# Policy Options for Water Management in the Verde Valley, Arizona

Prepared for

**The Nature Conservancy**
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While this report is the product of a collaborative effort, the conclusions presented herein are those of the authors.

Cover photos: Roundtail chub, locally known as the Verde trout (courtesy of Arizona Fish and Game Department); other photos by James Limbrunner.

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# Executive Summary

*A river is more than an amenity, it is a treasure. It offers a necessity of life that must be rationed among those who have power over it.*

Justice Oliver Wendell Holmes, opinion in the 1931 case of *New Jersey v. New York*

The water of the Verde Valley, both in the ground and flowing at the surface, is a natural resource that is critical to the regional economy, environmental sustainability, and quality of life—but the Verde River faces unprecedented threats from over-allocation, development, and lack of cohesive water management. This report presents the results of three related initiatives designed to examine possible futures for the Verde and provides information for stakeholders and decision makers regarding the Verde Valley's water resources, its economic value, and possible tools for sustainable water management.

Our analysis included modeling the effects of growth on river flows and on the regional economy. Population growth and development in the basin, if not mitigated, are likely to cause further decrease in the summer base flow in the Verde River. Decreases in the Verde River's flow have already been observed, and further reductions could have harmful side effects on the region's economy and could lead to federal intervention in local water management to maintain habitat for endangered species.

## Planning-Level Water Management Model

A planning-level water management model was developed for the Verde Valley to quantify the potential effects of two groundwater withdrawal scenarios on river flow and to study possible management alternatives.

Under a mid-range growth scenario, increases in groundwater withdrawal are projected to cause annual flow volume in the Verde River to decrease by about 3,000 acre-feet by 2050, equivalent to a flow-rate reduction of about 4 cubic feet per second. This scenario projects median summer monthly flow near Camp Verde to decrease by about 6 percent by 2050. Under a high-growth scenario, increases in groundwater withdrawal are projected to decrease annual flow volume in the Verde River by almost 8,000 acre-feet (or 11 cfs) by 2050. This high-growth scenario projects median summer monthly flow near Camp Verde to decrease by 15 percent by 2050.

Larger decreases in streamflow are likely in the future, with potential reduced inflow to the Verde Valley due to groundwater extraction in the Big Chino and Little Chino basins, climate change, and the arrival of effects caused by pumping in the Verde Valley prior the beginning of the study period. Without reduction of groundwater pumping, additional streamflow depletion in the years following 2050 is likely.

We considered four different water management alternatives for how they might affect streamflow and aquifer levels in the Verde Valley and the regional economy. The alternatives are generally analogous to management approaches implemented by states considered in the case studies:

**A0** No change in current management approach (base case)
**A1** State-level regulation

**A2** Regulation with market-based trading
**A3** Regional water management institution

Management alternatives that cap groundwater extraction can reduce projected streamflow depletion in the Verde River.

## Economic Analysis

Total economic activity in the Verde Valley amounts to approximately $1 billion to $1.5 billion per year. We examine how changes in water resources may impact economic values for the community that are closely related to use of the Verde River and related groundwater system, concentrating on economic values that: 1) are the largest water-related values; 2) have the greatest sensitivity to changes in flow or changes in groundwater levels; and 3) for which some form of quantitative valuation is feasible given available methods.

Among these economic values are $87.5 million per year for tourism activities closely related to water use on the Verde River—and the indirect economic boost when residents with incomes increased by tourism spend their earnings locally. A regional economic model (IMPLAN) generates an estimate of $16 million in multiplier effects from the $87.5 million, and creation of 737 jobs from tourism and recreation expenditures related to river use for which we had data.

**ES Table 1 Summary of Economic Values from the Middle Verde River (annual values, millions of 2010 dollars)**

| Sector | Current Annual Value, $Million |
|---|---|
| Recreation and Tourism | 87.5 * |
| Production Agriculture | 29 |
| Wine Industry | 5.5 * |
| Municipal/Residential | 13–17.5 |
| Commercial/Industrial | ** |
| Ecological | 15–22 |
| Total | 150–161.5 + |

* In addition to direct values, there are multiplier effects for these sectors.
** Commercial/industrial values are generally believed to be large but cannot be estimated given the difficulty in locating information.

Loss of flows in the Verde River and a lowering of the water table can adversely affect these economic values. The economic analysis presented here estimates the value of those water uses and the sensitivity of those values to changes in water availability. Streamflow changes estimated in this study were used to assess the potential loss of annual value derived from the Middle Verde River. The table below summarizes the results.

**ES Table 2: Summary of Economic Values from the Middle Verde River and Potential Loss of Annual Value (annual values, millions of 2010 dollars)**

| Sector | Sensitivity to Streamflow Change | Potential Loss of Annual Value, $Million |
|---|---|---|
| Recreation and Tourism | varies | 1.9–4.7 |
| Production Agriculture | medium | 2.5 |
| Wine Industry | ** | 0.3 |
| Municipal/Residential | ** | 1.8–5.3 |
| Commercial/Industrial | ** | 0–0.2 |
| Ecological | high | 0.9–3.3 |
| Total | | 7.4–16.3 |

** Groundwater dependent.

Several water management options for the Middle Verde River were shown to provide crucial methods for stopping streamflow depletion and groundwater level declines:

**Regulatory option:** protects existing uses by placing a cap on overall groundwater use in the Verde Valley. Regulations can impose costs on residential and commercial/industrial sectors if growth is restricted due to the groundwater use cap.

**Water marketing option:** allows transfers of groundwater and surface water rights that can mitigate losses. This scenario provides greater net benefit compared to the regulatory option because losses to residential and commercial/industrial sectors are avoided.

**Regional water management option:** builds on the water marketing option with better coordination of local water management and potentially provides money through collected fees or water rights sales that can be used to promote projects that increase available supplies or reduce water demand, such as water conservation, increased water recycling, or stormwater capture.

## Case Studies

We present three case studies of water management in Western states, examining how different regions have approached the question and addressed the complex decisions involved in sustainable groundwater management to maintain instream flows.

The **Middle Rio Grande Basin in New Mexico** suffers from groundwater overdraft and faces the challenge of growing water demands, primarily driven by rapid population growth. Unlike in Arizona, New Mexico has engaged in conjunctive management for decades, with the state requiring the acquisition of water rights for most new groundwater uses.

Despite the imposition of a cap on groundwater withdrawals by the state, program rules allow new water uses as long as the user promises to offset these in the future. Proponents praise this incremental approach, which has allowed continued development. Critics call it a giant loophole that allows environmental degradation to continue or even worsen, while putting off the difficult decisions about land fallowing or the expense of securing alternative water supplies.

Recent water policy developments have been motivated by the need to protect the endangered silvery minnow; a regional coalition created to comply with the Endangered Species Act has attracted substantial federal funding, with Congressional authorizations of $116 million since 2003. The city of Albuquerque has also made tremendous strides in reducing per capita water use, although population growth continues to be a major driver behind water use and declining aquifer levels in the basin.

In the **Deschutes River Basin in Oregon**, water managers and policymakers have recognized the importance of dealing with groundwater to protect surface water flows. Market-based strategies provide for continued growth and maintain a healthy river. Oregon has the most comprehensive and straightforward laws to protect instream flow, which has served as a model to other states as they seek to preserve river flows for recreation and habitat.

In 2005, Oregon launched the Groundwater Mitigation Program, stipulating that new groundwater permits could not be issued in the Deschutes unless the applicant could mitigate the impact of the withdrawal on streamflow with a similar amount of water put instream. Groundwater pumpers can purchase “mitigation credits,” and the state created “mitigation banks” to facilitate transactions among willing buyers and sellers and to avoid profiteering.

Oregon’s Conserved Water Program creates an incentive for irrigators to participate in water conservation programs that benefit wildlife. A portion of the water saved through water efficiency upgrades is dedicated to instream flow, while irrigators retain the remainder of the savings which can be applied to additional land, sold, leased, or donated for instream use.

The **Edwards Aquifer in south central Texas** is an important groundwater resource, supporting thousands of acres of irrigated agriculture and supplying water to San Antonio, the country’s seventh-largest city. Texas created the Edwards Aquifer Authority (EAA) in 1993 for the express purpose of preserving spring flows and maintaining endangered species habitat, and gave it the power to regulate water users. The EAA was tasked with capping pumping at specific levels and buying down existing water rights by 2008, at a potential cost of hundreds of millions of dollars. Today, all wells producing more than 17 gallons per minute from the Edwards Aquifer must be permitted. Pumpers must hold rights and must pay fees for their water use. The EAA is now self-sustaining, with the majority of its revenues coming from permit fees.

In addition, the city of San Antonio has taken strong steps to protect the aquifer and its water supplies. Since voters approved a 1/8-cent sales tax, the city has spent more than $135 million to protect natural lands within the aquifer’s recharge zone. Recently, the city has focused on purchasing *easements* rather than buying land outright. This program has allowed land to stay in the hands of private owners and preserves traditional land uses like ranching, hunting, or fishing while maintaining aquifer recharge and protecting water quality.

## Water Management and Policy Options

In Arizona, 35% of natural perennial-flowing rivers have been altered or lost as a result of dams, diversions, and groundwater pumping. There are a number of aspects of a healthy river. In this report, we have focused on maintaining instream flows, and specifically on how excessive groundwater withdrawals can reduce flows, causing harm to the river, wildlife, and the communities around it.

Any pumping in an aquifer that is geologically connected to a river will affect flows in the river. It is more difficult to measure the extent and movement of groundwater than surface waters, making it more challenging to regulate and manage. In Southwestern rivers like the Verde, the effects of pumping may not be seen for decades. This long time lag prevents the public from seeing and understanding groundwater-surface water connections, creating an additional barrier to crafting meaningful policies to protect rivers from over-pumping.

Arizona reformed the way groundwater is managed in the state with the passage of the Groundwater Management Act in 1980. As a result, the use of groundwater in Arizona is highly regulated within Active Management Areas (AMAs), of which there are currently five. The five AMAs cover 80% of the population, but only 13% of the land, leaving rural areas of Arizona with few options for controlling overexploitation of groundwater. Declaring a Verde AMA will not be sufficient to protect the river from groundwater overdraft, as the law provides few means to protect rivers.

To better manage groundwater and protect instream flows in the Verde River Basin, several elements are needed.

In this report, we present over a dozen policy and management alternatives. Reforming water management is almost never fast or easy, but all of the options presented are drawn entirely from experiences that have worked in other Western states. Successful approaches must however be adapted to fit the unique legal, cultural, and hydrologic setting in Arizona and the Verde Valley. The options can be broken down roughly into four categories:

**Water management**
- –Enhance water conservation and efficiency
- –Increase the use of recycled water
- –Modernize irrigation infrastructure
- –Enhance aquifer recharge

**Legal reforms**
- –Advocate for legal protection of instream flows
- –Require reporting of water use
- –Regulate groundwater pumping to sustainable levels
- –Mitigate new water uses
- –Deal with exempt wells
- –Press for adjudication of water rights
- –Pursue endangered species act protections for the Verde's aquatic species

**Economic and market-based measures**
- –Charge groundwater extraction fees
- –Allow interested parties to purchase or donate water for instream flow
- –Create water banking

**Administrative or institutional actions**

–Create the Verde River Active Management Area

–Create a Verde River Conservation District

Our analysis demonstrates that the water resources of the Verde River basin, if managed wisely, can meet the needs of cities, farms, and nature, as well as provide for future growth. Cooperation, smart economics and planning, and efficient use can lead to a continued high standard of living for residents, robust economic activity, and maintenance of the magnificent ecological setting that attracts visitors from around the world.

**Verde River near Clarkdale, Arizona. Photo courtesy of Walt Anderson.**

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## Acronyms and Abbreviations

| | |
|---|---|
| ABCWUA | Albuquerque Bernalillo County Water Utility Authority (New Mexico) |
| ADWR | Arizona Department of Water Resources |
| af | acre-foot |
| AGWA | Association of Groundwater Agencies |
| AHRCC | Arizona Hospitality Research and Resource Center |
| AMA | Active Management Area (Arizona) |
| ASR | Aquifer Storage and Recovery |
| BiOp | Biological Opinion |
| BPA | Bonneville Power Administration (Oregon) |
| CAP | Central Arizona Project |
| cfs | cubic feet per second |
| CYHWRMS | Central Yavapai Highlands Water Resources Management Study |
| DFC | Desired Future Conditions (Texas) |
| DRC | Deschutes River Conservancy (Oregon) |
| DWA | Deschutes Water Alliance (Oregon) |
| EAA | Edwards Aquifer Authority (Texas) |
| EARIP | Edwards Aquifer Recovery Implementation Program (Texas) |
| ESA | Endangered Species Act |
| EUWD | Edwards Underground Water District (Texas) |
| FWS | U.S. Fish and Wildlife Service |
| GCD | Groundwater Conservation District (Texas) |
| GMP | Groundwater Mitigation Program (Oregon) |
| GNP | Gross National Product |
| GRP | Gross Regional Product |
| gpcd | Gallons per capita per day |
| gpd | Gallons per day |
| gphd | Gallons per household per day |
| GW | groundwater |

| | |
|---|---|
| HCP | Habitat Conservation Program |
| IFC | Instream Flow Council |
| IMPLAN | Impact Analysis and Planning (economic software) |
| LFCC | Low-Flow Conveyance Channel (New Mexico) |
| MRG | Middle Rio Grande (New Mexico) |
| MRGCD | Middle Rio Grande Conservancy District |
| MRGESCP | Middle Rio Grande Endangered Species Collaborative Program |
| NAU | Northern Arizona University |
| NARGFM | Northern Arizona Regional Groundwater Flow Model |
| NHDES | New Hampshire Department of Environmental Services |
| OASIS | Operational Analysis and Simulation of Integrated Systems |
| OWRD | Oregon Water Resources Department |
| OWT | Oregon Water Trust |
| SAWS | San Antonio Water System (Texas) |
| SRP | Salt River Project (Arizona) |
| SW | surface water |
| TNC | The Nature Conservancy |
| USBR | US Bureau of Reclamation |
| USEPA | US Environmental Protection Agency |
| USGS | US Geological Survey |
| WAC | Yavapai County Water Advisory Committee (Arizona) |

# 1. Planning-Level Water Management Model

A planning-level water management model was developed for the Verde Valley to study potential effects of two groundwater withdrawal scenarios on river flow, and to study possible management alternatives. A description of the Verde Valley study area is provided below, followed by the model description, analysis methods, and results.

## 1.1. Study Area

The Verde River, one of Arizona's few perennial streams, originates at the confluence of outflow from the Big Chino and Little Chino basins near Paulden, Arizona at a small reservoir called Sullivan Lake. The Verde River is an important source of water for communities in the Verde Valley (Figure 1) and for the City of Phoenix. Water from the Verde River is valued for its high quality (Wirt et al. 2004). The Verde River flows to the south and east, eventually joining the Salt River. The Upper Verde River, between Sullivan Lake and Clarkdale, discharges to the Verde Valley portion of the river, or Middle Verde. The river flows through the Verde Valley including the communities of Clarkdale and Cottonwood, and is joined by Oak Creek before flowing through Camp Verde to the southeast. Below Camp Verde is the Lower Verde River.

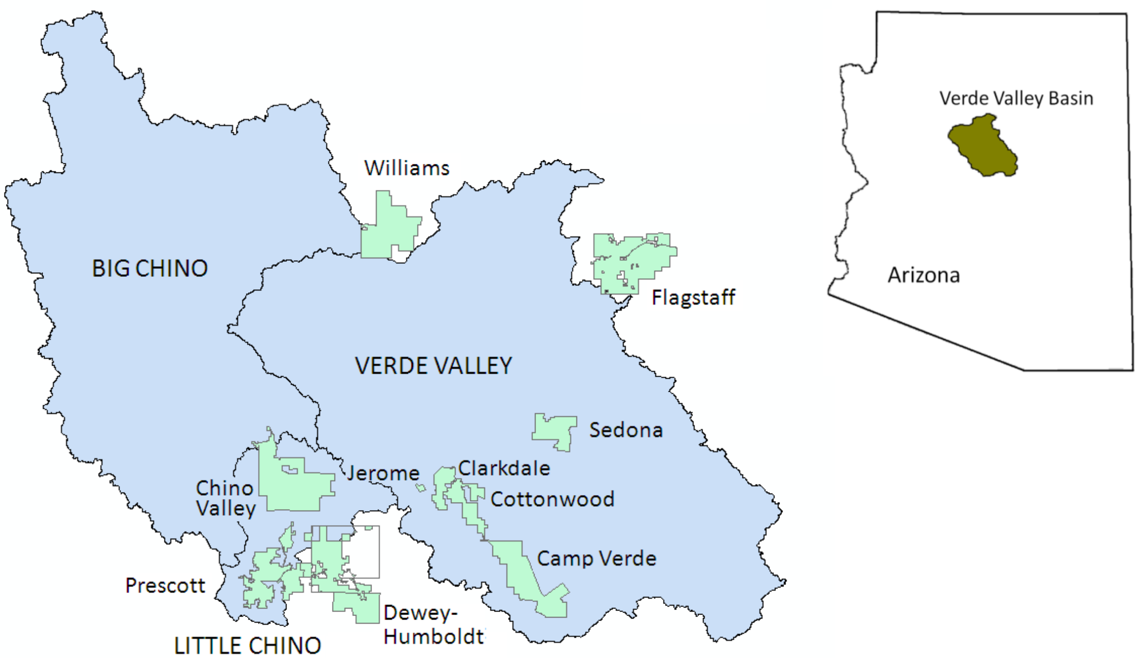


**Figure 1 Upper Verde River sub-basins and the Verde Valley**

This study focuses on the Verde Valley, encompassing the Middle Verde River and its tributaries between Clarkdale and Camp Verde.

### 1.1.1. Precipitation

The climate of the region is arid to semi-arid, with annual precipitation ranging between 10 inches per year at lower elevations to about 40 inches per year at higher elevations (Blasch et al. 2005).

Precipitation generally occurs in two distinct seasons, summer and winter. Summer precipitation is characterized by localized thunder storms, while winter precipitation is associated with moist air masses arriving from the west that rise over Big Black Mesa, the Mogollon Rim, and the Coconino Plateau (Blasch et al. 2005). The higher elevations in the Verde River watershed, with cooler temperatures and thinner soils, are key recharge areas for the aquifer that sustains both the river and the regional economy.

### 1.1.2. Recharge and Groundwater Storage

In the Verde Valley, it is estimated that about 4 percent of annual precipitation, primarily from winter storms, becomes recharge to the aquifer (Blasch et al. 2005). This represents an estimated annual volume of 130,270 acre-feet (Blasch et al. 2005). The volume of saturated sediment in the Verde Valley is estimated to be about 112 million acre-feet (Blasch et al. 2005). While these volumes appear large compared to annual groundwater withdrawals, the recent work of Leake and Pool (2010) shows strong connection in many areas of the Verde Valley between groundwater withdrawal and streamflow depletion. Based on projected groundwater withdrawal rates, this indicates that substantial reduction of streamflow in the Verde River is possible.

There is evidence that source water for the Verde River is diminishing. Since 1950, about 6 miles of perennial streams surrounding Sullivan Lake have become ephemeral, likely due to a combination of increased water withdrawals and climate factors (Wirt et al. 2004). Del Rio Springs, a source in the Upper Verde, is reported to now produce only half of its historic discharge (Wirt et al. 2004).

### 1.1.3. Arsenic

Blasch et al. (2005) report that water quality tests in the area found concentrations of some contaminants in excess of water quality standards including antimony, arsenic, fluoride, lead, nitrate, and selenium. Arsenic was found to exceed standards in the most samples and is correlated with the geology of the Supai Group and Verde Formation. Anecdotal evidence also indicates that there is concern over the presence of arsenic in groundwater and the impact it may have on future water development efforts and cost. Treatment technology is available to remove unsafe levels of arsenic from drinking water. For small municipal water suppliers, removal typically costs from $30 to $70 per household, per year (USEPA 2002). For individual homes, treatment is more expensive. Purchase costs range from $600 to $2,400, and have operating costs from $100 to $1,200 per year (NHDES 2006).

## 1.2. OASIS Model

We developed a planning-level model of the Verde Valley using OASIS software. Planning models are useful for studying the potential effects of management alternatives. OASIS with Operational Control Language™ (OCL) is a generalized program for modeling the operations of water resources systems. OASIS simulates the routing of water through a system represented by nodes and arcs. This routing accounts for both human control and physical constraints on the system.

OASIS contains both arcs and nodes. Arcs represent conveyance from one node to another, while a node represents a point of interest in the system. In the Verde Valley model, there are two node types:

- **Junction Nodes**: These nodes are used to model a point in the system where inflow (or outflow) occurs, or a junction of conveyance features (represented by arcs).
- **Demand Nodes**: Demand nodes are nodes to which water is delivered. In the Verde Valley model, there are three demand nodes representing agricultural use.

Figure 2 shows the Verde Valley OASIS model schematic, containing the basic elements of the system, inflow, outflow, and surface water withdrawals.

The OASIS model simulates monthly river flows, and can be modified to test the effects of a range of conditions or management decisions. Primary inputs are monthly average inflows that were calculated from daily average flow data available from U.S. Geological Survey (USGS) gages, irrigation withdrawals, and projections of streamflow depletion within the Verde Valley as discussed below. The model output is a time series of monthly average flow in each of the links shown in Figure 2.

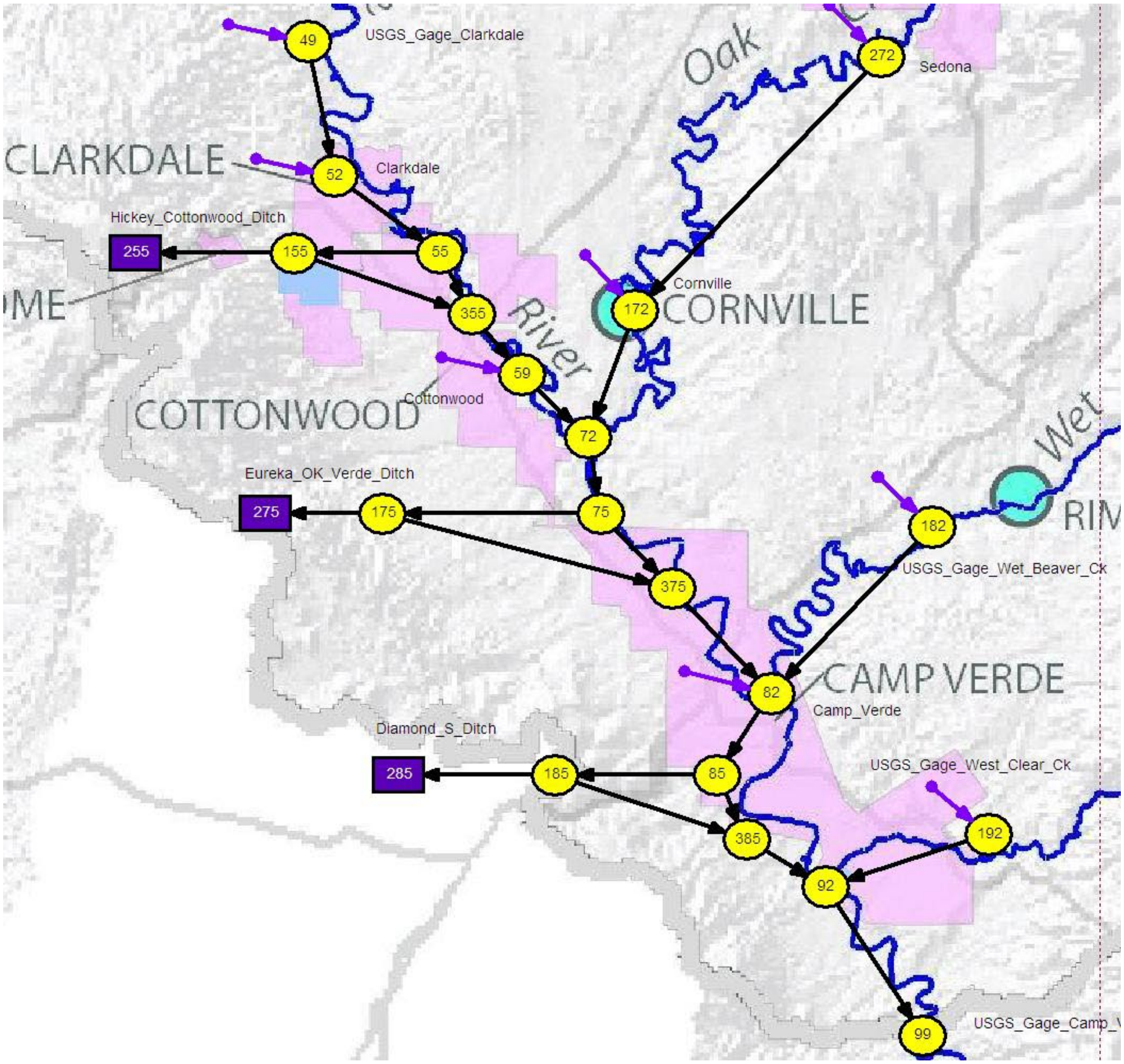


**Figure 2 Verde Valley OASIS model schematic. Background image adapted from Leake and Pool (2010).**

### 1.2.1. Surface Water Inflow

Daily historic flow data were obtained from the USGS for the period between January 1989 and December 2010. USGS gage locations included:

- Verde River near Clarkdale (09504000),
- Verde River near Camp Verde (09506000),
- Oak Creek near Sedona (09504420),
- Oak Creek near Cornville (09504500),
- Wet Beaver Creek near Rimrock (09505350), and
- West Clear Creek near Camp Verde (09505800).

