Smart Markets for Groundwater Trading in Western Nebraska: The Twin Platte

October 2016

Case Study

Final Report on Political Economy of Water Markets

AMP Insights

ecosystem economics

The Rockefeller Foundation

Smart Markets for Groundwater Trading in Western Nebraska: The Twin Platte

A Case Study for the Political Economy of Water Markets Project

October 2016

Richael K. Young[i]

---

[i] Mammoth Trading, Inc., P.O. Box 22845, Lincoln, Nebraska 68542-2845, richael@mammothtrading.com

Preface

This paper is one output of a project entitled "The Political Economy of Water Markets." The project was carried out by Ecosystem Economics LLC and AMP Insights LLC. The outputs of the project include a final report and a set of case studies.

The final report comes in three parts:

1. "Healthy" Water Markets: A Conceptual Framework by Bruce Aylward, David Pilz, Megan Dyson and Carl J. Bauer
2. Political Economy of Water Markets in the Western United States by Bruce Aylward, David Pilz and Leslie Sanchez
3. Comparative Analysis of Legal Regimes with Respect to Fostering "Healthy" Water Markets by David Pilz, Megan Dyson, Bruce Aylward, Carl J. Bauer and Amy Hardberger

The eight case studies consist of the following.

1. The Evolving Water Market in Chile's Maipo River Basin by Carl J. Bauer
2. Addressing Overallocation and Water Trade in New South Wales, Australia: Namoi Basin Groundwater by Megan Dyson
3. Evolution of Australian Water Law and the National Water Initiative Framework by Megan Dyson
4. Opportunities for Surface Water Right Marketing in Idaho's Rapidly Urbanizing Treasure Valley by Jeff Fereday
5. Texas Groundwater Markets and the Edwards Aquifer by Amy Hardberger
6. Oregon's Umatilla Basin Aquifer Recharge and Basalt Bank by Martha Pagel
7. Truckee-Carson Surface Water Markets in Northern Nevada by Leslie Sanchez, Bruce Aylward and Don Springmeyer
8. Smart Markets for Groundwater Trading in Western Nebraska: The Twin Platte by Richael Young

The studies and reports can be downloaded from the AMP Insights website at http://www.ampinsights.com/rock-report.

For further information on this work please contact Bruce Aylward at bruce@ampinsights.com.

Acknowledgements

This paper was prepared with financial support from The Rockefeller Foundation. All errors and omissions remain the responsibility of the author.

Author

Richael Young specializes in market design for the exchange of natural resource rights. As an economist, engineer, and entrepreneur, she brings together complementary skillsets for natural resources management and policy. She strives to create tailored and cost-effective solutions that achieve local economic and environmental goals. In 2014, Richael cofounded Mammoth Trading, where she serves as president. In this capacity, Richael led the development and implementation of the first smart market for groundwater in the world. Mammoth Trading's smart markets help communities put limited water to its most productive uses, all while meeting regulatory obligations.

Introduction

Groundwater is a critical resource for agricultural, industrial, municipal, and environmental uses. Approximately one-fifth of total water use in the United States comes from groundwater withdrawals, extracted at an estimated rate of 227,000 acre-feet per day (Maupin et al 2014). Of this, about 70 percent is used for irrigated agriculture. The heavy reliance on groundwater has in some areas diminished groundwater availability and well yields and depleted hydrologically connected surface waters. In response, groundwater management has emerged to include limits on well drilling, pumping, and irrigated area. To provide more flexibility to groundwater users, several management agencies have allowed the transfer, or trading, of groundwater use permits. The purpose of this case study is to describe an agricultural market for the exchange of groundwater use permits in the Twin Platte Natural Resources District (NRD) in western Nebraska.

The first section describes the evolution and typology of market-based structures for water trading; water is transacted through several mechanisms in the United States, each of which creates different incentives for participants. The second section highlights general market imperfections that should be considered in the design of regulatory rules for trading. The third through sixth sections focus on the particular "smart" market for agricultural groundwater trading in the Twin Platte NRD, including its features and structure, participants, imperfections, and opportunities for legal improvements. The last section makes concluding remarks.

The insights in this case study are informed from the author's experience developing water markets and individual meetings with more than 200 agricultural producers, water managers, state policymakers, and other water use practitioners in the western United States.

I. Water Markets

Water transactions occur and evolve through many processes, including bilateral contracts or "coffee shop" markets, brokerage, bulletin boards, auctions, or algorithmic clearing ("smart" markets). This section outlines the primary features of each and how those features affect market participation. Importantly, different structures may favor either the buyers' or sellers' side and create varying transactions costs.

Bilateral Contracts

The simplest and most decentralized water transactions occur through bilateral contracts, or "coffee shop" markets. In these markets, individual buyers and sellers find each other through informal mechanisms, such as through word of mouth or local community gathering places, and make arrangements themselves. They work to identify one another, negotiate prices and water rights quantities, and obtain regulatory approval. Bilateral contracts are very common in water transactions, especially in agriculture to urban or environmental uses, but also in agricultural water trades. Time and effort exerted for staff or individuals to search for interested parties, negotiate contracts, and obtain regulatory approval are generally high. However, there are no additional third-party costs or fees for compensation for the set-up or operation of such a decentralized approach.

Brokerage

A slightly more sophisticated approach involves representation of the buyer or seller. Real estate agents have been known to represent individual buyers or sellers in water rights transactions. Agents can help to identify interested parties with which to trade, negotiate prices on behalf of their client, and obtain regulatory approval. This model is common in Australia, in combination with electronic bulletin boards, described in the next section. Brokerage helps to reduce some of time and hassle associated with water rights transactions, though the broker commission adds its own transaction cost.

Bulletin Board

Bulletin boards create a centralized hub for trading by allowing parties to indicate interest in trade. Typically, they will list name, contact information, and water rights information. Price is generally, though not always, withheld, to be negotiated after initial contact between the parties. Bulletin boards can be physical or electronic: the Roza Irrigation District in Washington State has a physical bulletin board in its office for sellers to post on that buyers can reach out to; the Edwards Aquifer and Australia have electronic bulletin boards posted on websites. Importantly, though this information is online and may expedite some of the legal transfer process, it is not a “smart” or algorithmic market. Bulletin boards, though centralized, rely on individuals manually identifying trades between one buyer and one seller.

