

Case Studies Outlining Challenges and Opportunities for Agricultural Water Conservation in the Colorado River Basin

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1. INTRODUCTION

In most parts of the western United States, water demand is expected to outstrip its supply. The Colorado River, which supplies water to millions of people and supports the irrigation of millions of acres of land, has been dealing with this problem fueled by the current 15-year drought and the situation is projected to worsen in the future due to population growth and climate change. As the main user of the river's water, agriculture has become one of the main targets for implementing water conservation practices to save water and provide it to domestic and environmental uses. This has raised serious concerns associated with jeopardizing food security and there are significant social constraints as well.

Through a comprehensive literature review, we have produced 78 case studies across the western United States, as well as an international one that shed light on various ways water has been diverted for agricultural use and how that water has been managed and its use changed over time to meet agricultural and other objectives. We have reviewed local, regional, statewide, and basin-wide programs instituted to better manage the water for purposes such as improving agricultural productivity and meeting endangered species and water quality goals. We have categorized these into three general types:

- *Original water resources development projects*: the original projects that made it possible to use river water for agriculture through such means as diversion and storage;
- *Programs and regulations*: local, regional, statewide, and basin-wide processes and programs that have been instituted to better manage the water for purposes such as improving agricultural productivity, meeting endangered species and water quality goals, and conjunctively using groundwater and surface water;
- *Operation enhancements and water use change*: cases where practices such as system enhancements, conservation, efficiency enhancement, and in general changes made in agriculture, either management or efficiency, has increased agricultural security or made water available for municipal water use, environmental instream flows, or groundwater recharge.

In choosing which cases to include, we considered variety in approach, type of organization, size and geography. As we shared our work with others in the business of agricultural water management, we learned of additional cases to study. Sixteen of the case studies belong to the first category (Table 1). Thirty-six of them review programs and regulations being implemented to enhance water management. Twenty-six of them evaluate conservation and efficiency enhancement efforts. Geographically, fifty-six of these examples evaluate the aforementioned projects within borders of the Colorado River Basin in all seven states, including Upper Basin states (Colorado, New Mexico, Utah, and Wyoming) as well as Lower Basin states (Arizona, California, and Nevada). There are six multistate case studies. Twenty-two examples review programs and projects that have been implemented in the western United States, outside the borders of the Colorado River Basin. The international one, which fits into the “programs and regulations” category, reviews a case in Australia’s Murray-Darling Basin where long-lasting and severe drought conditions pushed the federal government to adopt new policy that considerably changed the traditional water rights paradigm.

Through this report, we have identified projects, irrigation districts, ditch companies, and partnerships that have successfully implemented conservation programs, and have also explored various approaches for optimizing use of agricultural water through improving on-farm and delivery system infrastructure and changing management at all levels. The case studies can be used in university curricula and as a showcase for decision makers at all levels and scales, from the farm scale to the USDA. These examples illustrate the sociological, economic, and legal challenges that must be overcome in order to conserve

agricultural water. They can be used by other entities who plan to implement water conservation programs. Using these examples along with actual data about water conservation programs, a conceptual framework can be developed to demonstrate how agricultural water management organizations and agricultural producers could use available technology to improve their infrastructure and management in order to benefit from operational flexibility and increased profit, while conserving large amounts of water—if economic, legal, institutional and cultural barriers can be addressed.

Our intention here has been to provide only basic information about these case studies and provide a foundation for the reader to start their research. We tried to concisely address the main points about each example that can be cited and provide the corresponding links in the reference section. Though we have been careful to cite information accurately, there may be statements made here that some disagree with. In addition, many of these cases are ongoing, such that readers need to check to see what has progressed since these case studies were developed. The reader can use these case studies to gain a general knowledge or use them as a first step of research to be built upon.

Table 1. List of the case studies grouped into the three types

Original Water Resources Development Projects	
1	Hohokam Irrigation Canals
2	The Yuma Project and Yuma Auxiliary Project
3	The Gila Project
4	Central Arizona Project
5	Maricopa-Stanfield Irrigation and Drainage District
6	Grand Valley Project
7	The Dolores Project
8	Colorado-Big Thompson Project
9	Uncompahgre Project
10	Colorado River Storage Project Act
11	New Mexico’s Gila River Project Proposal
12	Lake Powell Pipeline Proposal, Utah
13	Central Utah Project
14	San Juan County Utah Multiple Use Project
15	High Savery Dam and Reservoir: Improving Agriculture and the Environment
16	Animas – La Plata Project
Programs and Regulations	
1	Water Conservation Efforts in Wellton-Mohawk Irrigation & Drainage District
2	Gila River Indian Irrigation District’s Water Right Settlement
3	Arizona Best Management Practices Program
4	Arizona Groundwater Management Code
5	Arizona Assured & Adequate Water Supply Programs
6	Arizona Water Banking Authority
7	Arizona Groundwater Banking
8	PVID/MWD Forbearance and Fallowing Program

- 9 IID/MWD Water Conservation Program
- 10 Colorado River Quantification Settlement Agreements
- 11 Coachella Valley Water Management Plan
- 12 Yampa/White/ Green Basin
- 13 Colorado Water Bank (West Slope Water Bank)
- 14 Lower Gunnison Salinity Control Project
- 15 North Fork River Improvement Association
- 16 Split Season Approach to Water Use in the Little Cimarron River, the Gunnison River Basin
- 17 Lower Colorado River Basin Intentionally Created Surplus Forbearance Agreement
- 18 Great Basin Land and Water
- 19 The SNWA Water Resources Portfolio
- 20 San Juan River Settlement Agreement
- 21 Uinta Basin Salinity Control Project
- 22 Ferron Salinity Project
- 23 Wyoming Watershed Management and Rehabilitation Plan
- 24 The San Juan River Basin Recovery Implementation Program
- 25 Colorado River System Conservation Program
- 26 Upper Colorado River Endangered Fish Recovery Program
- 27 Colorado River Basin Salinity Control Project
- 28 Freshwater Trust
- 29 Lower Yuba River Accord
- 30 Arkansas Basin Roundtable's Template for Ag to Urban Water Transfer
- 31 Super Ditch
- 32 The Cap, Murray- Darling Basin - Australia
- 33 Yakima River Basin Integrated Water Resources Management Plan
- 34 Yakima Basin Water Transfers Working Group
- 35 Elephant Butte Irrigation District / Audubon
- 36 Cache County's Water Future

Operations Enhancement/Water Use Change

- 1 YMIDD/CAGRDR Pilot Fallowing and Forbearance Agreement (Pilot Agreement)
- 2 Diamond S Ditch: Automated Gates for Verde River Increased Flows
- 3 Arizona Land and Water Trust
- 4 Public Private Partnership for the San Pedro River's Flow Augmentation
- 5 All American Canal Lining Project
- 6 Coachella Canal Lining Project
- 7 Grand Valley Water Management Plan
- 8 Orchard Mesa Irrigation District Canal System Improvement Project

- 9 Montezuma Valley Irrigation Company Water Leasing Proposal
- 10 Relief Ditch Diversion Modification
- 11 Sunset Canal Improvement Project
- 12 The Confluence Nature Park Project
- 13 Using Coalbed Methane Produced Water
- 14 Ute Mountain Ute Tribe Improved Irrigation Water Technology and Management
- 15 West Side Irrigation District Urban to Ag Transfer
- 16 South San Joaquin Irrigation District's Pilot Pressure Irrigation Project
- 17 Umatilla Groundwater Relief
- 18 Central Oregon Irrigation District Piping Project
- 19 Three Sisters Irrigation District piping project
- 20 Manastash Creek Implementation Plan
- 21 North Fork Blackfoot River, Montana
- 22 Barker Ranch, Lower Yakima River
- 23 Columbia Basin Project Irrigation Districts
- 24 Sunnyside Canal Improvement Project
- 25 SCADA & Water Measurement Project - Lower Yellowstone
- 26 Aurora Water: Alternative Transfer Methods in the Arkansas Basin

2. ARIZONA

2.1. Original Water Resources Development Projects

2.1.1. Hohokam Irrigation Canals

Hohokam Irrigation Canals are the first known water diversion system in the Colorado River Basin. Early residents of Salt Valley established agricultural fields along the margins of the Salt River, a tributary of the Colorado River, and relied on floodwater irrigation. Later, they introduced canal irrigation, which eventually created the Hohokam culture in southern Arizona. Hohokam irrigation engineers designed the first large canals sometime between A.D. 600 and 700. The Hohokam canal systems are famous for their size and sophistication. These canals transported large quantities of water onto the upper terrace of the Salt River. Between A.D. 700 and 900, Hohokam people developed large integrated canal systems on both the north and south sides of the river. By A.D. 1200, they had built hundreds of miles of canals to transfer water from the Salt and Gila Rivers to their lands [1]. Out of an estimated total of 500 miles, archaeologists had explored approximately 150 miles of these ancient canals by 1920. The largest recorded single Hohokam canal was 20 miles in length, while the majority of the canals were more than 12 miles. The canals' cross sectional dimensions were 18 to 26 meters (59 to 85 feet) in width and about 6.1 meters (20 feet) in depth [1]. These canals probably served nearly 50,000 people at a time [2]. It is estimated that about 28.25 million cubic feet (800,000 cubic meters) of soil may have been removed to construct the main canals in Canal System 2, which probably supplied over 10,000 acres of land [1].

It appears that the engineers considered the local topography, the dips and slopes, drainages and soils. They also included a series of physical elements in the canal system, including a weir at each canal's junction with the river to control the level of water in the river, and a head gate inside the canal to regulate the rate of water diversion. They also tried to keep a constant water velocity at different canal sizes to avoid both erosion and sedimentation. The construction, maintenance, and operation of these canals must have been a substantial and well-organized task involving people from all villages along the main canal. They must also have had strong leadership to regulate water allocations and facilitate conflict resolution. They must have had a hierarchical institutional system in place with well-defined leadership roles, which had created a complex sociopolitical structure [1].

2.1.2. The Yuma Project and Yuma Auxiliary Project

The U.S. Bureau of Reclamation initiated the Yuma Project in 1905 and authorized the Yuma Auxiliary Project in 1917 [3]. The projects are located in Yuma County, Southwest Arizona, where the climate offers a 365 day per year growing season [4]. However, intense heat during the summer months and an average annual precipitation rate of only 3.5 inches [5] doesn't support agricultural activities. The United States Reclamation Service (Bureau of Reclamation) created the Yuma Project to supply water to irrigation lands by diverting water from the Colorado River [4] using a system of infrastructures including Laguna Dam, the Boundary Pumping Plant, an unnamed power plant, and a system of canals, laterals, and drains [6]. The project is divided into the Reservation Division, which includes 14,676 acres in California, and the Valley Division, which covers 53,415 acres in Arizona [6]. As Reclamation and local farmers found Yuma Mesa to be a suitable location for growing citrus fruits, Reclamation authorized the Yuma Auxiliary Project. This project, which is often referred to as Yuma Mesa, the Mesa Division, or Unit "B," is an addition to the southern tip of the Yuma Project. It was initially planned to have four divisions (A, B, C, and D) to irrigate 45,000 acres of farm land on Yuma Mesa [4]. Except Unit "B," the three other units were never developed and the Yuma Auxiliary Project was reduced to 3,305 acres in size by an act on June 13, 1949 (63 Stat. 172) [7].

2.1.3. The Gila Project

More than one-third of Arizona's total agricultural activities are practiced in Yuma County, returning a gross annual revenue of over \$3 billion [8]. To supply water demands of agricultural irrigation, investigations of the Gila Project (originally named Parker-Gila Project) was authorized on December 21, 1928 [9]. The construction of the project took a long time as it was hindered by labor shortages in the 1940s. However, since irrigation was necessary to control dust near the Yuma Army Air Field as an important base during WWII, the government proceeded with its construction and its final phase was completed in 1957 [8]. The project is divided into two divisions: the Wellton-Mohawk Division and the Yuma Mesa Division, which is further subdivided into three units: the Mesa Unit (south and southeast of Yuma), and the North Gila Valley and South Gila Valley Units (northeast and east of Yuma) [10]. The project diverts 300,000 acre-feet of the Colorado River water for beneficial consumptive use in each division. The project provides irrigation service to approximately 98,000 acres of land in the two divisions, including 65,000 acres in the Wellton-Mohawk Division (reduced from 75,000 acres—explained later in the Wellton-Mohawk Irrigation and Drainage District's section) and 42,131 acres in the Yuma Mesa Division [10]. The Gila Project includes the Mesa Unit Canals and distribution system (which was rehabilitated in 2004-2005 to reduce water losses from seepage, increase control of water usage, and enhance the operational efficiency of the canal), the Gila desilting works at Imperial Dam, North Gila Valley's lateral system, South Gila Valley's canal and pipeline distribution, the Wellton-

Mohawk Canal distribution and drainage systems and protective works. In addition to agriculture, this project also benefits multiple domestic, municipal and industrial water users.

2.1.4. Central Arizona Project

In 1944, Arizona ratified the Colorado River Compact and received a 2.8 million acre-feet annual allotment from the Colorado River. This water was in more demand for urban and agricultural use in the central parts of Arizona; however, the state was unable to transfer the water where it was demanded and to use the full allocation. Therefore, the water flowed downstream to California. To deliver the full allocation of Colorado River and to help Arizona conserve its groundwater supplies by substituting them with surface water from the Colorado River, the Central Arizona Project (CAP) was developed. It was constructed by U.S. Bureau of Reclamation at a cost of \$4 billion and is today operated by the Central Arizona Water Conservation District. Construction began in 1973 and took about 20 years to be completed. CAP is a 336-mile long system of aqueducts, tunnels, 14 pumping plants, and pipelines, which transfer 1.5 million acre-feet of Colorado River water from Lake Havasu at the Arizona-California border to the southern boundary of the San Xavier Indian Reservation southwest of Tucson [11]. The project has about 90 wholesale customers consisting of cities, industries, agriculture (including 16 irrigation districts), and tribes. Almost 47% of the supplies fulfill Indian water rights settlements [12]. According to Reclamation, CAP provides water to over 5 million people to meet partial or full irrigation water demand for up to 700,000 acres of non-Indian agricultural lands and up to 136,900 acres of tribal lands [13]. CAP employs two levels of conservation: it works cooperatively with industries, towns, and cities to reduce water use, and also is working with the Bureau of Reclamation to operate the Yuma Desalting Plant in order to save 100,000 acre-feet a year in Lake Mead [12]. The Yuma Desalting Plant was constructed in 1992 and it has been maintained but operated only on two occasions since then. It has not operated primarily because of surplus and then normal water supply conditions on the Colorado River [14]. Additionally, the operating costs of the desalination plant for each acre-foot are four times higher than the corresponding costs of CAP water [15]. Based on a study by Arizona State University's Carey School of Business, CAP generated more than \$1 trillion of Arizona's gross state product from 1986 through 2010. Its economic benefit in recent years has been quantified to be \$100 billion per year, accounting for one-third to nearly one-half of the entire Arizona gross state product [16]. There are, however, significant concerns about the CAP's operation. First, new environmental regulations regarding energy production may impose a significant cost on CAP's users as they may increase energy cost of pumping and water delivery. The second major issue is whether there will be potential shortage on the Colorado River which would significantly affect agriculture [12].

2.1.5. Maricopa-Stanfield Irrigation and Drainage District

Maricopa Stanfield Irrigation & Drainage District was formed in 1962 to provide irrigation water for agricultural use. Their water allocation from CAP is 110,000 to 120,000 acre-feet per year. Annual water use of the district has been from 274,000 acre-feet to about 330,000 acre-feet based on 2006-2008 data. Therefore, the CAP water is supplemented by groundwater resources. The District receives its CAP water through one aqueduct turnout and operates 75 miles of main conveyance canals, 136 miles of lateral canals and pipelines, 186 farm turnouts and 396 irrigation wells to serve an area of approximately 148,000 acres. The canals are mainly concrete lined [17].

