either not disclose that there is a budget constraint or to disclose that a constraint exists, but not to specify at what level. In the former case, strategic bid shading should be minimized, though the auction may be perceived as less transparent, and in the event that the constraint is severely limiting, auction participants may feel taken advantage of. The latter option is advantageous, though in the public or non-profit context it may not be possible to guard the budget constraint in confidence. Alternatively, the auctioneer can disclose any budget cap on a strategic case by case basis. That is, in cases where the budget cap will not be constraining and thus might encourage inflation of bids, it could be kept secret, while it could be made public in other circumstances to encourage competitive bidding. This possibility requires some knowledge or estimate of how competitive the bidding is likely to be; transparency may require that the decision whether to disclose a budget constraint be taken before this knowledge is available.

### **Quantity Targets or Quota**

The second major type of financial constraint frequently found in auctions is unit caps. In the reverse auction context, this type of cap is defined as a maximum number of units the auctioneer will acquire. The implications of this type of cap for auction outcomes and bidding behavior are parallel to those of the budget cap. That is, disclosure that there is a unit cap may either encourage more competitive (lower) bids or inflated bids depending on how competitive the market is. The disclosure of the level of a unit-cap will allow the informed bidder to strategically increase the rents from their resource sale. On the other hand, announcing that a unit cap is in effect without specifying the level may reduce spurious bidding. As with the budget cap, the likely effect of disclosure will depend on the level of participant competition relative to the cap; if that auctioneer can determine that the target quantity will be obtained easily given the number of bidders, disclosure of a cap can be used to encourage competitive bidding.

## Reserve Prices

Reserve prices are widely used in both single and multi-unit auctions to guard against extremely low or high bids being accepted in regular and reverse auctions, respectively. Klemperer (2002) highlights the importance of specifying an appropriate reserve price by citing the example of mobile phone license auctions in Switzerland. In that case, the Swiss government set the reserve price at a small fraction of the expected reasonable revenue based on outcomes in other European countries. When the field of bidders shrank, eliminating the need to bid competitively, the bidders bid at very low levels with success thanks to the inadequate reserve price which failed to protect against such an adverse outcome, and the auction failed to generate the expected revenue.

Especially in thin markets for goods without well-established values, appropriate reserve prices are essential in avoiding embarrassing failure of an auction. In short, reserve prices should be set at levels that reflect an acceptable outcome to the auctioneer. Once the decision to use a reserve price is made, the question of whether to divulge its existence or level to market participants arises. The tradeoffs are similar to those involved in implementing a budget constraint. Disclosure of the reserve price alerts auction participants to the auctioneer's valuation of the object at auction. In a conventional auction, this can lead bidders to lower bids to that level, reducing the auctioneer's surplus gained when bidders reveal their true willingness to pay through competitive bidding. It should be noted that this outcome is not assured; if the market is competitive, the bids of others may play a larger role than the reserve price in determining bidding. At the same time, if participants know that a reserve price exists, they will have a reduced incentive to submit extreme bids that seek to exploit weak demand or poor auction design because there is some likelihood that the reserve price would preclude acceptance of such bids. Of course, determining an appropriate reserve price can be difficult, especially for goods whose market values are unknown.

### 2.4.4 Information Management

As is apparent from the previous discussion, sub-optimal auction outcomes often follow from failure of bidders to bid as they would in a competitive situation. For this reason, it is important that information disclosed to auction participants not serve to inform them that competition is weak. Klemperer (2002) describes several auctions of the public domain that ended embarrassingly after bidder learned that they did not need to bid competitively. The expectation of competitive conditions will lead to competitive bidding in a self-fulfilling prophecy. As such, the *perception* of competition is essential.

If participants believe that they need not bid their private values to succeed, then bid shading will follow predictably and the auctioneer's surplus will decrease. Such bid shading can be the result of collusion or other explicit manipulation of the auction, but just as often is the utility maximizing behavior of individual strategic bidders. Thus, regardless of the auction design chosen, careful attention to not revealing any information that could betray a lack of competitive conditions is essential.

## **2.4.5 Participation**

While informed design and information disclosure decisions can help to discourage bid shading or prevent it from ruining auction outcomes, true competition will render the above concerns moot. Indeed, Hailu and Thoyer (2005) find that the efficiency of outcomes increases significantly as the number of participants and attendant amount of competition increases from low levels. Above all else, the design of an auction that will attract enough participants to be competitive is of primary importance. Although careful attention to the issues described above can allow auctions to be successful absent robust competitive bidding, attracting large numbers of participants is crucial to avoiding problems from the outset. In addition, if an efficient outcome is defined as one in which water is allocated from the lowest value to the highest value uses, then the more participants the auction involves, the more likely it is that one with the highest private resource value will be among the bidders.

With this in mind, auctions can be designed in ways that will attract larger numbers of participants. Klemperer (2002) points out that participation in auctions is never costless, and that individuals will only choose to enter if they have some chance of success. Thus, lowering participation costs can improve outcomes by attracting more bidders. Klemperer (2002) cites the example of the 1991 U.K. sale of television franchises to illustrate this point. In that case, entry costs were very high given the requirement that participants submit a detailed programming plan prior to bidding. All potential bidders save the incumbent deemed their chances of success too slight to justify the cost, and faced with no competition, the incumbent won with a low bid.

Auction format can also play a role in shaping odds of bidder success. On this note, sealed-bid approaches which create the possibility of those with low private resource values winning can encourage participation by those who might sit out an English auction (Klemperer 2002). Successful auction design should be informed by ways to attract more bidders, and thereby to ensure more competitive bidding.

## **2.5 Auctions of Water Rights**

In the application of auction approaches in the context of water rights, several of the theoretical concerns mentioned above merit additional discussion. In particular, the role of informational asymmetry is prominent in the case of reallocation of thinly traded rights to new uses. Further complicating matters, heterogeneity of water rights by location and other parameters demands attention in auction design. Finally, simplicity of auction design and reliability/predictability of the auction outcome can be of large importance in the policy context; addressing these concerns may demand sacrifice of some efficiency.

### **2.5.1 Informational Asymmetry**

The role of informational asymmetry in emerging markets for water rights makes auction mechanisms particularly attractive. Stoneham et al. (2002) point out that if significant informational asymmetry exists, traditional methods of correcting market failures can be difficult to implement efficiently. For example, Pigouvian taxes used to manage externalities require some knowledge of resource values to be correctly gauged. However, because water markets are notoriously thin, market prices are not well defined. Saleth et al. (1991: 327) explain that “the

economic infeasibility of establishing elaborate conveyance systems between streams and disincentives caused by impaired rights... limit the geographic scope of water exchanges and result in a thin water market.”

Further, even if prices for limited transfers (for example, between irrigators in the same irrigation district) are known, the risk associated with transfers to new areas or uses imply that such prices may not be relevant. Stoneham et al. (2002) also point out that variation in soil quality, microclimates, and other farm-specific traits create information asymmetries even among agricultural users. Also, because most of the trade is expected to reallocate water from the agricultural to urban, environmental, and development use, informational asymmetries abound between the parties to most potential trades. That is, conservation buyers may not have accurate information about the value of water used in agriculture while farmer or ranchers often have little sense of the environmental or development value of their rights.

In this context, negotiating trades of water rights is challenging for several reasons. First, potential trades are difficult to identify because parties do not necessarily know with whom there is a high probability of reaping gains from trade. Second, limited information increases the risk that parties will come to a deal that does not reflect market prices (or which sets a problematic precedent for future market prices), and will thus be subject to criticism, political rancor, or embarrassment (Simon 1998; Cummings et al. 2004). Further, if competition is not robust, informational asymmetry can lead to opportunities for bid shading and the accrual of information rents. Auctions, by virtue of the fact that they can solicit bids from all potential trading partners, use competition between potential traders to maximize value to the auctioneer. Important in this process is that the auctioneer need not know the private values or the market values of water or the products in which water is a factor of production. A well-designed auction will yield the auctioneer the best price independent of knowledge or negotiating skill (Chan et al. 2002). In addition, implementation of an auction can provide valuable information on water market conditions. In turn, this price discovery can inform future transactions.

### **2.5.2 Heterogeneity of rights**

If larger numbers of bidders yield better auction outcomes, then other things being equal the heterogeneity of water rights will be a significant obstacle to auction design. Water rights vary greatly in terms of reliability, volume, and delivery cost. In the American West, variation in priority dates of rights means that in practice some have constant access to water while others rarely are served. In addition, water rights are variously defined in terms of duty, or volume of water per acre of irrigated land. Further, depending on whether the right is served by a well, direct diversion, or through an irrigation district, conveyance costs will vary.

In a multi-unit auction, bids are ranked for acceptance based on their attractiveness in terms of price. However, if there is heterogeneity in the rights being auctioned, then ranking bids becomes difficult. The most common way to address this potential problem is to limit the scope of the auction to only rights that are equivalent or that meet some minimum criteria. In practice, this can mean limiting eligible rights by location, water source, or some other parameter. This, in turn, will depress the numbers of auction participants, and thus raise other efficiency concerns because it will limit competition. Depending on administrative rules, thin markets may be exposed to manipulation by third party interference (Colby 2000). Given that smaller markets are

more vulnerable to bargaining-related distortions achieving a competitive result will depend on the size of the market (Saleth et al. 1991).

Another approach to this problem is to develop an index to rank heterogeneous bids. This is in practice difficult, and may expose auctions to inefficient outcomes if the indexing algorithm is known. An implementation of such a mechanism is discussed below in section 2.6.3 in the context of Australian biodiversity and land conservation contracts.

### **2.5.3 Simplicity**

As mentioned above, auctions and trade in water rights is a nascent phenomenon. In addition, trade may involve individuals with limited computational ability rather than sophisticated institutions. Further, allocation of and trade in water rights is frequently contentious and politically sensitive. Colby (2000) points out that reallocation of natural resources through market based mechanisms is often controversial because it is opposed by those economically dependant on lower value resource uses. Further, the impetus to trade is often created by changing regulatory conditions, resource exhaustion, or both

In this context, pragmatic concerns about the understandability of auction rules and the confidence in the general shape of auction outcomes merit attention (Cummings et al. 2004). At the same time, more complex auction approaches have been shown to increase efficiency in other settings (Cummings et al. 2004). Thus, policymakers and auctioneers potentially face a tradeoff between implementing an accessible auction design and maximizing gains from trade. Though little research has been possible in this area due to limited knowledge of the counterfactual, some laboratory experiments suggest that more complex designs hold promise. Fortunately, there is some variation in design among the few auctions that have been implemented to date, enabling limited comparison.

## **2.6 Historical Water and Natural Resource Auctions**

There are many examples of historical natural resource auctions. The federal government has widely used auctions to sell timber, energy, and other resources (Simon 1998). The USDA has used auction methodologies to distribute contracts under its Conservation Reserve Program (Chan et al. 2003). A reverse auction was used to acquire fishing boats in efforts to reduce capacity in the Pacific Groundfish fishery. More recently, auction methodologies have been used to obtain leased water for the Klamath Basin Water Bank and water users in Colorado (Water Strategist, 5/2006, 6/2006). The Washington State Department of Natural Resources sold a 1,370 acre-foot groundwater right for \$250/ acre-foot using an auction process, though the single (and successful) bid was submitted at the reserve price (Water Strategist 5/2006). Single water rights have even been auctioned on ebay (uswaternews.com). Private auctions of water rights are less common, though several isolated transactions have occurred.

A few examples of natural resource auctions merit specific examination for their relevance to the context of water resources. Several previous single-unit auctions of water rights have been implemented throughout the West, though they are of limited interest because they do not require the same design considerations to guard against collusion as multi-unit auctions. In Georgia, auctions were used to induce irrigators to suspend irrigation in the Flint River Basin in 2001 and

2002. The Edwards Aquifer Authority in Texas has also used auctions to reduce consumptive use in efforts to protect spring flows. Finally, a pilot program in Australia developed a methodology for conducting a multi-unit procurement auction of heterogeneous conservation contracts which has applicability in the context of water resources. These efforts are discussed below.

### **2.6.1 Georgia Irrigation Reduction Auctions**

In response to legislation requiring the use of an “auction-like process” to obtain agreements to suspend irrigation in the event of declared drought in Georgia’s Flint River Basin, irrigation reduction auctions were conducted in each of the 2001 and 2002 drought years (Petrie et al. 2004). Extensive laboratory experiments were used to inform auction design, and in 2001 the state Environmental Protection Division ultimately chose a multi-round, iterative approach (Cummings et al. 2004). In the auction, irrigators submitted bids for the per-acre price at which they were willing to suspend irrigation on all of the acres covered by a given permit. Discriminatory pricing was used in which each accepted bid would be paid the amount of the bid to suspend irrigation. While the acquisition budget was public knowledge, the target acreage for irrigation suspension was not disclosed in a deliberate effort to discourage bid shading. Participation was voluntary, but in the event that the auction failed to acquire agreements to suspend sufficient irrigation, the state had the authority to order involuntary suspension of irrigated acres, beginning with the most recently established rights. Clearly, this format implies that the participants faced different incentives depending on when their rights were established. Bidding behavior was not separately explored on this parameter (Petrie et al. 2004).

The 2001 auction featured multiple rounds of bidding, though the number of potential rounds was not determined in advance. After each round, bidders were informed whether their bid would be accepted if the auction were to end at that time. Bid revisions were permitted in each subsequent round, and rounds were to continue until either (1) the Environmental Protection Division Director ended the auction or (2) no further bid revisions were received.

The multi-round approach facilitated price discovery through participant learning in the nascent market. Bids typically declined across rounds as provisionally rejected bidders sought to submit more competitive bids. After 5 rounds of bidding, a total of 33,006 acres were withdrawn from irrigation at cost of \$135.70 per acre (Petrie et al. 2004).