Auctions

A typical auction runs where there is a single seller and multiple buyers who sequentially outbid one another, with the highest bidder taking all. A reverse auction does the opposite, where a single buyer is looking for the cheapest water, and sellers undercut one another where the lowest offeror wins the contract. In either case, multiple auctions (reverse auctions) may happen in sequence so that different sellers (buyers) can list their offer (bid). However, there are also cases where only a single seller or buyer exists in the market. Districts controlling the growth of groundwater use in eastern Nebraska have discussed auctioning off pumping rights; in this case they would be the only seller (a monopoly). The Department of Ecology of the State of Washington ran a reverse auction in 2015 to buy back water rights, making it the only buyer (a monopsony). Such situations where there exists only one seller or only one buyer create significant market power and may generate perceptions of unfairness on the other side. This is because auctions are structured so that one side of the market extracts all of the economic gains from the other side. Participation in state-run reverse auctions has been low in part because the concept has been unpopular among water rights holders, who do not wish to sell water at lowest price to governmental entities.

Smart Markets

A “smart” market is an electronic clearinghouse, which uses an algorithm to simultaneously match many buyers with many sellers in an automated fashion (McCabe et al 1991, Raffensberger et al 2009, Murphy et al 2000, Young and Brozovic 2016). If there are additional regulatory constraints, they may be incorporated. Smart markets leverage the power of computer optimization in order to maximize the economic gains of trading activity and are customizable so that a particular water management agency's rules may be incorporated exactly. In addition to surface and groundwater, smart markets can be used to trade a variety of other natural resources use rights that are constrained, monitored, and enforced, such as air and water quality pollutants, wetland habitat, stormwater retention credits, and other ecosystem services.

Smart markets offer several advantages. First, like bulletin boards and auctions, they provide a centralized hub for trading activity, eliminating the time and effort exerted in finding others interested in trade. Instead, a participant simply enters bid or offer information. Aside from reducing search costs, smart markets improve on auctions by acting to pool and electronically clear bids and offers, enabling simultaneous matching of many buyers to many sellers rather than matching a single buyer to a single seller, which may be impracticable and is generally economically inefficient. This results in additional gains of trade, as a single buyer and seller often don't have the exact same requirements for water transfers. Instead of seller with 100 acre-feet of water having to find a buyer who needs exactly that amount, she can sell to several buyers, each needing different but smaller quantities. The reverse is also true: a smart market can aggregate many sellers' water rights for a large bidding quantity. Without pooling and electronic clearing, this is very difficult to manually orchestrate.

The tailored algorithm of the smart market is capable of automating regulatory compliance. As previously mentioned, the algorithm can incorporate every regulatory rule for transfer. A computer can electronically check such arduous rules instantaneously, a considerable savings on the staff time needed for review. The algorithm considers the entire pool of participants and determines which parties are eligible to trade with one another within the local regulations. Such a system has the advantage of eliminating the possibility for human error in checking eligibility requirements. Of course, programming these rules into the algorithm itself takes considerable time and technical expertise. For this reason smart markets are likely to be more beneficial where trade volume is high enough for the smart market to lower aggregate transaction costs and recoup the costs in its development.

II. Market Imperfections

Market Design

One of the most fundamental aspects of water markets is that they must reflect geophysical relationships (Kuwayama and Brozovic 2013, Brozovic and Young 2014). Due to physical or natural limitations, water may only flow so far, which therefore limits the ability to transfer water across large distances. This is not necessarily undesirable, but a feature of system or infrastructure limitations. Even within a smaller watershed, the network of tributaries, subbasins, and conveyance must be considered. Further, the rules for water trading must prevent third-party impacts, including impairments on other water rights holders or environmental ecosystems. This may require that the rules incorporate more complex hydrologic relationships, including damage factors and trading ratios (Kuwayama and Brozovic

2013, Brozovic and Young 2014). The Twin Platte Natural Resources District, whose rules and market design are discussed later, is a tangible example.

Water trading, for surface or groundwater, requires a physical or legal limitation on the right to use water. In the case of groundwater, if there were no restrictions on drilling or pumping additional groundwater, there would be no incentive to purchase such rights, and therefore no market. Typically, a cap, or limit on the number and extent of groundwater pumping rights is established to meet a regulatory obligation (e.g. meeting streamflow compliance) or policy goal (e.g. not exceeding the aquifer's sustainable yield). Setting the cap correctly is an important challenge in starting a water market. If the cap on water usage is too high, a market would enable the additional, or "slack", permits to be put to use elsewhere, resulting in aggregate increases in consumptive water use (Palazzo and Brozovic 2014). As a result, some regulatory agencies have stipulated that only the historical water use may be transferred through a market, though this still may create incentives for overuse. In Australia's case, the government invested billions of dollars in buybacks to prevent slack permits from entering the market.

If such constraints and considerations are not incorporated into the market design, it is possible that a market could exacerbate water scarcity, degrade environmental quality, and even devalue water rights. A poorly designed market can be worse than no market at all.

Asymmetric Information

Governmental agencies are responsible for the permitting and regulatory aspects of water rights, including market design, monitoring, and enforcement. Such responsibilities cannot be delineated to private entities. Several governmental agencies, in attempts to assist their water users more effectively trade, have also setup and operated the market mechanism itself. While this is done with the best of intentions, it can create asymmetric price information and general distrust among water users. Some agricultural producers have refused to participate in water markets, not because they would not be profitable, but because producers have concerns that the price information they disclose on a market could be used against them in the future. Disclosing water rights values to the very entity responsible for regulating the commodity can create uneasiness among water users. This may result in lower market participation and economic inefficiency.

Another concern with government-run markets is in the case where the governmental agency is interested in also participating—as a buyer or seller—in the market. With insider information on prices, the agency is in a distinct conflict of interest to simultaneously participate on and operate the market. Such a practice creates valid concerns for misuse. As a result, it could be desirable to promote public-private partnerships, where the agency retains full control of permitting and regulatory compliance and a private entity handles the financial side. The permitting and financial transactions can be thought of as two aspects of trading that can be handled separately.

Prices

Confidentiality of price information is one of the most underappreciated aspects of trading. The collection of price information requires individuals to disclose sensitive financial data about themselves to the public; while unintentional, mandatory price disclosure may create an obstacle that is insurmountable to some market participants. Instead, it may be desirable to forego price disclosure to encourage more trading activity.

Price setting has also been an obstacle, where the regulator will set a static price that participants either take or leave. Importantly, the value of water varies over space and time such that there is no single “market price” for water at a single point in time, nor is that price static, but ever-changing with weather conditions, crop conditions, commodities prices, and more. Water values are idiosyncratic to reflect the specific condition, use, and time, and a market mechanism should allow for such variability.

III. Case Study: TPNRD Background

High Plains Aquifer

Many regions rely on groundwater as a clean and reliable source of water for urban and agricultural demands. In the United States, approximately 15 million acres of farmland and 1.9 million people depend on the High Plains Aquifer, which underlies portions of eight states in the central US (USGS 2013, USDA ERS 2015). The High Plains Aquifer, also known as the Ogallala Aquifer, is the largest in North America. The depth to the water table ranges from land surface to more than 300 feet, and the underground gradient of the aquifer is such that it flows west to east at approximately 1 foot per day (Gutentag 1984). The aquifer, which is unconfined, is hydrologically connected to local surface water sources throughout.