2.2. Programs and Regulations

2.2.1. Water Conservation Efforts in Wellton-Mohawk Irrigation & Drainage District

Wellton-Mohawk Irrigation and Drainage District (WMIDD) and the Bureau of Reclamation have implemented multiple programs including: the Wellton-Mohawk Salinity Control Project, Drainage Reduction Program, and The Settlement Act. Located in Southwestern Arizona along the Gila River, the district was originally established to serve a maximum of 75,000 acres, or to consumptively use 300,000 acre-feet of Colorado River water [18]. In Wellton-Mohawk, consumptive use has been defined as the difference between the amount of water diverted and that returned to the Colorado River main-stem [19]. In 1961, Reclamation started to pump excess irrigation water from Wellton-Mohawk, which had drainage problems, in order to control the groundwater level and protect the agriculture from high groundwater levels. The pumped water was discharged into the Colorado River above Morelos Dam, where 1,360,000 acre-feet of the water allocated to Mexico is diverted. This practice highly increased the salinity of Mexico's water allocations and created conflicts [20]. Therefore, an agreement (Minute 242) between the United States and Mexico was signed on August 30, 1973 to reduce river water salinity. To reduce return flows and to help meet water quality commitments to Mexico, the following efforts were undertaken within the boundaries of Wellton-Mohawk: acreage reduction, irrigation scheduling, precision land-leveling, improved farm ditches and turnouts, and soil swapping [18]. Additionally, the Yuma Desalting Plant was constructed to treat saline agricultural return flows from the WMIDD. However, except for two occasions, this plant has not operated since construction as discussed in Section 2.1.5. The on-farm improvements were funded by the USDA Soil Conservation Service, now called National Resources Conservation Service, from 1974 through 1986 [18].

In addition, the Truckee-Carson-Pyramid Lake Water Rights Settlement Act (Settlement Act) [21], which specifies an interstate water allocation between California and Nevada, describes the settlement of Native American water rights claims at Pyramid Lake, and designates water supplies for certain environmental objectives in Nevada [22]. The Settlement Act was passed by the Congress and signed by the president into Public Law 101-618 in 1990. Through this act, the Secretary of the Interior was authorized to purchase rights to 22,000 acre-feet of water from the mainstem of the Colorado River from willing irrigation districts. This water was purchased from Wellton-Mohawk and the federal government contributed \$47 million to rehabilitate the district's existing irrigation system, to design and construct additional facilities, and to pay certain Central Arizona Project operation, maintenance and replacement charges [23]. WMIDD saved this water by reducing the total irrigable area from 75,000 to 65,000 acres, and ultimately to 62,750 [20].

2.2.2. Gila River Indian Irrigation District's Water Right Settlement

In the *Winters vs. United States* case, the U.S. Supreme Court entitled tribes with reservations to access sufficient water to remain self-sufficient in 1908. Federal government has been allocating water for tribal settlements since 1976. Through the largest Indian water settlement in U.S. history, the Gila River Indian Tribe (GRIT) received in 2004 the rights to over 600,000 acre-feet a year, or enough to serve a city of three million people. Of this settlement, 311,800 acre-feet is to be delivered through the Central Arizona Project (CAP). This has created concerns for some Arizonans who believe such a large delivery of CAP water to GRIT will affect Arizona's potential to grow in the desert. The Tribe's challenge is to find a way to use the water since it holds the rights to more water than it can currently use. Many Arizonans assumed that the Indian tribes would lease water allocated to them to cities through long-term contracts, but the Gila River community prefers to put almost all of their water into agricultural use

instead of leasing it to off-reservation cities. The Tribe has said, however, they might sell one-time water credits to cities or other water users who are in need of an immediate water supply [24].

To divert its water from the CAP, the community plans to build or refurbish at least 1,700 miles of canals to irrigate over 100,000 acres by 2029. They have also installed Rubicon gates for flow control and measurement. However, it is not clear what is going to happen to the CAP water between now and 2029 [24]. The 22.6-mile Southside Canal, which cost about \$41 million, meets the Pima Canal, a \$2 million concrete structure, and moves along the southern border of the Gila River Indian Community. This system will allow water to move across the Community within hours [25]. Through 2030, the community will spend the remaining funding of \$625 million to construct other canals and the completed system will enable them to irrigate 77,000 acres [25].

2.2.3. Arizona Best Management Practices Program

Agricultural activities in Central Arizona contribute \$9.2 billion toward the state's economy [26]. To keep the farming industry on a sustainable path, the Arizona State Legislature authorized through A.R.S. § 45-566.02 a water conservation program for the agricultural sector based on best management practices in 2002 [27]. The program was developed with grant assistance from the Natural Resources Conservation Service, and partners include the University of Arizona and USDA-Agricultural Research Service [28]. This voluntary program, which covers five counties and about 600,000 irrigated acres [28], aims to provide an alternative conservation program at least as effective as the earlier Base Program of 1980, but with fewer constraints [27].

This program provides incentives to farmers to follow suggestions from the Arizona Department of Water Resources and the goal is to ensure that 80% of the water applied to crops is absorbed and not wasted [29]. Approved BMPs are separated into four distinct categories: 1) Water Conveyance System Improvements, 2) Farm Irrigation Systems, 3) Irrigation Water Management, and 4) Agronomic Management. For a list of approved best management practices in each category please visit: <http://www.azwater.gov/AzDWR/Watermanagement/AMAs/documents/ListofBMPs.pdf>. Each BMP has a point value based on its potential contribution for water conservation. A BMP program applicant should score at least 10 points, but they can only score a maximum of three points in each category to balance between categories, while a minimum of two points in the Farm Irrigation Systems category and a minimum of one point in the other three categories is required [30]. Since 2004, sixty-nine farms and almost 41,000 acres have been enrolled in the BMP Program [27]. Through the BMP program, farmers receive incentives if they follow recommendations from the Arizona Department of Water Resources. Additionally, the state offers farmers tax credits equal to up to 75% of the cost of installing water efficiency improvement systems [31]. Between 2004 and 2008, sixty-nine farms and approximately 41,000 acres enrolled in the BMP Program [27].

2.2.4. Arizona Groundwater Management Code

Due to concerns about groundwater overdraft in Arizona as a threat to prosperity and quality of life, the Arizona Legislature created the Groundwater Management Code in 1980 [32]. The primary goals of the program include [33]: 1) To control severe groundwater overdraft in many parts of the state; 2) Allocate the state's limited groundwater resources to most effectively satisfy the changing demands; and 3) Augment Arizona's groundwater with water supply development. Three levels of water management were defined due to different groundwater conditions: general provisions that apply statewide (the lowest level of management), Irrigation Non-Expansion Areas (INAs—intermediate level of management), and

Active Management Areas (AMAs—the highest level of management), which has the most extensive provisions and is applied to where groundwater overdraft is most severe. Three INAs (Douglas, Joseph City, and Harquahala) and five AMAs (Phoenix, Pinal, Prescott, and Tucson, and the Santa Cruz) were created. Designating new AMAs and INAs to protect the water supply is the Department’s authority, but local residents may also vote to create them. The six key provisions of the code include [33]: 1) Create a program of groundwater rights and permits; 2) Prohibit irrigation of new agricultural lands within AMAs; 3) Prepare a series of water management plans for each AMA for conservation targets; 4) Require developers to demonstrate a 100-year assured water supply for new growth; 5) Meter or measure water pumped from all large wells; and 6). Report water withdrawal and use annually.

2.2.5. Arizona Assured & Adequate Water Supply Programs

To address the problem of limited groundwater supplies in Arizona, and protect and preserve limited groundwater supplies within Arizona’s five Active Management Areas (AMAs), areas with heavy reliance on mined groundwater, Arizona Department of Water Resources adopted two programs: Assured Water Supply Program and Adequate Water Supply Program. Assured Water Supply Program was created in 1980 as a part of the Groundwater Code and is practiced within AMAs. This program applies when a subdivision, six or more parcels with at least one parcel having an area less than 36 acres, is being developed. Based on this program, developers must demonstrate all of the following criteria before recording plats or selling parcels: physical, legal, and continuous water supply availability for the next 100 years, the financial capability to construct any necessary water storage, treatment, and delivery systems, proof of sufficient quality of water for the proposed use, consistency of the proposed water use with the management goal of the AMA, consistency of the proposed water use with the current management plan of the AMA. Failure to demonstrate an assured water supply will prevent the developer from selling lots. The Adequate Water Supply Program, created in 1973 in response to the marketing of lots without available water supplies, is practiced outside the AMAs as a consumer advisory program and is not as protective as the Assured Water Supply Program. The purpose of this program is to assure that real estate buyers are informed about any water supply limitations. Only the first five criteria of the Assured Water Supply Program must be demonstrated to obtain a Designation of Adequate Water Supply from ADWR [34].

2.2.6. Arizona Water Banking Authority

Arizona once underutilized its full 2.8 million acre-foot share of Colorado River water [35]. In order to enable full utilization of the state's Colorado River entitlement and develop long-term storage credits for the unused portion of the entitlement, the Arizona Water Banking Authority (AWBA) was established in 1996 [36]. Since its establishment through 2013, the Bank has delivered about 4.1 million acre-feet for storage [37]. The stored water in the bank will be used to: supply municipal and industrial demands and serve communities along the Colorado River at the time of shortage, fulfill the state’s water management objectives, comply with water rights settlement agreements among Indian communities, and assist Nevada and California through interstate water banking [36]. The Bank pays the delivery and storage costs to convey the Colorado River water to central and southern Arizona through the Central Arizona Project. The water is stored either at Underground Storage Facilities (USFs), facilities that physically store water in the aquifer through direct recharge, or Groundwater Savings Facilities (GSFs), indirect recharge facilities that replace pumped groundwater with surface water instead [38]. The AWBA obtains its funding from three sources: fees for groundwater pumping collected within the Phoenix, Pinal and Tucson AMAs, property tax in the three county CAP service area, and a general fund in an annual amount

appropriated by the Arizona Legislature and the Governor. In addition, the Southern Nevada Water Authority provides an additional fund for interstate storage pertaining to the Arizona-Nevada Shortage Sharing Agreement [39].

2.2.7. Arizona Groundwater Banking

At the beginning, CAP water was more expensive than pumped groundwater, discouraging farmer participation. Farmers in Maricopa-Stanfield Irrigation & Drainage District and Central Arizona Irrigation and Drainage District exclusively pumped groundwater at a rate of 300-400 thousand acre-feet per year. On the other hand, cities used to leave their excess allotments on the Colorado River water in the river that would flow downstream. Irrigation districts worked with CAP to create pricing programs that would encourage use of the CAP water. To reduce groundwater pumping and overdraft, while avoiding losing water downstream to other users, Arizona passed legislation in 1990 to make available to farmers the cities' unused allotments on the Colorado River, i.e. CAP surface water supplies, available to farmers at an incentivized rate to be substituted for groundwater withdrawal. Cities would receive storage credits which enable them to use the stored CAP water in the future for drought mitigation or to supply increased urban demands [40].

2.3. Operations Enhancement/Water Use Change

2.3.1. YMIDD/CAGRDR Pilot Fallowing and Forbearance Agreement (Pilot Agreement)

The Yuma Mesa Irrigation and Drainage District (YMIDD) and the Central Arizona Groundwater Replenishment District (CAGRDR) initiated a Pilot Fallowing and Forbearance Agreement in January 2014. Based on this agreement, volunteer farmers will be paid to fallow their lands in order to reduce diversion from the Colorado River. The agreement was prompted due to concerns about reduced water levels in Lake Mead and the main purpose of this pilot agreement is to conserve water in the Colorado River system to be maintained in Lake Mead. The agreement contains two three-year enrolment cycles through Dec. 31, 2019. If either or both parties terminate the pilot agreement, the second cycle will not be practiced and it shall terminate on Dec. 31, 2016. A maximum of 1,500 acres of land per year in the YMIDD, which is less than 10% of the district's total irrigated land, will be fallowed. Each participating landowner can fallow a maximum of 18% of their land and they are obligated to control weeds and dust on their fallowed land and maintain the ditch structures to avoid injury to downstream users. Land owners who decide to stay in the program for the second three-year cycle must fallow another section of their land. Farmers will be paid a base rate of \$750 per acre of fallowed land by CAGRDR, and YMIDD will receive an annual adjustment rate of minimum 2% and maximum 6%. The program will result in an estimated water savings of about 9,000 acre-feet per year.

2.3.2. Diamond S Ditch: Automated Gates for Verde River Increased Flows

In Verde Valley, Central Arizona, the most downstream of the seven main irrigation ditches is the Diamond S, a five-mile long conveyor of water to more than 400 acres of crops and landscaping for about 80 different users. Diversions for irrigation were in excess of actual demands, sometimes drying up most of the Verde River for several miles. In 2008, scientists with The Nature Conservancy (TNC) identified diversions for irrigation as major threats to the river [41]. In order to restore flows in the Verde River,

Arizona's only wild and scenic river, with no sacrifice to crop production or the local economy, TNC partnered with farmers to automate the structure that diverts water from the river to farm fields so as to keep a constant flow of water in the ditch [42]. They installed two automated ditch gates with a sensor to monitor water levels, a motor that automatically controls the gate with the level changes, and a small solar panel to power the system. Each automation system cost about \$10,000 and the district is paid up to \$10 per acre-foot of unused irrigation water. The total project payment to the ditch company was less than \$25,000, which was funded by TNC with assistance from the Bonneville Environmental Foundation, Coca-Cola, and a campaign called Change the Course [43]. The automated gates have increased flows in the river by 5 cfs, approximately doubling the river flow in dry summer periods. A "minimum flow target" was set to be at least 30 cfs by 2020, which is about 43% of the historic low flow. This target applies to the river through the entire valley, not just the Diamond S reach [41]. Therefore, TNC is working with upstream districts to encourage them to upgrade their irrigation systems and leave more flow in the river. The additional flow during the summer enhances fish and wildlife habitat, while kayakers, tubers, and others who want to enjoy the beauty of the protected wild and scenic river can take advantage of it.

2.3.3. Arizona Land and Water Trust

The Arizona Land and Water Trust (originally Arizona Open Land Trust) has been seeking ways to address both land and water conservation through water agreements. It cohosted a series of "Ranching into the Future" workshops in 2007 for information sharing with farmers, ranchers and other landowners and to engage landowners directly to learn about their concerns and needs. At one workshop, a rancher on the Upper Gila River was persuaded to temporarily shut off a well and fallow a 100-acre alfalfa field. Not using water for 5 years increases the risk of loss of the water right under state law abandonment principles. Therefore, the farmer and ALWT signed a three-year water rights lease agreement in 2012. Since there is no change in the use of the water right in the temporary agreement, this transaction did not require approval by state officials. Based on the agreement, the farmer avoids pumping about 600 acre-feet of water per year in order to boost flows in the Upper Gila River for environmental purposes. ALWT pays the farmer for this water saving practice. ALWT key strategies include: building trust through partnership with local, land based, and credible entities, and offering resources to help landowners benefit from conservation. ALWT is collaborating with the University of Arizona and other scientists to ensure that the reduced pumping actually increases the river's flow. If it is proven that this has been a successful project, ALWT will arrange additional temporary water lease agreements in the Upper Gila River [44].

2.3.4. Public Private Partnership for the San Pedro River's Flow Augmentation

The San Pedro River, which starts in Mexico and flows into Arizona, provides critical riparian habitat for millions of migratory birds, an endangered aquatic plant, and many vulnerable animal species. Streamflow reduction in the river due to droughts and increasing human water demands has adversely affected wildlife and fish, while also threatening the long-term reliability of water supplies for human water demands. Each year in June, The Nature Conservancy (TNC) works with over 100 community members in the U.S. and Mexico to map the river and its tributaries, particularly where the river continues to flow during the driest time of the year. They created a groundwater simulation model with local, state and federal partners to better understand aquifer flows that augment the river flow. Using this information, TNC identified best locations for groundwater recharge projects that enhance the San Pedro River flows. They partnered with the Department of Defense, which has a very large base in the drainage – Ft. Huachuca, to acquire key agricultural lands and are now designing aquifer recharge projects. Their

partners include: Cochise County, local developers, private foundations and Natural Resource Conservation Service districts. TNC concludes that future water issues in the West should not be focused on conflict, while they can be addressed through public-private partnership, smart science, technical tools, and infrastructure. In addition, they believe it is important to simultaneously address the water needs of all water sectors [45].