In the 2002 auction, a different approach was used, partially to safeguard against bid shading resulting from learning from the 2001 auction. In particular, the threshold for accepted bids was radically raised in the final round of the 2001 auction, leading to fears that bidders in 2002 would not bid competitively in anticipation of a high reserve price in the last bidding iteration. Instead, the Environmental Protection Division instituted a sealed bid auction with a publicly known reserve price and a single round of bidding. Petrie et al. (2004) highlight the advantages that this auction procedure brought in terms of simplicity of administration. They also found that there was sufficient competition that the reserve price did not serve as a benchmark for bids, and in fact that average accepted offer price was lower in 2002 than in 2001. Unsurprisingly, individual bidders tended to reduce their bid level from 2001 to 2002 if their 2001 bids were above the reserve price, while low bidders in 2001 generally raised bids in what was presumably an effort to capture increased rents.

The 2001 and 2002 Flint River Basin irrigation reduction auctions provide a valuable case study in practical auction design. In particular, the 2001 auction's multi-round framework allowed more control over auction results as administrators could signal to bidders through the provisional acceptance or denial of bids. In contrast, the 2002 auction's single-round sealed bid approach was a successful follow-up effort, though price discovery and experience 2001 surely contributed to this result. In both years, participation numbers seem to have been sufficient to ensure a competitive outcome despite disclosure of program budgets and the reserve price. In 2001, 347 permits registered for the auction; in 2002, eligibility only increased. Petrie et al. (2004) assess bids in relation to crop prices and conclude that the auction led farmers to bid their true values to suspend irrigation.

### **2.6.2 Edwards Aquifer**

Reverse auctions have been used on several occasions to suspend irrigation in the Edwards Aquifer area near San Antonio, Texas. In 1997, the Edwards Aquifer Authority, the administrative body charged with protection and management of the aquifer, used a reverse auction to obtain temporary agreements from rightholders to suspend irrigation to some 10,000 acres in order to preserve spring flows. While this initial auction was at first opposed by irrigators, in the end, suspension of irrigation was more lucrative than renting farmland, and the acreage targets were obtained (Colby 2000).

In 2003, the San Antonio Water System used an online reverse auction to obtain permanent rights to pump 10,000 acre-feet of pumping rights to the capacity limited Edwards Aquifer. The auction featured a posted reserve price disclosing the maximum amount that the system was willing to pay for water. Bidders then could submit and revise online bids to sell rights. Nine bids were received, all at the reserve price (Eckhardt 2003). Although bids were not lowered through competition, the auction was considered a success.

The Edwards experience, though limited, is interesting for its use in the context of permanent water right sales. Further, it illustrates the potential for bids to cluster at a revealed reserve price. At the same time, given the low number of bidders, the public reserve price may have served to convey a price signal to interested sellers that helped to avoid failure of the auction to match buyers and sellers. Still, compared with true competitive market, it is likely that the sellers were able to reap some information rents. It also provides an example of a non-conservation application of a reverse auction to procure water for municipal use.

### **2.6.3 The Australian BushTender Trial**

The BushTender Trial was a pilot program using auctions to allocate biodiversity contracts in Victoria, Australia. Biodiversity contracts are agreements with landowners to take certain actions to preserve or enhance the conservation value of their land. Actions include fencing of streams, protection of wetland or forests, and suspension of farming or grazing, for example. In the program, a single-round, first-price, sealed-bid auction was used to purchase conservation contracts from landowners (Stoneham et al. 2004). The auction used discriminatory pricing and no reserve price. While this approach is fairly standard, the auction is of interest in the water resources context for its success in allocating heterogeneous goods using a first-price approach. Specifically, as discussed above in section 2.3.2, heterogeneity of water rights can impede

auction mechanisms. In this context, any successful effort to adapt auctions to heterogeneous goods is of clear interest.

In BushTender, auction administrators essentially developed a score with which to rank bid on a cost per unit basis. This “Biodiversity Benefits Index” was a function of two subcomponents measuring different aspects of a conservation proposal, the “Biodiversity Significance Score” and the “Habitat Services Score”. Using the index, it is straightforward to rank bids and determine which auction offers to accept. The approach is similar to the Environmental Benefits Index (“EBI”) currently used to rank bids in the USDA’s Conservation Reserve Program (Chan et al. 2003; Simon 1998).

While use of the index approach is straightforward, it raises several other interesting considerations. First, transaction costs clearly increase due to the need to assess each proposal in order to assign it a score. Second, there is the separate issue of whether to disclose the score to participants. On the one hand, knowledge of their score will help mitigate the enormous informational asymmetry that is present in the “market” for something as ephemeral as conservation contracts. At the same time, if a bidder learns that he has a high score (perhaps due to the presence of unique habitat or populations on his property), then he can use this information to raise his bid and extract information rents from the auction in great excess of his private resource value. In the end, BushTender chose to navigate this tradeoff by revealing only the Habitat Services Score to landowners, holding the Biodiversity Significance Score in confidence. Stoneham et al. (2004) also highlight the trade off between short term cost effectiveness gains from withholding information from participants and the long term potential benefits as knowledge of the conservation value of land spurs investment in habitat, potentially increasing the supply through the substitution effect (investment is shifted to conservation from other uses as the opportunity cost of other uses increases).

Clearly, the BushTender experience could be extended to water rights. The ability to rank water rights that vary in duty, rate, location, and reliability on a single scale would enable a conservation auction to be conducted on a wider scale. Increased competition could result in lower conservation costs and increased eligibility might provide access to ‘unique’ water rights that would not otherwise be obtainable through an auction framework. At the same time, implementing a ranking system is a difficult process that is perhaps doomed to be controversial and expensive if not subjective. This is made slightly less difficult by having a single buyer (auctioneer), precluding the need for consensus between institutional buyers on any ranking criteria. In a two-sided approach, such a process may prove impossible, as diverse buyers would likely not be able to agree to a single scale for the ranking of bids. Nonetheless, the BushTender trial provides a useful framework for applying auction tools in the natural resources context of heterogeneous commodities.

### **3. Ochoco Irrigation District Streamflow Restoration Auctions**

In 2003 and 2004, the DRC utilized procurement (“reverse”) auctions to acquire temporary instream transfers of water (“instream leases”) from Ochoco Irrigation District (“OID”) patrons for environmental restoration in the Crooked River. Following on the heels of a posted-offer approach to lease acquisition in 2002, the experience provides an opportunity to examine the functionality of the auction approach as it changes over time, and to contrast it with the posted-

offer methodology. While a complete program evaluation is not possible due to uncertainty about how the water market would have developed absent the use of auctions, a comparison of results year-to-year nonetheless provides a valuable case study.

### **3.1 Background/Prior Market Experience**

By 2003, the DRC had for several years run an annual program to acquire instream leases from irrigators in the Deschutes Basin. Though the program evolved over time, compensation was based on a posted-offer system in which a standing offer was made to all irrigators in a given district to pay them a fixed price for the temporary instream transfer of their water rights for the season. The 2001 program paid a fixed price per acre of water rights across all districts. This approach resulted in differing prices per acre-foot of water leased due to variation in the duty, or volume, of water per acre of water rights across irrigation districts. In 2002, the program was refined to pay a fixed price of \$7 per acre-foot of water right across all districts. Due to varying duties associated with water rights in different districts, this approach resulted in per acre offers from \$7 to \$39 per acre in different districts. Although this initial step towards price discrimination was successful in increasing the amount of water leased instream in 2002, program participation in the Ochoco Irrigation District was limited. There, rightholders were paid \$28 per acre (with a duty of 4 acre-feet per acre) to forego their right to irrigate and lease their water rights instream. At this price, a single water user participated, leasing a total of 114 acres.

In 2003, the posted-offer program methodology was replaced with a reverse auction for Ochoco Irrigation District. The posted-offer leasing program was retained in other local irrigation districts. An auction was appealing in the district for several reasons: (1) DRC staff recognized that the fixed price methodology was not successful in OID at current offer levels, (2) lack of knowledge of water values in OID, driven in part by a different composition of water users than in other districts made revision of a posted-offer approach an exercise in guesswork, and (3) district management was accepting of the auction as a way to provide additional value to irrigators. As described above, a reverse auction held the promise of enabling cost-effective water procurement even in the context of DRC's limited knowledge of OID patrons' private water values.

The Columbia Basin Water Transactions Program (CBWTP), in which the DRC participated as a local implementing agency, agreed to fund this novel approach as part of its funding for the DRC's leasing program. The CBWTP is a program promoting transactional approaches to streamflow restoration in the Columbia Basin. The CBWTP is funded by Bonneville Power Administration and managed by the National Fish and Wildlife Foundation out of its Portland office ([www.cbwtp.org](http://www.cbwtp.org)).

### **3.2 Methods**

After a brief literature review, a single-round sealed-bid discriminatory auction with reserve price was selected. This choice reflected several program priorities. First, the single-round auction had the advantage of simplicity, which was a priority given the unfamiliarity of all parties with auction allocation (and indeed market-based allocation) of water rights. Given the importance of avoiding misunderstandings in this first auction, a simple approach was deemed

essential. Further, the single-round has lower transaction costs than a multi-round approach. Methodology was the same in both the 2003 and 2004 Ochoco Irrigation District Auctions.

Timeliness was also central for the participants: the farmers and the DRC. For the farmers there existed a brief decision window between when water allocations for the year were set by the district and before operating loans and initial preparations for farming needed to be undertaken. An important concern for the DRC was the need to begin the instream leasing administrative paperwork for winning bids in time to have the water legally ‘protected’ by the beginning of the irrigation season. Under the posted-offer leasing program in 2001 and 2002, severe delays in the approval of leasing paperwork undercut the restoration benefit of the leases because legal protection of instream flows was not in effect at the beginning of the season in some cases. These factors suggested a logical period in late January or early February when the auction should be conducted.

Discriminatory pricing offered the appeal of simplicity and also the potential for lower acquisition costs given a low level of concern about collusion. Concerns about collusion were moderate due to the small sums involved and poor information environment (which made assessment of the level of competition difficult). In addition, it was felt that the use of reserve prices mitigated the liability related to potential collusive activity and the DRC chose to implement a reserve price to guard against losses to collusion or unexpectedly high bid values. Each year a budget was set, up to whose exhaustion all bids below the reserve price would be accepted from lowest to highest.

Bids were enumerated in terms of cost per acre of water rights leased. Because water rights in OID all have the same duty (volume) of water per acre of rights, ranking bids in terms of acres was valid. Further, bidding by the acre was practical, because although water rights in OID have a permitted duty of 4 acre-feet per acre, the actual allotment of water varies by year with hydrologic conditions. As a result, the DRC assumed the risk that the actual water allotment might diverge from pre-season expectations. In the auction, bidders had to decide on how many acres of land they would be willing to forego irrigation in order to formulate a bid. Importantly, lack of summer precipitation means that ceasing irrigation in the high desert of Central Oregon requires foregoing crop production on tracts whose water rights are leased. In this respect, the conditions in the OID auction were different from the Georgia irrigation suspension auction, where crop production is possible without irrigation.

It is noteworthy that while bidders were free to (and presumably did) bid to lease the water rights appurtenant to their land with the lowest production value, they were not able to bid to forego the use of some portion of water on lands that would be irrigated. In Oregon, water rights are defined in terms of rate, duty, and acres covered. As elsewhere in the West, irrigators are not permitted to spread their volume allotment (duty) over “new” non-permitted acres. In addition, state law precludes the leasing of a portion of the volume of water from acres that will still be irrigated. As such, the water rights to the acres that have the lowest marginal value can be leased, but the marginal water applied to acres cannot be leased. This hinders efficient reallocation of water rights, and precludes certain bidding schemes, such as those discussed by Hailu and Thoyer (2005).

The process (in 2003) was as follows. On January 29<sup>th</sup>, the DRC mailed bid packets to all 147 district patrons who owned at least 10 acres of water rights. Due to difficulties in accounting for extremely small water leases, participation was limited by the district to rightholders with at least 10 acres of water rights. Packets were sent in a district envelope and contained letters from the district and the DRC explaining the auction, a bid form, and a return stamped envelope addressed to the DRC. In the letters the DRC pledged to accept all bids up to a total of \$50,000 as long as the bids were below a reserve price per acre set at the sole discretion of the DRC. Auction bids had to be received by the DRC by 5pm on February 18, 2003, to be included in the auction. DRC pledged to notify bidders of bid acceptance or rejection by February 28, 2003. Although contact information was provided, no inquiries regarding the auction procedure were received.

As this was the first local auction of water rights and the DRC was serving as buyer and auctioneer, a transparent and fair process was of high importance. In order to ensure that participants (including participants in subsequent auctions) would trust that the DRC was not behaving strategically during the auction process, the reserve price was set by the DRC and mailed to the OID manager prior to the opening of the bids to avoid the appearance of post facto manipulation. The actual opening of bids and the reserve price letter were conducted at 9:00 am on February 19, 2003 at the Ochoco Irrigation District office in Prineville. In attendance were the OID Manager, two OID Board Members, DRC staff and a DRC Board Member. The DRC's certified public accountant attended the auction ceremony in order to witness and certify the results.

After the auction, DRC staff informed auction participants as to whether their bids were successful. For accepted bids, the DRC completed the necessary paperwork to effectuate the lease and coordinated collection of signatures and timely filing of the lease. A streamflow monitoring program was used to ensure that leased water was not diverted during the irrigation season.

In 2004 the same process was followed. The letter from the district to patrons reported on the results from the previous year's auction, including the DRC's reserve price and the acres leased.

### **3.3 2003 Results**

In 2003, DRC staff explored several ways of arriving at a reserve price in the context of limited information about the market. First, the price per acre foot of streamflow restoration (accounting for reliability of water rights leased) in Tumalo and Squaw Creek irrigation districts from the previous season was applied to expected restoration from the OID leases to calculate a reasonable price point for acquisition of restoration water in high-cost districts. This yielded a price of approximately \$30 per acre-foot. Second, academic studies of the potential for leasing water in the North Unit Irrigation District provided some basis for the expectation that water could be leased for \$25 per acre-foot in the basin (Stevens et al. 2000). Third, an analysis using the known and expected characteristics of OID to calculate the break-even point at which the DRC should be indifferent between purchasing a district water right and paying of the assessment, and leasing the water in perpetuity, was conducted. This analysis found that given low risk-free interest rates, \$25 per acre-foot was a reasonable amount to pay for a perpetually leased water right in OID relative to outright purchase at existing prices for in-district transfers (note that outright purchase was not necessarily a streamflow restoration option in 2003).

