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Where's the Water?
Using Geospatial Tools to Facilitate Water Wheeling for the Central Arizona Project

by

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Abstract

Long-term drought and changing demands on the Lower Colorado River Basin are driving the development of agricultural water markets. Initiating new markets, for improved efficiency and water resource management flexibility, may require the identification of good information sources, and building of relationships. The objective of the research was to focus on these initial aspects of creating functioning water markets through the use of decision-support tools for attaining basic location, agricultural production and price information for immediate use. Alternative water transfer markets for Colorado River surface water are emerging from a policy proposal called "wheeling." In this Arizona case study, potential applications of the wheeling policy could include the transfer of agricultural surface water from places like Yuma and La Paz Counties in Arizona to municipal and industrial uses in Arizona's urban areas. Geospatial tools such as the U.S. Department of Agriculture's CropScape and the Water Governance Relationship Geodatabase provided the necessary geographic information to target agricultural users, like irrigation districts and tribal lands, for wheeling. Consumptive irrigation requirement (CIR) (feet/year) and the water use value ($/acre foot) characteristics for specific crops allowed identification of a set of target crops within individual agricultural areas for possible transfers. Areas with the highest percentage of target crops were considered the preferred target for making social capital investments in relationship building for possible wheeling policy applications.

Keywords: geospatial, water transfer markets, wheeling, Arizona, CAP

Table of Contents

Table of Contents, *continued.*

Abbreviations and Acronyms

ADWR	Arizona Department of Water Resources
AMA	Active Management Area
AOI	Area of Interest
ATM	Alternative (Water) Transfer Market
CAGRD	Central Arizona Groundwater Replenishment District
CADWR	California Department of Water Resources
CAWCD	Central Arizona Water Conservation District
CAP	Central Arizona Project
CDL	Cropland Data Layer
CIR	Consumptive Irrigation Requirement
CRIT	Colorado River Indian Tribes
CWSD	California Water Supply and Demand Model
FRIS	Farm and Ranch Irrigation Survey
LCRB	Lower Colorado River Basin
MSA	Municipal Service Area
MWD	Metropolitan Water District of Southern California
NASS	National Agricultural Statistical Service
PVID	Palo Verde Irrigation District
PWSWG	Poudre Water Sharing Working Group
USDA	United States Department of Agriculture
WGRG	Water Governance Relational Geodatabase
WMIDD	Wellton-Mohawk Irrigation and Drainage District
YMIDD	Yuma Mesa Irrigation and Drainage District

Where’s the Water?
Using Geospatial Tools to Facilitate
Water Wheeling for the Central Arizona Project

Introduction

Over the last sixteen years, the U.S. Southwest has experienced one of the worst droughts in over a century (CAP, 2014). The drought has diminished stored water in the Colorado River reservoir system, setting the stage for deficit-induced management practices. In addition to drought, water resource development for growing metropolitan centers has steadily changed the region’s water-use profile from traditional agricultural use to modern municipal needs (Luckingham, 1983). It has been suggested by Culp, Glennon and Libecap (2014), that to continue providing water to the communities and farmlands of the region and to abate future water shortages, the Colorado River Basin states need to better enable transfers of water from one user type to another by revising legal policies and establishing market institutions (p. 2-7).

However, what kind of legal policy revisions can achieve this right now? How exactly can water market institutions help communities cope with shortage in the immediate future? According to the Western Governors Association (2012), “[water] markets function best when there is transparent, publicly available information on transactions, including the location and price," (p. 60). But, such transparency in high functioning markets doesn't just appear out of thin air. At the start, finding solutions may require the identification of good information sources and relationship building. The objective of the research was to focus on these initial aspects of creating better functioning water markets with the immediate use of decision-support tools for attaining basic location, agricultural production and price information. The specific context for the research was framed by an alternative water transfer policy proposal called "wheeling" and the social capital investment opportunity this policy could provide. Wheeling, a resource management policy traditionally used in the energy industry, would move Colorado River surface water across the Arizona landscape on existing infrastructure, allowing for the delivery of water to different regions of the state (CAP, 2014).

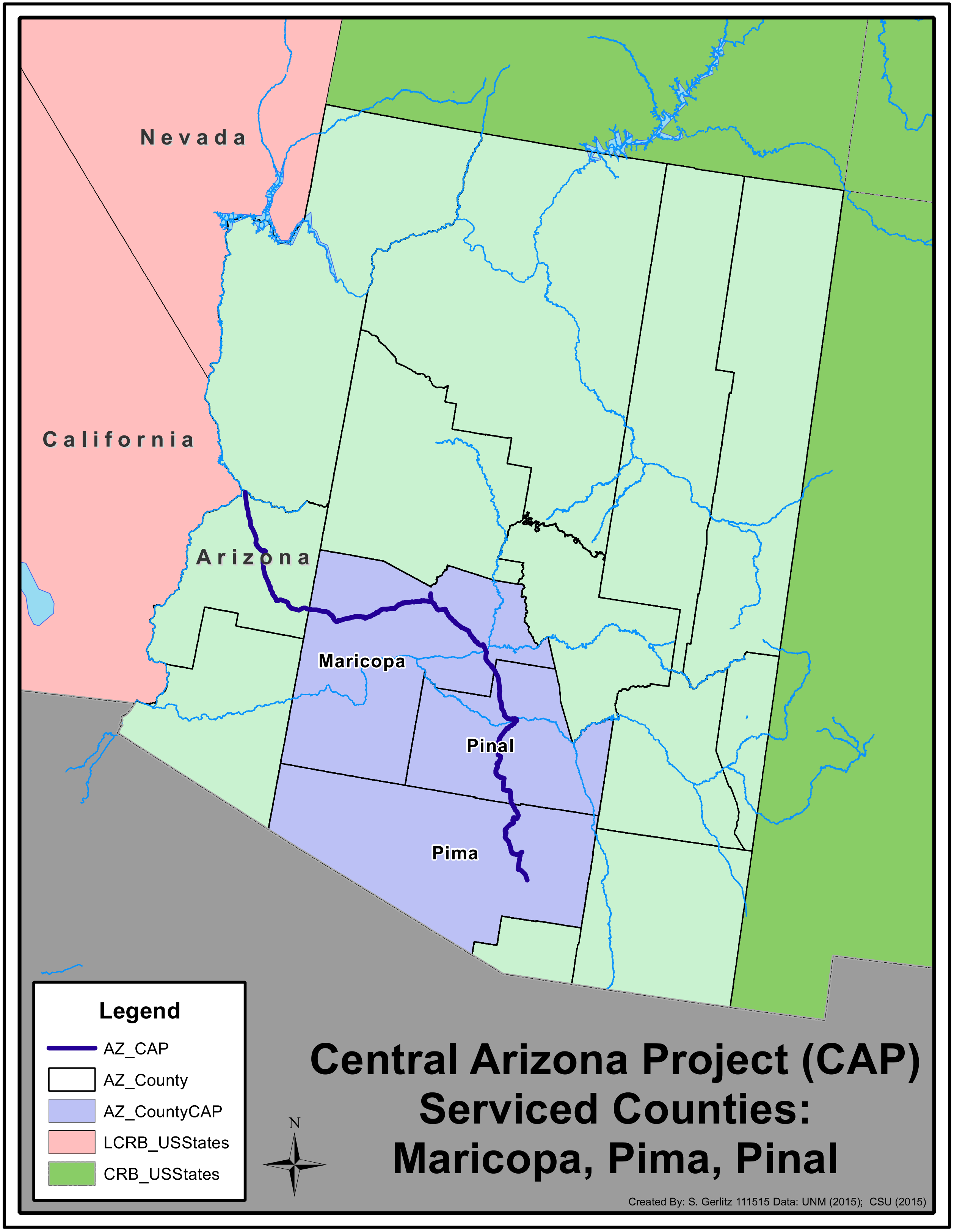
Wheeling involves using a federal water delivery system called the Central Arizona Project (CAP) to transport and deliver "Non-Project" water over 300 miles from the main stem Colorado River to the cities of central Arizona (Fig.1). Non-Project water includes any other water besides CAP deliveries, including additional Colorado River water or imported groundwater (McCann & Seasholes, 2012). This policy was recently proposed by the Central Arizona Groundwater Replenishment District (CAGRD) in a 2015 water plan as a way to address shortage while providing water market options to agricultural and urban communities alike (CAP, 2014; McCann & Seasholes, 2012).

Wheeling water resources can be loosely compared to the 1989 Office of Technology Assessment's description for wheeling electricity: "the use of the transmission facilities of one system to transmit power produced by other entities," (1989, U.S. Congress). This definition, when considered in terms of water transfers, roughly explains the CAP's ability to transfer water from one entity or source to another utilizing existing infrastructure. In terms of social capital investment, finding the right tools to identify locations for potential wheeling water transfers for an entity such as CAP is an important first step in the process.

To identify where to invest social capital for building relationships and initiating water wheeling, this research evaluated a set of publically-available decision supports tools that could aid a potential buyer (i.e., a water lessee, such as a municipality or groundwater district) in the geographic targeting of likely sellers through geographic and agricultural production characteristics. The research was restricted to four decision support tools within two southwestern Arizona counties where potential sellers may be located, and one evolving institutional arrangement—wheeling from on-river agricultural areas to the CAP-serviced municipalities of central Arizona.

The decision support tools included (a) U.S. Department of Agriculture (USDA) National Agriculture Statistics Service's (NASS) web-based platforms CropScape and Quick Stats, with additional information from the USDA 2012 Census of Agriculture and 2014 Arizona Bulletin (USDA NASS, 2015); (b) Geographic Information System (GIS) data from Colorado State University's Water Governance Relational Geodatabase (WGRG) (Laituri, 2014) which was operated in ESRI ArcGIS 10.1; (c) the consumptive irrigation requirements (CIR) (feet/year); and (d) water use values ($/acre foot) for Arizona crops. Sources for CIR and water use values included the 2013 Farm and Ranch Irrigation Survey (FRIS), (USDA NASS, 2014), the California Department of Water Resources 2014 CIR averages (Cooley, 2015), a 1982 report on Arizona CIR (Erie, French, Bucks & Harris, 1981) and the California Water Supply and Demand (CWSD) Model (Ackerman & Stanton, 2011). Data from the four decision-support tools were compiled into a custom Microsoft Excel spreadsheet.

One of the key research findings was the various discrepancies between geospatial results when applying different agricultural datasets to the same area. Cotton was found to be the target crop with the most variability between the datasets and value categorizations. Also, the importance of polycentric water governance was identified in La Paz County, which had less water user groups than Yuma County. La Paz was also identified from the research as the best target for social capital investment based on the defined set of target crops. The research findings also illustrated that the geospatial targeting of crops is critical, because after fallowed and idle cropland is considered, the next phase of water transfers could target agricultural land in production. Knowing where to invest social capital now could help Arizona address Lower Colorado River Basin shortage in the future.



Pg. 7, Figure 1. *CAP serviced counties,* (Gerlitz, 2015).

Background

The Central Arizona Project

Since the mid-twentieth century, population increases and economic development throughout the West have shifted the focus of water resource management from agriculture to municipal planning (Gammage, 2011). The massive population growth in central Arizona provides a prime example of the need to find new or different sources of water for growing cities (Luckingham, 1983; Beard, 2015). In particular, the Central Arizona Project (CAP) surface water deliveries provide the region with a structurally and legally complex water source. The CAP, and its special multicounty water district, the Central Arizona Water Conservation District (CAWCD), has been charged with managing this need (Glennon, 1995). As a water governance institution, the CAP and CAWCD address the challenges of supplying, storing, treating, maintaining, protecting and sharing water for growing populations and competing usage types (Sternlieb & Laituri, 2015; Eakin et al., 2015). The proposed wheeling policy is one part of the larger water planning goals for the CAP, which includes the ability to offer contracts for the long-term delivery of other (Non-Project) water (CAP, 2015).

The self-described mission of the CAP (2015) is to be “the steward of central Arizona’s Colorado River water entitlement and a collaborative leader in Arizona’s water community.” CAP is Arizona's largest water provider, supplying 80% of the state’s population by bringing 1.5 million acre-feet of water from the Colorado River to central and southeastern Arizona each year. CAP water is delivered to over 5 million people residing in Maricopa, Pima and Pinal counties. Structurally speaking, CAP consists of a 336-mile long system of aqueducts, tunnels, pumping plants and pipelines which lift the water over 2900 vertical feet (CAP, 2015).

For over half a century Arizona fought to obtain rights and build a delivery system to transport water from the Colorado River to farms, cities and towns of the central and southeastern parts of the state (Glennon, 1995). Although construction on the project didn't get approval until 1968 under the *Colorado River Basin Storage Act*, the vision for the project was conceived several decades prior (Reisner, 1993). As early as the 1920's, the citizenry recognized the need to import Colorado River water to the region (Zarbin, n.d.). The Bureau of Reclamation completed planning in 1947 when a perfect storm of disagreement broke out as Arizona lobbyists and California congressman contentiously pushed for and against the project (Tarlock et al. 2009). This water dispute led to the 1963 U.S. Supreme Court case, *Arizona vs. California* (Zarbin, n.d.).

The two states had a history of disagreement in regards to the 1922 Colorado Compact (Fig. 2), which over-allocated total available water to each of the seven basin states and Mexico (Reisner, 1993; U.S. Supreme Court, 1963). The 1928 *Boulder Canyon Project* Act allocated 2.8 million acre feet to Arizona and 4.4 million acre feet to California, however California had extensively developed their water sooner than Arizona (Edwards & Hill, 2012). The movement to secure its "rightful share" of the river was thoroughly supported by the majority of Arizonans at the time and was viewed as the way to secure future prosperity (Zarbin, n.d.). The CAP was in a standstill from 1947 until the Court decision in 1963 ruled in Arizona's favor. By approving the construction of the project in 1968, the Court decision and subsequent legislation (*Colorado River Basin Storage Act*) enacted the doctrine of prior appropriation placing Arizona junior to California's senior status for the water rights to the river (Dozier & McCann, n.d.). The first agricultural water deliveries from the CAP began in 1985 however the vast infrastructure system was not fully complete until 1992 with costs upwards of $5 billion making it the largest and most expensive water project ever constructed in the United States (Hanemann, 2002).

With the use of groundwater traditionally supporting regional agriculture, under its initial inception the CAP was designed to help alleviate aquifer depletions and was designated for farmers (Zarbin, n.d.). However, the project's costs and non-subsidized water rates were a disincentive for agricultural use, and has lead to the distribution of project water to municipal and industrial uses (Reisner, 1993; Hanneman, 2002). Rapidly urbanizing Maricopa County, in particular, has seen a decline in irrigated agriculture over the last hundred years (Fig. 3) consistent with predictions made by William E. Martin and others (Young, R.A. & Martin, W.E., 1967; Martin, W.E., Ingram, H. & Laney, N.K., 1982; Martin, W.E., 1988) in the decades prior to CAP completion (Hanneman, 2002; USDA NASS, 2012).

The trend of decreased agricultural use and the dedicated municipal use of CAP water is likely to continue (CAGRD, 2014; Western Governors Association, 2012). According to a study from the W.P. Carey School of Business at Arizona State University (ASU), the top five sectors of Arizona's economy that have benefited the most from the CAP include: government, healthcare, real estate/travel, finance/insurance & retail, which lie in stark contrast to the project's original agricultural intent (James, T. Evans, A. & Madly, E., 2014). This ASU study suggested that the CAP has generated $1 trillion of Arizona's gross state product (GSP) from 1986 to 2010 and currently accounts for one-third of annual GSP (James et al., 2014). This regional economy supports more than 5 million people. With more than 80% of the state's population living in the CAP-serviced counties of Maricopa, Pima and Pinal, the water market will continue to adapt and reflect these changes (CAP, 2015). For smaller cities of the CAP, including municipalities within the Central Arizona Groundwater Replenishment District

(CAGRD) Municipal Service Areas (MSAs), the changes in the water market brought forth from wheeling could provide more options for water resource managers.

Wheeling Policy in Arizona

History of wheeling policy development. Since 2012, the CAP and its governing entity, the CAWCD, have been actively planning for the contractual and structural needs for a wheeling-based alternative transfer market. Traditionally used in the energy industry, wheeling would move surface water across the Arizona landscape on existing infrastructure, delivering water to different regions of the state (CAP, 2014). Wheeling involves using the CAP system to transport and deliver "Non-Project" water. Non-Project water includes any other water besides CAP deliveries including additional Colorado River water or imported groundwater (McCann & Seasholes, 2012). Wheeling was first considered as a long-term solution for supplying water to the region in 1983 and was authorized in 1988 under the *1988 Master Repayment Contract* (U.S. Bureau of Reclamation, 1988). The *1988 Master Repayment Contract* is between the Bureau of Reclamation and the CAP, however it (including the wheeling-specific provisions) has yet to be fully authorized. Currently, CAP is working to resolve the legal, financial and operational issues related to how this contract applies to wheeling (McCann & Seasholes, 2012). The desired outcome is for CAWCD to be able to offer contracts, with the approval of Reclamation, for the long-term reliable delivery of Non-Project Water, thus increasing the delivery capacity of the CAP system (CAP, 2015).

The backbone and underlying statutes as well as the contentious uncertainties of the recent wheeling policy developments are found in the *1988 Master Repayment Contract* (See Appendix A) under Sections *8.17 (Rights Reserved to the United States to Have Water Carried* *by Project Facilities* and *8.18* (*Wheeling Non-Project Water),* (McCann & Seasholes, 2012; Reclamation, 1988). These sections contain the key issues that must be first resolved, which include: availability of project capacity (*8.18*), federal rights in water transportation (*8.17*) and the identification and quantification of additional capacity associated with system improvements (McCann & Seasholes, 2012). The subsequent stakeholder meetings, which were held in 2014, started to develop solutions to these issues.

Stakeholder meetings. The first stakeholder meeting was held in March 2014 and reintroduced the baseline elements of the policy. As defined in a presentation by Seasholes (2014), "wheeling contracts are tied to a specific supply, with a defined volume and duration, issued to a user that has satisfied all regulatory requirements." Regulatory approvals were included in the language to limit speculative activity and to assure public review and oversight. Wheeling costs as determined in the third stakeholder meeting held in May 2014, were vague, which prompted a response from different stakeholder groups including the Arizona Municipal Water Users Association (CAP, 2014). During this stage of the meetings, a review of the policy language found that the associated costs could heavily burden the initial wheeling policy users. Infrastructure costs (including pumping plant improvements, new spillway construction and canal lining), water quality mitigation, system losses, energy sources and CAWCD Board review were areas for concern (Seasholes, 2014).

The CAP staff have since responded to the stakeholder's concerns and clarified their positions in the *Major Elements of the CAP Staff Proposal for Wheeling Non-Project Water* (See Appendix B) document from September, 2014 (CAP, 2014). This document provides the policy assumptions on which the research was conducted and designed (See Appendix B). The key element being that until Reclamation approval is granted, the certainty needed to design this research to a specific wheeling contract was not feasible.

Major elements for wheeling Non-Project water. The first consideration for wheeling proposals is the capacity of the CAP system. Specifically, any delivery capacity increases to the system will include necessary improvements and requires review from Reclamation. The review from Reclamation will determine how much capacity and in turn the CAP-arranged contracts will be tied to the capacity volume deemed appropriate under the review, all of which are based on the original *Contract* (CAP, 2014). The capacity issue is critical to wheeling because in a shortage situation, the ability to transport water on CAP infrastructure could become a feasible solution when project-water is unavailable. In contrast, with full-delivery of CAP project water, the capacity for wheeling on the existing infrastructure would merit federal review.

The staff proposal also emphasized that all costs are to be paid by the wheeling parties and collected through an up-front fee with annual rates tied to specific system improvement projects. Other costs paid for by a wheeling party also include: current market energy rates (pumping-plants), turn-in design, construction and equipment costs, water quality impact analysis, water quality monitoring equipment and testing, water metering and telemetry as well as legal and administrative review costs. Some of these costs are only applicable to certain sources of wheeling-water, such as imported groundwater (Seasholes, 2014).

The wheeling contracts are open to all parties including Tribes within Arizona and will be tied to specific intrastate transfers of legal and physical water supplies. Duration of the contract, especially for long-term leases, and the number of parties contracting that specific supply can be flexible and are not specified by the CAWCD review. Contracts can be modified and transferred to another party as long as an “Intent to Contract” agreement specifies time and performance-based benchmarks to secure regulatory approval. Approval includes environmental approvals, like NEPA, as well as existing CAP processes for attaining public feedback. Basic operation details include a 5% system loss factor, state-administered water quality standards and the ability to purchase alternative energy, although the CAWCD has deemed those purchases an unrealistic option at this time (CAP, 2014). The major assumption that can be made under the current policy language is that for Non-Project, main stem Colorado River surface water and for the potential alternative transfer market development, the consent of the Arizona Department of Water Resources (ADWR) and Reclamation is required (Seasholes, 2014).

Recent developments. As of February 2016, wheeling has been incorporated into a draft *CAP System Use Agreement* (CAP, 2016). The agreement will create "new flexibility" in the use of the CAP canal to benefit water users in CAP's service area. This development is important because the internal CAP wheeling policies and operations could provide a framework from which wheeling could be expanded into Yuma and La Paz counties (CAP, 2016).

Central Arizona Groundwater Replenishment District (CAGRD) Proposal

Draft proposals for wheeling water transfers have been developed over the last three years for the CAGRD Active Management Areas (AMAs) of Maricopa, Pima and Pinal counties with mention in its *2015 Plan of Operation* (CAGRD, 2014). Policies like wheeling could help entities, such as the CAGRD, develop a more robust water market for Arizonans. A robust water market is based on the premise that if senior water rights holders have more options to lease or sell, and buyers have more market choices, mutually beneficial arrangements will occur (Easter & Huang, 2014). Potential wheeling partners include twenty-two municipal water providers located throughout the Phoenix, Pinal and Tucson AMAs (Table 1) (CAWCD, 2013).

For these municipalities, CAGRD has focused on surface water within their own regional irrigated agriculture, which could be transferred, leased or fallowed. However, the *2015 Plan* developed a pilot fallowing program that wheeled unused main-stem, Non-Project Colorado River water to CAP-serviced AMAs (Fig. 4). The CAGRD developed this program with the Yuma Mesa Irrigation and Drainage District (YMIDD), geographically separate from the CAGRD, located in the southern Arizona county of Yuma (CAP, 2014). This pilot program provided a trial implementation for wheeling outside of CAP governance however it’s details and outcomes were not considered further for this research. Instead, the research focused on the preliminary steps necessary to find a water market scenario where wheeling could occur.

Water Transfer Markets

The term water market refers broadly to all market-based reallocation mechanisms, including water transfers (Easter & Huang, 2014). A water transfer is the sale or lease of the right to divert a certain amount of water. Typically, a water transfer takes the form of a voluntary agreement that results in a temporary or permanent change from one entity or user to another, a change in location or a change in type of water use (Western Governors Association, 2012). Formal and informal water transfer markets are utilized in the Southwestern U.S. and include permanent transfers, a water market-based sale of a water right, and temporary transfers, a water market-based lease for the water. Both types of transfers redistribute or reallocate the water right (Easter & Huang, 2014).

Formal markets enable transfers across large geographic areas and are governed by state and federal laws and rules. Limitations of formal markets include large upfront costs for infrastructure, including canals and control structures (Easter & Huang, 2014). In contrast are informal markets, which develop locally to allow the trade of water among neighboring farmers and are operated based on rules informally developed at the community level. Trade of water is more immediate, such as for the use of water the next day, week or irrigation turn. These types of markets can be used to allocate water without large investments in management or infrastructure yet they are very limited in scope and do not involve the exchange of water over a very large area or among different sectors (Easter & Huang, 2014).

All twelve western states including the Lower Colorado River Basin states of Arizona, Nevada and California, have used water transfers to address water shortages (Western Governors Association, 2012) but not as readily as one might expect (Culp et al., 2014). The legal framework and price variability were noted by Culp, Glennon and Libecap (2014) to hinder the development of water transfer markets however, the proposed wheeling policy could help change some of these challenges to market development. The CAGRD pilot-fallowing program with YMIDD could be considered as an alternative to the traditional formal and informal water transfers markets.

Alternative transfer markets (ATMs). Alternative transfer markets (ATMs), are a "suite of tools, like leases, rotational fallowing, split-season uses, and water banks…that…avoid the permanent dry-up of agricultural land," (Western Governors Association, 2012, p. 1). ATMs are increasingly being used to mitigate scarcity situations, like the current U.S. Southwest drought, and are useful throughout the entire Colorado River Basin. For example, the Palo Verde Irrigation District (PVID) in Southern California entered into a fallowing agreement with the Metropolitan Water District of Southern California (MWD) in 2009 (PVID, 2015). This program provided an array of compensation options for farmers with the resulting water savings transferred to MWD for urban use. Options included market value payments per acre fallowed and additional compensation per acre of water transferred. These options provide farmers with a revenue stream and risk mitigation while providing reliable delivery for municipalities (Culp et al., 2014). Another example includes ATMs for the Upper Colorado River Basin developed by the Poudre Water Sharing Working Group (PWSWG). The group's 2015 report assessed the possibility of water transfers from irrigation companies to domestic water providers. The PWSWG focused on methods that allowed farmers to lease water temporarily to cities while keeping ownership of the water in agriculture. They found specific techniques like changing to crops that require less water, fallowing land and deficit irrigation were applicable for ATM development (PWSWG, 2015).

Based on similar techniques as those used in the Colorado River Basin, researchers Bjornland and Rossini (2010) found that water markets in Australia have allowed irrigators to achieve the highest possible return from declining resources while reducing economic hardship, ultimately managing drought situations. One way this was achieved was by moving water from lower valued crops (rice) to crops with more flexible irrigation demands and higher return value (fruit trees). Agricultural use is the dominant water use in the U.S. Southwest, making the value of crops important to market developments. According to works published by Easter and Huang (2014), ATMs have potential gains over spatial and temporal allocation inefficiencies and allow for societal gains through the changes in the perceived or actual value of a particular water use. All three examples illustrate how alternative water markets "provide maximum flexibility in responding to changes in agriculture," (Easter & Huang, 2014, p. 45) which in turn can allow for a robust market where wheeling-based water transfers can develop.

Social Capital

However, the proposed wheeling policy is not only dependent on water market flexibilities, but is also dependent on having wheeling parties or partners involved and directing the process. At present, the CAWCD (which includes CAGRD) has working relationships throughout the CAP serviced areas of central Arizona as well as federal agencies involved with Lower Colorado River Basin (LCRB) water governance. To wheel Non-Project water from different regions of the LCRB, knowing which parties or partners to target is just as essential to the process as calculating water volumes and land values (Willardson, 2014). According to City of Phoenix water resource representative Kathryn Sorensen, "having relationships helps you have conversations when you want new solutions," (Walton, 2015). Furthermore, Ostrom (2009) suggests that "cheap talk," i.e. informal face-to-face communication, promotes cooperation and creates joint strategies for those involved in the decision-making process.

To build relationships through "cheap talk" and to find new solutions for the emerging water market, the engagement and empowerment of existing water users through consent and compensation is essential (Easter & Huang, 2014). According to authors from Easter and Huang (2014), "this provides a starting point from which a market can begin to efficiently allocate the resource to its highest-valued use," (p. 44). Thus, initiating relationships in order to engage potential wheeling partners could be considered an investment in social capital.

A breadth of literature has been devoted to defining social capital across the disciplines of social science and economics and has been applied to the interdisciplinary nature of water resource issues (Castle, 2002). As defined by Woolcock (2001) in Castle (2002), social capital is "the norms and networks that facilitate collective action," (p. 334). The combination of geographic and economic information when coupled with supportive actions is considered by

Eakin et al. (2015) as social capital. This definition of social capital promotes the use of shared values, trust and leadership to organize and effect change, particularly for facilitating water transfers (Castle, 2002). In other words, social capital, and the investment in it, includes building social relationships between individuals and communities alike (Barnes-Mauthe et al., 2015).

For socio-ecological systems like water resources, social capital is important because those who have a greater extent or diversity of relationships can be in a position to influence the process (Barnes-Mauthe et al., 2015). For the emerging water transfer markets, Castle (2002) suggests social capital can be used as a diagnostic tool to determine the potential of a rural area to achieve a specific objective. In this case, the objective is to find mutually beneficial wheeling partners. Eakin et al. (2015) noted the mutual need for farmers to build social capital in order to actively shape their communities instead of just reacting to policies developed for them. Wheeling could provide the flexibility in the Arizona water transfer market needed to allow social capital investment both from municipalities to agricultural regions and vice versa.

Institutions & Water Governance

How and where to finding wheeling partners as a means to invest in social capital. In order to understand the social capital landscape of potential wheeling partners in Arizona, it is important to understand the institutional arrangements of the region. Since social capital can be assessed by the structure of ones' social network, assessing the structure of water governance institutions is an important element of the social capital investment process (Barnes-Mauthe et al., 2015). An institution can be defined by "the formal and informal rules and norms that govern actors, resources and their interactions in any given situation," (Eakin et al., 2015). Elinor Ostrom (2011) defined institutions as "the rules that humans use when interacting within…structured situations," (p. 3). According to Grafton, Landry, Libecap and O'Brien

(2009), having the appropriate institutional and legal framework for a water transfer can successfully change the designation of water to a higher value application.

Three basic types of water governance regimes and the institutional arrangements which support them have been reviewed for the application to the CAGRD case study: a state, or hierarchical regime (Bromley, 1992), a common-pool regime (Ostrom, 2011) and the polycentric framework under which multiple regimes operate (Sternlieb & Laituri, 2015). Water governance regimes are based on the concept of "property" (i.e. water rights) as not an object for ownership but a benefit, or income stream (Bromley, 1992). The ownership or control of the benefit stream is dictated by a system of authority, or regime. The regime is a reflection of how individuals interact with one another in regards to the specific property (Bromley, 1992).

Under the institutional arrangement of the state property regime, the "top-down" direction of the U.S. Bureau of Reclamation has been the predominant water governance structure for the CAP, acting as an intermediary between individual water users and federal water projects (Benson, 2013). This is common to irrigated agriculture in the Western U.S. (Benson, 2013). Water governance can also be categorized under a common-property regime (Ostrom, 2011). In this regime structure, water is a common-property, non-excludable and a public benefit stream (Bromley, 1992; Fernald et al, 2012; Ostrom, 2009). Examples include fishery co-ops (Wilson et al., 1994), forest harvesting communities (Ostrom, 2011) and in terms of water resources, the acequia system of irrigated agriculture of the U.S. Southwest (UNM School of Law & The Utton Center, 2013).

For the proposed wheeling policy for the CAGRD, both of these regimes are interwoven throughout the CAP. These regimes play into the polycentric framework of the LCRB. Ostrom (2009) has defined the polycentric regime as having "many centers of decision-making that are formally independent of each other," which can be viewed as "an interdependent system of relations," (p. 411). This definition supports the geographic theory on urban areas that proposes that the water governance institutions of cities cannot be strictly defined as individual entities, but as a "system of cities" (Ernston et al., 2010). Sternlieb and Laituri (2015) discuss the differences in governance patterns specifying the differences between hierarchical structures of polycentricism and traditionally nested or internal systems of governance (Fig. 5). Their geospatial research has visualized the polycentric nature of the entire Colorado River Basin across multiple scales of water governance and throughout all types of institutional arrangements (Sternlieb & Laituri, 2015).