3. CALIFORNIA

3.1. Programs and Regulations

3.1.1. PVID/MWD Forbearance and Fallowing Program

A 35-year Forbearance and Fallowing Program officially began on January 1, 2005, to transfer water from Palo Verde Irrigation District (PVID) to Metropolitan Water District of Southern California (MWD), which supplies domestic water demands for 16 million people in Southern California. Discussions about this program were initiated in the 1980's. Between 25,000 to 118,000 acre-feet per year will be transferred to MWD, totaling an estimated 1.8 to 3.9 million acre-feet over the lifespan of the agreement [46]. Since the beginning of the program, the saved water has varied from about 32,750 to 120,250 acre-feet per year [47]. The need to support the \$800 billion economy of Southern California in light of predicted future water supply shortages forced MWD to pursue applicable options for improving the reliability of its water resources. On the other hand, PVID sought ways to stabilize the farm economy and found agricultural water conservation as an efficient way.

Based on this program, between 7% to 28% of farmlands, or 6,487 to 25,947 acres, are allowed to be taken out of production for fallowing each year [46]. The portion of the land that is left fallowed should be maintained to meet approved soil and water management plans and should be rotated every one to five years [47]. Participating farmers receive a one-time payment of \$3170 per acre and an annual payment of \$602 for the first year, with an agreed upon price escalation for the following years [40]. Capital costs were \$82.8 million and total annual payments through 2013 have been \$111.1 million to landowners and farms owned by MWD as well as \$3 million to PVID for administrative costs. The capital costs included \$73.5 million for one-time payments to landowners who enrolled in the program, \$3.3 million for environmental documentation and implementation, and \$6 million for local community improvement programs [47]. However, some of the agricultural community fear that these types of agreements open a way towards reallocating agricultural water to other users and agricultural water users may lose their water right over time [48]. In addition, while fallowed land still requires attention, this practice reduces crop production and likely income from that land even if the lost income is made up for by the lease of the water [49]. Other effects on the rural community, such as loss of employment of farm workers and reduced sales for agricultural products increase the existing concerns. MWD appropriated a \$6M fund for community improvement programs, such as education and job retraining of workers impacted by the fallowing, and to mitigate injury to other affected parties [50].

3.1.2. IID/MWD Water Conservation Program

In 1988, Imperial Irrigation District (IID) and Metropolitan Water District of Southern California (MWD) signed a 35-year cost based water conservation and transfer agreement. A three-member

committee was established consisting of one member from MWD, one member from IID and a neutral member to develop and select the conservation measures to construct and the verification methods used to validate the amount of conserved water. Based on this agreement, MWD pays the costs of water conservation measures in IID, including maintenance and replacement for the period of the transfer agreement, and receives the conserved water [51]. The 1988 Agreement was amended in the 2003 Quantification Settlement Agreements (explained in the next section) and extended to 2041 or through the QSA term, whichever is later [47]. Fifteen new efficiency projects were identified in the 1988 Agreement and in the December 1989 Approval Agreement among IID, MWD, Palo Verde Irrigation District and the Coachella Valley Water District [52]. Projects included lateral interceptors, reservoirs, concrete lining of main and lateral canals, non-leak gates, system automation, and a change from 24 to a 12-hour delivery schedule. While the primary focus of the program was on modernizing and rehabilitating IID's distribution system, on-farm irrigation system improvements and water management projects were also included. The on-farm improvements consist of tail water return systems, irrigation evaluations, pilot linear move, and drip irrigation systems [47]. Water efficiency conservation projects provided greater water management flexibility for farmers and opportunities for farmers to apply water effectively [52]. Between 1998 and 2013, an annual average of 105,009 acre-feet per year, ranging between 101,940 and 109,460 acre-feet per year, has been saved. Through 2013, a total of 1,841,242 acre-feet have been used by MWD and 159,381 acre-feet have been stored in Lake Mead for MWD. In addition, 137,156 AF have been used by Coachella Valley Water District [47].

3.1.3. Colorado River Quantification Settlement Agreements

In October 2003, after about 10 years of discussions and negotiations, San Diego County Water Authority (SDCWA) and Imperial Irrigation District (IID) along with Coachella Valley Water District (CVWD), Metropolitan Water District of Southern California (MWD), the state of California, and the U.S. Department of the Interior signed a set of approximately three dozen agreements to conserve and transfer Colorado River water within California. The complete set of agreements is known as the Colorado River Quantification Settlement Agreements (QSA) [53]. Major features of the QSA include: quantifying IID's Colorado River annual entitlement at 3.1 million acre-feet; quantifying CVWD's Colorado River annual entitlement at 330,000 acre-feet; settling conflicts among the four agencies and the seven Colorado River Basin states; IID developing a Market-Based efficiency conservation program for 310,000 acre-feet annually; providing for large-scale water transfers; providing for lining portions of the All American and Coachella canals [54]. SDCWA's incentive for these agreements was the fact that they had recognized and predicted that California will ultimately be limited to its annual Colorado River apportionment of 4.4 million acre-feet, which happened the same year as QSA's initiation. Seeking additional and independent supplies of water, SDCWA found IID as a logical partner to obtain water from, due to their geographic proximity to MWD's Colorado River Aqueduct and IID's water entitlement of more than 3 million acre-feet per year.

Based on the QSA, IID will develop delivery system and on-farm efficiency conservation projects for the water transfer. During the construction period, a ramp-up schedule was agreed to for delivery to SDCWA. In order to meet the early water transfer demands of the ramp-up schedule as well as environmental mitigation issues, fallowing was allowed during the initial 15 years. The IID fallowing program requested volunteer landowners to fallow some of their fields and receive payment based on the verified amount of water conserved. After the 15 years, water must be conserved through on-farm and delivery system efficiency only. MWD delivers the conserved water via the Colorado River Aqueduct to the SDCWA and CVWD receives conserved water via the All-American Canal. Based on the QSA, IID will conserve and transfer 200,000 acre-feet to SDCWA and 103,000 acre-feet per year to CVWD, on a ramp-up basis. The ramp-up schedule was initiated with conserving 10,000 acre-feet of water per year in

2003 and the conservation quantity will increase to 303,000 acre-feet per year through 2021. The initial term of this agreement is 45 years, which can be renewed for an additional 30 years if both parties agree [55]. In 2008 IID began the delivery system conservation and in 2013, IID began the voluntary on-farm conservation program.

The Water Authority pays for the verified water conserved on a yearly basis. Payments to IID have also been set on a ramp-up schedule, which started at \$258 per acre-foot in 2003 and increases to \$624 in 2015 [56]. Each year, the IID Board of Directors sets conservation payment rates for the on-farm fallowing and efficiency projects. Since 2003, the fallowing participants have been paid between \$60 and \$175 per acre-foot. In 2013 and 2014, the price per acre-foot paid to on-farm conservation participants was set at \$285 per acre-foot [47]. After 2015 through 2034, the payments from SDCWA to IID will increase based on the annual increase in the Gross Domestic Product Implicit Price Deflator, published by the Bureau of Economic Analysis of the U.S. Department of Commerce. As of 2035, either the Water Authority or IID may elect a market price using a formula described in the agreement. After 2035 and under certain conditions, a shortage premium price can also be imposed [55].

Based on several years of studies a plan was developed to determine how the 303,000 acre feet of water would be conserved by efficiency conservation. The Definite Plan optimized efficiency efforts while minimizing costs using detailed delivery system and on-farm field by field computer model simulations. The final recommendation was 103,000 acre feet would be conserved by delivery system improvements and 200,000 acre feet would be conserved by on-farm efficiency improvements. On-farm efficiency efforts the farmers have made since 2003 include: lining farm head ditches, installing tile drains, leveling farmland, and implementing a number of water management and efficiency conservation measures. The delivery system efficiency projects include lined canals, regulating reservoirs, implemented canal seepage recovery programs, interceptor and cross-tie canals, system-wide improved water measurement and automation, and non-structural measures to enhance the efficiencies of the conveyance and distribution system [57]. All water conserved must be verified and quantified based on new measurement devices and computer decision support systems.

The QSA included mitigation of all environmental impacts of water conservation efforts within Imperial County, the Salton Sea, as well as MWD and CVWD conserved water service areas. The SDCWA is also responsible to mitigate any environmental impacts of the transportation of the conserved water on the Colorado River between Imperial Dam and Lake Havasu [58]. The Salton Sea provides habitat for fish and migratory birds. However, salt build up and diminished water supply has long been threatening this important habitat. Under the QSA, in addition to IID's efforts in mitigation of environmental impacts of water conservation to Salton Sea, the state of California may purchase water from the IID for sale to the MWD, generating funds for the Salton Sea restoration program. Through 2017, IID will deliver "mitigation" water from the fallowing program to the Sea in order to make up reduced inflows due to the water transfers during that period. A restoration project is scheduled to start in 2018, which is intended to prevent decline in the size of the Salton Sea by about 60%, and a tripling of salt concentration in the river [59]. This is an ongoing issue and the information provided here are the most recent update to date.

Upon the execution of the QSA, a number of Imperial Valley parties brought litigation against the validation of 13 of the QSA related contracts to assure they comply with the state and federal law, and to review the IID environmental impact report [60]. Due to these litigations, the IID water transfer and a number of other pieces of the QSA were invalidated by a trial court. This ruling was reversed by California's Third District Court of Appeal in December 2011 [61]. Ultimately, a Sacramento Superior Court judge validated the QSA and rejected all of the remaining legal challenges after 10 years of litigations in July 2013 [62]. There have, however, been ongoing socioeconomic concerns about fewer job opportunities for agricultural workers and reduction in demand for goods and services, affecting local businesses. On the other hand, it is expected that hundreds of new jobs will become available through

efficiency-based conservation upon full implementation of the QSA, resulting in increasing economic stimulus to Imperial Valley [63]. In order to mitigate the socioeconomic impacts from the water transfer, the Water Authority provides \$30 million to IID from 2003 to 2017 [64].

3.1.4. Coachella Valley Water Management Plan

In order to address concerns about groundwater overdraft, Coachella Valley Water District (CVWD) initiated a planning process in the early 1990s in its Lower Valley. This plan was expanded to include the entire Coachella Valley in 1995 and ultimately resulted in development of the Management Plan in 2002 [65]. An updated draft of the plan was released in December 2010 [66]. To reliably, sustainably, and cost effectively supply current and future water demands, the 2002 Water Management Plan has set four objectives [66]: 1) Eliminate groundwater overdraft and its corresponding adverse impacts; 2) Maximize opportunities for conjunctive use; 3) Minimize adverse economic impacts to the water users in Coachella Valley; and 4) Minimize environmental impacts. In order to achieve these objectives, the district has focused on three areas for its conservation efforts: agriculture, urban and golf. The program proposes to reduce agricultural water use by 14% by 2015; to decrease urban water use by 20% through conservation by 2020; to achieve 10% water conservation for golf course water use at existing courses; and to establish new golf courses 25% more efficient than the existing courses of similar size [67]. Additional supplies will also be developed through: acquisition of imported supplies, increased recycled water use, canal water loss reduction, desalinated drain water, stormwater capture, and development of local groundwater supplies for non-potable use [66].

The 2010 Water Management Plan Update has the same basic goals as the original 2002 plan, but it reflects a more holistic planning approach. To reflect the water resources uncertainties, the updated plan has refined the following objectives: Current and future demands must be met with a 10% supply buffer; long-term groundwater overdraft should be eliminated; water quality should be managed and projected; state and federal laws and regulations must be complied with; future costs should be managed; and adverse environmental impacts should be minimized. The 2010 updated plan uses a building block approach for agricultural conservation. In the building block approach, each block is practiced if the previous one fails. The building blocks are listed as: 1) Grower education and training; 2) District-provided services (including district-funded conservation programs); 3) Irrigation upgrade/retrofit; 4) Economic incentives; and ultimately 5) Regulatory programs [66].

3.2. Operations Enhancement/Water Use Change

3.2.1. All American Canal Lining Project

One of the key agreements in the 2003 Colorado River Quantification Settlement Agreement was to line with concrete the All American Canal. Main partners of the canal lining project included the San Diego County Water Authority, the Imperial Irrigation District, the Bureau of Reclamation, and the California Department of Water Resources. This project along with the Coachella Canal Lining Project is considered as a critical component of the San Diego County Water Authority's long-term water supply diversification strategy to help mitigate future water shortages. The All American Canal Lining Project (AACLP), which was funded by the state of California and the Water Authority, replaced 23 miles of an earthen canal in Imperial County with a concrete-lined canal to save the water that once was lost to seepage. The Imperial Irrigation District provided construction management and ongoing operation and maintenance of the canal, while the Bureau of Reclamation maintains its ownership [68].

The All American Canal, located adjacent to the U.S.-Mexico border, conveys about 3.1 million acre-feet of water per year. The canal was constructed in the 1930s through sand [69]. To reduce seepage, the AACLP began in 2007 and was completed in early 2010 [68]. Annually, 67,700 acre-feet of water is conserved by the AACLP, which is transferred to San Diego to meet the potable water supply needs of about 500,000 people [69]. This allocation of water to the Water Authority is valid for a period of 110 years. Indian tribes in northern San Diego County, San Luis Rey Settlement Parties, will also receive a portion of the conserved water to resolve long-standing disputes [70].

However, the water that once seeped from the All-American Canal into the ground recharged the aquifer beneath the Mexicali Valley. The AACLP has blocked this groundwater recharge, affecting thousands of acres of farmland in Mexico with an estimated damage of more than \$80 million per year [71]. Farmers in Mexicali were forced to fallow their lands with significant environmental and socioeconomic impacts as well as health problems. The business community of Mexicali, a border city in Baja California, Mexico along with entrepreneurs and lawyers, initiated litigation against the United States to argue that this project is a violation of the National Environmental Act of the United States and to reclaim water rights. They believed that the environmental impact assessment studies had not considered the environmental consequences to 600 acres of wetlands in the Mexicali rural area [72]. This litigation was eventually rejected and the canal was built.

3.2.2. Coachella Canal Lining Project

In addition to the All American Canal Lining Project, the Coachella Canal Lining Project was also developed to conserve water and comply with provisions contained in the 2003 Quantification Settlement Agreement. The fund for this project was authorized by California Water Code under the General Fund's Colorado River Management Account. The project also received \$9.65 million from Proposition 50 [73]. Parties involved and responsible for this project include: San Diego County Water Authority (SDCWA), Coachella Valley Water District, Imperial Irrigation District, State of California, U.S. Bureau of Reclamation, and San Luis Rey Indian settlement parties. The Coachella Canal, a branch of the All-American Canal in southeastern California, transfers Colorado River water 123 miles from the All-American Canal to more than 85,000 acres of highly productive agricultural land northwest in the Coachella Valley [47]. A 36.5-mile section of the canal was unlined, resulting in about 32,350 acre-feet per year water loss through seepage [74]. Under this project, which was completed in December 2006, 35 miles of concrete-lined canal were constructed in parallel with the existing Coachella Canal, resulting in an annual savings of 26,000 acre-feet of water. Additionally, the project also included a variety of check structures, canal crossings, flow measurement structures, and environmental mitigation measures. The California Department of Water Resources funded 70% and the SDCWA funded the remaining capital costs. The Coachella Valley Water District, SDCWA, and the San Luis Rey Indian Water Rights Settlement Parties share the annual operating costs [47]. The total water conservation from this project along with the All American Canal Lining Project is about 93,700 acre-feet per year [73]. SDCWA receives 77,700 acre-feet of conserved water per year for 110 years. The remaining 16,000 acre-feet of water per year belong to San Luis Rey settlement parties, which contain several bands of Mission Indians in northern San Diego County [73].