The overuse of groundwater can result in myriad private and public externalities, which have been well documented in the media and scientific literature (Laukaitis 2015, Hathaway 2011, McCarl et al 1999; Steward et al 2013). These include well interference, diminishing well yields, land subsidence, seawater intrusion, or the depletion of hydrologically connected surface water sources. In the High Plains Aquifer, diminishing saturated thickness and well yields have been cause for voluntary groundwater management restrictions in Northwest Kansas Groundwater Management District #4, where producers hope to stretch the life of the aquifer so that a rural livelihood is possible for their children and grandchildren. In other cases, there has been landmark interstate litigation over groundwater pumping-induced stream depletion, the subject of Kansas’ lawsuit against Nebraska and Colorado on surface water deliveries owed in the Republican River, a river connected to the High Plains Aquifer. Stream depletion, aside from harming downstream surface water rights holders, may also impair aquatic habitat for threatened or endangered species.

As a result of interstate litigation, local concerns for groundwater sustainability, and growing interests to protect aquatic habitat, groundwater management emerged, though on a hyper-localized scale. In the United States, there is no national policy on the use of groundwater; it is instead delineated to the states to manage, each with varied laws and policies. Forty autonomous management districts in eight states manage the High Plains Aquifer, creating a living laboratory for innovations in groundwater management (Figure 1). The focus of this case study will be on agricultural groundwater use, as the bulk of groundwater used in the High Plains is for irrigated agriculture, and the market mechanisms to transfer pumping rights.

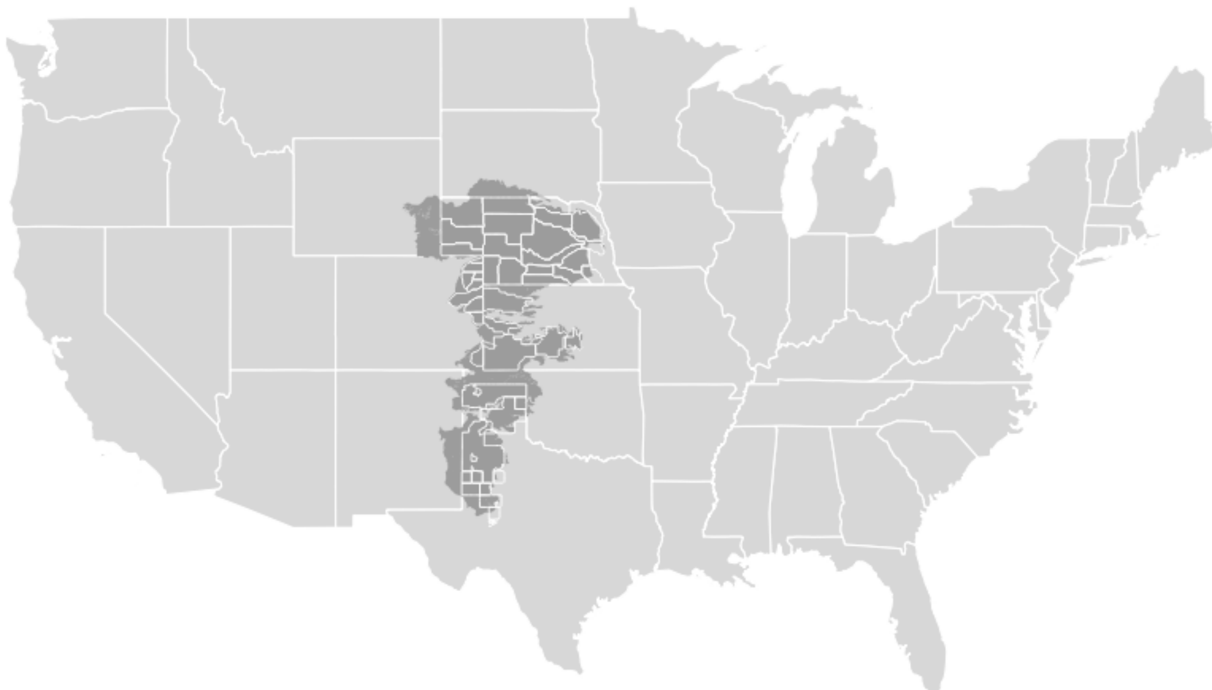

Figure 1: The High Plains Aquifer is located in the central United States and is governed by more than 40 management districts across eight states (Young and Brozovic 2016).

Nebraska

Two-thirds of the High Plains Aquifer is within Nebraska. Overall, groundwater levels of the aquifer have remained constant since development, despite the fact that Nebraska is the top irrigated state by acreage at 8.3 million irrigated acres (USDA NASS 2012), a large fraction of which are groundwater-irrigated (Johnson et al 2011). This is in contrast with the southern and central parts of the aquifer that have been rapidly declining, as is the case in southwest Kansas and panhandle of Texas (USGS 2015). Importantly, Nebraska's Sandhills in the north have afforded it high recharge to its portion of the HPA. A geologic formation in the aquifer that sits near the border with Nebraska and Kansas effectively disjoints the aquifer so that little groundwater in its northern portion flows to the central and southern portions of the aquifer.

Though groundwater depletion is not a serious concern in most parts of Nebraska, stream depletion is and has been the impetus for groundwater management in the state. Stream depletion by groundwater pumping occurs when groundwater pumping reduces the baseflow upon which an adjacent surface water source is dependent. This may result in diminished streamflow for surface water rights holders or endangered species. The connection between groundwater and surface water is now commonly acknowledged and accepted among both scientists and policymakers, giving rise to calls for the "conjunctive management" of surface and groundwater. The science behind their interactions is ever-improving so that we can now describe the effect of stream depletion of a groundwater well by knowing factors including its extraction rate, distance from the stream, and aquifer properties. The science is increasingly being incorporated into regulations, though these regulations still are imperfect, as our ability to monitor groundwater usage and its effects is also imperfect, be it for technological, political, or financial obstacles.

Nebraska delineates authorities to manage groundwater to its 23 Natural Resources Districts (Figure 2). Importantly, the jurisdictions of the NRDs follow watershed boundaries rather than political ones. Their boards are locally elected, so that regulations can reflect local economic needs, while the state has enough oversight to ensure that the NRD meets its responsibilities to manage groundwater. NRDs have authority to levy taxes and to craft, monitor, and enforce regulations. Regulations to date have included well moratoria, certification of irrigated acreage, groundwater pumping allocations, continuing education requirements, and more.