The polycentrism found throughout the LCRB and CAP could allow the wheeling policy to navigate throughout the multi-layered institutions and governance systems as well as the different property regimes. For example, the CAGRD water governance has the following institutions: Reclamation, ADWR, CAP, CAWCD, AMAs, Irrigation Districts, Counties, Municipal Service Areas (MSAs) and Tribes (Fig 6). The institutional norms and property regimes of each individual governance unit could be streamlined under the existing wheeling language albeit, Reclamation approval is granted (Seasholes, 2014). Contracts made between wheeling partners could cross the aforementioned institutional barriers and governance boundaries currently found in Arizona (Sternlieb & Laituri, 2015). First identifying the governance structures, with the use of geospatial tools, could aid development of alternative water transfer markets across the social capital landscape.

Decision-Support Tools

In the Western U.S., water resource managers are embracing geospatial tools to perform a variety of research analyses to develop policies. In particular, the Western States Water Council promotes the use of satellite monitoring systems and geospatial data to inform decision-making (Willardson 2014). The quantification and identification of agricultural and urban water demand, estimating water use and monitoring commodity market fluctuations can be conducted using geospatial tools such as satellite imagery, thermal infrared imaging and other geoprocessing technologies (Willardson 2014). Creating transparency and access to this sort of information is essential for water market development. However, a steep learning curve often exists to access, as well as operate these technologies, creating barriers for non-experts (Braden et al., 2014). To enable the use of geospatial tools for water transfer policies like wheeling, McInery and others (2014) argued that the tools should be catered to the user group(s) while being able to visualize the interwoven science and policy of water resources (McInery et al., 2014).

USDA NASS CropScape. Fortunately, geospatial tools are becoming more publicly available to a range of skill levels. One such tool is a remote sensing derived, web-based GIS program called CropScape (USDA NASS, 2015). Created by the U.S. Department of Agriculture (USDA) National Statistics Service (NASS), this tool provides agricultural cropland cover data for all forty-eight conterminous states with data ranging from 1997 to 2014 (Craig, 2010). As explained by Han, Yang, Di and Mueller (2012), addressing the difficulties of finding and operating geospatial tools were considered in the development of CropScape: "CropScape uses intuitive building of the end user's skills and experiences to design a user interface that is effective for both beginners and advanced users" (p. 112).

Cropland cover for a specific location, called the area-of-interest (AOI), can be generated from this program. The AOI is available for the forty-eight contiguous states, by federal agriculture district or county and can be defined by the tool operator. CropScape provides geospatial data layers by year and crop type, creates spreadsheets and draws simple user-friendly maps and charts (Boryan et al., n.d.). The data is rooted in remote-sensing technology and traditional ground survey verifications (Craig, 2010). All types of land cover data are obtained from satellite images by automatic classification or photo-interpretation. Area, by crop identification code, is estimated by simply measuring the area covered by each land cover class (Gallego, 2004). Primary geospatial data output for these measurements are in pixelated form and defined as "pixel count." The total pixels per cropland cover code are then converted to an estimated acreage.

The advantage of CropScape is its compatibility with other geospatial tools such as Google Earth, Q-GIS and ESRI ArcGIS (Han et al., 2012). CropScape's ability to generate agricultural data by specified AOI for the desired temporal period was the key component for this research project. Perrone and Hornberger (2012) point out "knowledge of the details of changes in irrigated land provides information useful for exploring more effective water management strategies," (p. 1). This supports the utilization of CropScape to generate a foundation from which water resource policy dialogue can begin. Braden and others (2014) found that to address water issues and problems including policies like wheeling, broad community access to natural and social system scientific data is essential. All potential wheeling partners, including mangers, planners, elected officials and farmers need accessible technology to make and implement water resource management decisions regardless of the scale of use (Eakin et al., 2015).

USDA NASS Quick Stats vs. state specific data. The web-based program called Quick Stats is publically available from the USDA and is used to access a large collection of data, analysis, and statistics (USDA NASS, 2015). Located within the USDA's Research, Economics and Education section, Quick Stats aids the department's mission to develop "sustainable, competitive … as well as strong communities… through integrated research, analysis, and education," (USDA NASS, 2015). Quick Stats is designed to provide census data and/or surveyed agricultural estimates as broad or as specific as needed (USDA NASS, 2015). Housed under five sectors (i.e. Animals and Products; Crops; Demographics; Economics; Environmental), Quick Stats builds queries of the agricultural census and survey statistics based on the simple filtering rules of What, Where, and When (USDA NASS, 2015). However, individual, state-specific reports are an easier resource to locate and glean the same information from. Annual state-based statistical bulletins, like the *2014 Arizona Bulletin*, provide overviews for the specific region including individual counties, drawing from the same sources as the Quick Stats program but in a more user-friendly format.

Consumptive irrigation requirement. Consumptive Irrigation Requirement (CIR) was the physical metric used for targeting social capital investment. CIR, for the purposes of this research, is a combination of different agriculture terms typically used in the development of irrigation schedules (Erie et al., 1981). Consumptive use is defined by Erie et al. (1981) as, "the unit amount of water used on a given area in transpiration, building of plant tissues, and evaporation from adjacent soil" (pg. 2). Another term pertaining to the use of CIR is irrigation water requirement. Erie et al., (1981) defined irrigation water requirement as "the amount of water necessary for a particular crop's consumptive use (consumptive water requirement)," (pg. 3). However, CIR was clearly defined by Pochop and others (1992) as "the consumptive use requirement of a crop minus precipitation" (pg. 2) and is the chosen definition for this research. CIR data was collected from three sources including the 2013 Farm and Ranch Irrigation Survey (FRIS) (USDA NASS, 2014, Table 36), a 1982 report for Maricopa County, AZ (Erie et al., 1981) and the California Department of Water Resources (CADWR), (Cooley, 2015).

Water Governance Relational Geodatabase. A Colorado River Basin specific geodatabase was assembled by Laituri in 2014. The Water Governance Relational Geodatabase (WGRG) provides another "geospatial method to examine the governance of water resource use by sector" and across scientific disciplines (Sternlieb & Laituri, 2015, p. 52). Collins and Law (2013) define a geodatabase as "a database or file structure primarily used to store, query, and manipulate spatial data. Geodatabases store geometry, a spatial reference system, attributes, and behavioral rules for data," (p. 729). This geodatabase was developed to understand the institutional structure for the basin including physical, geopolitical, legal and cultural boundaries (Sternlieb & Laituri, 2015). This geodatabase can also examine all the water governance institutions in the basin as well as provide a range of qualitative and quantitative data (Attachment 3).

The ESRI ArcGIS 10.1 platform is commonly used for geoprocessing both for the WGRG and CropScape data. Geoprocessing is the operation of a GIS to manipulate GIS data which in turn "helps define, manage, and analyze the information used to form decisions," (Collins & Law, 2013, p. 730). Although, not a totally unrestricted software tool, the variations of ESRI ArcGIS can be sourced on the web through its online program ArcGIS Online and from other open-platform sources such as Q-GIS, AZGEO, Google Earth, etc. (Collins & Law, 2013, p. 148). The WGRG decision-support tool was used to delineate the agricultural water governance boundaries (counties, irrigation districts, Tribes, etc.) in southern Arizona for social capital investment (Fig. 7).

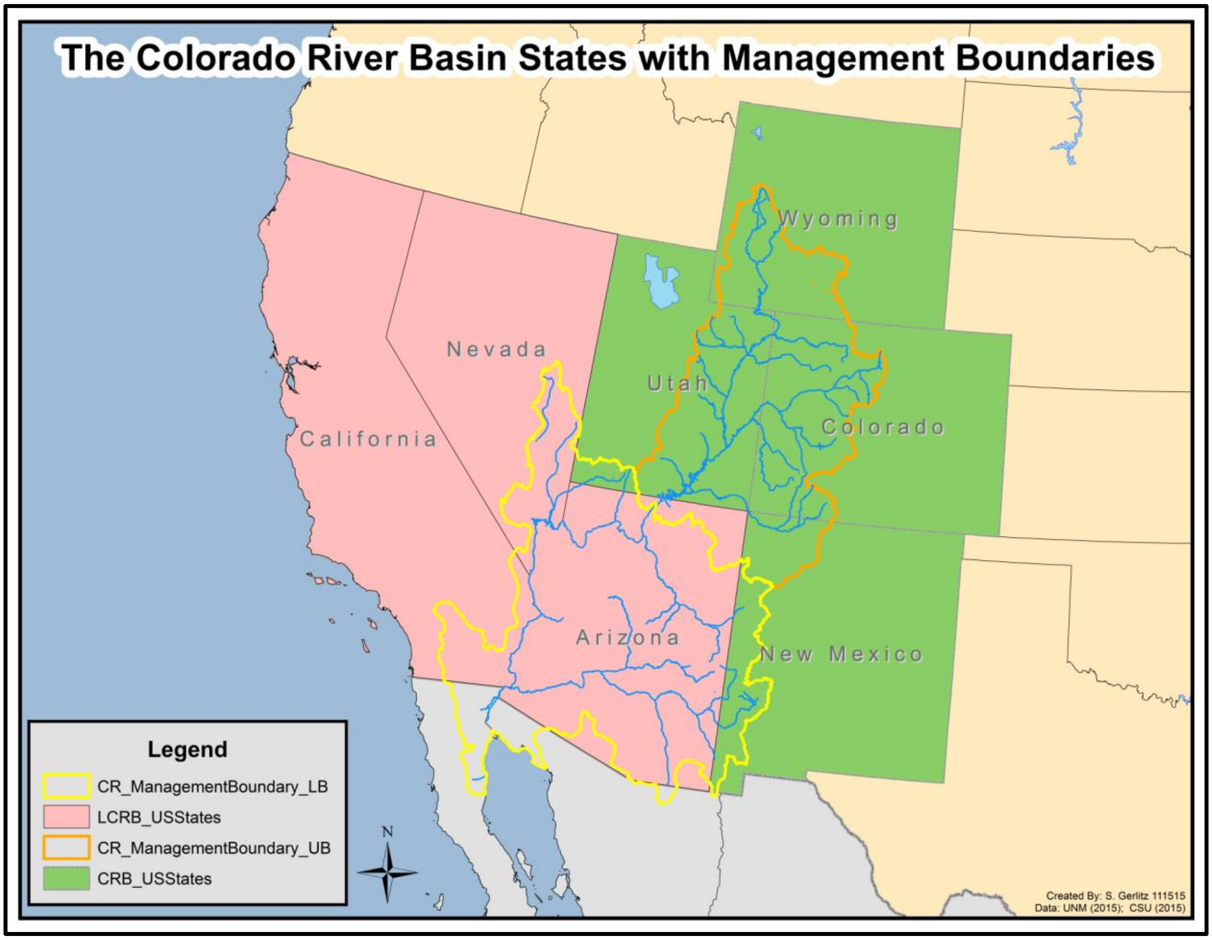
California Water Supply and Demand model. Social capital investment, and the search for where to invest for wheeling purposes, focused on low-valued, highly consumptive agricultural uses. The use of regional values of crops per water unit provided the low-valued economic aspect to the social capital investment locational search while seasonal rates of CIR isolated the highly consumptive crops. Specifically, the California Water Supply and Demand Model (CWSD) output for Arizona was used to provide average water values by crop type to reflect the agricultural water values available for alternative water transfer markets. The values as seen in Table 2, are based on a model, developed for California, from Stanton and Fitzgerald (2011) at the Stockholm Environment Institute-U.S. Center (Stanton & Fitzgerald, 2011).

The model was developed to examine how climate change could affect California’s water supply and demand, in economic terms, and focused on the energy, agriculture and urban sectors (Stanton & Fitzgerald, 2011). Specifically for this research, the Arizona values were pulled from a supplementary model developed for Western states that was based on the original CWSD model assumption that “crop and animal water use by county is a function of projected summer temperatures by county,” (Stanton & Fitzgerald, 2011, p. 4) and that water can be transported without cost, within the state. The latter assumption is akin to the most basic element of wheeling in Arizona, which is that the costs of water transport are unknown at this point in the policy development.

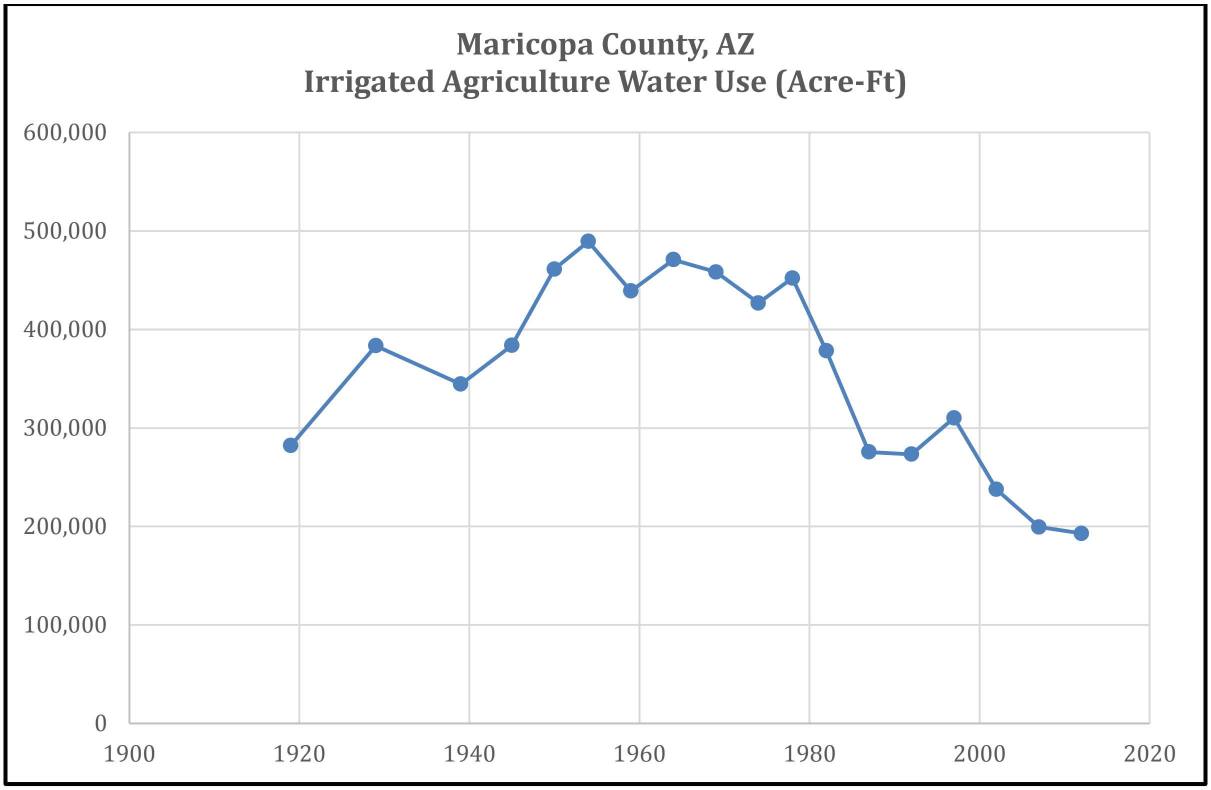
Furthermore, the model was designed with the economic measuring unit by county, with data accrued from the USDA NASS Quick Stats 2007 Census output (Ackerman & Stanton, 2011). These values were converted into the 2014 consumer price index for the research. The model’s use of the county as the smallest unit of measurement is advantageous to this research and the institutional arrangements of the wheeling policy as the county is the largest unit of water governance to be examined. Additionally, the customization of crop values by individual states is beneficial for capturing the regional agriculture, which is inherently different throughout the Colorado River Basin and the U.S. Southwest (Stanton & Fitzgerald, 2011).

The original model estimated water use for 27 irrigated crop categories and five livestock categories in California (Stanton & Fitzgerald, 2011), however in Ackerman & Stanton's (2011) analysis, average values for ten grouped crop categories for the Southwest and California, and even further specificity for the Western states were developed (Table 2). Arizona has eight crop categories and an average for all crops available from the model (Ackerman & Stanton, 2011). Furthermore, economic value determination methods from Gleick, Cooley and Groves (2005) classified major crops into four broad categories: Field, Vegetable, Orchard, Vineyard (Gleick et al., Appendix 2, p. 2) These classifications were further considered in Groves, Maytac and Hawkins's (2005) definitions for effective crop water use. In Groves et al. (2005), which was later applied to the CWSD model (Ackerman & Stanton, 2011; Stanton & Fitzgerald, 2011), high value crops were considered all truck crops, trees, vines; while low value crops included grain, rice, cotton, sugar beets, corn, safflower, dry beans, other field, pasture and alfalfa (p. 68).

Pg. 13, Figure 2. *1922 Colorado Compact states*, (Gerlitz, 2015).



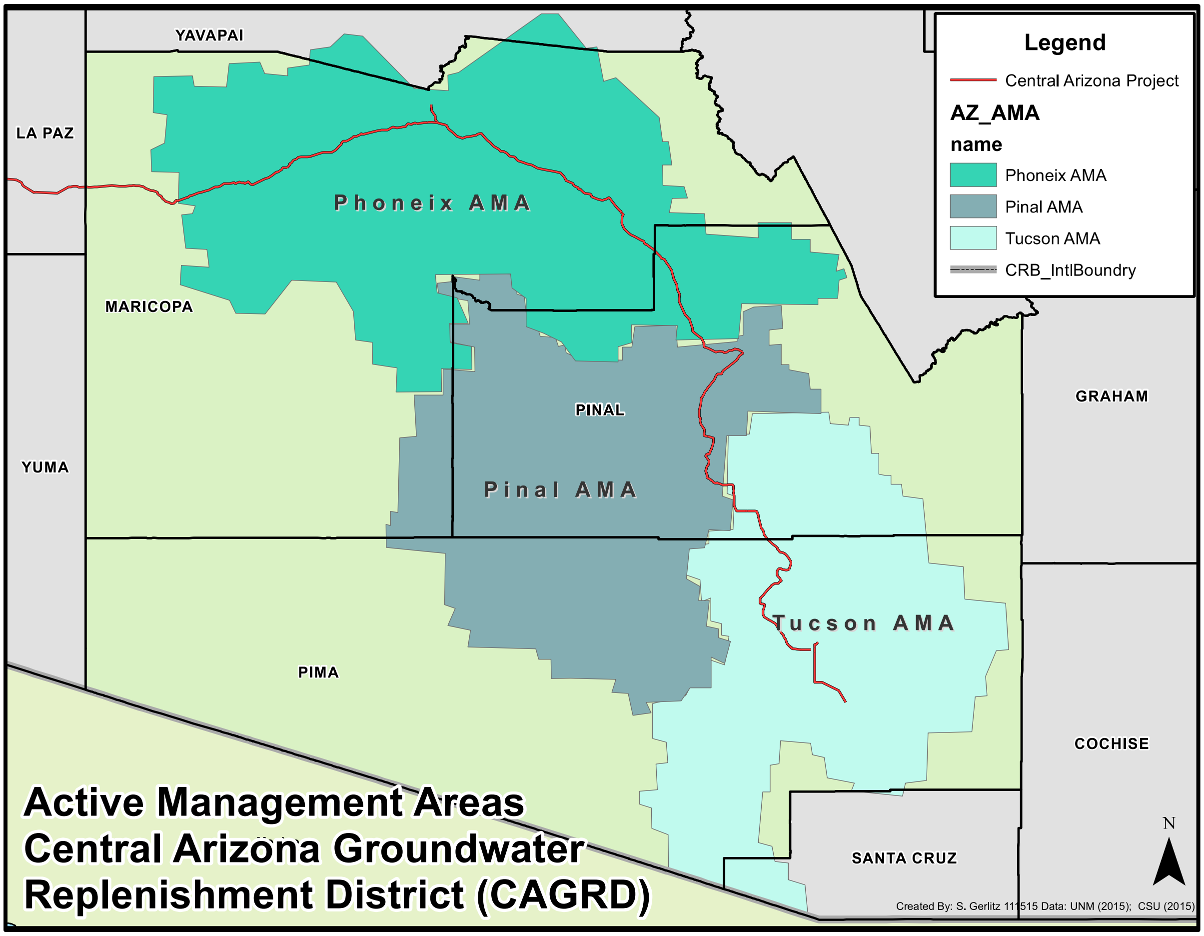
Pg. 14, Figure 3. *Irrigated agriculture, Maricopa County, AZ*, (Adapted from Fleck, 2015).



Pg. 19, Table 1. *CAGRD municipal water providers by Active Management Area,* (Gerlitz, 2015).

PHOENIX AMA	PINAL AMA	TUCSON AMA
City of Avondale	City if Casa Grande	City of Tucson
Apache Junction WUCFD	City of Eloy	Sahuarita Water Co.
City of El Mirage	Johnson Utilities, LLC	Flowing Wells Irrigation District
City of Goodyear	Town of Florence	Spantial Trail Water Company
Chaparral City Water Co.		Metropolitican Domestic Water Improvement District
City of Surprise		Town of Maran
City of Scottsdale		Town of Oro Valley
Johnson Utilities,LLC		Vail Water Co.
Town of Gilbert		Willow Spring Utilities, LLC

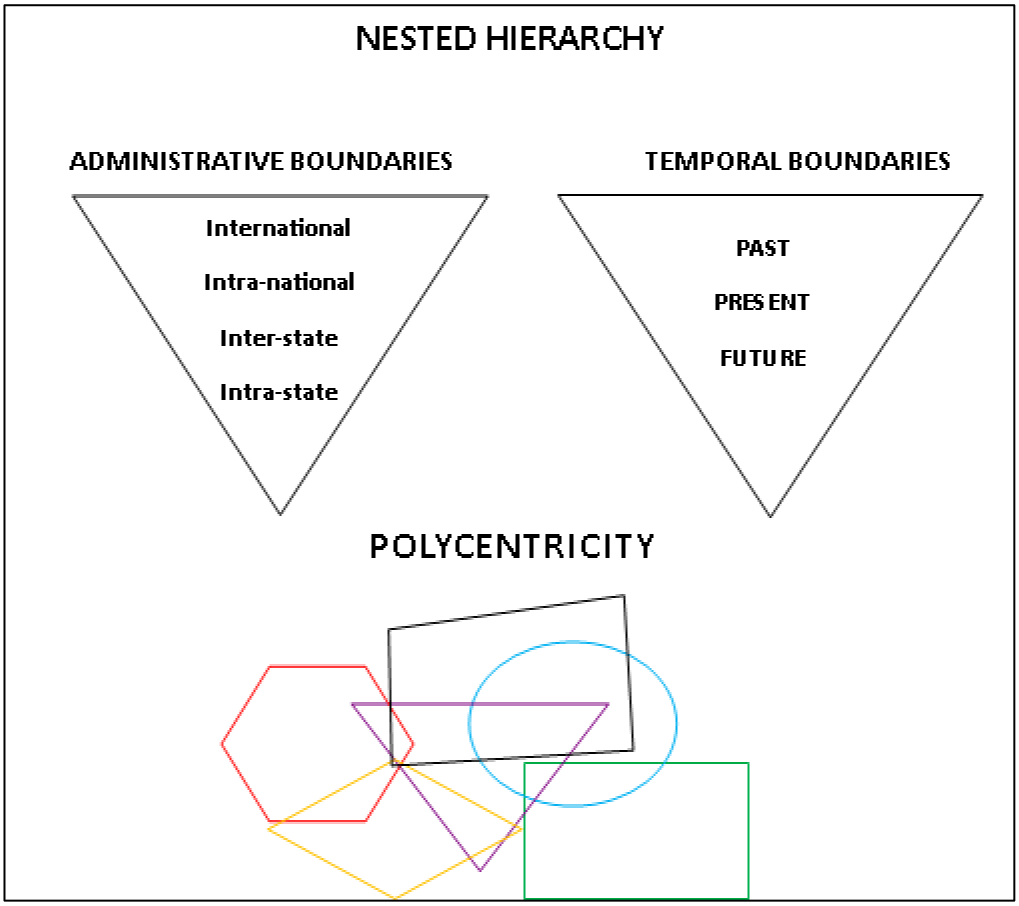
Pg. 19, Figure 4. *CAGRD Active Management Areas*, (Gerlitz, 2015).



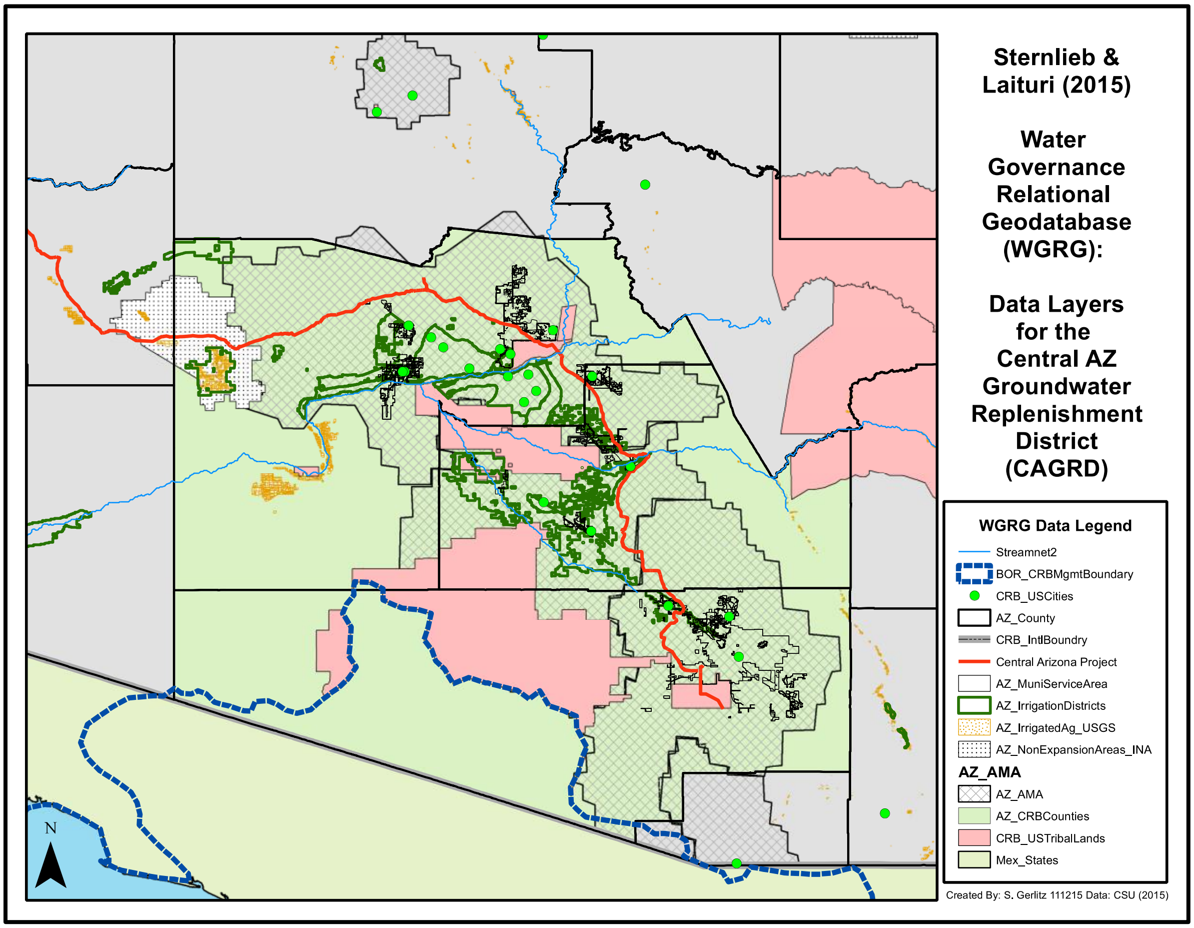
Active Management Areas
Central Arizona Groundwater
Replenishment District (CAGRD)

Created By: S. Gerlitz 111515 Data: UNM (2015); CSU (2015)

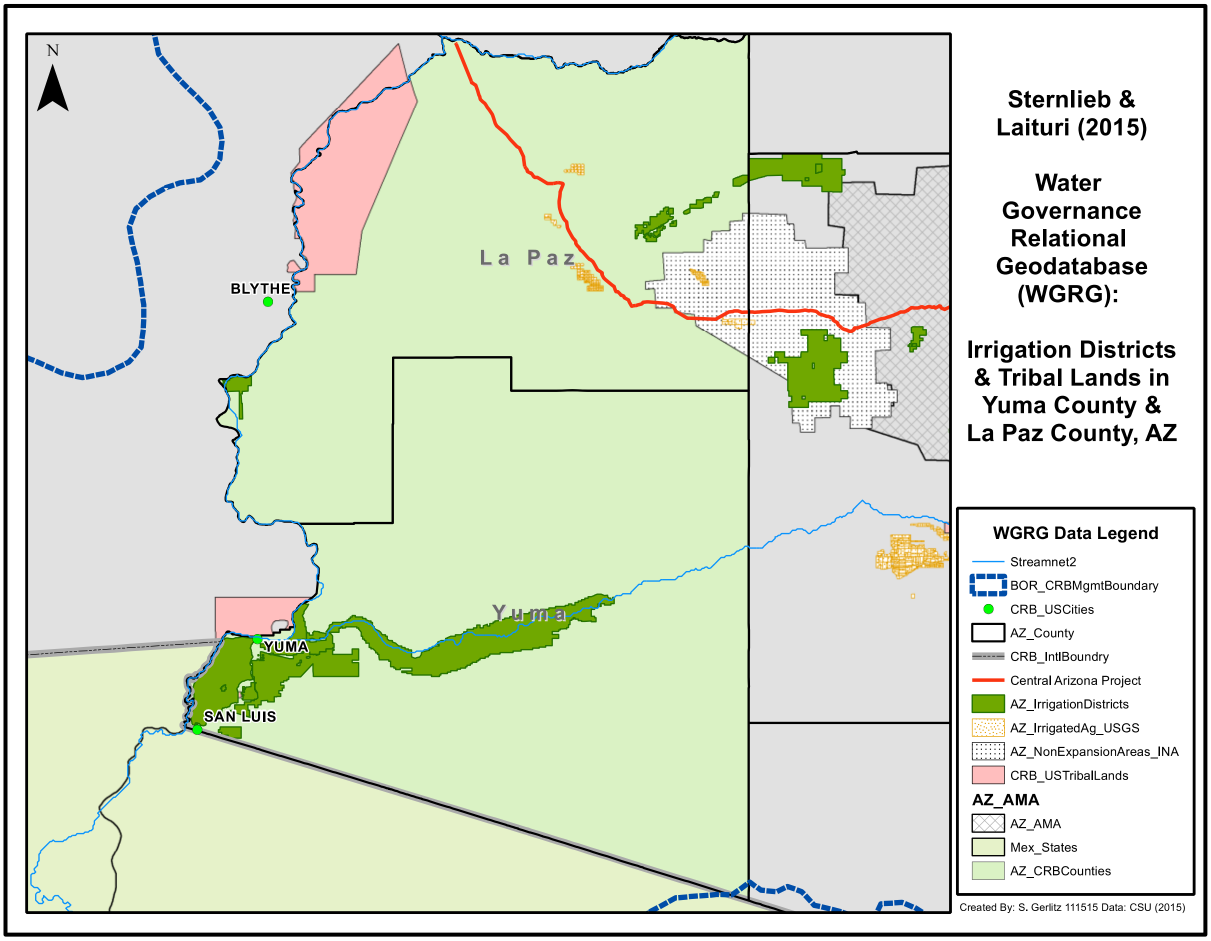
Pg. 25, Figure 5. *Conceptual governance patterns: Nested hierarchy and polycentricism,* (Adapted from Sternlieb & Laituri, 2015, p. 39)



Pg. 25, Figure 6. *Water Governance Relational Geodatabase layers for the CAGRD*, (Gerlitz, 2015).



Pg. 29, Figure 7. *Southern Arizona social capital investment areas*, (Gerlitz, 2015).



