Water Auction Design for Supply Reliability: Design, Implementation, and Evaluation

Michael O'Donnell, Research Assistant, and Dr. Bonnie Colby, Professor
The University of Arizona
Department of Agricultural and Resource Economics
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Please communicate comments and suggestions to Colby at:
bcolby@email.arizona.edu
520-730-5889

This guidebook is part of an ongoing series intended to assist public agencies, non-profit organizations, and the private sector with design and implementation of water acquisition programs to improve water supply reliability during drought and under climate change. While this guidebook addresses the use of auctions, others being developed will discuss water supply reliability contracts, regional water banks and other topics responsive to stakeholder interests in innovative acquisition programs.

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The purpose of this guidebook is to provide an overview of what steps are needed to create an effective water acquisition program using an auction, as well as to provide the reader with a concise menu of decision and evaluation criteria. This guidebook examines design and implementation factors, as well as the potential shortcomings of each proposed auction design.

Although water auctions have been used in the USA and abroad, they have their own unique

considerations and auction design needs to reflect the goals of the water acquisition program.

Considerations in Any Water Auction[1]

Water auctions can generally be described as a special type of auction called a procurement auction. In a conventional auction, several bidders attempt to purchase a particular item from a singular seller of the item (the auctioneer). In a procurement auction, however, several bidders compete to sell a particular item to one purchaser (the auctioneer).[2] Conventional auction principles can be applied to procurement auctions which fit a typical water acquisition scenario: one purchaser and many sellers (Hartwell 2007). It is also generally assumed that revenue equivalence exists amongst auction designs (Vickrey 1967; Milgrom 1989).[3] The building blocks of water auctions are described below.

First, it is important to determine who is eligible to participate in the auction. The auctioneer must determine whether geographical restrictions are necessary (Garrick 2008; Hartwell 2007). For instance, it may not be appropriate to allow out-of-state water entitlements[4] to be included in an auction. Further, it may also be advantageous to refine the geographic restrictions to those entitlements that can serve the goals of the particular auction, for example, if the entitlements are from within particular river basin(s) or regions.

Second, it is necessary to determine which entitlements, or what type of entitlements, will be included in the auction. For example, it may be advisable to only allow entitlement holders that actively use their water allotment and have a minimum entitlement amount to participate in an auction (Hartwell 2007). This requirement serves at least two purposes. First, if the entitlement holder is not actively utilizing her entitlement but the water is still auctioned, and potentially transferred out of the area, return flow patterns will be disrupted which may impact other downstream water entitlements and downstream ecosystems.[5] Second, by only allowing volumes of water that are above a minimum

[1] In any arrangement transferring water, the buyer and seller should proceed with caution. State and federal laws may limit either the volume of a proposed transfer or the location of transfer. Local laws should be consulted. For a state statutory example, *see* footnote 9, below.

[2] In a procurement auction, the auctioneer's objective is to obtain the resource at the lowest possible cost. Additionally, in a procurement auction, bidders are attempting to sell an item (or service) at the highest possible price. This is contrasted with a conventional (non-procurement) auction where the auctioneer's objective is to sell the item at the highest possible price and the bidder is attempting to buy the item (or service) at the lowest possible cost.

[3] Revenue equivalence implies that regardless of the specific auction design chosen, the dollar value of the winning bid is expected to be the same. To sustain this result, however, several assumptions are required. They are: independence of bidders' values, bidder risk neutrality, lack of bidder budget constraints and that all bidder values are drawn from the same distribution (Krishna 2002). These assumptions often are not satisfied in practice.

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

[5] If the purpose of the auction is to acquire wet water, it may be necessary to ensure that the auction is restricted to the most senior or "drought proof" types of entitlements in a region and to entitlements which have been regularly exercised.

threshold level, costs of administering the auction are contained.[6]

After a threshold level is set, it is necessary to determine how much of their entitlement the bidders can offer for auction. In some auctions, participants were required to place their entire entitlement amount (or consumptive use volume) in auction (Cummings 2003), while in other auctions participants were able to auction a portion of their entitlement amount (Hartwell 2007). An advantage of the full entitlement requirement is that it simplifies post-auction monitoring (Cummings 2003). Counterbalancing this, however, was that most of the participants owned more than one entitlement, so auctioning one (or more) entitlement would not severely handicap their agricultural activities. If post-auction monitoring is not problematic then allowing participants to auction portions of their entitlement may lead to preferable results.[7]