4. COLORADO

4.1. Original Water Resources Development Projects

4.1.1. Grand Valley Project

In order to reliably supply irrigation water demands of thousands of acres of farmlands and orchards in Grand Valley, the Secretary of the Interior approved the plan for the construction of the Grand Valley Project by the Bureau of Reclamation in 1907. On January 5, 1911, the project was approved by the President and was allocated \$1,500,000 for its construction, which was delayed until September 23, 1912, when the Secretary of Interior gave the Reclamation Service authorization to begin construction [75]. The first irrigation water supplied by the project was in 1915, when the project was 60% complete [76]. The project is operated on the north side of the Colorado River in Grand Valley by Grand Valley Water Users Association and on the south side of the Colorado River and east of the Gunnison River by Orchard Mesa Irrigation District [77]. This project fully supplies water demands of 33,368 acres of land and provides supplemental water to nearly 8,600 acres of fertile land in west-central Colorado. Its features include: a diversion dam, a power plant, two pumping plants, two canal systems totaling 90.1 miles, 166 miles of laterals, and 113 miles of drains [76]. In addition to irrigation, the project water is used for hydropower generation at the Grand Valley Power Plant, completed in 1933 by Grand Valley Water User's Association with a capacity of 3.0 megawatts. The water was also used for cooling purposes at the Cameo Power Plant, built in the late 1950s by Public Service Company [75]. This power plant is no longer in operation. The region's urban population growth has also recently increased the use of project water for municipal and industrial purposes.

4.1.2. The Dolores Project

The Dolores Water Conservancy District (DWCD) was formed in 1961 to supply water for irrigation, municipal and industrial users, recreation, fish and wildlife, and hydroelectric power from the Dolores River. The District was authorized for the Dolores Project in 1968. Local voters accepted up to \$26 million repayment obligation to the United States. The project's construction was, however, delayed by President Carter due to settlement of Indian water rights. Construction of McPhee Dam, the principle storage feature of the Dolores Project, began in 1980 and was completed in 1986. The project has since been operated by the DWCD. Main features of the project include: 80 miles of canal, seven pumping plants, 82 miles of buried pipe laterals, and the 11.5 megawatts Towaoc Power Plant [78]. The Dolores Project provides water to: irrigation of 28,000 acres of full service land in Montezuma and Dolores Counties; 7,600 acres of full service land on the Ute Mountain Ute Tribe Reservation; municipal water for the City of Cortez, Town of Towaoc, and Town of Dove Creek; a cold water trout fishery; native fishery; wetlands and wildlife habitat; supplemental irrigation water to the Montezuma Valley Irrigation Company; and recreation on McPhee Reservoir [79].

4.1.3. Colorado-Big Thompson Project

The Northern Colorado Water Users Association, formed in 1935, pushed the idea of transferring Colorado River water to the East slope of the Rocky Mountains, a possibility which had been explored since the 1880s. Due to the need for an organization with taxing authority and the ability to contract with the federal government, the Northern Colorado Water Conservancy District was created in 1937, shortly

after the Water Conservancy Act was passed. The construction of the Colorado-Big Thompson (C-BT) Project began in 1938 and the project was completed after 19 years in 1957. For the project's construction, the Association signed a repayment contract with the United States in 1938 to pay up to \$25 million during a 40-year repayment period. The final construction cost of the project was almost \$162 million [80]. C-BT stores, regulates, and diverts Colorado River water from the western slope of the Rocky Mountains to the eastern slope 3,800 feet beneath the Continental Divide through the 13.1-mile Alva B. Adams Tunnel [81]. The Project consists of 12 reservoirs, 35 miles of tunnels, 95 miles of canals, seven hydroelectric power plants, and 700 miles of transmission lines [82]. Each year, the project collects on average more than 200,000 acre feet of snowmelt on the West Slope and delivers it to more than 640,000 acres of irrigated farm and ranch land and 860,000 people in portions of eight counties within Northern Water boundaries in the east slope [83].

Upon its full completion, 97% of C-BT's water deliveries were for agricultural purposes and 85% of the C-BT allottees, those who own units of project water, represented irrigated agriculture. However, the number of agricultural allottees decreases every year and today only about one-third of C-BT units are owned by the agricultural sector [80]. Meanwhile, municipal holdings increased from 18% of the total to 41% and industry holdings increased from less than 1% to 4% from 1962 to 1992 [84]. Although farmers currently make up less than a third of the total number of allottees, they still use the majority of the C-BT water. This has been made possible because of C-BT's great operational and institutional flexibility and transferable water allotment system that allows municipal share holders rent their shares. C-BT allows trades in terms of "allotments," a share of the aggregate project water supply for a given year. Each season, users can rent their excess water to other water users within the area served by the C-BT, or, with higher transaction costs, to users not on the C-BT delivery system. On average, approximately 30% of C-BT water is involved in rental transactions each year; the agricultural sector is a net rentee and cities are net renters of water [84].

4.1.4. Uncompahgre Project

Constructed by the Bureau of Reclamation and operated by the Uncompahgre Valley Waters Users Association (UVWUA), the Uncompahgre Project was authorized by the Secretary of the Interior on March 14, 1903 in response to the 1902 Reclamation Act, which had selected the Uncompahgre Valley for immediate development. The project provides storage in Taylor Park Reservoir on the Taylor River, a tributary of the Gunnison River Basin, and diverts water from the Gunnison Diversion Dam, on the Gunnison River, through the Gunnison Tunnel and the South Canal to the Uncompahgre River. The South and West Canals distribute the waters of the Gunnison and Uncompahgre Rivers. The Bureau of Reclamation began the construction in July 1904. The Gunnison Tunnel and the Gunnison Diversion Dam were completed in 1909 and 1912, respectively. Reclamation transferred the project's operation to the UVWUA in 1932. In 1937, Taylor Park Dam was built and some rehabilitation works were done including: enlargement, lining, and smoothing portions of the Gunnison Tunnel, replacing some of the wooden structures with concrete and steel structures, relining portions of the canals, and constructing a drainage system. Originally called the Gunnison Project, the Uncompahgre Project currently supplies full irrigation water to about 76,300 acres of land in west-central Colorado [85].

4.1.5. Colorado River Storage Project Act

The Colorado River Storage Project (CRSP) act was authorized in 1956 to allow comprehensive development of the water resources of the Upper Basin states. This act resulted in construction of one of

the most complex and extensive river resource developments in the world [86]. The main purpose of the act was to provide long-term regulatory storage of water in the Upper Basin to develop its apportionments of the Colorado River while meeting Lower Basin's entitlements [87]. In addition to regulating the flow of the Colorado River and storing water for beneficial consumptive use, other purposes identified in the 1956 act include: providing for reclamation of arid and semi-arid lands, providing flood control, and generating hydropower. The project also provides for recreation and enhances fish and wildlife habitat [86]. CRSP has had significant economic impact in the West [88]. This project includes four initial storage units: the Wayne N. Aspinall Unit in Colorado (Blue Mesa, Crystal, and Morrow Point Dams), Flaming Gorge Unit in Utah, Navajo Unit in New Mexico, and Glen Canyon Unit in Arizona. Glen Canyon Dam, which is the key unit for controlling water releases to the Lower Basin, is the largest facility. The combined live storage capacity of the CRSP main storage unit dams is about 30.6 million acre-feet. These dams' power generation capacity exceeds five billion kilowatt-hours of energy annually [86]. There are also a number of participating projects authorized by the act to deliver irrigation water to farms and provide municipal and industrial water. Initially, 11 participating projects were authorized. Subsequent legislation, including a big environmental battle over Echo Park, increased the total number of these participating projects to 23, but one of them was eliminated later. These participating projects develop water in the Upper Colorado River system for irrigation, municipal and industrial uses. More than 554,000 acre-feet of water is supplied by the participating projects for irrigation with a gross crop value of more than \$49 million per year [89].

Located in west-central Colorado, the Wayne N. Aspinall Unit was authorized as part of the 1956 CRSP Act, along with three other initial CRSP units. The project, which overlays part of the Uncompahgre Project, was originally named the Curecanti Unit. In 1980, the name was changed to honor U.S. Representative Wayne N. Aspinall, who was a strong proponent of water resources development in the western states, especially in Colorado, and was instrumental in the passage of the CRSP Act [90]. The Aspinall Unit consists of three dams in the upper part of the Black Canyon of the Gunnison: Blue Mesa Dam (completed in 1955 with the capacity of 940,800 acre-feet [91]), Morrow Point Dam (constructed in 1968 with the capacity of 117,190 acre-feet [92]), and Crystal Dam (built in 1976 with the capacity of about 26,000 acre-feet [93]). These dams regulate the river flow and provide water storage and hydroelectric power generating opportunities along a 40-mile reach of the Gunnison River [90]. In addition to providing habitat for a cold water fishery, the three basins provide a range of water recreation opportunities including: sail boating, windsurfing, water skiing, and cold-water fishing [94].

The CRSP Act established the Upper Colorado River Basin Fund (Basin Fund), which is a separate fund in the Treasury of the United States. Money is transferred to the Basin Fund from the General Fund of the Treasury. Revenues from operation of the CRSP and participating projects, mostly from sales of hydroelectric power and transmission services, are also deposited in this fund. Revenues from municipal and industrial water service sales, rents, salinity funds from the Lower Colorado Basin, and miscellaneous revenues collected due to the operation of the CRSP and participating projects are also deposited in the Basin Fund. This fund is first used to repay costs associated with the operation, maintenance, and replacements of the CRSP initial units, and the remaining part is used to repay the United States Treasury Department for the construction costs of the CRSP initial units allocated to the power purpose and to irrigation; the construction costs of the participating projects allocated to the irrigation investment and above the irrigator's ability to pay; and a part of salinity investment and operation costs [95]. The fund is also used for: cost sharing for Colorado River Basin Salinity Control Program; the most portion of the cost of the Glen Canyon Adaptive Management Program; cost sharing for the Upper Colorado and San Juan Endangered Fish Recovery Implementation Programs; water quality studies; and consumptive use studies. The Basin Fund is managed by Western, which is responsible for transmission and marketing of CRSP power, collecting payment for the power, and transfer of revenues for repayment to the United States Treasury Department [95]. Revenues from hydropower generation at the CRSP initial units were

used to fund these participating projects and the revenue from these smaller projects is used to repay the costs of irrigation features [89].

4.2. Programs and Regulations

4.2.1. Yampa/White/ Green Basin

The Yampa/White/Green Basin Roundtable, concerned about poor physical and legal reliability of its water resources, especially during droughts, is trying to find ways to guarantee current and future water supply for both consumptive and non-consumptive uses. The Roundtable is one of the basin groups established by the Colorado's Water in the 21st Century Act to assist the state in its water planning. The Roundtable believes that their goals can be achieved by appropriately planning storage, delivery, and administrative structure. For example, interstate delivery compliance might be timed to meet endangered fish recovery program flow targets, or in planning for additional storage in the system, the balance between high spring flow for both recreational and ecological demands should be considered. The Roundtable also believes that it is critical to develop a framework protecting an apportioned supply within each drainage basin in its Basin Implementation Plan. These three basins in Northwest Colorado are relatively underdeveloped, with limited storage, and are independent for local water planning as there are no diversions between them. On the other hand, population growth imposes additional municipal needs, additional irrigated agricultural areas have been identified in Statewide Water Supply Initiative studies, and the energy sector will potentially have the greatest growth in consumptive water demand. The Roundtable believes that these demands should be supplied in a way that the non-consumptive needs, such as endangered species, riparian plant communities, sport fisheries, rafting, and ecological integrity, are not sacrificed. However, relatively junior water rights within these basins makes them considerably vulnerable to any action to limit consumptive use due to any inter-basin/intrastate compacts and threatens the physical and legal reliability of their water resources [96].

4.2.2. Colorado Water Bank (West Slope Water Bank)

The Colorado River Water Conservation District devised a model for water banking and is working with ranchers and conservation organizations in order to make water a profitable crop through a market-based approach to water conservation. Still in the development stage, the Colorado River Water Bank would provide municipalities on the east slopes of Colorado's Rocky Mountains a mechanism to buy water consumption rights from agricultural water right holders on the west slope [97]. It is estimated that the water bank could save a maximum of about 200,000 acre-feet water, requiring deficit irrigation or fallowing on 130,000 to 260,000 acres on the West Slope [47]. This would increase the security of the Upper Colorado River Basin water supplies and reduce the potential negative impacts of persisting drought conditions [98]. Based on the 1922 Colorado River Compact, Section III(d), Upper Basin states (Colorado, New Mexico, Utah, and Wyoming) are obligated not to cause flow at Lees Ferry, Arizona, to deplete below 75 million acre-feet during any consecutive 10-year period. Since drought began in 2000, the average annual flow has dipped below 10 million acre-feet per year. This water deficit may cause the Lower Basin states to institute a forced "compact curtailment," which would cut junior water rights (established after 1929) until the 10-year rolling average goes above the Compact minimum, while pre-compact senior water rights would be relatively unaffected. Therefore, the east slope municipalities with junior water rights are the most vulnerable entities, while urban population growth in the area is forcing them to increase and secure their water supplies. The uneven distribution of senior Colorado River water rights throughout the state and the difference in water prices on the east and west slope make water

banking a viable strategy [97]. Some other benefits of water banks can be summarized as: they allow water users to allocate scarce water in the most cost-effective way; they also reduce transaction costs by standardizing agreement terms and monitoring performance, which encourages more water conservation deals and promotes water conservation for environmental purposes [97].

The Water Bank operation would be as follows: agricultural water users who volunteer to participate in the program would be compensated to temporarily fallow, split season irrigate, or deficit irrigate lands with pre-compact water rights. The pre-compact water rights are valuable because a curtailment should not directly affect them and they can provide a secure source of water. The saved water would be stored in the Water Bank and post-Compact water users would subscribe to the bank for access to pre-Compact water. The post-Compact consumptive use in Colorado is currently about 1.2 million acre-feet per year and the Water Bank could only partially compensate potential Colorado River curtailments [47].

The Water Bank Group members, who financed the feasibility study, include representatives of the Colorado River Water Conservation District, Colorado Water Conservation Board, Front Range Water Council, Southwestern Water Conservation District, and The Nature Conservancy. Phase 1 of the feasibility study quantified post-Compact water rights, and water supply available to the Water Bank from pre-Compact agricultural rights. Based on the results from Phase 1 of the study, a 25 to 50 percent participation rate would be required to meet significant water uses. The feasibility of deficit irrigation and fallowing (for pre-1922 irrigation systems) as well as evaluation of methods for measuring water savings will be assessed in Phase 2. Economic and environmental considerations will be evaluated in Phase 3 [47].

4.2.3. Lower Gunnison Salinity Control Project

In 1974, the Colorado River Basin Salinity Control Act (Public Law 93–320) authorized the Secretary of Interior to plan and construct salinity-control projects in the Colorado River Basin in order to control the salinity of water delivered to users in the United States and Mexico. The Lower Gunnison Salinity Control Project (LGSCP), begun in 1986, was one of the first projects to mitigate salinity in the Lower Gunnison and Uncompahgre River Basins [99]. Hydrosalinity studies estimate the annual salinity load of the Lower Gunnison Basin to be 1,440,000 tons, including 840,000 tons from agricultural practices. From this, 440,000 tons per year would be delivered from field irrigation and supply delivery ditches and 400,000 tons per year from canals and laterals. Through the LGSCP, the Bureau of Reclamation, U.S. Department of Agriculture—Natural Resources Conservation Service, and the Bureau of Land Management have collaborated and reduced salt loading to the Colorado River by approximately 227,100 tons per year through on-farm and off-farm practices. On-farm practices include: improved irrigation efficiency, and improved irrigation technology such as periodic move systems, continuous move systems, and other high tech systems. Off-farm conservation is mostly practiced through lined canals and laterals. In the Lower Gunnison Basin, about 669 miles of canal or laterals (out of nearly 1,345 miles) have been treated. Irrigation methods have been improved on approximately 62,306 acres out of 171,000 total irrigable acres. Reduced salinity has resulted in increased crop production and decreased operating costs. In addition, enhanced irrigation efficiency has increased drought resiliency [100].