With a range from \$25 to \$30 per acre-foot and an expected average delivered duty of 3 acre-feet per acre (less than the 4 acre-foot per acre permitted duty), \$75 per acre was chosen as a conservative reserve price by the DRC. Although this price was somewhat arbitrary in the context of an unknown quantity of water to be potentially acquired, DRC staff deemed it a reasonable average price for acquisition of up to 2000 acre-feet of restoration leases (which would be the amount leased if the entire \$50,000 budget was expended).

The 2003 auction received 8 bids from 7 different parties to lease 616.7 acres of water rights instream. Bids ranged from \$29 to \$108.50 per acre, with an average bid of \$80 and a median bid of \$85. This resulted in the acceptance of 3 bids and the leasing of 196.9 acres of water instream. A total of 787 acre-feet of paper water rights were leased at a maximum rate of 2.365 cfs. The water was protected from the point of diversion downstream through the lower Crooked River to Lake Billy Chinook. The district allotment for the year was set at 3 acre-feet per acre yielding a ‘wet’ water lease of 591 acre-feet. The average cost of accepted bids was \$53.35 per acre, or approximately \$18 per acre-foot of wet water. The complete schedule of bids is presented below in Figure 1.

**Figure 1. 2003 Ochoco Irrigation District Auction Bids**

Bidder		Bid 2003 (Reserve Price \$75)				
ID	Acres	Total Bid	Per Acre Bid	Accepted	Buyer's Surplus	
1	40.6	\$ 1,189	\$ 29.00	✓	\$	1,868
2	6.3	\$ 315	\$ 50.00	✓	\$	158
3	150.0	\$ 9,000	\$ 60.00	✓	\$	2,250
4	81.9	\$ 6,920	\$ 84.50			
4	60.0	\$ 6,510	\$ 108.50			
5	90.0	\$ 7,650	\$ 85.00			
6	67.4	\$ 6,066	\$ 90.00			
7	120.5	\$ 11,990	\$ 99.50			
		<b>Average</b>				
<b>Total</b>	<b>616.7</b>	<b>\$ 49,640</b>	<b>\$ 80.49</b>		<b>\$</b>	<b>4,275</b>
<b>Total Accepted Bids</b>	<b>196.9</b>	<b>\$ 10,504</b>	<b>\$ 53.35</b>			
<b>Percentage of Bids Accepted</b>	<b>32%</b>	<b>21%</b>				

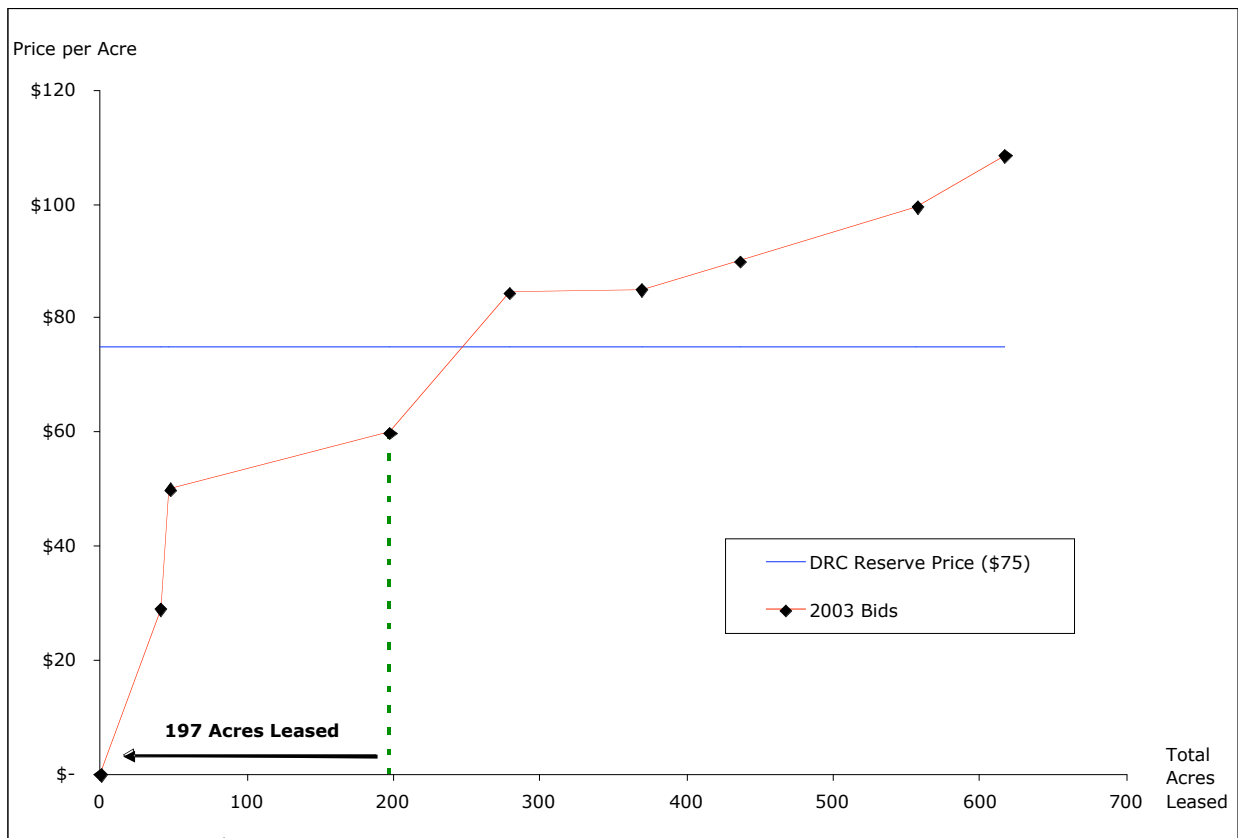
A simple examination of the bid schedule yields several preliminary insights. First, it is clear that the reserve price functioned to prevent the acceptance of several relatively expensive bids. Under the assumption that the reserve price was set equal to the conservation value of the water rights, the choice to use a reserve price was validated as the price avoided the acceptance of 5 high end bids above \$75. Under this same assumption, they buyer's surplus can be calculated for each bid by multiplying the number of acres sold by the difference between the reserve price and bid. The results suggest the auction yielded a total surplus to the DRC of \$4,275, or 41% of total lease expenditures in OID.

The wide variance in bids suggests significant heterogeneity in the private value of water rights. Wide variance in private resource values is plausible given the mixed land use in OID; in this auction, some participants were commercial farmers while others did not appear to actively use their water (bidder 1 leased water instream each year from 2002 to 2004). In general, the higher bids came from larger landowners who were likely engaged in commercial farming. This is consistent with the experience in the Georgia Irrigation reduction auction, where participants with rights to irrigate more land bid at higher levels than those with fewer acres. This may reflect

higher private resource values due to economies of scale in agricultural production (Petrie et al. 2004).

On the other hand, lower bids were primarily from small-scale hobby farmers or those who might not have used water rights absent the auction. Thus, the auction was successful by both standard measures; assuming that the bid schedule approximated private water values, social efficiency was realized by leasing water from rightholders with the lowest marginal use values. At the same time, the DRC was able to acquire water in a cost-effective manner by buying low on the supply curve. Auction results are depicted below in figure 2.

**Figure 2. 2003 OID Auction Bid Schedule, Reserve Price, and Total Acres Leased**



The reserve price of \$75 was slightly below the average bid value of \$80.49. As a result, the reserve price eliminated several bids. Several interpretations of this outcome present themselves. First, if all bids are taken as accurate representations of the value bidders placed on their water rights, then potential gains from trade are limited because resources are already allocated efficiently. In particular, assuming that the bids above the reserve price were submitted primarily by commercial farmers, then the value of water as a factor in agricultural production exceeded the DRC's willingness to pay for conservation water. This interpretation implies that the potential for market-based allocation of water to environmental use is limited.

An alternative hypothesis is that some of the bids or the reserve price did not reflect private resource values. One explanation for this could be loss aversion whereby rightholders were

reluctant to acknowledge the low value of their assets through low bids. Perhaps more likely is that it is the result of bid shading on the part of bidders or the DRC that backfired as an effort to gain rents and led to the loss of potential gains from trade. That is, auction participants may have bid higher than their actual valuation of the resource. In so doing, their bids exceeded the reserve price (which may in itself have been shaded downward, below the actual conservation value of the water) and no trade was consummated. As a result, any opportunity for gains from trade was lost. The submission of two bids at different levels by bidder 4 possibly reveals efforts to shade at least one bid upwards in order to take advantage of limited competition and accrue rents. Alternatively, the marginal value of water on the two tracts may differ.

The reality is that bid shading may be a rational response to uncertainty in an iterative game. To some extent both irrigators and the DRC knew that regardless of the mechanism, the DRC would be trying to lease water in OID in the future. Therefore, there was an incentive for the DRC to downplay their willingness-to-pay and for the irrigators to overstate their private resource values. That information asymmetries abound in water markets has already been explained. This information-poor, strategic behavior-rich environment then arguably manifested itself in the relatively high portion of bids rejected at levels just above the reserve price in the auction. Interestingly, this potential for initially high rejection rates for bids is one of the main arguments for a multi-round iterative auction. It is also one grounds for conducting practice auctions prior to the real bidding.

Although the DRC single-round auction did not allow for bid revision, the implementation of the auction using the same structure in 2004 provides an interesting opportunity to contrast the two years' results. Given that several bidders participated in both years, the repeated auction created opportunities for learning similar to those present between rounds of an iterative auction

### **3.4 2004 Results**

In 2004, the instream leasing auction in Ochoco Irrigation district was repeated with a few minor modifications. For the second year in a row, the DRC offered to spend up to \$50,000 to lease water for streamflow enhancement, accepting bids to sell from lowest to highest subject to a reserve price. Once again, letters were sent to all eligible district patrons explaining the program. The only difference in the 2004 auction for the farmers was that they were informed about the results of the first year's auction.

The DRC examined the 2003 auction results and the program goals for 2004 in choosing the reserve price. Staff noticed that in the 2003 auction an increase of \$15 in the reserve price would have doubled the quantity of water obtained. In addition, deeper snowpack in 2004 led to expectations that each acre leased would yield more water in 2004 than was available in 2003; thus, the DRC opted to set the reserve price at \$91 per acre.

In 2004, nine individuals submitted a total of 10 bids to lease a total of 642 acres of water rights. The average and median bids were \$67.20 and \$60 per acre respectively. Bids ranged from \$29 to \$85 per acre, so that all bids fell below the reserve price of \$91. Consequently, all bids were accepted and the DRC leased 642 acres instream. Due to ongoing revisions of the district water right maps, minor revisions to some bids were made, though the auction results were not significantly impacted. This level of leasing translates into a streamflow enhancement of 6 cubic

feet per second in the Lower Crooked River for the irrigation season. Total DRC buyer's surplus in the 2004 auction was \$15,286, or some 35% of the total lease expenditure in OID.

**Figure 3. 2004 Ochoco Irrigation District Auction Bids**

Bidder		Bid 2004 (Reserve Price \$91)				Alternative Buyer's Surplus (R.P.= \$75)		Buyer's Surplus	
ID	Acres	Total Bid	Per Acre Bid	Accepted					
1	40.6	\$ 1,177	\$ 29.00	✓	\$	1,868	\$	2,517	
2	105.4	\$ 6,324	\$ 60.00	✓	\$	1,581	\$	3,267	
3	150.0	\$ 9,000	\$ 60.00	✓	\$	2,250	\$	4,650	
4	35.3	\$ 2,085	\$ 59.00	✓	\$	565	\$	1,131	
4	41.6	\$ 3,075	\$ 74.00	✓	\$	42	\$	707	
5	40.0	\$ 3,000	\$ 75.00	✓	\$	-	\$	640	
8	11.0	\$ 385	\$ 35.00	✓	\$	440	\$	616	
9	32.4	\$ 2,430	\$ 75.00	✓	\$	-	\$	518	
10	24.9	\$ 1,992	\$ 80.00	✓	\$	-	\$	274	
11	161.0	\$ 13,685	\$ 85.00	✓	\$	-	\$	966	
		<b>Average</b>							
<b>Total</b>	<b>642.2</b>	<b>\$ 43,154</b>	<b>\$ 67.20</b>		<b>\$</b>	<b>6,746</b>	<b>\$</b>	<b>15,286</b>	
<b>Total Accepted Bids</b>	<b>642.2</b>	<b>\$ 43,154</b>	<b>\$ 67.20</b>						
<b>Percentage of Bids Accepted</b>	<b>100%</b>	<b>100%</b>							

Note: Bidder ID numbers are consistent between Figures 1 and 3 to facilitate evaluation of individual bidder behavior.

Clearly, the 2004 auction was successful in leasing more water than the 2003 auction, in which only 3 of 8 bids were accepted. This increase in auction trade was a result of the different bid functions and reserve prices between the two years, which themselves may have been influenced by other exogenous factors. While in 2003 the reserve price fell below the average bid, the higher 2004 reserve price at \$91 did not disqualify any bids. Further, bids were lower in 2004, probably reflecting learning on the part of repeat bidders.