A related legal consideration is whether individuals may auction a volume based upon a permitted (or diversion) volume, or whether the auction should be designed to consider consumptive use amounts (Garrick 2007). In order to determine the volume that an entitlement-holder may transfer, it may be necessary to consider the type of right being transferred. For instance, if a water right is arising from an imported water supply, the State may not require return flows to be left in the river because absent the import of the water, the return flows would have not been available in the first place. Similar idiosyncratic issues may need to be considered on a case-by-case basis. This is particularly important in states that practice the doctrine of beneficial use because while the entitlement holder has ownership over the volume that she beneficially uses, in many cases she may only transfer a volume of water that she consumptively uses (*see*, Arizona Revised Statutes (A.R.S. 45-141(b)).[8,9] This is because downstream users benefit from the runoff, or unused portions by upstream users, and can claim legal injury if the return flow volumes that they have come to expect and beneficially use are not available (A.R.S 45-141). Because it is difficult to determine the exact volume that is consumptively used, it may be necessary to instead use a proxy in order to estimate the volume.[10] Regardless of the method chosen, it

[6] If the auction is designed to occur in several subsequent years, it may be necessary to require rotation of eligible participants to broaden overall participation. In addition, it may be useful to rotate the specific tracts of land on which irrigation is being foregone in order to minimize possible environmental impacts from continuously fallowing the same fields (IID 2007).

[7] This is based mainly on the assumption that individuals will be more likely to participate in an auction if they can determine what portion of their entitlement (or consumptive volume) they are willing to auction, rather than being required to auction an entire entitlement amount. As a result, a larger volume of water at a lower price per unit may be obtained.

[8] Although the doctrine of beneficial use is a well know water law concept and codified in statute, it can become complex as implemented across various jurisdictions. For an interesting discussion, see Neuman 1998.

[9] For instance, Section 1725 of the California Water Code reads in part: "A permittee or licensee may temporarily change the point of diversion, place of use, or purpose of use due to a transfer or exchange of water or water rights if the transfer would only involve the amount of water that would have been consumptively used or stored by the permittee…"

[10] It may be necessary to consult local laws and consider precedent in other water transfers to determine how the consumptive volume is determined. This is for two main reasons. First, in order for a valid transfer to occur, both parties must agree, and be clear, on the volume to be

must be clear to all participants exactly how the calculation is made.

In the case of a water auction, an additional consideration is what units of volume to use in conducting the auction. Both Hartwell (2007) and Cummings (2003) provide examples of actual auctions conducted on a basis of price per acre of land removed from production.[11] However, auctions could be conducted on a basis of acre-foot[12] or any other standard volumetric unit. What is critical, is selecting a quantity that is relatively easy to calculate and is well understood by the participants.

Another important consideration is whether to incorporate information technology into the auction design. Information technology can aid in streamlining many facets of the auction process including bid submission and data collection, and it facilitates communications between the bidders and auctioneers. Cummings (2003) provides an example of how bids can be submitted in several different locations but can be quickly compared as a result of using the internet. Hartwell (2007) explains how the Deschutes River Conservancy used a combination of fax machines and telephone calls to collect bids in an ascending bid groundwater auction and immediately posted those bids online. This method provided the bidders with instantaneous and up to date information so that they could revise and resubmit bids.[13] Bjornlund (2003) discusses how the internet is used in South Australian spot water market in an interactive manner for the same purpose. Rather than occurring once a year, however, the South Australian internet auctions are conducted weekly.

Despite these successful uses of information technology in facilitating the auction process, it is not used in every instance. Potential participants may not all have access and experience with using the technology (Hartwell 2007). If the auction is conducted entirely over the internet, but some participants do not have access to the internet or have misgivings with the technology, then there will be reduced participation. The level of information technology used must be considered and perhaps training administered for likely participants.

With water auctions, timing is important because the individuals most likely to participate in the transaction are farmers that need to plan participation based upon crop planting cycles (Jenkins 2007; Cummings 2003; Hartwell 2007). Because an important intermediate goal of any auction is robust

transferred. Second, there are often state and federal laws that restrict the volume that may be transferred. If these laws are violated, the agreement may be invalidated.

[11] Conducting auctions in terms of acres of land removed from production may only be practicably employed when the duty of all of the participants' water rights are nearly the same per acre of irrigated land. For instance, in the Deschutes River auction, the duty of all of the participants' water rights was 4 acre feet of water per acre of land. This allowed the participants to submit a bid based upon the amount of acreage they wished to take out of production rather than being required to submit a bid based upon acre-feet. *See*, Hartwell 2007.

[12] An acre-foot of water is defined as a volume of water that would cover one acre to a depth of one foot. http://www.merriam-webster.com/dictionary/acre-foot.

[13] Because bidders may be able to more effectively collude or bid shade with multiple rounds, care must be taken when using this type of iterated approach. Nevertheless, despite the risks, this type of auction design can bring about desired results (Cummings 2003; Bjornlund 2003).

participation, it is important to conduct the auction at a particular time that minimizes uncertainties created by the auction. The auction should be held early enough in the annual crop planting cycle so that the participants can plan their farming operations and leasing portfolio simultaneously.