4.2.4. North Fork River Improvement Association

North Fork River Improvement Association (NFRIA), a “solution-focused” non-profit organization, was formed in 1996 to improve stream stability, riparian habitat, and ecosystem function along the North

Fork of the Gunnison River. The organization is a coalition of landowners, farmers, ranchers, environmentalists, irrigation companies, outdoor enthusiasts, in-stream gravel mining companies, and individual members [101]. It was developed due to the problem of high bank erosion along the river and aimed to research new and innovative solutions [102]. NFRIA promotes community improvement and sustainable agricultural practices and strives to support the restoration of the North Fork into a healthy, usable, and sustainable river. They pursue their goals with grants from over 60 local, state, and national organizations and individual donations from their members [101]. As one of their first achievements, they obtained funding to specify the river's problems, quantify these problems, and develop recommendations for its restoration. This Community Based Assistance Grant was awarded by the EPA in 1996. This study found that channelization was the primary cause that destabilized the riverbanks and degraded the riparian vegetation along the banks. After this study, they raised \$410,000 from 24 different cooperating government agencies, private foundations, corporations, and local in-kind donations of services to restore 1.5 miles of the North Fork in order to reduce erosion and improve water quality, stabilize the channel, increase the density and diversity of the riparian vegetation, and enhance fish and wildlife habitat. They also constructed a reliable and efficient irrigation diversion to divert a full decree of water while removing impediments to fish migration and recreational boating. This project, which was completed in Feb. 2000, was judged a great success by government agencies, the association, and the local community. Since then and in collaboration with its partners, NFRIA has restored 6 miles of highly impacted stream and floodplain and reconstructed four irrigation diversions [102].

4.2.5. Split Season Approach to Water Use in the Little Cimarron River, the Gunnison River Basin

In a collaboration between the Colorado Water Conservation Board (CWCB) and the Colorado Water Trust, an innovative agreement was made in 2015 to use the same water rights for both restoring stream flows and preserving agriculture [103]. This agreement will help restore late summer flows to a 5-mile reach of the Little Cimarron River in the Gunnison River Basin [104]. This reach has historically had low to no flows as the result of water diversions. Based on this agreement, a ranch irrigated from the McKinley Irrigation Ditch will stop diverting water from the Cimarron River in mid-summer and leave the water in the river for instream flow use by the CWCB, as the only entity in Colorado that can hold instream flow water rights [103]. It will leave 5.8 cubic feet per second of water in the river in late summer [105]. Until mid-summer, the ranch will continue diverting water for irrigation [104]. This will allow the agricultural water rights holders to continue their agricultural activities in early summer and then choose to be compensated for leaving the water in the river in late summer and early fall. This case became possible as the Western Rivers Conservancy purchased a 214-acre ranch, which was on the market as 35-acre lots with the water rights marketed separately. Then, with help from the Walton Family Foundation, the Water Trust purchased the water rights associated with the ranch and the CWCB board agreed to purchase a permanent “grant of flow restoration use” from the Water Trust. Although the water right holder and ranch owner are both conservation organizations, the main goal of this agreement is to provide a new water-sharing model for private agricultural water rights holders [104]. The split season use of water approach acknowledges and preserves the values of both irrigated agriculture and restoring flow to a local river. This concept can be practiced under current state law with no need for change in the state law and has statewide application. The main challenge would be to find a water right in proximity of a reach that needs water, which is available in the market [105].

4.3. Operations Enhancement/Water Use Change

4.3.1. Grand Valley Water Management Plan

In response to the U.S. Fish and Wildlife Service call for more water for the fish in the 15-mile reach of the Colorado River and as part of the Upper Colorado River Endangered Fish Recovery Program, the Bureau of Reclamation and the Grand Valley Water Users Association (GVWUA) developed the Grand Valley Water Management Plan (GVWMP). The plan includes seven new canal check structures and a bypass pipeline (all constructed in 2000–2001), a pumping station at Highline Lake, an integrated SCADA system, rehabilitation of eight existing canal check structures in the Government Highline Canal, and the Palisade return flow pipeline [106]. The project is operated, managed, and maintained by GVWUA, which delivers water to 23,340 acres of land via the 55-mile long Government Highline Canal and 130 miles of pressurized pipelines [107]. Prior to these enhancements, the system was run in a very inefficient way with lots of spilled water, in part because of the travel times (24 hours) from the top of the system to the bottom. Now, it is much more tightly managed and less water is put into the system. The capital cost of the project was about \$8 million and it also had \$1.25 million in capitalized annual cost, equivalent to \$11.73 per acre-foot per year. Capital costs were financed by the Recovery Program, funded through federal appropriations, Colorado River Storage Project hydropower revenues, and cash and in-kind contributions from non-federal entities. A grant from the Colorado Water Conservation Board to the GVWUA funds the increased annual operations and maintenance costs of the project [108]. GVWMP's initial goal was to save approximately 28,500 acre-feet of water per year to augment instream flows in the 15-mile reach. However, in practice the project has exceeded this goal and the average water savings over the 2002 to 2010 period of operation has been 36,463 acre-feet per year [108]. Another document reports the annual average of 49,900 acre-feet of water saving [107]. In spite of these water savings, the farming community still receives their entire titled allocation, while being reimbursed for operating the new infrastructure. The main concern about this plan is that Colorado water law does not support protecting conserved water for instream flow purposes, but since there is no other diversion in that reach, others may not be able to use that water. However, to secure the saved water in the future, legal protection might be required [108].

4.3.2. Orchard Mesa Irrigation District Canal System Improvement Project

In order to increase the reliability of water supply in the Orchard Mesa Irrigation District (OMID) Division of the Grand Valley Project, the Bureau of Reclamation proposed to construct system improvements in OMID on behalf of the Upper Colorado River Basin Endangered Fish Recovery Program. This project, which was proposed in 2013, was in response to the U.S. Fish and Wildlife Service identification of the need for additional flows within the 15-Mile Reach and the Recovery Program identification of the proposed project as a source to contribute additional flows. The 15-mile reach starts from the Grand Valley Irrigation Company Diversion Dam near Palisade to the Colorado River confluence with the Gunnison River (River Mile 171 to 185). The project is expected to be fully operational in 2016 and it is estimated that it will result in 17,000 acre-feet saving in irrigation water. In addition, the project reduces pumping by 28,000 acre-feet annually, which would reduce energy demand for pumping. Water saved through the system improvements will be used to augment and restore instream flows and to assist in recovery of four endangered fishes. The water will then be redirected to the Grand Valley Power Plant to increase hydropower generation. The system improvement will also reduce agricultural, municipal, and industrial water shortages. Proposed improvements include: construction of a new 80-100 acre-foot regulating reservoir, improved water level control, installation of a SCADA System, increased pump capacity, construction of interties between two canals to balance flows in the irrigation

system, reduction of canal and lateral seepage by lining and piping, and improved operations [109]. The project is being implemented with a budget of \$16.5 million. Construction of check structures was completed in 2014, and the regulating reservoir is estimated to be complete in 2015 [47].

4.3.3. Montezuma Valley Irrigation Company Water Leasing Proposal

In 2011, the board of directors of Montezuma Valley Irrigation Company, which supplies water to a large area around Cortez and Dolores, proposed to its shareholders the concept of leasing water on a short-term, trial basis, to the Colorado Water Conservation Board to augment flows downstream of McPhee Dam. This was conceptualized as a win-win situation because the flow would enhance downstream fish habitat desired by environmental groups, while the lease proceeds could be used by the Montezuma Valley Irrigation Company to fund enhancement of the irrigation system in order to mitigate water shortage problems. Private interests, conservation organizations and other nongovernmental sources were to provide the funds for the lease [110]. Based on this proposal, up to 6,000 acre-feet of water would be supplied in three out of 10 years, to be released from McPhee [110]. Later, this was narrowed down to three out of five years. The water conservation board could use the water for a maximum of 120 days during the irrigation season (typically May 15 to Oct. 15) [111]. The MVIC board of directors, in addition to wanting to use the lease proceeds for infrastructure improvements, saw their proposal as a proactive step toward securing their water rights, given concerns about potential future endangered species issues. The region is a habitat to some sensitive fish species and the board believed that if these species get listed as threatened or endangered, the region's water managers would potentially lose control of the river, which would threaten irrigation water supply. After many meetings, the board's proposal was voted down by its shareholders in 2012. It was not clear to shareholders who currently are not getting as much water as they desire how leasing water could in the long run provide them that water by improving the delivery system. Further, many shareholders believed that leasing water for environmental purposes might lead later to environmental groups demanding that water without compensation, if it could be shown the farmers did not need it.

4.3.4. Relief Ditch Diversion Modification

Trout Unlimited approached irrigators who divert water within the Gunnison Gorge National Conservation Area, Colorado, to build trust and explore ways to: develop a sustainable diversion structure that provides a better management of irrigation water to the Relief Ditch, enhances the riparian environment while reducing erosion, reduces fish entrainment, removes a barrier to fish movement, and creates safe boater passage and fishing access [112]. The Relief Ditch Diversion Modification Project replaces a pushup dam on the Gunnison River with a permanent diversion, installs a modern head gate on the ditch, and rehabilitates the eroded riverbanks at the diversion point [113]. It will also move the diversion point upstream by 250 feet and remove railroad rails that were driven into the river bed [114]. The modifications seem necessary due to concerns about erosion and riparian degradation, native fish populations, fish entrainment, poor water control, fish passage barrier, and boater hazard. Total project costs were estimated to exceed \$900,000 [115]. Trout Unlimited funded \$737,190 through a variety of funds, including, CWCB Species Conservation Trust Fund [116].

5. NEVADA

5.1. Programs and Regulations

5.1.1. Lower Colorado River Basin Intentionally Created Surplus Forbearance Agreement

Based on the Law of the River, once the tributaries water became commingled in Lake Mead, it no longer was Nevada's water. The Intentionally Created Surplus (ICS) Forbearance Agreement, initiated in 2007, is an agreement among Southern Nevada Water Authority (SNWA), the Secretary of the Interior, and some lower basin water users who agreed to allow the SNWA to convey its formerly called "in-state water" to the Colorado River and receive credits [117]. The lower basin entities that signed the agreement include: Arizona Department of Water Resources, Palo Verde Irrigation District, Imperial Irrigation District, City of Needles, Coachella Valley Water District, The Metropolitan Water District of Southern California, and the Colorado River Commission of Nevada [118]. If the created water is not used in the same year, it is converted to extraordinary conservation ICS credits. SNWA can create up to 300,000 acre feet of credits in Lake Mead for future use, like a bank account [119]. SNWA has three types of ICS projects: tributary conservation, groundwater imported, and system efficiency. For the tributary conservation ICS, SNWA conveys water from the Muddy and Virgin Rivers to Lake Mead and receives over 30,000 acre-feet per year of consumptive use rights. The water authority also has purchased the permits to use up to 15,000 acre-feet per year of the Coyote Spring Valley water to develop groundwater imported ICS. Through system efficiency ICS, SNWA will receive at least 400,000 acre-feet at a maximum rate of 40,000 acre-feet per year beginning in 2011. In addition, Extraordinary Conservation allows water users to implement a water conservation project, such as land fallowing or canal lining and save it in Lake Mead. This form of ICS is not available during declared shortages [119].

5.1.2. The SNWA Water Resources Portfolio

In its 2009 Water Resource Plan, the Southern Nevada Water Authority (SNWA) has employed a portfolio approach to evaluate its overall resource options and make appropriate decisions about its water supplies. The Plan's current and future resources portfolio includes conservation, Colorado River water, groundwater resources and augmentation. It prioritizes these resources considering their reliability, availability, accessibility, cost and need. In developing this diversified portfolio, the SNWA has considered the fact that it has a right to Nevada's unused Colorado River water as part of its 1992 Colorado River water contract. In addition to supplying their demands through Nevada basic apportionment, unused apportionment, and return-flow credits, SNWA uses the following mechanisms: flood control surplus, domestic surplus, intentionally created surplus, and banked resources. SNWA purchases or leases water from individual shareholders of irrigation companies and pays for the irrigation companies' assessment studies, which contributes to the companies' long-term stability. They believe partnerships with agricultural users can be beneficial without impacts to food production, and can prevent future conflicts [120].

6. NEW MEXICO

6.1. Original Water Resources Development Projects

6.1.1. New Mexico's Gila River Diversion Project Proposal

Based on the 2004 Arizona Water Settlement Act (AWSA), New Mexico has the right to develop 14,000 acre-feet of the Gila River's water. The AWSA gave New Mexico \$66 million in federal funding to enhance the water supply in southwestern parts of the state. For over a decade, the New Mexico Interstate Stream Commission (ISC) has been seeking a practical way to take advantage of this federal funding. The commission considered 15 different proposals [121]. Despite multiple controversies, in November 2014, the ISC voted on a large-scale proposal to divert the water from the last remaining stretch of the Gila River [122]. In June 2015, the Commission also approved a joint powers agreement crucial to moving forward with this project in southwest New Mexico [123]. On Nov. 23, 2015, the Interior Secretary, Sally Jewell, signed an agreement with New Mexico water managers to run a federal environmental review, which requires another round of extensive studies before the 2019 deadline, when the project must be approved or rejected by the government [121].

According to some preliminary benefit and cost estimates of diversion and non-diversion projects, conducted by Bureau of Reclamation, the costs of the diversion proposals are greater than the benefits, and a number of threatened and endangered species and cultural resources could also potentially be impacted [124]. Estimated capital costs of the Gila River diversion project are \$350 to \$450 (several times higher than the federal subsidy). These costs still exclude the costs of terminal storage, distribution, and water treatment, costs of infrastructure to access water from Sycamore Canyon, the annual exchange costs to be paid to Arizona for using Gila River water in New Mexico, and about 6,140 acre-feet per year of evaporation that would have to be paid for [124]. Other concerns cited by opponents include [125]: 1) There is no need for Gila River water since even the future water demands in the area could be met through agricultural and municipal water conservation as well as sustainable use of groundwater. 2) Gila River water is expensive as New Mexico must pay the Central Arizona Project to replace Gila River Indian Community water that it diverts; exchange costs are \$1.65 million/year in 2010 and rise annually; and the state should pay for operation and maintenance costs that are not covered by the AWSA (estimated at \$6.6 million/year).

6.2. Programs and Regulations

6.2.1. San Juan River Settlement Agreement

After over 20 years of efforts to adjudicate the Navajo Nation's water rights, on April 19, 2005, the State of New Mexico and the Navajo Nation signed a settlement agreement to adjudicate these rights and provide necessary water development projects for the Navajo Nation in exchange for a release of enough water to avoid displacement of non-Navajo water users in the basin that would affect the local economy [126]. Settlement Agreement was executed on December 17, 2010, and final decrees were entered on November 1, 2013 [127]. Under the Settlement Agreement, Navajo Nation's water right for irrigation and domestic water use, with the priority date of June 1, 1868, is 56% of New Mexico's Compact apportionment [128]. This equals to an annual average diversion of 508,000 acre-feet or the amount of water required to supply an annual average depletion of 270,000 acre-feet from the San Juan River at Navajo Reservoir, whichever is less [129]. In addition to the water rights, the settlement agreement

specified that: If there is enough water available without impairment to water rights in New Mexico, the Navajo Nation may divert supplemental water; Subject to no impairment of other water rights, additional ground water development and forbearance of surface water rights can be implemented on Navajo lands; Navajo Nation would have a small quantity of rights it has acquired under state law and would have additional rights to de minimus residential domestic and stock uses; Navajo Nation would also have a contractual right to store water in Ridges Basin Reservoir for supplying Nation's demands and may reuse tail water or wastewater so long as the Nation's diversion and depletion rights are not exceeded [128].

6.3. Operations Enhancement/Water Use Change

6.3.1. Sunset Canal Improvement Project

Sunset Canal Company proposed the Sunset Canal Improvement Project to enhance approximately 11 miles of the New Mexico section of the Sunset Canal, which diverts the Gila River water to irrigated croplands within the Virden Valley. This diversion serves 2,236 acres in New Mexico and another 316 acres in Arizona. Sunset Canal Company is planning to install a water transmission pipeline within the existing canal and place sealed valves and water meters for individual users. The cost of this project has been estimated to be about \$18 million. The canal improvement proposal has been developed due to long-term concerns about the maintenance, slopes stability, sediment capture below steep slopes, and water loss through infiltration, evaporation, and plant uptake in the open unlined canal in current condition. It has been estimated that the water loss through canal seepage is about 20%, which is expected to be conserved by the canal improvement project [130].