Pg. 30, Table 2. *Value of crops per acre-foot of water for Arizona, California and the Southwest average*, (Adapted from Ackerman & Stanton, 2011).

CWSD MODEL RESULTS: ARIZONA		**CPI INFLATION CALCULATOR***
CROP CATEGORY	2007 $/AF	2014 $/AF
Other crops and hay	$171	$195
Cotton and cottoneed	$238	$272
Other grains, oilseeds, dry beans/peas	$243	$277
Wheat	$441	$504
Fruits, tree nuts, and berries	$772	$881
Dairy, cattle (including water for hay)	$783	$894
Vegetables, melons, sweet potatoes	$2,875	$3,283
Nursery, greenhouse, floriculture, sod	$15,370	$17,549
Average for all crops	$1,101	$1,257
CWSD MODEL RESULTS: SOUTHWEST		
CROP CATEGORY	2007 $/AF	2014 $/AF
Other crops and hay	$121	$138
Rice	$172	$196
Corn	$290	$331
Cotton and cottonseed	$337	$385
Other grains, oilseeds, dry beans/peas	$217	$248
Wheat	$341	$389
Fruits, tree nuts, and berries	$1,370	$1,564
Dairy, cattle (including water for hay)	$878	$1,002
Vegetables, melons, sweet potatoes	$2,254	$2,574
Nursery, greenhouse, floriculture, sod	$28,265	$32,272
Average for all crops	$1,199	$1,369
*http://data.bls.gov/cgi-bin/cpicalc.pl?cost1=1.00&year1=2007&year2=2014		

Methods

The USDA NASS CropScape platform is accessed from the following web address: http://nassgeodata.gmu.edu/CropScape (USDA NASS, 2015). The CropScape tool was used first to find cropland cover acreage values for the entire state of Arizona for data year 2014. Next, La Paz and Yuma Counties were examined. ESRI ArcGIS 10.1 processed the CropScape data and provided a way to visualize the polycentric institutional arrangements of the Colorado River Basin with geospatial data from the WGRG (Laituri, 2014). The geodatabase isolated the water user groups as “Area(s) of Interest” (AOIs) to import into CropScape and then, the 2014 data for each AOI was exported and analyzed in Microsoft Excel (Excel). See Appendix C for a step-by-step process for importing an AOI from the WGRG and attaining cropland data layers and associated attributes.

Following CropScape, the USDA Quick Stats program was reviewed for usability to compare with the geospatial-based data. USDA Quick Stats platform is accessed from the following web address: http://quickstats.nass.usda.gov. The learning curve required to use this web-based platform proved more troublesome than beneficial to the project. Preliminary investigation found the Quick Stats database to be more complex than CropScape, with variable datasets dependent on individual crop types, the geographic location, as well as the year. As a substitute, the USDA NASS *Arizona Field Office 2014 Annual Statistics Bulletin* provided crop production data including total acres harvested and the total value for major crops for data year 2013, which was the most recent (USDA NASS, 2014). The *Bulletin* is available at http://www.nass.usda.gov/Statistics_by_State/Arizona. Furthermore, CIR values for Arizona were not found in the initial review of USDA Quick Stats but were identified in Table 36 of the 2013 FRIS state-specific information (USDA NASS, 2014).

CIR was further investigated by two other sources. The first source was a 1982 report on Maricopa County agriculture (Erie et al., 1981). The Erie et al. values were average water application depth, reported by total inches-per-season. Inches-per-season were converted into feet per year (Attachment 1). Average values for crops unavailable from the Erie et al. dataset were pulled from Figure 3 of the Pacific Institute's *California Agricultural Water Use: Key Background Information*, which reported average water application depth in feet per year (Cooley, 2015).

Lastly, for crop water use value data, the California Water Supply and Demand (CWSD) Model for the Southwest and Arizona (Ackerman & Stanton, 2011) was assigned to the CropScape output. Reported in 2007 dollars, these values along with the USDA NASS *Bulletin* values were converted into 2014 dollars with the Consumer Price Index (CPI) Calculator (U.S. Bureau of Labor Statistics, 2016). All water use values in this research were reported in 2014-dollar values.

Excel was used to organize and manipulate crop acreage data from the CropScape tool, data from the USDA 2012 Census FRIS table and USDA NASS 2014 *Bulletin* (USDA, 2015), regional crop water use values from the CWSD model (Ackerman & Stanton, 2011) and Arizona CIR charts (Erie et al., 1981). The research spreadsheet is provided as an attached document with specific details about how data was organized (Attachment 1). The spreadsheet was designed to compare and access data across all decision-support tools to target low-valued, highly consumptive crops, both with tables and with GIS data layers.

ESRI ArcGIS 10.1 created maps for the CIR values (FT/YR), water use values ($/AF), target crops and sensitivity analyses for the two counties and four individual water user groups

(Attachment 2). The creation of the maps required crop name assignments by cropland data layer (CDL) gridcodes from CropScape. CDL gridcode assignments to the different agricultural datasets required the development of crop-naming categorizations. GIS data layers were created for each crop name and value categorization group, including all dataset combinations and sensitivity analyses. The Excel worksheet includes all GIS data layer "Query by Attributes" scripts that identified individual gridcodes by categorization group (Attachment 1). The categorizations used to create GIS layers are described below.

Crop Name (CDL Gridcode) Categories

Spanning multiple USDA NASS sources, state specific metrics and peer-reviewed journal data, the social capital investment targeting required a divergence from the CropScape-only naming structure. To append CropScape data crop names (total acres/gridcode) to CIR (FT/YR) and water use value ($/AF), four data source groups were developed. The first was based on the USDA 2012 Census's FRIS 2013 values. The second was a combination of CIR metrics from Erie et al. (1981) and the California Department of Water Resources (CADWR) state averages (Cooley, 2015). The third group was based on the USDA NASS 2014 Bulletin for Arizona. However, the majority of water use values for the research were drawn from the last name group, developed from the CWSD model (See Appendix D), (Ackerman & Stanton, 2011).

USDA CropScape. The 2014 CDL gridcode numbers and the associated crop names from the CropScape data served as the baseline for all CIR and water use values for the research. Seventy gridcodes (USDA NASS, 2015) out of a possible 121 types for data year 2014 were identified for the entire state of Arizona.

USDA NASS 2014 Bulletin for Arizona. The *Bulletin* contains multi-year Census and Survey data sources allowing in some instances, crop names in-line with the CropScape gridcodes. However, the crop names are generalized for standard crops, like wheat and corn with only a few specific crops found within Arizona, like cotton. Sixteen crop name categories from the 2014 *Bulletin* were identified for crop water use value. Unfortunately, this naming system was limited due to data gaps for the most recent year (2013) and was only applicable to nine CropScape gridcodes (See Appendix D).

USDA NASS 2013 Farm and Ranch Irrigation Survey (FRIS). The Arizona CIR values from Table 36 of the FRIS were less specific than CropScape, but were applicable for the majority of crops. Of note was the "All other crops" name category found in the 2012 Census, which provided direct definitions of CIR for CropScape gridcode (44) "Other Crops".

Erie et al. & CADWR. The 1982 USDA publication based on the CIR values found in Erie et al. (1981) provided a list of 32 crops. When the Arizona-specific CIR values from Erie et al. lacked a direct match, the California Department of Water Resources (CADWR) naming system was utilized (Cooley, 2015). CADWR provided a list of 20 crop categories from which to assign to the proper gridcodes. These broad categories were first assigned to a gridcode, but when unsuitable, the crop categories provided further classification into a total of 82 specific crops.

California Water Supply and Demand (CWSD) model. The CWSD naming group provided a base of eight crop categories for Arizona. When unsuitable, the Southwest averages were applied expanding the range of names to eleven. When further specification was needed to assign a dollar value for a gridcode not available from the model, the CADWR crop categories (20 crop types) and associated definitions (82 crops) were used (See Appendix D).

Consumptive Irrigation Requirement (CIR) Categories

After developing a process for crop naming, consumptive irrigation requirement (CIR) values were defined. CIR was defined by the depth of water applied in a growing season in feet-per-year. Depending on this depth, a HIGH, MEDIUM, or LOW value was assigned. Gridcodes were represented in ESRI ArcGIS 10.1 by color types blue (LOW 0-2.5 FT/YR), orange (MEDIUM 2.51-3.75 FT/YR) and red (HIGH +3.76 FT/YR) (Table 3).

To assign a specific CIR value designation to gridcodes, the value-by-name assignments were conducted for Erie et al. and CADWR as well as for the USDA FRIS metrics. When a combination of two gridcode name types composed an individual gridcode, metrics for each individual crop were added, or an average was calculated. For example, (230) DblCropLettuce/Cotton would have a sum of (227) Lettuce and (2) Cotton (Fig. 8). Double-cropped gridcodes (231—238) often had some of the highest CIR values. Generalized values were sometimes applied to a crop with further specifications. For example, wheat was divided into (22) Durum Wheat, (23) Spring Wheat and (24) Winter Wheat in CropScape but lacked the specific CIR values from Erie et al., CADWR or USDA FRIS (Fig. 9). Comments were inserted into each individual value's cell within the attached Excel spreadsheet. This Excel feature provided a way to manipulate existing CIR data sources and explained the custom calculated value designations with their source(s) (Attachment 1).

Erie et al. & CADWR. This CIR data group served as a baseline to assign feet-per-year values to HIGH, MEDIUM or LOW designation (Table 4). Limitations in the CIR assignments for this group led to the removals for (31) Canola, (35) Mustard, (44) Other Crops and (57) Herbs, which were left out of the analyses. In addition, (44) Other Crops was not easily definable from Erie et al. or CADWR and was not used for the Target AOI or sensitivity analyses.

USDA NASS 2013 Farm and Ranch Irrigation Survey (FRIS). As the most current CIR data set, FRIS Table 36 provided ample values for Arizona's CIR including a value for (44) Other Crops which was lacking in the Erie et al./CADWR group. Gridcodes (31) Canola, (35) Mustard and (57) Herbs had similar definition issues as the Erie et al./CADWR group (Table 5).

Crop Water Use Value ($/AF) Categories

Defined by a HIGH, MEDIUM, or LOW determination, the dollar values provided an economic metric for agricultural water use in the case study regions. While differing in approach, (revenue based versus model output), the two categorical groups provided a general assessment of crop water value. All dollar values were converted from the existing data source value to the 2014 CPI calculated amount, thus providing a connection for the 2014 CropScape data (U.S. Department of Labor, 2016). Crops were identified for water use value by the following definitions with acreage pixels represented in ESRI ArcGIS 10.1 by color types green (HIGH +$1000/AF), yellow (MEDIUM $300-999/AF) and light blue (LOW $1-299/AF) (Table 6). Like the custom calculations conducted in Excel for CIR, a similar approach was used for water use values. For example, double crop plantings were the sum of each individual crop gridcode value, ($/AF) (Fig. 10). Double-cropped gridcodes (231—238) that included (227) Lettuce often had some of the highest water use values.

USDA NASS 2014 Bulletin for Arizona. The USDA NASS group had the most recent Census data for Arizona agriculture. From the report's 2013 data set for acreage, yield, production, price and value metrics, the dollar value of the water was calculated. With the inclusion of a CIR value from the USDA FRIS Table 36, MEDIUM and LOW valued crops were identified. All calculations were performed in the Excel spreadsheet (Attachment 1). The crop water use value ($/AF) was identified for eight major crops (Table 7). For example, "Corn for Grain" was determined by the relation of "Value of Production" to "Harvested Acres" divided by USDA FRIS Table 36 CIR value for (1) Corn. Then the 2014 CPI calculator converted the 2013 value into $455/AF (Fig. 11) (U.S. Department of Labor, 2016). Due to the limitations in available 2013 data as well as crop name categorization challenges, further application of this naming group to all possible gridcodes was not conducted.

California Water Supply and Demand (CWSD) model. Where the USDA NASS group lacked in categorization options, the California Water Supply and Demand (CWSD) model provided a broad set of categories. The model was designed with the assumption that "crop…water use by county is a function of projected summer temperatures by county," (Stanton & Fitzgerald, 2011, pg. 10). This approach to determining average crop water use dollar values stemmed from the model's focus on how climate change Affects water supply and demand, in economic terms. This approach applied to the wheeling policy focus on this research because climate change and LCRB supply shortages are driving the need to find ATMs. Secondly, the original data used in the model was county-based, from the USDA 2007 Census. All values for CWSD crop categories were reported in 2014-dollar values with comments similar to the CIR groups (Table 8).

Target Area of Interest (AOI)

The target social capital investment type for CIR was the HIGH value (+3.76 FT/YR). Each naming group (Erie et al./CADWR), (USDA FRIS) were identified and mapped individually but were also combined in the final target maps. The target social capital investment type for the dollar value by crop water use was LOW ($1-299/AF). Each naming group (CWSD), (USDA

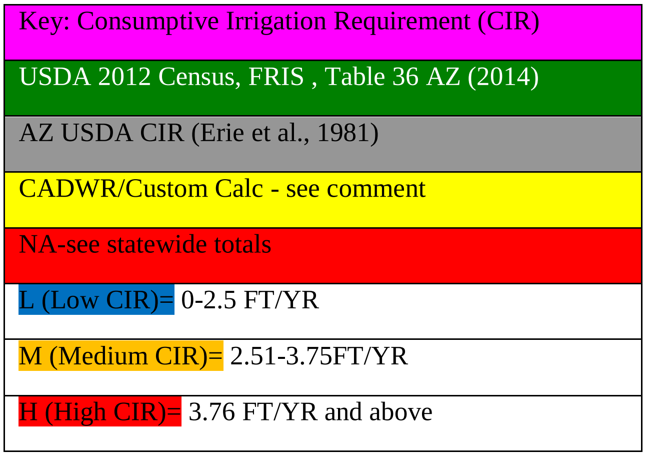
NASS) were identified and mapped individually but were also combined in the final target maps. Target crops were identified by color type purple (TARGET).

USDA NASS 2014 Arizona report and USDA FRIS Table 36. The USDA-based target values consisted of five gridcodes, selected from a total of 20 crops which fit either HIGH CIR or LOW water use value definitions. Target gridcodes for this group were (2) Cotton, (27) Rye, (36) Alfalfa, (37) Other Hay/Non Alfalfa and (41) Sugarbeets (Table 9).

Erie et al.-CADWR-CWSD. The Arizona-California based target values consisted of four gridcodes, selected from a total of 21 crops, which fit either HIGH CIR or LOW water use value definitions. Target gridcodes for this group were (4) Sorghum, (36) Alfalfa, (37) Other Hay/Non Alfalfa and (176) Grass/Pasture (Table 10).

Combined groups. The combined target values included seven gridcodes, selected from the two groups (Table 11). The combined target values were used in the results and include gridcodes (2) Cotton, (4) Sorghum, (27) Rye, (36) Alfalfa, (37) Other Hay/Non-Alfalfa, (41) Sugarbeets and (176) Grass/Pasture.

Pg. 43, Table 3. *Key for consumptive irrigation requirement*, (Attachment 1, Gerlitz, 2016).



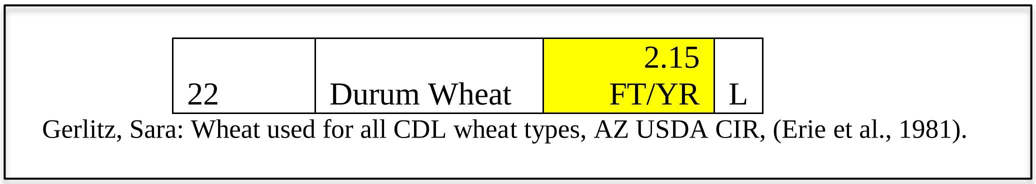
Key: Consumptive Irrigation Requirement (CIR)
USDA 2012 Census, FRIS , Table 36 AZ (2014)
AZ USDA CIR (Erie et al., 1981)
CADWR/Custom Calc - see comment
NA-see statewide totals
L (Low CIR)= 0-2.5 FT/YR
M (Medium CIR)= 2.51-3.75FT/YR
H (High CIR)= 3.76 FT/YR and above

Pg. 43, FIGURE 8. *Comment example for CIR*, (Attachment 1, Gerlitz, 2016).

232	Dbl Crop Lettuce/Cotton	4.14 FT/YR	H

Gerlitz, Sara: Sum lettuce and cotton, AZ USDA CIR (Erie, et. Al, 1981).

Pg. 43, FIGURE 9. *Comment example for CIR*, (Attachment 1, Gerlitz, 2016).



22	Durum Wheat	2.15 FT/YR	L

Gerlitz, Sara: Wheat used for all CDL wheat types, AZ USDA CIR, (Erie et al., 1981).

Pg. 43, Table 4. *CIR values by gridcode for Arizona: Erie et al. and CADWR* (Attachment 1, Gerlitz, 2016).

GRIDCODE	CROP NAME	CIR (FT/YR)	RANK
234	Dbl Crop Durum Wht/Sorghum	6.56	H
236	Dbl Crop WinWht/Sorghum	6.56	H
235	Dbl Crop Barley/Sorghum	6.49	H
36	Alfalfa	6.19	H
37	Other Hay/Non Alfalfa	6.19	H
238	Dbl Crop WinWht/Cotton	5.57	H
4	Sorghum	4.41	H
176	Grass/Pasture	4.36	H
27	Rye	4.25	H
232	Dbl Crop Lettuce/Cotton	4.14	H
74	Pecans	4.00	H
75	Almonds	4.00	H
204	Pistachios	4.00	H
225	Dbl Crop WinWht/Corn	3.78	H
59	Sod/Grass Seed	3.63	M
72	Citrus	3.63	M
41	Sugarbeets	3.57	M
67	Peaches	3.45	M
68	Apples	3.45	M
71	Other Tree Crops	3.45	M
77	Pears	3.45	M
2	Cotton	3.43	M
212	Oranges	3.26	M
226	Dbl Crop Oats/Corn	2.90	M
205	Triticale	2.86	M
230	Dbl Crop Lettuce/Durum Wht	2.86	M
211	Olives	2.85	M
233	Dbl Crop Lettuce/Barley	2.79	M
231	Dbl Crop Lettuce/Cantaloupe	2.27	L
22	Durum Wheat	2.15	L
23	Spring Wheat	2.15	L
24	Winter Wheat	2.15	L
21	Barley	2.08	L
43	Potatoes	2.03	L
47	Misc Vegs & Fruits	1.92	L
208	Garlic	1.92	L
216	Peppers	1.92	L
219	Greens	1.92	L

Pg. 43, Table 4. ...*continued*, (Attachment 1, Gerlitz, 2016).

GRIDCODE	CROP NAME	CIR (FT/YR)	RANK
245	Celery	1.92	L
246	Radishes	1.92	L
243	Cabbage	1.74	L
49	Onions	1.70	L
214	Broccoli	1.64	L
1	Corn	1.63	L
42	Dry Beans	1.63	L
209	Cantaloupes	1.56	L
48	Watermelons	1.55	L
213	Honeydew Melons	1.55	L
244	Cauliflower	1.55	L
28	Oats	1.48	L
69	Grapes	1.44	L
206	Carrots	1.38	L
61	Fallow/Idle Cropland	1.09	L
227	Lettuce	0.71	L
44	Other Crops	0.00	L

Pg. 44, Table 5. *CIR value by gridcode for Arizona: USDA NASS 2013 FRIS, Table 36,* (Attachment 1, Gerlitz, 2016).

GRIDCODE	CROP NAME	CIR (FT/YR)	RANK
238	Dbl Crop WinWht/Cotton	7.9	H
232	Dbl Crop Lettuce/Cotton	7.8	H
231	Dbl Crop Lettuce/Cantaloupe	7.5	H
225	Dbl Crop WinWht/Corn	6.93	H
236	Dbl Crop WinWht/Sorghum	6.7	H
234	Dbl Crop Durum Wht/Sorghum	6.7	H
230	Dbl Crop Lettuce/Durum Wht	6.7	H
226	Dbl Crop Oats/Corn	6.33	H
235	Dbl Crop Barley/Sorghum	6.1	H
233	Dbl Crop Lettuce/Barley	6.1	H
36	Alfalfa	5.4	H
2	Cotton	4.5	H
44	Other Crops	4.2	H
41	Sugarbeets	4.2	H
209	Cantaloupe	4.2	H
213	Honeydew Melons	4.2	H
37	Other Hay/Non Alfalfa	3.9	H
59	Sod/Grass Seed	3.63	M
212	Oranges	3.6	M
211	Olives	3.6	M
204	Pistachios	3.6	M
77	Pears	3.6	M
75	Almonds	3.6	M
74	Pecans	3.6	M
72	Citrus	3.6	M
71	Other Tree Crops	3.6	M
68	Apples	3.6	M
67	Peaches	3.6	M
41	Sugarbeets	3.57	M
176	Grass/Pasture	3.5	M
24	Winter Wheat	3.4	M
23	Spring Wheat	3.4	M
22	Durum Wheat	3.4	M
227	Lettuce	3.3	M
4	Sorghum	3.3	M
246	Radishes	3.1	M
245	Celery	3.1	M
244	Cauliflower	3.1	M

Pg. 44, Table 5. …*continued*, (Attachment 1, Gerlitz, 2016).

GRIDCODE	CROP NAME	CIR (FT/YR)	RANK
243	Cabbage	3.1	M
219	Greens	3.1	M
216	Peppers	3.1	M
214	Broccoli	3.1	M
208	Garlic	3.1	M
206	Carrots	3.1	M
49	Onions	3.1	M
48	Watermelons	3.1	M
47	Misc Vegs & Fruits	3.1	M
205	Triticale	2.86	M
28	Oats	2.8	M
27	Rye	2.8	M
21	Barley	2.8	M
1	Corn	2.53	M
42	Dry Beans	2.2	L
43	Potatoes	1.9	L
61	Fallow/Idle Cropland	1.09	L

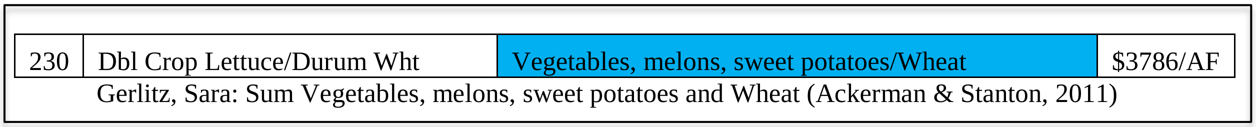
Pg. 44, Table 6. *Key for water use value*, (Attachment 1, Gerlitz, 2016).

Key Water Use Values ($/AF) by Crop Type
USDA NASS AZ 2013 Values (2014 adjusted) (USDA, 2014)
CWSD$ Values (2014 adjusted) (Ackerman & Stanton, 2011)
substitutes-see comment
NA
L (Low $/AF)= $1-299
M (Medium $/AF)= $300-999
H (High $/AF)= $1000+

Pg. 45, Table 7. *Water use values by gridcode for Arizona: USDA NASS 2014 AZ Bulletin*, (Attachment 1, Gerlitz, 2016).

GRIDCODE	CROP NAME	$/AF (2014 adj)	Value (adj.)
1	Corn	455	M
36	Alfalfa	305	M
2	Cotton	258	L
21	Barley	248	L
22	Durum Wheat	248	L
23	Spring Wheat	248	L
24	Winter Wheat	248	L
37	Other Hay/Non Alfalfa	224	L
4	Sorghum	132	L

Pg. 45, Figure 10. *Comment example for water use value categorizations*, (Attachment 1, Gerlitz, 2016).



230	Dbl Crop Lettuce/Durum Wht	Vegetables, melons, sweet potatoes/Wheat	$3786/AF

Gerlitz, Sara: Sum Vegetables, melons, sweet potatoes and Wheat (Ackerman & Stanton, 2011)

Pg. 45, Figure 11. *Example of water use value calculation*: *USDA NASS 2014 AZ Bulletin*, (Attachment 1, Gerlitz, 2016).

(GRIDCODE) Crop Name:

[('Value of Production'/'Harvested Acres') / CIR (FT/YR)] = $/AF (2013) ~ CPI Calculator (2014) = **$/AF**

(1) Corn:

[(57,834,000/51,000) / 2.53] = $448/AF (2013) ~CPI Calculator (2014) = **$455/AF**

Pg. 45, Table 8. *Water use value by gridcode: Erie et al., CADWR and substitute,* (Attachment 1, Gerlitz, 2016).

GRIDCODE	CROP NAME	($/AF)	RANK
59	Sod/Grass Seed	17,549	H
231	Dbl Crop Lettuce/Cantaloupe	6,565	H
230	Dbl Crop Lettuce/Durum Wht	3,786	H
233	Dbl Crop Lettuce/Barley	3,560	H
232	Dbl Crop Lettuce/Cotton	3,554	H
246	Radishes	3,283	H
245	Celery	3,283	H
244	Cauliflower	3,283	H
243	Cabbage	3,283	H
227	Lettuce	3,283	H
219	Greens	3,283	H
216	Peppers	3,283	H
214	Broccoli	3,283	H
213	Honeydew Melons	3,283	H
211	Olives	3,283	H
209	Cantaloupes	3,283	H
208	Garlic	3,283	H
206	Carrots	3,283	H
49	Onions	3,283	H
48	Watermelons	3,283	H
47	Misc Vegs & Fruits	3,283	H
67	Peaches	881	M
68	Apples	881	M
69	Grapes	881	M
71	Other Tree Crops	881	M
72	Citrus	881	M
74	Pecans	881	M
75	Almonds	881	M
77	Pears	881	M
204	Pistachios	881	M
212	Oranges	881	M
225	Dbl Crop WinWht/Corn	835	M
234	Dbl Crop Durum Wht/Sorghum	781	M
236	Dbl Crop WinWht/Sorghum	781	M
238	Dbl Crop WinWht/Cotton	775	M
226	Dbl Crop Oats/Corn	609	M
235	Dbl Crop Barley/Sorghum	555	M

Pg. 45, Table 8. …*continued*, (Attachment 1, Gerlitz, 2016).

GRIDCODE	CROP NAME	($/AF)	RANK
22	Durum Wheat	504	M
23	Spring Wheat	504	M
24	Winter Wheat	504	M
28	Oats	504	M
42	Dry Beans	504	M
1	Corn	331	M
4	Sorghum	277	L
21	Barley	277	L
2	Cotton	272	L
205	Triticale	236	L
27	Rye	195	L
36	Alfalfa	195	L
37	Other Hay/Non Alfalfa	195	L
41	Sugarbeets	195	L
43	Potatoes	195	L
176	Grass/Pasture	195	L
31	Canola	NA	NA
35	Mustard	NA	NA
44	Other Crops	NA	NA
57	Herbs	NA	NA
61	Fallow/Idle Cropland	NA	NA

Pg. 45, Table 9. *Target AOI crops by gridcode: USDA NASS 2013 FRIS, Table 36 and USDA NASS 2014 AZ Bulletin,* (Attachment 1, Gerlitz, 2016).

Crop Name	CDL HCIR USDA	L$ USDA	TARGET AOI
Corn		1	
Cotton	2	2	**2**
Sorghum		4	
Barley		21	
Rye	27	27	**27**
Alfalfa	36	36	**36**
Other Hay/Non Alfalfa	37	37	**37**
Sugarbeets		41	**41**
Potatoes		43	
Pecans	74		
Almonds	75		
Grass/Pasture		176	
Pistachios	204		
Triticale		205	
Dbl Crop WinWht/Corn	225		
Dbl Crop Lettuce/Cotton	232		
Dbl Crop Durum Wht/Sorghum	234		
Dbl Crop Barley/Sorghum	235		
Dbl Crop WinWht/Sorghum	236		
Dbl Crop WinWht/Cotton	238		

Pg. 46, Table 10.*Target AOI crops by gridcode: Erie et al., CADWR and CWSD* (Attachment 1, Gerlitz, 2016).

Crop Name	CDL HCIR ERIE/CADWR	L$ CWSD	TARGET AOI
Cotton		2	
Sorghum	4	4	**4**
Barley		21	
Rye	27	27	
Alfalfa	36	36	**36**
Other Hay/Non Alfalfa	37	37	**37**
Sugarbeets		41	
Potatoes		43	
Pecans	74		
Almonds	75		
Grass/Pasture	176	176	**176**
Pistachios	204		
Triticale		205	
Dbl Crop WinWht/Corn	225		
Dbl Crop Lettuce/Cotton	232		
Dbl Crop Durum Wht/Sorghum	234		
Dbl Crop Barley/Sorghum	235		
Dbl Crop WinWht/Sorghum	236		
Dbl Crop WinWht/Cotton	238		

Pg. 46, Table 11. *Combined Target AOI crops by gridcode,* (Attachment 1, Gerlitz, 2016).

Crop Name	Erie/CADWR&CWSD	USDA NASS	COMBINED
Cotton		**2**	**2**
Sorghum	**4**		**4**
Rye		**27**	**27**
Alfalfa	**36**	**36**	**36**
Other Hay/Non Alfalfa	**37**	**37**	**37**
Sugarbeets		**41**	**41**
Grass/Pasture	**176**		**176**

Results

Yuma County

Yuma County, Arizona is located on the state's Colorado River border next to California and Mexico, in the most southwestern region of the state. Yuma's agricultural profile is diverse across both crop types and the assigned crop water use and CIR values. The size of the majority of farms range from 1-9 acres or 10-49 acres with a total of 562 farms as indicated by the USDA's 2012 Census of Agriculture profile (USDA NASS, 2012). Yuma County saw a 24% increase in the number of farms for the five-year period between the 2012 and 2007 Census. Major crops were reported in 2012 to be "vegetables, harvested, all", "lettuce", "wheat for grain", "durum wheat for grain", and "forage-land used for all hay and haylage, grass silage, and greenchop". The county ranks fourth in forage-land and holds the top position in vegetables, lettuce, wheat and durum wheat for Arizona counties (USDA NASS, 2012; Table 12). The combined target crop acreage values for Yuma County are shown in Figure 12. From the CIR maps and water use value maps, the visualization from the CropScape data showed a mix of all CIR as well as all water use designations. The use of color variations for the different pixel types was well illustrated in this county.

Ten water user groups were found from the WGRG to be located completely within the county (Laituri, 2014). Nine irrigation districts, and one Tribe, the Cocopah Indian Tribe, were identified for the social capital investment targeting exercise. The raw CropScape geospatial data, filtered for crop-only gridcodes, showed high-density agricultural both on the Colorado River and the Gila River Valley. For the AOI targeting, all ten user groups were included in the maps, however individual analysis was conducted for one high density area along the Colorado River and one large and self-contained water user group on the Gila River.

On-river agriculture (Cocopah Indian Tribe/YCWUA). The on-river group selected from Yuma County (Cocopah Indian Tribe/YCWUA) is a small area with a dense amount of target gridcodes located within multiple water user group boundaries (Fig. 13). Three total and two identifiable water user groups in this on-river area are the Cocopah Indian Tribe's northwest boundary and a portion of the Yuma County Water Users Association (YCWUA). For the Cocopah Indian Tribe, a total of 1,818 agricultural acres were identified from the 2014 CropScape CDL data for the WGRG defined area (Table 13).

The Cocopah Indian Tribe had similar acreage across the top six gridcodes including target crops and non-target crops. For example, target gridcodes (36) Alfalfa had 334 acres, (176) Grass/Pasture had 356 acres while non-target gridcode (227) Lettuce had 381 acres. Other non-target gridcodes had relatively higher totals than the remaining target gridcodes. Non-target gridcodes (22) Durum Wheat had 119 acres, (47) Misc Fruits & Veg had 165 acres and (230) Dbl Crop Lettuce/Durum Wht had 155 acres for 2014 CDL gridcodes. No (27) Rye was identified.