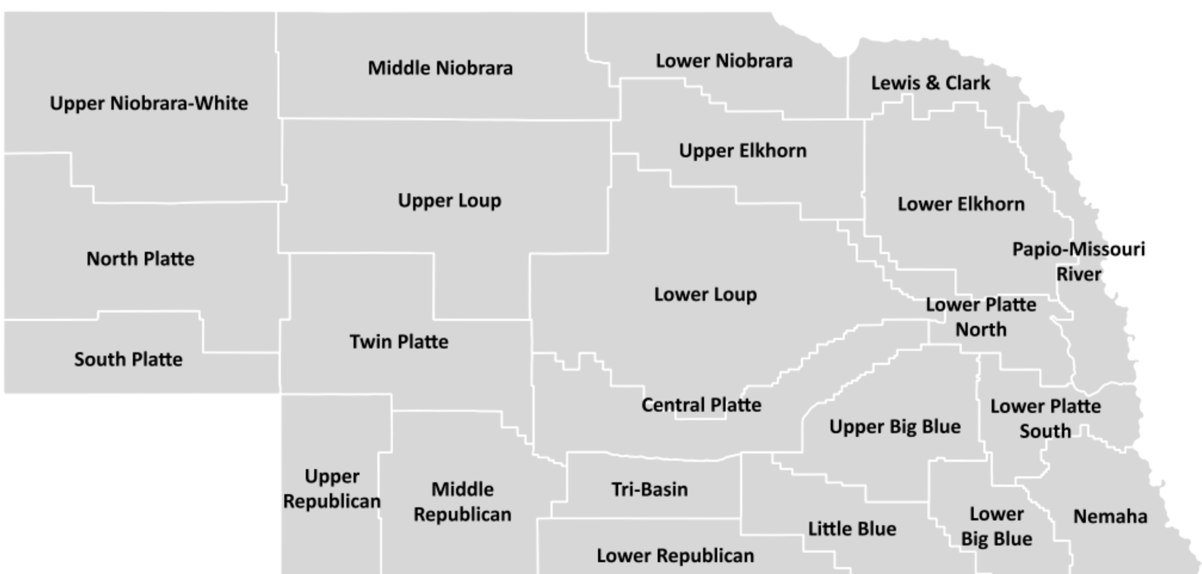

Figure 2: Nebraska's 23 Natural Resources Districts, which are responsible for groundwater management (Young and Brozovic 2016).

Nebraska's precipitation gradient is large, at about 35 inches annually in the southeast and 14 inches in the west (Ferguson et al 2011), such that irrigation in the eastern part of the state is rare while a near necessity in the western part. Groundwater management concerns are as varied as its precipitation patterns; Nebraska NRDs have dealt with groundwater depletion, stream depletion, well interference, and contamination by agrichemicals. With varied concerns and its local approach to management, Nebraska has become a living laboratory for innovations in groundwater management. In this case study, the focus is on the Twin Platte Natural

Resources District, which faces concerns from stream depletion, and its nascent groundwater market.

Twin Platte Natural Resources District

The Twin Platte Natural Resources District is home to four counties and 325,000 irrigated acres of farmland. It is one of several Nebraska groundwater management districts along the Platte River, a river basin that spans the three states of Wyoming, Colorado, and Nebraska. The Platte has its headwaters in the Rocky Mountains in Wyoming, forming the North Platte River, and Colorado, forming the South Platte River. These flow westward into Nebraska, joining at their confluence within the Twin Platte NRD. The Platte River discharges into the Missouri River at the eastern border of Nebraska near Omaha. The Platte is a braided stream, or one that is slow, meandering, and has many small sand islands that serve as critical wildlife habitat. The Platte is a thoroughfare, called the Central Flyway, for the iconic sandhill and whooping cranes that migrate between Canada and Mexico.

In the Platte River Basin, the whooping crane is one of three federally listed endangered species, along with the least tern and pallid sturgeon; the threatened piping plover also share this habitat. Colorado, Nebraska, Wyoming, and the U.S. Department of Interior entered in 2007 into a cooperative agreement to reduce negative impacts to streamflow to these species' habitat. Importantly, this regulatory environment is one of pre-compliance, that is, done in advance of litigation or binding court orders. By 2019, the Twin Platte NRD aims to return 7,700 acre-feet of water to the river through education, stronger regulations, and incentive-based programs, including retirements and agricultural transfers (TPNRD Integrated Management Plan 2012).

In addition to the cooperative agreement, the state water regulatory authority, the Nebraska Department of Natural Resources (DNR), in 2004 determined the western portion of the District to be overappropriated and the eastern portion fully appropriated (TPNRD IMP 2012). By 2007, there was a district-wide well drilling moratorium with restrictions on the growth of irrigated acres. Groundwater pumping in the District is not metered to provide flexibility to their agricultural producers. Metering is extremely unpopular among producers, and often politically infeasible to initiate. Meter equipment and staff time to conduct readings can also be cost-prohibitive for a district, so the Twin Platte only monitors the irrigated acreage of farms in their jurisdiction.

IV. Case Study: TPNRD Market Description

Facing expansions in groundwater pumping amid obligations to reduce stream depletion, the TPNRD board enacted a well drilling moratorium and restricted the growth of irrigated acreage. The TPNRD verified and certified existing irrigated acreage, called certified irrigated acres (CIAs). Anyone caught irrigating lands uncertified are subject to strict penalties. However, recognizing that the economic landscape might change regarding who would or wouldn't be interested in irrigating, the District did not outright prohibit the expansion of irrigation: Instead, it required agricultural producers interested in expanding their own production to obtain appropriate offsets from producers who already had CIAs. In essence, the TPNRD, in looking for flexible management solutions, capped, certified, and allowed the trading of CIAs, forming the regulations of a groundwater market.

Unit of Trade

Importantly, there are no volume-based irrigation allotments or allocations in the TPNRD. Other NRDs in Nebraska have volumetric restrictions (the Upper Republican NRD has an allocation of 13 acre-inches per irrigated acre), which are metered, monitored, and enforced. In the TPNRD, while there is a cap on the total number of irrigated acres, there is no such cap on the amount of groundwater extracted at the well. Therefore, buyers and sellers in the TPNRD exchange CIAs, or the right to irrigate a specified number of acres. Trades are based on irrigated acres (area-based) rather than groundwater pumped or consumptive use (volume-based). The NRD annually conducts flyovers and aerial image processing to ensure compliance.

While there is variability between fields in water application and consumptive use, the differences in this District are small due to rather homogenous crop water requirements (Figure 3, Young 2014). Growers in the Twin Platte almost exclusively grow corn and soybeans, requiring 14-16 inches of irrigation application (Figure 3). In regions or management districts where there is more diversity of crops or water use requirements, area-based trading is likely insufficient; meters and volume-based trading would be better suited.