At the conclusion of the auction, it is necessary to determine how and when winning bidders will be compensated. A simple method of compensation is to pay a lump sum amount to the winning bidders by a specified date.

Another, more complex, method is to pay the winning bidders in installments. For instance, in one water transaction, participants were paid in three installments: the first installment was paid within sixty days of entering into the agreement, the second installment was paid within six months of entering into the agreement but only after bidder compliance had been verified, and the third installment was paid once it had been determined that all of the provisions of the agreement had been met, and no later than sixty days from the contract termination date (IID 2004b). Various payment schedules and methods may be devised. These should be explicitly described in auction program information for potential participants.

Potential Water Transfer Complications

Before individual auction methods are examined, it is important to briefly enumerate the potential complications inherent in any transaction that moves water from one user and/or location to another. These include: a) the financial and environmental costs of moving the water from one place to another may exceed the benefits gained from trading water (Hartwell 2007); b) water rights can be difficult to measure or vague; c) geographical boundaries and legal restrictions may limit water-trading. For instance, state law may not permit interbasin transfers or interstate transfers (Hartwell, 2007; Garrick 2008); d) statutory protection and political considerations may require consideration of environmental or third parties impacts resulting from the transfer (Colby 2000; Hartwell 2007); e) there may be conveyance loss due to evaporation or seepage.[14]

Overview of Water Auction Design

Procurement auctions can be broken into three different types: ascending auctions, descending bid auctions, and sealed bid auctions (Hartwell 2007). In an ascending auction, the price starts at a relatively low level and begins to rise. The winner is the participant that is the first to stop the rising price of the item. This ensures that the bidder who wishes to sell the item at the lowest possible price is victorious.[15] In contrast, in a descending bid auction, the bid price starts at a relatively high level and begins to fall. In this scheme, bidders

[14] It is important to note that auction rules may be designed to mitigate the negative impacts of these potential complications in some cases. For instance, with respect to potential environmental or third party impacts a system of rotating eligible participants (or tracts of land) may be used. An alternative strategy may be employed whereby the auctioneer takes a predetermined percentage of the auction revenue and distributes that to the impacted parties and/or localities. The auctioneer needs to be aware of potential complications and must be creative in devising solutions when attempting to address them.

[15] Using the language of economics, this ensures that the participant that places the lowest value on the resource is selected and is able to sell the item at the lowest possible price.

compete to bid the price downwards until no participant wishes to challenge the preceding bid. The bidder with the lowest bid is the winner. In a sealed bid auction, the participants submit confidential bids, the bids are collected and the auctioneer chooses the lowest bid.

Sealed bid auctions offer a further complication because the winner of the auction may receive one of two prices (Hartwell, 2007). The first, and most obvious, price that the winner may receive is the amount that they submitted in their winning bid. The second is the winner receives the Vickrey price (Vickrey, 1961); that is, the price that was submitted by the second place bidder. The purpose of using the Vickrey price is that it is said to induce truthful bids on the part of the bidders by reducing the bidders' incentive to misstate their value for the resource; a Vickrey auction is used to minimize the possibility of bid shading by the participants.[16] Despite this expected advantage, Vickrey auctions are rare in practice (Rothkopf 1990).

[16] In a procurement auction, bid shading occurs when bidders submit bids that are higher than they privately value the resource.

Sealed Bid Multiple-Unit Procurement Water Auctions

The auction types above may be applied to a wide variety of auction designs. Modifications can be made to the generic types depending on what is being auctioned and the goal of the auction. In the case of a water auction, the overarching goal is often to acquire the maximum volume of water at the minimum price. Although there is generally only one purchaser of water, the purchaser may accept bids from more than one participant. Accordingly, water auctions generally take the form of a sealed-bid multiple-unit procurement auction (Hartwell 2007).

In a multi-unit auction, more than one unit of a resource is auctioned (Hartwell 2007; Rux 2008; Cummings 2003). In the case of a water auction, participants submit bids that contain different volumes of water and corresponding different prices per unit of water. The process is further complicated because water is not necessarily homogeneous. As a result, the auctioneer is required to compare disparate bids of a heterogeneous resource.[17] This difficulty may be alleviated through two main practices: a) requiring that the water entitlements offered for auction be as nearly homogenous as possible[18] and b) by

[17] Variability may exist due to different priority dates, location in a particular basin affecting conveyance costs, water quality, etc.

[18] For instance, in the Deschutes River Auction, the participants all had the same duty of water per acre and a relatively non-variable supply. Nevertheless, the auctioneer assumed the risk that water allotment may diverge from expectations (Hartwell 2007). Another practice that may be utilized is to only allow right-holders that own rights that were granted prior to a particular priority date to participate. Other methods for ensuring water homogeneity may be utilized.

using a sealed bid technique to conduct the auction.[19] Any other method/practice becomes unwieldy because of difficulties in comparing bids on a per unit basis.