7. UTAH

7.1. Original Water Resources Development Projects

7.1.1. Lake Powell Pipeline Proposal, Utah

Washington County Water Conservancy District, which supplies water to St. George City in southwest Utah, proposed building a pipeline to bring Colorado River water from Lake Powell to Washington and Kane counties. The Lake Powell Pipeline Development Act, passed by the Utah State Legislature in 2006, authorized the Board of Water Resources to build the Lake Powell Pipeline [131]. Through this pipeline system, water will be pumped underground about 138 miles from Lake Powell to Sand Hollow Reservoir in Hurricane [132]. At full development, the pipeline will deliver up to 82,000 acre-feet per year to Washington County Water Conservancy District and 4,000 acre-feet per year to Kane County Water Conservancy District [131]. In the absence of the pipeline, this Utah share of Colorado River water is currently flowing down to the Lower Colorado River Basin states [133]. The Division of Water Resources' 2008 cost estimate for the entire project was \$1.006 billion [134]. However, newer cost estimates range from \$1.4 to \$2.4 billion [135]. The entire repayment of this project is to be provided by the taxpayers of Washington and Kane Counties.

Washington County, with the current population of approximately 150,000, is forecasted to grow to nearly 200,000 by year 2020, and up to 580,000 in the next 50 years [136]. Despite the high population growth rate, Washington County's St. George City, located in the driest county in the second driest state

in the country, has the highest per capita water consumption rate for desert cities in the U.S. (335 gallon per capita per day) [137]. The Lake Powell Pipeline project has been proposed to address water demands of increasing population in the region. However, critics believe that the initial study was conducted prior to the Great Recession and incorporated an excessive rate of growth, outdated and high water use rates, and unreasonably low water conservation expectations to justify the need for the Pipeline. In addition, critics believe effects of the long-term drought and rising temperature levels in the West have not been considered. [138]. They believe project costs, initially estimated at \$250 million and now exceeding \$2 billion, will be imposed on the region's small communities. And they say it has not been clarified how the Water District will pay the multimillion dollar annual bond payments. Utah economists' new studies show that water revenue would need to increase 370%, which might require a drastic, ten-fold increase in impact fees [133].

7.1.2. Central Utah Project

The Bureau of Reclamation was authorized to plan and construct the Central Utah Project, the largest water resources development program in Utah, on April 11, 1956, under the Colorado River Storage Act. To facilitate the planning and construction, the project was divided into six separate units, Vernal, Bonneville, Jensen, Upalco (authorized by the 1956 Act), as well as Uintah (authorized by a subsequent 1968 Act) and Ute Indian Units de-authorized in the Reclamation Projects Authorization and Adjustment Act (CUPCA) of 1992, Public Law 102-575 [139]. Construction began in 1966 and continued until 1992 [140]. Main reasons for very slow progress in construction process include: complex environmental analyses; the complexity of the project; and inadequate and sporadic Federal funding. To speed up the construction process, state and local officials asked Congress to empower the Central Utah Water Conservancy District (CUWCD) to complete the planning and construction of the Bonneville Unit, which was the remaining portion of the Central Utah Project. In response, Congress enacted CUPCA in October 30, 1992. This was for the first time in history that Congress designated a local entity (the CUWCD) as the planning and construction entity for a major Federal water project.

The largest unit is the Bonneville Unit, located on both sides of the Wasatch Mountains in central and northeastern Utah. This unit expands in both Uinta Basin (a segment of the Colorado River Basin on the east side) and Bonneville Basin (a segment of the Great Basin on the west side). All other units are located in the Uinta Basin [139]. The project supplies 62,000 acre feet of water per year for irrigation to over 30,000 acres agricultural lands and 94,750 acre feet per year for municipal and industrial purposes, meeting water demands of about 400,000 people [140]. The municipal share includes diversion of 20,000 acre-feet per year to the Metropolitan Water District of Salt Lake City, which was approved on May 16, 1986, and began in 2005 in 4,000 acre-foot increments over a 5-year period. [141]. The project has made it possible for Utah to divert a portion of its allotted share of the Colorado River water to 10 counties (originally 12 counties before Millard and Sevier Counties were withdrawn from the Central Utah Water Conservancy District) [139]. To make the CUP affordable, it was designed to be built as a multi-use project and costs were allocated among all of them. The project's reimbursable water uses are municipal, industrial, agricultural; and non-reimbursable uses are recreation, fish and wildlife, flood control, etc. This cost allocation strategy reduced the overall cost of the project to the district petitioners of water and taxpayers [141].

7.1.3. San Juan County Utah Multiple Use Project

San Juan County Water Conservancy District worked with the City of Blanding and Blue Mountain Irrigation Company to build a reservoir above Monticello in San Juan County, southeast Utah. This reservoir has made 25,000 acre-feet of Colorado River water available to San Juan Water Conservancy District through the law of the river. Farmers who used to irrigate their lands by snow pack and ditches changed their water right into a storage right so they could use it for sprinkler irrigation. The sprinkler system is much more efficient (65% compared to 30% with flood). They also have more flexibility on the timing of irrigation. If the irrigators wanted to use ground water, they would have to pump it from 2000-foot deep wells, which would have been too expensive. The Utah Division of Water Resources provided some of the funding for the project through loans with zero percent interest. If the project was to only supply agriculture, it could not have been approved. Participation of municipal partners helped it happen. They also involved Fish and Wildlife for recreation and 500 acre-feet should be saved for a conservation pool for fishing.

7.2. Programs and Regulations

7.2.1. Uinta Basin Salinity Control Project

The Bureau of Reclamation began implementing salinity control projects in the Uinta Basin in 1986. However, Natural Resources Conservation Service (Soil Conservation Service at the time) had started on-farm improvements in 1981 under its Agriculture Conservation Program. Based on hydrosalinity studies, the Uinta Basin's estimated salinity load transferred to the Colorado River is approximately 500,000 tons per year, including 328,120 tons from agricultural practices. The salt load from agricultural practices comes from both on-farm practices, 208,120 tons per year, and off-farm practices, 120,000 per year. Key accomplishments of the Uinta Basin Salinity Control Program include: treatment of nearly 653 miles of canal and laterals out of 1,761 miles and enhanced irrigation methods on about 126,600 acres out of 211,600 total irrigable acres [142]. Through NRCS on-farm efficiency improvements, the average irrigation efficiency in the Uinta Basin has improved by 30% (from 30% to 60%), mostly due to sprinkler systems. Additionally, by 1990, local farmers had benefited from approximately \$23 million in irrigation equipment and \$8 million in technical assistance. Through 2005, NRCS spent about \$67 million in the Uinta Basin. Farmers were required to share 30% of costs [143]. In February 2014, URS performed "Comprehensive Planning Studies for Salinity Control Measures in the Upper Colorado River Basin" for the Bureau of Reclamation. To evaluate the performance of the program they administered a survey to the farmers. Based on the responses, multiple farmers expressed appreciation for the ease of completing on-farm treatments; the majority of them quickly noticed increased yields following on-farm efficiency enhancements; and some reported decreases in operating cost, depending on the type of irrigation system installed. In addition, irrigation efficiency improvement practices are thought to increase drought resiliency [142].

7.2.2. Ferron Salinity Project

After eight years from the beginning of its construction, the Ferron Salinity Project was completed in 2006, as a result of collaboration among USDA-Natural Resources Conservation Service, the Bureau of Reclamation, Ferron Canal and Reservoir Company, as well as national, state and local partners [144]. The goal was salinity improvements through more efficient conveyance and irrigation methods. The

Salinity Irrigation Environmental Quality Improvement Project (EQIP) saves an estimated annual 47,000 tons of salt from entering the Colorado River [145]. Salt accumulation has been decreased by reducing deep percolation, eliminating canal and ditch seepage, and installation of pressurized sprinkler systems [146]. The Bureau of Reclamation funded enhancement of the delivery system. The on-farm irrigation systems were developed through EQIP and state parallel funding. The project includes 175 miles of pipe fed by two laterals from Millsite Reservoir and three regulating ponds [145]. Approximately 10,000 acres of alfalfa, row crops and pastureland have been equipped with pressurized sprinkler irrigation systems [147]. This has increased the overall irrigation efficiency from about 30% to 67% [146]. Additionally, the more efficient conveyance and irrigation systems have extended the irrigation season into the fall and increased productivity by about 1-2 tons per acre in the form of a third cutting for producers [147]. The Ferron project has benefitted the entire community by providing more water for the city and residents [144]. One of the most interesting aspects of this project is that it has 100% of the producers' participation [147]. The project cost was about \$20 million and annual costs are imposed by annual loan repayments and maintenance [47].

7.3. Operations Enhancement/Water Use Change

7.3.1. The Confluence Nature Park Project

The Virgin River Land Preservation Association (VRLPA) in partnership with a variety of entities, including the Washington County Water Conservancy District and the state of Utah, converted agricultural lands in the Virgin River Valley of southwest Utah that was targeted for development, into a 350-acre county park and nature reserve. The Confluence Nature Park, located immediately downstream of a major water diversion and the mineral Pah Tempe Hot Springs discharge, helps restore streamflow, while diluting and cooling the Virgin River to improve the chances of survival for several at-risk fish species. The region has recently experienced rapid urban growth mostly onto farmlands. The project was created on three properties, retaining irrigated fields, ponds and water rights. The VRLPA initiated negotiations with the three landowners. After they came to consensus with one landowner, the other two agreed to proceed with the deal. The Trust for Public Land also helped negotiate and close the initial deal. The \$5 million of this project was provided by a variety of sources, including the state, private donors, the federal government, the Washington County Water Conservancy District and the Conservation Fund [44].

8. WYOMING

8.1. Original Water Resources Development Projects

8.1.1. High Savery Dam and Reservoir: Improving Agriculture and the Environment

The High Savery Dam and Reservoir's construction was authorized by Wyoming Legislature in 1984 in order to mitigate the impacts of Wyoming's only large transbasin diversion, which removed 21,000 acre-feet from the basin. The reservoir, with a capacity of 23,000 acre-feet, was built on the Savery Creek, a tributary to the Little Snake River in the Green River drainage in south central Wyoming and northwest Colorado. The success of this project was due to a broad coalition among the agricultural community, wildlife and conservation organizations, and government entities at local, state, and federal levels. The

mitigation started in the early 1980s and took over 20 years to permit and build. Construction funds were leveraged from a variety of sources, including the US Department of Interior, Natural Resource Conservation Service, Wyoming Wildlife & Natural Resources Trust Fund, US Fish and Wildlife Service-PFW, and Wyoming Water Development Commission. The reservoir has a multiple level outlet system designed to maintain downstream temperature for fisheries. They have also constructed barriers against non-native fish moving upstream. In order to get the project permit, they had to mitigate wetland and stream channel impacts and enhanced environmental attributes along the river corridor to maximize the benefits of the stored water. The reservoir provides late season irrigation water for ranchers, while creating a fishery and recreation. Project proponents believe that water storage increases flexibility in a community to support local fisheries, improve agricultural irrigation, and creates a buffer against energy and municipal water demands. They also believe identifying mutual values and benefit help a project's success through increased collaborations [40].

8.2. Programs and Regulations

8.2.1. Wyoming Watershed Management and Rehabilitation Plan

Wyoming Water Development Commission (WWDC) funds irrigation improvements for ditch companies with severance tax dollars. Before such funds are granted, watershed planning must be in place. In order to promote this watershed-based planning, WWDC has developed a Watershed Management and Rehabilitation Plan for the state. Based on their plan, watershed description and inventory studies shall include: 1) Land uses and management activities (such as agricultural, urban, suburban, exurban, cultural resources, and wildlife as well as human influences including grazing, mining, oil and gas production, etc.); 2) Surface and subsurface geology; 3) Estimations of hydrology of the watershed; 4) Evaluation of channel structure, morphology, and stability of stream systems; 5) Description of irrigation systems within the watershed including identification of issues with water supply, erosion, conveyance losses, seepage, and recommendations for upgrades, modifications, operational improvements, and efficient technologies; 6) Description of water and air quality within the watershed; 7) Evaluation of water storage and flood control demands and opportunities within the watershed; 8) Evaluation of stream gauge coverage and period of record within the watershed along with recommendations for supplemental temporary gauging sites and data collection. In general, the plan shall identify required land and management methods; address irrigation supply systems and recommend upgrades, modifications, operational improvements and efficiency management techniques; identify upland water development opportunities; specify the interrelationships between water management, irrigation rehabilitation opportunities, and overall health of the watershed.

8.3. Operations Enhancement/Water Use Change

8.3.1. Using Coalbed Methane Produced Water

A proposal has been made in south-central Wyoming to treat produced water from coal bed methane mines in the region and discharge it into the streams or make it available for irrigation. It has been estimated that if approved, this practice can provide an additional 3,500 acre-feet of water per year. Produced water is a byproduct of the process of developing, extracting, or disposing energy-related products. It is produced in large volumes during the extraction of hydrocarbon energy resources, such as coal. To produce coal bed methane, an increasingly important source of energy in the U.S., coal beds are

de-watered and the produced water is either discharged into surface waters or re-injected back into the ground [148]. Treating and using produced water for other purposes not only may reduce energy companies' costs associated with re-injecting it into the ground (as the benefit from selling that water covers treatment costs), it also diminishes environmental concerns, augments streamflow, and secure agricultural water supply. Some legislative activity shows interest in utilizing such technology. For instance, the More Water, More Energy, and Less Waste Act of 2007 was introduced to the U.S. House of Representatives "to facilitate the use of water produced in connection with development of energy resources for irrigation and other beneficial uses in ways that will not adversely affect water quality or the environment [149]." The bill directs the Secretary of the Interior, acting through the Commissioner of Reclamation, the Director of the U.S. Geological Survey, and the Director of the Bureau of Land Management (BLM), to conduct research to identify the obstacles to decrease the volume of produced water and the actions that help reduce or eliminate such obstacles along with the associated costs and benefits. [150]. Although it appears to be a win-win situation, proponents believe that energy companies have been hesitant to make any change in their current activities due to concerns about the Bureau of Land Management's bureaucratic system.

9. MULTI-STATE PROJECTS WITHIN THE COLORADO RIVER BASIN

9.1. Original Water Resources Development Projects

9.1.1. Animas – La Plata Project

The Animas-La Plata (A-LP) Project was authorized by the Colorado River Basin Project Act of September 30, 1968 (Public Law 84-485) [151]. The primary purpose of the project was originally to provide irrigation water, which was later changed to municipal and industrial water supply. The project is located in La Plata and Montezuma Counties in southwestern Colorado and in San Juan County in northwestern New Mexico. The original A-LP project consisted of three reservoirs, Howardsville, Hay Gulch, and Meadows Reservoirs, and 48 miles of canals and tunnels to deliver water from the Animas Basin to the La Plata Basin, for irrigation purposes [152]. However, U.S. Fish and Wildlife Services issued an endangerment finding for the original project, and said only about 50,000 acre-feet could be diverted to protect the endangered fish. Hence the project was totally re-envisioned. On September 30, 1986 through the signing of the Colorado River Basin Act, Congress officially authorized the construction of the Animas-La Plata Project. In December 1986, two Indian tribes, the Ute Mountain Ute and Southern Ute tribes, became a part of A-LP by signing the Colorado Ute Indian Water Rights Final Settlement Agreement. Based on this agreement, the Utes gave up their claims in the San Juan River Basin in exchange for water in A-LP and \$60 million in development funds [152]. This agreement modified the A-LP Project from an irrigation project of 191,200 acre-feet per year of depletion to an exclusively municipal and industrial water supply project of 57,100 acre-feet per year of depletion [153]. Entities involved in the 1986 Agreement include: United States, the State of Colorado, the Ute Mountain Tribe, the Southern Ute Indian Tribe, the Colorado Water Resources and Power Development Authority, the Animas-La Plata Water Conservancy District, the New Mexico Interstate Stream Commission, the San Juan Water Commission, and Montezuma County, Colorado. The A-LP Project created Lake Nighthorse near Durango, Colorado, with an annual storage capacity of 120,000 acre-feet. In 2000, the 1986 Ute Settlement Act was amended by the U.S. Congress to authorize the final configuration, cost sharing, and financing of the A-LP. The United States Department of Interior funded the A-LP Project through the Bureau of Reclamation. The 2000 amendment also addresses non-Tribal municipal and industrial water capital repayment obligations for the A-LP Project [153]. The Colorado project features were transferred

from construction status to operation and maintenance status in March 2013. Work on completion of the transfer stipulations is continuing [151].