From these daily data, monthly average flows were calculated, creating a time series of 22 years, or 264 months in length.

Local inflow, or the flow arriving to a river or stream between gage locations, was calculated for the Cornville reach of Oak Creek by subtracting the monthly average flow observed near Sedona from the observed monthly flow at the downstream Cornville gage. Local inflow at Cornville was assumed to be the difference between flow at Cornville and flow at Sedona. Negative inflows represent a situation where the flow downstream in Oak Creek was less than flow measured upstream. Reasons could include losing stream reaches and irrigation withdrawals.

### 1.2.2. Verde Valley Inflow

The existence of a perennial river in an arid environment is made possible by groundwater that discharges from an aquifer into the river channel, a phenomenon called base flow. In the model, inflow points were assigned at nodes 52 (Clarkdale); 59 (Cottonwood); and 82 (Camp Verde). These inflows represent both local surface water inflow and groundwater inflow to the stream. It was assumed that each of the three ungaged locations in the model (Clarkdale, 52; Cottonwood, 59; and Camp Verde, 82) receive monthly inflow from groundwater and local surface runoff that is proportional to inflow observed at the Clarkdale gage. This proportional inflow was represented with an inflow coefficient that was calibrated to obtain a close match between modeled and observed outflow downstream at the Camp Verde gage.

### 1.2.3. Irrigation Withdrawals

Irrigation withdrawals were assumed to occur at three locations in the model representing upstream, middle, and downstream withdrawals at nodes 55 (Hickey-Cottonwood); 75 (Eureka-OK-Verde); 85 (Diamond S). A base value for agricultural demand of 17,800 acre-feet per year was taken from CYHWRMS (2010). It was assumed that this demand was evenly distributed among the three modeled diversions and that irrigation withdrawals occur in the months of May, June, and July. Dividing total irrigation demand over three months, and among the three irrigation demand locations in the model, resulted in a base seasonal monthly irrigation demand of 1,978 acre-feet at each location.

At each of the modeled ditch diversion points, it was assumed that 95% of the river flow is diverted into the ditch. This assumption appears reasonable based on field observation. Diversions in excess of irrigation demand are returned to the river downstream from each ditch at nodes 355, 375, and 385 respectively.

### 1.2.4. Model Calibration

Streamflow records from the USGS site near Camp Verde were used to adjust the two parameters in the model. We scaled the local inflow coefficient and the agriculture demand during model calibration to create a simulated time series that matched flow observed at the Camp Verde gage, and to match the long-term sum of flow observed at the Camp Verde gage.

We applied a scale factor of 0.89 for agricultural demand and a local inflow coefficient of 0.171 for each of the three local inflow points (Clarkdale, Cottonwood, and Camp Verde). Figure 3 shows the comparison between modeled and observed monthly streamflow over the period between January 1989 and December 2010. The model closely approximates observed flow over the range of historic flows observed in the record. In Figure 4, the lower range of flows observed near Camp Verde are compared with calibrated model results. The model also does a good job at approximating agricultural withdrawals in the summer months.

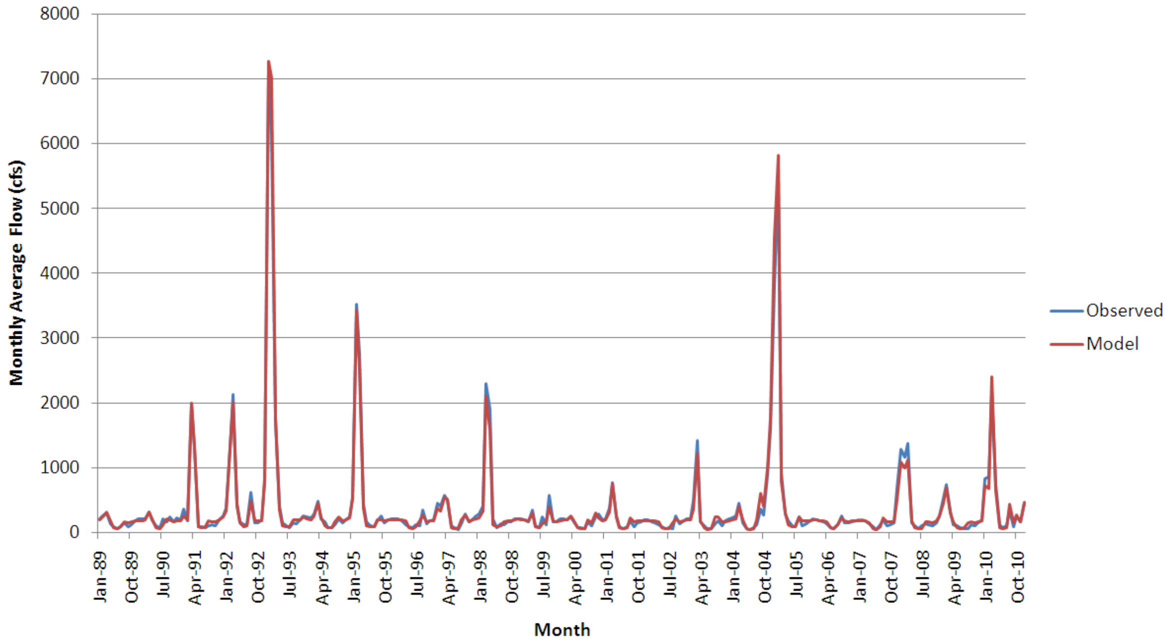

**Figure 3 Comparison of OASIS simulated monthly average flow and measured flow at USGS Gage 09506000 Verde River Near Camp Verde, AZ**

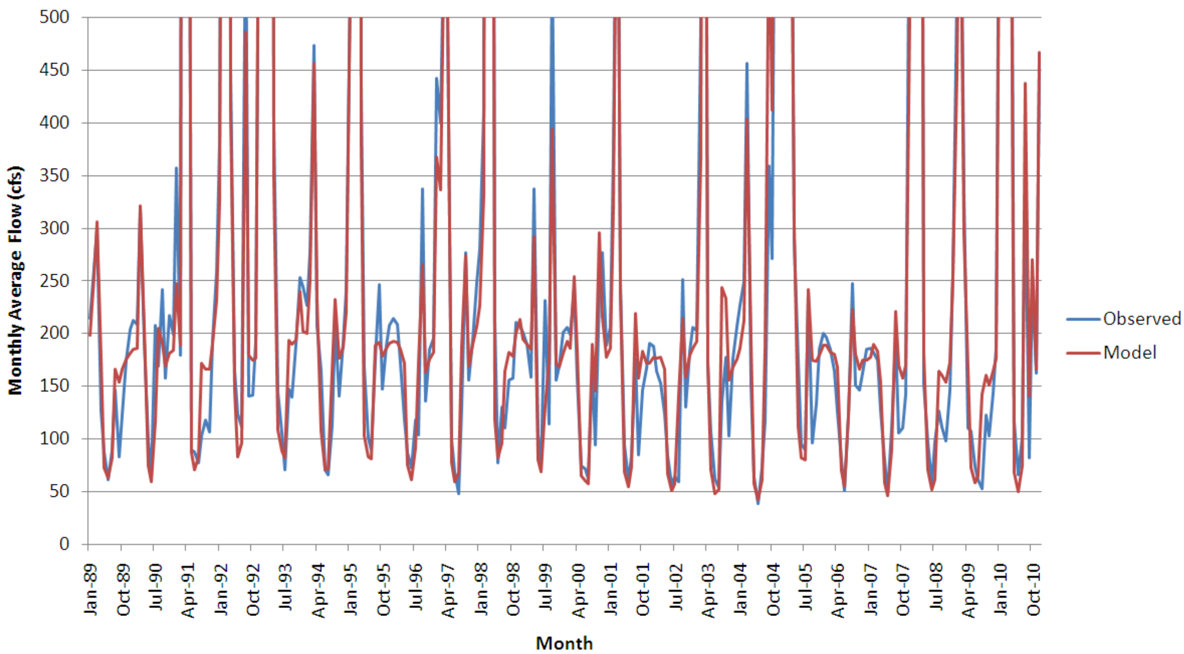


**Figure 4 Comparison of OASIS simulated monthly average flow and measured flow at USGS Gage 09506000 Verde River Near Camp Verde, AZ (lower flow range)**

Additionally, we compared OASIS model results with results of a longitudinal flow survey that was performed along the Middle Verde River in June 2007 (Bills 2008). We found a good agreement between modeled monthly average flow for June 2007 and the measured flows, as shown in Figure 5.

OASIS is not a spatially referenced model; therefore the modeled flow locations were approximated based on clearly identifiable features in the Bills (2008) flow survey, such as tributary confluences and agricultural withdrawal locations. Differences between modeled and observed flows at other locations are likely partially the result of using an "average distance" approach for plotting intermediate model flow locations. This is especially evident for the return flows between the Cottonwood Ditch and Oak Creek. The location of the two OASIS flow locations between the Cottonwood Ditch and Oak Creek (links 355–59 and 59–72) are not spatially specified, and "moving" them downstream toward Oak Creek in Figure 5 would bring the OASIS curve closer to the observed flow survey. More accurate representation of ditch return flow location could be incorporated into the OASIS model in the future if needed.

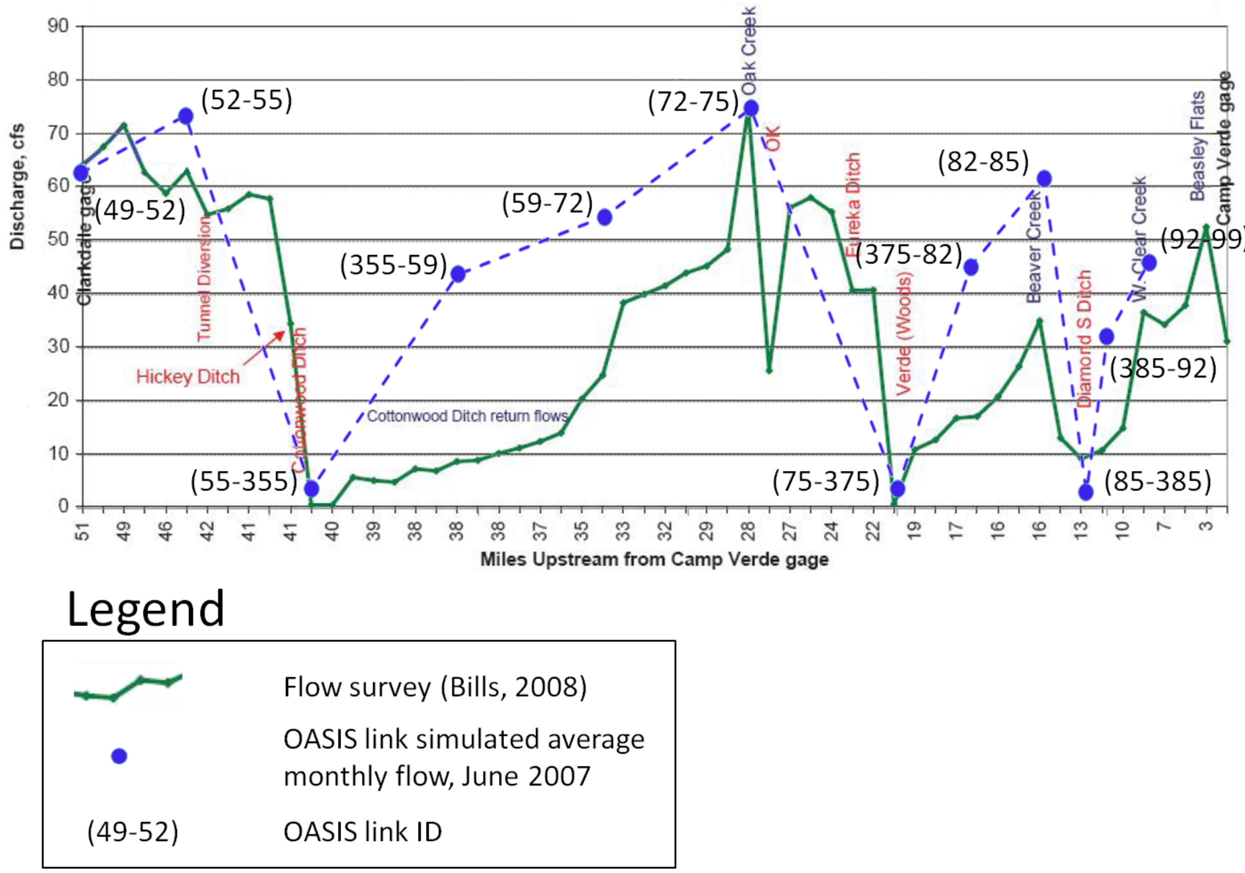


**Figure 5 Comparison of OASIS simulated average flow June 2007 and flow survey (from Bills 2008)**

The OASIS model reasonably simulated observed flows at Camp Verde. Next, we added streamflow depletion estimates to the simulation in order to study how future river flow may be impacted by changes in groundwater pumping through time.

### 1.2.5. Scenarios of Future Groundwater Use

We estimated groundwater use in the Verde Valley Sub-basin based on data provided by the Yavapai County Water Advisory Committee (2008). Figure 6 shows the location of consolidated well points from the Yavapai County Water Advisory Committee (WAC) 2008 study for long-term development scenarios in the Verde River watershed. Each of the well points shown in Figure 6 was assigned a pumping rate as part of the WAC study; these data were provided to us as a GIS database.

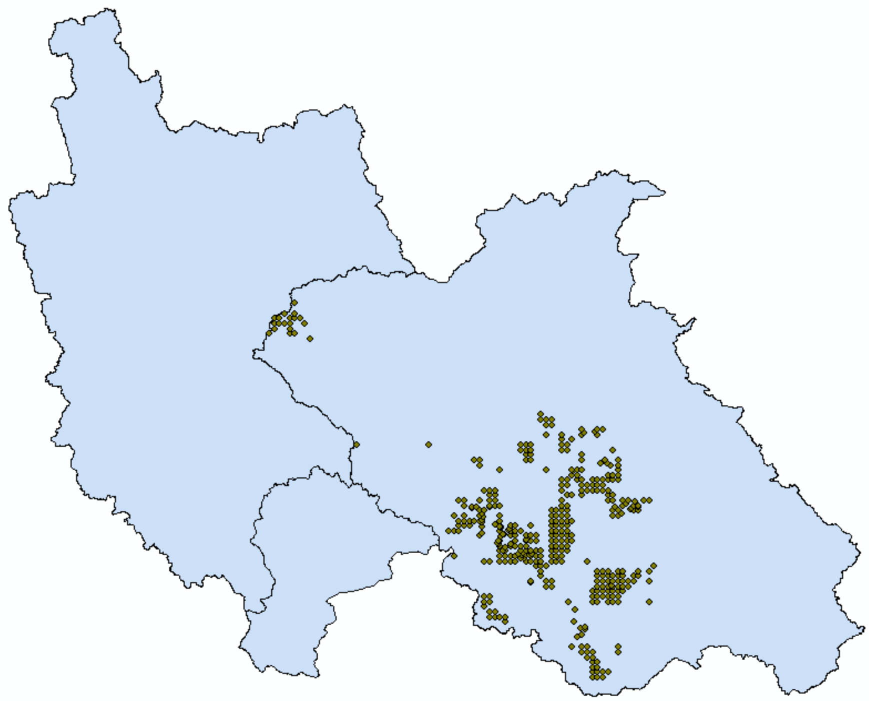

**Figure 6 Well point locations, Verde Valley (from WAC 2008)**

We studied two withdrawal scenarios, S1 and S2, developed by the Yavapai County WAC. The scenario S1, known as the General Plan Scenario, is based on a growth projection from a present population of 210,750 to 577,970 in 2050 (Yavapai County WAC 2008). Under S1, groundwater withdrawal in the Verde Valley Sub-basin is projected to increase from about 14,600 acre-feet per year to 22,500 acre-feet per year in 2050. The second scenario, S2, represents faster growth, with projected withdrawals reaching 40,100 acre-feet per year by 2050. Figure 7 shows projected pumping rates for both scenarios.

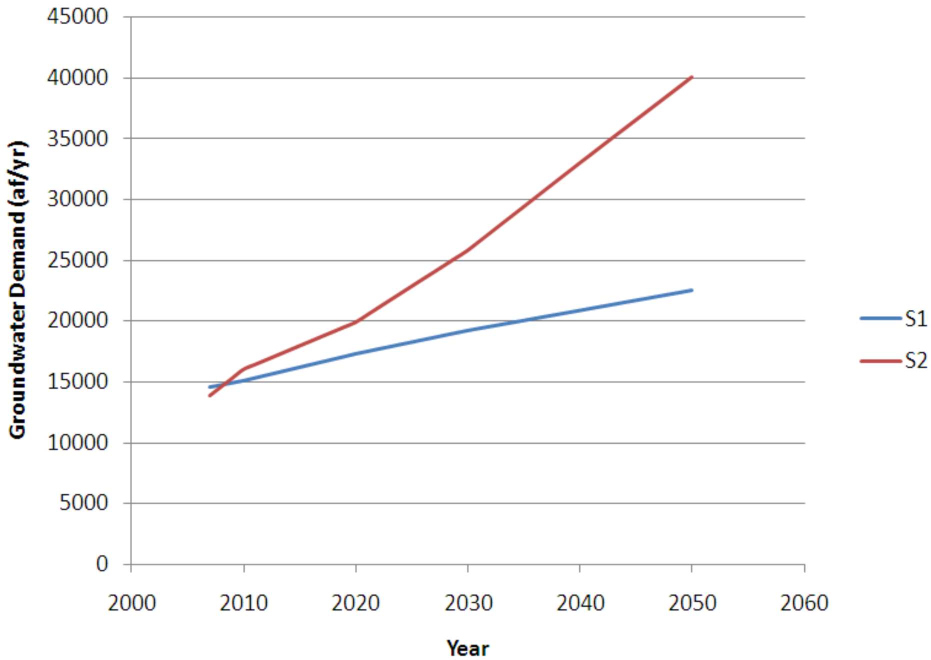


**Figure 7 Projected pumping rates for scenarios S1 and S2**

The WAC study database contained projected pumping volumes for the S1 and S2 scenarios for every 10 years. We interpolated the decadal projections to yield estimated pumping rates for each year in the simulation at each well location.

### 1.2.6. Streamflow Depletion Estimates

The recent study by Leake and Pool (2010) used the Northern Arizona Regional Groundwater Flow Model (NARGFM) to estimate the response through time of streamflow depletion due to the initiation of well pumping at any location in the Verde Valley. The results were reported as “fraction of withdrawal” that would manifest as streamflow depletion in the years following the beginning of pumping. When pumping is initiated, water is first drawn from aquifer storage. As aquifer pressure, or water table elevation, is reduced the gradients that deliver groundwater to the stream are reduced, causing a reduction in base flow. This reduction in base flow is called “streamflow depletion.” An example streamflow depletion fraction curve for one well location from the Verde Valley is shown below in Figure 8.

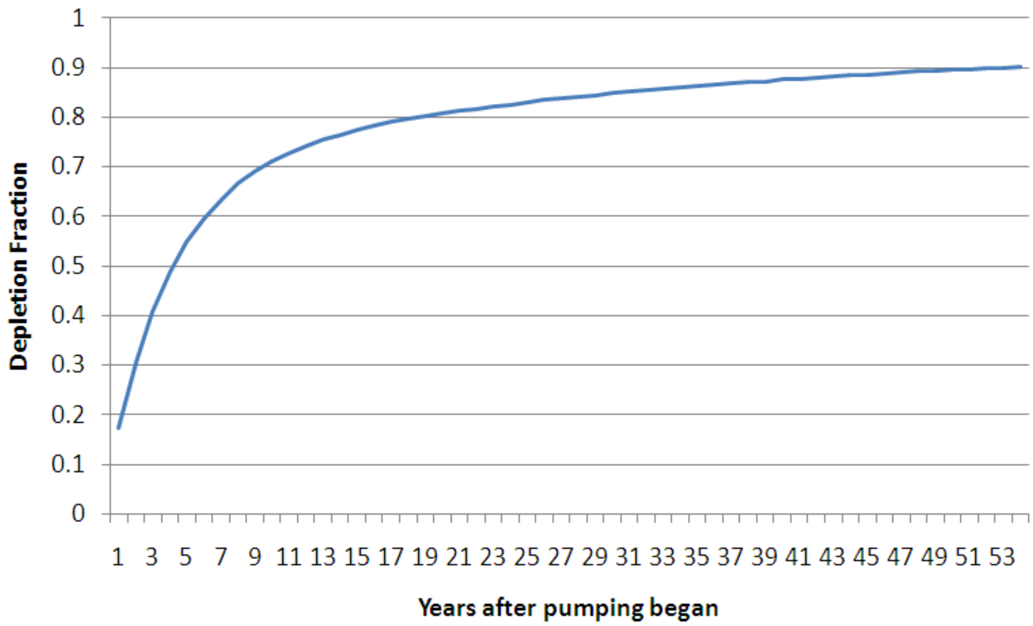


**Figure 8 Example depletion fraction curve for a location in the Verde Valley, well point 102**

Leake and Pool (2010) show streamflow depletion fractions in the Verde Valley approaching 1 over time, meaning that eventually the full withdrawal rate from groundwater will be manifested as streamflow depletion. Long delay times are common, especially for deep wells and those located far from the stream.

We made minor adjustments to the USGS streamflow depletion fraction file, including the elimination of "dry cell" indicators. We replaced these values with the last available depletion fraction in the time sequence. We replaced any negative depletion fractions with zero.

The latitude and longitude of the well points from the WAC (2008) database were used to associate them with the nearest NARGFM cells for which streamflow depletion estimates were provided. An assumption was made that a well is screened in the shallowest active layer from the NARGFM. Well locations were assigned to groundwater flow cells, and a streamflow depletion response curve from Leake and Pool (2010) was assigned to each pumping location.

Figure 9 shows an example of increasing pumping rate for one location, interpolated from the WAC (2008) database. From this, the differential pumping rate, or new pumping that is initiated in each year, can be determined as shown in Figure 10.