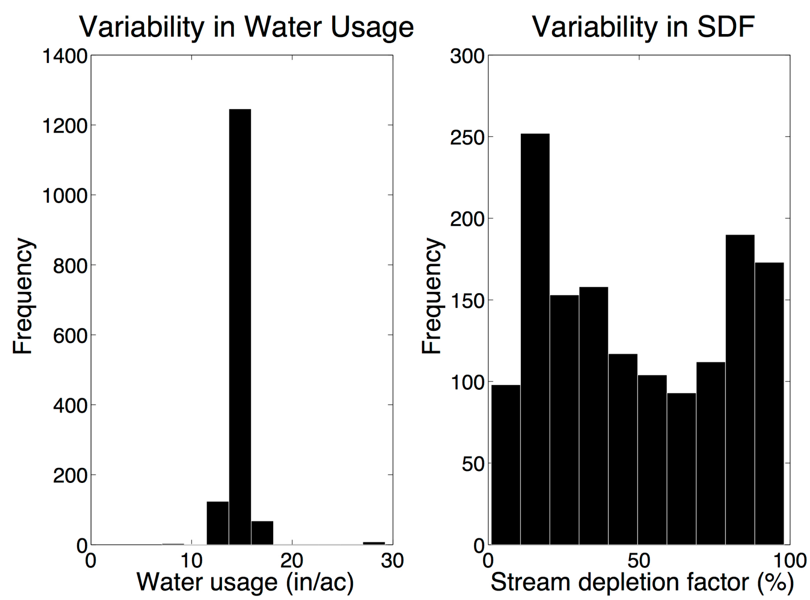

Figure 3: Estimates of water usage variability and stream depletion factor (SDF) variability in the Twin Platte NRD (Young 2014). The product of water usage and the SDF gives the total amount of stream depletion to an adjacent surface water source. Since the effect is multiplicative and water usage fairly homogenous in the TPNRD, the SDF is the dominant factor on a groundwater well's damage to streamflow (Young 2014).

There are tradeoffs associated with the level of monitoring, discussed in detail later in the case study. In summary, area-based markets translate to low monitoring costs to the regulatory agency. For various reasons, it may be politically, financially, or practically infeasible to monitor groundwater. The Twin Platte's regulations therefore limit or reduce farm size rather than groundwater pumped, an adjustment at the extensive rather than the intensive margin.

Further, there is built-in flexibility to the growers, who may use more or less groundwater annually depending on seasonal weather conditions. Instead of having to adhere to a strict or inflexible allocation, the growers have the ability to apply however much water is required. Because energy can be an expensive agricultural input, there is little incentive to over-pump. There are downsides to area-based trading, though. First, because there is no allocation, growers in the TPNRD have little need to lease extra or excess water—they can fulfill seasonal water requirements without fear of exceeding a regulatory cap. For this reason, all transfers of CIAs are permanent (sales), and not temporary (leases). However, economic theory suggests that trading is most cost-effective when producers can make and monetize adjustments on the intensive (volume), rather than extensive (area), margin. Ignoring monitoring and enforcement costs, the basic insight is that growers like those in the Twin Platte could collectively make more money while using the same amount of water with volume-based trading, which lends itself to lease and derivatives markets, as well as a permanent one.

Spatial Externality

Reallocating groundwater pumping is likely to change the timing, magnitude, and location of the damages to streamflow; that is, stream depletion is a spatially heterogeneous externality. To ensure that groundwater trading does not impair downstream surface water users or exacerbate stream depletion, a number of trading rules have been codified into the regulations governing trade that reflect the hydrologic science. For example, trading ratios (in this case, stream depletion factors, or SDFs) are often used to compare the relative environmental damage (stream depletion) between a buyer and seller, with adjustments made accordingly (Kuwayama and Brozovic 2013, Brozovic and Young 2014, Young 2014). In moving groundwater pumping to a location that would induce higher stream depletion, the number of groundwater permits (CIAs) would shrink proportionately. However, the reverse is not true in the Twin Platte: moving from a higher-damage to lower-damage location does not result in the growth of CIAs per TPNRD trading regulations. Such an asymmetrical trading scheme is called "unidirectional"; while unidirectional trading is not a first-best solution, it can hedge against uncertainty or slack in the market or assist to meet policy objectives of reducing groundwater overuse (Brozovic and Young 2014, Young 2014). In practice, trading ratios change the effective prices between buyers and sellers, making it costly to move groundwater pumping to locations inducing larger stream depletion. Stream depletion factors can be highly variable across space (Figures 3 and 4).