For the larger, neighboring YCWUA water user group, a total of 48,052 agricultural acres were identified from the 2014 CropScape CDL data for the WGRG defined area (Table 14). The YCWUA had high acreage for (227) Lettuce and (230) Dbl Crop Lettuce/Durum Wht with low comparable acreage values for the target gridcodes. For example, (227) Lettuce acreage was 14,304 acres while the target gridcodes (36) Alfalfa was 3,175 acres and (2) Cotton only at 845 acres. With a paltry 0.4 acres identified as (27) Rye, Cocopah Indian Tribe, like most of the state, had a very low amount of this target gridcode present.

The reason this small on-river agriculture area was chosen for Yuma County analyses was the overlap of multiple water user groups in a very small region. In the polycentric framework as provided in the WGRG, this on-river agricultural area (Cocopah Indian Tribe/YCWUA) included, overlapped, held, or were part of seven governance boundaries within Arizona (Fig. 14). Its proximity to Mexico and California's Fort Yuma Indian Reservation, located in Imperial County, should also be considered however this Tribe was not counted towards the water governance total because the wheeling policy is focused on intrastate ATMs.

Wellton-Mohawk Irrigation and Drainage District (WMIDD). In contrast, the Wellton-Mohawk Irrigation and Drainage District (Wellton-Mohawk) was selected for its distance from the Colorado River and its relative isolation in regards to the other agricultural districts Yuma County. Wellton-Mohawk is also the largest water governance entity in Yuma County. A total of 75,065 agricultural acres were identified from the 2014 CropScape data for the WGRG defined area (Table 15). With the exception of (61) Fallow/Idle Cropland, (22) Durum Wheat (4,213 acres) and (72) Citrus (1,257 acres), the highest acreage crops are target gridcodes as illustrated in Figure 16. No (27) Rye was identified.

Wellton-Mohawk had three water governance boundaries in the polycentric governance review (Fig. 16). While located in the Gila River Valley, Wellton-Mohawk receives water from the main-stem Colorado River through a series of canals (WMIDD, 2016). Yuma Mesa Irrigation and Drainage District (YMIDD) and Yuma County Water Users Association (YCWUA) were located nearby Wellton-Mohawk along with a few unidentified water users from the WGRG's "BOR irrigation district" layer, which were located within its boundary. There were seven city locations as well. For identifying a target AOI for Yuma County, Wellton-Mohawk is a good option.

La Paz County

La Paz County, Arizona is located on the state's Colorado River border with California, north and up-river of Yuma County. The size of the majority of farms range from 50-179 acres with a total of 125 farms as indicated by the USDA's 2012 Census of Agriculture profile (USDA NASS, 2012). La Paz County saw a 26% increase in the number of farms for the five-year period between the 2012 and 2007 Census. Major crops were reported in 2012 to be "forage-land used for all hay and haylage, grass silage and greenchop", cotton ("all cotton" and "upland cotton"); and wheat ("all", "for grain" and "durum for grain"). The county ranks third in forage-land and cotton production for the state and fourth in wheat (USDA NASS, 2012), (Table 16).

From the CIR maps and water use value maps, the visualization from the CropScape gridcode designations showed a majority of HIGH and MEDIUM CIR as well as MEDIUM and LOW water use value crops. The combined map, shown in Figure 17 provides a clear view on where the county's agriculture is located, in terms of social capital investment targeting of HIGH CIR and LOW valued crop water.

Three water user groups were found from the WGRG to be located completely within the county (Laituri, 2014). Two irrigation districts, Cibola Irrigation and Drainage District (Cibola) and McMullen Irrigation and Drainage District (McMullen) and one Tribal entity, the Colorado River Indian Tribes (CRIT) were identified for the social capital investment targeting exercise. The raw CropScape geospatial data, filtered for crop-only gridcodes easily located these three water user groups prior to the WGRG identification.

The on-river CRIT and Cibola water governance boundaries show the agriculture hub of the county. McMullen, on the other hand, located to the east and off-river is a groundwater dependent irrigation district that has existing water transfer contracts with the City of Phoenix

(Carr, 2010). Its inclusion in the analyses was to provide a variety of agricultural water users for La Paz County. For the county targeting, all three were included in the maps however individual analysis was conducted for the on-river water user groups.

Cibola Irrigation and Drainage District (Cibola). Cibola Irrigation and Drainage District is a small water governance region located in the southwest, on-river portion of La Paz County. A total of 5,371 agricultural acres were identified from the 2014 CropScape data for the WGRG defined area (Table 17). With the exception of (61) Fallow/Idle Cropland and (71) Other Tree Crops, the highest acreage crops are target gridcodes as illustrated in Figure 18.

In the polycentric framework as provided in the WGRG, Cibola's water governance boundaries were completely contained (Fig. 19). Cibola had only one city located within the vicinity and had California water governance boundaries shared on or across the Colorado River. Palo Verde Irrigation District (PVID) located in Imperial County, CA was the only nearby water user group.

Colorado River Indian Tribes (CRIT). The Colorado River Indian Tribes is the largest water governance entity located along the Colorado River in La Paz County. A total of 97,026 agricultural acres were identified from the 2014 CropScape data for the WGRG defined area (Table 18). With the exception of (22) Durum Wheat, (61) Fallow/Idle Cropland and (71) Other Tree Crops, the highest acreage crops are target gridcodes as illustrated in Figure 20.

In the polycentric framework as provided in the WGRG, CRIT's water governance boundaries were completely contained (Fig. 21). CRIT had two cities located within its governance boundary and one city outside. The only major water governance boundary layer associated with CRIT is the WGRG's 'CRB Indian Lands' layer that incorporates the majority of CRIT, including lands in California and throughout the river floodplain (Laituri, 2014). This water governance boundary excludes the southeast corner of CRIT. Outside of CRIT on the California side of the river is the northeastern extent of Palo Verde Irrigation District, located in Riverside County, CA. CRIT also shares the river with San Bernardino County, CA.

Sensitivity Analysis

HIGH CIR (FT/YR). To test the sensitivity of the CIR and water use value definitions by crop type, a separate analysis was conducted for each county and for the four featured water user groups. HIGH CIR sensitivity was changed from +3.76 FT/YR crops to +2.0 FT/YR crops. This expanded the range of possible gridcodes from 23 to 53. The Cibola and Wellton-Mohawk maps show the combined HIGH CIR layers with an overlay of the Sensitivity Analysis (Figures 22-23). At smaller spatial scales, such as in the Cibola map, the sensitivity analysis layer is easier to identify. However at a larger scale, with few polycentric boundaries, such as in Wellton-Mohawk, a big-picture view of an agricultural region is well-defined.

LOW Value ($/AF). LOW value sensitivity was changed from $1-299/AF crops to $1-199/AF crops. This decreased the range of possible gridcodes from thirteen to seven. The on-river area of Yuma County (Cocopah Indian Tribe/YCWUA) and CRIT maps show the combined LOW dollar value layers with an overlay of the Sensitivity Analysis LOW value layer (Figures 24-25). At smaller spatial scales, such as in the on-river Yuma County map, the sensitivity analysis layer further refines individual pixels. However at a larger scale, such as the CRIT map, in an already majority LOW value AOI, the Sensitivity Analysis layer is easy to identify, typically located in the same areas as the original layer.

Target AOI. Target AOI sensitivity was the combination of the two adjusted variables. Initially, the total possible number of gridcodes expanded but in combination the total was re-restricted. The main result of the sensitivity analysis was the exclusion of (2) Cotton (Table 19).

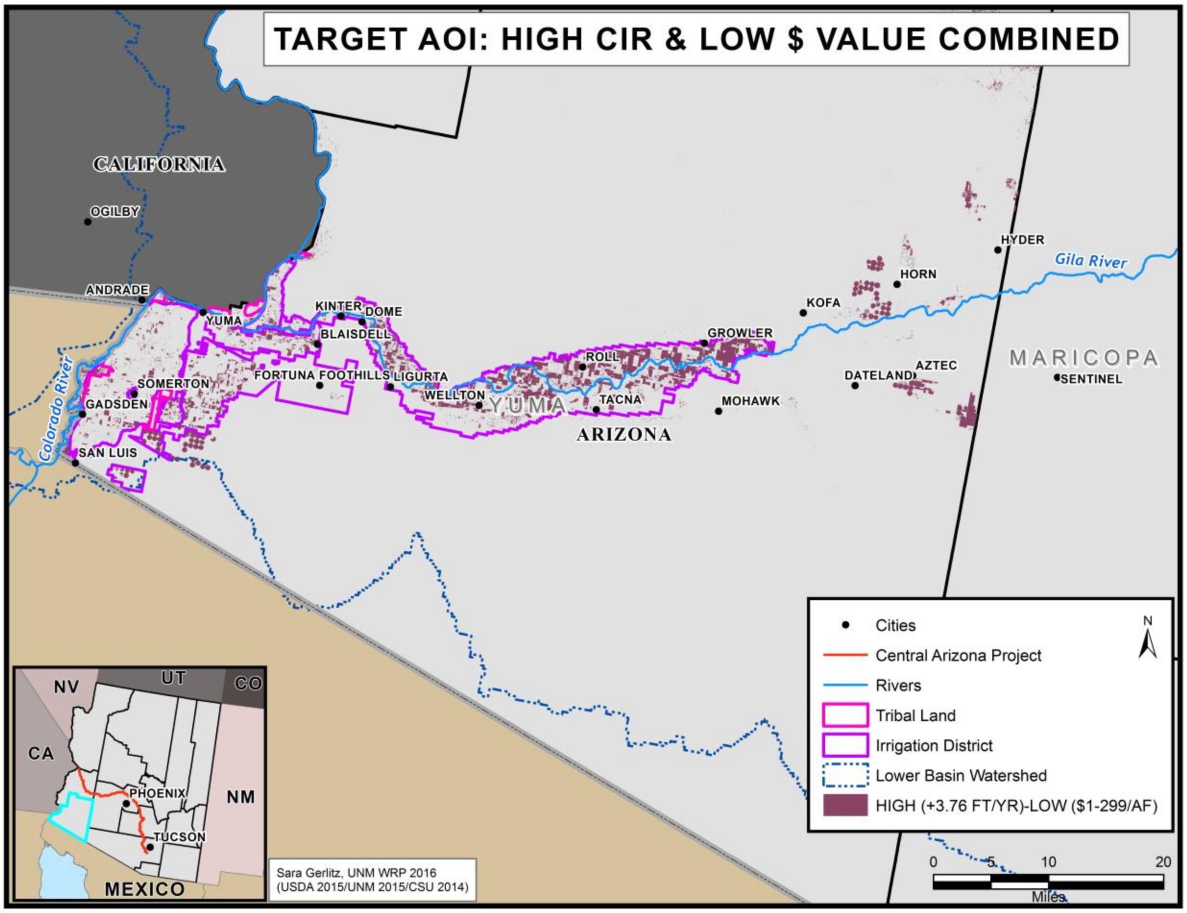
Pg. 58, Table 12. *Yuma County crops by acreage and gridcode,* (Attachment 1, Gerlitz, 2016).

GRIDCODE	CROP	ACRES
36	**Alfalfa**	**55401**
61	Fallow/Idle Cropland	41128.6
230	Dbl Crop Lettuce/Durum Wht	25959
227	Lettuce	23023.6
72	Citrus	15798
176	**Grass/Pasture**	**12188.1**
47	Misc Vegs & Fruits	11804
22	Durum Wheat	10710.7
232	Dbl Crop Lettuce/Cotton	8849.8
2	**Cotton**	**5885**
37	**Other Hay/Non Alfalfa**	**3772.9**
231	Dbl Crop Lettuce/Cantaloupe	2900.2
214	Broccoli	2388.1
1	Corn	1901.9
243	Cabbage	1501.8
21	Barley	1358.6
209	Cantaloupes	1082.2
59	Sod/Grass Seed	960.1
71	Other Tree Crops	694.1
4	**Sorghum**	**641.4**
244	Cauliflower	603.1
75	Almonds	559.3
219	Greens	551.8
42	Dry Beans	549.3
28	Oats	455.5
48	Watermelons	447.5
44	Other Crops	443.7
49	Onions	386.3
57	Herbs	226.6
74	Pecans	198.4
24	Winter Wheat	151.2
233	Dbl Crop Lettuce/Barley	121.6
27	**Rye**	**116.3**
211	Olives	40.5
212	Oranges	36.7
234	Dbl Crop Durum Wht/Sorghum	17.6
213	Honeydew Melons	16.2
246	Radishes	11.6

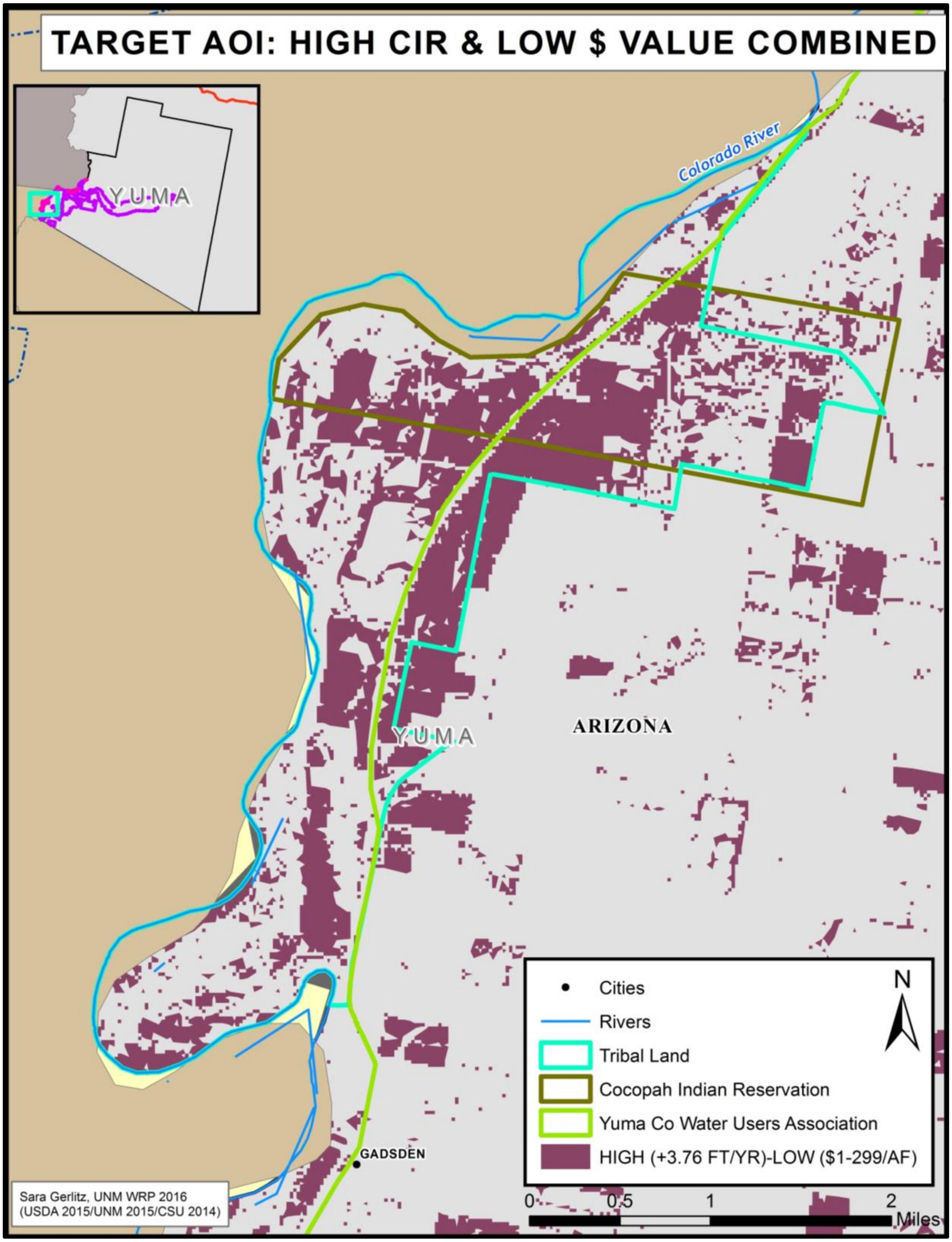
Pg. 58, Table 12. …*continued*, (Attachment 1, Gerlitz, 2016).

GRIDCODE	CROP	ACRES
35	Mustard	10.5
41	**Sugarbeets**	**5.8**
208	Garlic	4.7
235	Dbl Crop Barley/Sorghum	3.1
206	Carrots	2.2
67	Peaches	0.9
238	Dbl Crop WinWht/Cotton	0.9
	TOTAL ACRES	**232,910**
	% ACRES IN TARGET AOI:	**33.4**

Pg. 57, Figure 12. *Yuma County target AOIs*, (Attachment 2, Gerlitz, 2016).



Pg. 58, Figure 13. *Cocopah/YCWUA target AOIs,* (Attachment 2, Gerlitz, 2016).



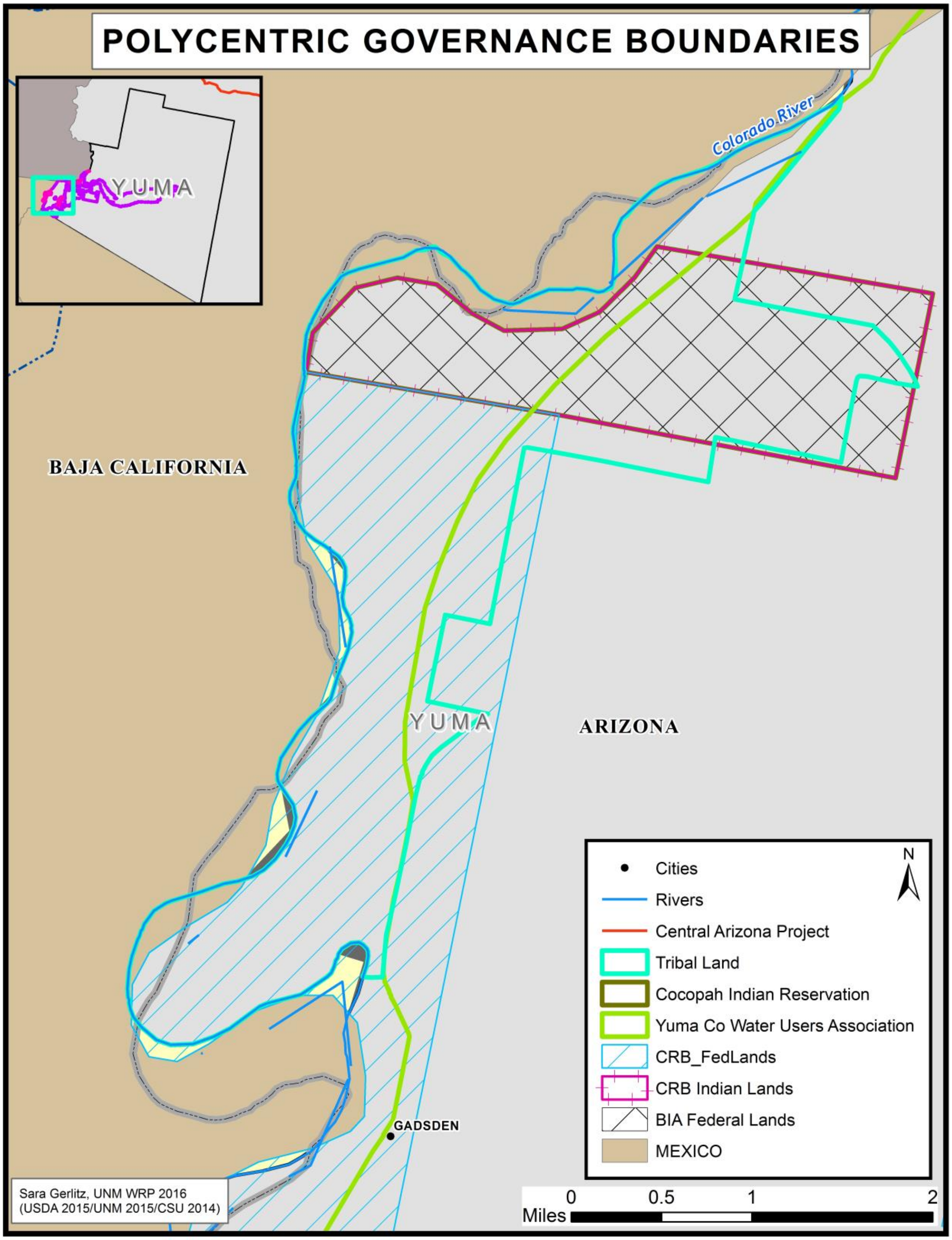
Pg. 58, Table 13. *Cocopah Indian Tribe crops by acreage and gridcode,* (Attachment 1, Gerlitz, 2016).

GRIDCODE	CROP	ACRES
227	Lettuce	381.6
176	**Grass/Pasture**	**358.5**
36	**Alfalfa**	**334.3**
47	Misc Vegs & Fruits	165
230	Dbl Crop Lettuce/Durum Wht	154.6
22	Durum Wheat	119.4
61	Fallow/Idle Cropland	77.2
72	Citrus	48.3
232	Dbl Crop Lettuce/Cotton	40.5
2	**Cotton**	**37.6**
37	**Other Hay/Non Alfalfa**	**16.2**
57	Herbs	15.1
74	Pecans	14.9
214	Broccoli	9.3
231	Dbl Crop Lettuce/Cantaloupe	9.3
28	Oats	7.8
212	Oranges	7.8
209	Cantaloupes	7.6
219	Greens	3.8
41	**Sugarbeets**	**2.9**
42	Dry Beans	2
49	Onions	2
48	Watermelons	0.9
75	Almonds	0.7
44	Other Crops	0.2
71	Other Tree Crops	0.2
211	Olives	0.2
244	Cauliflower	0.2
	TOTAL ACRES	**1818.1**
	% ACRES IN TARGET AOI:	**41.2**

Pg. 589, Table 14. *YCWUA crops by acreage and gridcode*, (Attachment 1, Gerlitz, 2016).

GRIDCODE	CROP	ACRES
230	Dbl Crop Lettuce/Durum Wht	14308.4
227	Lettuce	14304.4
22	Durum Wheat	3702.2
36	**Alfalfa**	**3174.5**
232	Dbl Crop Lettuce/Cotton	2904
231	Dbl Crop Lettuce/Cantaloupe	1840.1
47	Misc Vegs & Fruits	1799.6
176	**Grass/Pasture**	**879.6**
2	**Cotton**	**845.1**
72	Citrus	519.3
243	Cabbage	493.5
244	Cauliflower	456.1
214	Broccoli	450.1
219	Greens	426.1
209	Cantaloupes	358.3
37	**Other Hay/Non Alfalfa**	**355.6**
61	Fallow/Idle Cropland	266.2
42	Dry Beans	259.8
74	Pecans	137.4
57	Herbs	116.3
233	Dbl Crop Lettuce/Barley	109
1	Corn	106.1
49	Onions	83.8
48	Watermelons	56
212	Oranges	28.2
75	Almonds	27.1
211	Olives	20.5
28	Oats	10
41	**Sugarbeets**	**5.6**
44	Other Crops	2.4
4	**Sorghum**	**2**
246	Radishes	1.8
59	Sod/Grass Seed	0.9
21	Barley	0.7
71	Other Tree Crops	0.7
27	**Rye**	**0.4**
208	Garlic	0.4
	TOTAL ACRES	**48052.2**
	% ACRES IN TARGET AOI:	**11.0**

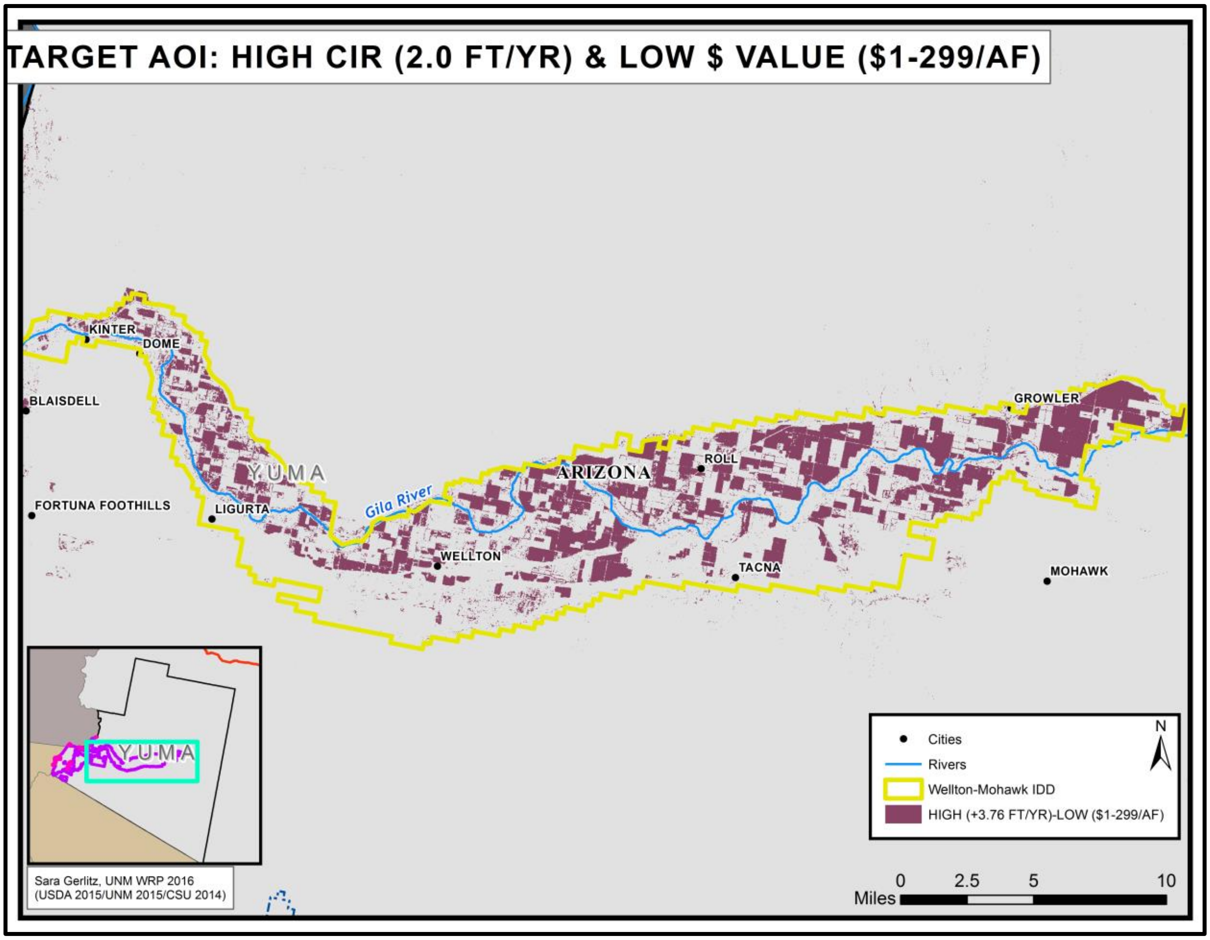
Pg. 59, Figure 14. *WGRG polycentric boundary layers for Cocopah/YCWUA,* (Attachment 2, Gerlitz, 2016).



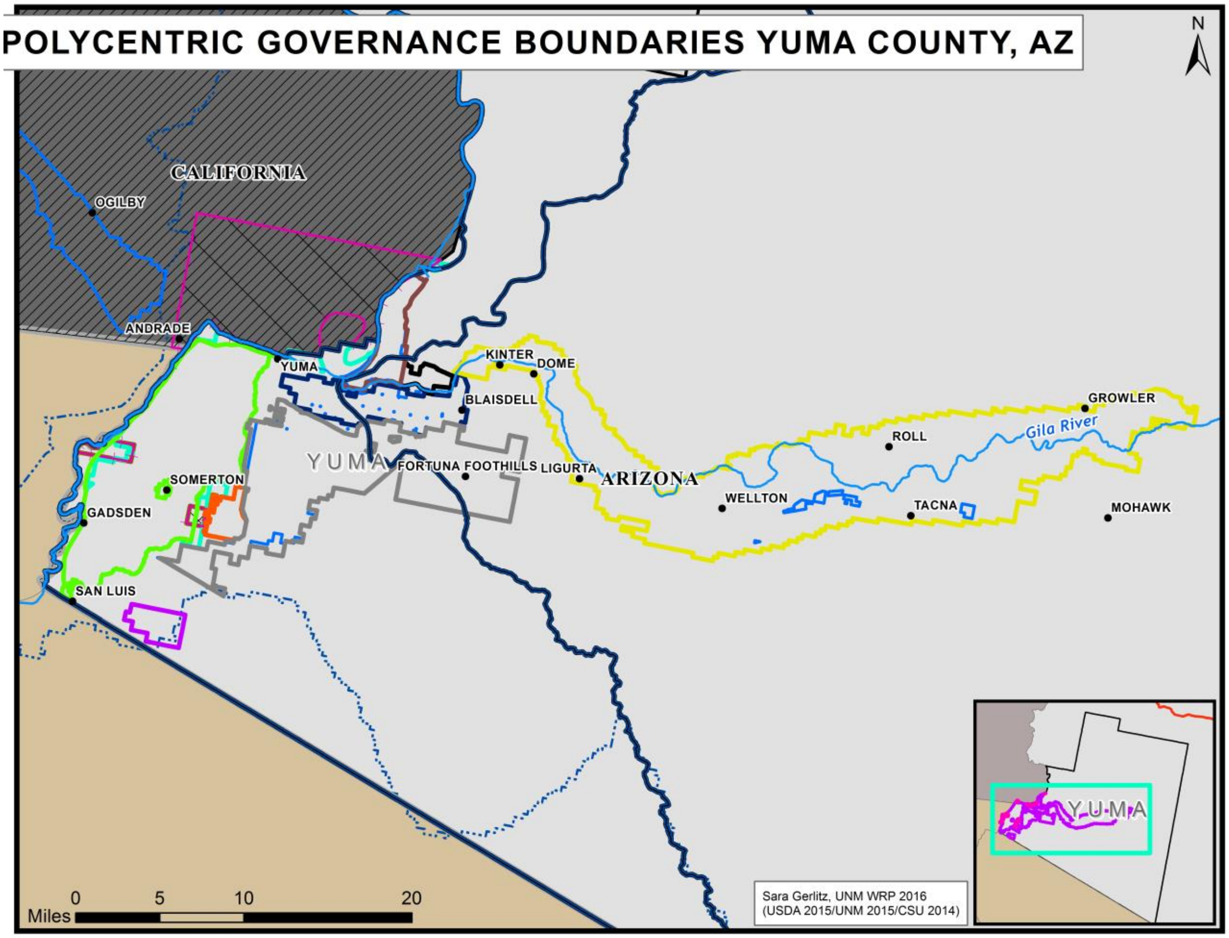
Pg. 59, Table 15. *Wellton-Mohawk crops by acreage and gridcode*, (Attachment 1, Gerlitz, 2016).