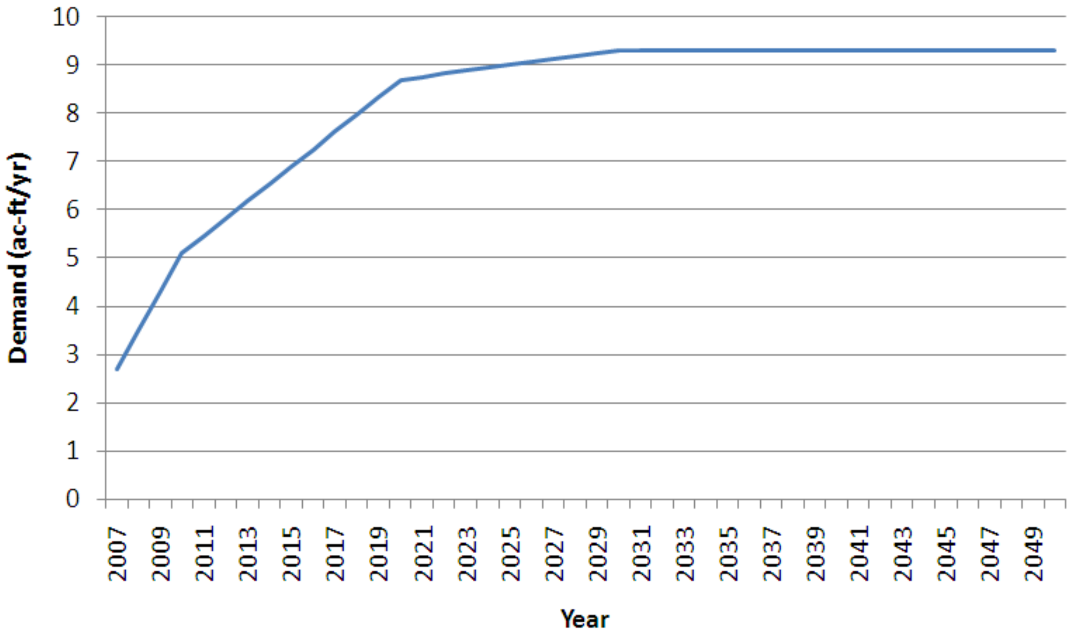


**Figure 9  Example pumping rate for a location in the Verde Valley, well point 102**

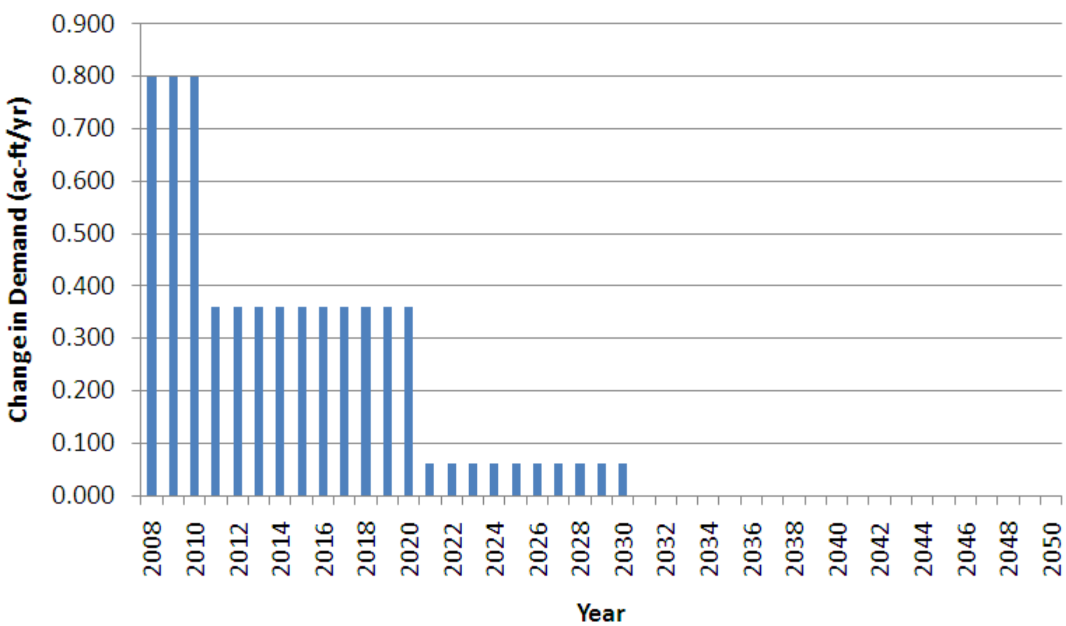


**Figure 10 Example differential pumping rate for a location in the Verde Valley, well point 102**

Any pumping that is initiated in a particular year produces a characteristic signal of streamflow depletion in the years following initiation. Because of this, any change in pumping rate between one year and the next (Figure 10) begins producing streamflow depletion according to the characteristic curve (Figure 8) provided for each location in the Verde Valley by Leake and Pool (2010). For each year in the study period where there is a change in pumping rate, a new response curve begins in that year. At each location, the responses from all changes in pumping rate were summed. Figure 11 shows the total projected streamflow depletion during the study period for one well point location.

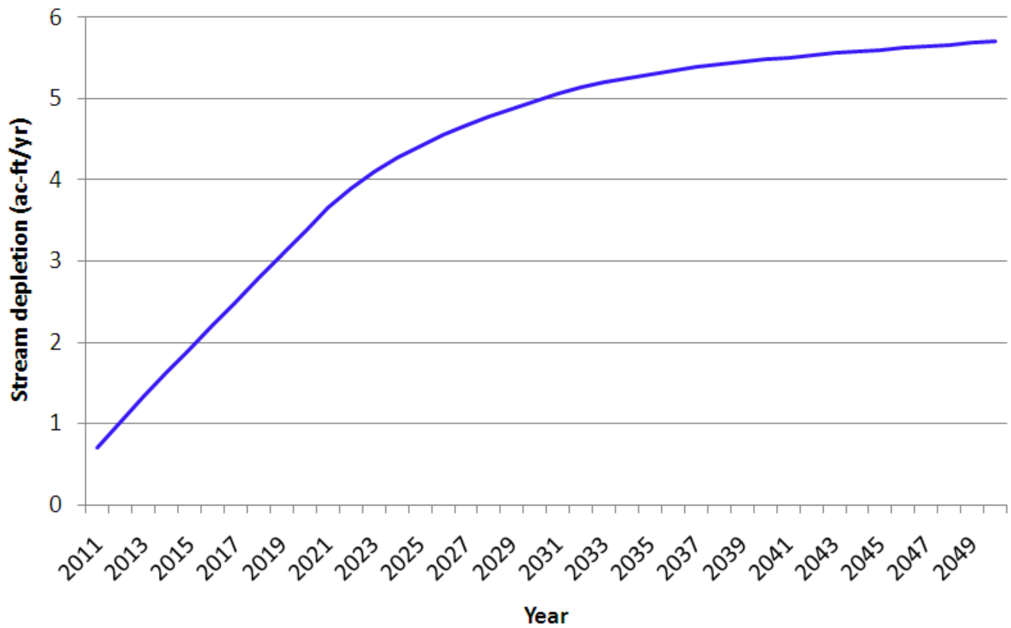


**Figure 11 Example total streamflow depletion for a location in the Verde Valley, well point 102.**

This analysis was repeated for all well locations in the Verde Valley from the WAC 2008 database and the results were summed to produce total projected streamflow depletion in the Verde Valley due to pumping initiated after 2007, shown in Figure 12.

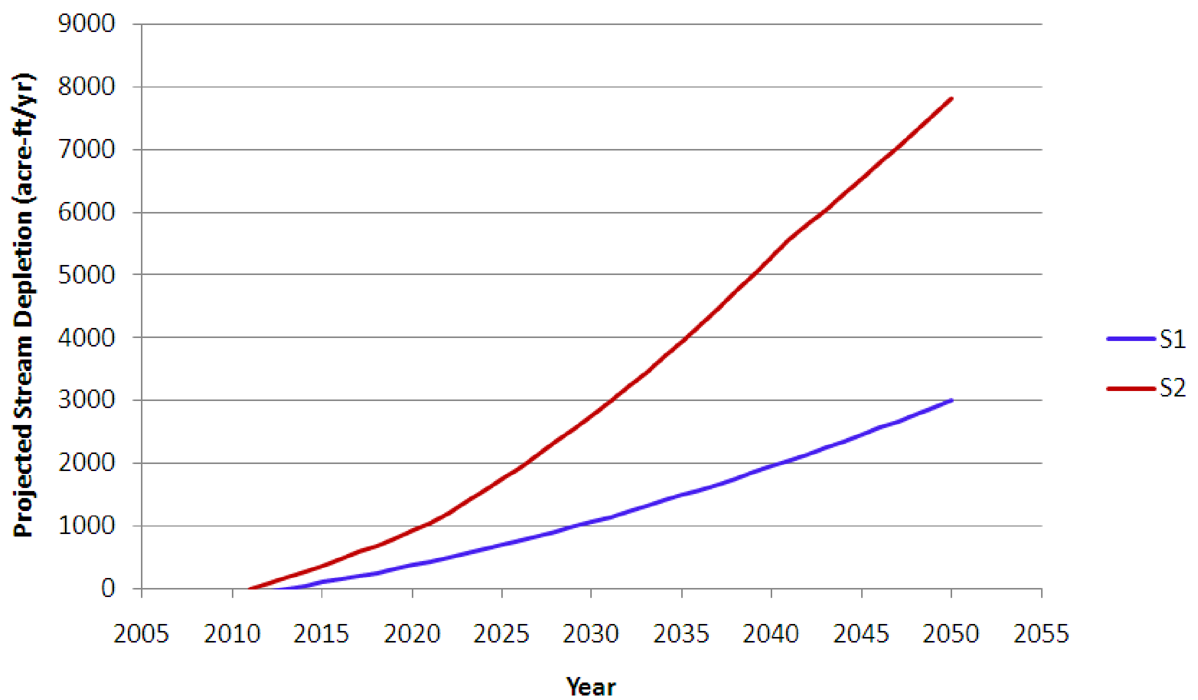


**Figure 12 Projected annual streamflow depletion Verde Valley, S1 and S2 scenarios**

Overall annual streamflow depletion volume (Figure 12) was disaggregated into 12 equal monthly depletion volumes, and then distributed to the nodes in the OASIS model based on local drainage area, as shown in Table 1.

**Table 1 Allocation of streamflow depletion by sub-area**

| Node | Name | Flow Reduction Allocation |
|---|---|---|
| 52 | Clarkdale | 17.7% |
| 59 | Cottonwood | 17.7% |
| 82 | Camp Verde | 17.7% |
| 272 | Sedona | 15.5% |
| 172 | Cornville | 8.1% |
| 182 | Wet Beaver Creek | 7.4% |
| 192 | West Clear Creek | 16.0% |

### 1.2.7. OASIS Model Simulation of Monthly Streamflow for Future Scenarios

Projected streamflow depletion at 5-year increments (2015 to 2050) was used in the OASIS model to simulate future flow conditions. These streamflow depletion values are shown below in Table 2.

**Table 2 Projected streamflow depletion at 5-year increments**

| Year | Streamflow Depletion (acre-feet/year) | |
|---|---|---|
| | S1 | S2 |
| 2015 | 98 | 367 |
| 2020 | 373 | 923 |
| 2025 | 699 | 1,742 |
| 2030 | 1,064 | 2,753 |
| 2035 | 1,489 | 3,936 |
| 2040 | 1,947 | 5,287 |
| 2045 | 2,460 | 6,535 |
| 2050 | 2,998 | 7,820 |

The model simulation approach was to run the historic data set (1989 to 2010) using the streamflow depletions at 5-year increments as shown in Table 2. By running the model over the historic record with expected future increases in streamflow depletion, the simulation provides an estimate of what the future might look like, based on flow that has been observed in the past coupled with projected future streamflow depletion at specific points (5-year increments) in time. This analysis approach is called a time-slice method.

Running the OASIS model over the 22-year historic record from 1989 to 2010, and including future streamflow depletion that is projected for a single future year from Table 2, produces eight simulated "future records" of 264 months (22 years). Each of these eight simulated records corresponds to one of the 5-year increments shown in Table 2. By taking the projected future streamflow depletion at a particular future year (Table 2) and simulating the effect it would have had on the entire historic streamflow record, metrics can be developed describing the likely impact that future increased pumping in the Verde Valley is likely to have on flow in the Verde River.

The 264 months of simulated record can be divided into 4 sets of 66 months for each of the seasons. The summer season was assumed to correspond with the irrigation season of May, June, and July. For each of the 5-year increments shown in Table 2, the 66 simulated monthly flows for each season were used to estimate the median, 25th, and 10th percentile monthly flow. Figure 13(a) shows projected future streamflow by percentile under the S1 scenario. Figure 13(b) shows the corresponding percent reduction in streamflow percentiles for the S1 scenario. Results are reported similarly for S2 in Figure 14.

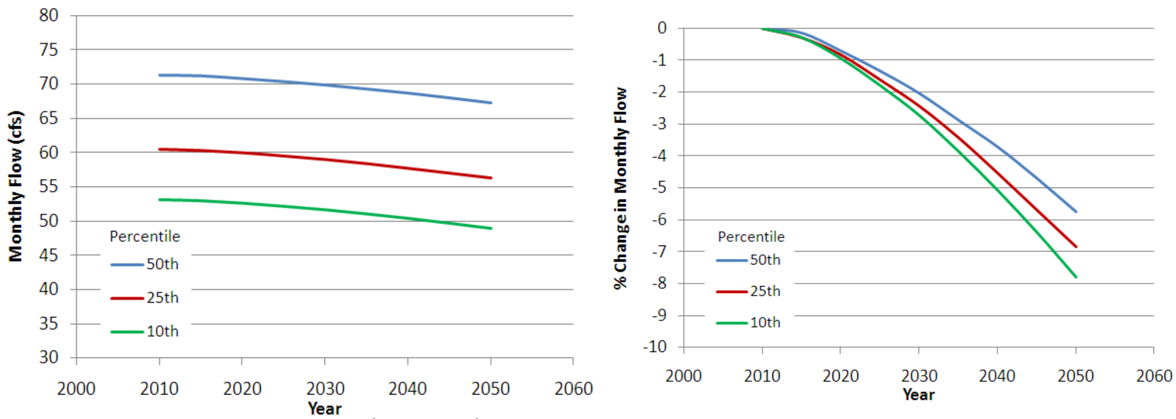


**Figure 13 (a) Projected median, 25th, and 10th percentile summer monthly flow near Camp Verde for the S1 scenario, and (b) percent change**

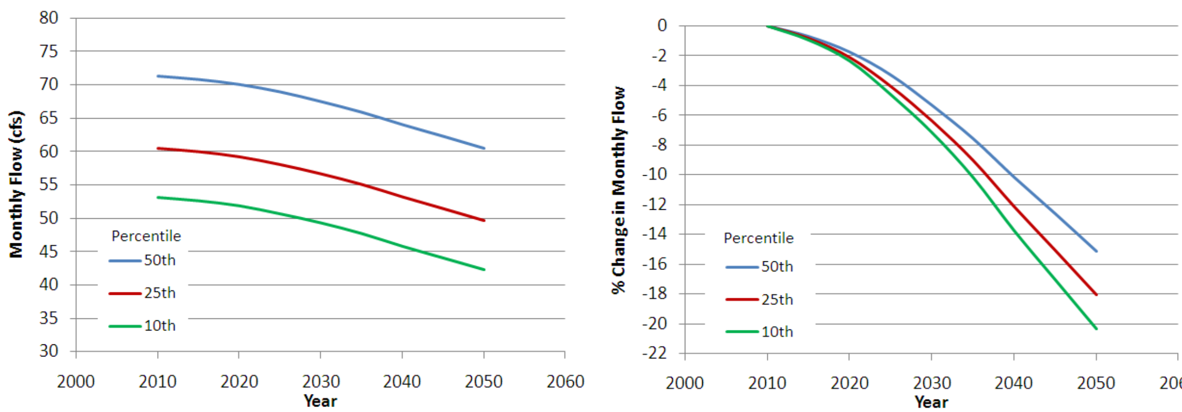


**Figure 14 (a) Projected median, 25th, and 10th percentile summer monthly flow near Camp Verde for the S2 scenario, and (b) percent change**

## 1.3. Discussion

The projected streamflow depletion values from Table 2 represent possible future conditions at 5-year increments during the study period. The simulation was performed using the historic inflows between January 1989 and December 2010 and each of the projected future streamflow depletions, meaning that at each 5-year increment there were 22 years of simulation results. From these simulated results the median summer monthly flow was calculated. This represents a middle value for average monthly flow in the summer. Under the simulated conditions, it is expected that summer monthly average flow will be greater than the median value half of the time, and below the median for the other half.

Figure 13(a) shows that under the assumption of the S1 pumping scenario, median summer monthly flow in the Verde River near Camp Verde is expected to decrease from about 71 cfs to about 67 cfs. As shown in Figure 14(a), under S2, median summer monthly flow near Camp Verde is expected to decrease to about 61 cfs. These changes in median summer monthly flow represent a 5.75% change for S1 and a 15.15% change for S2.

The 25th percentile value represents an average monthly flow that is exceeded in three-quarters of the simulation's summer months. It is expected that the 25th percentile flow will be exceeded 75% of the time. The 10th percentile flow represents the average flow in a month that was exceeded in nine out of ten summer months in the simulation. The 25th and 10th percentile summer monthly flows represent dry times.

Figure 13(b) and 14(b), which show percent changes in summer monthly flow under S1 and S2, indicate that the low flows are more sensitive to the simulated streamflow depletion than median flow. Because these low flow times can represent critical periods for wildlife, the reduction of low flows may have a more detrimental impact on wildlife than the reduction of median flows.

### 1.3.1. Analysis Limitations and Additional Influences on Future Streamflow

This study was focused on analyzing future streamflow change that is related to increases in pumping in the Verde Valley. Increased pumping in the Verde Valley is likely to be one cause of future reduction of streamflow in the Verde River. However, there are other factors which are likely to have significant impact on future flow of the river, including:

- increasing groundwater withdrawal in the Big Chino and Little Chino basins;
- climate change; and
- pre-2007 pumping in the Verde Valley.

The impact of these factors will be cumulative and could be significant relative to the streamflow changes found in this analysis. Each is discussed below.

### 1.3.2. Increasing Groundwater Withdrawal in the Big Chino and Little Chino basins

The trends in groundwater development that are predicted for the Verde Valley are also likely in other communities in Arizona, including in the Big Chino and Little Chino basins. Because the headwaters of the Verde River are formed from springs draining the Big Chino and Little Chino basins, there is a connection between groundwater resources in those basins and flow in the Verde River. In order to assess the sensitivity of summer monthly average flow in the Verde Valley to changes in base flow received from upstream, we estimated a representative value of base flow that enters the Verde Valley at Clarkdale. We then re-ran the simulation model with a 10% and 20% reduction of that base flow.

Marshall et al. (2010) found that base flow in the Middle Verde River and Upper Verde River is well approximated by median daily average flow. The long-term median daily average streamflow at the USGS gage near Clarkdale (gage 09504000) for the period between January 1, 1989 and December 31, 2010 is 79 cfs. This flow rate is assumed to represent base flow arriving in the Verde Valley from upstream. A 10% reduction in base flow would be a reduction of 7.9 cfs, and a 20% reduction would correspond to a reduction of 15.8 cfs. We included flow reductions of 7.9 cfs and 15.8 cfs at Clarkdale, and re-ran the OASIS model using 2050 stream depletion projections under S1 and S2, and found the simulated median summer monthly average flow for the model link near Camp Verde. The results of the simulations are shown in Figure 15

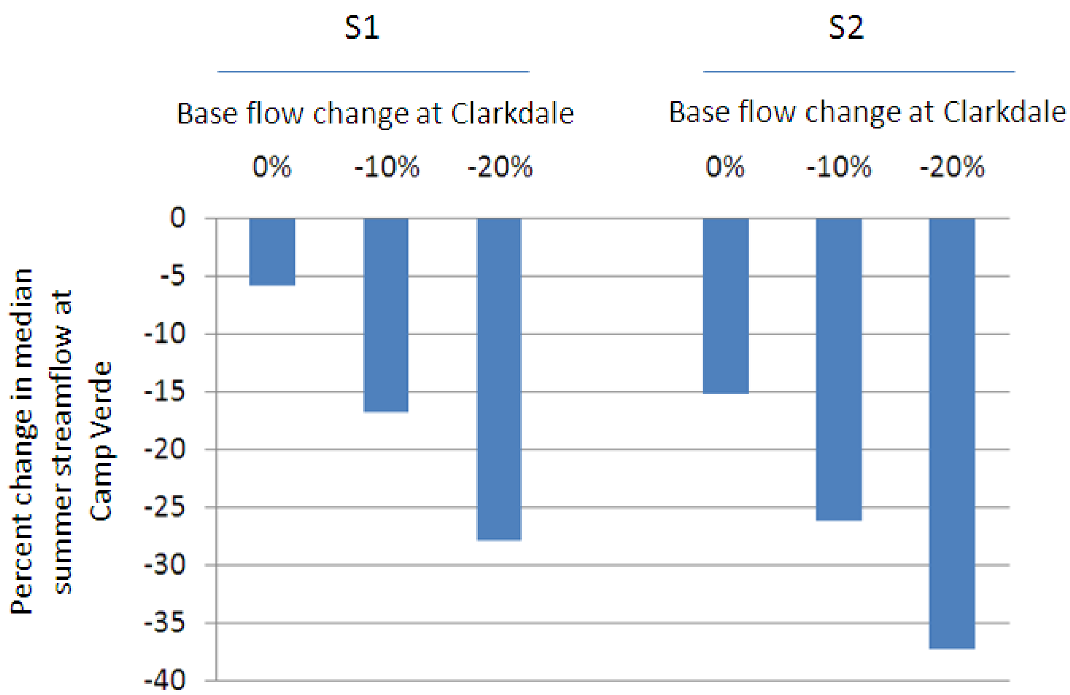


**Figure 15 Change in year 2050 median summer monthly streamflow at Camp Verde, AZ due to changes in upstream base flow received at Clarkdale, AZ**

The values depicted in Figure 15 represent changes in Verde River summer monthly flow at Camp Verde for the two groundwater withdrawal scenarios S1 and S2, and for various assumptions regarding changes in base flow received from upstream at Clarkdale. The 0% bars for S1 and S2 represent the results for "no change" in upstream base flow. The results are the same as those shown above in Figure 13(b) and 14(b), of a 5.75% reduction in Verde Valley flow under S1 and a 15.15% reduction under S2. The -10% bars represent changes to median summer monthly flow assuming 10% reduction in base flow received at Clarkdale from upstream. Under this assumption, S1 median summer monthly flow would be reduced by 16.83%, and S2 median summer monthly flow would be reduced by 26.23%. For a 20% reduction in base flow received from upstream at Clarkdale, S1 median summer monthly flow would be reduced by 27.91%, and S2 median summer monthly flow would be reduced by 37.31%. The analysis indicates that median summer monthly flow in the Verde Valley is sensitive to changes in base flow received from upstream.

### 1.3.3. Climate Change

The Verde Valley could experience additional streamflow reduction due to climate change. There is consensus that the southwestern United States is likely to become warmer and drier under likely climate change scenarios (Alexander et al. 2011). These conditions would combine less precipitation with increased evapotranspiration and are likely to result in decreased runoff and streamflow.

In a recent study, the Bureau of Reclamation projected how climate change will affect runoff changes in three sub-basins of the Colorado River watershed. Relative to a 1990s baseline, average annual runoff is projected to decrease by 3.5%, 8.5%, and 7.4% for the decade of 2050 in the Green River near Greendale, the Colorado River at Lees Ferry, and the Colorado River above Imperial Dam (Alexander et al. 2011). Christensen et al. (2004) studied potential effects of climate change on runoff in the Colorado River basin with results indicating an 18% decrease in annual runoff, relative to simulated historical runoff, during the period from 2040-2069.

Our analysis focused on the effect of growth and development and increased groundwater use in the Verde Valley on river flows. We did not analyze the effects of upstream pumping and climate change. However, each of these additional stressors are extremely likely to reduce flows in the Verde River in the near future.

### 1.3.4. Pre-2007 Pumping in the Verde Valley

An important limitation of the analysis presented here is that the streamflow depletions reported are those estimated to result from increased pumping that was initiated only after the beginning of the WAC (2008) database, in year 2007. Thus, this study focuses on only recent and future increases in pumping in the Verde Valley. Because of the potentially long lag time between pumping initiation and the arrival of effects in the river, there may be significant future streamflow depletion due to pumping that was started before 2007 and has not yet been observed in the Verde River streamflow record.

In order to test the potential effects, we performed an additional analysis for S1 and S2, assuming that all pumping recorded at the start of the WAC (2008) database was initiated in 2007. Because most, if not all, of the ongoing pumping reported in 2007 was initiated earlier, it is likely that some of the effects of this pumping are already present in the streamflow record. Assuming that all pre-2007 pumping is initiated in 2007 is likely to overestimate streamflow depletion in the projection, due to “double counting” of some streamflow depletion that may already be present in the observed streamflow record.

The assumption that all pumping begins in 2007 provides an upper-bound on the estimates of streamflow depletion due to pumping in the Verde Valley, by capturing all future streamflow depletion, regardless of when pumping was initiated, and by transferring any past streamflow depletion that may already be present in the streamflow record into the study period. The results are shown below in Figures 16 and 17. As expected, significantly larger streamflow depletions result.

Because of the assumption that all pre-2007 pumping was initiated in 2007, streamflow depletion due to post-2007 pumping in the Verde Valley is not expected to reach the levels shown in Figures 17a through 18b by 2050, however the information does suggest that observed streamflow depletion will be larger than the projections made above that were based only on future pumping increases that are projected in S1 and S2, shown below as dashed lines.