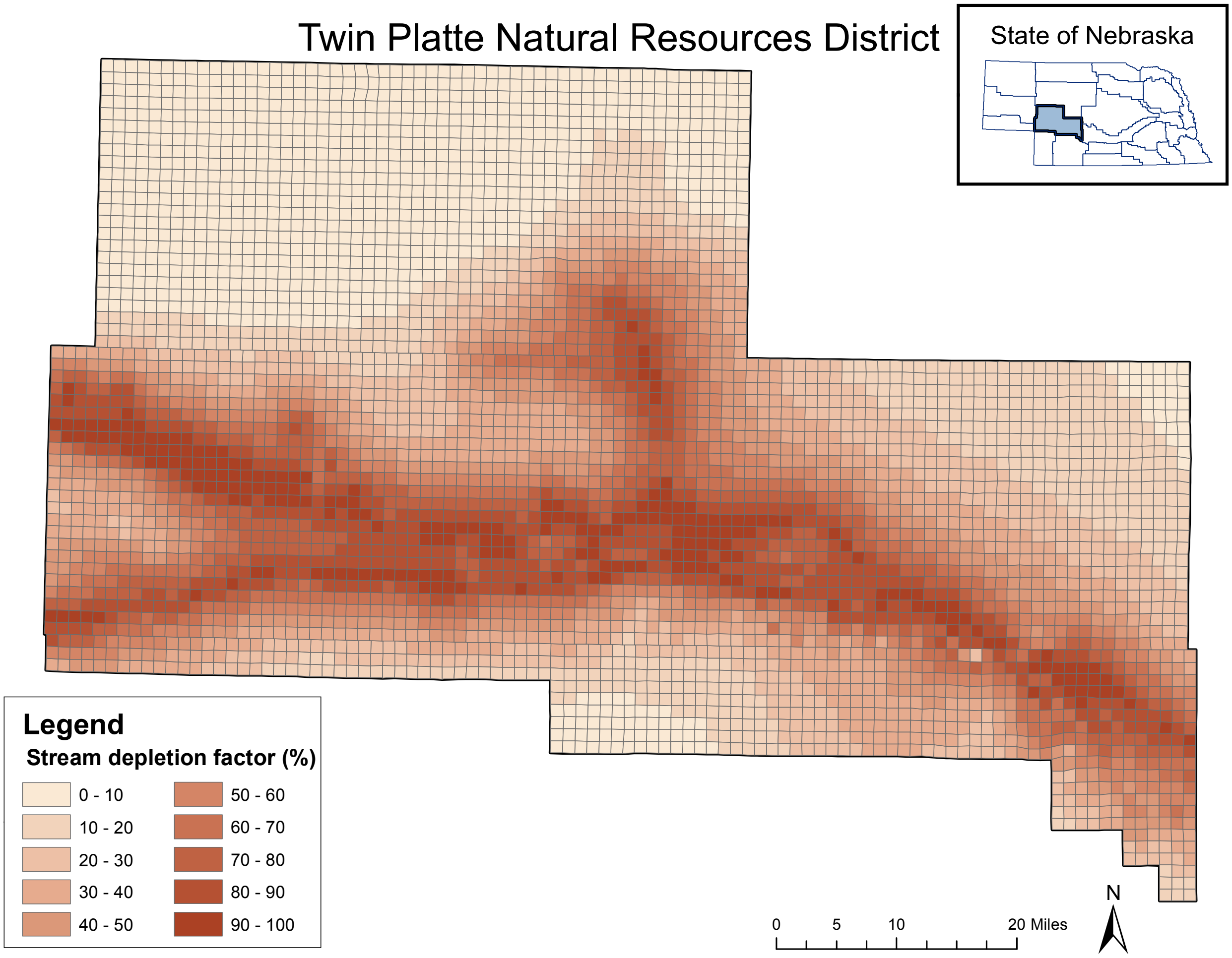

Figure 4: The stream depletion factor varies across space in the Twin Platte NRD (Young 2014).

The TPNRD market rules incorporate other geophysical relationships and concerns, including estimated consumptive use, flow zones, soil types and slopes, subbasin boundaries, and buffers around municipal drinking water supplies. While such rules thin the market so that fewer buyers and sellers are eligible to trade, it also helps to prevent third-party impacts.

Conveyance

Unlike surface water markets, conveyance of groundwater is not required nor poses practical constraints (Brozovic and Young 2014). Rather than the groundwater itself being transferred, it is the right to pump groundwater that is being bought and sold. Still, there are physical limitations to how far a buyer and seller may transfer groundwater permits in that there must be hydrologic connectivity between them. A buyer in California could not acquire groundwater permits from someone in Nebraska because there is no hydrologic connectivity. Oftentimes, there are even regulatory hurdles to inter-district trading overlying the same aquifer, such as between the Twin Platte NRD and its neighboring district, the Central Platte NRD. This section focuses on the intra-district trading between agricultural groundwater users within the TPNRD.

Market Participants

The Twin Platte NRD's largest responsibility, like that of most NRDs in Nebraska, is agricultural groundwater management. There is little competition between sectors for water use. NRDs, per Nebraska State Legislative Bill 1226, assume responsibility to acquire groundwater rights in the event of municipal growth, which it would accomplish through the permanent retirement of CIAs. The TPNRD has not faced this issue yet, as the communities and cities have not experienced much growth and subsequent increases in municipal water demands. Yet, if they were to, they would purchase the appropriate number of CIAs that would account for the change in consumptive use from irrigated agriculture to municipal use. The TPNRD is also subject to its own transfer rules.

While the TPNRD must offset additional municipal use, it is not required to do so for new industrial users with large water requirements. The industrial users must acquire their own CIAs, and these are also subject to the transfer rules, plus adjustments based on the comparative consumptive uses between irrigated agriculture and the new use. Though trading has happened between the industrial and agricultural sectors in the past, activity is dominated between agricultural users.

Among agricultural trades, buyers are looking to expand production capacity. Some buyers are interested in acquiring larger quantities of groundwater rights so that they can irrigate land that is currently in dryland production. Such an investment would also require drilling a new well and installing irrigation equipment. Other buyers are looking for smaller quantities, hoping to expand the number of CIAs on a currently irrigated field. Sellers typically look to sell groundwater rights from land with poor or generally unproductive soils, from odd-shaped fields that cannot be irrigated with center pivots, or from land where they otherwise underutilize its irrigation rights. In general, groundwater rights are moving to farms with better irrigation technology and to producers who are more technologically savvy. Trading activity and pricing are largely influenced by commodities prices, meaning that more recently trading has stagnated with depressed corn prices.

Barriers to Trade

While economic theory suggests that trading mechanisms for resource management are highly cost-effective, they are challenging to set-up and operate in practice (Young and Brozovic 2016). From the regulatory perspective, there is significant risk and uncertainty in developing rules that reflect hydrologic relationships and needs for local economic stability. The proper balance between science-based and clear rules can be difficult to strike. Some regulatory agencies have understandably feared the unintended consequences of trading, and have therefore responded by adding such restrictive rules that trading is practicably infeasible. While this is not the case in the Twin Platte, it is important to note that any additional rules, even science-based, will thin the market. Sometimes, this outcome is desirable; other times, it's counterproductive.

On the water users end, there are also several practical obstacles to trading. In the Twin Platte, producers have trouble identifying an interested party, negotiating a price, obtaining regulatory approval, and protecting sensitive financial information (Young and Brozovic 2016).

The first and often most significant barrier to trade is simply identifying another interested party. Most buyers and sellers find one another through word of mouth, calling friends and neighbors or the NRD itself. As mentioned, this decentralized approach is often referred to as a "coffee shop" market. One groundwater manager expressed the difficulty of trading, saying, "I have no idea where to point them: perhaps to Craigslist, to newspapers, to neighbors and friends? There's no marketplace for this." Unlike equipment, seeds, and fertilizer, there is no centralized dealer where producers can acquire or sell water rights.

After finding an interested party with which to trade, price negotiations begin. Most farmers are wary of this process, as it requires disclosing personal and sensitive financial information about their value of water, oftentimes to friends, neighbors, or community members whose social circles intersect their own. Producers have strong privacy concerns regarding their data and price information.

Even if two parties have successfully negotiated a contract, the deal is still contingent on regulatory approval. Given the complex and nuanced nature of the rules, most individuals—producers, real estate agents, and lawyers—lack the technical expertise to understand and manually check the pages of eligibility requirements for transfers. As a result, many deals are faultily matched and once submitted, fail to gain regulatory approval. One farmer who had had bad experiences with the process said, "I got better things to do with my time than memorize those rules." This is especially true for the many producers who farm in multiple districts, each with nuanced rule sets.