**Figure 4. 2004 OID Auction Bid Schedule, Reserve Price, and Total Acres Leased**

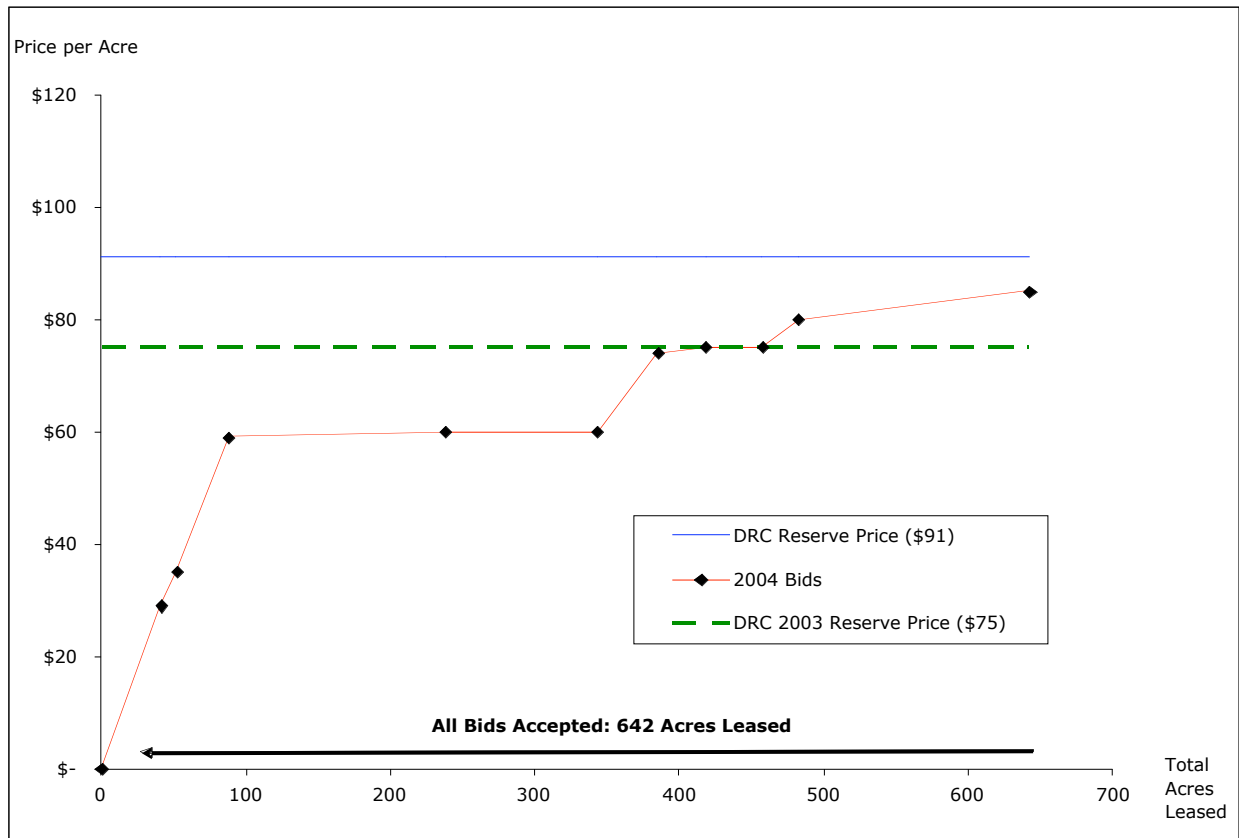


Figure 4 above depicts the 2004 OID auction results. The hypothesis that some 2004 bidders scaled their bids in a learning response to the 2003 reserve price is supported by the clustering of bids at the \$75 level. By setting their bids around the \$75 level, these bidders presumably sought to maximize rents while still guarding against bid disqualification by slotting bids below the expected value of the reserve price. Of course, the bidding environment did not remain static as the DRC reserve price was raised; as a result, bids above the 2003 reserve price were in the end accepted.

The strategic revision of bids based on the 2003 experience and learning in the emerging water market is further illuminated by examination of behavior by individual bidders.

**Figure 5. Participant Learning between the 2003 and 2004 OID Auctions**

Bidder ID	Auction Bids				Strategic Bid Revision 2003 to 2004	
	2003 Per Acre Bid	Accepted	2004 Per Acre Bid	Accepted	Present	Description
1	\$ 29.00	✓	\$ 29.00	✓		
2	\$ 50.00	✓	\$ 60.00	✓	✓	Increasing Rents, Bid Kept below 2003 Reserve
3	\$ 60.00	✓	\$ 60.00	✓		
4	\$ 84.50		\$ 59.00	✓	✓	Bid lowered to below 2003 Reserve Price; Hedging
4	\$ 108.50		\$ 74.00	✓	✓	Bid lowered to below 2003 Reserve Price; Hedging
5	\$ 85.00		\$ 75.00	✓	✓	Bid lowered to 2003 Reserve Price
6	\$ 90.00				n/a	
7	\$ 99.50				n/a	
8			\$ 35.00	✓	n/a	
9			\$ 75.00	✓	n/a	
10			\$ 80.00	✓	n/a	
11			\$ 85.00	✓	n/a	

Note: Bidder ID numbers are consistent between Figures 1, 3 and 5.

Figure 5 facilitates examination of bidder learning by tracing individual bidding behavior from the 2003 through the 2004 auction for the five bidders who participated in both years. Of the three 2003 bidders whose bids were accepted, two elected to leave their bids unchanged in 2004. Bidder 2 submitted a successful bid at \$50 in 2003 and revised his bid upwards to \$60 for 2004. Assuming private water use values remained the constant between the years, this revision allowed the bidder to increase rents to his water right lease. It is also noteworthy that the 2004 bid was not increased past the 2003 reserve price (in fact, the 2004 bid was well below the 2003 reserve price of \$75); thus, bidder 2's learning arguably reflected a conservative appetite for risk, perhaps resulting from a low private value for water right use. Farmers may face significant weather-related risk to productive use of their land, which may translate into willingness to bid at low levels for a guaranteed income from a parcel (Stoneham et al. 2002).

The fact that two of the three successful bidders from 2003 did not modify their bids in 2004 suggests that these bidders were pleased with their outcomes. At the same time, it does not support any general notion that bidding success makes one less likely to revise a bid in subsequent years. Besides being purely anecdotal, there is reason to think that these bidders had less information access than some other participants and were less actively engaged in managing their water rights. This conclusion is supported by knowledge of the bidder identities (they were not commercial farmers engaged in active use of their water rights, nor were they active in the irrigation district, whereas some other participants sat on the district board). Further, their initial lower bids suggest low private resource values; in this scenario it may be that the investment in learning and strategic bid revision was not worth the potential gain.

Of the two bidders (who submitted three bids) who were unsuccessful in 2003 and participated in the 2004 auction, both revised their bids in a manner consistent with learning and strategic bidding behavior. In particular, bidders 4 and 5 both submitted 2004 bids that were below the 2003 reserve price of \$75.

Bidder 4, who submitted two bids in each year, reduced his bids from \$84.50 and \$108.50 to \$59 and \$74 respectively. This bidding behavior reflects not only concern with exceeding the reserve price, but also strategic bidding in competition with other bids. Presumably, the bids falling just

below round bidding figures suggest a willingness to forfeit a potential \$1 per acre gain in order to increase chances of bid acceptance should the total bidding exceed the \$50,000 budget, necessitating the rejection of some bids that were below the reserve price. Finally, bidder 4 submits two bids, hedging against the risk of exceeding the reserve price by accepting lower rents on a portion of the leased water rights. As mentioned previously, this assumes like marginal utilities of water across land holdings.

Bidder 5 exhibits similar behavior in reducing a 2003 bid of \$85 to a 2004 bid of \$75. Assuming that underlying private resource values were approximately constant for this bidder, it seems that learning the 2003 reserve price helped this bidder to calibrate his 2004 bid at a level that maximized expected rents while still guarding against bid rejection through exceeding the reserve price.

The above discussion illuminates evidence of learning on the part of bidders between the 2003 and 2004 OID auctions. In short, many bidders exhibit behavior consistent with the use of information gleaned in 2003 to maximize their expected utilities in the 2004 auction. This is entirely consistent with expected behavior. At the same time, the difference in auction result in 2004 cannot be entirely attributable to changed bidder behavior. While bidder behavior in 2004 seems based on the expectation that other aspects of the auction would be approximately constant year to year, in reality this was not the case. If the supply function changed in 2004 due to strategic bid revision, then the other primary driver of the different auction outcome occurred on the demand side with the changing of the DRC reserve price. In addition, external factors including demand for agricultural products and hydrologic conditions doubtless informed 2004 bidding.

In a demand side analog to the bidders lowering bids to below the 2003 reserve price, the DRC raised the reserve price in 2004 to \$91, a figure that was above the average bid of \$80 in 2003. Further, \$91 is just above a stark increase in the marginal cost of water in the 2003 bid schedule (bids were submitted at \$90 and \$99.50), possibly revealing strategic behavior by the DRC in setting the reserve price. This combination of downward revision of auction bids coupled with a rise in reserve price resulted in a dramatic increase in acres leased, as no 2004 bids were disqualified by the reserve price. In fact, the total value of the accepted bids exceeded \$43,000, utilizing 86% of the available budget. In sum, learning from the 2003 auction experience shaped behavior on both supply and demand sides of the 2004 OID instream leasing auction. The results of this learning in terms of efficiency and gains from trade are discussed below.

### **3.5 Efficiency and Gains from Trade**

#### **3.5.1 2003 Auction**

As previously mentioned, information asymmetries resulting from a lack of previous market activity likely contributed to the failure of a large number of bids in the 2003 OID auction. As a result, the auction failed to maximize aggregate social utility through trade, assuming the failed bids were submitted somewhat above the bidders' private resource values, which fell below the \$75 reserve price. Given the evidence from downward revision of bids in the 2004 auction, this seems a reasonable assumption. If this were not the case, then there were no potential additional gains from trade in 2003.

Assuming that private water values were approximately constant between 2003 and 2004, the reduction of bids in 2004 to below \$75 suggests that the single-round auction in 2003 did not provide sufficient opportunity for price discovery, and thus failed to maximize gains from trade. Bidding behavior in 2004 suggests that had the bidders known the DRC's resource valuation (at the 2003 reserve price of \$75), bids would have been submitted below this level as they were in 2004.

This failure of a large number of bids has implications for allocational efficiency as well. While there is support for the idea that the water that was leased had the lowest marginal values of the water that was bid, the failure of bids discussed above suggests that some water was used in a lower value out-of-stream use instead of being leased. Again, the divergence between the private water value of the bidders and the bid as submitted (as evidenced by bid-revisions in 2004) made this social misallocation of resources possible. At the same time, it should be noted that the gap between the highest accepted bid (\$60) and the lowest rejected bid (\$84.50) is large, and it is likely that the private values of the leased water rights was lower than the private values of the failed bids. Note also that of the bids rejected in 2003, only one bidder submitted a bid below \$60 in the 2004 auction, further suggesting allocational efficiency.

Assuming some consistency in the difference between private resource values and bid levels across bidders, the three water rights that were leased in 2003 were plausibly the rights with the lowest private values. Thus, while socially optimal allocation would have required that more water be leased instream, the rights that were leased instream yielded the largest social benefit per acre because they were previously being employed in low-value out-of-stream uses. At the same time, the cost to the DRC was minimized through the discriminatory pricing auction design.

This gain from trade can be measured by comparing the bid prices (supply function) to the reserve price (constant demand function). As the demand function is constant, this entire difference is surplus accruing to the DRC. As depicted in figure 1, this surplus was \$4,275 for 2003.

### **3.5.2 2004 Auction**

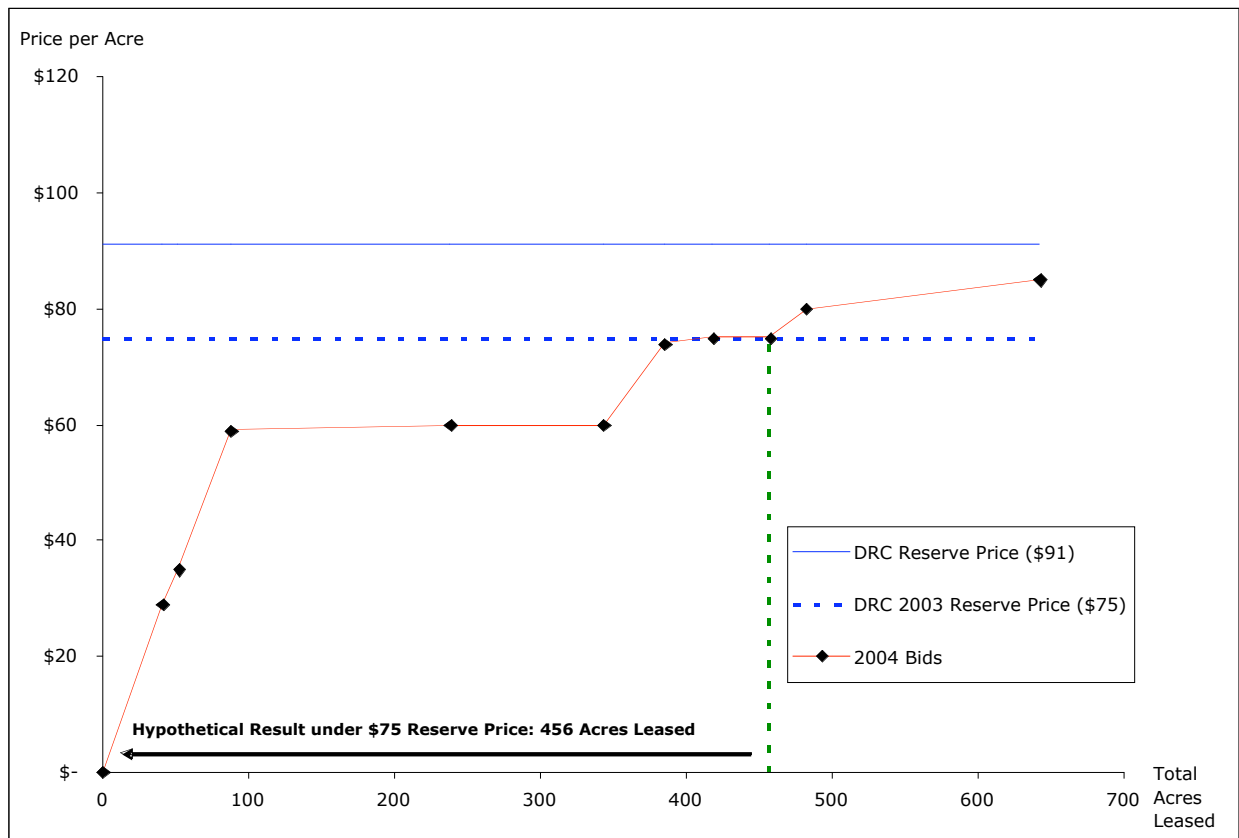
As described above, learning from the 2003 auction experience led to revision of both bids and the reserve price and ultimately more trade in the 2004 auction. The revision of bids and increased number of acres leased has diverse implications for allocational efficiency and surplus from trade.