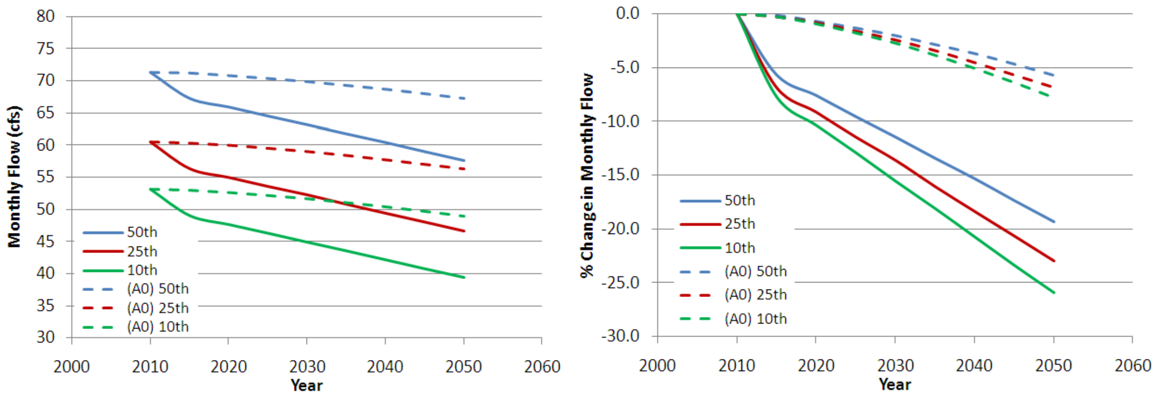


**Figure 16 (a) Projected median, 25$^{th}$, and 10$^{th}$ percentile summer monthly flow near Camp Verde, S1, and (b) percent change. (Pre-2007 pumping assumed to be initiated in 2007.)**

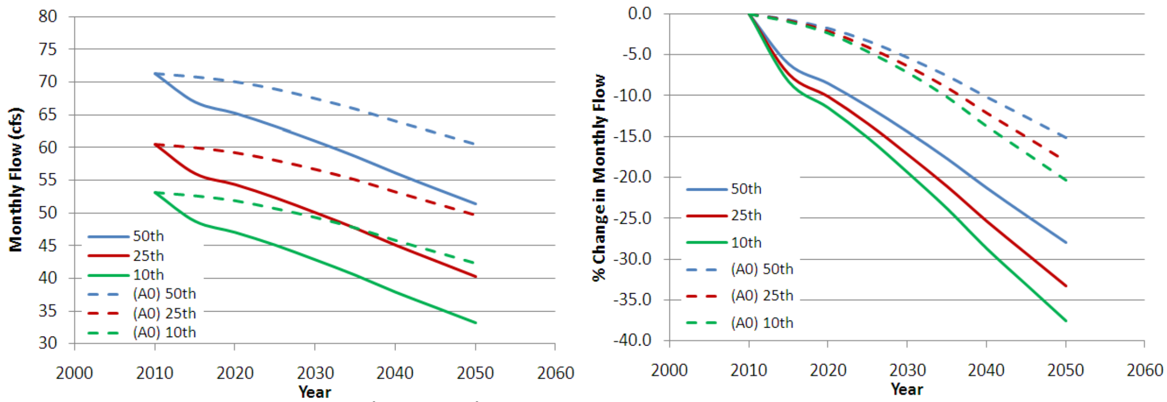


**Figure 17 (a) Projected median, 25$^{th}$, and 10$^{th}$ percentile summer monthly flow near Camp Verde, S2, and (b) percent change. (Pre-2007 pumping assumed to be initiated in 2007.)**

### 1.3.5. Changes in Ditch Withdrawals

The Bureau of Reclamation (2010) in CYHWRMS assumed generally that irrigation demand in the Verde Valley in 2050 would be two-thirds of 2006 demand. The simulation model analysis presented here assumed surface water withdrawals by the ditches remain the same during the study period. It is unclear whether a reduction in surface water used for irrigation would result in a reduction in ditch withdrawals, however a reduction of ditch withdrawals could represent a significant source of increased flow to the Verde River.

### 1.3.6. Streamflow Depletion Beyond 2050

Although the study period ends in the year 2050, additional streamflow depletion will continue in the decades following 2050. Under S1, groundwater withdrawal rate in the Verde Valley is expected to increase by about 7,900 acre-feet per year between 2007 and 2050. Under S2, the expected increase is 26,200 acre-feet per year. Eventually, all of the increased pumping will manifest as streamflow depletion.

The streamflow depletion projections of about 3,000 acre-feet per year for S1 and about 8,000 acre-feet per year for S2 by 2050 represent only a portion of the eventual streamflow reduction that is expected.

## 1.4. Water Management Alternatives

Four water management alternatives were considered for their potential impact on streamflow and economics in the Verde Valley. We chose management alternatives that are analogous to management approaches implemented in the case studies, to test how different alternative could affect flows in the Verde River. The first management alternative (A0) was chosen as a base case in which it is assumed that there is no change in current management approach:

- (A0) No change in current management approach.

The additional management approaches from the case studies can be summarized as:

- (A1) State-Level Regulation (Middle Rio Grande River Basin, New Mexico);
- (A2) Regulation with market-based trading (Deschutes River Basin, Oregon); and
- (A3) Regional water management institution (Edwards Aquifer, Texas).

### 1.4.1. Alternative A0: No Change in Current Management Approach

Under this scenario, the results shown in Figures 13 and 14 are applicable. Assuming no change in management approaches to development predicted by S1 and S2, a reduction of median summer monthly flows due to increased pumping in the Verde Valley is expected to be 5.75% under S1 and 15.15% under S2. Additional factors including reduction in upstream base flow, climate change, and pre-2007 pumping in the Verde Valley are likely to further reduce streamflow.

### 1.4.2. Alternative A1: State-Level Regulation

In New Mexico, water users must apply for a permit to drill a new well or increase pumping from existing wells. The State Engineer must approve all new pumping of groundwater. Under this type of system, the state has the authority to cap pumping expansion. If state-level regulation were applied in the Verde Valley, objectives of the regulation might be to limit drawdown in the regional aquifer and to mitigate streamflow decrease in the Verde River resulting from increased groundwater withdrawal.

In this management alternative, it is assumed that state-level regulation allows an increase in groundwater withdrawal of only 20% above withdrawals in the year 2007. In the Verde Valley, 2007 groundwater withdrawals were about 14,600 acre-feet per year. A regulation allowing an increase of 20% in pumping would cap annual withdrawal at about 17,500 acre-feet per year. At that level, under withdrawal scenario S1, limitation to development is projected to occur in the year 2021. For S2 the cap is projected to be reached in 2014. The capped pumping rates are compared with S1 and S2 in Figure 18(a). A comparison of projected streamflow depletion under the capped scenario is shown in Figure 18(b). Projected median, 25$^{th}$, and 10$^{th}$ percentile summer monthly flow and percent changes for S1 and S2 with a cap on pumping 20% above current levels are shown in Figure 19 and Figure 20. The cap on groundwater extraction is shown to reduce projected streamflow depletion in the Verde River.

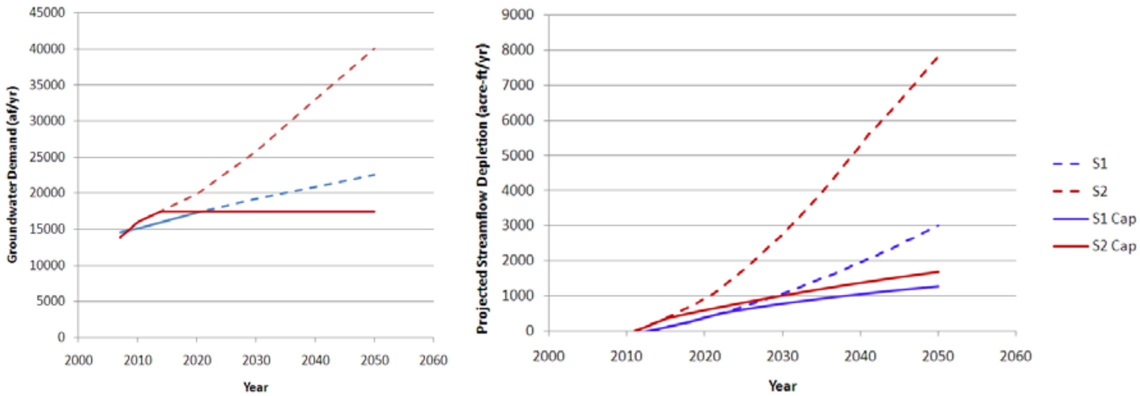


**Figure 18 (a) Capped pumping rates, Management Alternative A1, and (b) Projected annual streamflow depletion including cap scenarios**

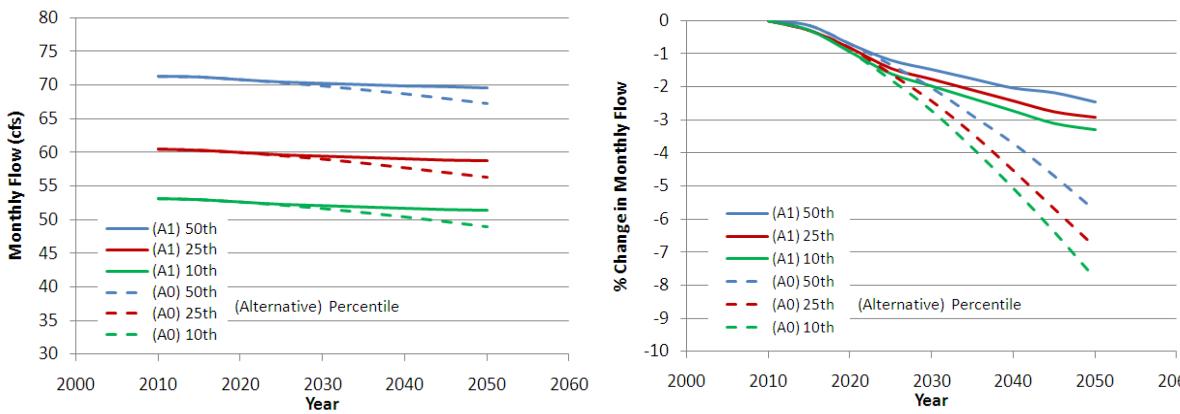


**Figure 19 (a) Projected median, 25th, and 10th percentile summer monthly flow near Camp Verde, S1 with cap at 20% increase, and (b) percent change**

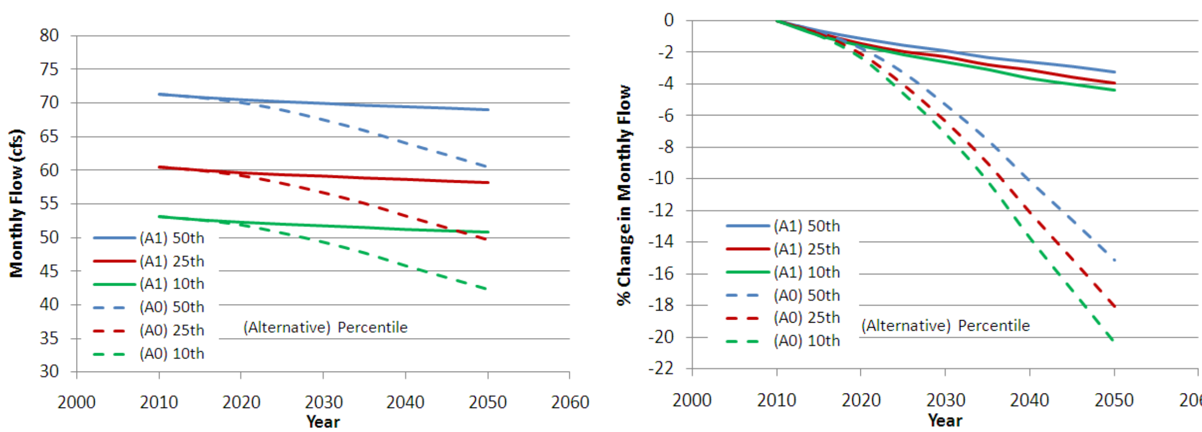


**Figure 20 (a) Projected median, 25th, and 10th percentile summer monthly flow near Camp Verde, S2 with cap at 20% increase, and (b) percent change**

Under a pumping cap scenario, flow reductions projected for the Verde River are substantially mitigated.

### 1.4.3. Alternative A2: Regulation with Market-Based Trading

The Deschutes River Basin has attracted a great deal of attention because water managers and policymakers have recognized the importance of dealing with groundwater to protect surface water flows. They have set up market-based strategies with the dual goal of providing for continued growth and maintaining a healthy river. In the Deschutes, flow standards were set and in-stream flow was given water rights. Under Oregon law, all wells must be permitted and permits cannot be issued for proposed wells that interfere with existing water rights.

The introduction of a market mechanism in a capped system enables trades, sales, and leases of water, and is intended to make water use more economically efficient under a new, stricter regulatory environment.

Assuming that the cap on groundwater withdrawals from A1 is retained, transfers among users could ease the limitations to growth that are anticipated. In terms of streamflow depletion, the results of alternative A2 would be nearly the same as A1. If pumping were stopped at one location to transfer rights to another, there would be no net change in pumping. Although a groundwater extraction location change would change the streamflow depletion response curve from Leake and Pool (2010), it is assumed that on average these location transfers would have little effect on streamflow depletion. Similarly, if surface water withdrawals were sold to residences rather than applied to fields, the calculation of streamflow would remain unchanged.

### 1.4.4. Alternative A3: Regional Water Management Institution

The creation of a water management district by the governments of the Verde Valley could represent a valuable first step in finding a local solution to water resources issues.

In the Edwards Aquifer case study, the Edwards Aquifer Management Authority has the authority to grant permits, to enforce water conservation during periods of drought, to collect fees, and to undertake improvement projects such as recharge programs and effluent reuse facilities.

In the Verde Valley, a district could be instituted to have authority to reduce withdrawals equitably among rights holders during times of drought. Additionally, the district could have the authority to collect revenues through a tariff structure based on type of use and quantity of water used. These funds could support paid district staff that administer a water market, and collect water management-related data. The funds could also support improvement projects.

Improvement projects could include recharge facilities, effluent reuse programs, and efficiency programs aimed at improving the productivity of consumed water. Improved stormwater capture and effluent reuse might also be used to create additional water rights that, when sold, could defray costs of the projects.

A district with a more limited role might also be valuable. A key limitation to future management of water in the Verde Valley is the lack of adjudicated rights. Without certainty over ownership, it is difficult for efficient or sustainable decisions to be made.

It is likely that any viable solution to water management in the Verde Valley will need to be based on informed, cooperative decisions among the interested parties. In working toward this goal, a water management district could be instituted by joint action of the Verde Valley governments with the mission of data collection and documentation. The district could be funded jointly by Verde Valley governments to a level that is commensurate with its mission. The knowledge-base developed by the district might serve as a foundation for a locally organized water rights negotiation process. Ideally, the generation of local consensus on fair allocation of water rights could serve as a locally derived basis for state-level adjudication.

With a primary mandate to collect data and information, the water management district could be instituted to

- meter and maintain a database regarding water withdrawals; and
- measure streamflow in the Verde River between Clarkdale and Camp Verde.

By having shared information on withdrawals, Verde Valley governments will be more informed when negotiating joint solutions and when making water management decisions. Data collected on streamflow changes over time between Clarkdale and Camp Verde will be useful to confirm or adjust streamflow depletion estimates and to understand how development patterns and water use are affecting instream flow. In time, the information developed by the district could serve as part of a transparent, consensus driven, local water rights allocation process.

It will be important that individual parties in the Verde Valley organize and cooperate with each other to manage water not only for individual goals, but also for a collection of goals and values that will benefit the region as a whole. These goals could include livelihoods, economic development, maintenance of environmental resources, and providing for the future. In its 2004 report, the Yavapai County Water Advisory Committee stated that, of the alternatives they studied, integrated management is likely to have the highest degree of success in achieving these goals, but the approach will be challenging to implement (WAC 2004). The formation of a district that is charged with the collection of data could be a first step in building the institutional infrastructure, cooperation, and information necessary to work toward integrated water resources management objectives.

## 1.5. Conclusions

Under the S1 mid-range growth scenario, increases in groundwater withdrawal are projected to cause annual flow volume in the Verde River to decrease by about 3,000 acre-feet by 2050. Under S2 high growth scenario, increases in groundwater withdrawal are projected to decrease annual flow volume in the Verde River by almost 8,000 acre-feet by 2050.

For S1, increases in groundwater withdrawal are projected to cause median summer monthly flow to decrease by about 6 percent near Camp Verde by 2050, and under S2, increases in groundwater withdrawal are projected to decrease median summer monthly flow by about 15 percent near Camp Verde by 2050.

Larger decreases in streamflow are likely to be observed in the future. Potential additional causes for streamflow depletion include reduced inflow to the Verde Valley due to groundwater extraction in the Big Chino and Little Chino basins, climate change, and the arrival of effects caused by the initiation of pumping in the Verde Valley prior to the beginning of the study period. Without reduction of groundwater pumping, additional streamflow depletion in the years following 2050 may also be expected.

## 1.6. References


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# 2. Economic Analysis

A variety of uses of the Middle Verde River are supported by surface water or hydrologically-connected groundwater. Each water use contributes economic value, as well as social and environmental value, to the Verde Valley. Loss of flows in the Verde River and a lowering of the water table can adversely affect these economic values. This economic analysis estimates the value of those water uses and the sensitivity of those values to changes in water availability.

## 2.1. Study Approach

The two main objectives of the economic analysis were to:

1) Estimate the value of uses of the Middle Verde River and its related groundwater system, and estimate the change in value of those uses from potential reductions in water resource availability or accessibility over time

2) Gain insights about how water resource management options may affect the economic value derived from the Verde River

This study estimates the value of the water-related resources of the Middle Verde River. This is done by relying on estimates from local data or local studies, to the extent possible, and supplementing that information with estimates from similar situations in the Western United States when necessary.

Many resources and values in the Verde Valley would not exist without the Verde River. However, to narrow the focus, the study concentrates on economic values that:

1) Are the largest water-related values

2) Are most sensitive to changes in flow or changes in groundwater levels

3) For which quantitative valuation is feasible given available methods and data

## 2.2. Types of Value: Market and Nonmarket

### 2.2.1. Traditional, Commerce-Oriented Values

Economic value at a community level can be described in many ways, but traditionally it is quantitatively measured only through a few basic statistics. In this report, we start with the traditional measures, and then add additional values where feasible and suitable for the purpose of examining how changes in water resources for the Verde Valley may impact economic values for the community that are closely related to use of the Verde River and related groundwater system.

Economic activity typically is measured as "gross product" which can be derived from data observed from market transactions, such as sales or income. This is a reflection of the value of commerce conducted within a given area, within a given year. At the national level, this type of measure is referred to as Gross National Product (GNP), which also is referred to as Gross Domestic Product (GDP), and it reflects the net value added or final demand for the outputs generated in a year.

The regional counterpart to GNP is Gross Regional Product (GRP), which is estimated at the county-wide level. For Yavapai County as a whole, GRP was reported as approximately $4.5 billion for 2009 (MIG, Inc. 2011). No statistics are available on GRP for the Verde Valley portion of the county. As an approximation, one can allocate a share of this county-wide estimate to the Verde Valley based roughly on the share of county population (on the order of 30%), and deduce that the level of economic activity in the Verde Valley probably amounts to approximately $1 billion to $1.5 billion per year.

Within this measure of economic commerce, some specific businesses and activities provide a large share of the total value. For example, in economically strong years, the Salt River Materials Group Phoenix Cement Plant in Clarkdale generates product sales with a value of approximately $100 million and employs approximately 150 to 180 people in those good years (personal communication Gregg St. Clair, Salt River Materials Group, 2011).

In addition, expenditures made in the Verde Valley by tourists and recreational visitors for activities closely related to water use on the Verde River amount to $87.5 million per year just for those using the state parks, national monuments, fishing sites, and the Verde Canyon Railroad (as detailed below). The total value of tourism in the Verde Valley is much higher when we consider values not closely linked with the Verde River. And even for those closely associated with the Verde River and its related groundwater system, the total value of tourism resources probably amounts to a considerably higher amount when other activities such as birding are also factored into the accounts (they were not included here due to a lack of available data on local visitation).

Further, spending locally by those visiting from outside the Verde Valley provides an indirect or induced economic boost to the local economy. This is sometimes referred to as an economic multiplier, and arises when those residents with incomes increased by tourism expenditures in turn spend some of their additional earnings on other locally provided goods and services. A regional economic model (IMPLAN) generates an estimate of $16 million in multiplier effects from the $87.5 million in direct tourism and recreation expenditures, and creation of 737 jobs just from the tourism and recreation expenditures closely related to Verde River use for which we had data.

### 2.2.2. Values beyond Commerce: Nonmarket Values

Based on the above, it is evident that the Verde Valley's natural resources contribute significantly to the economic vitality of the region. While commerce is important, there also are other important values held by the community that are not reflected in the traditional economic activity metrics.

These values include the enjoyment of the natural aesthetics and outdoor activity opportunities afforded by the Verde River and other natural features of the region. The value of visual amenities and access to quality water-based and other recreational opportunities (for example boating, fishing, wildlife observation, hunting, biking) provide considerable value to many local residents, but are not included in the traditional economic metrics such as GRP because there are no direct market transactions to track and measure.

These “nonmarket” values are important to many residents, and may be referred to generally as an indication of the “quality of life” enjoyed by those residing in the Valley. Economists can use nonmarket valuation techniques to estimate the monetary worth of some aspects of these values . For example, recreational demand models, such as travel cost techniques, can be applied to deduce the economic welfare or utility enjoyed by recreational anglers, and hedonic value models can be applied in some instances to estimate the monetary impact of visual amenities on increasing local residential property values. However, such techniques are expensive, data intensive, and time consuming to apply. As such, we cannot provide monetary estimates for the quality-of-life values that residents derive from the Verde River and other water and natural resources in the Verde Valley, but it is important to recognize these values exist and may be considerable.

Another nonmarket value pertains to the ecologic value provided by the aquatic and riparian habitat offered by the Verde River and its environs. Ecologic services include support for both common and rare types of flora and fauna, including threatened and endangered species. Some of these ecologic values can be roughly approximated (as described below) using various proxy measures for what economists refer to as nonuse values (which may include bequest and stewardship values reflecting a desire to preserve species and ecosystems for future generations). While difficult to measure with confidence, residents and non-locals may collectively assign considerable value to the Valley’s nonmarket ecologic services.

## 2.3. Economic Analysis of Baseline Value and Loss of Value Due to Change in Water Resource Availability

The Verde River and its waters are used for many things. This include agriculture, recreation and tourism, municipal use, residential use through wells, commercial and industrial uses, and ecological values.

### 2.3.1. Agriculture

Agriculture in Yavapai County is generally comprised of production agriculture (crops or livestock sold to the market), as well as organic and other crops produced and sold directly to the public at roadside stands and an expanding wine industry.

#### *2.3.1.1. Production Agriculture*

Approximately 30 irrigation associations have been reported to divert surface water in the Verde Valley (ADWR 22009). Pasture was reported by the Arizona Department of Water Resources to be grown on about two-thirds of the irrigated land. Other crops included alfalfa, corn, wheat, vegetables, and orchards (ADWR 2000).

**Verde Valley farms.  Photo courtesy of Dan Campbell.**

Bureau of Economic Analysis data indicate that from 2002 to 2008 average sales of crops and livestock in Yavapai County was $54.3 million. Average sales from livestock and livestock products accounted for a majority of that total, at $47.6 million (Bureau of Economic Analysis 2010).

Also included in the reported overall sales of crops and livestock in Yavapai County is local sales of organic and other locally grown produce. Direct sales in 2007 in Yavapai County totaled $541,000. Direct sales increased by 140% from 2002 to 2007, with a 6% increase in the number of farms. (Bureau of Economic Analysis 2010), Thus, direct sales have a relatively small monetary benefit compared to the rest of agricultural sales in the county. However, direct sales have important noneconomic benefits. The growth of these sales helps preserve open space and agricultural heritage, values supported by many community members.

Yavapai County ranchers and farmers sold $54.3 million of food commodities per year (2002-2008 average) but spent $59.5 million to raise them, losing an average of $5.2 million in production costs each year. These reported losses may help explain why agricultural water use is expected to decline into the future.

Available data on crop acreage as of 2000 was used to apportion Yavapai County sales (and expenses) to the Middle Verde study area. ADWR 2000 provides a breakdown of agricultural acreage and water use as of 2000. Acreage in the Williamson Valley, the Big Chino Valley, and the Middle Verde totaled 9,164, with just over 32,000 acre-feet of water use. The Middle Verde share of acreage was 59% and the Middle Verde share of water use was 53%. This share of water use was used to apportion the value of overall production agriculture sales in Yavapai County to the Middle Verde. The Middle Verde share of overall sales was computed to be $29 million per year in sales ($33 million in expenses).

#### *2.3.1.2. Wine Industry*

The wine industry in the Verde Valley is growing rapidly. The first vineyard was established in 2000, and sales have been estimated to double for each of the last three years as the number of vineyards and wineries has expanded. As of 2011, there were 14 vineyards, 13 wineries, and 10 tasting rooms in the Verde Valley (Glen 2011). Winemaking is concentrated in the Page Springs area, Cottonwood, and Jerome.

**Alcantara Winery. Photo courtesy of Dan Campbell.**

Direct sales in fiscal year 2009-2010 were estimated to total $5.5 million. This includes the sale of grapes or juice to wineries; wine sales in tasting rooms, direct-to-consumer sales of wine (through tasting rooms, by internet/mail, or other methods); sales to wholesalers; sales to retailers; sales of non-wine products; special events; custom-crush fees; vineyard management fees; and other revenue sources (Glenn 2011).

Total expenditures in fiscal year 2009-2010 were estimated to be greater than direct revenues. This is expected for an industry that is rapidly expanding and is making the expenditures necessary to support that growth. Expenditures totaled approximately $9.4 million, with approximately $2.0 million in the form of payroll, $6.6 million in expenses paid to other businesses, and approximately $0.8 million total in local, state, and federal taxes (Glenn 2011).