GRIDCODE	CROP	ACRES
36	**Alfalfa**	**29261.1**
61	Fallow/Idle Cropland	9632.4
230	Dbl Crop Lettuce/Durum Wht	6852.6
22	Durum Wheat	4213
2	**Cotton**	**3488.5**
227	Lettuce	3377.1
232	Dbl Crop Lettuce/Cotton	3182
176	**Grass/Pasture**	**2815.3**
37	**Other Hay/Non Alfalfa**	**1839.4**
1	Corn	1656.6
214	Broccoli	1529.6
47	Misc Vegs & Fruits	1260.3
72	Citrus	1256.8
243	Cabbage	871.6
59	Sod/Grass Seed	853.8
231	Dbl Crop Lettuce/Cantaloupe	739.2
209	Cantaloupes	629.2
71	Other Tree Crops	399.2
75	Almonds	291.6
48	Watermelons	268.4
49	Onions	195.5
42	Dry Beans	125
57	Herbs	66.7
28	Oats	62
219	Greens	54.5
24	Winter Wheat	27.4
44	Other Crops	26
244	Cauliflower	21.1
213	Honeydew Melons	13.1
211	Olives	11.6
233	Dbl Crop Lettuce/Barley	11.6
35	Mustard	10.5
246	Radishes	6.9
4	**Sorghum**	**4**
21	Barley	3.8
208	Garlic	2.7
74	Pecans	2.4
212	Oranges	1.1
67	Peaches	0.9
206	Carrots	0.7
	TOTAL ACRES	**75065.2**
	%ACRES IN TARGET AOI:	**49.8**

Pg. 59, Figure 15. *Wellton-Mohawk target AOI,* (Attachment 2, Gerlitz, 2016).



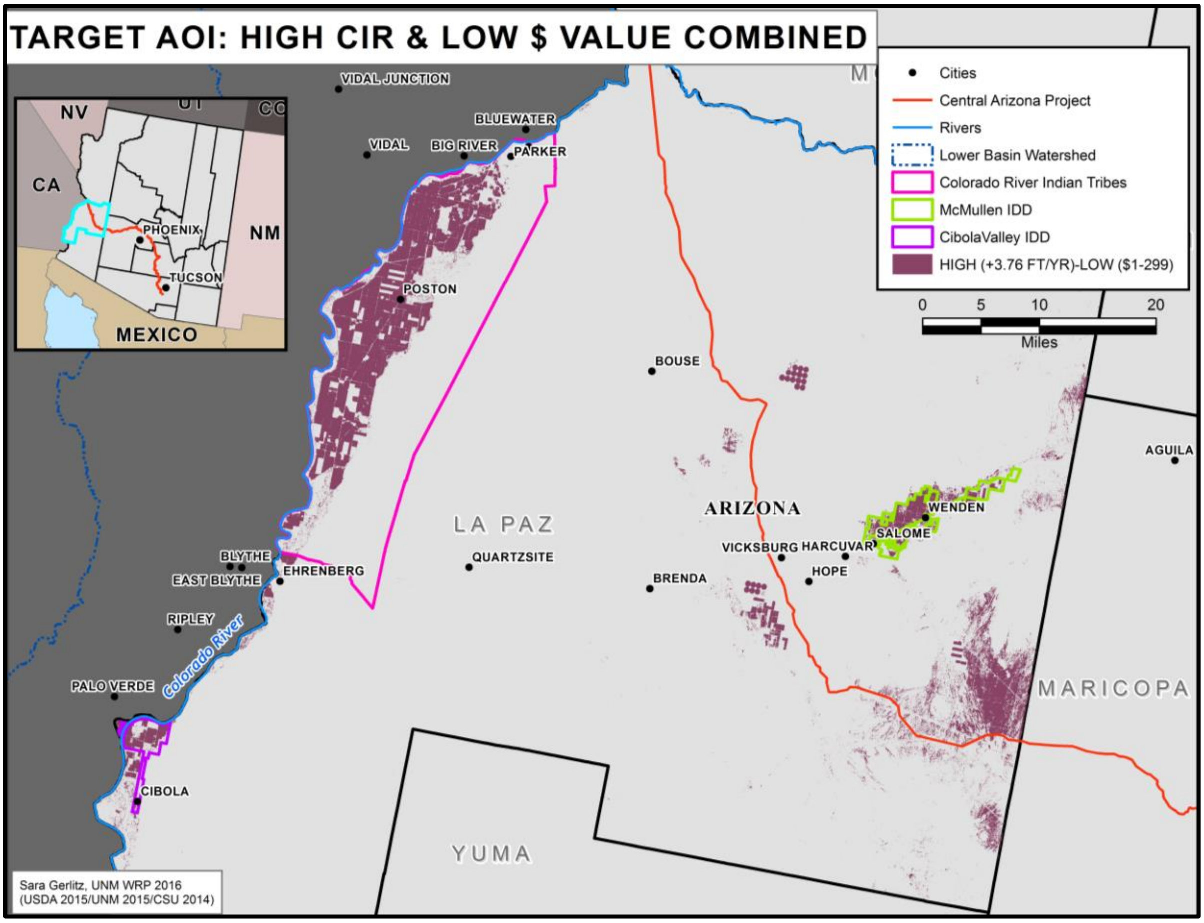
Pg. 59, Figure 16. *WGRG polycentric boundary layers for Yuma County*, (Attachment 2, Gerlitz, 2016).



Pg. 60, Table 16. *La Paz County crops by acreage and gridcode,* (Attachment 1, Gerlitz, 2016).

GRIDCODE	CROP	ACRES
36	**Alfalfa**	**68346.3**
176	**Grass/Pasture**	**57541.9**
61	Fallow/Idle Cropland	24999.6
2	**Cotton**	**13325.4**
71	Other Tree Crops	6171
22	Durum Wheat	5392.4
37	**Other Hay/Non Alfalfa**	**3917.5**
49	Onions	844.4
208	Garlic	654.5
28	Oats	407.6
72	Citrus	219.5
47	Misc Vegs & Fruits	192.1
214	Broccoli	181.3
1	Corn	163
4	**Sorghum**	**127.4**
21	Barley	92.7
227	Lettuce	65.2
42	Dry Beans	56.7
75	Almonds	38.9
243	Cabbage	38.7
232	Dbl Crop Lettuce/Cotton	32.5
67	Peaches	30.7
31	Canola	26.5
209	Cantaloupes	19.6
230	Dbl Crop Lettuce/Durum Wht	18.5
44	Other Crops	15.3
59	Sod/Grass Seed	11.1
211	Olives	5.6
74	Pecans	5.3
213	Honeydew Melons	3.8
235	Dbl Crop Barley/Sorghum	3.6
24	Winter Wheat	3.3
234	Dbl Crop Durum Wht/Sorghum	2
231	Dbl Crop Lettuce/Cantaloupe	1.3
219	Greens	0.9
236	Dbl Crop WinWht/Sorghum	0.9
	TOTAL ACRES	**182957**
	% ACRES IN TARGET AOI:	**78.3**

Pg. 60, Figure 17. *La Paz County target AOIs*, (Attachment 2, Gerlitz, 2016).



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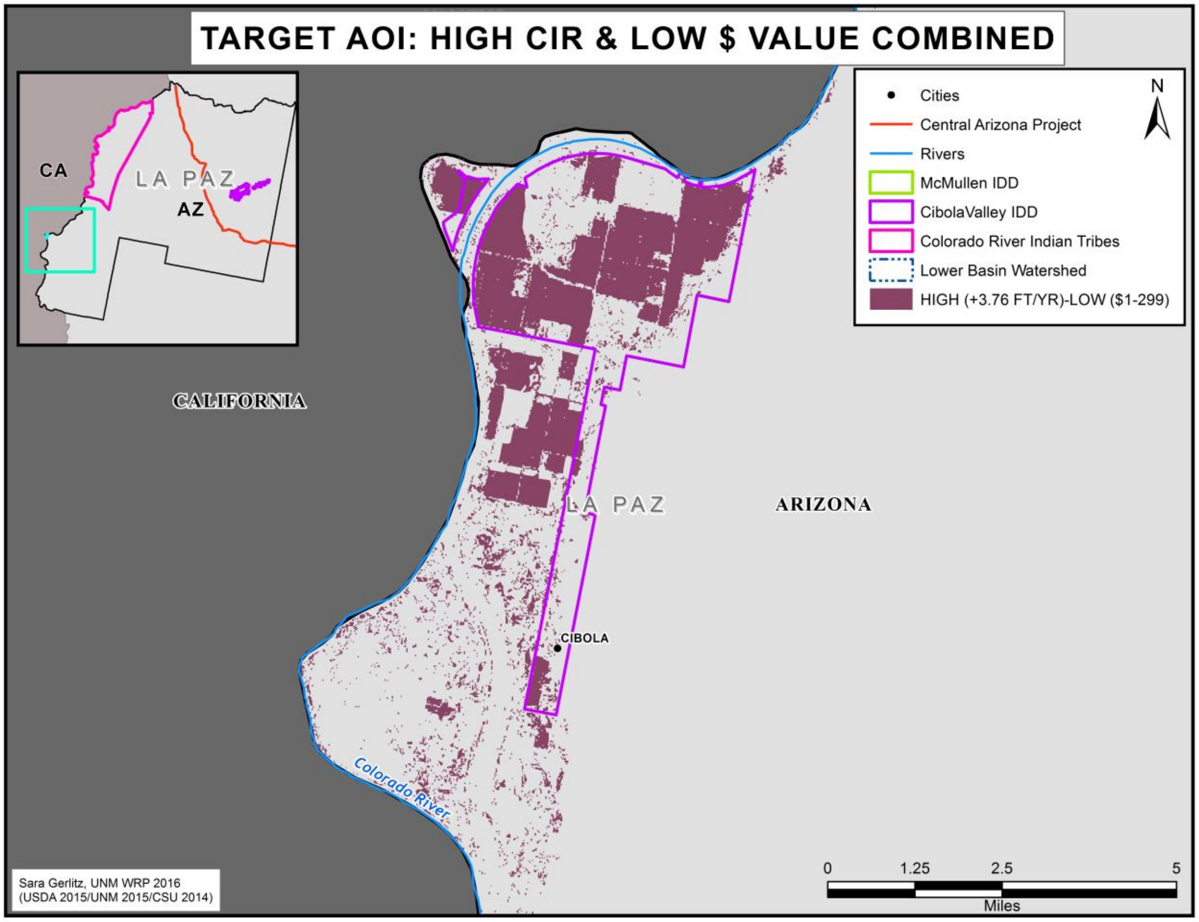
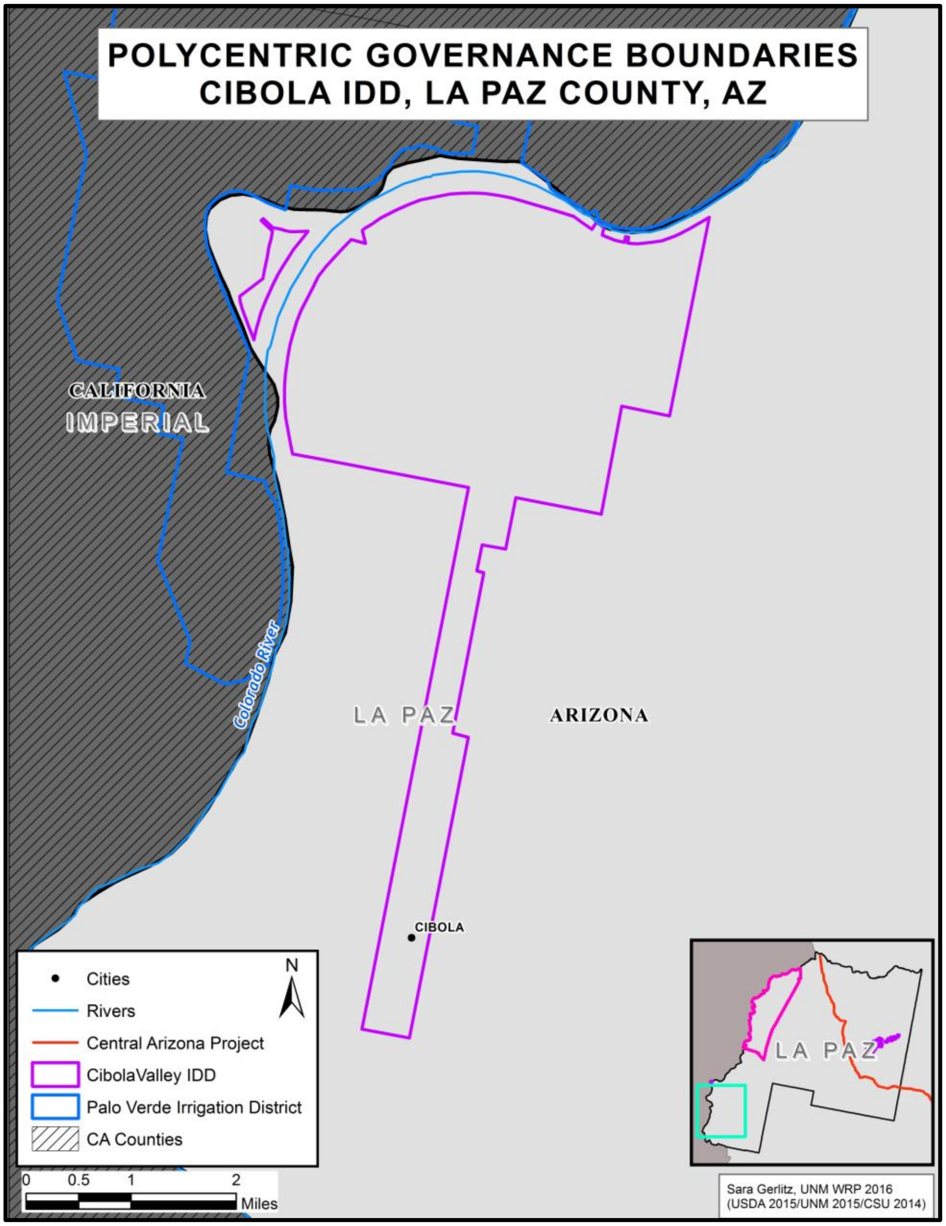
Pg. 61, Table 17. *Cibola crops by acreage and gridcode*, (Attachment 1, Gerlitz, 2016).

GRIDCODE	CROP	ACRES
2	**Cotton**	**1825.4**
36	**Alfalfa**	**1275**
71	Other Tree Crops	1119.3
61	Fallow/Idle Cropland	573.6
176	**Grass/Pasture**	**484.8**
47	Misc Vegs & Fruits	27.1
232	Dbl Crop Lettuce/Cotton	14.7
22	Durum Wheat	10
209	Cantaloupes	9.6
227	Lettuce	8.9
75	Almonds	7.6
37	**Other Hay/Non Alfalfa**	**4.7**
59	Sod/Grass Seed	2.9
1	Corn	2.4
72	Citrus	1.8
230	Dbl Crop Lettuce/Durum Wht	1.8
231	Dbl Crop Lettuce/Cantaloupe	0.7
214	Broccoli	0.4
243	Cabbage	0.4
	TOTAL ACRES	**5371.1**
	% ACRES IN TARGET AOI:	**66.8**

Pg. 61, Figure 18. *Cibola target AOIs,* (Attachment 2, Gerlitz, 2016).



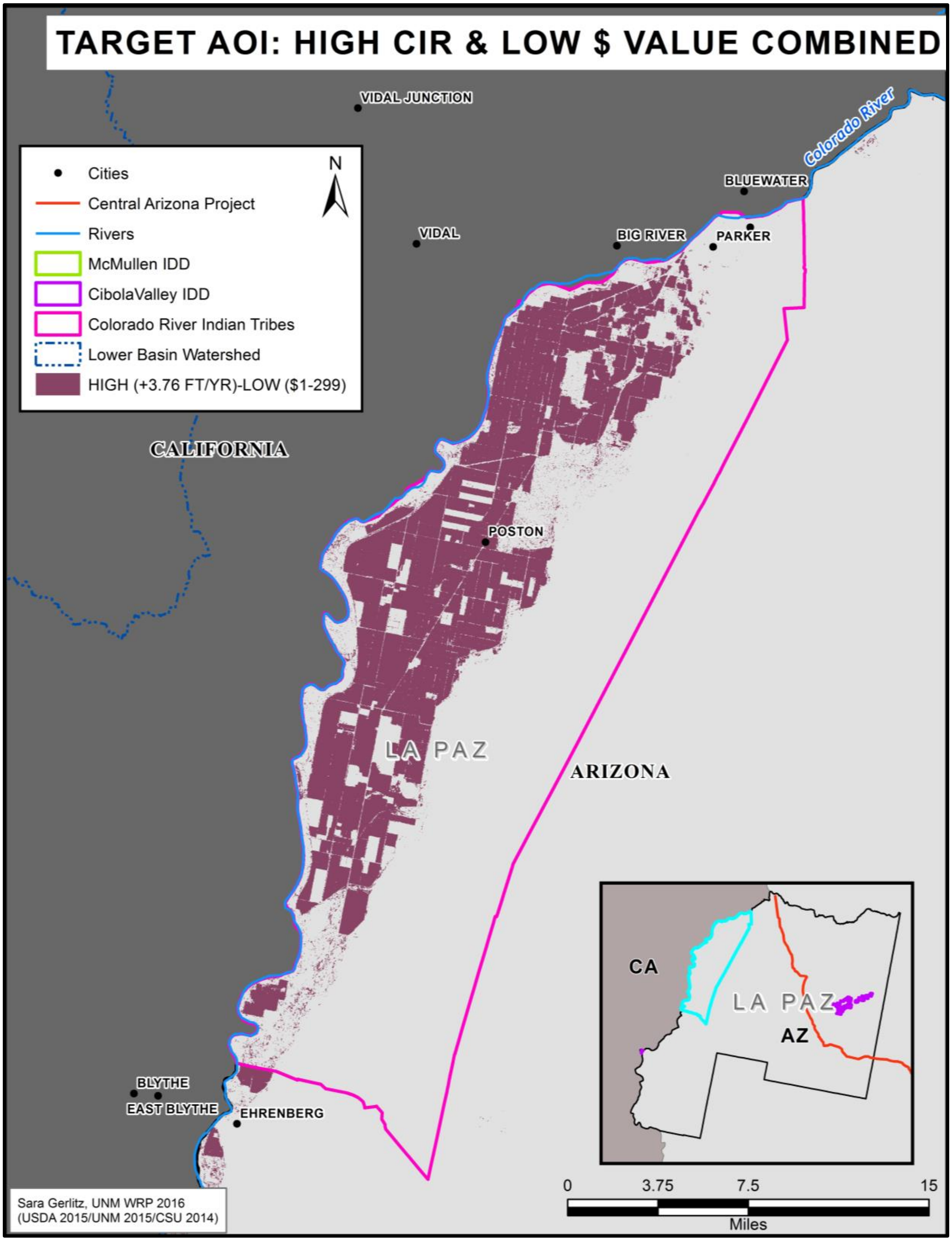
Pg. 61, Figure 19. *WGRG polycentric boundary layers for Cibola*, (Attachment 2, Gerlitz, 2016).



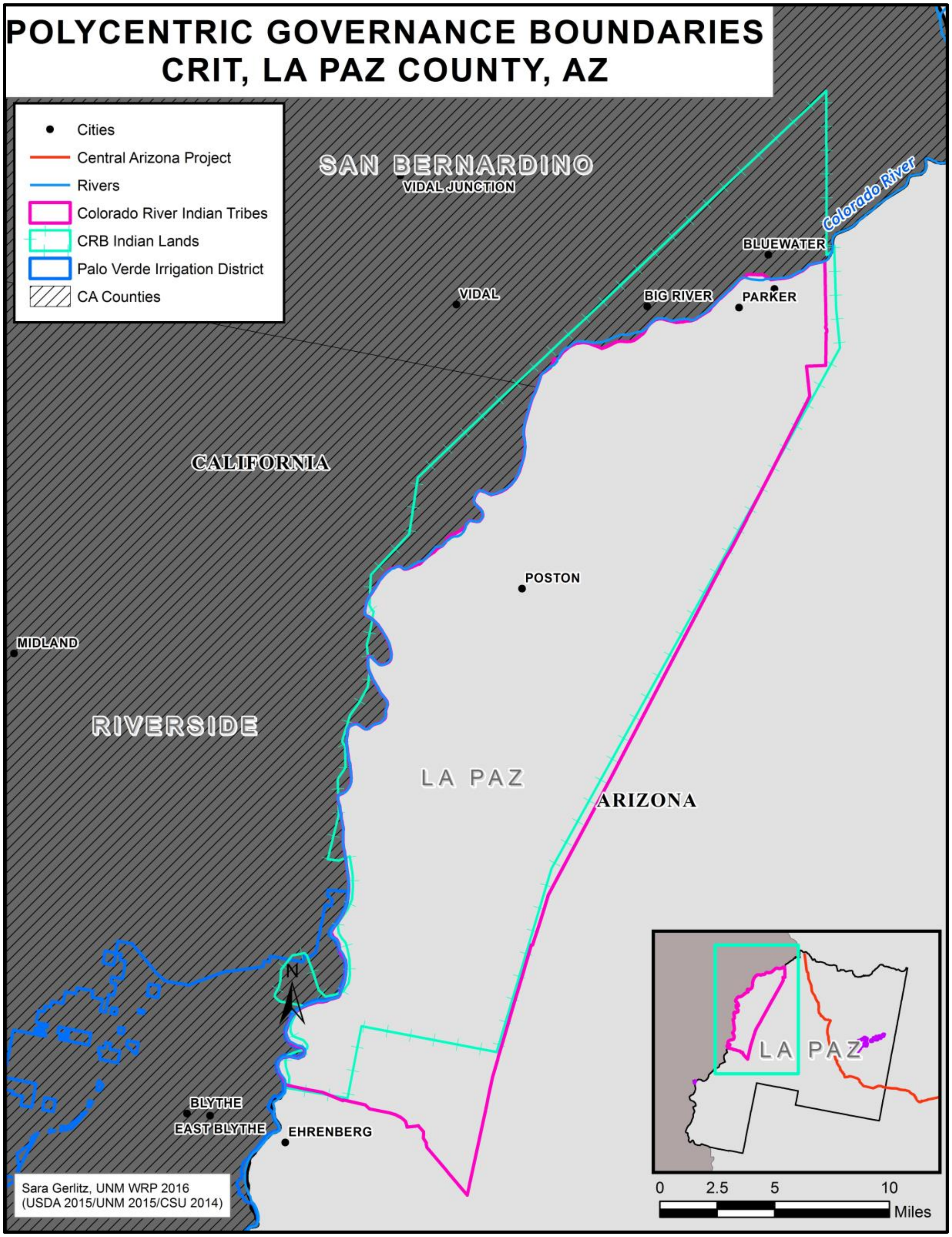
Pg. 61, Table 18. *CRIT crops by acreage and gridcode,* (Attachment 1, Gerlitz, 2016).

GRIDCODE	CROP	ACRES
36	**Alfalfa**	**59319.3**
61	Fallow/Idle Cropland	11537.2
2	**Cotton**	**8735.7**
176	**Grass/Pasture**	**5759.1**
22	Durum Wheat	3891.9
37	**Other Hay/Non Alfalfa**	**3651.7**
71	Other Tree Crops	1798.3
49	Onions	844
208	Garlic	636
28	Oats	394.1
214	Broccoli	177.5
47	Misc Vegs & Fruits	68.7
72	Citrus	48.5
227	Lettuce	42.5
67	Peaches	28
31	Canola	26.5
44	Other Crops	12.7
243	Cabbage	11.3
1	Corn	8.9
232	Dbl Crop Lettuce/Cotton	7.6
209	Cantaloupes	7.3
230	Dbl Crop Lettuce/Durum Wht	6.2
211	Olives	5.3
213	Honeydew Melons	3.3
59	Sod/Grass Seed	2.4
75	Almonds	1.1
24	Winter Wheat	0.4
4	**Sorghum**	**0.2**
231	Dbl Crop Lettuce/Cantaloupe	0.2
	TOTAL ACRES	**97,025.90**
	% ACRES IN TARGET AOI:	**79.8**

Pg. 61, Figure 20. *CRIT target AOIs,* (Attachment 2, Gerlitz, 2016).



Pg. 61, Figure 21. *WGRG polycentric boundary layers for CRIT,* (Attachment 2, Gerlitz, 2016).



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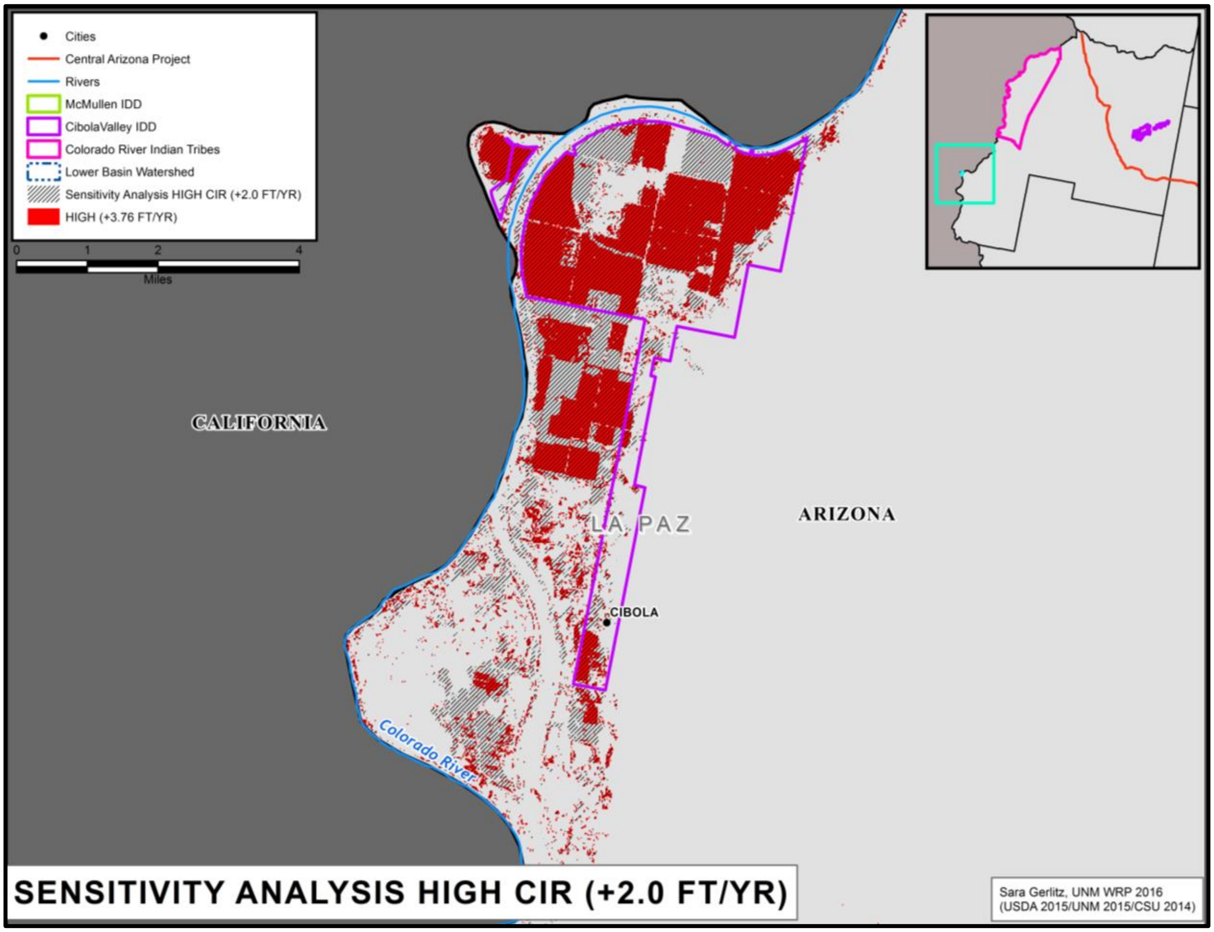
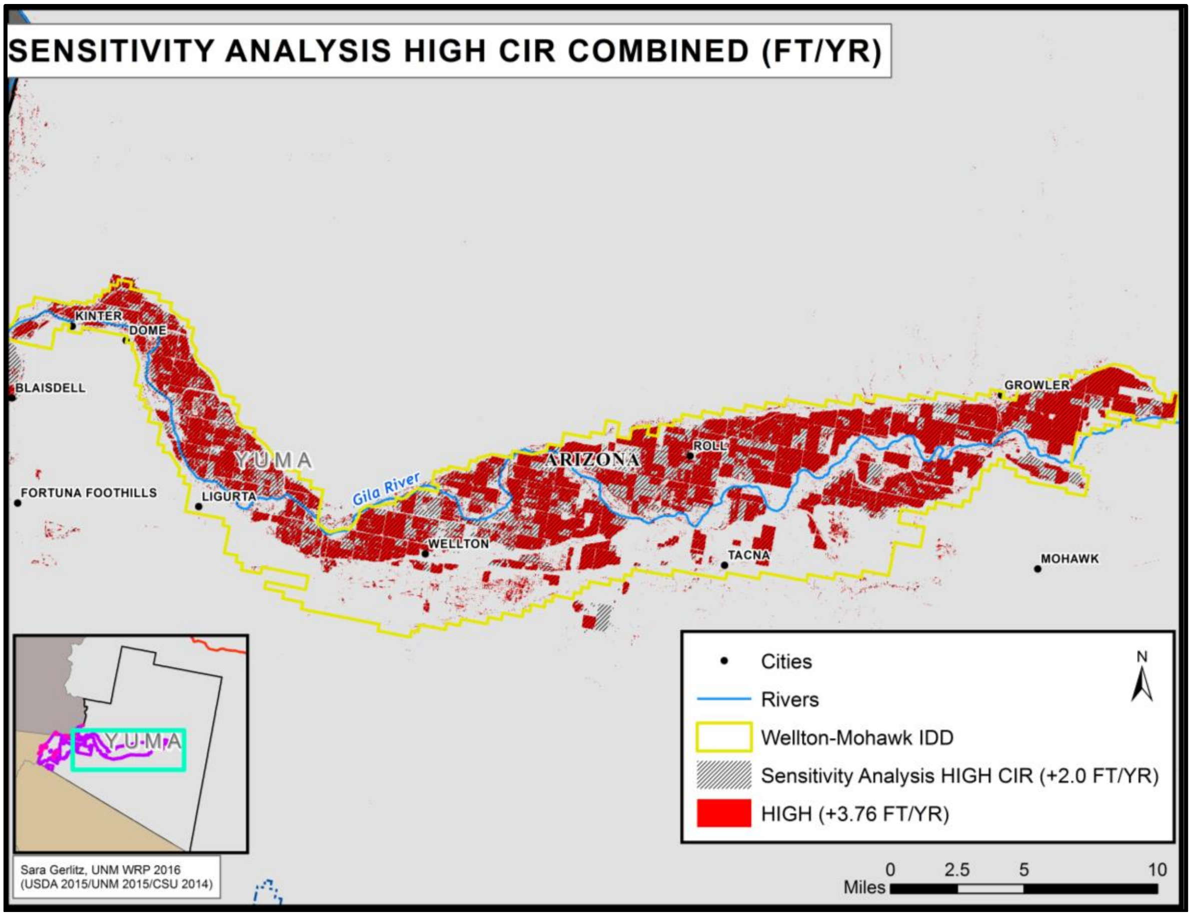
Pg. 62, Figure 22. *HIGH CIR sensitivity analysis for Cibola,* (Attachment 2, Gerlitz, 2016).



Pg. 62, Figure 23. *HIGH CIR sensitivity analysis for Wellton-Mohawk,* (Attachment 2, Gerlitz, 2016).