Sealed bid multi-unit procurement auctions, like any other auction type, have their own unique complications. The first consideration is whether to create an auction that has a discriminatory price structure or a uniform price structure. A discriminatory price structure is one in which each winner receives the respective amount of the submitted/accepted bid. Whereas, a uniform price structure is one in which each winner receives the same price, regardless of the submitted bid: the auctioneer sets a maximum threshold for bid acceptability and each participant whose bid is less than this threshold is paid the maximum threshold price (Hartwell 2007).

While economic theory indicates revenue equivalence among auction designs (Vickrey 1961; Milgrom 1989), when economists have tested these theoretical results experimentally in the context of a hypothetical water auction, revenue equivalence has not been achieved (Tisdell, 2004). In particular, uniform price auctions tend to outperform discriminatory price auctions because bidders tend not to overstate their value for the resource as dramatically (Hailu, 2007).[20] Despite these experimental findings, both the Deschutes River Conservancy in Oregon and the Environmental Protection Division in Georgia utilized a sealed bid multi-unit procurement discriminatory auction to acquire water from appropriators. In both instances, the discriminatory method was chosen out of political concern; the water agencies believed that appropriators would be less likely to participate in an auction where every bid that was accepted was paid the same per unit amount rather than each bidder's true marginal value for water (Hartwell 2007; Cummings 2003).

Another important consideration is whether to conduct a single round auction or a multiple round (iterative) auction. In the case of a single round auction, each bidder submits a single bid and bids are either accepted or rejected at the conclusion of that one round. In an iterative auction, bids are collected and provisionally accepted or rejected. The bidders, even the bidders whose bids were provisionally accepted in the previous round, are then allowed to submit another round of bids and those new bids are again either provisionally accepted or rejected. This process continues for either a predetermined number of rounds, or until bidders are satisfied with the results and no longer wish to submit new bids (Cummings 2003).[21]

In general, the benefit to conducting a single round auction is that it is simpler both to administer and for the participants (Hartwell

[19] This facilitates a multi-unit auction because the auctioneer can more easily compare disparate bids by calculating a price per unit of resource acquired. Due to time constraints and impracticability, other auction methods are not amenable to this type of calculation.

[20] In computer simulations of markets with little participation, discriminatory auctions lead to extreme overbidding, whereas uniform pricing produces relatively more consistent and predictable results (Hailu 2005).

[21] If an iterative approach is used, an important consideration is how much and what type of information to provide to the participants between rounds. This consideration is discussed *infra*.

2007). However, the advantage of conducting an iterative auction is that in theory it will maximize participation and minimize procurement costs.

Regardless of whether discriminatory or uniform auctions are chosen and whether a single round or iterative rounds are used, it is also necessary to develop a decision rule that separates winners from losers. In a procurement auction, there are several ways to accomplish this. The first way is to set a cap on the price per unit that will be accepted by the auctioneer (Hartwell 2007). This cap is generally referred to as the reserve price. Under this scheme any bid that is below the reserve price is accepted and any bid above the reserve price is rejected. A potential problem is that the auctioneer is required to accept all bids regardless of the volume of water required or the budget for the program. This happened in the 1991 California Drought Bank (Howitt 1994; Israel and Lund 1995).

Another way to determine winners is based on a fixed maximum budget (Hartwell 2007). In a procurement auction, bids are ranked from lowest to highest and the auctioneer accepts the bids from lowest to highest until the budget cap is reached. Alternatively, a quota, or a maximum unit amount of water, may be fixed for the auctioneer to acquire. In practice, both a reserve price and a budget cap can be used to minimize the per-unit cost paid for water (Hartwell 2007; Cummings 2003). Using both a reserve price and a budget cap is generally preferable to using either method alone because it simultaneously minimizes the likelihood of overpayment per unit and it also ensures that the overall budget is not exceeded.

In a similar vein, it is important to consider the possibility of ties (Cummings 2003). To motivate this concern, consider a situation in which reserve price is set and a budget cap is set. Suppose that there are two equal bids which are below the reserve price, but the acceptance of both bids would place the auctioneer above the budget cap. The auctioneer needs some type of rule that governs such a situation. In the Georgia water auctions, the auctioneer set a rule that in the event of a tie, the winners would be randomly selected up until the point at which the budget cap is exceeded. Although it is not absolutely necessary for the winner to be chosen randomly it is likely the preferable method because it will reduce the likelihood that the participants will view the auction as unfair.

Tie breaking rules are important not only because of the pragmatic concern of choosing the winners, they also reduce the likelihood that the participants collude in an effort to subvert the auction. That is, if the participants know that the tied winners will be chosen at random when the budget cap is exceeded the incentive to collude will be minimized and competitive bidding is more likely to occur (Cummings 2003).