In addition to the $5.5 million in direct output value, the local wine industry's sales are estimated to provide an additional regional economic impact of $3 million per year. This is based on how wine industry sales stimulate spending in the local economy—"indirect effects" from winemakers' spending with their suppliers and "induced effects" from spending in the economy by winemakers' employees. Indirect economic effects were measured using the IMPLAN model (Glenn 2011).

Total statewide contributions from the wine industry were calculated to be almost $25 million, including direct revenue and its multiplier effects from "backward linkages" in the economy to industry suppliers, local forward linkages though affiliated industries such as wholesale trade or groceries stores, other local tourism through visits to tasting rooms, and economic contributions to other counties in Arizona (Glenn 2011).

### 2.3.2. Recreation and Tourism

Recreation and tourism is a growth sector in the Verde Valley. There is a wide variety of recreation and tourism resources in the Valley. This report concentrates on some of the high-value resources for which estimates of value were available. Those resources include Arizona State Parks, National Monuments, fishing on the Verde River and its tributaries, and the Verde Canyon Railway. Together, these resources generate more than $87.5 million in direct revenues per year. A summary of the benefits from each recreation and tourism resource is shown in Table 3. Estimates for each resource are detailed below.

**Table 3 Summary of recreation and tourism direct expenditures/sales, regional economic impact, and employment (millions of 2010 dollars, except where noted)**

| Category | Annual Direct Expenditures/Sales, $M | Multiplier Effect, $M | Employment (persons) |
|---|---|---|---|
| State Parks | 35.3 | 14.0 | 575 |
| National Monuments | 33.7 | | |
| Fishing | 8.0 | 2.0 | 112 |
| Boating | 0.5 | * | |
| Verde Canyon RR | Approx. 10 + | * | Approx. 50 |
| Total | **87.5 +** | | **737** |

* Not estimated.

#### *2.3.2.1. Arizona State Parks and National Monuments*

The state parks on the Verde River and its tributaries include Dead Horse Ranch State Park on the Verde River and Red Rock State Park and Slide Rock State Park on Oak Creek. Expenditures by visitors from outside of the area were reported in a study of Arizona state parks conducted in 2007 by Northern Arizona University (NAU). This study reports expenditures associated with visits to state parks by non-local residents (i.e., residents from outside of Yavapai County and residents living more than 50 miles from the park). Although the study was published in 2009, as noted, the expenditure data reported in the study are based on a survey conducted in 2007. To account for this, we adjusted the expenditure data based on the percentage change in total visits to each park from 2007 to 2010. For this exercise, we used visitation data compiled by the NAU Arizona Hospitality Research and Resource Center (AHRCC). Table 4 shows direct expenditures for the applicable state parks in 2010 dollars and using the number of visits from 2010.

**Dead Horse Ranch State Park. Photo courtesy of Dan Campbell.**

**Table 4 Annual direct expenditures by visitors to state parks (millions of 2010 dollars)**

| State Park | Expenditure, $M |
|---|---|
| Dead Horse Ranch | 8.7 |
| Red Rock | 8.3 |
| Slide Rock | 18.3 |
| Total | **35.3** |

There are two national monuments in the area: Tuzigoot National Monument and Montezuma's Castle National Monument. Visitation and expenditure data for these two monuments were obtained based on information collected as part of the 2009 study *Economic Benefits to Local Communities from National Park Visitation and Payroll* (Stynes 2011). These data were adjusted to 2010 values by the author of the study and supplied directly for this study. Expenditure surveys were not conducted at these specific locations, but expenditures were estimated based on data from similar sites. Only non-local spending is included in the analysis. As shown in Table 5, expenditures by non-local site users total $33.8 million for the two monuments combined.

**Table 5 Direct expenditures by visitors to national monuments (millions of 2010 dollars)**

| National Monument | Expenditure, $M |
|---|---|
| Tuzigoot | 5.1 |
| Montezuma's Castle | 28.7 |
| Total | **33.8** |

We calculated the regional economic impact of spending at state parks and national monuments by entering data on direct expenditures into using IMPLAN. This is an economic model that can estimate economic multipliers for any geographic region and then calculate the consequences of projected economic transactions within that region.

We mapped the specific spending categories to the appropriate economic sectors using IMPLAN. We did not include expenditures related to park admission fees or camping, as these expenditures result in revenues for the state or federal government, not the local economy (and it is not clear how or where these revenues are re-spent). Expenditure data were then input into IMPLAN to gauge the effect of changes in expenditures on the local resource. The IMPLAN analysis shows that 575 jobs are associated with visitation at state parks and national monuments and the additional regional economic output associated with these parks is $16.6 million.

#### *2.3.2.2. Boating on the Verde River*

The Middle Verde River supports boating with kayaks, canoes, and inner tubes. Boating the river requires knowledge of river access points and river flow levels. A local company called Sedona Adventure Tours provides that local knowledge through guided and unguided boat trips and tubing. Statistics on boating on the Verde River not associated with Sedona Adventure Tours were not available, but boating counts are expected to be relatively small. Sedona Adventure Tours serves approximately 6,800 customers per year, 90% of which are for river-related trips, which include include:

- Verde River kayak trips are guided trips down the Verde River from Clear Creek River Access Point to Beasley Flats Recreation Area. Single and double kayaks are available to accommodate adults and children. A shuttle from Sedona, bottled water and snacks are provided.

- Water to Wine tours combine a kayak trip on the Verde River with wine tasting at Alcantara Vineyards. The river trip lasts an hour and a half and ends near the Alcantara property. Wine tasting is also about one and one half hours. A shuttle from Sedona is provided.

- Unguided tubing trips are also offered. Tubes and water cannons can be rented for a floating down the Verde River from Clear Creek River Access Point to Beasley Flats Recreation Area. A life jacket and helmet are available to rent. The float takes one to two hours.

- Unguided kayak rentals are also offered. Participants are provided with kayaks, paddles, and life jackets. Helmets are optional and water cannons are available seasonally. Participants are shuttled up to Clear Creek River Access Point and float down the Verde River to Beasley Flats Recreation Area. The float takes two hours to four hours.

**Boating on the Verde River. Photo courtesy of Jeanmarie Haney.**

Revenue from water-related trips run by Sedona Adventure tours is estimated to be approximately $500,000 per year. This estimate does not include an estimate of how many of the Water to Wine tours are actually Grand Water to Wine Tour version, which cost $10 more for a more extensive trip. This may be balanced somewhat by the fact that we assumed that all trips are paid at the adult price, but children's trips are $10 less for Verde River trips.

### *2.3.2.3. Fishing on the Verde River and Tributaries*

The Middle Verde River and its major tributaries, including Oak Creek, Wet Beaver Creek, and West Clear Creek, provide an important fishing resource to the Verde Valley. The Verde and its tributaries include over a dozen species introduced for sport fishing, including trout, catfish, sunfish, and bass.

To estimate the economic impact, we relied on visitation and expenditure data collected by the Arizona Department of Game and Fish as part of the 2001 report *The Economic Importance of Fishing and Hunting in Arizona* (Silberman 2001). Information collected as part of this report includes visitation data (angler days) to different fishing areas in the state, including specific reaches on the Verde River. Specific reaches utilized included: Oak Creek Upper and Lower Reaches, Dead Horse Lake, Verde River Camp

Verde Reach, West Clear Creek and Wet Beaver Creek. The number of local versus non-local visits was also reported for each county in the state.

First, we determined total angler days (by both local and non-local residents) for applicable Verde River reaches. We then applied the ratio of local versus non-local fishing visits estimated for all of Yavapai County (local versus non-local visits was not reported for individual reaches). Based on these data, we estimated that there were about 63,800 visits (angler days) by non-locals to affected reaches in the Verde River Valley in 2001 (the year the report was conducted). Due to lack of additional information, we assumed that the number of visits remained relatively stable over time.

Next, we adjusted the fishing expenditure data reported to better fit the affected sites. For example, we excluded expenditures associated with motorboat maintenance because there is very little motorboat activity at these sites. after this adjustment, our estimated expenditures per angler day amounted to $168 compared to the unadjusted estimate derived from the report of $192 (adjusted from the report's 2001 dollars to 2010 dollars based on the consumer price index). When multiplied by total estimated angler days at the affected reaches, the total direct spending associated with fishing activity by non-local residents amounts to more than $10.7 million.

To adjust for possible double-counting between fishing expenditures and expenditures at Dead Horse Ranch State Park, in which the same overnight expenses might be accounted for twice, the direct revenue from fishing was adjusted downward by 25%, to $8 million per year.

According to regional economic analysis using IMPLAN, spending on fishing in the Verde Valley supports 112 jobs, provides $3.4 million in wages, and provides a regional economic output associated with fishing of approximately $2.6 million. As with the direct spending estimates from fishing, we adjusted the regional economic output estimate from fishing downward by 25% to account for potential double-counting with Dead Horse Ranch State Park, resulting in an estimate of $2.0 million.

#### *2.3.2.4. Verde Canyon Railway*

The Verde Canyon Railway provides four-hour round-trip scenic tours through the Verde Canyon along the Verde River. The railway serves approximately 100,000 riders per year. An online estimate sets revenue for the Verde Canyon Railway at more than $10 million per year, with approximately 50 employees (Manta 2011).

### 2.3.3. Municipal and Residential Use

The municipal and residential sector is the largest use of groundwater in the Verde Valley. This includes publically owned water utility systems such as Cottonwood, Clarkdale, Sedona, and Jerome, as well as privately owned public water systems and residential private well use (exempt wells).

Two approaches were taken to frame the value of baseline residential water use. First, a range of price per thousand gallons from rate structures for the City of Cottonwood and Town of Clarkdale were used to calculate a range of total costs paid every year by all residential water users. Both the City of Cottonwood and the Town of Clarkdale have increasing block rate structures, whereby water users pay more per thousand gallons for using greater amounts of water during a billing period. Clarkdale volumetric rates range from $4.35 per thousand gallons for the first block up to $9.60 per thousand gallons for the top (7th) block. Volumetric rates for the City of Cottonwood range from $3.13 per thousand gallons for the first block up to $6.13 per thousand gallons for the top (3rd) block. Use of a range of $1,500 per acre-foot, which is roughly $4.60 per thousand gallons, to $2,000 per acre-foot, which is roughly $6.15 per thousand gallons, gives a range in value from $13.1 million to $17.5 million when multiplied by roughly 26,500 households for all water systems and exempt wells.

The second approach utilizes values documented in the peer-reviewed economics literature. These studies have surveyed the willingness-to-pay of residents in various locations in the Western United States in order to secure reliable water supplies (i.e., this reflects household annual values to avoid situations where water shortages are severe enough to result in significant water use restrictions being imposed). Values from the literature range from $1,660 to $4,720 per acre-foot (after adjustment to 2010 dollars) (Michelson, McGuckin and Stumpf 1998; Griffin and Mjelde 2000; as interpreted in Raucher et al. 2005). Use of the low end of the range from the literature to conservatively correspond to the least-severe shortage conditions gives a value of $14.5 million per year. This value falls within the range of values derived from the cost-based approach described above, which ranges from $13 million to $17.5 million based on water rates. We used this range of values to represent the baseline value of residential use. Additional value is derived from non-residential use for public water systems, but this value is small in comparison. (For instance, approximately 80% of Cottonwood water system use is single-family residential).

### 2.3.4. Commercial and Industrial Use

This study concentrates on the largest water users in the commercial and industrial sectors in the Verde Valley. For commercial water use, the largest water users are golf courses. The data on groundwater use by golf courses show they accounted for 8% of total estimated groundwater use in 2010.

The largest industrial users in the Verde Valley are cement and construction aggregate companies. Data on these groundwater users show that they accounted for about 5% of estimated groundwater use in 2010.

Data on commercial and industrial revenues were not readily available due to the proprietary nature of the information. There is evidence, however, that the annual value of industrial operations is large. In a year with normal demand, the Salt River Materials Group Phoenix Cement Plant in Clarkdale has revenue of approximately $100 million and employs 150 to 180 people (personal communication Gregg St. Clair, Salt River Materials Group 2011).

### 2.3.5. Ecological Resources

There are a wide variety of ecological resources associated with the Verde River ecosystem. The river supports a wide variety of wildlife, including thousands of breeding birds; native fish; aquatic mammals such as beavers, otters, and muskrats; desert eagles; and many other species. The river has 10% of the rare cottonwood-willow forest type.

This study uses values associated with threatened or endangered species to represent the value of ecological resources. Listed species include the bald eagle, the Southwestern willow flycatcher, the spikedace, the razorback sucker, the loach minnow, and the Gila chub. Candidate species include the Roundtail chub and the Yellow-billed cuckoo.

Two different approaches might be used to gain an understanding of the value of threatened or endangered species. These approaches are not directly comparable, but both provide some evidence of the value of the resource for which there is no formal market in which values can be observed. First, examples of programs to restore habitat and protect endangered species in other locations in the Western United States can indicate the potential cost of species recovery or habitat restoration programs for the Verde River. Costs associated with maintaining or enhancing a resource should be considered a lower bound of the total value of a resource. Second, values from the peer-reviewed economics literature regarding the public's willingness-to-pay to protect threatened and endangered species can be applied to the Verde River.

For the endangered species recovery programs, we noted examples from the Rio Grande in New Mexico and the Deschutes in Oregon. The Middle Rio Grande Endangered Species Collaborative Program (MRGESCP) is designed to protect and improve the status of endangered species along the Middle Rio Grande of New Mexico while simultaneously protecting existing and future regional water uses. Program activities include water acquisition and management, habitat restoration, endangered species monitoring, and silvery minnow propagation. The MRGESCP spent approximately $130 million from FY2001 to FY2009, or approximately $16.3 million per year. The Middle Rio Grande covers approximately 160 miles from Cochiti Dam to Elephant Butte Reservoir. Thus, the yearly restoration cost is approximately $102,000 per mile.

There are many potential uncertainties and problems associated with extrapolating cost-per-mile estimates derived from one location to another, including that the market for water purchases is almost certainly different in the other location and that the extent and type of any riparian habitat restoration would likely be different. However, if the cost-per-mile from the Middle Rio Grande were applied to the 61 miles of the Middle Verde River, the cost of restoration on the Verde would be approximately $6 million per year.

Another example of an endangered species recovery program in the Western United States comes from the Deschutes River Basin. The Deschutes is part of the larger Columbia River Basin, where efforts are underway to preserve threatened and endangered fish such as salmon, steelhead, and bull trout. The Deschutes River Consortium (DRC) has paid a total of approximately $52 million from its inception in 1998 to 2010 for water leasing, conservation, and transfers in the Deschutes Basin. This spending applies to the whole Deschutes Basin, but concentrates on the middle Deschutes and its tributaries. This total does not include spending on riparian habitat work that is also part of the effort to support threatened and endangered fish (personal communication to Bruce Aylward by Scott McCaulou, DRC Program Director 2011). If the $52 million expenditure was divided over 13 years of DRC existence and by approximately 50 total miles of the Deschutes River, the yearly cost would be about $80,000 per mile. While this cost-per-mile calculation is very rough given that total miles for the Deschutes does not match the miles in the middle Deschutes (which is 31 miles on the mainstem) and its tributaries, and does not include spending on riparian restoration, it potentially indicates that costs in the Deschutes may be roughly of the same order as costs in the Middle Rio Grande.

The second approach to valuing endangered species of the Verde River is to explore a range of values from the economics literature. This approach better reflects the full value that households may have to protect a resource. A review of studies on protecting special status species showed that bids per household ranged from a low of $8 to protect non-salmon endangered species up to $157 to protect salmon in the Pacific Northwest (Raucher et al. 2006) (adjusted to 2010 dollars). Bids to protect salmon were consistently higher than for other species, and so they were removed from the range to be used in this study. after this adjustment, bids to protect endangered species from the literature (after updating to 2010 dollars) range from:

- $8.33 per household to preserve the striped shiner (from Wisconsin, state listed as endangered but not federally listed) (Boyle and Bishop, 1987) to
- $12.40 per household for the federally listed endangered Colorado pike minnow in New Mexico (Cummings et al. 1994). This species is one of the species listed in the Verde.

The choice of which households might be willing to pay for endangered species protection in the Verde Valley, and for ecological values there in general, depend on the expectation about the location of the households that will benefit. Research has shown that willingness to pay declines gradually with distance away from the site, but that those within several hundred miles of a site hold significant value (93% of total) and even residents at the opposite coast can hold 80% of the full estimated value depending on the profile of the resource being valued (Loomis, 1996). And, while visitation to the Verde Valley is not necessary for households to value ecological resources in the Verde Valley, the Verde Valley Tourism Survey (AHRRC 2008) shows that visitors to the Verde Valley come from many different locations spread throughout the state of Arizona, and from almost every state in the nation.

We estimated the number of households in Yavapai County and surrounding counties using 2009 population estimates from the U.S. Census Bureau. We used county-level estimates of number of households that are tabulated in years between the decennial census, and the number of persons per household from the 2000 census (U.S. Census Bureau 2010). Multiplying values per household from the literature by an estimated 1.75 million households in counties surrounding and including Yavapai County creates a range of value from $14.6 million to $21.8 million per year. To understand the sensitivity of this calculation to the selection of geographic extent of households, two sensitivity analysis calculations were made. If applied only to over 90,000 Yavapai County households, the value ranges from $771,000 to $1.15 million. If applied to an estimated 2.5 million households in Arizona, the total value ranges from $20.8 to $31.0 million.

### 2.3.6. Summary

Table 6 shows a summary of the economic values for these sectors described above. The current annual value is estimated for each use when possible. Sensitivity to streamflow is listed for each surface water use. The potential change in annual value based on projected change in streamflow or groundwater levels is shown in the last column. Potential changes in economic values for these uses are discussed in detail below.

**Table 6 Summary of economic values from the Middle Verde River (annual values, millions of 2010 dollars)**

| Sector | Current Annual Value, $M |
|---|---|
| Recreation and Tourism | 87.5* |
| Production Agriculture | 29 |
| Wine Industry | 5.5* |
| Municipal/Residential | 13–17.5 |
| Commercial/Industrial | ** |
| Ecological | 15–22 |
| Total | **150–161.5 +** |

M = millions

* In addition to direct values, there are multiplier effects for these sectors.

** Commercial/industrial values are generally believed to be large but cannot be estimated given the difficulty in locating information.

## 2.4. Estimates of Changes from Baseline Values due to Water Resource Impacts

The values outlined in the preceding section can be affected by changes in streamflow or groundwater level declines. This section describes estimates of the sensitivity of streamflow and groundwater levels to groundwater pumping in the Middle Verde, and then discusses the sensitivity of the economic value of water uses to those changes.

### 2.4.1. Effect of Groundwater Pumping Over Time in the Verde Valley on Streamflows

As discussed in the Section 1.2 of this study, the effect of groundwater pumping on surface water resources in the Verde Valley was modeled from 2006 to 2010 to match the time period for the groundwater scenarios. The modeling shows that groundwater pumping will deplete median streamflows (those that occur 50% of the time) in the Verde River over time. Scenario S1 is projected to deplete median streamflows by up to 6% by the year 2050 and S2 up to 15% by 2050. The analysis is likely to underestimate streamflow depletions over this time frame for two reasons. First, pumping from several decades prior to 2006 is omitted in the modeling and, due to the long time required for groundwater pumping to result in effects on surface water flows, that pumping is expected to result in additional streamflow depletions over the study period that currently are not represented. Secondly, pumping in the Little Chino Basin and Big Chino Basin was not included in the analysis. Only pumping from the Verde Valley was included. To the extent that increased pumping in the Little and Big Chino basins affects the headwaters of the Verde River, further streamflow depletions in the river over time would be expected.

### 2.4.2. Sensitivity Rating for Changes in Streamflow and Groundwater Levels

Different uses of the river have different sensitivities to streamflow. Some uses, especially those that involve direct instream use of the water (e.g. boating or fishing), may be directly affected by changes in streamflow. In contrast, other activities, such as near-stream uses including hiking, may only see modest impact from reductions in instream flows. The sensitivity of water uses to changes in river flow was represented on a three-point scale:

0 = no sensitivity

1 = low sensitivity

2 = medium sensitivity

3 = high sensitivity

To calculate the overall impact, this sensitivity rating was multiplied by the percent reduction in median streamflow for the demand scenario under consideration (S1 = 6%, S2 = 15%). For example, if a use is given a low sensitivity rating, then it is assigned a 1 out of a maximum rating of 3. The ratio of the sensitivity rating to the maximum sensitivity rating (1/3) is then multiplied by the percent reduction in streamflow for the scenario under consideration. Under S2, the percent reduction is 15% and the ultimate overall impact is 5% (1/3 * 15% = 5%).

While some uses depend on surface water availability, others depend on groundwater. The most recent reported evidence of the rate of groundwater declines in the Verde Valley is 1.75 feet per year as measured in the City of Cottonwood from 1994 to 2004 (Clear Creek Associates 2009). This estimate is used in this study to represent the current and future rate of groundwater level decline. Using this estimate, over 70 feet of groundwater decline would occur in the Verde Valley over the study period (2010-2050).

### 2.4.3. Changes in Baseline Economic Values

#### *2.4.3.1. Production Agriculture*

Production agriculture is believed to rely almost entirely on surface water supplied from irrigation ditches during non-drought conditions. The Verde River is occasionally completely diverted during the summer by large irrigation ditches, however river flow reconstitutes rapidly downstream with return flows to the river. Moreover, during normal water availability conditions, shortages are not believed to exist. Agricultural irrigators generally have the most senior rights on the river. However, not all irrigators have senior rights. Based on conversations with area irrigators, we believe that a 15% reduction in summer base flow, will cause water shortages for junior agricultural irrigation rights holders. Thus, production agriculture was rated as having “medium” sensitivity to future depletions in base flow in the Verde River.

Applying the medium sensitivity rating to the range of decrease of median base flow projected (6% to 15% decrease in median flow) and the annual baseline of $29 million in revenue would result in a potential decrease in value of $1.1 million under S1 and $2.9 million under S2. This is likely an over-estimate of losses because while much of the investment in agricultural production is made before water availability is known, there will be an opportunity to reduce expenses (variable costs) related to production. Also, only junior irrigators will experience losses, and it is not known currently what percentage of all production agriculture irrigators have junior water rights.

In addition, agricultural users in the Middle Verde Sub-basin are reported to have 1,200 wells that are used to provide backup irrigation during drought (ADWR 2009). Groundwater level declines of 70 feet are assumed to necessitate drilling of new wells to replace some of the 1,200 wells. Irrigated acreage for production agriculture in the Verde Valley is projected to decline by one-third in the future according to projections from the Central Yavapai Highlands Water Resources Management Study (CYHWRMS 2010).

If one-third of agricultural water users stop producing, in accordance with the projected decline in agricultural water use from 2010 to 2050, 800 wells would be left. Not all wells will likely be replaced. Assuming that half of the 800 wells are replaced, at a cost of $75,000 per well for an 800 gallon-per-minute (gpm) well drilled to 500 feet, the cost of new wells is $30 million. When amortized over 20 years at a 5.5% interest rate, the annualized cost for replacement groundwater wells is $2.5 million per year. The change in operating cost is expected to be very small compared to the capital cost, and was not calculated due to lack of data on the volume and timing of backup agricultural well use.

In order to avoid double-counting between the potential losses from surface irrigation described above and the estimate of replacement cost for wells, we used only the replacement cost for wells to estimate production agriculture losses.

#### *2.4.3.2. Wine Industry*

Currently, the extent to which Verde Valley vineyards are irrigated with groundwater as compared to surface water is unclear. Groundwater irrigation is assumed to be the most applicable method for irrigation in the wine industry. We assumed that each vineyard will need to drill new wells in response to groundwater declines during the study period. The cost for an 800-gallon-per-minute well is assumed to be $150 per foot. Assuming a well depth of 1,000 feet, the cost would be $150,000 per well. Assuming some degree of customization (e.g., installing gravel pack), a total cost of $200,000 per well is assumed. Assuming that 20 wells are needed in total for 14 or more vineyards, a total investment of $3.0 million will be needed over the study time frame. When amortized over 20 years at a 5.5% interest rate, the annual cost is $251,000 per year for the wine industry. The change in operating cost is expected to be small relative to the capital expense, and was not calculated due to lack of data on the volume of water use by local vineyards.

#### *2.4.3.3. State Park and National Monument Value*

Each state park and national monument was rated according to sensitivity to changes in flow. Table 7 and Table 8 show those ratings and the effects of decreases in streamflow on the baseline values for those resources. Sensitivity ratings for the state parks and national monuments were derived from discussions with managers for each location.

Even though a resource manager at Slide Rock State Park conjectured that park visitorship could possible drop if river flows decline, base flow, we assigned the park a sensitivity rating of 0 (i.e., no impact due to water level changes). This is based on the fact that the park's location along Oak Creek north of Sedona means that it is unlikely to be affected by groundwater pumping in the Verde Valley. Groundwater levels in Sedona are reported to have remained stable over time, and Oak Creek is fed by numerous springs that are not expected to be impacted by groundwater pumping in the Verde Valley.