First, bid revision based on learning from the 2003 auction had a multifaceted effect on the DRC's surplus. The downward revision of bids implies reduced seeking of information rents and a larger surplus for the DRC. That is, the 2003 reserve price functioned well as a signal of demand and led to bid revision that enabled gains from trade. On the other hand, assuming unchanged private resource values, bidder 2, who raised his bid from 2003 to 2004, was able to capture increased rents at direct cost to the DRC. Specifically, assuming an unchanged private resource value, bidder 2 garnered informational rents of \$10 per acre through upward revision of his bid in 2004. He also increased the number of acres bid for from 6.3 to 105.4, perhaps in expectation of this increase in rents. Figure 6 below provides a graphic illustration of the 2004

gains from trade and allows a comparison of the 2003 and 2004 results in the artificial scenario in which the reserve price was held constant over the two year period.

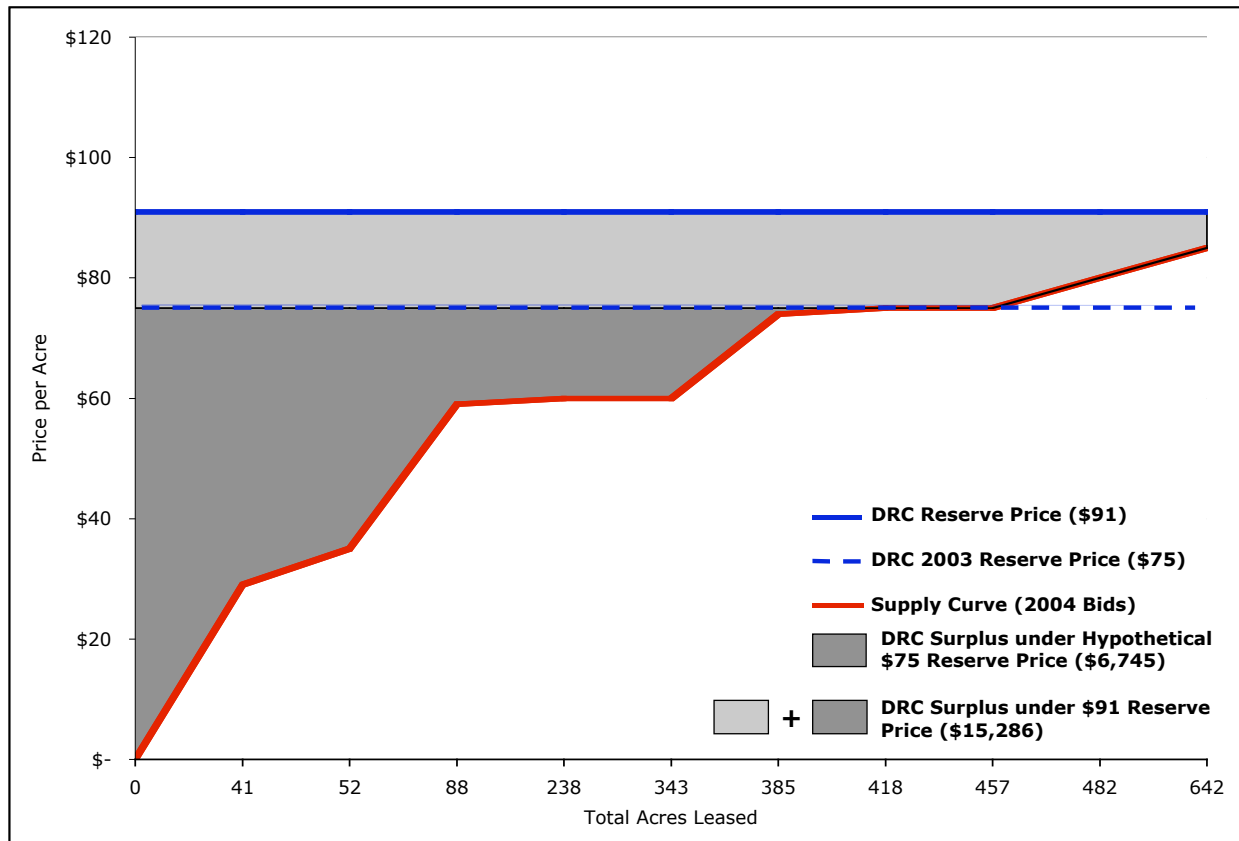
Figure 6 below illustrates that had the reserve price been held constant at \$75 in 2004, 456 acres would have been leased. This exercise allows us to assess the effect of bidder learning on gains from trade in 2004 in isolation from the change in reserve price. Under this scenario, the acreage leased would have increased 2.5 fold, and the DRC surplus associated with these leases would have been \$6,745, as compared with \$4,275 in 2003. Thus, it is clear that the exchange of information on market norms resulting from the 2003 was responsible for a significant component of the increase in success in the 2004 program. At the same time, the consumer surplus per acre decreased with additional leasing. This analysis assumes that the underlying valuations of water right holders did not change between 2003 and 2004, and that as a result all changes in bidding behavior were attributable to learning rather than some exogenous factor. By keeping reserve price constant and assuming no change in the DRC’s valuation of water used instream for environmental purposes, we are able to “difference out” changes in the surplus due to DRC strategic bidding and conclude that the additional \$2,470 in surplus in is the net effect of bidder learning between the two years. Under the admittedly ambitious assumption that external conditions remained constant between the two auctions, this amounts to a 57% increase in surplus attributable to bidder learning. Repetition of the auction led to improved results both in terms of social utility gains from trade and DRC surplus.

**Figure 6. 2004 Auction Results under Hypothetical \$75 Reserve Price**



This static analysis does not fully reflect the reality of the 2004 auction results. As we know, the actual reserve price was revised upwards from \$75 to \$91 in 2004, reflecting perhaps a reassessment of either the value of water for streamflow restoration or the seller's reserve price in light of modest success in leasing in 2002 and 2003. Under the \$91 reserve price, the DRC surplus is \$15,286, reflecting both gains from trade of bids that were accepted between \$75 and \$91 and recognition of increased surplus of \$16 per acre leased at bids below \$75. Surplus under each reserve price scenario and the actual 2004 bids is illustrated below in Figure 7.

**Figure 7. 2004 Auction Consumer Surplus under Different Reserve Prices**



### 3.6 Cost of Water

The experience with the 2003 and 2004 OID instream leasing auctions provides some insight into the cost structure of water obtained for streamflow restoration. Note that this information is not generalizable to other areas due to the extremely local nature of water markets. The analysis is conducted in terms of acres of water leased instream.

The average cost of water acquired was \$53.35 per acre of water rights in 2003 versus \$67.20 in 2004. As explained above, this discrepancy in average cost of water actually leased resulted from much less water being leased in 2003. Under a schedule of increasing marginal costs of water, as is intrinsic in a discriminatory multi-unit procurement auction, this result is expected. At the same time, the average cost of water for all bids in the auction actually declined from \$80.49 to \$67.20 between the two years as a result of the learning process and strategic bid reduction. The

average cost of water in the two years under a situation in which the reserve price was held constant at \$75 would have been \$53.35 versus \$58.38 in 2003 and 2004, though again for different total acreage leased. The marginal cost of water at the 2003 leasing level of 197 acres was \$60 per acre in both years. At the level of acquisition that would have resulted from keeping the reserve price constant in 2004 (456 acres at \$75), marginal costs would have been \$99.50 and \$75. Finally, the marginal cost of leasing the full 642 acres actually leased in 2004 would have been \$108.50 and \$85 in 2003 and 2004. This assumes that additional supply is available at the highest observed marginal cost in 2003. As expected, marginal costs are lower in 2004 for acquisition of large amounts of water, while cost differences are less discernable at lower rates of leasing. This is due to the downward revision of bids that were above the 2003 reserve price in the 2004 auction. It is possible that marginal costs would increase in another iteration of the auction as bidders seek to edge their bids closer to the last observed reserve price of \$91. Absent running an additional auction there is no way to test this hypothesis.

### **3.7 Summary and Enabling Conclusions**

The experience in Ochoco Irrigation District provides an interesting case study in the use of auction mechanisms to acquire temporary instream transfers of water rights for environmental restoration. Compared with previous posted-offer methods, the auction was successful at increasing the number of acres leased and ensuring low restoration costs. Initial informational asymmetry impeded trade in the first year of the auction; in this context, the use of a reserve price served to guard against high priced offers, encourage competitive bidding, and signal willingness to pay for restoration water. Participant learning informed bidding in the second year of the auction, leading to larger gains from trade and increased streamflow restoration. The improved outcome in 2004 highlights the importance of price discovery through repeated auctions in the information-poor environment of water markets, although it must be acknowledged that the benefits of price discovery and learning can be offset by bid-shading or other strategic behavior in repeated auctions with the same format. The experience in OID parallels the success that the Flint River Auction in Georgia enjoyed under its multi-round approach. The results suggest that similar learning and improved outcomes can be produced through repetition of single-round auctions over multiple years.

Several tentative conclusions can be drawn from this experience. First, it is possible to use auction methodologies successfully in thin water markets. Second, repetition of an auction allows for improved outcomes through both participant and auctioneer learning. Third, auction design should incorporate reserve prices or other features to guard against undesirable outcomes. Finally, supply of water available for acquisition exhibits an increasing marginal cost schedule as expected, though there is some expectation that the use of reserve price will lead to flattening of the curve over time. It is clear that well-crafted auctions are a valuable tool in market-based streamflow restoration efforts, even on a localized scale.

## **4. 2004 Groundwater Mitigation Credit Auction**

### **4.1 Groundwater Mitigation**

In response to recognition that there is a dynamic connection between groundwater and surface water flows in a large portion of the Upper Deschutes River basin, the Oregon Water Resources

Commission, after a lengthy public process, adopted a set of rules whereby new water rights could be established. Under the rules, a moratorium on new groundwater development was lifted and new water right applications could be granted provided applicants obtained offsets to ‘mitigate’ the impact of new well use on existing surface water rights, including instream water rights.

The rules establish a system of offset units, called ‘mitigation credits’, which must be obtained in sufficient quantity to fulfill an administratively determined ‘mitigation obligation’ proportionate to the impact of the new water development. A mitigation credit is a means of accounting for water that is consumptively used and is measured volumetrically in acre-feet. For example, if a groundwater applicant wishes to irrigate one acre of land with a total seasonal volume of three acre-feet, OWRD has determined as a reference point that 1.8 acre-feet would be lost to evapotranspiration. In this case, the applicants’ mitigation obligation would be 1.8 mitigation credits. In addition, mitigation credits are accrued and consumed in specific Zones of Impact, or sub-basins in which groundwater withdrawal has shown a localized effect on aquifer levels.

Permanent mitigation credits can be created through either permanent retirement of an existing groundwater right in the impact zone or instream transfer of a surface water right in or above the impact zone. Alternatively, temporary credits can be created through a series of annual instream leases in lieu of a permanent transfer. In all three scenarios, the Oregon Water Resources Department awards mitigation credits in proportion to the amount of discontinued use. Mitigation credits are fungible and the system was designed with the expectation that most new water users would obtain their required mitigation credits through purchase. The complete program is governed by Oregon Administrative Rules 690-505-0000 through 0630.

Temporary credits may only be acquired from a chartered mitigation bank and are created by an instream lease or a time-limited transfer. These credits must be renewed annually or replaced by permanent credits during the life the water right permit. Groundwater mitigation banks must be chartered by the OWRD. During the period covered here the DRC operated the sole chartered Groundwater Mitigation Bank, selling temporary credits established through its instream leasing program, though permanent credits could be obtained through other channels.

By 2004, a large backlog of demand for mitigation credits had developed. This was due to the accumulation of applications for new water rights that were subject to the mitigation rules for several years during the groundwater rulemaking and establishment of initial credits. In fact, even after the rules were adopted, additional time elapsed before the first mitigation credits were established. As a result, there were relatively few sellers and many buyers of credits during the initial years of the mitigation credit market. The market itself was composed of two de facto sub-markets. A number of buyers chose to purchase temporary credits from the DRC’s bank, in order to obtain a final order and expedite groundwater pumping on their property. Others chose to postpone their water use while pursuing the purchase of permanent mitigation credits.

During 2003 and 2004 a prima facie lawsuit against the mitigation rules brought by Waterwatch of Oregon and other protestants was in front of the State Supreme Court. There was therefore uncertainty regarding the future of the mitigation program. For those entities seeking to develop large groundwater rights, caution was generally the rule in moving permit applications forward. This legal uncertainty had different implications for different types of mitigation credits.

Holders of temporary credits were more exposed to any legal rejection of the rules because the mitigation of their impact was contingent on a series of future instream leases. Critics held that permanent water rights could not be offset by temporary transfers. Water users who had already established their groundwater permit using permanent mitigation credits were generally seen as less vulnerable to any rescission of the mitigation framework. As result, during 2004 then there was perhaps a premium associated with the few permanent credits available.

## **4.2 Auction Methodology**

In this context of ample demand and no established market for credits, sellers of mitigation credits face significant uncertainty as to the value of their assets. Consequently, bilateral negotiation entailed significant risk for both buyers and sellers, primarily as a result of informational asymmetries. Without knowledge of the value that applicants for new water rights put on those rights (and thus on the mitigation credits and other factors required to develop the rights), a seller risks failing to maximize resource rents by pricing the credits too low. In raising prices to avoid this, the seller risks pricing credits too high and precluding gains from trade. This risk is all the more severe given that new water development in the basin is often for uses unfamiliar to those who hold the water rights converted to credits. Credit developers may therefore have little sense of the value of water in these newer uses.

As described above in Section 2, an auction can be used to maximize seller revenue in such a situation without the seller knowing the values that prospective buyers place on the resource. Given this, the DRC proposed the use of an auction to sell mitigation credits on behalf of a client, Deschutes Irrigation, LLC that had acquired permanent credits from a seller of such credits. As a niche business aimed at providing full service to prospective groundwater clients, Deschutes Irrigation was motivated by the desire to increase local understanding of the program, to signal that some (even if limited numbers) of mitigation credits were available and to explore the private resource value held by groundwater applicants. They also of course wanted to find an effective way to sell the mitigation credits at the highest price.