Another important consideration is the determination as to how much information to provide to the participants and what kind of information to provide to them (Hailu 2007). Information disclosure should be designed to build participant confidence in the process to maximize participation and simultaneously minimize the likelihood that participants

overstate their bids (Hartwell 2007; Cummings 2003; Garrick 2008). In any sealed-bid auction, the type of information that may be provided to the participants includes: whether a reserve price exists and, if so, the level of the reserve price, and whether a budget cap (or procurement quota) exists and the level of the cap or quota. If an iterative approach is utilized, the participants may be notified between rounds which bids are provisionally accepted or the price for which bids are provisionally accepted (Cummings, 2003). So that the participants perceive the auction to be fair, the participants should be informed in advance of how a tie breaking operates.

Determining the optimal amount of information to provide the participants is a delicate balancing act. On the one hand, by providing more information the auctioneer is creating an environment where the participants are more likely to feel comfortable with the auction process and thus more likely to participate. On the other hand, the more information that is provided to the participants, the greater their ability to submit collusive bids (such as all submitting the same price). In the case of the Deschutes River auctions, the auctioneer instructed the participants that a reserve price existed but they were not provided the amount of the reserve price (Hartwell 2007). In the subsequent year's auction, the participants were told that a new reserve price existed and they were informed as to the level of the prior year's reserve price. Hartwell (2007) concluded that the participants acted strategically based upon this disclosure of information in the second year because many of the submitted bids in the second year were near to the disclosed first year's reserve. The presence of a budget cap was also disclosed to the participants; however it is unclear whether the amount of the cap was disclosed (Hartwell 2007).

Participant trust is an important aspect of a successful water auction, and providing information to the participants may be a means of acquiring that trust, as is concluded in the Yakima River water auction (Rux 2008). In that instance, there was virtually no participation (only one bid received) and no water obtained by the auctioneer. A focus group was conducted to determine why the auction failed. The most common response was that eligible participants did not bid because they did not trust the auction process nor did they trust the auctioneer. Despite these findings, it is unclear exactly what information could have been provided to the potential bidders to remedy the lack of trust in this instance.

Photo Source: Bonnie Colby

Possible Modifications to the Typical Water Auction Design

Although most water auctions have historically taken the form of a typical sealed bid procurement auction, the auctioneer may elect to utilize a more sophisticated method. A more complex process may be used in an effort to minimize some of the potentially negative consequences, or complications, associated with using the typical auction design. Below is an explanation of benefits and costs of two such methods: the submission of complete supply schedules and an indexing scheme.

One possible variation to the standard procurement auction design is to allow the bidders to provide a bid schedule rather than one bid. (Hartwell 2007; Hailu 2007). In this method, bidders do not submit one bid with one price; rather, each bidder submits a bid that contains the different acceptable prices for various quantities of water. At low prices the volume of water offered is expected to be low, but as prices increase the volume of water offered by farmers is also expected to increase – much like a standard supply curve. This takes into consideration participants' different marginal values for water and allows for the proper alignment of incentives. In theory, this method would provide optimal results; however, as a practical matter it is a relatively difficult process to undertake. First of all, it is necessary to explain to each of the participants how the auction operates and to ensure the participants are comfortable with the auction design. Because this is a radically different from a typical auction it may be difficult to obtain the requisite trust.

Second, logistical considerations make this method relatively complicated. As a practical consideration, it is necessary to compare complete supply curves to determine the winners rather than simply comparing single bids. In doing so, the auctioneer will be able to accept portions of bids rather than having to accept or reject entire bids. Further, the auctioneer may be required to determine which final portions of bids to accept so that the budget cap is not exceeded but a maximum amount of the resource is acquired.[22] While economic theory indicates that results from this type of auction lead to cost effective water acquisition results, it is likely that difficulties would overwhelm the theoretical appeal.

Another possibility is to rank bids based upon a predetermined indexing scheme. Bryan (2005) explains that the index may take one of several forms including: the Environmental Benefits Index (EBI), Habitat Hectares Approach (HHA), a risk analysis method, or some other variation. The United States Department of Agriculture (USDA) sanctions the use of the EBI and enumerates criteria for ranking bids (Bryan 2005; USDA 1999). Under the EBI approach, an indexed value is calculated based upon six environmental

[22] There are four potential methods to cope with this scenario. However, the analysis is further refined to a double-sided auction, meaning that the bidders submit supply schedules while the auctioneer has a predetermined demand schedule. The analysis is only slightly more complicated under the scenario of a strict budget cap; nevertheless, the four methods are still the same: single increment spread, market-maker liquidity, large spread, and iterative bidding (Hartwell 2007, 39-44).

factors and one cost factor.[23] Bids are then ranked and compared.