**Table 7 State Park decrease in baseline annual value due to potential decrease in streamflow (annual values, in millions of 2010 dollars)**

| State Park | Baseline Value, $M | Sensitivity to Streamflow Decrease | Loss in Value Under S1, $M | Loss in Value Under S2, $M |
|---|---|---|---|---|
| Dead Horse | 8.7 | High | 0.5 | 1.3 |
| Red Rock | 8.3 | Low | 0.2 | 0.4 |
| Slide Rock | 18.3 | None | 0 | 0 |
| Total | **35.3** | | **0.7** | **1.7** |

**Table 8 National Monument decrease in baseline value due to potential decrease in streamflow (annual values, in millions of 2010 dollars)**

| National Monument | Baseline Value, $M | Sensitivity to Streamflow Decrease | Loss in Value under S1, $M | Loss in Value under S2, $M |
|---|---|---|---|---|
| Tuzigoot | 5.1 | Low | 0.1 | 0.3 |
| Montezuma's Castle | 28.7 | Low | 0.3 | 1.4 |
| Total | 33.8 | | 0.4 | 1.7 |

#### *2.4.3.4. Fishing*

The value of fishing associated with the Middle Verde River was judged to have high sensitivity to potential decreases in flow. Decreases in Verde River base flow are expected to decrease the river's value as a sport-fishery. Fishing experience is generally decreased by significantly higher-than-normal or lower-than-normal flows. The authors of the 2008 report *Ecological Implications of Verde River Flows* (Haney et al.) note that with extreme low flows, sport fish such as trout, bass, and catfish are expected to suffer from increased water temperatures, a lack of dissolved oxygen in the water, and an increase in physical crowding leading to increased competition and more disease. The report says that "… well before that, rainbow trout would likely disappear and smallmouth bass could be expected to overrun most other species with high numbers of sexually mature small (stunted) individuals. Water clarity also declines with reduced flow, which would affect bass feeding and catchability to anglers" (Haney et al. 2008). Applying the high sensitivity rating to the range of decrease of median base flow projected (6% to

15% decrease in median flow) and the annual baseline of $8 million in value results in a potential decrease in value of $0.5 million under S1 and $1.2 million under S2.

#### *2.4.3.5. Verde Canyon Railway*

The Verde Canyon Railway would not exist without the Verde River, which carved a path through the canyon. The railway experience depends greatly on the natural beauty provided by the Verde River ecosystem, including the wildlife that can be observed from the train. However, railway representatives state that visitation does not depend on the level of flow in the river, and therefore no loss of value is projected for changes in median streamflow in the river as projected for this study. Some of the railway's trips are themed around Verde River wildlife, such as eagles, or around natural displays, such as the fall colors. Railway representatives stated that if changes in flows in the river were large enough to affect wildlife dependent on it, then railway visitation would be affected in the long run (personal communication Theresa Propeck, Verde Canyon Railroad, April 2011).

#### *2.4.3.6. Municipal and Residential*

For the municipal and residential water use sectors, future vulnerability to changes in water supply availability is due to declines in groundwater levels (not surface water availability). Use of the 1.75-feet-per-year groundwater decline estimate noted earlier would imply 70 feet of decline over the study period.

We assumed that if aquifer levels drop 70 feet, existing household wells will no longer have access water. We did not include effects on new wells, as we assumed that they will be drilled to sufficient depth. The cost of deepening a residential well by 100 feet, including a new well pump, is estimated to be $5,000 per well. The number of existing exempt wells is calculated from the water use projections for 2010 for both demand scenarios. For scenario S1, the number of existing wells is estimated to total 5,500; under S2, existing wells are estimated to total 5,800. As shown in Table 9, the annualized value of well deepening is estimated to be $2.3 million under S1 and $2.4 million under S2 (annualized over 20 years using a 5.5% interest rate).

**Table 9 Municipal and residential annualized cost due to groundwater level declines**

| Deepening for Existing Exempt Wells | | Developing New Wells for Municipal Growth | |
|---|---|---|---|
| Scenario | Cost | Scenario | Cost |
| S1 (5,500 wells) | $2.3 million | S1 (15 wells) | $1.8 million |
| S2 (5,800 wells) | $2.4 million | S2 (44 wells) | $5.3 million |

For municipal well use, well deepening is usually not be feasible because of difficulty re-drilling through the same bore hole on deeper wells. Instead, new wells will be required to meet demand growth. Assuming an average capacity of 300 gallons per minute, or 485 acre-feet per year, the number of new wells required under S1 is calculated to be 15; the number of new wells under S2 is 44. Assuming an average cost of $300,000 per well and an operating cost of $0.60 per thousand gallons, the annualized cost of new wells under S1 is $1.8 million per year; under S2, the cost is $5.3 million per year (capital cost annualized over 20 years at a 5.5% interest rate).

#### 2.4.3.7. Commercial and Industrial

It is not clear whether the value of commercial and industrial activity in the Verde Valley is directly linked to river flows and aquifer levels. We assumed that new wells will be needed to meet demands due to growth. Under the S1 low-growth scenario, there is no projected demand growth in groundwater use by commercial or industrial users. Under the S2 scenario, the WAC projects the need for nine additional wells. Assuming a cost of $50,000 per well and a pumping cost of $25 per acre-foot, the annual cost of new wells under S2 is $147,000 (amortized over 20 years at a 5.5% interest rate).

#### 2.4.3.8. Ecological Value

Threatened and endangered species in the Middle Verde River are very sensitive to changes in base flow of the river. Scientists expect native fish species to decline as base flow declines because of higher water temperatures, lack of dissolved oxygen in the water, and an increase in physical crowding leading to increased competition and more disease. Among bird species, the health of the southwestern willow flycatcher is linked to the health of the cottonwood-willow forest. Declines in base flow of up to 15% are not expected to affect the health of the cottonwood-willow forest, which could be effected by lower groundwater tables. However, the numbers of prey insects are likely to decline with drops in base flow, effecting the insect-eating southwestern willow flycatcher and yellow-billed cuckoo (Haney et al. 2008).

Using a rating of “high” for sensitivity to changes in river flow, the potential loss of value for a 6% reduction of median streamflow under scenario S1 ranges from $0.9 million to $1.3 million. The potential loss of value for a 15% reduction of median streamflow under S2 ranges from $2.2 million to $3.3 million.

#### 2.4.3.9. Summary

Table 10 summarizes the river-related economic values for the sectors described above, and adds the sensitivity to streamflow is listed for each surface water use. The potential loss in annual value based on projected change in streamflow or groundwater levels is shown in the last column.

**Table 10 Summary of economic values from the Middle Verde River and potential loss of annual value (annual values, millions of 2010 dollars)**

| Sector | Current Annual Value, $ million | Sensitivity to Streamflow Change | Potential Loss of Annual Value, $ million |
|---|---|---|---|
| Recreation and Tourism | 87.5 * | varies | 1.9–4.7 |
| Production Agriculture | 29 | medium | 2.5 |
| Wine Industry | 5.5 * | ** | 0.3 |
| Municipal/Residential | 13–17.5 | ** | 1.8–5.3 |
| Commercial/Industrial | *** | ** | 0–0.2 |
| Ecological | 15–22 | high | 0.9–3.3 |
| Total | 150–162 + | | 7.4–16.3 |

* In addition to direct values, there are multiplier effects for these sectors.

** Groundwater dependent.

*** Commercial/industrial values are generally believed to be large but cannot be estimated given the difficulty in locating information.

## 2.5. Water Management Options

This study examines the effect of potential options for management of the Verde River and its associated water uses. A baseline reflecting continuance of status quo conditions and three management scenarios are explored in this study. A review of projected water use into the future is presented first, followed by an outline of the management options and a discussion of economic values under each option.

### 2.5.1. Water Use Projections for the Verde Valley

In order to understand the implications of different water management options, we need to understand how these options will affect water consumption. To develop these projections, we relied on long-term development scenario projections of groundwater use for the Verde Valley developed by the Yavapai County Water Advisory Committee (WAC). The scenarios developed by the WAC project groundwater use from 2006 to 2050. Total groundwater use under these scenarios is shown in Table 11.

The S1 development scenario is referred to as the General Plan Scenario because it utilizes a combination of population projections from the Arizona Department of Economic Security or projections consistent with the general plans for each municipality if available. The S2 development scenario represents significantly faster growth. The WAC development scenarios for groundwater use generally project municipal use, residential use from exempt wells, and commercial and industrial use.

**Table 11 Projected groundwater demand under WAC development scenarios for the Verde Valley sub-basin (acre-feet)**

| Year | S1, acre-feet | S2, acre-feet |
|---|---|---|
| 2007 | 14,600 | 13,900 |
| 2010 | 15,200 | 16,000 |
| 2020 | 17,300 | 19,900 |
| 2030 | 19,200 | 25,800 |
| 2040 | 20,900 | 33,000 |
| 2050 | 22,500 | 40,100 |

We combined water use projections from two sources to provide a complete projection of both groundwater and surface water use over the study period. The 2008 WAC report covered only groundwater use. Projection of surface water use by sector, including agriculture, were obtained from the *Central Yavapai Highlands Water Resources Management* Study (CYHWRMS 2010). The resulting projection of water use under the S1 and S2 water use scenarios is shown in Table 12.

**Table 12 Projected water demand, groundwater and surface water (acre-feet)**

| Year | Municipal/ Residential | Commercial/ Industrial | Agriculture |
|---|---|---|---|
| S1 Demand Scenario GW + CYHWRMS Ag SW | | | |
| 2010 | 12,200 | 3,000 | 17,300 |
| 2050 | 19,500 | 3,000 | 11,900 |
| S2 Demand Scenario GW + CYHWRMS Ag SW | | | |
| 2010 | 12,900 | 3,200 | 17,300 |
| 2050 | 34,800 | 5,300 | 11,900 |

GW = groundwater; SW = surface water; Ag = agriculture

CYHWRMS = Central Yavapai Highlands Water Resources Management Study

It is possible that some surface water use, especially for the commercial and industrial sector, is not captured under this combined projection. However, data were not available to improve upon this projection with any confidence.

Water use for agriculture is projected under the CYHWRMS study to decline from 17,279 acre-feet in 2010 to 11,889 acre-feet in 2050 (a savings of 5,390 acre-feet per year by 2050). This decline in agricultural water use was derived by setting total 2050 agricultural water use at 66% of the 2006 value, reflecting the judgment of representatives of the planning areas for the study and the study's technical committee that irrigated acreage for agriculture would decline by one-third during this time period (CYHWRMS 2010b). CYHWRMS applied estimates from ADWR's 2000 Verde River Watershed Study from to estimate agricultural water use per acre. We confirmed that this estimate represents "consumptive use" of water by crops in the Verde Valley (and therefore does not include losses during diversion to evaporation or seepage). Consumptive use, rather than total withdrawal, is the correct measure to use to understand water amounts that might be transferred to other uses.

The projected decline in agricultural water use under the CYHWRMS study is based on an assumption that irrigated acreage will decline 33% by 2050, and is not a certainty. It also possible that there will be less decline or no decline in total irrigated agricultural acreage.

### 2.5.2. Water Management Option Definitions

Water management options for the Middle Verde River that were considered in this study include:

**A0. Baseline: Continuation of status quo**

Under this option, agricultural, municipal/residential, and commercial/industrial water uses continue into the future. Changes in water use by sector were based on projections by the WAC for groundwater uses and CYHWRMS for surface water use (agriculture). We assumed that reported rates of groundwater-level decline (1.75 feet per year) will continue over the planning period.

**A1. State-level regulation**

Under this option, a cap is placed on groundwater use at 20% above current levels. Groundwater withdrawals would be limited to 17,500 acre-feet per year in the Verde Valley. No new water uses would be allowed once the cap is reached. Under pumping scenario S1, the cap would be reached in the year 2021; under S2, the cap would be reached in 2014.

**A2. Water marketing: Regulation with trading**

Under this option, the cap on groundwater use of 20% above current levels is assumed to apply (as in the above management option); however in this option trading of water rights is allowed. With a local water market system, these rights could be transferred to a new use through a private sale. Thus, a groundwater right held by any right-holder could be sold to another use if the original use were to cease operation or permanently reduce water use. Similarly, surface water rights held by agriculture could be sold to other uses if reductions in irrigation were made. Transferring a surface water right to a groundwater right would be allowed under this option, and both sales and leases of water rights would be possible.

**A3. Regional management institution (i.e., a special district)**

Under this option, the cap on groundwater use and the option of water rights trading are allowed. In addition, the special district can reduce withdrawals equitably during times of drought. The district would collect revenues through a tariff structure based on type of use and quantity of water used. These funds will support paid district staff who administer the water market and collect water management-related data. The funds will also support improvement projects. These could include recharge facilities, effluent reuse programs, and efficiency programs aimed at improving the productivity of consumed water. Improved stormwater capture and effluent reuse could be used to create additional water rights that, when sold, could defray costs of the projects.

### 2.5.3. Baseline (Status Quo) Option

The baseline option assumes that current water use and current water management continue into the future over the analysis period. As discussed above, current groundwater use is projected by the WAC for the general plan scenario (S1) and a scenario with more aggressive growth (S2). Groundwater use projections were combined with a projection of surface water use for agricultural irrigation from CYHWRMS.

Groundwater modeling for this study shows that groundwater pumping will deplete median streamflows (those that occur 50% of the time) in the Verde River over time. Scenario S1 is projected to deplete median streamflows by up to 6% by the year 2050, S2 up to 15% by 2050.

According to assumptions made in the CYHWRMS study, irrigated acreage in agriculture is projected to decline in the future, resulting in up to 5,390 acre-feet per year of water use savings by 2050. There is some question as to what would happen to this agricultural water savings over time under the baseline. Theoretically, it could be either left in the stream or transferred to other uses. It does not seem likely that existing water rights would be abandoned, leaving water in the stream. However, no other surface water users are assumed in this analysis other than in agriculture, so any transfers would by definition offset groundwater demand. Transfers from surface water to groundwater are assumed not to be allowed under the baseline. And even if transfers from groundwater to surface water were allowed, there is a time lag in the connection between groundwater and surface water, potentially meaning that the effect on streamflows from reduced groundwater pumping would be significantly delayed.

To understand the potential impact of projected agricultural water savings on streamflow if it was left in stream, we converted acre-feet per year of potential savings to flow in cubic feet per second (cfs) by dividing by 724 cfs per acre-foot. The savings is approximately 10% of the median summer base flow. The savings would more than offset streamflow depletions from groundwater pumping under S1: the net effect would be a 4% increase in streamflows (10% increase compared to 6% decrease). Under S2, the savings would offset a majority of the streamflow depletions from groundwater pumping: the net effect would be a 5% decrease in streamflows (10% increase compared to 15% decrease).

Under the baseline S1 scenario, population is steady and agriculture decreases, resulting in a 4% net increase in streamflow. This would benefit other surface water users because more water is available; we calculated the economic benefits of this increase using the same method as for a reduction in streamflow. Under the baseline S2 scenario, river flows decrease by 5%, causing economic losses to surface water users. Groundwater losses under both scenarios are not affected by changes in streamflow. The economic value of groundwater use is greater than for surface water. We classified analyzed the economics of production agriculture related to groundwater, as we expect that irrigators will have to replace backup wells. We assumed that water savings from decreased agriculture remain in the Verde as instream flow. Net economic losses total $2.7 million under S1 and $11 million under S2.

### 2.5.4. Regulatory Management Option

The regulatory management option has the effect of preserving existing uses at the time of the cap (2021 for S1 and 2014 for S2). If agricultural water savings is assumed not to add to streamflow (see discussion in the previous section), then the avoided losses total $7.4 to $16.3 million per year, once the cap is implemented. If agricultural water savings is assumed to be left in the stream, then avoided losses under the regulatory management scenario would be $2.7 million under S1 and $11 million under S2.

Once the groundwater-use cap is reached, there will be unmet future demand for groundwater, because transfers from surface water to groundwater use are not allowed under this management option. Groundwater use under the regulatory management option is capped at 17,500 acre-feet per year. This cap is reached in 2021 under the S1 water use scenario and in 2014 under the S2 water use scenario. Thus, the water use-cap results in unmet demand for the municipal/residential sector under both the S1 and S2 scenarios and unmet demand for the commercial/industrial sector under the S2 scenario. Table 13 shows this unmet demand for public water systems, private wells, and commercial/ industrial use.

**Table 13 Lost groundwater use by 2050 due to cap (acre-feet)**

| Scenario | Public Water System | Private Wells | Commercial/ Industrial | Total Un-met Demand |
|---|---|---|---|---|
| S1 | 4,800 | 225 | 0 | 5,100 |
| S2 | 18,800 | 1,900 | 1,900 | 22,600 |

The housing industry could possibly lose value under a regulatory management option if growth is stopped due to the groundwater cap. Unmet demand for public water systems and private wells was translated into a count of the number of homes by dividing unmet demand in acre-feet by 0.33 acre-feet of typical water use per year per home. Assuming that the average value of a home in the Verde Valley is $200,000 and that approximately 60% of that value comes from construction (Emrath 2010), the resulting loss in value ranges from $48 to $57 million annually under scenario S1, and $121 to $194 million annually under scenario S2.

Economic value associated with commercial and industrial water use will be lost due to the effect of the cap under scenario S2, but not under scenario S1 for which commercial and industrial groundwater demand is projected to remain constant over time.

### 2.5.5. Water Marketing Management Option

The water marketing management option allows trading of water rights for both groundwater and surface water. Water use for agriculture is projected under the CYHWRMS study to decline from 17,279 acre-feet in 2010 to 11,889 acre-feet in 2050. Due to this projected decline in water use, agriculture is a likely source of water for transfers. Table 14 shows the amount of water potentially available from agriculture for transfers. The first column shows the amount of water available from the projected decline in agricultural surface water use. The second column shows all of the water that is available if all agricultural water use as of 2050 was also to cease. The table shows that unmet demand from scenario S1 (5,050 acre-feet) can be met by water that is available from the projected decline in agricultural water use (5,390 acre-feet). Thus, there is potential for no housing industry losses under scenario S1 under the water marketing management option.

Table 14 also shows that unmet demand under scenario S2 cannot be met by the projected decline in agricultural water use alone. In fact, the unmet demand for water for public water systems alone under scenario S2 could not be met even if all water currently used in agriculture were transferred to meet public water system demand by 2050.

**Table 14 Water supply potentially available from agriculture (acre-feet), compared to unmet demand by scenario**

| Ag Projected Reduction 2010 - 2050 | Ag 2050 Water Use | Total Potential Ag Supply |
|---|---|---|
| 5,400 | 11,900 | 17,300 |

**Total unmet demand by scenario (from Table 13)**

| Scenario | Public Water System | Private Wells | Commercial/ Industrial | Total Unmet Demand |
|---|---|---|---|---|
| S1 | 4,825 | 225 | 0 | 5,050 |
| S2 | 18,836 | 1,898 | 1,878 | 22,612 |

This management option uses the same cap on groundwater use, that is, 17,500 acre-feet per year, as is used under the regulatory management option. Shifting the agricultural irrigation savings to support residential growth means that the possibility that savings goes to support streamflows no longer exists. Thus, the avoided economic losses due to reduced streamflows stem from the full effect of groundwater pumping on streamflows. Avoided losses total $7.4 to $16.3 million per year, once the cap is implemented.

Therefore, the benefits of the water marketing management option are: 1) costs of restricting growth under the regulatory management option would be avoided if enough permits are sold to meet residential demand; and 2) costs related to streamflow declines and groundwater-level declines from groundwater pumping will be avoided once the cap is implemented.

#### *2.5.5.1. Examples of Market Prices for Water Right Sales*

Sale of water rights under the water marketing option is considered a transfer from those buying permits to those selling, and is not considered a benefit or a cost in aggregate. The sellers get the money from the transaction, while the buyers show that the use of the water is worth at least as much to them as they pay for the water right. Each party gains in the transaction.

Evidence from market transactions for sales of water rights in the Western United States can potentially inform the value of water rights that could be created under the water marketing management option.

Sales of Truckee River water in Washoe County, Nevada, have been active due to a requirement for developers to provide water for mitigation of water used for development. Market prices for water sales are reported in the publication *The Water Strategist*. Permanent sales of water rights have roughly averaged $10,000 per acre-foot over the eight years from 2001 to 2009, after adjustment to 2010 dollars.

Sale of water rights on the Rio Grande averaged approximately $5,500 over the period 2001 to 2009, after adjusting to 2010 dollars. The Truckee River market may be closer to potential conditions on the Middle Verde River than the Rio Grande because the market was designed to help mitigate the water use impact of development. In fact, values from the Truckee could potentially be conservative when compared to recent values for shares of the Colorado Big-Thompson water project, where values have nearly reached $20,000 per acre-foot due to development pressures.

Table 15 shows potential value of permits created under the water marketing management option. Assuming $10,000 per acre-foot for the permanent sale of a water right, the value of the projected reduction in agricultural water use from 2010 to 2050 is potentially worth $54 million (i.e., this is an estimate of the amount of money that would flow to agricultural entities that sold their water rights during this period). Another example might include aggressive conservation in the municipal/residential water use sector. Assuming a 33% reduction from 2010 water use under S1 in the municipal/residential sector, 4,011 acre-feet of water conserved. We estimate that $40 million worth of permanent rights could be sold under this scenario.

**Table 15 Examples of value of permits of assets created under water marketing management option**

| Sector | Sales Volume (at $10,000/acre-foot) |
|---|---|
| Agriculture Projected Reduction (2010–2050) 1 | $53.9 M |
| Municipal/Residential Sector Aggressive Conservation 2 | $40.1 M |

[1] Projected baseline reduction in agriculture water use from 2010 to 2050 is equal to 5,390 acre-feet.

[2] Assumes 33% reduction from 2010 water use under S1 of 12,153 acre-feet, which is equal to 4,011 acre-feet.

### 2.5.6. Regional Water Management Option

The special district created under the regional water management option may be able to support projects to improve water management in the region. Funding for those projects could come from fees collected by the water management agency and possible sale of rights from water conserved due to projects enabled by the special district.

Potential projects may include ditch lining, use of wells instead of surface water diversions in agriculture, or financial support for increased water recycling in municipal or industrial sectors. The City of Cottonwood provides examples of water recycling projects currently being implemented in the region. Cottonwood's current plant treats 3–4 million gallons per month that is released to Del Monte Wash. Cottonwood's planned new recycled water plant will treat 300,000 gallons per day of recycled water to even stricter standards and will use technology to remove any endocrine-disrupting compounds or other components of concern. Cottonwood will require new subdivisions to use recycled water for irrigation through a separate piping system (purple pipe). The capital cost for this new reclaimed water plant is estimated to be $5.4 million (personal communication Dan Leuder, City of Cottonwood Water and Wastewater Utility 2011)

## 2.6. Conclusions

The Verde River provides many economic values that are difficult to fully capture monetarily. Documented economic values from use of the river and related water resources are greater than $150 to $161.5 million per year in direct revenues for the uses assessed here. Due to data limitations, we were unable to estimate the existing value of industrial and commercial use of river water. We have estimated the economic value of future water resource impacts on this sector, and on recreation and tourism such as birding that are closely related to water availability.

Potential decreases in streamflow due to groundwater pumping that are projected through 2050 are relatively small. Under the S1 growth scenario, otherwise known as the General Plan Scenario, potential decreases in streamflow are projected to reach 6% by 2050. Under the more aggressive S2 scenario, potential decreases in streamflow are projected to reach 15% by 2050. Also, recent declines in groundwater level in the aquifer show a 1.75-foot-per-year drop in water level. If that rate of decline were to continue over the study period, it would result in 70 feet of groundwater level decline.

Due to relatively small declines in streamflows and groundwater levels, economic value at risk is also relatively small. Some instream uses are very sensitive to flow changes, but other uses have low sensitivity. The total economic value at risk was estimated to range from $7.3 to $16.2 million annually.

The water management options investigated in the study provide crucial methods for stopping streamflow depletion and groundwater level declines.

The regulatory option protects existing uses by placing a cap on overall groundwater use in the Verde Valley. However, regulations have the potential to impose significant economic cost on residential and commercial/industrial sectors if growth in those sectors is restricted due to the groundwater use cap. The water marketing scenario allows transfers of groundwater and surface water rights that can mitigate losses. All of the unmet demand under scenario S1 can be met from the decline in agricultural water use that is already projected through 2050. The aggressive growth projected under scenario S2 cannot be met without significant reductions in existing water use to supplement the already projected decline in agricultural water use. The water marketing scenario provides greater net benefit compared to the regulatory option because losses to residential and commercial/industrial sectors are avoided.

The regional water management option builds upon the water marketing option by allowing for better coordination of local water management. This option potentially provides money through use of collected fees or water rights sales that can be used to promote projects that increase available supplies or reduce water demand. Under this final option, a water management agency such as a special district could support projects such as water conservation, increased water recycling, or stormwater capture. The City of Cottonwood’s proposed new water recycling plant is an example of project that can increase renewable supplies that can be used to offset groundwater use.