9.2. Programs and Regulations

9.2.1. The San Juan River Basin Recovery Implementation Program

The San Juan River Basin Recovery Implementation Program (SJ RIP) was initiated in November 1992 after the governor of the State of New Mexico signed a “Cooperative Agreement.” The signing of this agreement followed the discovery of two endangered fishes, Colorado Pikeminnow and Razorback Sucker, in the San Juan River. The San Juan River Basin is the second largest subbasin of the Upper Colorado River Basin, which covers southwest Colorado, southeast Utah, northwest New Mexico, and northeast Arizona. The original 1992 document was modified by the Coordination Committee in 2006, 2010, and 2012 [154]. This program which is a partnership among the Secretary of the Interior, the governors of the states of Colorado and New Mexico, the Navajo Nation, Jicarilla Apache Nation, Southern Ute Indian Tribe and Ute Mountain Ute Indian Tribe will be implemented through 2023. The main goals of the program are to conserve populations of the two endangered fishes, while proceeding with water development in the basin [155]. The need for this plan was realized due to the increasing water development impacts, such as: water depletion, water quality degradation, contaminants from irrigation return flows, increased sediment, and temperature changes [156]. Program elements include: managing and augmenting populations and protecting genetic integrity; protecting, managing, and augmenting habitat; managing nonnative species; monitoring and evaluating fish and habitat in support of recovery actions; as well as coordinating and assessing program’s progress toward recovery information and education [154]. The required flow for fish recovery is provided by adjustments in Navajo Reservoir’s operations as: 1. Peak release rate of 5,000 cfs during the spring months; 2. Minimum release rate of 250 cfs during the summer, fall and winter months; 3. Spike releases of excess storage water from storm runoff in Navajo Reservoir during the summer, fall and winter months [157].

9.2.2. Colorado River System Conservation Program

The four largest cities that obtain a portion of their drinking water from the Colorado River (Denver, Las Vegas, Phoenix, and Los Angeles) came up with an innovative idea to pilot a conservation fund for two years, as of 2014, to pay volunteer farmers, industries and municipalities to reduce their use of Colorado River water. The water can be saved through practices such as fallowing farm fields, installing more efficient irrigation systems, recycling industrial supplies, etc. Each city will contribute \$2 million and the Bureau of Reclamation will fund \$3 million, totaling \$11 million. Upon termination of the two year pilot program, if its success is proven, the four cities will expand the funding and invest in more water-saving projects [158]. The Colorado River System Conservation Program’s main goal is to maintain the levels of Lake Mead and Lake Powell high enough to delay or avoid the declaration of a water shortage and call on the river [158]. This program has been set up for emergency short-term drought mitigation and would be terminated if Colorado River flows increase to levels that can sustain Lake Powell [159].

The move was initiated following predictions of federal forecasters addressing a potential decline of over 30 feet in Lake Mead [160]. As the four cities get a portion of their water supply from the Colorado River, a water shortage in the river would threaten the reliability and security of their water supply. Las Vegas gets approximately 90% of its water from Lake Mead and is most at risk. In mid-April, 2014, the

lake's level was only 48 feet above the city's uppermost intake pipe, with projections that there is a 50% chance that Lake Mead could drop to "dead pool" by 2036. Phoenix receives nearly 47% of its water from the Colorado River, and the Central Arizona Project, which delivers Colorado River water to Phoenix and Tucson, could see reductions of up to 11.4% in its annual allocation [158].

Program's participants can legally sign a water contract, but the program does not clarify what happens if these deals affect other water users who are not involved in the agreement. Critics of the program say it does not account for some current issues such as climate change and shifts in water demand from agriculture to municipal use. They believe that current law does not give farmers the flexibility to save water without losing their water rights. Additionally, a lack of incentives prevents farmers from water saving [159].

9.2.3. Upper Colorado River Endangered Fish Recovery Program

The Upper Colorado River Endangered Fish Recovery Program (Recovery Program) was initiated in 1988 to revive four species of endangered fish: Humpback Chub, Bonytail, Colorado Pikeminnow, and Razorback Sucker. The program was started following the signing of a cooperative agreement among the Governors of Colorado, Utah, and Wyoming; the Secretary of the Interior; and the Administrator of Western Area Power Administration. In 2001, these parties extended the agreement to September 30, 2013 [161]. The Upper Colorado River Basin is home to 14 native fish species, including the four endangered species, which are found only in the Colorado River system [162]. Through the Recovery Program, which is a unique partnership of local, state, and federal agencies, water and power interests, American Indian tribes, local landowners and environmental groups, the efforts for revival of endangered species are undertaken while water use and development proceeds to meet human demands in compliance with interstate compacts and applicable federal and state laws [161]. The program has seven elements to achieve recovery of the fishes: instream flow identification and protection; habitat restoration; nonnative fish management; propagation and stocking; research and monitoring; information and education; program management [163]. Habitat restoration is accomplished through construction and operation of fish passages at irrigation diversion dams; construction and operation of fish screens to prevent fish from being trapped in irrigation diversion canals; and acquisition, restoration, and management of floodplain habitat to serve as fish nursery areas [164]. This program has been characterized by its cost-effectiveness and collaborative on-the-ground achievements toward overcoming the challenges of water development and management, while recovering endangered fish species. It was recognized by the Department of the Interior with a Cooperative Conservation Award in 2008 [164].

9.2.4. Colorado River Basin Salinity Control Project

The construction, operation, and maintenance of projects to control the salt load delivered to Mexico, via the Colorado River, were authorized the Colorado River Basin Salinity Control Act, Public Law 93-320, passed in 1974. In 1994, Public Law 98-569 amended the 1974 Salinity Control Act and authorized the Secretary of Interior to develop a comprehensive program for minimizing salt loads from lands administered by the Bureau of Land Management (BLM) through improved vegetation cover, better use of onsite precipitation, and stronger plant root systems [165]. The Act and its amendments also authorized the Secretary of Agriculture to enhance and protect the quality of the Colorado River water for use in the United States and the Republic of Mexico [166]. Prior to this program, the Colorado River carried an annual average salt load of about 9 million tons at Hoover Dam [167] imposing significant cost to agriculture, while harming municipal and household pipes and fixtures. These costs in the United States`

portion of the Colorado River Basin range between \$500 million and \$750 million per year and could exceed \$1.5 billion per year in the future in the absence of salinity control projects. Additionally, over \$100 million is expected to be imposed to the Republic of Mexico annually [165].

Title I of the Colorado River Basin Salinity Control Act provided the means to comply with the U.S. obligations to Mexico, addressed in the 1973 agreement between the two governments (Minute No. 242 of the International Boundary and Water Commission). This agreement provides that the United States shall ensure the annual water delivery of 1.36 million acre-feet to Mexico upstream of Morelos Dam with an average salinity of no more than 115 +30 parts per million above the annual average salinity of Colorado River water arriving at Imperial Dam (average annual differential of salinity above and below Imperial Dam). Title II authorized specific salinity control units upstream of Imperial Dam to meet the requirements of the Clean Water Act [165]. However, since the U.S. commitments have been set based on the average annual differential of salinity above and below Imperial Dam, the more salt is removed in the upstream, the more difficult it is to make the delivery to Mexico.

Reclamation and NRCS are mainly targeting to control the salinity at Imperial Dam, where irrigation induced salt loading is estimated to be about 37% of the salinity at Imperial Dam [100]. Reclamation, BLM, and NRCS plan to cost-effectively reduce salinity with a combined control target of 1.85 million tons per year by 2030. To date, they have been able to reduce Colorado River system's salt load by an estimated 1.295 million tons per year [165]. All the Basin States now benefit from the improved water quality. The benefit of salinity control has been estimated to be \$340 per ton in 1994 dollar values, as opposed to \$20 to \$100 per ton cost of salinity control [165].

9.3. Operations Enhancement/Water Use Change

9.3.1. Ute Mountain Ute Tribe Improved Irrigation Water Technology and Management

The Ute Mountain Ute Tribe Farm & Ranch Enterprises (UMUTFRE) proposed a project to the Bureau of Reclamation to conserve water using Supervisory Control and Data Acquisition (SCADA) technology and improved irrigation water management. The project was awarded in September 2010 and since completion, it has saved approximately 1,327 acre-feet of water annually [168]. The UMUTFRE is located in a 7,700+ acre agricultural project in Ute Mountain Ute Tribe Land, southwest Colorado. The project contains 109 center pivot sprinklers, which are supplied with water from the McPhee Reservoir via 40 miles of open canal and siphon pipe [169]. Conserved water is saved in the reservoir for other uses. In order to facilitate making precise decisions about the amount and timing of irrigation water, they have also installed automated irrigation management systems and soil moisture monitoring stations, integrated into a SCADA system [170]. Total project cost was approximately \$606,750 and Reclamation funded \$300,000 through WaterSMART Water and Energy Efficiency Grant [168].

10. PROJECTS OUTSIDE THE COLORADO RIVER BASIN

10.1. Programs and Regulations

10.1.1. Freshwater Trust

The Freshwater Trust is an Oregon-based organization that was created to maintain and restore biodiversity in rivers, while preserving agriculture. In collaboration with landowners and irrigation districts who own key water rights in the Pacific Northwest, the Freshwater Trust buys and leases water for instream flows. They receive approximately \$600,000 to \$1M dollars per year from the Bonneville Power Administration (BPA) as part of mitigation for BPA's storage projects in the Columbia River Basin. In one example, the Trust negotiate a "split year lease" with an Austin Ranch farmer. He agreed to terminate his irrigation season in the middle of July instead of September to meet mid-July water demand for fish. Proceeds from the leased water more than made up for the farmer's lost third cutting of hay, and because this was a split year lease, he still had the benefit of his first two cuttings—historically the most profitable ones. In another case in the upper Lostine River, the Trust sought opportunities to augment streamflow, but in that specific area, they had to deal with five irrigation ditch companies and more than 100 landowners. So, they signed a management agreement with the ditch companies to leave a certain amount of water in the river at specific times, while maintaining the water rights unchanged. The ditch companies took the responsibility to obtain the water such that the Trust did not need to contract with each irrigator individually. Additionally, since there was no need to modify rights, state regulation was not necessary, making the process much simpler [40].

10.1.2. Great Basin Land and Water

Great Basin Land and Water (GBLW), established as part of the 1996 Truckee River Water Quality Settlement, is a nonprofit organization which acquires water to enhance aquatic resources while accommodating growth. GBLW launched with the litigation settlement funds and then received congressional appropriation and federal grants. This organization buys water rights, occasionally along with the land associated with water rights, and converts the acquired water rights to instream flow rights, which are held by members of the partnership. GBLW's water right acquisition process is relatively fast as the acquisition is not practiced through conventional land or water trusts, which require time consuming negotiation and conservation easement processes. The organization uses dedicated sources of funding and retains an expert water lawyer to seek maximum conservation impact. Over the past 15 years, GBLW has completed more than 100 voluntary, market-based water rights transactions in the Great Basin. These transactions range from portions of a water right to more than 1,000 acre-feet of water rights on a permanent basis [171].

10.1.3. Lower Yuba River Accord

The framework of an agreement that was later named the Lower Yuba River Accord (Yuba Accord) was announced in 2005, by Trout Unlimited, the Bay Institute, California's Department of Fish and Wildlife, California Department of Water Resources, federal agencies, the Yuba County Water Agency, and irrigation districts [172]. The Yuba Accord was implemented as two one-year pilot programs in 2006 and 2007, and fully implemented in 2008 [173]. It provides significant benefits, including optimum flow requirements for salmon and steelhead, surface water supplies supporting the local agricultural economy,

as well as supplemental water supplies for cities, for farms and for the Bay-Delta and groundwater management [172]. The Yuba Accord has three main agreements: 1) To significantly augment instream flows for wild salmon and steelhead on the Lower Yuba River (by up to 170,000 acre-feet of additional water per year); 2) To assure on average 150,000 acre-feet per year water transfers to California's Natural Resources Agency for fish and wildlife, and to cities and farms supplied by the State Water Project and Central Valley Project; 3) To establish a series of conjunctive use agreements with seven local irrigation districts to actively manage both surface and groundwater resources and steward their water rights [40].

10.1.4. Arkansas Basin Roundtable's Template for Ag to Urban Water Transfer

The Arkansas Basin Roundtable is one of the basin groups established by the Colorado's Water in the 21st Century Act to assist the state in its water planning. The Roundtable formed a Water Transfer Guidelines Committee to determine, "If water is going to be transferred from agriculture, how can it be done without harming rural communities and other third parties to the transactions?" Since 1950, the basin has lost about 15% of its irrigated agriculture to urban water transfers and this rate has been projected to highly increase by 2030. After two years of facilitated meetings, the roundtable structured an ag to urban water transfer template with three focus areas: 1) What are the *considerations* to be addressed when contemplating a transfer? 2) What *questions* should be asked specific to each of those considerations? 3) What *mitigation* might be needed? Considerations could be based on effects on water quality, or the size of a transfer relative to an affected area. An example of questions could be "Will the transfer reduce the tax base of the affected areas?" A sample of a mitigation strategy would be "Assist in agricultural modernization such as niche market development [40]." Though the template was adopted by the Roundtable, it was never formalized due to conflict over how it should be applied. Some believed it should be used only as a voluntary guideline for those considering transfers; others thought it would "not have teeth" unless enacted legislatively. A third opinion was that efforts should be made to make farming more profitable, to encourage farmers to keep water in agriculture rather than being tempted to sell or lease for non-agricultural purposes.

10.1.5. Super Ditch

While most conservancy districts were formed to develop water resources, the Lower Arkansas Valley Water Conservancy District (LAVWCD) was formed in 2002 to protect water resources. In 2006, LAVWCD hired an engineering firm and an economist to conduct a feasibility study for cooperative leasing as an alternative to permanent dry-up of agricultural land from sales of water to municipalities. The study identified seven lower Arkansas ditch companies. Representatives from these seven ditch companies took a demonstrative field trip to Palo Verde Irrigation District, California, to learn about their lease contract with the Metropolitan Water District. In 2007-2008, the steering committee, made up of shareholders of multiple ditch companies, was formed to determine feasibility of establishing a "Super Ditch," a company that would lease water, conserved by fallowing land, to municipalities instead of selling it outright. In May 2008, two-dozen shareholders from six of the seven ditches signed on as incorporators. They adopted articles of incorporation, bylaws, and the secretary of State certified the incorporation of the Lower Arkansas Valley Super Ditch Company and the first Board of Directors. Inspired by the Palo Verde Irrigation District, LAVWCD conceptualized that farmers will have greater bargaining power if they work together in a rotational fallowing scheme and convert part of their land from growing crops to providing water. This may help them keep their agricultural communities viable. The revenue would be distributed to shareholders through dividends to be used for farm improvements, debt reduction, new equipment, or capital for launching new agri-business endeavors. Breakthroughs of

this idea include: no one is committed to sign a lease; Board of Directors appoints a team to negotiate the lease; farmers need to get respective ditch company approval to sign a lease; and Super Ditch shareholders will be the only ones who sign leases [174].

In 2012, the Super Ditch submitted a lease-fallowing pilot project with Fountain and Security, which was denied due to insufficiency of water to move [175]. In mid-July 2014, the company filed another pilot program with the Colorado Water Conservation Board. This project is under 2013 legislation, HB1248, encouraging demonstration of viability of lease-fallowing projects as alternatives to permanent dry-up of farms. This pilot project, which will lease water from several farms on the Catlin Canal to the town of Fowler over the next 10 years, was approved in September 2014. Seven participating farms with 1,128 acres will be fallowed on a rotational basis for up to three out of the next years 10 and supply 500 acre-feet water per year to Fowler [176]. As the HB1248 only authorizes municipal leasing, if this pilot project proves to be successful, Super Ditch might study methods for industrial or agricultural leases as well [177]. Activity in the Colorado Legislature that will impact the Super Ditch and other rotational fallowing efforts continues.