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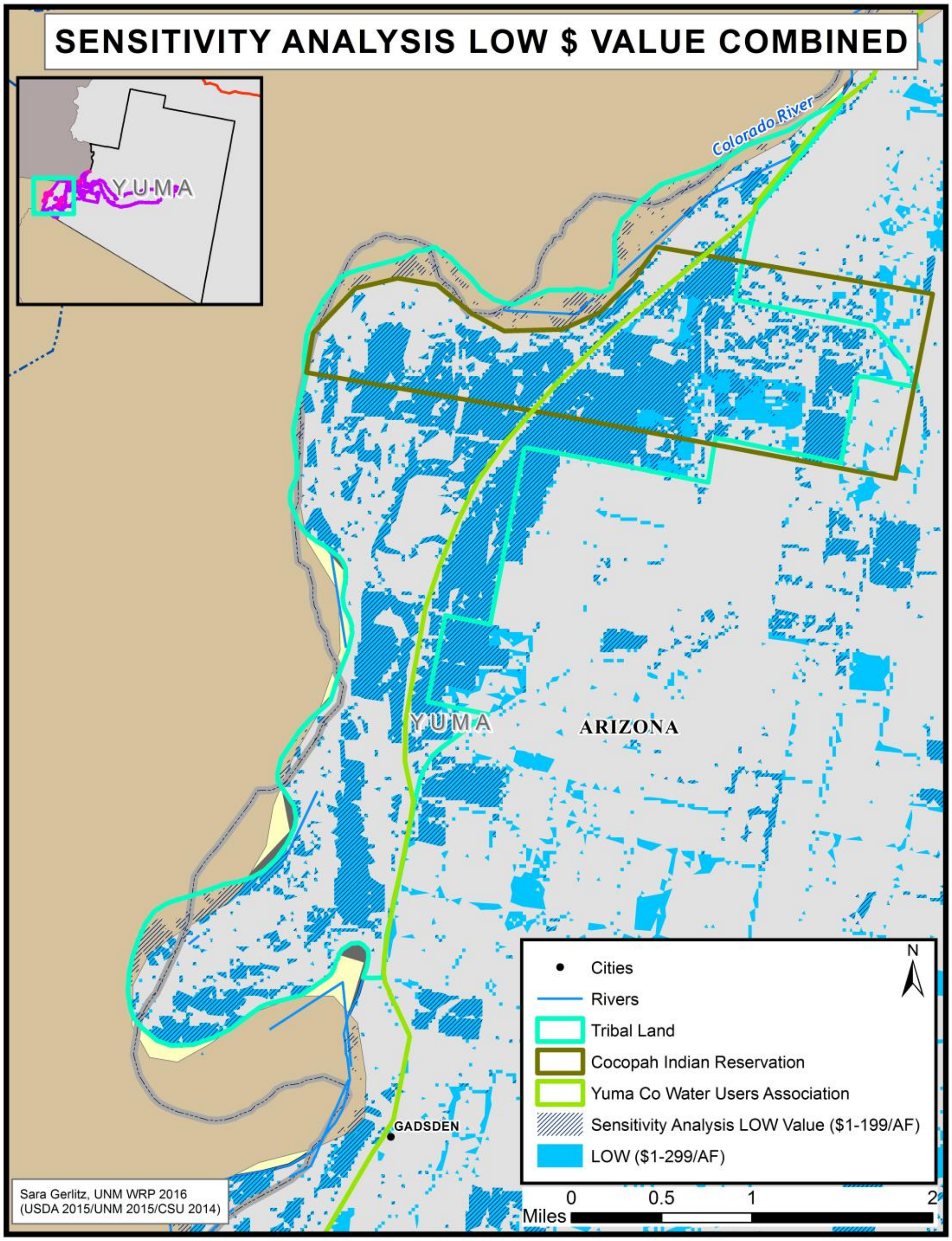
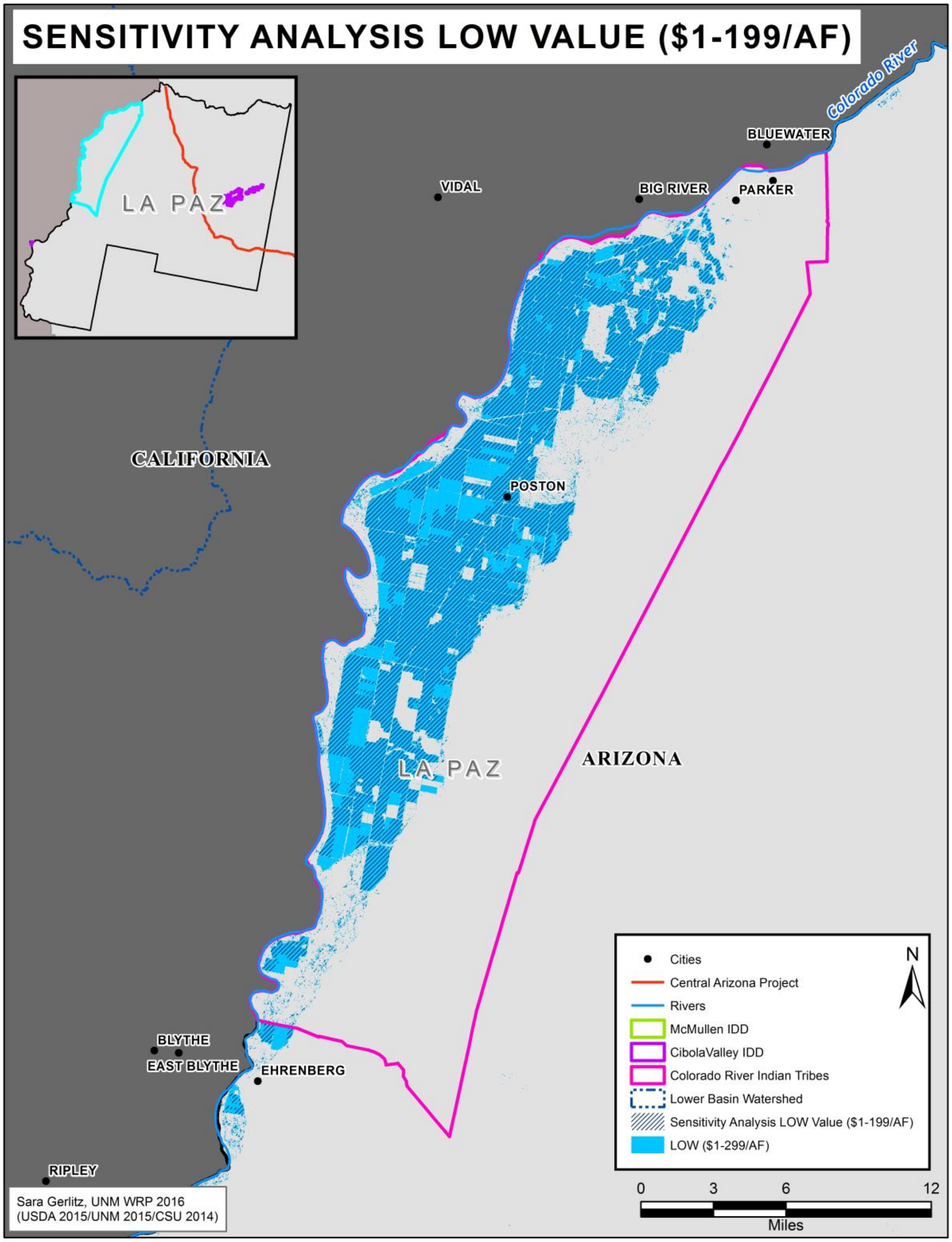
Pg. 62, Figure 24. *LOW water use value sensitivity analysis for Cocopah/YCWUA,* (Attachment 2, Gerlitz, 2016).



Pg. 62, Figure 25. *LOW water use value sensitivity analysis for CRIT,* (Attachment 2, Gerlitz, 2016).



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Pg. 62, Table 19. *Target AOI crops and sensitivity analysis,* (Attachment 1, Gerlitz, 2016).

Crop Name	Erie/CADWR&CWSD	USDA NASS	COMBINED	SENSITIVITY ANALYSIS
Cotton		2	2	
Sorghum	4		4	4
Rye		27	27	27
Alflalfa	36	36	36	36
Other Hay/Non Alfalfa	37	37	37	37
Sugarbeets		41	41	41
Grass/Pasture	176		176	176

Discussion of Results

From the geospatial tools developed and utilized in this case study research, the recommendation as to where to invest social capital for potential wheeling policy-based ATMs would be the CRIT water governance entity in La Paz County. For on-river, irrigated agriculture, CRIT had the highest percentage of agricultural acreage in target gridcodes (79.8%), as well as the most agricultural acreage for La Paz County (182,957 acres), (Table 20). While McMullen IDD had a slightly higher percentage (81.7%), it's location off-river and its utilization of groundwater over surface water disqualified this water user as the best place to start wheeling-based social capital investments. Yuma County had the most agricultural acreage (232,910 acres) but only 33.4% was target crops. On the county level, La Paz County is the recommended target agricultural region not only for the high percentage of target crops (78.3%) but also for its small amount of water governance institutions. With less polycentrism than Yuma County (Fig. 16), the initial search for wheeling partners is simplified (Table 21). In addition, geographically isolated AOI(s), like CRIT, Cibola and Wellton-Mohawk, are recommended targets for social capital investment because relationship-building in agricultural regions with only one water user group could prove easier than attempting to engage in areas with several.

CIR

The differences between the two CIR datasets was apparent in the Yuma County maps where the USDA NASS dataset had significantly more HIGH (red) crop gridcodes than the Erie et al./CADWR map (Figures 26—27). However, for an at-a-glance analysis of the CIR maps for the two counties, La Paz appears to have more HIGH and MEDIUM crops than Yuma regardless of the CIR dataset used (Figures 28—29). Also, on the smaller water user group scale, such as for Cibola, orCocopah Indian Tribe/YCWUA, the CIR at the pixel level shows the diversity of water use within an individual agricultural area. Mapped individually, the three CIR types are less pronounced than when visualized together.

Water Use Value

For the case study area, the LOW (light blue) water use value highlighted differences in the two counties. La Paz, while having pixels for all value categories was dominated by LOW and MEDIUM value crops, more so than Yuma County. A similar scale issue, as found in the CIR, applied to water use value maps as well. One important factor to consider was the USDA NASS maps lack of a HIGH (green) water use value layer, as none of the crops under that naming and value assignment category were present (Fig. 30). The CWSD model maps (Figures 31—32) visually aid the targeting process with the three color distinctions. Yuma’s smaller farm size and diversity of crops were well defined with the HIGH (green) water use value layer.

Target AOI Crops

The target crops layers generated in ESRI ArcGIS 10.1 have unique exclusions of certain gridcodes between the naming groups. The USDA NASS-based target group had a total of five gridcodes illustrated in the maps. This group’s map excluded (4) Sorghum and (176) Grass/Pasture and appear to be denser with less presence of scattered pixels throughout the AOI of interest (Fig. 33). The Erie/CADWR/CWSD maps show slightly less density in agricultural areas yet are more widespread throughout an AOI (Fig. 34). This layer excluded (2) Cotton, (27) Rye and (41) Sugarbeets. As (27) Rye and (41) Sugarbeets have very low acreages, the notable exclusion in this group is (2) Cotton. The combined layer had a total of seven gridcodes, accounting for the discrepancies between the two separate groups. The combined layer was the chosen layer in which to work for the social capital investment recommendations as well as for the sensitivity analysis (Fig. 35).

Sensitivity Analysis

For further investigation into the target crop designations, a sensitivity analysis of the agricultural datasets was performed. CIR values considered HIGH were re-defined to be at or above 2.0 FT/year, a 1.76-foot increase of the HIGH definition. The LOW water use value category was changed to $1-199 per acre-foot, a decrease in value of $100 from the original LOW value. The result of these changes in the different crop categorization groups was the exclusion of target gridcode (2) Cotton. The sensitivity analysis showed how different CIR definitions, more so than water use values, could produce different geospatial results for the case study region (Fig. 36). The restriction of the LOW water use value group to exclude crops worth more than $200/AF had little no change. The sensitivity of CIR was most prevalent in the USDA NASS 2013 FRIS group. One outcome from the sensitivity analysis was the exclusionary feature for (2) Cotton.

Water Governance

The polycentric governance throughout the case study area varied between the two counties. Yuma County, with ten water user groups, also had several other WGRG data layers (Federal Lands, BIA lands, BOR irrigation districts, international border, state border, etc.) to consider in terms of social capital investment. While having more individual groups could be beneficial in terms of targeting options, the heavy overlap of water governance in the on-river areas (Cocopah Indian Tribe/YCWUA) could prove more difficult to identify potential wheeling partners than from geographically isolated areas. For Yuma County, Wellton-Mohawk was determined to be the preferred water governance entity in which to invest social capital due to its location and high percentage of target crops (49.8%). Similar geographic isolation preference was found for La Paz County (Cibola/CRIT).

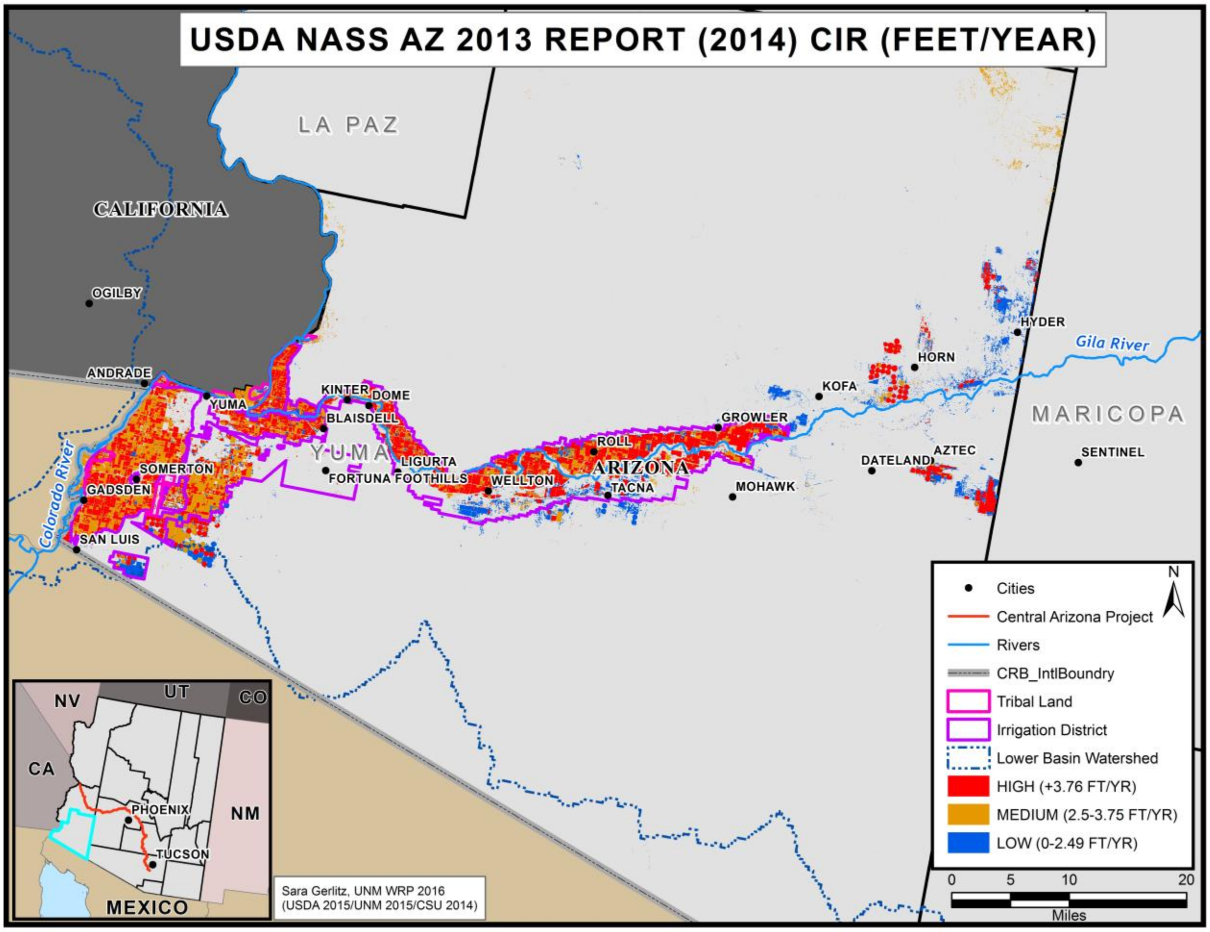
Pg. 86, Table 20. *Percent acres in target AOI crops,* (Attachment 1, Gerlitz, 2016).

WATER USER GROUP	COUNTY	ACRES	% ACRES IN TARGET
McMULLEN IDD	LA PAZ	10,030	81.7%
CRIT	LA PAZ	97,026	79.8%
LA PAZ COUNTY (ALL)	LA PAZ	182,957	78.3%
CIBOLA	LA PAZ	5,371	66.8%
WELLTON MOHAWK	YUMA	75,065	49.8%
COCOPAH	YUMA	1,818	41.2%
YUMA COUNTY (ALL)	YUMA	232,910	33.4%
YUMA MESA IDD	YUMA	21,606	32.7%
UNIT B IDD	YUMA	2,559	32.1%
HILLANDER C IDD	YUMA	2,704	19.8%
NORTH GILA VALLEY	YUMA	6,968	19.6%
STURGEST GILA MONSTER	YUMA	1,878	15.2%
YUMA CO WATER USERS	YUMA	48,052	11.0%
YUMA IDD	YUMA	11,284	5.1%

Pg. 86, Table 21. *Water governance entities per water user group (excluding California and cities layers),* (Attachment 1, Gerlitz, 2016).

WATER USER GROUP	COUNTY	POLYCENTRIC GOVERNANCE
CRIT	LA PAZ	1
CIBOLA	LA PAZ	1
WELLTON MOHAWK	YUMA	3
ON-RIVER YUMA CO AREA	YUMA	7

Pg. 86, Figure 26. *Yuma County CIR: USDA NASS 2012 Census, 2013 FRIS, Table 36* (Attachment 2, Gerlitz, 2016).



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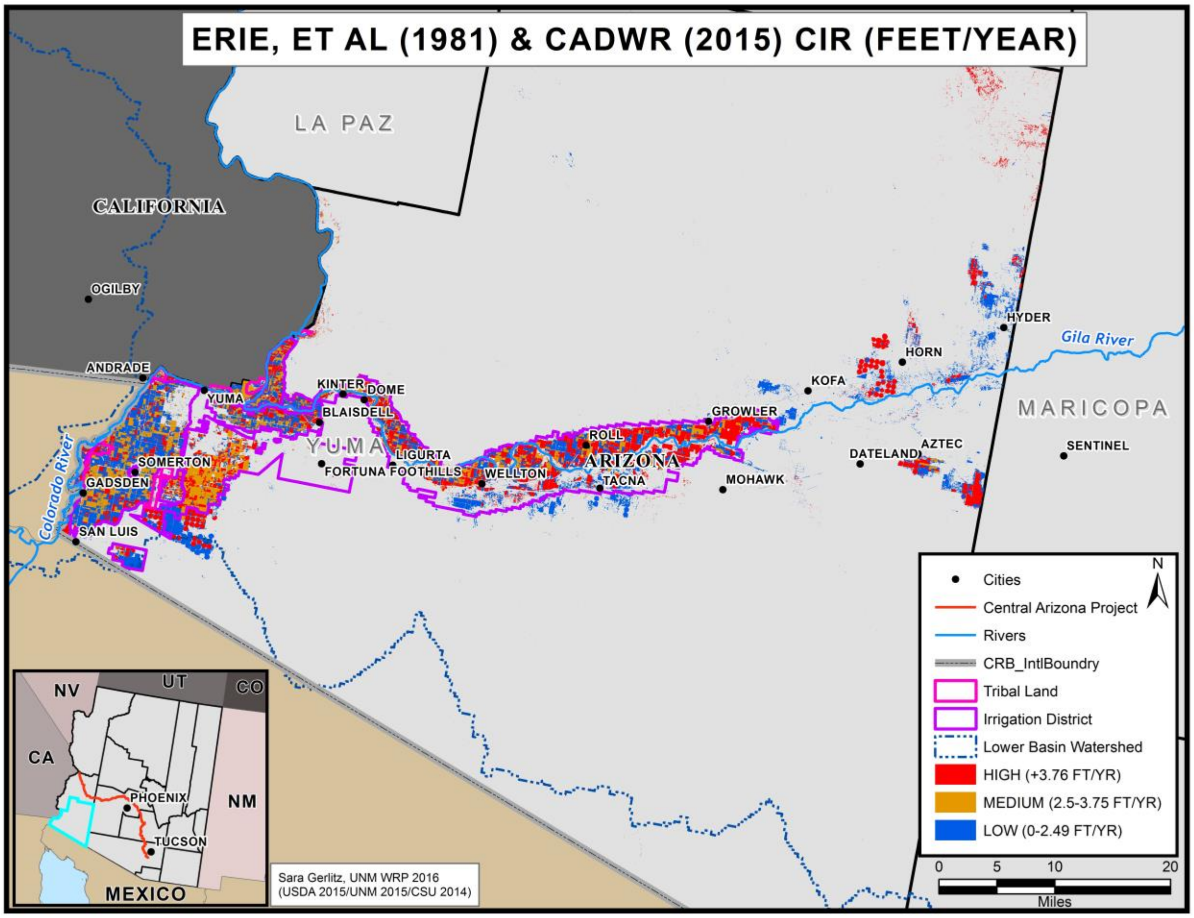
Pg. 86, Figure 27. *Yuma County CIR: Erie et al. and CADWR*, (Attachment 2, Gerlitz, 2016).



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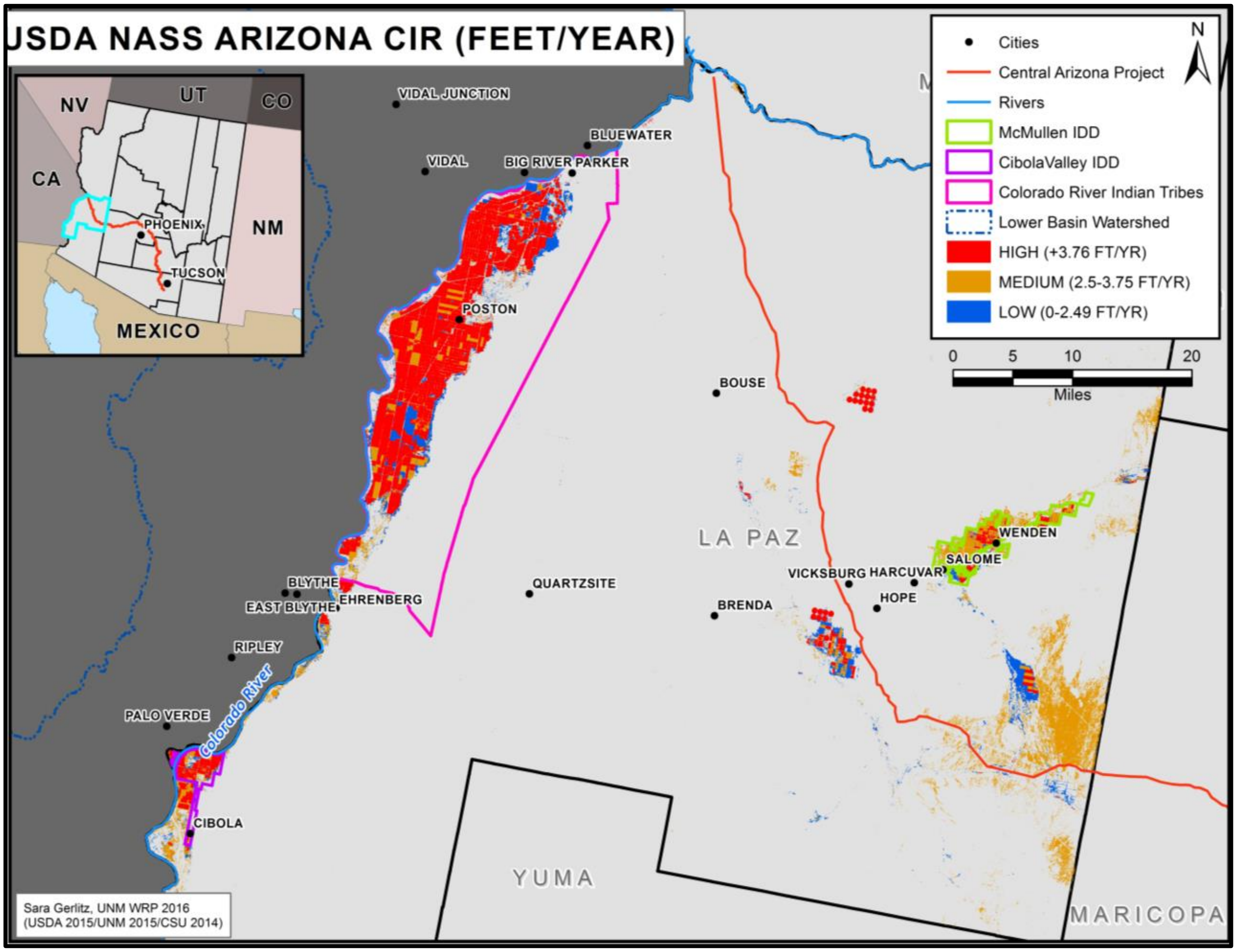
(USDA 2015/UNM 2015/CSU 2014)

Pg. 86, Figure 28. *La Paz County CIR: USDA NASS 2012 Census, 2013 FRIS, Table 36*, (Attachment 2, Gerlitz, 2016).



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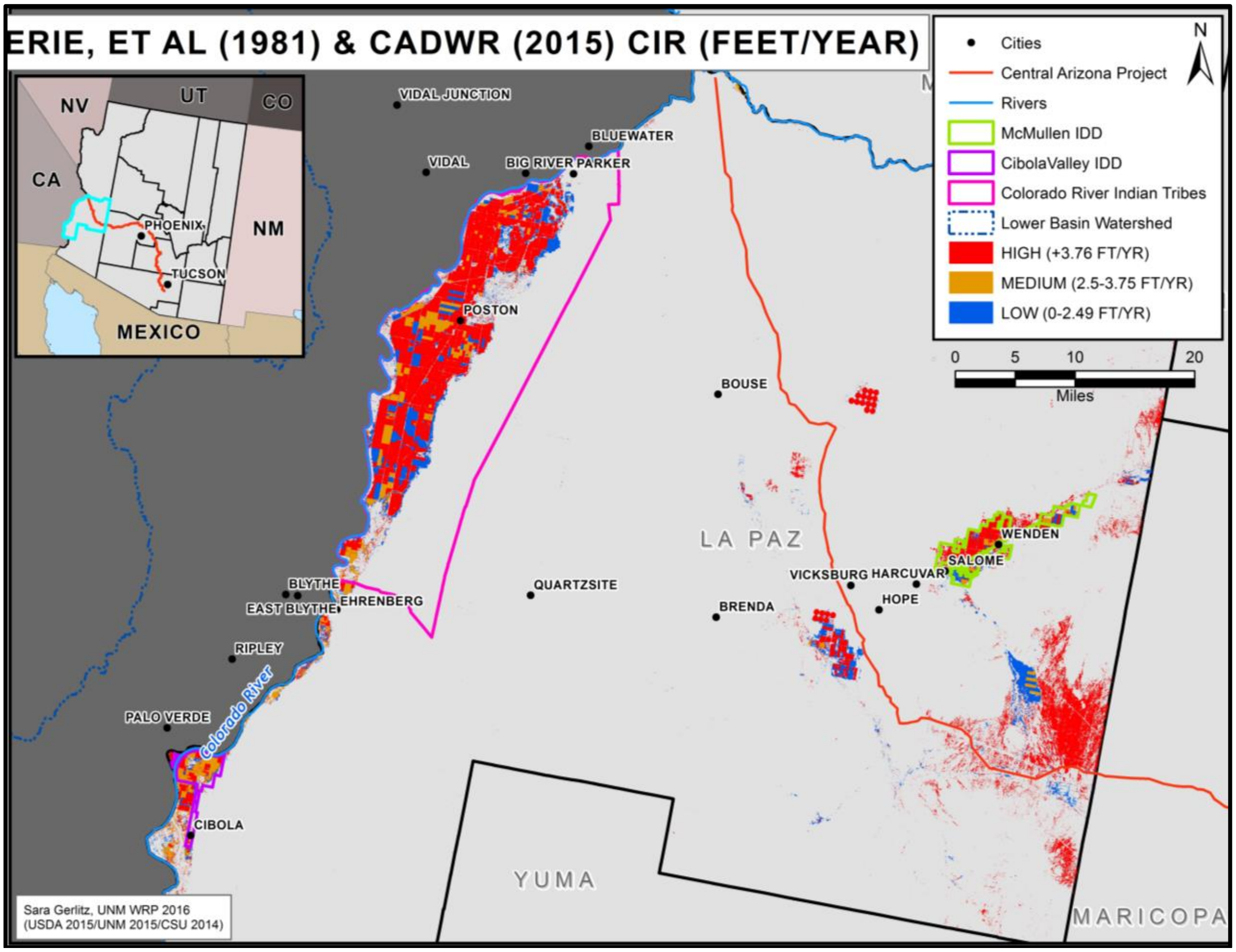
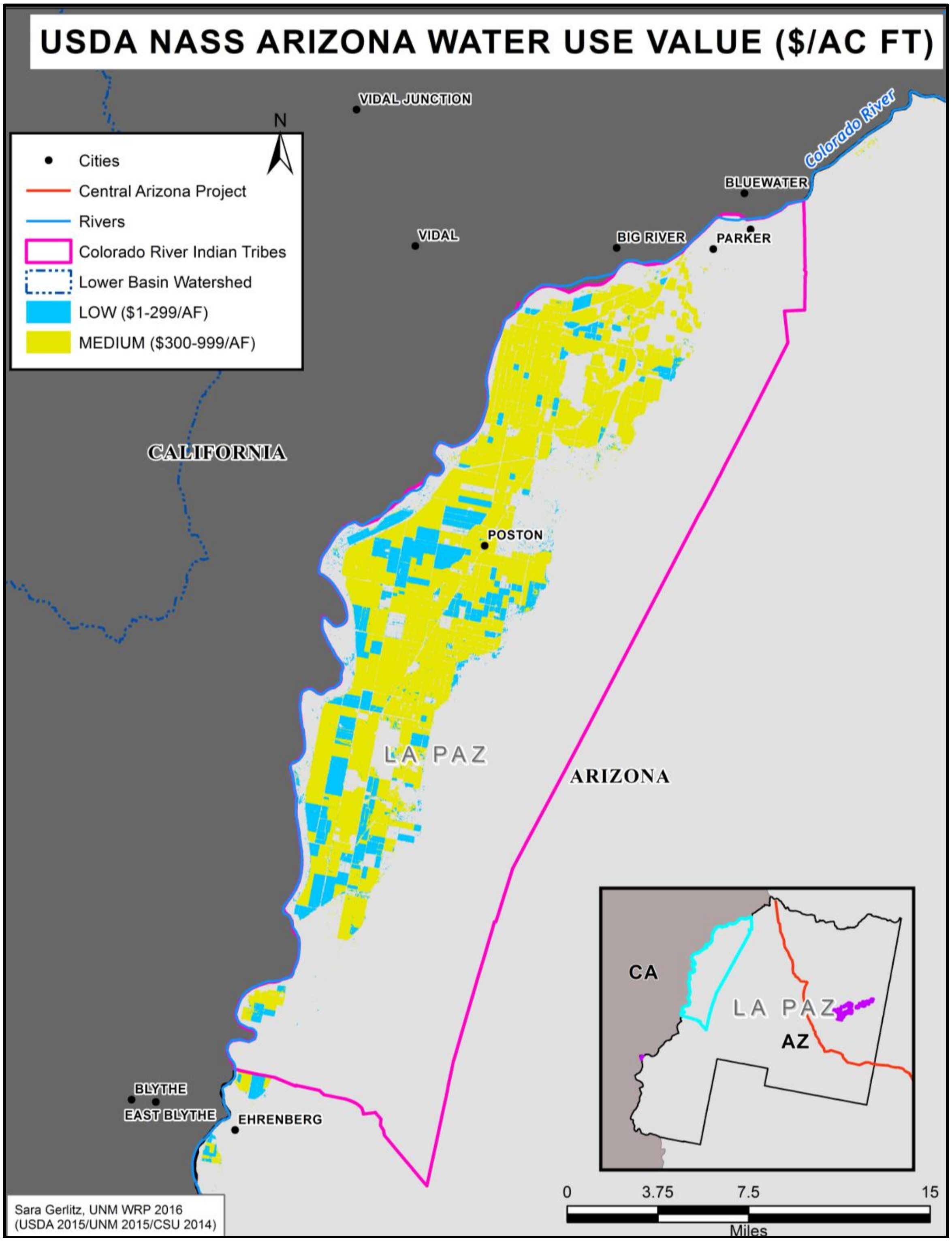
(USDA 2015/UNM 2015/CSU 2014)