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# 3. Water Management and Policy Options

*People who are self-governing can solve complex and important environmental problems without the need for centralized direction—in this case, a "water czar" or statewide bureaucracy. All that is required, along with their own will, effort, and creativity, is an enabling institutional environment.*

*When citizens have the opportunity to engage in self-governing, collective action, and innovative, entrepreneurial solutions are encouraged, we need not have a "tragedy of the commons."*

From the foreword to *Dividing the Waters* by William Blomquist

## 3.1. Introduction

Our focus in this report has been on seeking a balance between human needs for water with sustainable, healthy aquatic ecosystems. A free-flowing river has an intrinsic value for its beauty and scenery and for its ability to support plants and animals. It also has a real economic value. There are a number of aspects of a healthy river, but in this report, we have focused on maintaining instream flows, and specifically on how excessive groundwater withdrawals can reduce flows, causing harm to the river, wildlife, and the communities around it. In this section, we describe several policy and management options for sustaining groundwater aquifers and maintaining river flows.

The total volume of groundwater beneath the Verde has not been precisely quantified, but is likely sufficient quantities meet the all the domestic, irrigation, municipal, and industrial water needs of a growing population for many years to come. Mining groundwater, unfortunately, is accompanied by undesirable consequences that harm quality of life and threaten economic growth. First, groundwater pumping depletes the flow of surface springs and rivers. Any pumping in an aquifer that is geologically connected to a river will affect flows in the river. In Arizona, 35% of natural perennial flowing rivers have been altered or lost as a result of dams, diversions, and groundwater pumping according to a 2004 study by The Nature Conservancy.

In rural areas of Arizona, besides Active Management Areas (AMAs), where groundwater use is strictly regulated, the law provides few means to protect rivers. "The doctrine of reasonable use permits an overlying landowner to capture as much groundwater as can reasonably be used upon the overlying land and relieves the landowner from liability for a resulting diminution of another landowner's water supply" (from Arizona's 1999 Gila River System Adjudication, quoted in Boyd 2003, 1154). Former director of the Oregon Water Resources Department Martha Pagel calls "the scientific and public policy questions presented by the hydrologic connection between surface water and ground water… the most contentious and problematic water issues in the West" (Pagel 2002, 29).

The nature of groundwater makes it difficult to regulate and manage. In Southwestern rivers like the Verde, the effects of pumping may not be seen for decades. This long time lag is a barrier that prevents the public from seeing and understanding groundwater-surface water connections (Stillwell 2007). It is also a barrier to crafting meaningful policies to protect rivers. For example, Anderson and Snyder (1997a) write, "In many states, adjudication does not occur until overdraft causes harm to groundwater users, motivating them to file suit against one another." In a recent article in the journal *Ground Water*

(Bredehoeft and Durbin 2009), two noted hydrologists sum up this quandary: the public and politicians are not motivated to place curbs on pumping until the damages it has caused are evident. However, damage may not be seen over decades, or even until after pumping is ceased. As a result, springflow may continue to decline for decades, and not return to an equilibrium state for hundreds of years.

First, conjunctive management of surface and groundwater is needed. Hydrologists consider groundwater and surface water a single resource, and the laws of more Western states are beginning to acknowledge this reality. This is not so in Arizona, where different laws cover groundwater and surface water. These laws should be changed. Withdrawals of both groundwater and surface water should be limited to protect base flow in the river. The "safe yield", or maximum level of pumping that is sustainable and protects base flow, should be scientifically determined, and pumping should be capped at this level. Implementing a pumping cap will require regulation by some institutional entity.

Water regulation requires well-defined water rights and a supporting legal environment. Market-based mechanisms should be permitted to allow for flexibility of water uses under a cap, and to allow for re-allocation of water for recreation and wildlife away from traditional consumptive uses. Water conservation should be aggressively pursued to reduce the per-capita water footprint, and allow for continued development and a healthy economy. Decision-making should be open and transparent, and involve local stakeholders, to ensure that reforms work and are acceptable to the community. Finally, local decision-makers should organize themselves to preserve their water interests from exploitation from upstream and downstream water users.

### 3.1.1. Guiding Principles

If there is a consistent theme to the case studies presented in this report, it is that the task of changing laws and creating new institutions almost never happened quickly or easily. The following discussion draws entirely on experiences that have worked in other Western states. In this report, we have not dwelled on what is feasible in the current political climate. Of course this is a tremendously important consideration.

Nearly all of the water management reforms discussed here would require an act by the legislature or approval by voters. Some require new administrative bodies to be set up. Some involve new taxes or fees or increases to the cost of water. The consistent theme is that sustainable water management requires acknowledging that there are ecological and economic consequences to drilling too many wells in an aquifer and withdrawing too much water. Below are some of the common elements that guided our selection of policy options:

- Groundwater and surface water should be managed conjunctively, as a single resource.
- Diversions and withdrawals should ultimately be capped at the "sustainable yield" as defined by stakeholders.
- Existing water rights must be respected.
- A vibrant economy and way of life depend on a healthy river.
- Market forces should be allowed to operate, so that water is allocated to highest-value uses.
- Water management should be flexible to allow for unforeseen future water uses.

- Open, transparent, and stakeholder-driven processes are most likely to be acceptable and achieve long-term success.

### 3.1.2. Elements of River Restoration

Maintaining minimum flows is only one aspect of a healthy river. While instream flow has been our main emphasis in this study, it is worth considering the other elements. The Instream Flow Council (Locke et al. 2008) identifies eight components of *riverine resource stewardship*:

| | |
|---|---|
| **Legal:** | Laws can either provide or restrict opportunities for river protection or enhancement. |
| **Institutional:** | Implementation and enforcement of laws; sufficient resources for agencies. |
| **Public Involvement:** | Unless informed citizenry are involved in water allocation, often the best result is the status quo or worse. |
| **Hydrology**: | Deals with questions of stream flow and water movement. How much? When? How often? For how long? |
| **Geomorphology**: | The form of river and stream channels to support ecological and human uses; the interaction of water, rock, soil, and vegetation. |
| **Biology**: | Fish and other aquatic animals and plants, including riparian woodlands and floodplain ecosystems. |
| **Water quality**: | Pollutants, temperature, dissolved oxygen, and other parameters that affect wildlife and human uses. |
| **Connectivity**: | River systems provide pathways for the transport of a wide range of material, energy, and life. This transport moves:<br>• upstream and downstream (longitudinal connectivity)<br>• between surface and groundwater (vertical connectivity)<br>• between channel and floodplain (lateral connectivity)<br>• in time (temporal connectivity) |

### 3.1.3. Groundwater and the Commons

The theory of the commons maintains that users of a common resource are “unlikely to restrain their own behavior when the immediate benefits of their actions are their own but the costs are passed on to society as a whole (or other specific groups), and any longer-term or external benefits that might accrue from an individual’s self-instigated ‘moral preventive checks’ are undiscernible”(McCay and Acheson 1987). The theory can be extended to a groundwater aquifer where pumpers have no incentive to limit extraction to a “socially desirable level” (Sophocleous 2009, 563). In the following passage from the classic article “The Tragedy of the Commons” (Hardin 1968), consider the analogy between the pasture and a groundwater aquifer:

> Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons…As a rational being, each herdsman seeks to maximize his gain…Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another, and another…But this is a conclusion reached by each and every herdsman sharing a commons.

Each individual herder (or groundwater pumper) is locked into a system where it makes sense for him to exploit the resource for short-term gain, regardless of the impact to his neighbors or his own long-term interests. Hardin's tragedy of the commons has been criticized as abstract and simplified (McCay and Acheson 1987). Indeed, Hardin's model lacks one crucial element: cooperation. He assumes that resource users act in isolation, without talking to one another. In reality, there is a rich history of users of common-pool resources coming together and cooperating to manage them, as explored by Nobel Prize-winning political economist Eleanor Ostrom in books such as *Governing the Commons: The Evolution of Institutions for Collective Action* (1990)*,* and *Institutional Incentives and Sustainable Development: Infrastructure Policies in Perspective* (1993).

According to Ostrom's work, resource users in traditional and modern societies have used varieties of cooperation and collective action to manage common-pool resources. She contrasts this continuum of institutional arrangements with the view that resources should be allocated by government or left purely to markets. On one side of the argument, "policy makers frequently assert that water is 'different' from other commodities and that the government must allocate it" (Anderson and Snyder 1997b). On the other, neoclassical economists advocate solving the problem of overexploitation of common property resources by defining and enforcing property rights through institutional intervention. Resource markets are rarely unrestrained "free markets," as government institutions generally protect property rights and manage the resource under goals that promote the public interest.

Western states have used a combined approach that has been applied to surface water for over a century. Water rights were analogous to private property rights. However, in the late 1800s, states "feared that private ownership and water markets would lead to speculation and monopoly control" and so states restricted the property aspects of a water right, for example by specifying what constituted a reasonable use, or by banning transfers (Anderson and Snyder 1997b). Increasingly, states are moving to include groundwater rights under their systems of water rights. Property owners have often been opposed to an increase in government involvement in their affairs. However, when government clarifies rights and entitlements to groundwater, it protects current users' rights. Votteler (1998, 33–34) describes how landowners in Texas came around to the idea of groundwater regulation:

> Under a pure rule of capture system for water, property rights—in the economic sense—are an illusion. Existing users are not protected against installation of a well on an adjacent plot of land or against withdrawal of water from that well at a rate great enough to lower the water table below the well intakes of surrounding landowners. Indeed, it was this type of unrestricted extraction that ended the rule of capture for oil and gas in Texas, resulting in pooling of underground oil and gas resources. Since the advent of EAA, some of the most vocal opponents of government intervention have become ardent supporters of regulation because such an approach may eventually provide certainty through the creation of firm water rights.

### 3.1.4. Potential Water Policies and Management Options

In the following sections, we suggest several strategies that can be pursued, with a goal of managing water to support instream flows for a healthy river and vibrant local economy. We did not do a detailed analysis of the acceptability of these measures, or the politics of instituting these changes. In many cases, it could be very difficult to obtain approval by the voters or the legislature for what could be seen as controversial or progressive actions. Each and every proposed action has, however, been successfully applied in other areas of Arizona or in other Western states.

We believe that basin stakeholders should set clear goals for what they want the future to look like. A "best-management practices" approach may not be sufficient. One may implement worthwhile practices like conservation and low-impact development, but there is no guarantee it will lead to a desired end. As the saying goes, "If you don't know where you're going, you will probably end up somewhere else." It would be far better to work backwards from a set of "desired future conditions" and put in place policies and programs to help achieve those goals.

**Verde Valley agricultural community. Photo courtesy of Dan Campbell.**

## 3.2. Water Management Activities

The following sections describe water management activities that can be undertaken to increase water supply reliability and maintain aquifer levels. Water managers have two basic options: to augment supply or to limit demand. Because new supplies are few in the Southwest, we begin with activities to limit demand in homes and on farms through conservation, efficiency, and recycling. In the Verde Valley, there may be no public institution with the legal powers to undertake or finance such projects. We will briefly describe what such an institution would look like, and how it could be formed in the section 3.5, Administrative or Institutional Actions.

### 3.2.1. Enhance Water Conservation and Efficiency

Water conservation efforts in Arizona have been primarily applied within the five Active Management Areas, and require water providers to meet gallon per capita per day (gpcd) targets (Bell and Taylor 2008, 92). The current target for indoor water use for new residential development is 57 gpcd, with outdoor targets ranging from 178 gallons per housing unit per day (gphd) in Phoenix and 118 gphd in Tucson to 75 gphd in Prescott. The state also imposes conservation standards on users who use large amounts of water for cooling, turf, and landscaping. Further, water suppliers must reduce leaks so that "unaccounted for water" is no more than 10%, or 15% for small water suppliers.

Based on information in the USGS study of the Verde Valley's water budget (Blasch et al. 2005, 87), household water use in the Verde basin is approximately 133 gallons per capita per day (gpcd) or 310 gallons per household per day (gphd). This is much higher than the national average (62 gpcd), and higher than other southwest cities such as Albuquerque or Tucson (110 and 114 gpcd, in Cooley et al. 2007, 19). Thus, there is an opportunity to lower water use in the basin through household conservation and efficiency measures. Water conservation efforts should focus especially on outdoor water use, where a portion of the water applied to landscapes is consumed by evaporation and transpiration by plants.

University of Arizona law professor and water expert Robert Glennon has written extensively on the issue of groundwater overdraft. In the book *Water Follies* (2004), he argues that states should carefully craft conservation standards to promote sustainable groundwater use. Standards need to be simple to be effective:

> …complicated standards, fraught with complexity and elaborate monitoring and enforcement programs, may be counterproductive. They will result in countless drafts, innumerable public meetings, and detailed administrative rules and regulations. … and may be too complex to yield effective enforcement.

The Pacific Institute has written extensively on how water conservation and efficiency is an important part of water management. Across the west, water managers are increasingly turning to efficiency programs instead of seeking out new sources of water supply. Successful programs include conversion to "conservation rate" structures, rebates and incentives for efficient appliances and fixtures, and "cash for grass" programs. An overview of such programs is given in the report *Hidden Oasis: Water Conservation and Efficiency in Las Vegas* (Cooley et al. 2007).

### 3.2.2. Increase the Use of Recycled Water

Other options include re-using highly-treated effluent for nonpotable use, for example landscape irrigation. The practice of water recycling is becoming more common in the United States—all the golf courses in Albuquerque and Las Vegas use recycled water. Recycled water is usually conveyed in a separate "purple pipe" distribution system, and the EPA has published guidelines governing its handling and use (USEPA 2004). Water recycling has a number of benefits aside from reducing withdrawals: it can also save energy, decrease discharges, and prevent pollution (USEPA 2011).

In the Verde Valley, we observed a current practice of disposing of treated wastewater by evaporation. . Wastewater plants should investigate putting effluent to better use. Discharging effluent back to the river channel, to an injection well, or an infiltration gallery would help increase flow and recharge aquifer levels. This proposal may require more detailed study, and may require modification of plants' discharge permits issued by the EPA under the NPDES program (National Pollutant Discharge Elimination System).

### 3.2.3. Modernize Irrigation Infrastructure

Improvements to irrigation infrastructure may allow more flexibility and improvement to the river environment. The Department of the Interior has signaled that it considers agricultural efficiency an important component of meeting ecological flow requirements. In its *Water 2025* report (2003), the Bureau of Reclamation wrote:

> In many cases, implementation of new water conservation and efficiency improvements through cooperative partnerships will result in an increased ability to meet otherwise conflicting demands for water. Most irrigation delivery systems were built in the early 1900s and remain virtually unchanged today. These irrigation delivery systems can be modernized and retrofitted with new water management technologies. Water districts can install cost-effective water management technologies, using low-cost solar-powered components that allow remote water measurement and operation of deliveries through irrigation delivery systems. The initial investment in these systems, though significantly less than in the past, can still be burdensome to many water delivery organizations.

There are two important questions regarding irrigation efficiency enhancements. First, who shall pay for them? Second, who holds the rights to conserved water? Some analysts contend that an irrigator or a district should continue to hold all of the rights to conserved water, which they can then choose to apply to new lands or sell for municipal or instream use (e.g. Colby 1988; Boyd 2003). They contend that this will maximize the incentive for irrigators to participate in such programs, and thus will be the most effective.

Under most Western state's laws, conserved water is not covered under an existing permit. Water that is not applied to lands described in the original water right is not being put to beneficial use and is subject to forfeiture, where it passes to the next most junior appropriator. This "use it or lose it" policy were originally designed to prevent hoarding, but today they can be a disincentive to undertake in expensive conservation projects. A recent water rights fight in Washington state illustrates the importance of this issue. The Columbia-Snake River Irrigators Association, which irrigates 250,000 acres of prime farmland, filed a plan with the state to make its water deliveries more efficient. The district wished to use the water to irrigate an additional 20,000–30,000 acres, but the state countered that according to state law, the water is not their property, and instead would be left in the river to maintain stream flows for endangered fish and other wildlife (Kundert 2010).

Oregon's Conserved Water Program, described earlier, provides an alternative. Oregon created a system of "split incentives" where irrigators retain a portion of the water saved through conservation, and some conserved water is dedicated to instream flow. If public funding helps pay for a project, then more water is dedicated to the environment, although the irrigator always keeps at least from 25% to 75% of the conserved water.

 

**Figure 21 Before: A gravel and wood "push-up" dam that blocks fish passage on the upper mainstem John Day River, south of John Day… And after! The lay-flat stanchion dam includes a channel for fish to migrate past the dam. When the dam is lowered, the stream flows naturally (photos and caption from BPA 2009).**

We believe there is significant potential to be had from upgrading irrigators' "push-up dams" to permanent structures with gates and fish passageways. The key questions are whether these will be acceptable to irrigators and ditch companies, and of course, who will fund construction and ongoing operation and maintenance. On Oregon's John Day River, the state-owned Bonneville Power Administration has run a successful program to replace earthen push-up dams with permanent structures that offer better control over diversions and are more environmentally friendly (BPA 2009). Since 1999, the program has helped install 100 lay-flat stanchion dams (Figure 21). The dams have a channel for fish to migrate past the dam and can be lowered to allow the stream to flow naturally. Funding could also be obtained through a small additional sales tax, such as the 1/8 cent tax enacted by San Antonio, via donations or foundation grants, or via state and federal funding. The Bureau of Reclamation also has a competitive grant program called WaterSMART which has funded conservation projects across the west.

### 3.2.4. Enhance Aquifer Recharge

If it is found that withdrawals from the Verde aquifer exceed sustainable levels, managers have two choices: reduce withdrawals or increase recharge. Increased recharge, or "augmentation," could come from several sources: inter-basin transfers, intra-basin transfers, and local alternatives. Inter-basin transfers refers to water from outside the Verde River watershed, for example from the Colorado River basin via Central Arizona Project (CAP). New wells could be developed in neighboring basins and water conveyed to the Verde River Valley. Local alternatives consist of capturing and reusing stormwater from residential or commercial sites. Also, urban runoff could be collected and used for recharge of the Verde River.

We have not done a detailed analysis of the feasibility of any of these alternatives. Interbasin transfers are likely to be expensive and carry unacceptable environmental impacts. Of these, the most promising are projects to capture and infiltrate runoff or stormwater. Planning for projects of this type would need to include a legal assessment of the extent to which runoff or stormwater may already be appropriated for downstream use, an area where the law is currently murky (see e.g. Nellans 2011). The best areas for artificially enhancing recharge have the following characteristics (Blomquist, Schlager, and Heikkila 2004, 38-39):

- high amounts of sand and gravel
- high percolation rates
- high well yields
- high storage capacity
- no continuous clay layers

## 3.3. Legal Reforms

### 3.3.1. Advocate for Legal Protection of Instream Flows

Arizona should move to strengthen and clarify state laws regarding instream water rights. Instream water rights are not guarantees that a certain quantity of water will be present in the stream. Rather, when the quantity of water in a stream is less than the instream water right, regulators will require junior water right holders to stop diverting water. Arizona law currently recognizes water rights for instream flows, but there are parts of the instream flow law that need to be improved.

First, instream flow should be recognized as a beneficial use equal to traditional consumptive uses, which are currently given preference. The rules for appropriating water for instream use are described in Arizona Revised Statutes (A.R.S.) § 41-1008 and 41-1079, and ADWR provides instructions for filing such an application (ADWR 1991). Arizona statutes value "municipal, domestic, irrigation, stock watering, power, and mining" uses above "recreation and wildlife, including fish" (ADWR 2010). This clause means that "any number of interests could sabotage ecological restoration and enhancement projects dependent on instream flows" (Boyd 2003).

Second, the legislature should clarify that physical diversion from a stream is not necessary to establish a water right. Third, instream flow laws should allow transfers of existing water rights to instream flows. Under current rules, any person can appropriate water for instream flows in Arizona, but only government entities can transfer existing consumptive rights instream (Boyd 2003). Finally, the law should clarify the quantity of water that can be transferred or appropriated for instream use, and the reach to which an instream right applies. As an example, an irrigator may wish to retire several acres from production and transfer his water right to instream flow. How many acre-feet or cfs of streamflow does this translate to, and over what reach of the river? Typically, this requires expensive study by hydrologists and water rights examiners, an additional expense that may be prohibitive to the applicant and discourage transfers (Boyd 2003). Oregon is the only state that performs such studies on behalf of applicants, helping them avoid a significant added cost, although as noted previously, such reviews can take up to two years to complete.

Finally, Arizona should consider allowing both public and private organizations to purchase and lease rights for instream flow maintenance. A number of legal scholars (Colby 1988, 747; Boyd 2003, 1211) recommend allowing both public and private organizations to apply for and hold instream water rights. Boyd (2003) also argues that mandatory state ownership of instream rights "severely limits the willingness of many consumptive users to participate." Currently, Montana is one of the few states that allows individuals to hold instream water rights. He argues that "if the users themselves or the organization of their choice could control the instream rights, more people would be willing to transfer their rights instream." However, Boyd based his assessment on the first five years of Oregon's experiments to restore instream flows. The market for instream transfers developed slowly, but the number of transfers has increased dramatically in the last decade (Aylward 2008). In recent years, these programs have begun to show results, and millions of dollars have been spent to restore 1,600 cfs to Oregon rivers (OWRD 2010). There is the further advantage of the state holding it in trust for the public, in perpetuity, so that water can not be re-sold in the future for other uses.

Instream flow advocates can learn much from Oregon, which has the oldest instream flow programs of any state, and "one of the most comprehensive (and comprehensible) systems for transferring water rights to instream use" (Boyd 2003). Oregon's 1987 Instream Flow Act created minimum flows into instream rights to be held in trust by the state. The instream rights maintained the original priority date and were given the same legal status as other water rights. In addition, the Act defined instream uses as beneficial uses, and authorized state agencies to apply for instream water rights to support fish and wildlife, ecological values, recreation, scenic attraction, navigation, and pollution abatement. A major challenge for instream flow protection in Oregon is that instream water rights are often junior to other rights. To address this issue, the state put in place policies and programs that permit rights holders to sell, lease or donate water for instream flow, as described previously in the Deschutes River case study.

For those interested in examining instream flow laws and programs in more detail, Washington state also has clear laws and policies aimed at restoring river flows. The Washington Department of Ecology runs three market-based programs: the Trust Water Rights Program, the Water Acquisition Program, and Water Banking (Dept. of Ecology 2011). Another excellent resource is a book published by the nonprofit Instream Flow Council, *Integrated Approaches to Riverine Resource Stewardship: Case Studies, Science, Law, People, and Policy* (2008), which includes a chapter on legal tools for instream flow protection.

Passing instream flow laws and acquiring instream rights will not sufficient to maintain flows. Even in states with instream flow laws, enforcement is a challenge. Staff and financial resources are required to monitor stream flows and regulate junior water users to meet the flows, and protection of instream flows is not always a priority for the state. This lack of monitoring is one of the main hurdles in protecting stream flows nationwide, but in many locations volunteer monitoring has served as a successful deterrent. This is especially true where "regulation activity is complaint-driven because agency field staff lack resources to monitor and enforce basin closures and priority dates in areas targeted for streamflow restoration" (Garrick et al. 2009).

### 3.3.2. Require Reporting of Water Use

It is a business axiom that "you can't manage what you don't measure," and this extends to water. Good water management depends on having accurate information about water use on which to base regulatory and management decisions. The state of Arizona does not require that municipal water providers outside of Active Management Areas (AMAs) meter and report water use. Water suppliers must report their water use to ADWR if they serve 15 or more connections or 25 or more people, but in rural areas, there are few reporting requirements. Outside of AMAs, neither domestic or agricultural well users are required to measure or report their water use.

Hydrologic studies of the Verde River Basin (e.g. CYHWRMS 2009; Blasch et al. 2005) have been hampered by lack of accurate water use data. Analysts have had to estimate water use in the basin, because actual measurements were unavailable. The CYHWRMS study, for example, estimated that each well used 0.33 acre-feet per year, although no source is reported for this information. The USGS study estimated that each resident uses 133 gallons per day. With an average household size of 2.33, this is equivalent to 0.35 acre-feet per household. While both studies used similar values for domestic water use, they are only estimates; commercial and agricultural water use are even more variable and difficult to estimate. More accurate water balances could be performed if analysts had access to records of water use.

The author of a review of groundwater management across the High Plains Aquifer, which covers eight states from South Dakota to Texas (Sophocleous 2009), concluded that Kansas' system of water use reporting is among the best in the United States and should be emulated by other states. First, the Kansas Legislature made water-use reporting mandatory. Failure to file a timely, complete, and accurate report could result in fines of up to $250 per water right. Enforcement is rare, as 99.9% of all water use reports are filed each year.

In Kansas, the state Division of Water Resources reviews reported water use data and issues an annual statewide water use report, in collaboration with state planning agencies and the US Geological Survey. Local Groundwater Management Districts have regulations requiring water flow meters on almost all non-domestic groundwater wells. Tax incentives are provided to offset the cost of installing well meters, and districts provide assistance with testing and maintaining the water flow meters. In Kansas, water managers have a 25-year history of groundwater use. This information complements data from a network of groundwater monitoring well network. This information has revealed useful information, such as the relationship between water use and climatic conditions, as well as how the uptake of more efficient irrigation technology has caused groundwater use to decline. The information is all publicly available and provides an "accurate and reliable basis on which to base management decisions in Kansas" (Sophocleous 2009, 569).