In a HHA, characteristics of existing vegetation are compared against benchmark communities of mature stands in their natural undisturbed state (Bryan 2005; USDA 1999). In particular, aspects of vegetation in an area are scored and summed and are multiplied by the area of the site in order to calculate a magnitude of actions (Bryan 2005; Oliver 2003).[24] An index then may be created, as was the case of the Victorian Bush Tender trials, by multiplying the previously obtained score by a Biodiversity Significance Score. The Biodiversity Significance Score is a measure of the rarity of the ecological vegetation class. The result is then divided by the bid price to create a Biodiversity Benefits Index (Bryan 2005; USDA 1999).

Under a risk analysis framework, as was used in the Catchment Care Auction, a numeric value is obtained by calculating the environmental value of an area and determining the potential threat to that area (Bryan 2005). The risk of each site is calculated as the threat score multiplied by the respective environmental value score and summed over all threats (Bryan 2005).[25] Sites with the greatest environmental value and subject to the most serious threats are at highest risk. Participants then submit bids that outline a proposed method for reducing their respective environmental threat scores as well as a price for undertaking the action (Bryan 2005). Bids can then be indexed by using the following formula: benefit to be obtained multiplied by environmental value divided by the cost of the bid (Bryan 2005). This allows for a direct comparison of the bids in terms of an environmental benefit/cost ratio and allows the auctioneer to choose the bids that maximize this ratio.

A simplified comparison approach was utilized in the Edwards Aquifer region of Texas. In that example, irrigators were asked to submit bids based upon acres of land they were willing to fallow. (Colby and Pittenger 2006). Bids were evaluated based upon several criteria, including: crop types, irrigation system, commitment to dry land farming[26], and the bid price per acre. The Edwards Aquifer Authority favored fallowing lower valued crops to minimize local impacts and revenue losses to irrigators. In this example, bids were compared but no strict method of indexing was developed.

[23] To calculate the EBI, the following formula is used: EBI=N1+N2+N3+N4+N5+N6-N7 where the N's are equal to (with the following maximum number of points available): N1 is the wildlife factor (100 points), N2 is the water quality factor (100 points), N3 is the erosion factor (100 points), N4 is the enduring benefits factor (50 points), N5 is air quality benefits from reduced erosion (50 points), N6 is state or national conservation areas (25 points), N7 is cost factor. For a complete breakdown of how the points are awarded within each sub-category, see USDA (1999).

[24] "…[v]egetation assessed include physiognomy (e.g. presence of large trees, understorey), viability (i.e. presence of weeds, regeneration, litter, logs), and landscape context (e.g. area, shape, connectivity)." (Bryan 2005).

[25] "[The] environmental value of a site is derived from the site's Geomorphology, Hydrology and Remnant Vegetation characteristics. Sites may also be subject to specific threats. Threats are processes that degrade the biophysical environment including Bed Instability, Bank Instability, Dams and Offtakes, Patch Size, Invasive Weed Presence, Weed % Cover, and Grazing Pressure." (Bryan 2005).

[26] Clearly, this component of the index is only applicable to locations where non-irrigated farming is viable.

Although the above indexing methods apply mainly to auctions designed to improve environmental characteristics, they could be modified and used for other water auction purposes, such as supply reliability or reduced economic impacts. In the case of supply reliability, bids could be indexed by reliability characteristics of water sources. In the case of concern over local economic impacts, bids could be indexed based on crops grown or projected job and revenue losses.

Nevertheless, the cost and potential difficulty of undertaking a precise indexing approach, however, may be high. Specific criteria for the auction must be carefully designed in advance. This includes creating a set of goals to be achieved through the use of such an auction as well as creating a scoring algorithm. Also, the implementing organization must have staff competent to review water entitlements and to conduct a quantitative assessment. It is then necessary to conduct an analysis of the cost effectiveness of an individual bid and then rank all of the bids in order from most cost-effective to least cost-effective.

The most obvious potential benefit to this type of arrangement is that there is a simultaneous maximization of the auction purposes and a minimization of the cost. As a result, there is a common ground between those two interests and bids are accepted based upon what appears to be objectively reasonable. The drawback to this type of arrangement is that it is relatively difficult and expensive to administer. Land and water characteristics must be properly surveyed by an expert, risks must be calculated, and an analysis of those results must be undertaken. Nevertheless, on a situational basis, the benefits may outweigh the costs.

The second potential drawback is that the indexing process may not be viewed as fair and impartial. Despite the fact that algorithms may be used to calculate particular scores, staff or consultants will collect the original data, determine risk and potential benefits and input it into the algorithm. Landowners may not feel comfortable with participating in this type of arrangement and may object to intrusion on their land for surveying purposes as well as the indexing process.