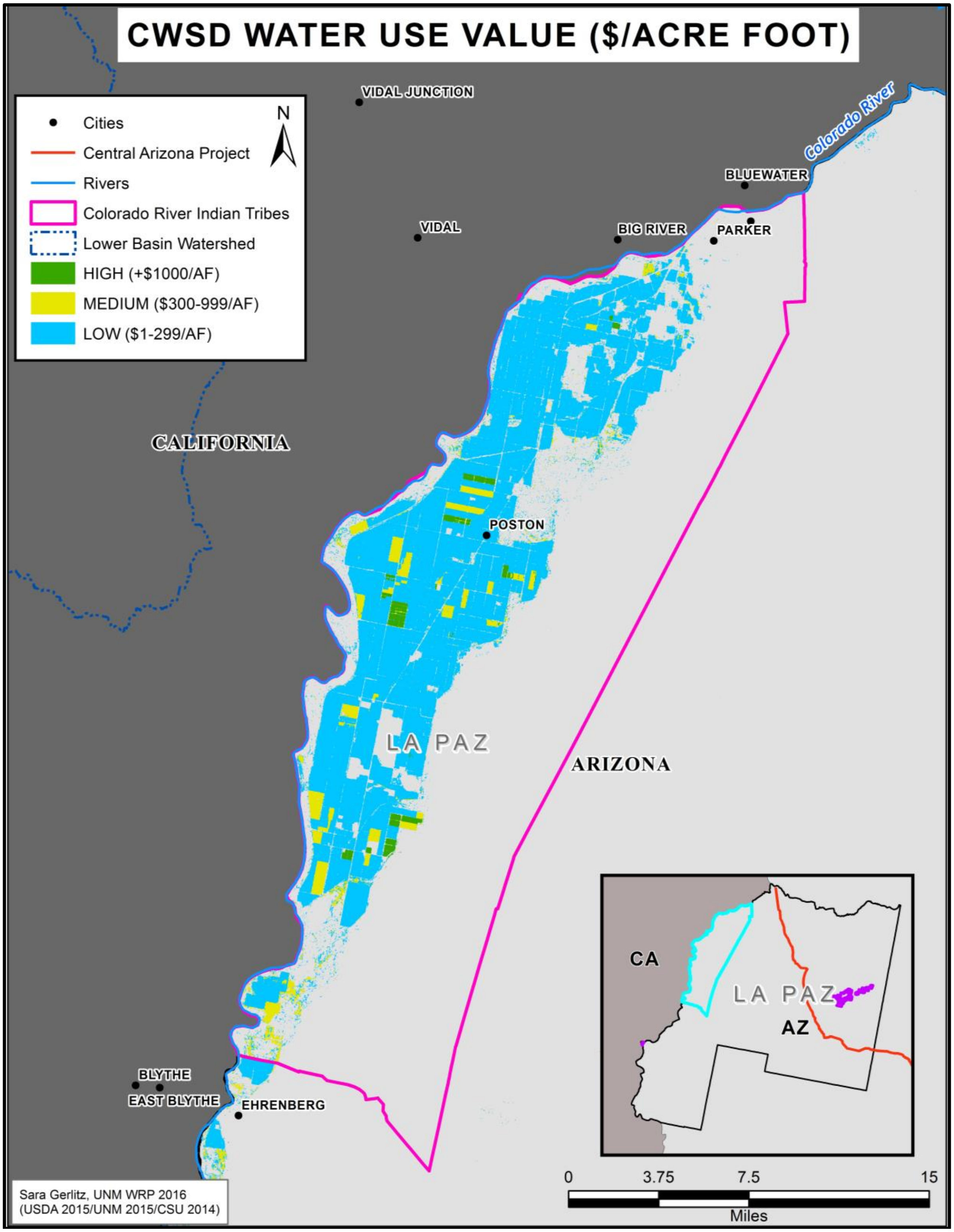
Pg. 86, Figure 29. *La Paz County CIR: Erie et al. and CADWR,* (Attachment 2, Gerlitz, 2016).



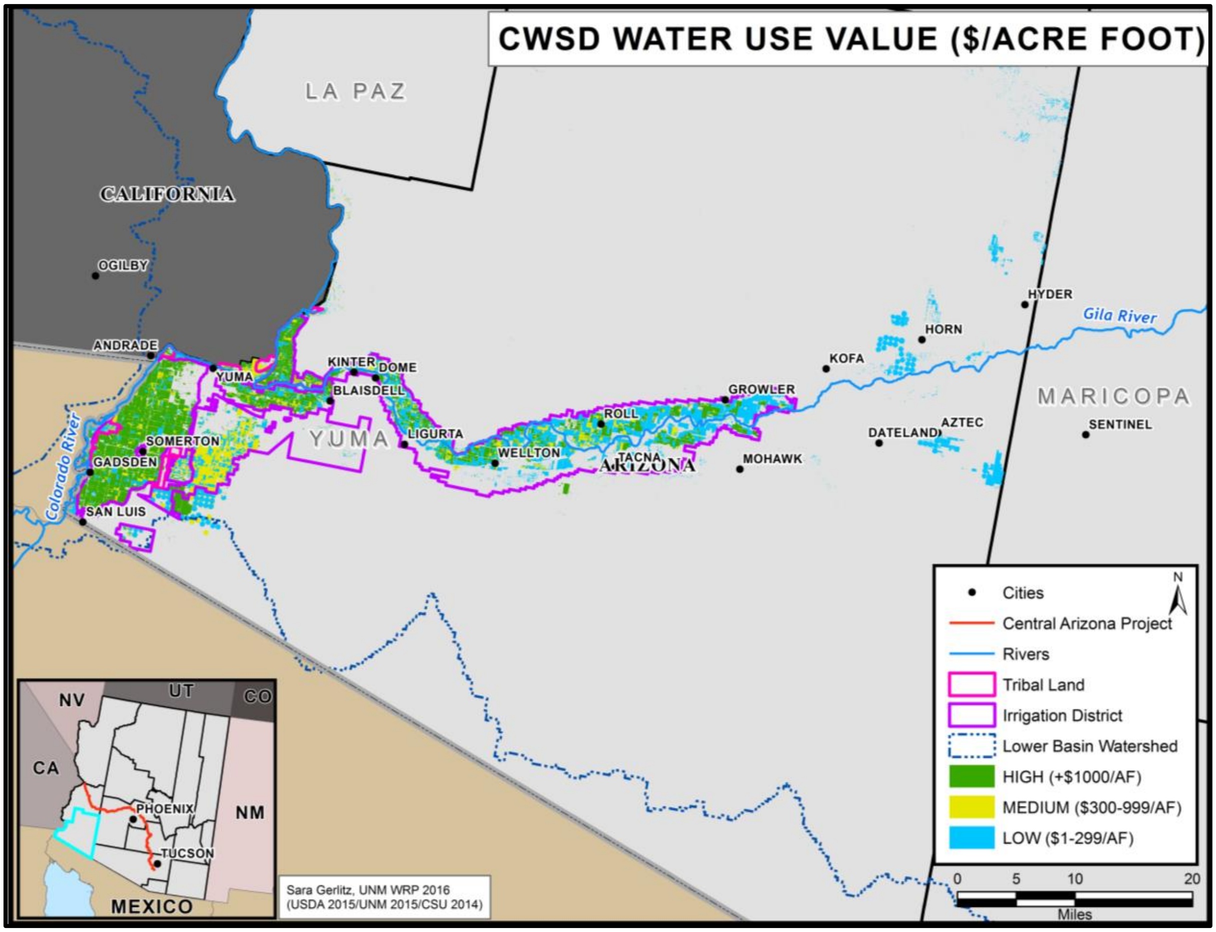
Pg. 87, Figure 30. *CRIT water use values: USDA NASS 2014 AZ Bulletin*, (Attachment 2, Gerlitz, 2016).



Pg. 87, Figure 31. *CRIT water use values: CWSD model*, (Attachment 2, Gerlitz, 2016).



Pg. 87, Figure 32. *Yuma County water use values: CWSD model*, (Attachment 2, Gerlitz, 2016).



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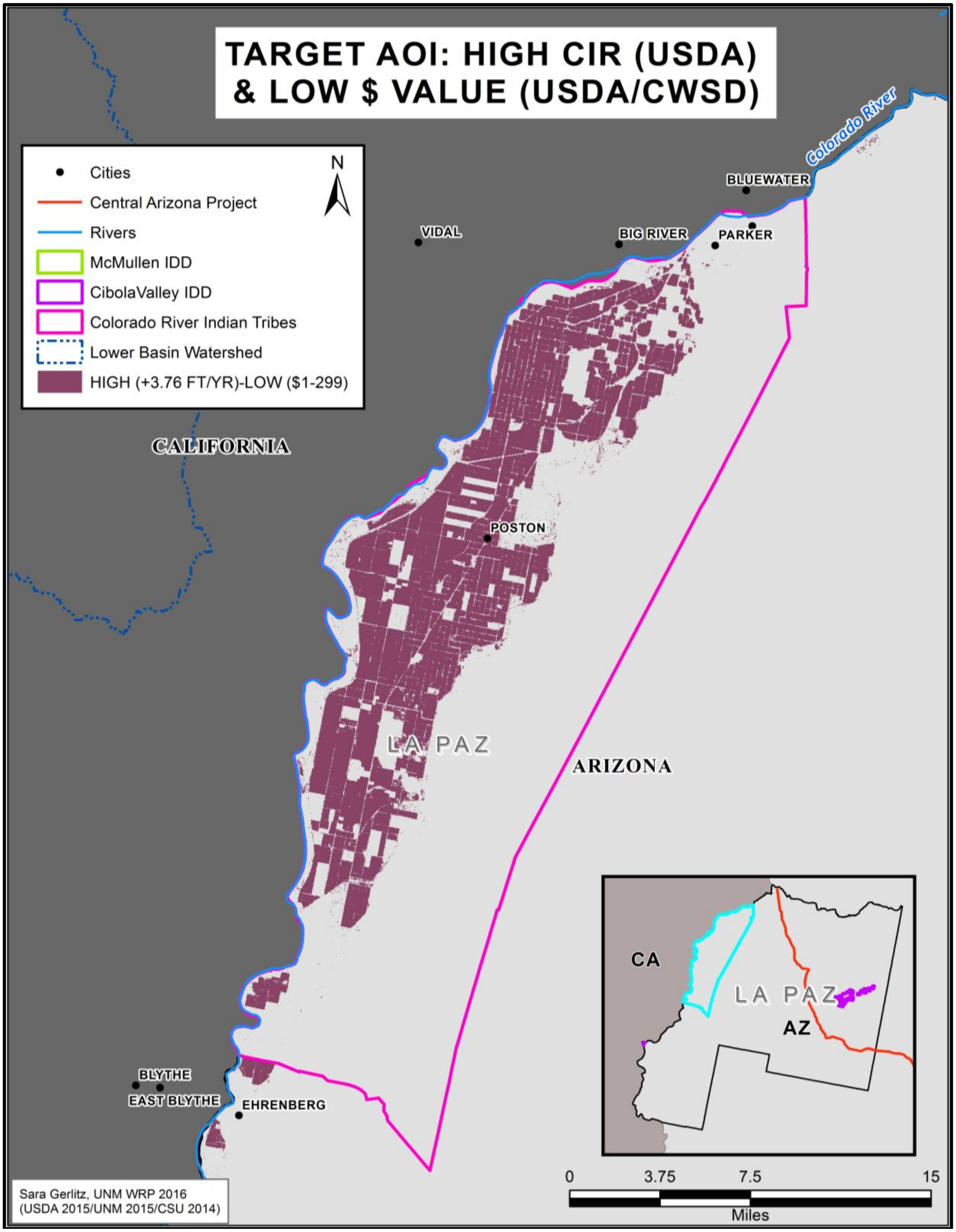
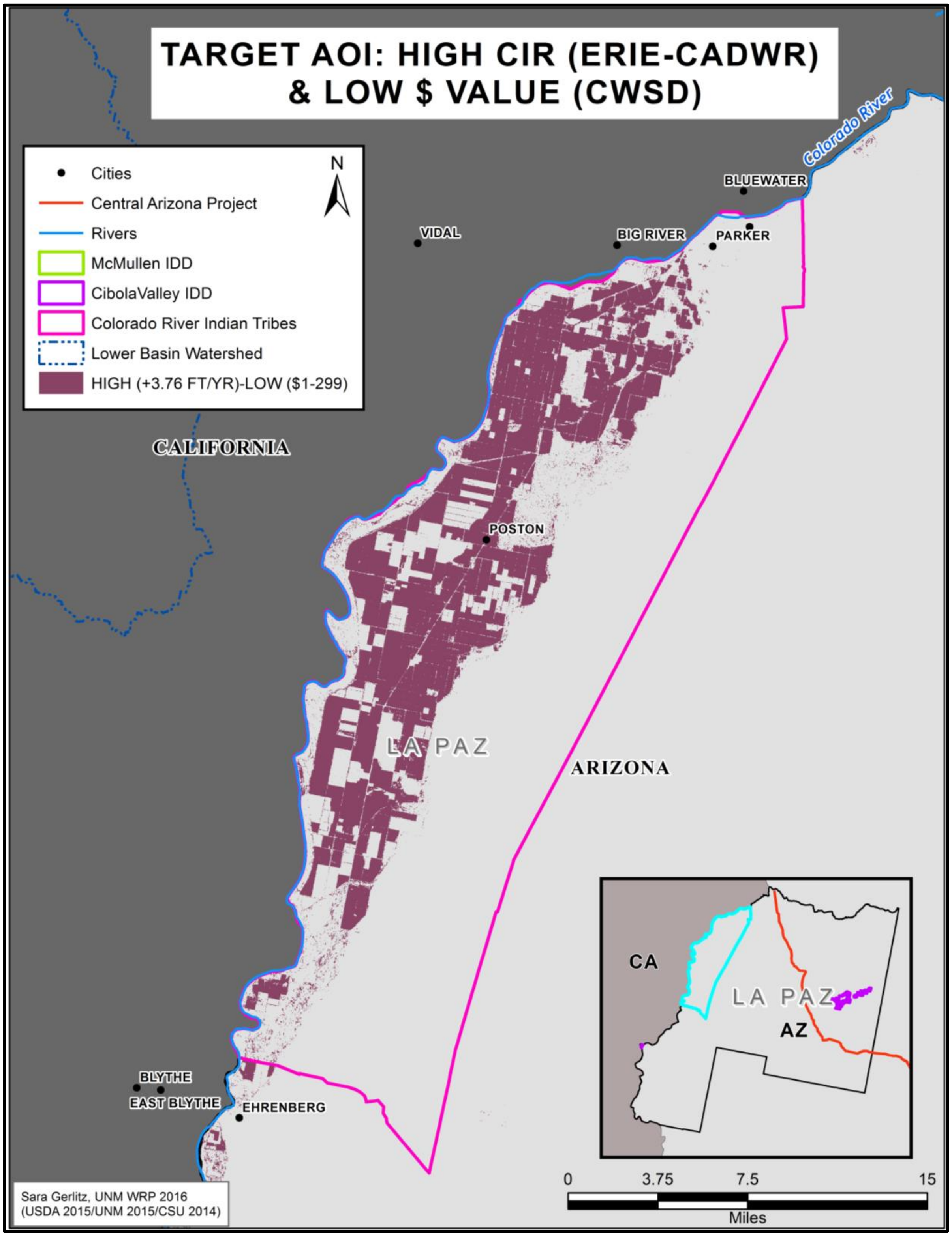
(USDA 2015/UNM 2015/CSU 2014)

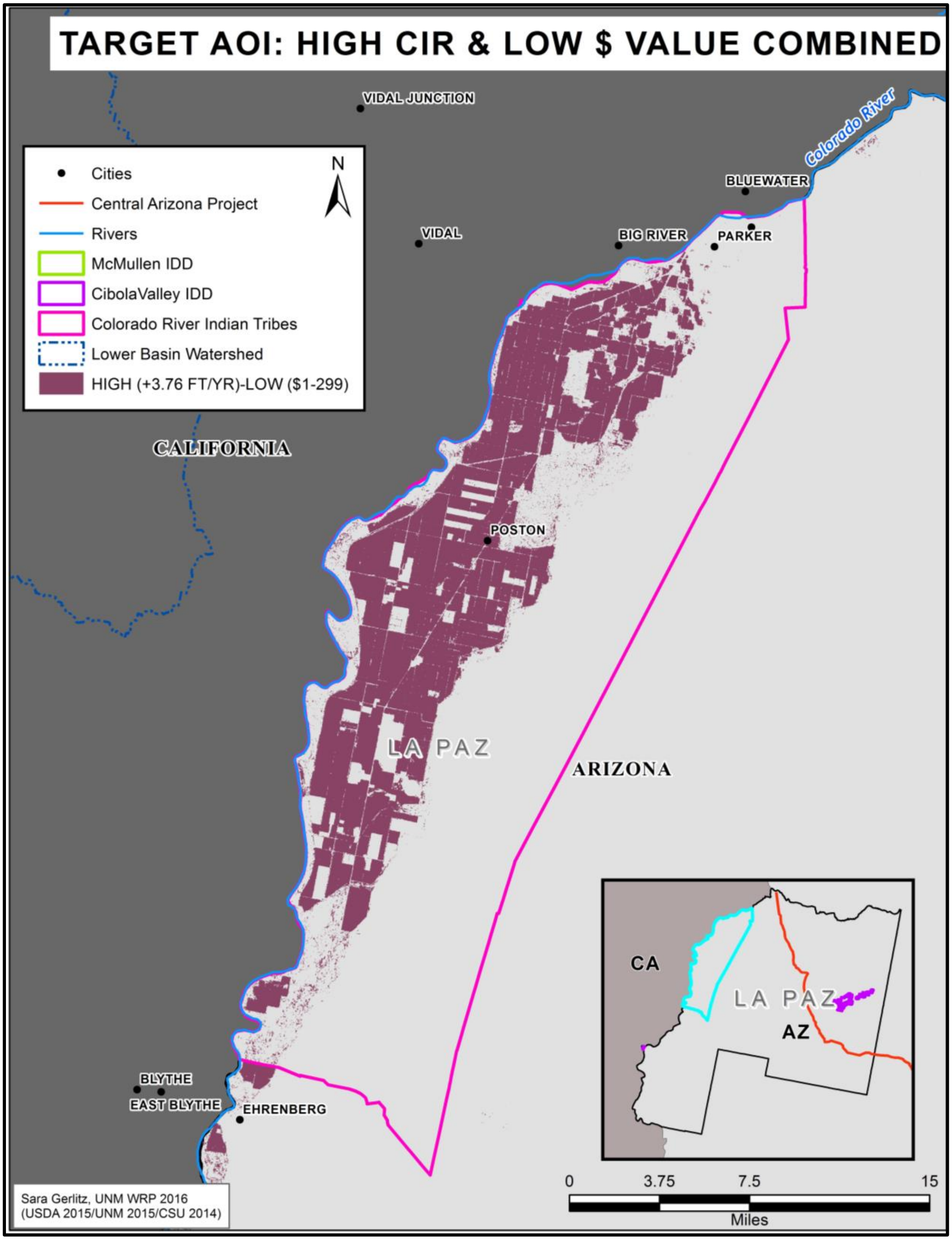
Pg. 87, Figure 33. *CRIT target AOI: USDA NASS 2012 Census, 2013 FRIS, Table 36 and 2014 AZ Bulletin,* (Attachment 2, Gerlitz, 2016).



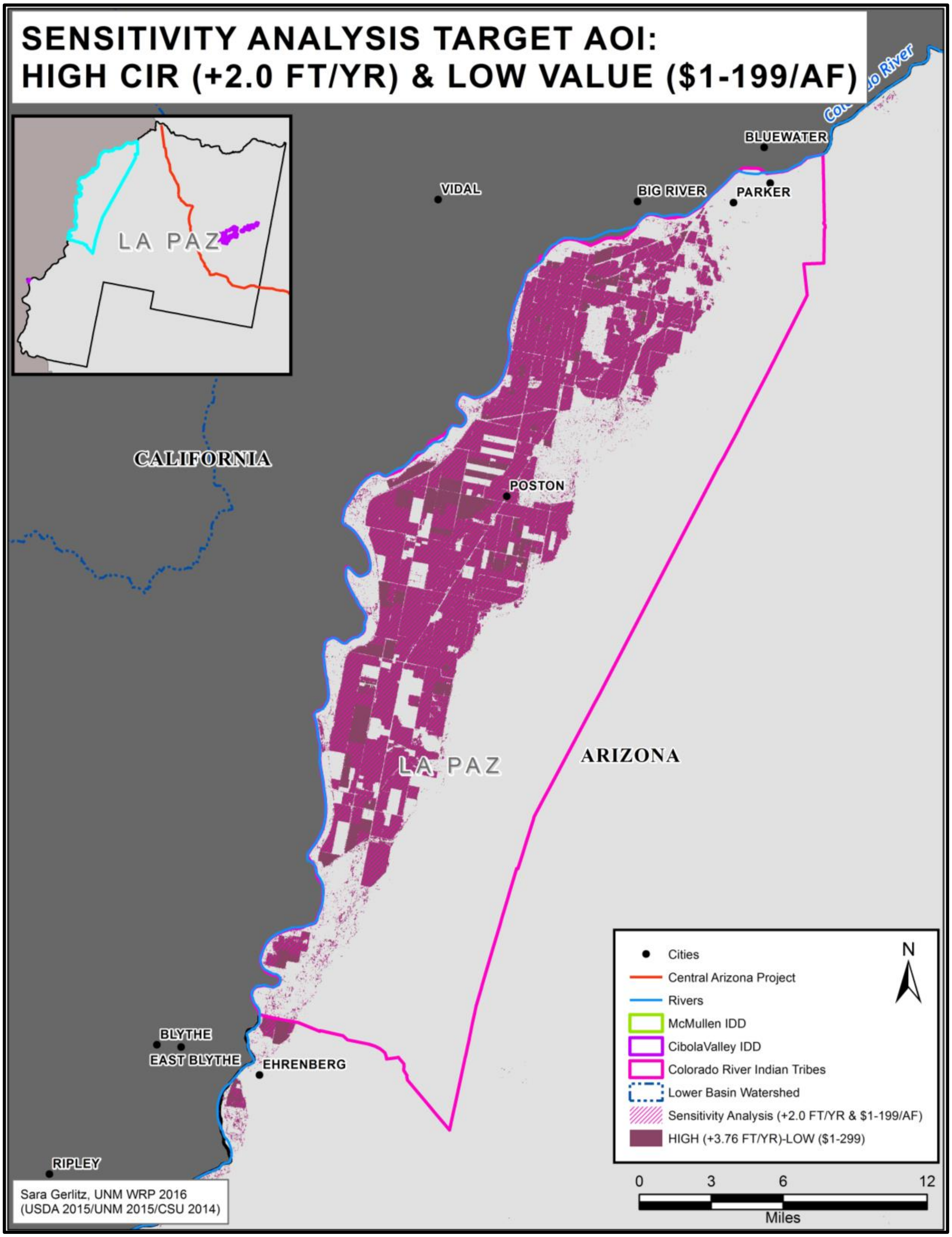
Pg. 87, Figure 34. *CRIT target AOI: Erie et al., CADWR and CWSD,* (Attachment 2, Gerlitz, 2016).



Pg. 87, Figure 35. *CRIT target AOI, combined datasets*, (Attachment 2, Gerlitz, 2016).



Pg. 88, Figure 36. *CRIT combined target AOI with sensitivity analysis*, (Attachment 2, Gerlitz, 2016).



Conclusions and Possible Future Research Applications

As argued from the evidence provided in this Arizona case study, utilizing geospatial tools such as USDA CropScape and the WGRG can provide adequate information for targeting social capital investment opportunities. Specifically, illustrating geographic areas of highly consumptive and low valued agriculture in Yuma and La Paz Counties is advantageous as the CAP slowly develops the wheeling policy for intrastate transfers of Non-Project water. The continual development of free, publically available decision-support tools, and the methods in which to use them, is essential for water resource management in Arizona as well as the entire Lower Colorado River Basin (Fishman, 2016).

CropScape, as a standalone geospatial tool, is a suitable resource for the initial steps of targeting agricultural areas for social capital investment. Its benefits include the relative ease-of-use of the platform and the ability for geoprocessing the raw data. Besides identifying AOI boundary locations, transferring the raw CropScape data to value assignments was the most important step to determine target locations. However, the acreage values are estimates; the accuracy of the data is based on satellite image quality and margins of error when conversions from raster-based pixels to acreage are performed (Han et al., 2012; 2014). These issues were accepted in the methods used for this research, however, for more quantitative applications, the shortcomings of the tool should be considered. On the other hand, the GIS tools (WGRG and ESRI ArcGIS 10.1) were successful in interpreting agricultural production characteristics on a geographic level. With these tools, the identification of water user boundaries and polycentric governance throughout Arizona facilitated the examination of the wheeling policy for ATM development.

The suite of publically available USDA NASS and USDA Census publications provided different information than CropScape and the WGRG, which was challenging to incorporate into the 2014 data. Also, the methods used for the name-assignments and value categorizations were not based on a statistical spread of the datasets, thus leaving the arbitrary categories open for scrutiny. However, the customized Excel spreadsheet did provide a way to interpret and apply the variability in information across all agricultural datasets for qualitative use.

The CIR data spanned a forty-year period from 1981 (Erie et al.) to 2014 (CADWR). Calculating the specific CIR value (FT/YR) for any given parcel of agricultural land, in any given growing season presented a challenging task. With a simplified and multi-sourced approach in this research, the CIR values illustrated the best publically available estimates for Arizona. Most importantly, the use of CIR and CropScape together, visualized the high consumptive use of irrigated agriculture. Whether from groundwater or Colorado River surface water, all thirteen water user groups are applying large volumes of water to a variety of crops.

The simple calculations and manipulations used to determine water use value ($/AF) in both the USDA NASS and CWSD datasets attempted to give a monetary estimate for locating target areas. The decision-support tools used to estimate this target variable were not ideal, as they did not consider external factors such as the price for the delivery of agricultural water, the location of the use or the water rights priority of the user. These factors, in addition to polycentric water governance and existing social capital, are essential parts of wheeling development. As discussed earlier, the CAP, CAWCD and Reclamation will need to find ways to address these issues to implement wheeling.

Finally, the data presented in this research is for actual farmland in production. The methods and subsequent results did not include gridcode (61) Fallow/Idle Cropland, as it is not an actual crop with applicable metrics. In terms of a target, this gridcode from CropScape was one of the highest acreage counts for the 2014 data, both for each county and individual water user groups. When calculated as a percentage of total agricultural land, this gridcode was notable (Table 22). From existing examples of ATMs (CAGRD pilot, MWD/PVID programs) throughout the basin, one could assume that fallowed land would be the first option for social capital investment. However, since little-to-no water is being applied, and no crops are growing, targeting this gridcode was not applicable in the research. Hence, identifying the agricultural land *in* production and the types of crops being grown is useful information for targeting social capital investment in this region.

With respect to both the fallowed land and the target crops, one water user group in particular illustrated another approach to identifying an AOI for wheeling. Hillander "C" Irrigation and Drainage District (Hillander C) is a small, geographically isolated water user group located just north of the Mexican border in southwestern Yuma County. This AOI displayed an extremely high percentage of (61) Fallow/Idle Cropland, (71.6%). In addition, existing agriculture largely consisted of the target crops. It also displayed a simple representation of the Sensitivity Analysis, which helped isolate the difference in cotton categorizations (Fig. 37). These three attributes of Hillander C, when coupled with water governance (Fig. 38), identify this irrigation district as a prospective target for wheeling. It also indicates the potential to identify agricultural areas by both (61) Fallow/Idle Cropland and target crop gridcodes in both rural and urban regions of Arizona.

The CAP-serviced counties of Maricopa, Pima and Pinal are changing the water use demands for their Colorado River surface water deliveries from agricultural use to municipal and industrial uses. Identifying the location for both fallowed land and productive agricultural land for wheeling within their own water governance boundaries is just as important as knowing where to look outside of the CAP. The development of ATMs internally could end up being the most likely application of wheeling in the near-term Lower Colorado River Basin shortage restrictions and drought conditions (CAP, 2016). The following application of this research to future work within the CAP is recommended and expounded on below.

Lower Colorado River Basin Shortage

The Colorado River and its tributaries provide surface water to nearly 40 million people and support the irrigated agriculture on which the nation's food supply is reliant (Culp, Glennon & Libecap, 2014). In addition to reservoir system supply issues, climate change, population and economic growth have steadily increased the demand on regional water resources. The 2007 Interim Agreement "Memorandum of Understanding" is a federal water resource management decision apportioning the three LCRB states and Mexico specific amounts of Colorado River surface water based on the reservoir system's surface level elevation. The surface level elevations of Lake Mead dictate how and where water is to be delivered, based on the complex priority system of the LCRB, which is of particular importance for Arizona and the CAP (CAP, 2014).

Lake Mead surface water level status. Shortages are defined by the surface elevations of Lake Mead and mandatory restrictions will fall on the junior priority status states of Arizona and Nevada, while California experiences no shortage restrictions (Table 23), (McCann & Cullom, 2014). Currently, the CAP has subcontracts with around sixty water providers, including irrigation districts, municipalities and tribal authorities (CAP, 2014). In 2012, the *Arizona Water Settlement Act* reallocated the CAP project water and clarified Tribal authority water priorities throughout the institution. Based on these updated water allocations, an internal set of priority statuses for each type of water user group have been developed and are important in terms of the larger basin apportionment issues. For example, under a Level 1 shortage (1075'), the shortage restrictions for Arizona would go into effect as seen in Table 22 (McCann & Cullom, 2014).