10.1.6. Murray- Darling Basin - Australia

As Australia's food basket, Murray-Darling Basin provides approximately 40% of the country's agricultural production. The devastating millennium drought from 1997 to 2009 reduced river flows in the basin to 40-60% of average, leaving many farmers with no water allocations for three years [178] and causing disastrous ecological damage. To achieve the goal of reducing water use by a third, the government employed two mechanism: 1) buying water rights; 2) increasing the efficiency of irrigation distribution systems through the Sustainable Rural Water Use and Infrastructure Program, which provides eligible applicants up to \$350,000 to modernize their system [179]. At the beginning, the government mostly focused on buying water rights, and about one-third of the government funds have been directed towards buying water rights from willing sellers, who either chose to get out of farming or switch to growing crops with less water consumption. This highly affected the rural community and now the government has largely shifted to increase efficiency. Therefore, more than two-thirds of investments have been directed into a Sustainable Rural Water Use and Infrastructure Program. This program supports installation of more efficient irrigation technologies like drip irrigation, or infrastructure improvements such as concrete lining of earthen ditches; upgrade, replace or reconfigure assets; improve metering [179]. In comparison with buying water rights, improving efficiency requires two to seven times greater investments. Since 2002, the Australian Commonwealth government has allocated equal to U.S. \$14 billion to achieve their water saving goals and to date, they have achieved 70% of the targeted reductions in water use [178].

10.1.7. Yakima River Basin Integrated Water Resources Management Plan

In 2009, Washington's Department of Ecology convened a diverse work group to develop a proposal for management of the Yakima River Basin. The consensus-based Yakima River Basin Integrated Water Resources Management Plan (the Integrated Plan) was completed in 2011 as the first basin-wide plan in the nation to address management issues of a water-short basin. The plan was prompted due to scientists' prediction that the Yakima Basin, the nation's second-largest agricultural production region, will probably experience 20 significant droughts in the next 100 years, resulting in a total of \$3 billion loss only to the farmers, neglecting losses to related industries, which may add another \$3 billion. The Integrated Plan includes seven major elements, including: 1) Construction of fish passages at six reservoirs; 2)

Conservation of up to 170,000 acre-feet water; 3) Structural/Operational changes to raise Cle Elum Lake by three feet, increasing its capacity by 14,600 acre feet, and to construct a pipeline between two other lakes; 4) Habitat/Watershed improvement to protect 70,000 acres of forest and shrub steppe; 5) Increase surface water storage by approximately 550,000 acre-feet; 6) Implement pilot projects to evaluate aquifer recharge and increase groundwater storage; 7) Use mechanisms such as water market and/or water bank, and facilitate water transfers between districts [180].

10.1.8. Yakima Basin Water Transfers Working Group

The Yakima Basin Water Transfers Working Group was established in 2001 to facilitate the voluntary transfer of water in order to provide water for current and future demands, while preserving existing water rights. It is a group of professional water managers, engineers, hydrogeologists, fisheries biologists, irrigation districts, law firms. These individuals volunteer to review water transfer proposals and provide recommendations to the Department of Ecology and the Bureau of Reclamation, which both provide recommendations to the Superior Court for temporary transfers. This process was used to transfer 40,000 acre-feet water during a four-month period in 2001 and 50,000 acre-feet in two months in 2005 [40]. It is seen as enabling fast and flexible water marketing to respond to rapidly changing needs.

10.1.9. Elephant Butte Irrigation District / Audubon

The Elephant Butte Irrigation District (EBID) and environmental groups, such as New Mexico Audubon, reported in 2010 that they were developing an environmental water transaction program to allow Audubon buy water rights from EBID's willing sellers. This program was being developed due to concerns about the National Environmental Policy Act's preferred alternatives, which would reduce depletions from agriculture without acquiring agricultural water rights on one hand and was not far reaching enough for environmental purposes on the other hand. The two entities started collaboration on a range of water sharing strategies in order to come up with a better solution. The best solution they came up with is to conceptually consider irrigating for habitat, similar to irrigating for a crop. Audubon offered to become an EBID constituent, like a farmer and EBID agreed. Surface water transfers from one farmer to another within EBID do not need permits from the State Engineers Office. Based on their consensus, EBID has the authority to approve or deny the transfers and the shareholders will not lose any water-rights. Water rights that Audubon acquires may provide habitat for some species susceptible to being listed as threatened or endangered. However, many obstacles would have to be overcome to finalize this agreement. Audubon must find a secure source of funding for water transfers. Agriculture-environment in-district transfers have not previously been allowed within the US Bureau of Reclamation's Rio Grande Project. EBID needs assurance that threatened or endangered species will not get precedence over agriculture in dry years and the water shortages will be shared [40].

10.1.10. Cache County's Water Future

The Bear River Development Act was passed in 1991. The act authorized the Utah Division of Water Resources to develop water storage facilities to store the Bear River's excess water in Cache County, and avail it to other areas in the state. Utah's population has doubled in the last 30 years and it is projected that the population will increase from about 3 million people to 5.5 million by 2050. Therefore, it is important to store winter flows to be used during summers. Since agriculture currently uses 82% of

Utah's water, another controversial option for managing the state's water is to convert agricultural water use, which will partly happen as agricultural land is sold and developed. In addition, Utah has begun to conserve water through efforts such as the Slow the Flow campaign and these efforts have resulted in 18% reduction in the per capita water use from 2000 to 2010 [181].

10.2. Operations Enhancement/Water Use Change

10.2.1. West Side Irrigation District Urban to Ag Transfer

This is a case where given significant drought conditions in 2014, the City of Tracy, California, decided to transfer their treated wastewater to agricultural water users. Fallowed farmland in several Tracy area irrigation districts were being impacted by state-imposed water restrictions due to severe drought. Districts with pre-1914 and riparian water rights were unharmed but others, such as West Side Irrigation District (WSID), were being hit hard. The State Water Resources Control Board had ordered the district to stop pumping irrigation water from the Old River and only 30% of normal was being delivered to growers in the old Plain View area. That had forced WSID to leave 25% of its irrigable lands fallowed and to abandon another 35%. To help WSID mitigate drought effects, the City of Tracy agreed to transfer a daily average of 27 acre-feet of its treated wastewater to the irrigation district [182].

10.2.2. South San Joaquin Irrigation District's Pilot Pressure Irrigation Project

California's South San Joaquin Irrigation District (SSJID) board in partnership with Stantec Consulting developed a pilot pressure irrigation project and irrigation program to improve delivery efficiency and service. In the SSJID service area, 3,800 acres of California's Central Valley, the farmers used to pay a flat rate of \$24/acre for irrigation water. However, the Water Conservation Act had recently mandated the SSJID to bill water deliveries volumetrically. This encouraged the irrigation district to increase the efficiency of their irrigation system. Stantec Consulting developed a web-based interface entitled "The Division 9 Irrigation Information Center," supplied with tools such as national weather service alerts for the area, weather forecasts, Doppler radar imaging, customizable and exportable/printable charts on past weather (rainfall, wind, temperature, humidity, evapotranspiration rates), water deliveries (time start, time end, total hours irrigated, average flow rate and total water delivered), and moisture sensor information. Each farmer has been assigned a unique platform and they use this system to schedule the date and number of hours of irrigation desired. The project also consists of a 19-mile network of pipelines with flexible pressurization, a 56-acre-foot water storage basin, a 1,225-hp pumping station containing seven vertical turbine pumps capable of pumping a total of 52.4 cfs, and a total of 55 solar-powered Field Telemetry Units controlling 77 customer connections. The Division 9 system has reduced water needs by up to 30%. It reduced spills to the drains by 5,000 acre-feet (or 1.96 feet of water per acre) in the 2012 irrigation year. Additionally, the Division 9 pressure system has reduced the acreage pumping from aquifers by 50%, decreasing the cost of running pumps and reducing diesel emissions, which has enhanced air quality, and improving crop yields by up to 30% due to the high quality surface water supply [183].

10.2.3. Umatilla Groundwater Relief

Northeast Oregon Water Association (NOWA) was formed in August 2013 and proposed the Umatilla Groundwater Relief to divert water from Columbia River to agricultural lands in the Umatilla Basin, East Oregon, and to recharge aquifers in the basin. The project would provide additional water for irrigators while upstream projects would benefit fisheries and wildlife. It would also reduce reliance on groundwater resources. Working with the Oregon Water Resources Department and the Governor's office, NOWA is securing three new water rights to divert an additional 500 cubic feet per second from the Columbia River. It could supply water demands of up to 200,000 acres of farmland for full production. NOWA would administer the water rights, and supply the water to critical groundwater areas. For this diversion, NOWA is designing a pipeline, using existing river infrastructure. This pipeline would pump water into three critical groundwater areas during peak irrigation season in summer. They are also considering constructing a new storage reservoir. A combination of public and private funding from NOWA members, including more than 50 municipalities, ports and farms, would fund the pipeline [184].

10.2.4. Central Oregon Irrigation District Piping Project

The Central Oregon Irrigation District, an agricultural, industrial, and municipal water supplier, piped 2.5 miles of open ditch, which helped reduce diversions by 19.6 cfs in the Deschutes River Basin. The saved water augments instream flow. This project was a response to Oregon's Conserved Water Program, which in addition to promoting water conservation, maximizes beneficial use of water, and also requires that a minimum of 25% of conserved water should be used for instream augmentation. The pipe also includes a hydroelectric generator with the capacity of 5 megawatt. Several sources funded the \$24 million cost of the project, including: Deschutes River Conservancy, US Bureau of Reclamation, Oregon Water Enhancement Board, Oregon Department of Environmental Quality and Oregon Department of Energy [185].

10.2.5. Three Sisters Irrigation District piping project

Through a partnership among USDA-NRCS, Three Sisters Irrigation District (TSID), Oregon Watershed Enhancement Board (OWEB), Confederated Tribes and several other natural resource entities, a project was funded, designed and provided with operational support [186]. TSID administered the project, which converted 10.3 miles of unlined main canal, which lost 40-75% of its water to seepage and evaporation [186], to buried pipeline; installed four new automated fish screen weir gates; and setup a Supervisory Control and Data Acquisition (SCADA) system. It is expected that these enhancements save 2,550 acre-feet of water per year in the upper Deschutes [185]. The saved water is purchased by the Deschutes River Conservancy for a protected instream right to restore habitat in Whychus Creek for endangered steelhead and threatened bull trout and other fish species. TSID is also trying to switch from rill and wheel line sprinklers to center pivot sprinkler systems on 30 of its member farms. Financial support for the on-farm conservation efforts was provided by the NRCS's Agricultural Watershed Enhancement Program (AWEP) [185]. There is a 400-foot elevation difference between the reservoir and the lowest ranch, which creates natural pressure and eliminates demands to pump water. Therefore, water users will receive pressurized water, reducing pumping needs and associated energy costs [187]. Farmers will no longer need to incur electricity costs for irrigation pumping. Additionally, this pipeline will increase the value of the land, make it easier to rent the land, lower the cost of farming, and enable farmers to grow new and different crops. Farmers will also spend less time checking and cleaning screens on irrigation canal pumps [186].

10.2.6. Manastash Creek Implementation Plan

The restoration projects in Manastash Creek in the Yakima River Basin, central Washington, are implemented by the Manastash Creek Steering Committee, formed in 2001, with assistance from the Kittitas County Conservation District. In 2007, an implementation plan was created for a project to restore 3.25 miles in lower reaches of Manastash Creek. The restoration was planned due to the concerns regarding to the threat of an Endangered Species Act lawsuit. Before the implementation of this project, lower Manastash Creek dried out in late-spring, just after the beginning of irrigation season. Flow restoration which would allow the river to flow year-round would provide habitat for more than 50 spawning pairs of steelhead per year and up to 1,000 Coho salmon. The ultimate goal is to conserve 6 cfs. The Trout Unlimited Washington Water Project (originally the Washington Rivers Conservancy), Kittitas Conservation District, Washington Department of Ecology, Bonneville Power's Columbia Basin Water Transactions program, and USDA-NRCS funded the project. It includes converting open ditches to pipes, consolidating diversions, improved on-farm efficiency and purchasing instream flow rights on a willing seller basis [188].

10.2.7. North Fork Blackfoot River, Montana

Trout Unlimited funded a project to conserve 18.5 cfs water for instream flow enhancement through a 30-year lease and a change of purpose of use. The saved water augments streamflow in an important bull trout creek that once suffered from habitat problems in late summer and early fall. To conserve this water, a farmer replaced a leaky irrigation canal with pumps and pipes and installed center pivot irrigation system and a solar-powered stock watering well.

10.2.8. Barker Ranch, Lower Yakima River

In order to restore a wetland refuge that depends on irrigation water, Washington's Columbia River Water Management Program funded a canal piping project in the water-short lower Yakima River, Washington. The wetlands on Barker Ranch are habitats to at least 175 different species of birds and other terrestrial wildlife, such as coyotes, badgers, and deer. Depending on the month, the project conserves between 3.5-10 cfs, totaling 6,436 acre-feet per year [189].

10.2.9. Columbia Basin Project Irrigation Districts

Through piping and lining of open ditches 5,450 acre-feet of Columbia River water is saved. It is to be spread to a groundwater-dependent area in East, South, and Quincy districts of the Columbia River in Oregon and Washington. This area was running out of groundwater resources and had to rely on higher water diversions from the Columbia River, and it would otherwise need to convert to dryland farming. The conserved water will not increase instream flows. Instead, it is used for agriculture to reduce dependency on groundwater [189].

10.2.10.Sunnyside Canal Improvement Project

Through a settlement agreement in the Yakima Basin Water Rights Adjudication, Sunnyside Valley Irrigation District will make canal improvements in order to reduce its annual diversion. Two thirds of this water savings, 19,450 acre-feet per year, will benefit instream flows. The remaining water savings, 9,712 acre-feet per year, will be used for irrigation purposes. The agreement is among the Bureau of Reclamation, the Washington Department of Ecology (WDOE), the Yakama Nation, and the Sunnyside Division Board of Control (SDBOC). Sunnyside Valley Irrigation District is the operating entity for SDBOC. Reclamation funds 65% of total project costs with WDOE and SDBOC each financially support 17.5% [108]. Some of the major components of this project include: replacement of 30 existing check drop structures with automated gates to maintain a consistent water elevation in the canal; installment of a Supervisory Control and Data Acquisition system; construction of three re-regulation reservoirs [190].

10.2.11.SCADA & Water Measurement Project - Lower Yellowstone

The Lower Yellowstone Irrigation Project Board of Control in Montana will create SCADA communications with 17 key sites along the Lower Yellowstone Irrigation Project's 330-mile distribution system. This is accomplished by installing or enhancing water control structures, such as spillway structures, pumping stations, and monitoring stations. They will also install a new diversion structure equipped with fish screens. These improvements are expected to reduce the diversions from the Yellowstone River by 40,000 acre-feet per year and the saved water will remain in the river. Bureau of Reclamation has funded 50% of the project's total costs [108].

10.2.12.Aurora Water's Rocky Ford Transfers

To secure additional municipal water supplies, Aurora Water purchased approximately 58% of water shares of the Rocky Ford Ditch Company, located in Otero County in the Lower Arkansas River Basin of Colorado, in 1987 (Rocky Ford I) [191]. All agricultural lands involved in this purchase were dried up and put back into native vegetation. In 1999, the second purchase of Rocky Ford Ditch shares was initiated to add an additional 36% of shares, then irrigating a total of 2,810 acres of land, to the first purchase (Rocky Ford II). Now, Aurora Water owns a total of 94% of the Rocky Ford Ditch [192]. The transfer and change of use for Rocky Ford II was approved by the Colorado Water Court and its decree was issued on January 28, 2004 [192]. This decree requires lands to either be re-vegetated, enrolled in the continued farming program, or be classified as "non-agricultural development". Approximately 880 acres of the 2,810 acres (31%) of the Rocky Ford Ditch II are enrolled in Continued Farming [193]. Water transfer from lands classified for re-vegetation required approval by a Court appointed expert panel. However, continued farming and non-agricultural development lands enabled Aurora to transfer the associated water immediately [192].

The amount of transferrable water was determined based on historic consumptive use analysis, which estimated this amount to be 1.76 acre feet per acre, using 30 years of historical data. The transferable water is diverted to the City of Aurora or stored in Pueblo Reservoir. From the remaining portions of the water, a portion is diverted as surface return flow into the Rocky Ford Ditch flume, where it is measured by a gate. Another portion is stored at Pueblo Reservoir and released later to mimic delayed return flows so that there is no injury to downstream water users. For the continued farming program, Aurora supported implementation of high-efficiency irrigation technology, such as drip irrigation, and provides

0.50 acre-feet per acre annually to the farms. The city will receive the rest of the water (1.26 acre-feet per acre per year) [193].

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