Most, if not all, transfers have happened between a single seller and single buyer, but oftentimes the number of CIAs available from the seller is different to those needed by the buyer. This is practically quite challenging and economically inefficient. These "lumpy" trades are often not considered in theoretical analyses, but in practice are critical in decision-making around water use.

Lastly, while the rules for groundwater trading in the TPNRD have existed for more than 10 years, several producers don't know that they exist or what trading could do for their business. Several misconceptions about markets emerge, including that they favor only large producers or that markets favor the buyer side. These examples likely come from past experience in the District, where the brokerage of water rights through real estate agents—who, in general, represent large farmers who are buyers in these transactions—is common.

While the NRD's transfer fees are low at $200 per application, transaction costs are high for trading, particularly for the time and effort exerted to find a willing and eligible party. While representation is not pervasive, those that do hire real estate agents in the area are charged about seven percent on the total sales price, covered wholly by the client (typically the buyer).

The following section describes how “smart markets” address these issues and in so doing reduce transaction costs of trading.

Smart Markets

Mammoth Trading, a private company that the author founded, developed and launched a smart market in the Twin Platte NRD in February 2014. This is the first application of a smart market for groundwater trading in the world. For two years in a row, the smart market has successfully received bids and offers, matched parties through electronic clearing, obtained NRD approval, and finalized the legal paperwork and financial transactions.

To participate, a producer enters a bid for or offer of CIAs into the market. From each form, the participant’s legal name, address, contact information is taken, along with the legal description of the property, number of CIAs to transfer, and price. Sellers submit their floor price, or their willingness to accept, in dollars per acre; buyers submit their ceiling price, or their willingness to pay, also in dollars per acre. In addition, sellers indicate verifiable practices for how they will reduce their irrigated acreage, whether it be through removing a tower or end gun, capping a well, or other acceptable practice to the TPNRD.

The legal description of the property is used to extract field-level characteristics that determine eligibility to transfer: SDFs, flow zones and subbasins, soil types and slopes, and whether it lies within critical buffer zones. Participants can enter a range or an exact quantity of CIAs they wish to transfer, which is another requirement the algorithm considers to satisfy matches.

Importantly, the smart market is anonymous and confidential. Unlike coffee shop markets, bulletin boards, or auctions, participants don’t know the reservation prices of the others in the market, of the parties with which they trade, or even with whom they trade. After matches are made, Mammoth Trading works with the TPNRD to obtain regulatory approval. While Mammoth Trading shares with the TPNRD the set of buyer-seller matches and their respective quantities of CIAs, it does not share the executed prices. To provide general price information to participants, Mammoth Trading does share the range in per-acre prices of bids and offers received in previous years. To date, it has seen prices ranging as low as $1,800 per acre in 2016 and as high as $3,200 per acre in 2014. Each year has also had variability between participants, demonstrating how the value of water is variable over space and time.

The anonymity and confidentiality have been very positive aspects of the smart market. Producers have shared that anonymous trades can remove the emotion out of water deals, enabling more transactions. Small and rural communities often have long histories of interpersonal relationships, which can either sweeten or sour a deal. The anonymity removes the bias in both directions so that all parties are neutral to one another. Furthermore, confidentiality ensures privacy of price information not only to other participants, but also to the very entity regulating the commodity—the NRDs. These are particular features of a smart market operated by a neutral third-party, rather than an NRD or another public agency.

Before launching, the smart market was rigorously tested by the TPNRD Board of Directors, whose members ran it through two trial runs to test its functionality and accuracy. Since launch, the market has lowered barriers to trade by reducing search and compliance costs. In summary, smart markets provide a centralized hub for trading activity; they are customizable to reflect specific regulatory rules for trades; they automate the process of regulatory compliance; and, operated by a neutral third-party, they can offer significant privacy safeguards.

V. Case Study: Market Imperfections

Market Design

Smart markets help reduce the barriers to trade, but they are still subject to the market design of the operating jurisdiction, and therefore to external limitations. In the regulatory environment of the Twin Platte NRD, where only permanent transfers are allowed, trading activity has stagnated in recent years and will likely continue to drop; there comes a point at which the available CIAs have been reallocated to their most profitable fields. After almost 10 years of permanent transfers, there are fewer and fewer jointly profitable trades. It is true that changes in cropping, commodities prices, technology, or producer behavior might redistribute profitability in the future, but the changes are likely to be modest. As a result, even a smart market, which will be most efficient of any market mechanism available, might eventually put itself out of business. This is not undesirable, but in fact an indication that the market achieved its potential of reallocating resources to their most profitable uses given the current market design.

As described, verifiability of the reduction in consumptive use is critical to any transfer. For area-based trading, this means that the verifiable practices create lumpiness in sellers' quantities for trade. Verifiability will continue to play a crucial role—and potentially, a significant obstacle, due to imperfect monitoring—in water markets transactions.

There are significant tradeoffs of monitoring and enforcement. More advanced monitoring enables more sophisticated trading contracts, including leases, futures, and options; it also requires additional resources for equipment and for staff time for monitoring and accounting purposes, in addition to overcoming strong opposition for well metering. While metering can be politically sensitive, it is possible that the District might experience additional economic gains. Metering provides monetary incentives for reducing consumptive use through on-farm conservation measures and adjustments at the intensive, rather than extensive, margin. Theoretically, more flexibility in market transactions should lead to more economically efficient outcomes, but these must be balanced by practical constraints.

Slack Permits

There is evidence that the District was lenient in certifying irrigated acres, though this was also to generate good will and buy-in from producers. Such excess in a market can lead to increases in consumptive use or increased stream depletion. It is important to be aware of slack permits or "paper water" entering the market, and address them with government buybacks, offsets, or unidirectional trading. Offsets and unidirectional trading schemes may not be economically efficient, but help to hedge against uncertainty and to voluntarily retire water rights, rather than through regulations.

VI. Case Study: TPNRD Policy Reforms

In order to improve transfers and market activity, the State of Nebraska might consider enacting clearer legislation on the severability of land and water (surface and groundwater) rights, and the processes to transfer water use rights. Currently, the process is little understood and different in each NRD. Further, the state DNR could develop and maintain a registry for surface and groundwater rights holders so that verifiability of ownership is clear. The transfer process could also be streamlined; currently it can take over a month to obtain NRD board approval and file appropriate documents with county courthouses. Instead, all of the documentation should reside within a state registry maintained by DNR.

There could be small opposition for improving market activity among individuals who fear that markets enable outsider investment and market speculation. However, given the localized nature of water market rules, there is little opportunity for either. It appears that such reforms have not happened yet largely because water markets are nascent and decentralized in Nebraska. In general, these legal reforms seem attainable, but would require buy-in from NRD staff and board members. If they can see how more transparent water rights ownership and streamlined transferability benefit both their resource stewardship goals and rural economy, there would be little opposition. Still, the Nebraska State Legislature operates such that a member would have to champion the bill, and so it would require finding a member especially enthused about water markets.