Post Auction Compliance and Evaluation

After a water auction is conducted, it is necessary to implement a monitoring and enforcement scheme to ensure that winning bidders comply with the terms of the auction. Typically this involves ensuring that participants cease irrigation on the lands their winning bid obligates them to refrain from irrigating for the time period agreed upon in the

auction program. Because monitoring and enforcement of irrigation for specific land parcels can be costly, it is important to utilize tools appropriate for the given situation. Regardless of what tools are utilized, it is important to clearly specify what agency is responsible for monitoring compliance and how that compliance will be determined.

Several tools to enforce the terms of the auction may be available. For instance, in some situations locking irrigation gates may be appropriate (IID 2004). Another manner of ensuring compliance is to utilize remote sensing imagery to ensure that water is not being used on specific tracts of land. Remote sensing imagery can distinguish whether land is being actively irrigated in many arid areas. A common manner of enforcement, however, may be to have enforcement staff drive through and inspect parcels that are no longer supposed to be irrigated.

Although water auctions are being used more frequently they are not commonplace. Consequently, it is important to evaluate auction performance so that design and implementation can be improved (*see*, Hartwell 2007; Cummings 2003; Garrick 2008; Bryan 2005; Rux 2008). To facilitate the evaluation, it is important to have specific goals beforehand against which the success of the auction can be assessed. Success can be determined in a variety of ways.

For instance, in the Georgia auctions, because the desired volume of water was acquired, the auction was declared successful. Nevertheless, when the results of the auction were analyzed, Cummings (2003) determined that the same volume of water could have been acquired in a more cost-effective manner. Another criterion could be used for evaluation; such as minimizing the total amount of money spent to acquire the resource (Hailu 2007). This criterion, however, seems to suffer from the same shortcoming as above in the sense that it does not appear to capture the true goal of a typical water auction – maximization of resource obtained while minimizing procurement cost (Garrick 2008; Bryan 2005).

An auction may seek to maximize benefit per dollar spent, with success based upon maximizing the benefit-cost ratio (Hailu 2007; Bryan 2005).[27] In practice, however, it is difficult to design and implement a simultaneous maximization and minimization auction. Therefore, it is advisable to create several criteria that operate as a proxy for evaluating success. Table 1, below, provides a general list of criteria that may be used individually or simultaneously to evaluate auction success, along with an explanation of the appropriate metric and how the metric may be calculated.

Summary

Auctions are one potentially valuable tool for acquiring water supplies as part of an overall strategy to cope with drought and adapt to climate change. This guidebook is part of an ongoing series intended to assist public agencies, non-profit organizations and the private sector with design and implementation of water acquisition programs to improve water

[27] In an auction that does not utilize an indexing method, this assumes that the volume of water obtained by the auctioneer is directly proportional to the environmental benefit.

supply reliability during drought and under climate change.

Table 1: Water Auction Evaluation Criteria

Type of Criteria	Explanation of the Metric
Total volume of water obtained	A goal in a water auction may be to maximize the volume of water obtained within a budget constraint. To calculate the total volume obtained, sum the volume of each accepted bid and compare against a predetermined target volume of water. Success may be judged by how close the acquired volume is to the target volume.
Total amount of money spent to procure water (inclusive of auction administration costs)	Generally a goal in any procurement auction is to minimize the money outlay to acquire the resource; or alternatively, to stay within a specified budget. The total amount of money spent may be determined by summing the money spent on each accepted bid. Success may be determined by not exceeding a predetermined budget. However, in order to achieve other auction goals, it is necessary to spend at least a minimum amount of money; therefore, it may be appropriate to set a budget range to judge success.
Average price paid per unit of water, to sellers and/or lessees	This metric focuses on the price paid per unit of water to sellers and/or lessees. To calculate, sum the payments for water to sellers and lessees, and divide by the volume of water obtained. The average price paid per unit of water can be compared against a predetermined target or against indicators of water's value. It is often compared with measures of water's economic value in regional agriculture. Success may be determined by whether the price paid is "high" compared with other measures of value, or high compared to a target.
Cost of administering the auction	The goal of a procurement auction is to acquire a resource at the lowest possible cost; however, this does not necessarily consider the cost to design, implement, monitor and evaluate the auction. Therefore, in order to determine auction success the cost element could include auction administration costs. In order to determine whether the auction itself was conducted in a successful manner, with respect to auction administration costs, sum the administration costs and compare the actual costs against a predetermined target.
Participation	In order for any auction to be successful, participation is crucial. The total number of participants may be compared against a target level of participation, or as a proportion of those eligible to participate. Success may be determined by how closely the actual participation compares to the target.
Absence of participant collusion	To achieve optimal results in an auction, collusion must be minimized. Although there is no direct method for calculating collusion a direct analysis of the bids may be used to determine whether it is likely that collusion has occurred.
Participant trust	In order to achieve other auction goals, participants must trust the auction process. Although the number of participants serves as a proxy for this, trust can be more directly assessed through the use of survey techniques. Participants may be asked, post-auction, whether they believed that the auction process was fair and whether they trusted the auction process. Non-participants may be asked what factors prevented their participation.