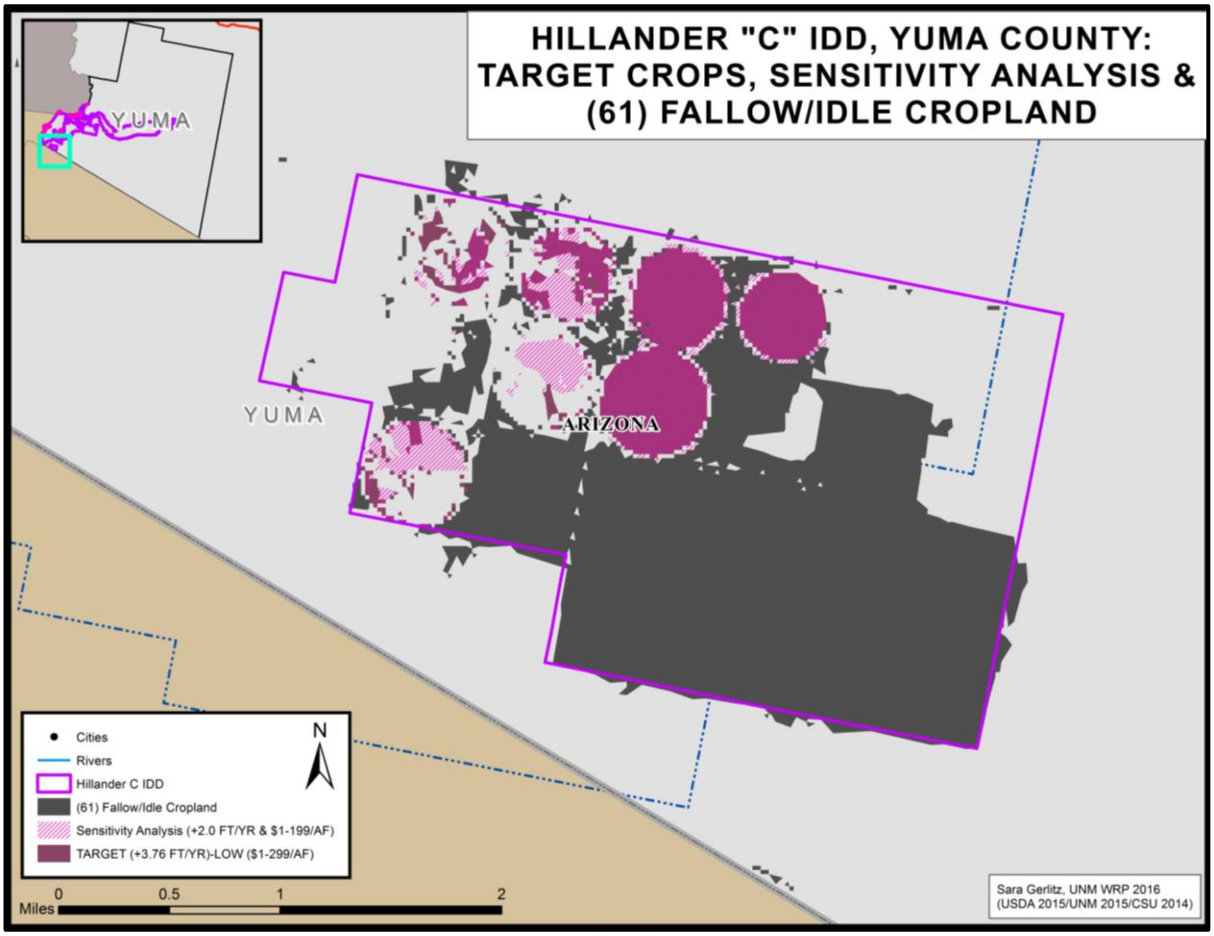
CAP priority levels. Figure 39 classifies CAP water deliveries into Priority 3, M&I Priority (Municipal, Industrial), Indian Priority, NIA (Non-Indian Agriculture) Priority, Ag Pool and Ag Pool Shortage and Other Excess Shortage (McCann & Cullom, 2014). The majority of the CAGRD water user groups are classified under the M&I delivery category (CAP, 2014). With a relatively high delivery priority, the M&I classified cities of the CAGRD are relatively secure under Level 1. However, the Other Excess Shortage under which the CAGRD replenishment is conducted is the first to be cutoff (McCann & Cullom, 2014). This reduction in Other Excess Shortage "will directly reduce or eliminate deliveries to the CAP excess supply for underground storage, and severely reduce the volume of CAP water available to [central AZ] agriculture," (CAP, 2014, p.1).

Identifying social capital investment opportunities within CAP. The potential for an elevation below 1000' carries a real danger of cutbacks to all Colorado River water users over the next decade (CAP, 2014). Wheeling water from sources both outside and within the CAP can provide additional options for the CAGRD "given the significant potential of water markets to alleviate growing water stress both in the long run and in response to short-term water variability" (Easter & Huang, 2015, p.36). Future work on applying wheeling solutions to the LCRB shortages is recommended. Applying similar geospatial methods from this research to target CAGRD water user groups where social capital investment for wheeling could occur is a natural next step for this project.

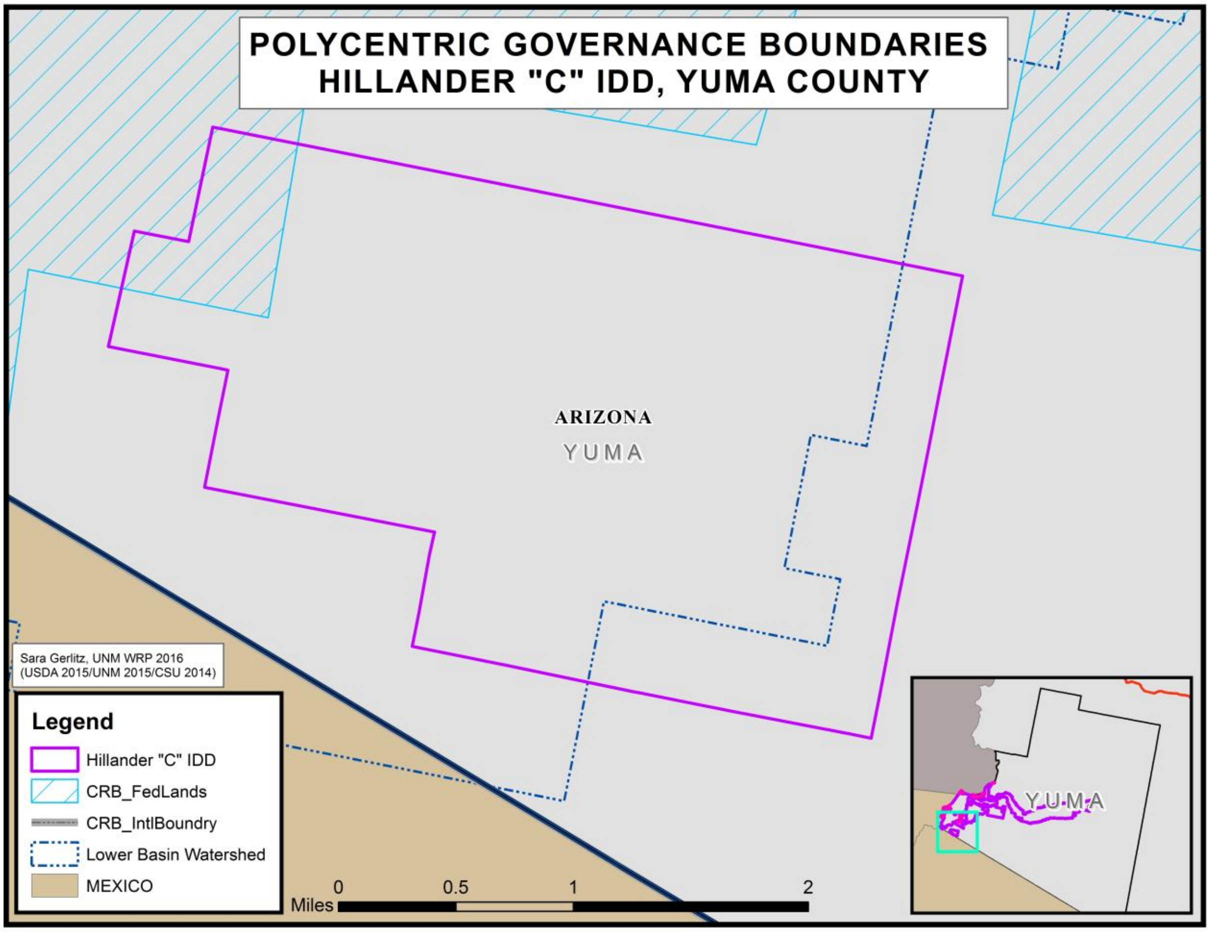
Pg. 103, Table 21. *Percent acres in gridecode (61) Fallow/Idle Cropland*, (Attachment 1, Gerlitz, 2016).

WATER USER GROUP	COUNTY	CROP ACRES	% ACRES IN (61) Fallow/Idle Cropland
HILLANDER C IDD	YUMA	2,704	71.63
YUMA COUNTY (ALL)	YUMA	232,910	17.66
LA PAZ COUNTY (ALL)	LA PAZ	182,957	13.66
UNIT B IDD	YUMA	2,559	13.24
WELLTON MOHAWK	YUMA	75,065	12.83
CRIT	LA PAZ	97,026	11.89
STURGEST GILA MONSTER	YUMA	1,878	11.67
CIBOLA	LA PAZ	5,371	10.68
McMULLEN IDD	LA PAZ	10,030	10.27
YUMA MESA IDD	YUMA	21,606	10.02
COCOPAH INDIAN TRIBE	YUMA	1,818	4.25
YUMA IDD	YUMA	11,284	3.69
NORTH GILA VALLEY	YUMA	6,968	1.43
YUMA CO WATER USERS	YUMA	48,052	0.55

Pg. 103, Figure 37. *Hillander C with target AOI, sensitivity analysis and (61) Fallow/Idle Cropland,* (Attachment 2, Gerlitz, 2016).



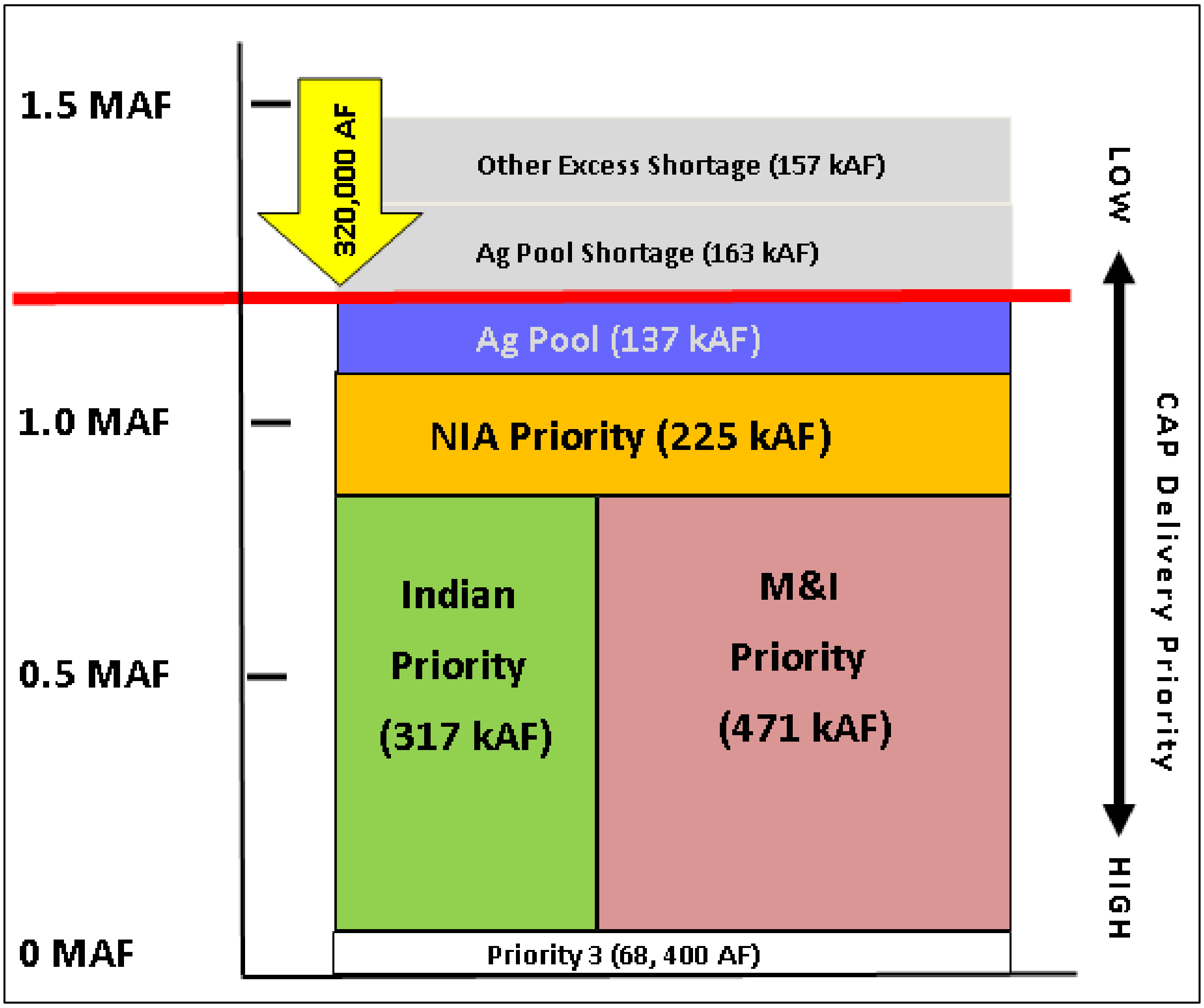
Pg. 103, Figure 38. *WGRG polycentric boundary layers for Hillander C*, (Attachment 2, Gerlitz, 2016).



Pg. 104, Table 22. *Lake Mead surface elevation-based shortage under 2007 Interim Guidelines, Reclamation,* (Adapted from McCann & Cullom, 2014).

Surface Elevation	Arizona Reduction	Nevada Reduction	Mexico Reduction
1075'	320,000 AF	13,000 AF	50,000 AF
1050'	400,000 AF	17,000 AF	70,000 AF
1025'	480,000 AF	20,000 AF	125,000 AF

Pg. 105, Figure 39. *Level 1 shortage, CAP delivery priority,* (Adapted from McCann & Cullom, 2014).



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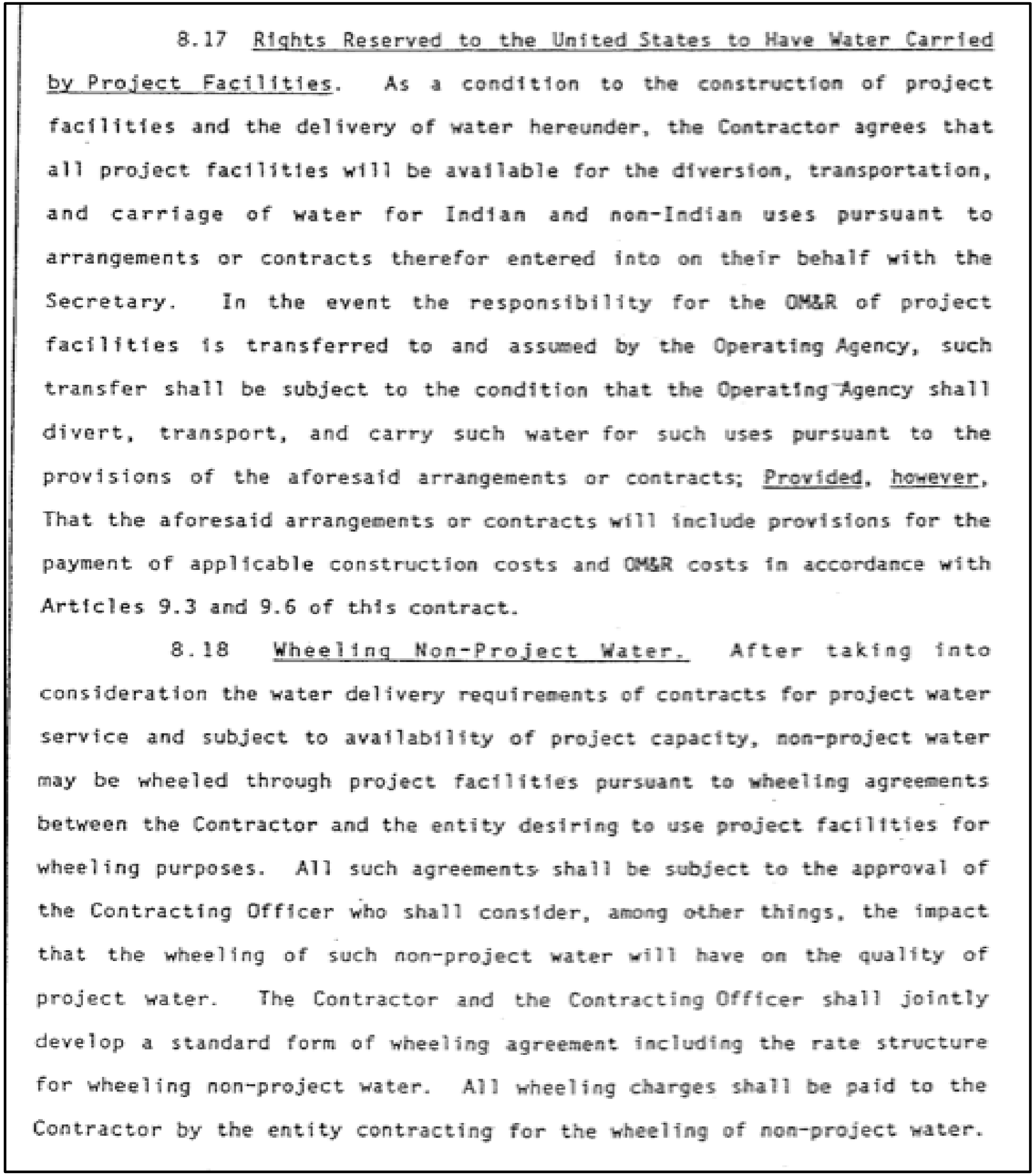
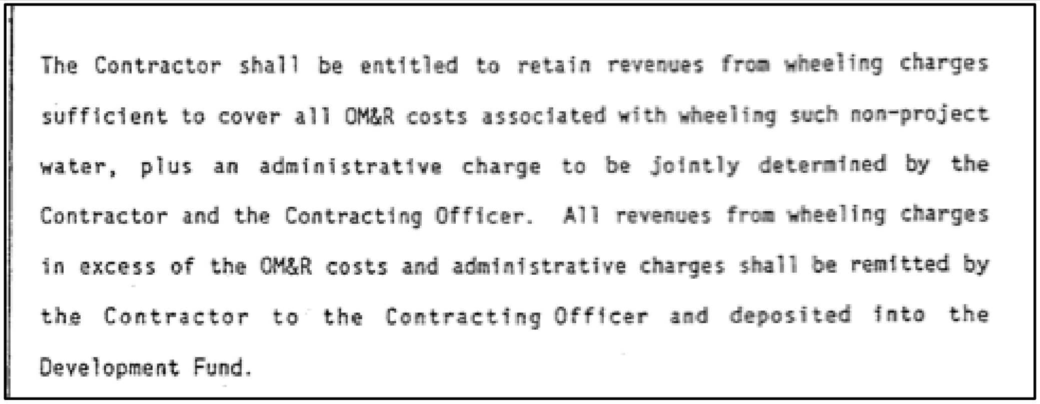
Appendix A

1988 Master Repayment Contract, Bureau of Reclamation



8.17 Rights Reserved to the United States to Have Water Carried by Project Facilities. As a condition to the construction of project facilities and the delivery of water hereunder, the Contractor agrees that all project facilities will be available for the diversion, transportation, and carriage of water for Indian and non-Indian uses pursuant to arrangements or contracts therefor entered into on their behalf with the Secretary. In the event the responsibility for the OM&R of project facilities is transferred to and assumed by the Operating Agency, such transfer shall be subject to the condition that the Operating Agency shall divert, transport, and carry such water for such uses pursuant to the provisions of the aforesaid arrangements or contracts; Provided, however, That the aforesaid arrangements or contracts will include provisions for the payment of applicable construction costs and OM&R costs in accordance with Articles 9.3 and 9.6 of this contract.

8.18 Wheeling Non-Project Water. After taking into consideration the water delivery requirements of contracts for project water service and subject to availability of project capacity, non-project water may be wheeled through project facilities pursuant to wheeling agreements between the Contractor and the entity desiring to use project facilities for wheeling purposes. All such agreements shall be subject to the approval of the Contracting Officer who shall consider, among other things, the impact that the wheeling of such non-project water will have on the quality of project water. The Contractor and the Contracting Officer shall jointly develop a standard form of wheeling agreement including the rate structure for wheeling non-project water. All wheeling charges shall be paid to the Contractor by the entity contracting for the wheeling of non-project water.



The Contractor shall be entitled to retain revenues from wheeling charges sufficient to cover all OM&R costs associated with wheeling such non-project water, plus an administrative charge to be jointly determined by the Contractor and the Contracting Officer. All revenues from wheeling charges in excess of the OM&R costs and administrative charges shall be remitted by the Contractor to the Contracting Officer and deposited into the Development Fund.

Appendix B

Major Elements of the CAP Staff Proposal for Wheeling Non-Project Water

CONTEXT

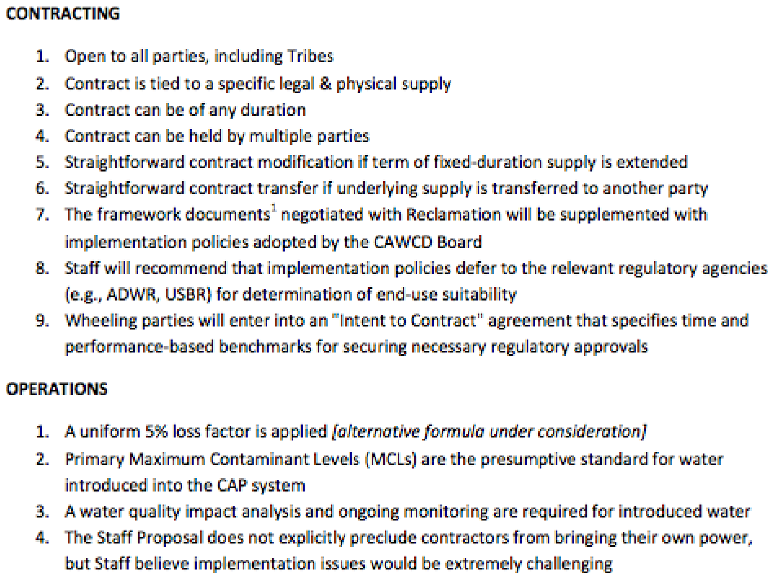
1. Wheeling Non-Project Water in the CAP system is specifically contemplated in section 8.18 of the 1988 Master Repayment Contract, and is a strategic goal of the CAP Board
2. The Staff Proposal consists of several parts:
    a. Standard Form of Wheeling Agreement
    b. Modifications to the Operating Agreement
    c. White papers on the Annual Operating Plan and Peak Suppression Facility
    d. Wheeling computer model
    e. Supplemental Staff Position Statements
3. The Staff Proposal reflects the views of CAP staff, and has not been officially endorsed by either the CAP Board or the Bureau of Reclamation

CAPACITY

1. Wheeling contracts are tied to increasing the delivery capacity of the CAP system
2. CAP will submit capacity improvement project plans to Reclamation for review
3. Reclamation will determine how much capacity the proposed project will add
4. That determination will result in Certified Additional Annual System Delivery Capacity
5. CAWCD can then issue wheeling contracts, up to the Certified volume
6. Access to the CAP system for Project Water, Federal wheeling (8.17), and CAWCD wheeling (8.18) is determined in the annual scheduling process
    a. Prior to completion of the improvement project, 8.18 wheeling contracts are subject to displacement by Project Water and 8.17 (i.e., 8.18 has lowest scheduling priority)
    b. After the completion of the improvement project, 8.18 wheeling contracts have scheduling priority similar to M&I subcontracts
7. Peak capacity constraints are addressed with dedicated recharge capacity ("Peak Suppression Facility") that will allow shifting of Project Water orders to shoulder months

COSTS

1. All costs are paid by wheeling parties
2. Costs are collected through an up-front fee and annual rate
3. Costs are tied to a specific system improvement project
4. Funds are used exclusively for system improvements, and are subject to Reclamation review
5. Other costs include a Capital Equivalency Charge, Fixed OM&R, and market rates for actual energy use



CONTRACTING

1. Open to all parties, including Tribes
2. Contract is tied to a specific legal & physical supply
3. Contract can be of any duration
4. Contract can be held by multiple parties
5. Straightforward contract modification if term of fixed-duration supply is extended
6. Straightforward contract transfer if underlying supply is transferred to another party
7. The framework documents[1] negotiated with Reclamation will be supplemented with implementation policies adopted by the CAWCD Board
8. Staff will recommend that implementation policies defer to the relevant regulatory agencies (e.g., ADWR, USBR) for determination of end-use suitability
9. Wheeling parties will enter into an "Intent to Contract" agreement that specifies time and performance-based benchmarks for securing necessary regulatory approvals

OPERATIONS

1. A uniform 5% loss factor is applied *[alternative formula under consideration]*
2. Primary Maximum Contaminant Levels (MCLs) are the presumptive standard for water introduced into the CAP system
3. A water quality impact analysis and ongoing monitoring are required for introduced water
4. The Staff Proposal does not explicitly preclude contractors from bringing their own power, but Staff believe implementation issues would be extremely challenging

Appendix C

CropScape Data Layer and ESRI ArcGIS Data Processing Methods

1) ACCESS CROPSCAPE WEBSITE http://www.nassgeodata.gmu.edu/CropScape
2) DEFINE AREA OF INTEREST (AOI) BY COUNTY
3) SELECT LAYERS
    a. Background Layers Folder-Default ON
    b. Cropland Data Layers-Year of Choice "2014" ON
    c. Crop Mask Layer-Default OFF
    d. Crop Frequency Layer-Default OFF
    e. Boundary Layers-"County" "State" ON
    f. Water Layers-Default OFF
    g. Road Layers-Default OFF
4) AREA OF INTEREST STATISTICS
    a. Export Table as .csv
        i. Ex) cdl_2014_04027.csv OPEN
        ii. Save to File Ex) SGerlitz/DATA/YUMA
            1. .csv
            2. .xlsx (Excel Workbook)
    b. Export the select crop(s)/land cover types for mapping
        i. Check VALUE (for all) or Specific Types
        ii. Download (as .tif) Ex) "NASS_DATA_CACHE-extract_59418000_CDL_2014_04027
        iii. Save to YUMA folder
5) IMPORT AOI (Compressed ESRI shapefile)
    a. Define AOI by agricultural water user
        i. ArcCatalog examine OnlinePilot_CRBGov.gdb (Laituri, 2014)
            1. Arizona->agricultural user feature classes
            2. View Contents/Preview-Geography, Table
            3. Look at individual agricultural users in feature class attribute table(s) Ex) "AZ_irrigation districts" -> "Yuma Mesa Irrigation & Drainage District", etc.
    b. ArcMap Add Data Layer Ex) "AZ irrigation districts"
        i. Build "New Blank Map" with WGRG (Laituri, 2014); TemplateData.gdb (UNM, 2015)
        ii. Add/arrange data for benefit of map use. Ex) cities, states, tribal lands, etc.
    c. Select particular institution from attribute table for AOI ESRI shapefile upload
        i. Selection->Create Layer from Selected Features
        ii. Rename New Layer as Appropriate for Map Use
    d. Toolbox: Feature Class to Shapefile [INPUT-.lYR; OUTPUT FOLDER-same as .lYR]
    e. Check on ArcCatalog
    f. Create Compressed .zip folder for CropScape import by selecting individual shapefile components as requested by CropScape import [.dbf .prj .sbn .sbx .shp .shx]
    g. CropScape Platform, Browse to newly compressed shapefile components
    h. Upload
6) DOWNLOAD NEWLY DEFINED AOI
    a. Area of Interest Statistics Button
        i. Select all CDL, VALUE
        ii. Export Table as .csv file
            1. Open in Excel, saved also as Excel Workbook .xlsx

Appendix D

Crop Name Categories (Water Use Values)

Table 23. *Water Use Value Categories-USDA NASS naming structure* (Gerlitz, 2016)

GRIDCODE	CROP NAME	USDA NASS Categories
1	Corn	Corn for Grain
2	Cotton	Upland Cotton
4	Sorghum	Sorghum for Grain
21	Barley	Barley
22	Durum Wheat	Durum Wheat
23	Spring Wheat	Other Wheat
24	Winter Wheat	Other Wheat
36	Alfalfa	Alfalfa Hay
37	Other Hay/Non Alfalfa	Other Hay

Table 24. *Water Use Value Categories-CWSD Model Naming Structure* (Gerlitz, 2016)

GRIDCODE	CROP	CWSD$ Category
1	Corn	Corn
2	Cotton	Cotton and cottonseed
4	Sorghum	Other grains, oilseeds, dry beans/peas
21	Barley	Other grains, oilseeds, dry beans/peas
22	Durum Wheat	Wheat
23	Spring Wheat	Wheat
24	Winter Wheat	Wheat
27	Rye	Other crops and hay
28	Oats	Other grains, oilseeds, dry beans/peas
31	Canola	
35	Mustard	
36	Alfalfa	Other crops and hay
37	Other Hay/Non Alfalfa	Other crops and hay
41	Sugarbeets	Other crops and hay
42	Dry Beans	Other grains, oilseeds, dry beans/peas
43	Potatoes	Other crops and hay
44	Other Crops	Other crops and hay
47	Misc Vegs & Fruits	Vegetables, melons, sweet potatoes
48	Watermelons	Vegetables, melons, sweet potatoes
49	Onions	Vegetables, melons, sweet potatoes
57	Herbs	
59	Sod/Grass Seed	Nursery, greenhouse, floriculture, sod
61	Fallow/Idle Cropland	N/A

Table 24. …*continued*, (Gerlitz, 2016).

GRIDCODE	CROP	CWSD$ Category
67	Peaches	Fruits, tree nuts, and berries
68	Apples	Fruits, tree nuts, and berries
69	Grapes	Fruits, tree nuts, and berries
71	Other Tree Crops	Fruits, tree nuts, and berries
72	Citrus	Fruits, tree nuts, and berries
74	Pecans	Fruits, tree nuts, and berries
75	Almonds	Fruits, tree nuts, and berries
77	Pears	Fruits, tree nuts, and berries
176	Grass/Pasture	Other crops and hay
204	Pistachios	Fruits, tree nuts, and berries
205	Triticale	Other grains, oilseeds, dry beans/peas & Other Crops, Hay
206	Carrots	Vegetables, melons, sweet potatoes
208	Garlic	Vegetables, melons, sweet potatoes
209	Cantaloupes	Vegetables, melons, sweet potatoes
211	Olives	Vegetables, melons, sweet potatoes
212	Oranges	Fruits, tree nuts, and berries
213	Honeydew Melons	Vegetables, melons, sweet potatoes
214	Broccoli	Vegetables, melons, sweet potatoes
216	Peppers	Vegetables, melons, sweet potatoes
219	Greens	Vegetables, melons, sweet potatoes
225	Dbl Crop WinWht/Corn	Wheat/Corn
226	Dbl Crop Oats/Corn	Other grains, oilseeds, drybeans/peas/Corn
227	Lettuce	Vegetables, melons, sweet potatoes
230	Dbl Crop Lettuce/Durum Wht	Vegetables, melons, sweet potatoes/Wheat
231	Dbl Crop Lettuce/Cantaloupe	Vegetables, melons, sweet potatoes x2
232	Dbl Crop Lettuce/Cotton	Vegetables, melons, sweet potatoes/Cotton
233	Dbl Crop Lettuce/Barley	Vegetables, melons, sweet potatoes/Other grains, oilseeds, dry beans/peas
234	Dbl Crop Durum Wht/Sorghum	Wheat/Other Grains, oil seeds, dry beans/peas
235	Dbl Crop Barley/Sorghum	Other grains, oilseeds, dry beans/peas x2
236	Dbl Crop WinWht/Sorghum	Wheat/Other Grains, oil seeds, dry beans/peas
238	Dbl Crop WinWht/Cotton	Wheat/Cotton and cottonseed
243	Cabbage	Vegetables, melons, sweet potatoes
244	Cauliflower	Vegetables, melons, sweet potatoes
245	Celery	Vegetables, melons, sweet potatoes
246	Radishes	Vegetables, melons, sweet potatoes