As part of its efforts to develop local water markets, the DRC felt that given the dearth of previous market activity, the auction would prove a valuable source of information on the value of credits (and hence water rights) in this nascent market. The resulting offer of 36 mitigation credits by DRC on behalf of Deschutes Irrigation, LLC was the first-ever auction of credits

### **4.2.1 Auction Design**

To maximize value of the credits for the seller, the DRC proposed a first-price English (ascending-bid) auction. Under this approach, bidders submit open bids to purchase mitigation credits. Bidding information is public, and as auction participants learn of others' bids, they can in turn submit bids at higher levels. This process continues for a specified period of time designed to allow bidders to compete with others for the limited amount of credits. Rather than bringing all auction participants together in one physical space to participate in a live auction run by an auctioneer, the mitigation credit auction was conducted via phone, fax and the DRC website. Bids were submitted by phone or fax and then posted on the DRC's publicly available website in real time. The on-line approach has the advantage of being convenient for bidders and allowing time for measured reflection and revision of bids.

In conjunction with this approach the seller established a reserve price which must be exceeded for bids to be filled. The website informed participants in real time of the value and scale of all previous bids and whether the reserve price has been met. Bids were accepted from 7 am to 7 pm on the day of the auction. At auction close, the bid at the highest value was accepted, provided it exceeded the reserve price. If this bid was for fewer than the 36 mitigation credits for sale, then the second highest bid was evaluated on the same basis and potentially accepted for sale of the remaining credits. This process continued until either all credits were sold or no bids in excess of the reserve price remained to be evaluated. Winning bids paid the amount of their bid; that is, the auction used discriminatory pricing.

#### **4.2.2 Bidding Strategy and its Implications**

In theory, a single-unit English auction will induce participants to continue raising their bids until they reach their private resource values or win the auction. As a result, they are generally considered efficient, in that they allocate resources to those who value them the most highly. In addition, a sale to the bidder with the highest resource value who bids that value maximizes revenue for the seller. This result is notably different than the considerations in a multi-unit sealed bid auction. Namely, given the lack of knowledge of others' bids and the inability to revise bids, the sealed bid auction (such as the OID auctions described above) leave significant room for strategic bid shading. As a result, designers of sealed bid auctions face numerous tradeoffs in choosing protocols to maximize expected revenues and ensure a socially efficient outcome in the presence of bid shading. As we show in the analysis of the 2003 OID auction alone, reaching these goals can be difficult in thin markets where resource values are not well known.

In a single-unit English Auction, strategic bid shading is not an issue because bidding up to one's private resource value is the dominant strategy. As a result, design is much more straightforward. However, although based on an English design, the mitigation credit auction will not necessarily perform like a single-unit auction because bidders are permitted to bid on fewer than the full 36 available credits. If all of the bidders could be expected to bid for the full 36 available credits, then this would essentially be a single-unit auction. However, given actual mitigation obligations of participants, it is assured that some bidders will be bidding for less than 36 credits. As such, it is not strictly necessary that a participant submit the highest bid in order to be successful. If the highest (first-winning) bid leaves enough remaining credits to satisfy the second bidder's bid, then that bidder would profit by NOT bidding his full resource value, because doing so would only increase his cost. This is a Nash strategy in which the optimal action depends on the action of others. It is in contrast with the dominant strategy in a single-unit English auction, which is optimal regardless of the actions of other participants.

Revising a bid upwards above the current highest bid is only optimal if 1) it is necessary to preserve a chance of winning the auction and 2) the current highest bid is lower than the revising bidder's value for the resource. In a single-unit auction, the first condition is always met, and bidders should revise their bids upwards until they reach their private values of the resource. In the multi-unit context, this condition is not always met; revision of the bid may not be necessary to preserve the possibility of reaping gains from the auction trade, but it will reduce consumer surplus in the event of a winning bid. In this situation, the optimal strategy is a function of expectations concerning the scope of other bids. Moreover, for the auctioneer, it is not certain

that bidders will bid their true values; as a result, the auction may not maximize the value of the sale and socially efficient allocation is not ensured.

The above concern about revenue maximization is lessened by uncertainty regarding the universe of possible bidders. If the needs of all bidders are known, then bidders could reap information rents using the above-described strategy with reduced risk. However, if there is uncertainty regarding the possible existence of additional bidders who may be observing auction proceeds but have yet to place a bid (and thus have yet to reveal their strategic interest), then bidding one's true value may be optimal, and the auction may be efficient. Clearly, the degree that risk of a late entry bidder could thwart a bid shading scheme depends on the sophistication of bidders and the extent they can obtain knowledge about the universe of potential participants.

### **4.2.3 Bidders**

Participation in the mitigation credit auction was limited to those with groundwater permit applications and an identified mitigation obligation. Participants were allowed to bid only for the number of credits specified in their mitigation obligation. These requirements limited the auction to those with a bona fide prospective use of the credits. These participation rules were conceived in an effort to avoid speculation or hoarding in the thin market for permanent credits.

As of April 30, 2004, there were 47 pending ground water applications in the Deschutes Ground Water Study Area. In aggregate, these applications were for a rate of 157 cubic feet per second and an annual consumptive use of over 41,000 acre-feet of water. Individual applications ranged between 2.67 and 21,000 acre-feet of consumptive use. 24 permit applications were for 36 acre-feet of use or less, and therefore had the possibility for satisfying their entire mitigation obligation from the auction.

A list of those groundwater applicants that had received their Initial Review (and therefore had an established mitigation credit obligation) from the Oregon Water Resources Department was compiled by the DRC. A letter announcing the auction was sent to a total of 43 potential participants explaining the auction. Of these, 10 registered to participate in the auction, and 7, or 15%, actually submitted bids. Interested parties were required to register with the DRC prior to participating in the auction. Winning bids were subject to a \$250 administrative fee. In addition, the DRC charged the seller a commission equal to 5% of the value of the winning bids. Note that this incentive structure aligned broker and seller incentives to maximize the value of the credit sales.

## **4.3 Results**

The live on-line auction for mitigation credits was conducted on May 26, 2004. Bids were accepted from 7am to 7pm. Bidders submitted bid via either phone or fax to the DRC staff who then immediately updated the publicly accessible bid schedule on the web site. The confidential reserve price was \$2,500 per credit, and bidders were informed whether their bid had satisfied the reserve price. The evolution of the bidding is presented below in Figure 8.

**Figure 8. 2004 Mitigation Credit Auction Bids**

Time of Submission	Bidder ID	Price per Credit [1]	Number of Credits	Cumulative Credits Bid [2]	Partial Bid Acceptible	Reserve Price Met
18:26	1	\$ 2,600	4.4	4.4	✓	✓
17:58	2	\$ 2,500	10	14.4	✓	✓
16:59	1	\$ 2,200	4.4	14.4	✓	
15:09	2	\$ 2,000	10	14.4	✓	
14:56	3	\$ 1,800	8.4	22.8	✓	
13:33	1	\$ 1,400	4.4	22.8	✓	
12:38	4	\$ 500	3.6		✓	
10:55	5	\$ 278	36			
9:20	6	\$ 1,000	4.2		✓	
8:12	7	\$ 500	14.5		✓	

Notes

[1] Bids rounded to the nearest dollar.

[2] The total number of acres bid at the bid price or above. Not calculated for bids at \$1000 or less.

The chart shows that only the final two bids met the confidential reserve price of \$2,500. These bids, submitted by bidders 1 and 2, were for a cumulative 14.4 mitigation credits. The auction resulted in two sales, one of 4.4 credits at \$2,600 per credit for a total value of \$11,400 and the other of 10 credits at \$2,500 per credit for a total value of \$25,000.

### 4.3.1 Analysis of Bids

Auction participants can be separated into two groups based on their bidding behavior. One group, comprised of bidders 4, 5, 6 and 7, is characterized by low bidding and no evidence of strategic behavior. Another set of participants includes bidders 1, 2, and 3 and features bids at higher levels that demonstrate some strategic bidding. An analysis of the bidding follows below for each of the groups.

#### Group 1- Non-Strategic Bidders

The bids submitted by bidders 4, 5, 6, and 7 (found below the horizontal line in Figure 8) show no clear bidding strategy. They are not revised upwards in response to not meeting the reserve price or being surpassed by a subsequent bid. In fact, the bid submitted by bidders 4 and 5 are lower than previously submitted bids which did not meet the reserve price, and thus could have been determined to have no chance of acceptance prior to being placed. Although the intentions of the bidders are unknown, it is plausible that they simply decided in advance to submit a bid at a certain amount and did so without reference to the state of the bids as reflected on the website. As they also did not revise their bids, we can conclude that either they had already bid their maximum willingness to pay or they simply were not engaged in the auction. As a result, their bids had little influence on the final auction results.

#### Group 2 – Strategic Bidders

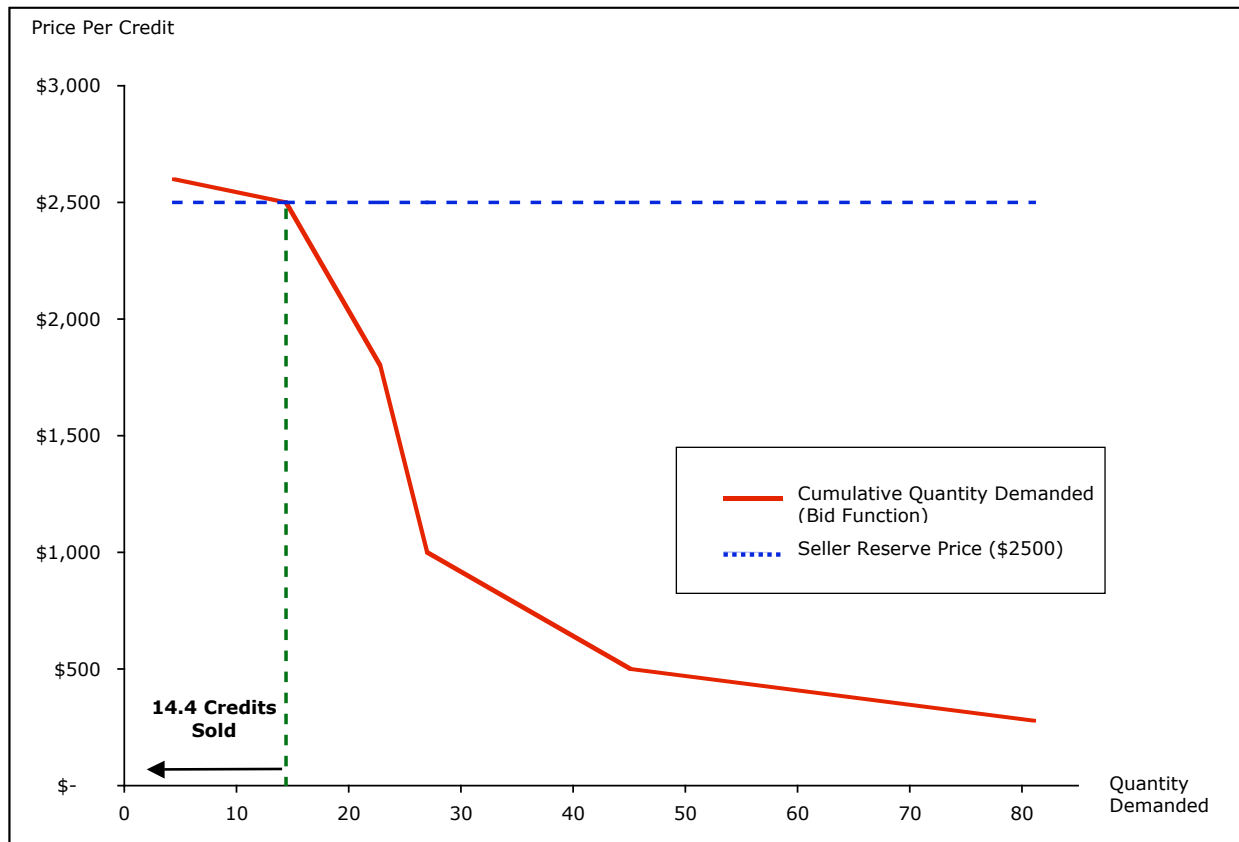
A second group including bidders 1, 2, and 3 exhibits at least some measure of competitive strategy in the placement of the bids. In total, these three participants submitted 6 bids at incrementally higher prices until the auction ended. Two of the three bidders revised prior bids in efforts to ensure that they would win the auction. It therefore appears that this group of bidders had consulted the web site for the status of the auction over the course of the day and that their bid revisions were informed by this information. In fact, the last four bids feature two bidders

leapfrogging each others offers until they had both submitted bids above the reserve price. In the end, these two bidders were successful.

Interestingly, bidders did not fully optimize their bids based on the available information. Specifically, it appears that concerns that bid shading might result from disclosing that the highest bid would not claim all of the available credits were in this case unfounded. Bidder 1, despite the opportunity, failed to exploit this design weakness, and thus failed to maximize information rents. The sub-optimality of his strategy is explained below.

Bidder 1's second bid was \$2,200 per credit for 4.4 credits. This bid did not meet the reserve price when placed, and therefore some upward revision was required for there to be a chance of the bid being accepted. Bidder 2 subsequently bid \$2,500 per credit for 10 credits. This offer met the reserve price, and this fact was disclosed, informing other bidders that the reserve price was at or below \$2,500. Note that at this point, a subsequent offer from bidder 1 only needed to meet a single condition in order to be accepted — it had to meet the reserve price. It was not necessary that the bid exceed the \$2,500 offered by bidder 2, because if bidder 2 were to win and purchase 10 credits, there would remain 26 credits to be allocated to lower bids that had also met the reserve price. In this situation, an optimal bidding strategy would have involved submission of a series of bids between \$2,200 and \$2,500 in order to feel out the reserve price. The lowest bid that met the reserve price would have maximized rents for bidder 1. If time or rules did not permit the submission of multiple bids as described above, then a bid of \$2,500 (or \$2,501 if equal bids were not allowed) would have given bidder 1 confidence that he had met the reserve price and would therefore be successful in the auction, even in the event that bidder 2 were to submit a subsequent bid (which itself would be sub-optimal in the same manner described above). Bidding a full \$100 above the last bid, as was the case with bidder 1's actual bid in this situation, increased costs while providing little benefit. One caveat to this statement is that if the bidder feared that large player might have submitted a last minute bid that would have obtained the entire lot of available credits, then bidding higher would have served to reduce this risk.