Sealed-bid Procurement Water Auction Checklist

This checklist is provided as a set of reminders intended to assist with the water auction design and implementation process.

Preliminaries

- ☐ **Determine volume of water desired.**
- ☐ **Set the auction date and implementation timeline.**
    - Are there seasonality or planting cycles to consider?

- Start of publicity, outreach and informational meetings.

☐ **Determine eligibility to participate.**
- Should there be constraints on the type or location of eligible water entitlements?

☐ **Determine the volume that each person may offer.**
- May individuals auction their entire entitlement amount? Their historical diversion amount? Their consumptive use amount?

☐ **Determine the units of volume to conduct the auction in.**
- Should the auction be conducted in terms of acre-feet, standardized water per acre amount or a different metric?

☐ **Determine the type of information technology to use.**
- Can any part of the auction be conducted over the telephone, fax, or internet? Is any other information technology consideration important?

☐ **Develop a public information and participant engagement plan and timetable.**

☐ **Determine how and when winning bidders will be compensated.**

Auction Design

☐ **Determine an auction budget.**
- Should a budget cap or a quantity quota be set? If so, should any or all of this information be divulged to the bidders?

☐ **Establish a tie-breaking rule.**
- Should the existence, or the operation, of the tie breaking rule be divulged?

☐ **Set a reserve price.**
- Should the existence, or the level, of the reserve price be divulged?

☐ **Set the number of rounds of bidding.**
- Should only one round be used? Should multiple rounds be used, but the number be predetermined? Should there be multiple rounds but the number not be predetermined?
  - Should the number or rounds be divulged? Should information be divulged between rounds? If so, how much and what type of information should be disclosed?

☐ **Determine what price the winning bidders will be paid.**
- Should a uniform price bid selection be used or a discriminatory price bid selection?
  - Should the existence of the uniform or discriminatory auction be divulged?

Post Auction Evaluation

☐ **Determine the evaluation methods to be used for auction success.**
- What type of metrics will be used to assess auction success? Should success be based upon obtaining a desired volume of water? Upon minimizing procurement costs? Upon minimizing auction costs? Based upon a calculation of benefit per dollar spent? Through the use of focus groups or surveys? Or some other method?
- Develop a plan to collect data needed for evaluation.

☐ **Monitor actual change in water use to assure compliance.**

☐ **Determine whether improvements can be made to the auction process for the future.**
- Were the goals achieved? If not, what can be done to improve the outcome?

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Glossary

Ascending Bid Auction - In an ascending bid procurement auction, the price starts at a relatively low level and begins to rise temporally. The winner is the bidder that first stops the ascending price and accepts that price in payment for the resource. In this way, the bidder that is willing to accept the smallest price for the resource is chosen as the winner.

Bid Shading – A process by which bidders attempt to conceal their true value of the resource. In a procurement auction, bidders attempt to shade their bids in such a manner that the auctioneer believes that they value the resource more highly than they really do in an effort to obtain a premium for the resource.

Budget Cap – In a water auction, a budget cap is the maximum total amount of money that the auctioneer is willing to spend to acquire the entire volume of water.

Descending Bid Auction - In a descending bid procurement auction, bidders bid down the price that they will accept sequentially until no bidder wishes to bid the price down any further. The bidder that will accept the lowest price is the winner.

Index – A method of ranking bids based upon predetermined set of criteria.

Iterative Auction – An auction that consists of more than one round of bidding where bidders are allowed to revise bids between rounds.

Multiple Unit Auction – An auction where more than one unit is placed for auction. In the case of a multiple unit water auction, participants submit bids consisting of various volumes of water.

Procurement Auction – An auction where the auctioneer's goal is to obtain (rather than sell) a particular item or resource.

Reserve Price – In a water auction the reserve price is the maximum amount of money that the auctioneer is willing to spend per given volume of water.

Revenue Equivalence – The theory that regardless of what auction design is used (ascending, descending or sealed bid), the chosen bid price is expected to be the same.

Sealed Bid Auction – An auction where bidders submit confidential bids. In a procurement auction, the auctioneer obtains the confidential bids and selects the lowest bidder as the winner.

Sealed Bid Multi-Unit Procurement Auction - An auction design particularly suited for water auctions because it permits the submission of bids that may vary in quantity.

Vickery Auction – In a procurement Vickrey auction, the winning bidder is paid the amount that the second place bidder submits. Under economic theory, this method minimized the threat of bid shading.