In addition to clearer state legislation, the TPNRD could also consider improvements to its trading rules. For example, if the TPNRD wished to move to volumetric rather than area-based trading, its Board of Directors would need to consider and act upon changes to its rules and regulations. The Board of Directors is a body that is locally elected and primarily comprises of agricultural producers. While the Board has been responsive to meetings its obligations for instream flow, there is typically very strong opposition among producers to well meters. Several producers argue that water applied is an imperfect measure of consumptive use and that metered allocations strip them of the flexibility to respond to field-specific conditions. The Nebraska Water Balance Alliance, a consortium of producers, has been working to demonstrate reductions in consumptive use through more sophisticated technology. It is conceivable that the TPNRD may move to metered allocations or a consumptive use approach in the future, but this will likely take several years and additional pressure from the State of Nebraska and the Federal Fish and Wildlife to continue reducing stream depletion.

VII. Conclusions

This case study has examined different types of market-based mechanisms for water trading, including bilateral contracts, brokerage, bulletin boards, auctions, and smart markets. Each mechanism requires different startup costs for development and varies in its transaction costs to participants. Smart markets are the most sophisticated, as they can electronically clear a pool of buyers and sellers and guarantee regulatory compliance. However, they can require significant time and technical expertise to develop depending on the complexity of the trading regulations.

Other considerations in market design, beyond the mechanism for trading, were discussed. In particular, setting the regulatory cap on water use is an important step before allowing trading. Markets should also reflect geophysical realities and prevent third-party impacts. Markets cannot function without strong monitoring and enforcement of resource use.

The case study looked at the evolution of groundwater trading in the Twin Platte Natural Resources District in western Nebraska, which has managed groundwater for the purpose of protecting hydrologically connected habitat in the Platte River. The TPNRD has a unique approach of trading area-based groundwater permits, which reduces monitoring and enforcement costs for the TPNRD staff and provides flexibility to groundwater users. However, area-based trading may be economically inefficient. The TPNRD was the first application of a smart market for groundwater trading in the world, reducing transactions costs to market participants and staff time for regulatory approval.

References

Brozovic, N.; Young, R. 2014. Design and implementation of markets for groundwater pumping rights. In: Easter, K.; Huang, Q., eds. Water markets for the 21st century: What have we learned? New York, NY: Springer Dordrecht Heidelberg: 283–304.

Ferguson, R.; Shaver, T.; Ward, N. 2011. Landscape Influences on Soil Nitrogen Supply and Water Holding Capacity for Irrigated Corn. http://watercenter.unl.edu/ResearchDB/publications/Ferguson_Landscape.pdf

Gutentag, E.D.; Heimes, F.J.; Krothe, N.C.; Luckey, R.R.; Weeks, J.B. Geohydrology of the High Plains Aquifer in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming. Retrieved May 2016 from https://pubs.er.usgs.gov/publication/pp1400B

Hathaway, D. 2011. Transboundary groundwater policy: Developing approaches in the western and southwestern United States. Journal of American Water Resources Association. 47(1):103–113.

Johnson, B.; Thompson, C; Giri, A.; Van NewKirk, S. 2011. Nebraska Irrigation Fact Sheet. http://agecon.unl.edu/a9fcd902-4da9-4c3f-9e04-c8b56a9b22c7.pdf

Kuwayama, Y.; Brozovic, N. 2013. The regulation of a spatially heterogeneous externality: Tradable groundwater permits to protect instream flows. Journal of Environmental Economics and Management. 66(2): 364–382.

Laukaitis, A. J. Drought’s toll on groundwater is steepest on record. *Lincoln Journal Star*. Retrieved December 2015 from http://journalstar.com/news/local/drought-s-toll-on-groundwater-is-steepest-onrecord/article_8c3d377d-7dd1-5d11-bdce-7498476a032f.html

Maupin, M.A., Kenny, J.F., Hutson, S.S., Lovelace, J.K., Barber, N.L., and Linsey, K.S., 2014, Estimated use of water in the United States in 2010: U.S. Geological Survey Circular 1405, 56 p., *http://dx.doi.org/10.3133/cir1405*.

McCabe, K. A.; Rassenti, S. J.; Smith, V. L. 1991. Smart computer-assisted markets. Science 254(5031): 534–538.

McCarl, B.; Dillon, C.; Keplinger, K.; Williams, R. 1999. Limiting pumping from the Edwards Aquifer: An economic investigation of proposals, water markets, and spring flow guarantees. Water Resour. Res. 35(4): 1257–1268.

Murphy, J. J.; Dinar, A.; Howitt, R. E.; Rassenti, S. J.; Smith, V. L. 2000. The design of` “smart” water market institutions using laboratory experiments. Environmental and Resource Economics 17(4): 375–394.

Palazzo, A.; Brozovic, N. 2014. The role of groundwater trading in spatial water management. Agricultural Water Management. 145:50–60.

Raffensperger, J. F.; Milke, M. W.; Read, E. G. 2009. A deterministic smart market for groundwater. Operations Research. 57(6):1333–1346.

Steward, D. R.; Bruss, P. J.; Yang, X.; Staggenborg, S.A.; Welch, S. M.; Apley, M. D. 2013. Tapping unsustainable groundwater stores for agricultural production in the High Plains Aquifer of Kansas, projections to 2110. Proc. Natl. Acad. Sci. USA 110(37):E3477–E3486.

Twin Platte Natural Resources District. 2012. Integrated Management Plan. Retrieved May 2016 from http://www.tpnrd.org/nusite/AmendedIMP2013.pdf

U.S. Department of Agriculture. Census of Agriculture Highlights: Irrigation. 2012. https://www.agcensus.usda.gov/Publications/2012/Online_Resources/Highlights/Irrigation/Irrigation_Highlights.pdf

U.S. Department of Agriculture. Economic Research Service. Irrigation & Water Use. Retrieved November 2015 from http://www.ers.usda.gov/topics/farm-practices-management/irrigation-water-use/background.aspx

U.S. Geological Survey. 2013. High Plains Aquifer System. Retrieved May 2016 from http://co.water.usgs.gov/nawqa/hpgw/HPGW_home.html

Young, R. 2014. Tradable permit systems for a spatially heterogeneous externality: A microparameter approach. Retrieved December 2015 from http://hdl.handle.net/2142/50622

Young, R.; Brozovic, N. 2016. Innovations in Groundwater Management: Smart Markets for Transferable Groundwater Extraction Rights. Technology and Innovation, *17*, pp. 219-226.