**Figure 9. Mitigation Credit Auction Bids vs. Reserve Price**



#### 4.4 Efficiency

The above discussion of bidding behavior allows us to make some tentative statements about the efficiency of the auction's results. Specifically, the lack of evidence of bid shading suggests that a socially efficient allocation of the mitigation credits, in which credits were allocated to those who valued them the most highly, was possible. At the same time, we should note that with only 7 of 47 groundwater applicants participating, it is unlikely that the price realized was at the market clearing level we would see in a more robust and competitive market. Additional marketing and direct mail efforts might have attracted more bidders to the auction, though it is possible that non-participants had low resource values and determined that their chances of winning were so low that the cost of participation was too high to justify participation. Further, given that the groundwater mitigation framework was under litigation at the time of the auction, risk-averse applicants with low resource values were conceivably inclined to await more clarity before pursuing a purchase of credits.

Nonetheless, from both a social and revenue generation perspective, the auction was able to effectively allocate the credits at relatively low transaction cost.

Specific analysis of the surplus created by the auction requires that we make assumptions about the client's valuation of the credits. If the assumption is made that the reserve price represents that value, the producer surplus from the auction sales was modest, at \$440 before transaction

costs. This represents the difference between reserve price and sale price times the number of credits sold at that price. Under this approach, only bidder 1's winning bid of \$2,600 generates a surplus equal to \$100 per credit or \$440. In addition, this implies that sales at the reserve price (such as the sale to bidder 2) produced no surplus for the seller and indeed were unprofitable once transaction costs were considered, which is clearly unlikely. This suggests that the actual cost of the credits sold was well below the reserve price, and that sales at the reserve price guaranteed some return to the seller. If we were to assume an (unsupported) 10% net return on sales at the reserve price, the total producer surplus of the auction would be \$3,490.

To continue the speculative backing out of the cost of credits, a 10% net (post transaction costs) return on sales at the reserve price would entail a resource cost of \$2,159 per credit. This is because the net proceeds after transaction costs (5%) of a sale at \$2,500 would be \$2,375, which represents a 10% return on \$2,159. Under these cost assumptions, the sale of 14.4 credits for a total revenue of \$36,400 that we observed in the auction implies a return of 11.23%, reflecting that 4.4 of the credits were sold at \$2,600 rather than the reserve price. Again, this analysis is exploratory only as the actual private return on sales of credits need not be 10%. In particular, given the thin market and lack of established market price, it is also possible that the reserve price reflects the expectation of a more outside return on investment.

#### **4.5 Conclusions**

Our analysis of the 2004 mitigation credit auction leads to several conclusions. First, the auction was successful in selling mitigation credits for more than the seller's reserve price at modest transaction cost. Though analysis of efficiency is limited by our knowledge of private resource values, the credits were allocated efficiently among those who participated in the auction.

The English auction design had some potential weaknesses which created the opportunity for bid shading. In future iterations, auctioneers could reduce this risk by selectively disclosing certain information. While efficient bid revision requires that bid per unit be made public, disclosure of the number of credits bid for is unnecessary and potentially counterproductive. This problem could also be mitigated by not disclosing the total number of mitigation credits for sale in the auction. Obviously non-disclosure of the number of credits available might limit participation in the auction because it increases risk for the participant and therefore might influence their cost-benefit analysis of whether incur the expense of participation (though the same can be said of having a confidential reserve price). An alternative would be to disclose that at least N credits were available, with N equal to some quantity that would meet the requirements of most potential participants. Even this may not be necessary, given that 6 of 7 participants in the auction were open to partial winning bids, meaning that they agreed to purchase a portion of the quantity of credits bid for at the price bid should supply be limited. Despite this, no evidence of bid shading is observable in the actual auction results.

Finally, in an information poor environment, the auction was effective in enabling learning about the value of mitigation credits. Although there have been few subsequent transactions, it is clear that some willingness to pay over \$2,500 per credit does exist. However, it is equally important that demand was insufficient to allocate all 36 credits at this price, suggesting a market clearing price at a somewhat lower level. For this reason, from the seller's perspective, the auction should be considered a success in capitalizing the value of some credits at a high level. It will be

interesting to observe subsequent transactions of mitigation credits as the market gravitates toward efficiency and increased liquidity.

## **5. Future Applications**

Analysis of the OID instream leasing auctions and the mitigation credit auction raises several interesting questions. On one level, the auctions seem to have been quite successful relative to previous efforts (whether bilateral negotiation or posted-offer approaches). They have the distinct advantage of harnessing competition to elicit information on private resource values. With this information, the auctioneer is then able to meet its goals at minimal cost through discriminatory pricing and the use of a reserve price. While this approach has clear merit for the auctioneer, it is less advantageous for the auction participants who must face competition without receiving the benefits of competition of others against the auctioneer. This is illustrated in the OID auctions where the DRC was able to essentially reap 100% of the surplus, although continued participant learning could facilitate bidder capture of more of the gains in future iterations.

### **5.1 Single versus Double Auctions**

In economic terminology, the single buyer framework seen in the OID auctions are similar to monopsony. In a classic monopsony, the demand is artificially limited to one buyer so that the market price falls short of the marginal benefit of consumption. In the mitigation credit auction, the dynamics resemble monopoly, in which supply is artificially limited to one seller so that the market price exceeds the marginal cost of production and a lower quantity is consumed. In the case of these auctions, true monopsony/monopoly power may not exist because the auction does not include all market participants, and therefore withholding of supply or demand does not necessarily change the market price. Nevertheless, Muller et al. (2002) find that use of market power persists even under a double-auction approach to emissions trading.

The auction framework employed in the DRC auctions, however, may serve to change the auction price and volume traded. That is, reserve prices are used to curtail demand or supply to levels that may be suboptimal. Analysis of the social efficiency implications of high reserve prices is only possible with additional information about other segments of the market. If there is robust demand from parties not participating in the market, then socially optimal allocation could be achieved by only selling to the highest auction bidders and selling the balance of available supply on the open market at like prices. Of course, unlike a classic monopoly situation, here there is no market price; transaction prices are determined by bids under the discriminatory pricing rule. Nonetheless, transactions only occur for offers that are the most advantageous for the auctioneer. For example, in the mitigation credit auction, selling the full 36 available credits would have required a lower price to clear the market. Rather, the seller simply sold fewer credits at a higher price. In some respects, a traditional single buyer/seller auction gives the auctioneer the option, expressed through the reserve price, to only effectuate transactions that meet their desired levels of profitability. As a result of this, transactions only occur along part of the demand or supply curve, and the auctioneer reaps most if not all of the consumer surplus. While this certainly is attractive from the auctioneer's perspective, it is less desirable for the bidders and fails to maximize efficiency through gains from trade.

The DRC experience in conducting both reverse (procurement) and traditional ascending bid auctions suggests a potential alternative approach. The two auctions could be married with submission of bids from both buyers and sellers that would function as demand and supply curves.

Ketcham, Smith, and Williams (1984) contrast posted-offer and double-auction pricing methods using a computerized simulation and find that prices are higher and efficiency lower under posted-offer approaches. To the extent that the single auctioneer with reserve price functions to some extent as a posted-offer mechanism in the DRC water right auctions discussed above, the double auction methodology discussed here may perform better in terms of efficiency. While more efficiency is preferable *ceteris paribus*, distribution of gains from trade may change, meaning that actual utility improvements for individual participants may not be uniform. This method could potentially be applied in many different water right contexts. Such an approach would have several attractive features. Of particular interest is that, in theory, if such an auction could attract sufficient participation to represent a competitive outcome, a market price (or at least a spread) could be established. This price discovery function could be invaluable in developing or thin water markets.

For participants, the presence of competition on both the supply and demand sides would reduce risk of the winner's curse that is present in the one-sided auctions. In a two-sided approach, a high willingness to pay would not necessarily lead to overpaying for a commodity because competition among suppliers would lead to a lower transaction price. From the buyer's perspective, multiple sellers would also drive down the price of supply (which are essentially their reserve prices), so a buyer could have increased confidence that they were paying something approaching market prices. In turn, they would then be more willing to bid their true resource values, which may have been previously shaded out of caution. Thus, the auction result would be more likely to reflect a socially efficient resource allocation.

On a broader level, a two-sided approach would produce a transaction price that was an approximate market price, assuming sufficient participation. This information would then be available to the market, and would serve as a reference point that would 1) potentially reduce speculative rents in other transactions and 2) facilitate informed decisions about water development needs. Absent a market price (or range) for mitigation credits, potential water developers must make decisions based on incomplete information. To the extent that their estimates differ from reality, they may make sub-optimal decisions as to the most efficient amount of water to demand. An added benefit in the Deschutes case would be that potential developers of mitigation credits would have some sense as to how to most efficiently do so. Finally, societal gains from trade would be maximized at competitive equilibrium price, though excess returns to the auctioneer would be reduced.

As described above, one of the most valuable aspects of the water auctions in the basin to date is the demand and supply information they provide. Competitive bidding is the key process that elicits this information. Efforts to create a two-sided approach must thus harness the power of competitive bidding in order to obtain the information necessary to establish a market clearing price. One potential approach to this market-design challenge is presented below.

## 5.2 Potential Double Auction Design

As with the two previously described auctions in the regional water market, homogeneity of the commodity traded is essential to the success of the allocation method. That is, while the approach described below is not restricted to a particular region, or type of water right, it is not robust to significant variation in the commodity traded. This is for several reasons. First, effective bidding is made difficult if there is uncertainty about the item up for bid. Further, competition on the supply side would be unfair if inferior water rights could be included along with those of superior priority, duty, or reliability

In the event of extreme heterogeneity in commodities, a series of one-sided single-unit auctions would be a better approach.

The importance of uniformity of the commodity being allocated makes this approach a natural fit in the Deschutes for mitigation credits in the general zone of impact. Alternatively, actual water rights could be allocated, though there would be a need to pre-certify the viability of all possible allocation outcomes. This might be accomplished by conducting a within-district auction limited to irrigation district patrons, conservation buyers, and those whose property is served by district conveyances. Finally, it is conceivable that some index could be used to rate diverse water rights on a common scale to facilitate bidding on a per unit basis. This would be possible only if the buyers could all agree on the indexing process; such as might be the case with conservation buyers or some other group with like interests. Note also that the administrative process of converting diverse conservation projects into mitigation credits essentially accomplishes this same indexing, creating a fungible ‘currency’ for water development

### 5.2.1 Bidding Procedure: Establishing Demand and Supply Functions

Bidding would be conducted in a manner similar to the leasing and mitigation credit auctions. However, in order to capture more information about demand and to maximize possibilities for trade, participants could submit a vector of bids to buy or sell different quantities of water at multiple pre-determined price points separated by a standard increment. In this way, participants are allowed to express varying marginal utilities of water. For example, a bidder might decide that if the price is \$500 per credit, they would like to irrigate a pasture, whereas at \$2,000 per credit, they would only want acquire rights to maintain a small green space and a few trees. The 2004 mitigation credit auction did not allow this in its bidding rules, but a vector of bids does. The suitability of this strategy in Oregon depends on the feasibility of partially perfecting a water right application under WRD rules, because if applicants are not able to mitigate their impact incrementally then demand for fewer mitigation credits than those required for their entire permit would effectively be zero.

Price intervals should be sufficient in number to approximately capture any individual’s demand curve, but not so many that participation is discouraged. Note that instead of bidding to buy or sell a specific item at a given price, participants express the quantity demanded or supplied at multiple prices. Examples of possible bids are depicted in the tables below.

**Figure 10. Individual Bids to Sell (Supply)**

Sale Price	Units Supplied by Bidder ID					Total Supply
	A	B	C	D	E	
\$ 100	0	0	1	0	0	1
\$ 200	0	0	2	0	0	2
\$ 300	0	0	3	0	0	3
\$ 400	0	0	4	0	0	4
\$ 500	0	0	5	2	0	7
\$ 600	3	0	6	4	5	18
\$ 700	4	0	7	5	10	26
\$ 800	5	0	8	7	13	33
\$ 900	5	0	9	7	15	36
\$ 1,000	5	10	10	7	15	47

**Figure 11. Individual Bids to Purchase (Demand)**

Sale Price	Units Demanded by Bidder ID					Total Demand
	F	G	H	I	J	
\$ 100	6	10	14	8	10	48
\$ 200	6	10	14	8	9	47
\$ 300	6	10	14	5	8	43
\$ 400	6	0	14	5	7	32
\$ 500	5	0	14	3	6	28
\$ 600	3	0	14	2	5	24
\$ 700	2	0	14	1	4	21
\$ 800	0	0	14	1	3	18
\$ 900	0	0	14	0	2	16
\$ 1,000	0	0	14	0	1	15

As these figures illustrate, the accepting a vector of bids from each participant will allow individuals with different supply or demand elasticities to bid more efficiently. Consider for example bidder B, who offers to sell 10 units at \$1000 each and no units at any other price. This behavior is similar to setting a \$1000 reserve price in a conventional auction, and expresses an infinite elasticity of supply between \$900 and \$1000. On the other hand, bidder H does not change quantity demanded with price over the relevant range, and this demonstrates extremely inelastic demand (elasticity of 0). Bidders C and I show more typical elasticities in their respective supply and demand.

### 5.2.2 Establishing the Market Price

Once the bid functions are submitted by both buyers and sellers, the aggregate supply and demand curves can be contrasted. As supported by theory and depicted below in figure 12 and in the graph of figure 13, as price rises, demand will decline and supply will increase until an equilibrium quantity and price point is approximately specified. Note that this approach differs somewhat from a typical *tâtonnement* approach to finding an equilibrium price. In particular, the method proposed requires only a single submission of bids, and is thus more practicable in thin markets. In order for this method to succeed, *the bid schedule must be a binding agreement to trade*, because non-binding bids would not reveal true demand but rather some option value. In contrast, a market manager in a *tâtonnement* process adjusts the price until he can match

tentatively expressed supply and demand. Only once this match occurs does trade occur. See Chan et al. (2003) for more details on this method of establishing market equilibrium price.

In the example, there is no single price *at which bids were taken* that precisely matches supply and demand. That is, at \$600 per unit demand outstrips supply, while the opposite situation ensues at \$700. Thus, the market clearing price can be assumed to fall somewhere between the price points where demand exceeds supply and supply exceeds demand, or between \$600 and \$700 in our example.

**Figure 12. Aggregate Bidding in the Example Two-Sided Auction**

Aggregate Bidding				
Sale Price	Units Demanded	Units Supplied	All Buyers Satisfied?	All Sellers Satisfied?
\$ 100	48	1		✓
\$ 200	47	2		✓
\$ 300	43	3		✓
\$ 400	32	4		✓
\$ 500	28	7		✓
\$ 600	24	18		✓
\$ 700	21	26	✓	
\$ 800	18	33	✓	
\$ 900	16	36	✓	
\$ 1,000	15	47	✓	

As the two rightmost columns in figure 12 illustrate, there is no single price that will clear the market perfectly. While this is an artifact of the specific bids schedules used in this example, in reality we can expect slight disequilibrium will be the rule rather than the exception, especially if discreet price points are used for bidding. It is thus important that a predetermined method be chosen to actually clear the market, even after bids are submitted. Ketcham et al. (1984) discuss a computerized trading system that allows bidder to respond to trade in random order in a double auction framework. In contrast, we opt for a more mediated approach. Four possible approaches are discussed below.

### Single Increment Spread

First, the market maker could accept all of the bids to sell units at \$600, and match them to 18 of the 21 bids to buy units at \$700. This would mean that only 86% of the demand at \$700 was met, and some method for choosing winners would be required. Possibilities include random lottery and priority by transaction size (in either direction). Further, if partial bids are not acceptable to all bidders, bidders could be chosen in such a way as to assemble demand for 18 units without subdividing bids. Regardless of the method for choosing the winners at this bid level, the market-maker would recoup a spread of \$100 (a single bidding increment) per unit sold. This approach is illustrated below in figure 13.

## Market-Maker Liquidity

Alternatively, if the market-maker had a private account, then it could provide either supply or demand to the market in order to ensure that all bids on either side of the spread were satisfied. In the example above, 3 additional units from the market-maker account would be sold to balance the supply of 18 at \$600 with the demand of 21 at \$700. Obviously this approach requires a market-maker that is willing to commit to transactions in advance; some compensation for this risk would likely need to be incorporated into any design. A similar situation occurs with specialist activity in stock exchanges. There, fees and commissions paid to the specialist provide compensation for the burden of providing liquidity to the market at the risk of trading unprofitably

## Large Spread

A third allocation method would be to accord the market-maker additional discretion to widen the spread. In some circumstances, widening the spread can perfectly match quantity demanded and supplied at two different prices, thus obviating the need for any lottery mechanism or additional liquidity. In the example above, units could be supplied to the market-maker at \$600 and then bought by participants at \$800. 18 units would trade hands and the spread would be 2 increments of \$100. While clearly generating more money per unit sold from the bigger spread, volume traded might fall (though it does not in our example), and fewer gains from trade would be made from a societal standpoint. Further, there is some doubt that participants would be willing to give the market-maker the leeway to widen the spread, as this might be perceived as unfair. Specifically, the wide spread approach transfers revenue to the market-maker while reducing the surplus available to participants (and society). In practice, this gives the market-maker an option to reduce levels of trade to garnish larger spread revenue which is a *post facto* version of discretion exercised by the auctioneer when setting the reserve price in a one-sided auction. Additionally, fear of the winner's curse in wide-spread transactions might lead to bid shading, which would hamper trade. This approach is illustrated below in figure 13.

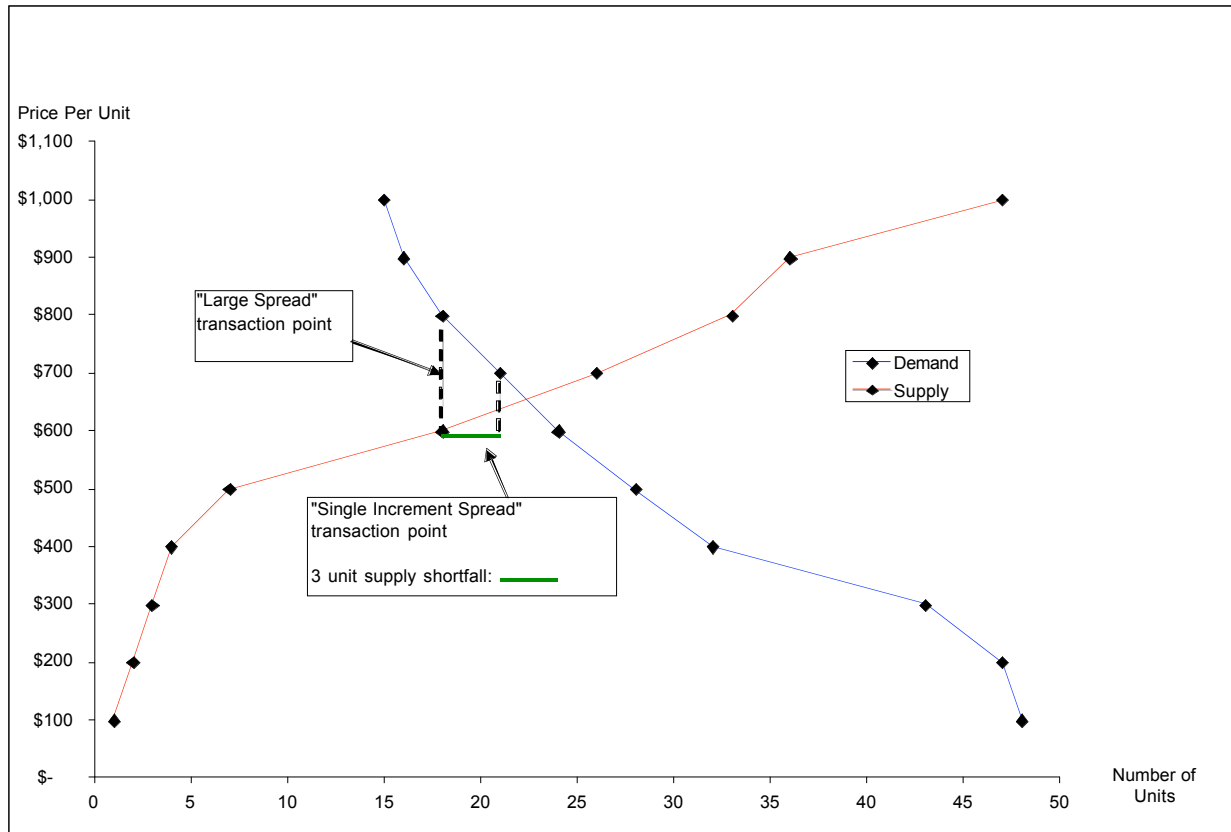
## Iterative Bidding

A final possibility for resolving slight imbalances around the equilibrium supply and demand involves using secondary process to reach the true equilibrium price. Depending on the number of participants on each side of the winning spread, the small imbalance in quantities supplied and demanded could be resolved using either informal negotiation or a second iteration of the bidding process with bids taken at increments within the spread. Note that the secondary process is only necessary on either the supply or demand side of the market. In our example, the 21 units demanded at \$700 needs to be reduced to 18 units demanded. Participants could express their demand for units at \$25 increments above \$700 until only 18 units are required. This process would widen the spread, probably producing a result similar to the wide-spread approach described above (unless demand functions changed or the curve was flat). Alternatively, a bidding process on the supply side could serve to determine how much more than \$600 would need to be paid per unit to ensure a sufficient supply of 21 units. This approach would narrow the spread and result in a larger quantity traded. In fact, this process could be conducted on both the supply and demand side of the auction simultaneously to approach the true equilibrium price.

Clearly, such an approach could pose practical problems by eliminating the spread as a revenue source while increasing administrative costs

It is noteworthy that while this approach can result in a higher quantity traded (and thus larger gains from trade and higher social efficiency), the two-step process would impose larger transaction costs on all involved. Potentially, the cumbersome process could discourage participation, hindering competition and offsetting efficiency gains.

**Figure 13. Two-Sided Auction Results and Market Price Establishment**



### 5.2.3 Covering Transaction Costs and Ensuring Environmental Benefit

Clearly, for it to make sense for the DRC or some other entity to coordinate the reallocation process under discussion, any efforts should fully cover transaction costs and ideally provide some environmental benefit. Because conservation benefits can take the form of either monies to be invested in conservation or actual water rights, it makes sense to examine the means to conservation ends in conjunction with covering allocation transaction costs.

#### Revenue Generation

Several options exist for the market-maker to receive funds from the allocation process. Any such funds can be used to both cover costs and invest in environmental restoration. First, to the extent that the market maker uses a spread in prices between purchases and sales in conducting trades, there will be revenue per unit sold equal to that spread. Wider spreads will generate more

revenue per unit, though reduced volume may result in lower absolute levels of revenue. Commissions could be levied on sales on a per unit or per transaction basis, and could be based on either a flat or percentage fee. In addition, a participation or registration fee could be charged prior to bidding in order to spread the administrative or conservation burden beyond the successful bidders. Perhaps ideally, a combination of these approaches could be used to insulate revenue generation from the vicissitudes of bidding behavior and auction results. A balance would also clearly have to be struck between revenue generation and the excess burden imposed by this tax on transactions.

### **Conservation Benefits**

In addition to potentially generating funds for conservation through some participation or transaction ‘tax’, the proposed two-sided allocation method could provide environmental benefits in other ways.

First, in the Deschutes, if mitigation credits were being allocated, then presumably diversionary surface water rights would be dedicated to instream use to generate the credits; though controversial, many feel that this transaction, while technically stream-flow neutral, provides ecosystem benefits. Under this logic, any effort to establish a more liquid market for mitigation credits has intrinsic environmental benefits.

Second, conservation buyers could use this market mechanism to acquire water rights or related mitigation credits for environmental use at low prices and transaction costs. Mitigation credits could be acquired and then held without being spent; this would be equivalent to financing the conservation actions underlying the credits without applying for the credits. Alternatively, credits could be used by conservation interests to enable groundwater – surface water source switches or other conservation actions

This result would be possible only if the two-sided methodology was able to attract sufficient participation to generate water prices below those seen in past transactions (including past auctions). In the Deschutes, given the DRC’s ability to use reserve prices and discriminatory pricing to acquire water in the past, it is not clear that the two-sided approach would provide a superior private outcome for the DRC or any other single player, despite the presumed social benefits from increased trade. At the same time, the two sided approach may be perceived as more equitable than discriminatory pricing approaches, and to the extent that this attracts additional supply to the market, conservation buyers could find themselves in a better position. This is also true if knowledge of a (presumably lower) competitive price can stem speculation that strains conservation budgets. In the end, whether a two-sided approach would be advantageous to a single conservation buyer is an open empirical question.

### **5.2.4 Other Considerations**

As any two-sided allocation method relies on competitive bidding from both buyers and sellers to reach an equilibrium market outcome, it is crucial that participation be robust on both sides of the procedure. In particular, insufficient participation could facilitate bid shading in efforts to reap excess returns. This is a specific risk if participants know or believe that they are one of few participants on their side of the bidding. Further, if there is robust competitive bidding on the

opposite side of the transaction, the likelihood of successful bid shading is heightened. This risk could be limited if the market-maker were able to participate in the procedure to balance supply and demand.

### **5.3 Summary**

This section described the potential of two-sided auction methodologies to allocate water rights and advanced a tentative auction methodology. The simultaneous use of bid (demand) and ask (supply) functions can be used to approximate a competitive equilibrium price; this should lead to increased gains from trade both through eliminating the market power of the auctioneer in a conventional auction and attracting participants with the promise of market prices. At the same time, the rents accruing to the auctioneer are reduced. Several potential methods for covering costs and enabling environmental restoration under the double-auction approach are available. Finally, as with all auction approaches, the key to successful implementation will be competitive bidding, which will in part be a function of attracting sufficient participants. In practice, this implies that a double-auction methodology is best suited to use allocating homogenous rights or mitigation credits for which there is presumably a relatively large market.

## **6. Conclusions**

Through examination of the results of multiple auctions of water rights in Oregon's Deschutes basin, this paper has illustrated both the promise and potential pitfalls of auctions as a tool in water allocation. When contrasted with posted-offer efforts, a reverse auction approach to acquisition of water rights for instream leasing in Ochoco Irrigation District produced superior outcomes. Learning from the initial auction results informed bidding in the second year of the program, allowing for still more gains from trade. An ascending-bid English auction to sell mitigation credits was also a success, though it failed to sell all of the available credits at the desired price level. In general, both of the auction types were well-crafted for the thin market conditions and potential lack of competition of emerging water markets. What few design liabilities existed were not exploited by strategic bidders.

Building on these efforts, a natural next step is to explore a double auction that holds promise of establishing a competitive equilibrium price. A tentative proposal for such a mechanism is presented and discussed in terms of design tradeoffs. A two-sided mechanism promises increased gains from trade but may reduce the surplus that has accrued to the auctioneer under the previous one-sided methods. Further, it is unclear whether a more efficient water market would yield increased environmental benefit relative to current approaches.

Finally, the key difficulty in actual and potential auctions is the limited ability to create competition among bidders. This problem arises from the naturally thin market conditions for a heterogeneous and extremely localized good such as water. Successful auctions will be those that can find ways to increase competition through higher levels of participation. As the market develops, we can expect less than perfect competition will be the rule rather than the exception; in this context auctions should be designed so as to be robust to imperfect competition.

Auctions have the potential to efficiently distribute resources and maximize value for the auctioneer, even absent any knowledge of participants' private resource values. As market

mechanisms are increasingly relied upon to reallocated water resources to emerging environmental and development needs, auctions have a key role to play. Although water has some intrinsic properties that make effective auction design challenging, careful consideration on the part of auctioneers can ensure successful outcomes.

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