### 3.3.3. Regulate Groundwater Pumping to Sustainable Levels

Water managers should establish the level of groundwater extraction that is sustainable. The USGS defines groundwater sustainability as "development and use of ground water in a manner that can be maintained for an indefinite time without causing unacceptable environmental, economic, or social consequences" (Alley, Reilly, and Franke 1999). Older definitions of aquifer "safe yield" focused on limiting pumping to the rate of recharge. Arizona's AMAs have the goal of reducing pumping to the rate of recharge by the year 2025. This definition of safe yield does not protect surface water flows.

Hydrological science tells us that capping groundwater extractions at a rate equal to recharge may not be sufficient to protect springflows or baseflows of rivers (Bredehoeft, Papadopulos, and Cooper 1982). This is because, over the long-term, inflows must equal outflows. Outflows from the aquifer are the sum of pumping and discharge to springs or rivers. Thus, as flows near average recharge, it must be accompanied by changes in other fluxes: either recharge must increase, or other outflows must decrease. This is a difficult and counterintuitive concept that is not well understood even by professional water managers.

Once a sustainable level of pumping is established, efforts should be made to limit withdrawals to this level. This is the controversial part. Currently, there seems to be no provision in Arizona law to allow for this. As noted, AMA regulations are not designed to protect surface water resources. Indeed, there are few states where water laws require that aquifers are managed specifically to maintain surface water flows.

The three case studies described in this report describe efforts to manage groundwater to protect surface water flows. Another example comes from Kansas, where, beginning in early 1990s, two local groundwater districts began "conjunctive stream-aquifer management" (Sophocleous 2009, 568). The districts amended their safe yield regulations to include base flow. State law in Kansas created local Groundwater Management Districts and gave them responsibility "to conserve and prolong the life of the aquifer and protect its water quality." The state also has a Minimum Instream Flow law, which requires that minimum desired streamflows be maintained in Kansas streams. Thus, these Kansas districts, which are in areas where streamflows have been depleted by groundwater pumping, have amended their rules in order to comply with state laws governing groundwater pumping and instream flow. All groundwater permit applications are evaluated to determine whether they are effectively drawing on base flow. If so, districts declare that the groundwater has already been appropriated, and the permit is denied.

Moving toward sustainable groundwater management means managing groundwater and surface water as a single resource, or engaging in "conjunctive management." Arizona law does not recognize the hydrologic connection between surface water and groundwater, or attempt to coordinate their management. State courts created the concept of "subflow," a small step in the right direction. The court ruled that a surface water right is necessary for pumpers close to the river. In fact, as we've seen, any groundwater pumping in an aquifer that is geologically connected to a river can affect its flow. Hydrologists do not recognize a separate phenomenon of "subflow," and Arizona should bring its water management laws in line with current scientific understanding.

Moving toward sustainable groundwater pumping may not be fast or easy. In the short-term, certain actions can provide an immediate benefit. Wells within a prescribed distance to watercourses or wetlands should be banned. These wells have the most immediate and direct impact on surface water levels and flows. Cities should investigate the feasibility of extending municipal piped water supply to homes on the valley bottomlands that are currently served by wells.

### 3.3.4. Mitigate New Water Uses

The concept of mitigation involves the use of "environmental offsets," and aims to counteract the impact of development to achieve a net neutral or beneficial outcome. The use of offsets is a common form of environmental regulation in the United States and Europe. For example, beginning in the 1970s, most states adopted a "no net loss" policy for wetlands. Rather than banning all development in wetland areas, developers were given the option of offsetting wetland loss by creating new wetlands elsewhere on an acre-for-acre basis. The early project-by-project mitigation approach has been criticized for being inefficient and producing poor results (McKenney 2005, 17). A new entrepreneurial approach to mitigation has emerged that created a “banking” framework. Under the banking approach, entrepreneurs invest in developing offsets (for example, a large wetland restoration project), and recoup their investment by selling “credits” to developers. The use of wetland banks to provide “compensatory mitigation” has risen dramatically in the last two decades. A 2005 inventory of U.S. wetland banks found a total of 450 approved mitigation banks and an additional 198 banks in the proposal stage (USEPA 2009).

The use of offsets to mitigate activities that cause environmental harm has become increasingly common. Today, there are mitigation schemes covering forests, endangered species habitat, air pollutants, carbon emissions, water pollutant discharges, and water use. The approach is generally seen as being friendly to development while preserving ecological values. The mitigation approach is not without its detractors, however. For general critiques of wetland mitigation, see for example Gardner, (2000) or Race and Fonseca (1996). A general criticism is that it is better to do no harm than to offset that harm: policies should seek to avoid or minimize environmental damage before allowing mitigation. More specific criticisms are aimed at the specifics of how offsets are provided, and whether they are sufficient to cancel out environmental harms.

In each of the case studies we examined in this report, basin water use was capped, and new water users are required to mitigate their water use through the purchase of offsets. Mitigation water is most frequently acquired by purchasing agricultural water rights and retiring land from production. In Oregon, under the Groundwater Mitigation program, all new groundwater users are required to acquire a water right, usually by purchasing an agricultural water right, where irrigated land is retired. Mitigation credits have also been developed through funding water conservation and efficiency projects. We also described how mitigation banks have been set up to simplify such transfers.

Theoretically, water supply augmentation projects can be used to create mitigation credits, although we found no examples in the literature. For example, an entrepreneur could build a project to capture stormwater runoff and allow it to infiltrate, artificially increasing recharge. There are reasons why private developers have not built augmentation projects: cost, uncertain returns, difficulty in finding financing for novel projects, difficulty in getting all the required permits, and uncertainty about water. Thus, government entities are typically the initiators of augmentation projects.

### 3.3.5. Deal with Exempt Wells

Most states that require a permit and a water right to pump groundwater grant exemptions for small household wells, or less frequently, for wells used for purposes such as livestock or mining. Water managers are becoming increasingly aware of the downside of having too many so-called “exempt wells.” In areas of Arizona outside of AMAs, the only requirement for most new wells is to file a notice of intent to drill and a completion report. Domestic wells pumping up to 56 acre-feet per year are exempt from permitting requirements (or up to 10 acre-feet in AMAs since 1983). While a single well may not have a large impact, their aggregate effect can be substantial. An article in the *High Country News*, known for its coverage of Western land and water issues, called the issue “death by a thousand wells” (Carswell 2009).

Many Western states have considered household wells to be *de minimus* extractions: they “use so little water from the aquifer and have such a trivial affect on other surface and groundwater users that it isn’t worth the time and money a state would have to spend to keep track of such wells” (Bell and Taylor 2008, 62). But in rapidly growing areas, “rural subdivision wells in hydrologically-stressed areas can have a substantial effect on water supplies.”

Several Western states have responded to the impacts of subdivisions with “show me the water laws.” For example, in Arizona, within AMAs, developers are required to demonstrate an “assured adequate water supply” for the next 100 years, as demonstrated by a hydrologic study. The rule covers subdivisions with six or more homes. Some developers have skirted this rule by building “wildcat” subdivisions of five units (Bell and Taylor 2008, 65).

**Farmland transforming to subdivisions. Photo courtesy of Dan Campbell.**

We believe it is important to account for exempt wells if groundwater is to be managed sustainably. At a minimum, all water users should be required to report water use on at least an annual basis. If a rights-based system is put in place, where groundwater users are required to obtain a water right or to purchase mitigation credits to offset the effects of pumping, it should include all wells, including those for household use. Ultimately, applying the same requirements to all water users will make the program simpler, more understandable, and easier to administer.

### 3.3.6. Press for Adjudication of Water Rights

A well-defined system of water rights is a prerequisite to establishing a system of tradable water rights such as those described in the case studies. For states to use market transactions as a means to support instream flows, there must be a system of quantified and enforceable water rights. According to ADWR, the Gila River Adjudication, a judicial process to resolve all the water rights on an entire river system, began in 1979, and contains 83,500 claims by more than 24,000 claimants. “Because of the complexity and number of claims, resolution is not expected for many years” (WEF 2007, 5).

Water rights are a form of private property rights, which are required for trading to take place. Environmental lawyer Todd Votteler describes the characteristics of an efficient property rights system (Votteler 1998):

1. Universality: All resources are privately owned, and all entitlements completely specified;
2. Exclusivity: All benefits and costs accrued as a result of owning and using the resources should accrue to the owner, and only to the owner, either directly or indirectly by sale to others;
3. Transferability: All property rights should be transferable from one owner to another in a voluntary exchange;
4. Enforceability: Property rights should be secure from involuntary seizure or encroachment by others.

In rural Arizona, where groundwater access is only governed by the doctrine of “reasonable use” and access is not limited, none of these characteristics is present under the rule of capture. There is no *universality*, as a pumper’s use of water is vulnerable to extraction by a neighbor. Neither does *exclusivity*, as owners do not have the option of leasing or selling their water.

Clarification of water rights entitlements, and the expectation that rights will be enforced, are necessary for market-based water transfers described elsewhere in this report. In order for groundwater users to participate in markets, groundwater rights must also be quantified.

### 3.3.7. Pursue Endangered Species Act Protections for the Verde’s Aquatic Species

In each of the three case studies we examined in this report, major changes to long-established water management systems were prompted by legal requirements to protect threatened and endangered species. The Western Governors Association, in its report *Water Needs and Strategies for a Sustainable Future* (2008), recommended investigating several courses of action to support the maintenance of instream flows, including examining “the merits of federal action to help expedite state general stream adjudications as a means to enhance the protection of species.” If one decodes this carefully worded statement, the WGA is recommending a long-time strategy used by environmental organizations, which is to pursue protections for aquatic species under the federal Endangered Species Act (ESA).

The Endangered Species Act has been called “nature’s safety net.” When other laws fail to protect plants and animals, the ESA is the last barrier to their extinction. Passed by Congress in 1966 and modified several times since then, the ESA directs the government to protect species and also "the ecosystems upon which they depend." The ESA requires the preservation of habitats of listed species and allows the government to acquire land for this purpose, allowing the U.S. Fish and Wildlife Service (FWS) to spend up to $15 million per year per species.

A number of revisions to the ESA since 1973 have made it a more flexible, permitting statute. For example, the original law made it illegal to "take" (kill or harm) a listed species. Since 1982, Congress has authorized "incidental takes" with a permit if it is done in conjunction with a "habitat conservation plan." The law requires the responsible agency, either the U.S. Fish and Wildlife Service or the National Marine Fisheries Service, to develop a "Recovery Plan outlining the goals, tasks required, likely costs, and estimated timeline to recover endangered species (i.e., increase their numbers and improve their management to the point where they can be removed from the endangered list)." Penalties for violating the Endangered Species Act by "taking" (harming, wounding, or killing) a listed species include a maximum fine of up to $50,000 or imprisonment for one year, or both, and civil penalties of up to $25,000 per violation.

Although many elected officials and water users in the west have resisted such federal action, viewing it as violation of states' rights, their lack of effective water management may ultimately result in the very intervention they hope to avoid. Furthermore, while federal laws such as the Endangered Species Act and the Wild and Scenic Rivers Act have imposed flow requirements on certain reaches, it is up to states to protect those reaches—required changes to water management are only possible through state law (Boyd 2003, 1208).

In order for a plant or animal species to receive protection under the ESA, it must be declared endangered or threatened by the U.S. Fish and Wildlife Service, an agency under the Department of Interior. Typically, this process is initiated through a petition or a lawsuit by citizens or an environmental organization. Organizations known for filing such lawsuits are WildEarth Guardians, the Sierra Club, the Center for Biological Diversity, and the Natural Resources Defense Council. As of 2009, there were a total of 1,890 (foreign and domestic) species on the list. There is currently a backlog of 251 plants and animals awaiting attention under the ESA, although the Fish and Wildlife Service has recently agreed to expedite their handling (Chaney 2011). In order for a species to be listed, one or more of these conditions must be present:

1. There is the present or threatened destruction, modification, or curtailment of its habitat or range.
2. There is an over utilization for commercial, recreational, scientific, or educational purposes.
3. The species is declining due to disease or predation.
4. There is an inadequacy of existing regulatory mechanisms.
5. There are other natural or manmade factors affecting its continued existence.

In 2009, the Roundtail Chub (locally known as the Verde Trout) was listed as endangered by the FWS, bringing the species under the protection of the Endangered Species Act. The listing of the Roundtail Chub followed from a lawsuit filed by the Tucson-based environmental organization Center for Biological

Diversity. According to The Nature Conservancy, the Verde historically supported at least 13 species of native fish, including 7 that are now considered threatened or endangered (TNC 2009).

With a listed endangered species, it is illegal to kill or harm even a single individual of the species; this would be considered a “take.” Under certain circumstances, it may is impractical to avoid activities that harm endangered species; in such cases, these activities may proceed but must be accompanied by a “take permit.” In order to receive a permit, the applicant must put in place an approved Habitat Conservation Plan (HCP). In other Western rivers, HCPs have entailed wide-ranging changes to basin-wide water management.

The Endangered Species Act is a powerful law that can compel state governments and private landowners to change the way they manage water to support healthy ecosystems. Pursuing ESA protections for aquatic species has been a strategy of last resort adopted by some environmental organizations responding to an environmental crisis. As can be seen in the case studies presented later in this report, ESA litigation, or the threat of a lawsuit, has provided the necessary “stick” that promoted reform in water management institutions. However, we have also seen that intervention by the courts in water management usurps local control and is undesirable for a number of reasons.

In several cases, courts have ruled that water management must be changed to maintain instream flows. In Texas in the 1990s, a federal judge appointed a water master to put in place a drought emergency plan to protect spring flows. While in this case the court’s intervention was necessary to prevent extinction, there are a number of disadvantages to a court-appointed “water czar” rather than developing local institutions for water management.

Courts are not the ideal venue for solving water disputes, for several reasons. First, courts lack expertise in biology and hydrology to establish good instream flow requirements. Second, court proceedings are inherently contentious, based on a model of plaintiff versus defendant, rather than bringing resource stakeholders together to seek consensus. Third, their decisions are binding and final, and they don’t allow flexibility to re-negotiate or to adapt water management plans over time. Finally, court-appointed arbiters often cancel irrigation deliveries so that more water remains instream (Votteler and Moore 1997). This raises obvious questions about whether this is the most fair, equitable, or economically efficient way to re-allocate water to the environment.

However, those involved with water management should be made aware of their responsibilities and liabilities under the Act. The case studies also show how parties have used endangered species recovery programs to rally around a common goal, to attract federal funding to support water management reform, and to invest in water conservation and efficiency.

## 3.4. Economic and Market-Based Measures

Over the past decade, regulators in Australia’s Murray-Darling River Basin introduced markets to reduce inefficient water use and benefit the environment. The thinking was “that the discipline of the market would drive up the cost until water found its ‘true value.’ If water was expensive, said the system’s advocates, then irrigators would use it more efficiently, reducing waste” (Cathcart 2010).

One frequently encounters talk of “markets” when the speaker is actually referring to the use of economic tools such as incentives for control of water (Dellapenna 2000). In the United States, there are few examples of true water markets (Michelsen 1994). Water markets are generally limited in their geographic area, and involve fewer participants than conventional markets for tradable commodities. Water markets are also less than efficient because of what economists call transaction costs, which are necessary to make trading work. “It takes time and money to identify willing sellers of water, to evaluate the value of their water rights, to determine whether the water rights of third parties may encumber the sale, to negotiate the terms, and to assess whether the proposed contract is enforceable” (Glennon 2004). Further, markets cannot be imposed on chaos. “If water markets are to flourish, there must be a system of quantified water rights that are transferable. Water markets can only develop if a farmer has a known and fixed right that she can sell or lease. Without a property right that is quantified and transferable, there will be no voluntary reallocation of water use” (Glennon 2004).

In the following sections, we first discuss the issue of water pricing, an application of economic principles to promote better water management. We go on to discuss the role that “buying back” excess water rights has played in restoring streams in other states, and how markets have helped to mitigate the burden of basin closure.

### 3.4.1. Charge Groundwater Extraction Fees

Many authorities point out that the best way to promote conservation of limited resources is by charging fees for its use (e.g. Clayton 2009; Glennon 2005). University of California economist David Zilberman calls pump taxes an “optimal policy” but notes that few jurisdictions have implemented one because water use is difficult to monitor, and enforcement of these policies is difficult (1999). In California, local Groundwater Management Districts use different means to raise revenue. First, they may use property tax assessments on land or homes. Others charge fees for groundwater extraction, a “pump tax” or for groundwater recharge (Freeman 2010). In Texas, the Edwards Aquifer Authority charges pumpers based on their water use, with payments referred to as an “aquifer management fee.” The Texas legislature capped the fee for irrigators at $2 per acre-foot, but municipal water users currently pay $39/af.

Residents may not uniformly support an additional tax on something that was customarily free unless they perceive the benefits. Voters in the Upper San Pedro River Basin in southern Arizona were asked, on the November 2010 ballot, whether or not to authorize the creation of a water management district with powers to propose taxes. The measure was narrowly defeated by 51% of the voters (Hess 2010), despite the fact that public opinion polls showed that a majority of residents supported paying fees of up to $75 per year to support restoring the river (Jonsson 2008).

A pump tax is a proven but often contentious way to limit demand to sustainable levels. To be effective at reducing water use, the tax must be set high enough so that a pumper would actually choose to limit his pumping rather than pay the fee. (An economist would say that this is the point where the cost of the next unit of water user equals the utility that a pumper derives from the use of that water.) This is problematic for a few reasons. First, this approach is rare. In the United States, utilities set water rates at a level to recover costs, and not sufficiently high to encourage conservation (Beecher et al. 1994; Hall and Hanemann 1996; Olmstead and Stavins 2009).

Every state has a consumer protection agency that prohibits utilities from over-charging for services. In Arizona, utility rates are regulated by the Public Utilities Commission and the Corporation Commission. It is questionable whether these public agencies would approve a new tax on pumping that was sufficiently high. Second, these costs will be unpalatable to voters, and hence to politicians. In California, groundwater districts have been routinely sued, with residents challenging the legality and constitutionality groundwater management fees or a pump taxes (CSDA 2011). Third, establishing high enough rates to be effective could be a burden to low-income residents. Equity issues can often be handled by setting up tiered rate structures, where a basic allotment is provided at low cost, and higher use is charged more heavily.

Thus, it is neither feasible nor may it be desirable to create a pump tax that is high enough to bring consumption to sustainable levels. However, charging groundwater users a modest fee can provide a number of benefits. An "aquifer management fee" as in the Edwards Aquifer, sends the message to pumpers that groundwater is a valuable commodity, even if the price is not high enough to encourage conservation. Second, the revenues from such fees can support a number of worthwhile activities; some of these are described below under the section on Creating a Verde River Conservation District.

**Tuzigoot National Monument above the Verde River. Photo courtesy of Jeanmarie Haney.**

### 3.4.2. Allow Interested Parties to Purchase or Donate Water for Instream Flow

The Oregon Water Trust, formed in 1993, was the nation's first water trust. In 1994, it initiated the first private lease of water for environmental purposes, paying $6,600 to a farmer not to irrigate his hay crop to protect spawning steelhead in Buck Hollow Creek. Since then, its success of the Oregon Water Trust has spawned the creation of similar organizations in Washington, Idaho, and Montana. Today, more and more environmental organizations and government agencies are financing instream flow by either "buying back" water or funding water conservation projects.

A total overhaul of our water laws and systems of allocation has been advocated in some quarters. For example, Pisani (1996) argues that the system of prior appropriation should be abandoned or modified. This would be extremely difficult, as this system is written into many states' constitutions, and a large body of law and custom has built up around it. Buy-backs are seen by many legal and economic analysts as more practical than changing laws (see e.g. Scarborough 2010). This is also the case outside the United States. In Australia, the government has dedicated over US$3 billion to buy back excess water rights in the over-allocated Murray-Darling River basin (Garrick et al. 2009, 379).

A system of documented and enforced water rights must be in place for such a system to work (Colby 1988, 747). The process of adjudication, or clarifying existing water rights, is underway in every Western state, but it is a lengthy process that is expected to take decades to complete. This is why we recommend that river advocates press for adjudication of water rights in the Verde River Basin in a section below. Lastly, California water lawyer Kelly Cole argues that making transfers to instream flow tax-deductible would increase the number of such donations (Cole 2008).

### 3.4.3. Water Banking

As we saw in the Deschutes and Edwards case studies, water banking has played a role in groundwater mitigation. Arizona has a water bank of sorts, but it does not have an environmental objective. The state created the Arizona Water Bank to store excess Colorado River water that is not needed during wet years. Water Banking is an "institutional mechanism that facilitates the legal transfer and market exchange of various types of surface, groundwater, and storage entitlements" (Tillman et al. 2011). Water banks do not operate like traditional financial institutions.

Water banking is useful for facilitating trade under a "cap and trade" system. When regulators cap extractions (sometimes referred to as basin closure), new water use must be accompanied by an equal decline in current water use. Banks play a role in creating markets for such exchanges, matching buyers and sellers. Thus, it does not seem that banks could immediately play a role in improving water management in the Verde. However, once water rights in the basin are clarified, and if changes are made to key state laws, banks could play a role in facilitating water transfers for environmental purposes.

What do water banks do? The following introduction is from *Analysis of Water Banks in Western States* (Clifford, Landry, and Larsen-Hayden 2004, 6-7):

> Some banks have taken a more active position by assuming the role of broker, clearinghouse, or market-maker. As a broker, the bank connects or solicits buyers and sellers to create sales. As a clearinghouse, the bank serves mainly as a repository for bid and offer information and facilitates the regulatory requirements for trades. And as a market-maker, the bank creates liquidity in the market by standing ready to purchase surplus water or sell reserve water within predetermined price ranges. The purpose of the market maker is to ensure that trades occur even when counter parties (e.g., buyers and sellers) are not present. Market makers can provide a valuable service in creating and maintaining

liquidity in newly formed markets that are thinly traded. Not all banks take an active role in exchanges and have opted to provide administrative services that facilitate sales and transfers. These services may include:

- Registry of water rights or entitlements
- Regulating or setting market prices
- Setting and implementing long-term strategic policies and daily operations
- Establishing whether the bank operates on a year-by-year or continual basis
- Determining which rights can be banked
- Quantifying the bankable water
- Specifying who can purchase or rent from the bank
- Setting transfer or contract terms
- Dealing with any regulatory agencies
- Resolving disputes

In the preceding analysis of water banking in Western states, the authors give the following guidelines to ensure that water banks meet environmental objectives:

- Ensure that bank exchanges do not negatively impact existing stream flow levels.
- Allow instream uses to be classified as a beneficial use.
- Provide incentives for deposits through nonuse and forfeiture protection
- Allow open participation in the bank by third parties that would acquire water for instream use.
- Grant priority for transfers that benefit instream flow.
- Establish standing offers to buy leases for instream flow in pre-recognized critical flow areas.

## 3.5. Administrative or Institutional Actions

In the following three sections, we describe administrative bodies that could take on responsibility for regulating groundwater use and engaging in river restoration activities. Broadly speaking, an Active Management Area would have the broadest powers to regulate water use; a special district would be able to carry out water projects but would likely have a limited regulatory role. Prospects for basin-wide water management are dim in the absence of an administrative body that overlies the multiple political entities in the basin. However, local governments can, and already do, play a role in river protection.

### 3.5.1. Create the Verde River Active Management Area

The use of groundwater in Arizona is highly regulated within "active management areas" (AMAs), of which there are currently five (ADWR 2003). The five AMAs cover 80% of the population, but only 13% of the land (Jonsson 2008), thus leaving rural areas of Arizona with few options for controlling overexploitation of groundwater. There are six key provisions in AMAs:

1. Establishment of a program of groundwater rights and permits.
2. A provision prohibiting irrigation of new agricultural lands within AMAs.
3. Preparation of a series of five water management plans for each AMA designed to create a comprehensive system of conservation targets and other water management criteria.

4. Development of a program requiring developers to demonstrate a 100-year assured water supply for new growth.
5. A requirement to meter/measure water pumped from all large wells.
6. A program for annual water withdrawal and use reporting. These reports may be audited to ensure water-user compliance with the provisions of the Groundwater Code and management plans. Penalties may be assessed for non-compliance.

One option is to press for creation of a Verde Valley Active Management Area with these powers. AMAs can be created by the legislature, or by a majority of voters in a region (ADWR 2003). The director of ADWR can create new AMAs if he determines that:

1. Active management practices are necessary to preserve the existing supply of groundwater for future needs;
2. Land subsidence or fissuring is endangering property or potential groundwater storage capacity, or;
3. Use of groundwater is resulting in actual or threatened water quality degradation.

In the five AMAs in Arizona, local managers must develop plans to limit withdrawals by the year 2025. AMAs are managed to control overdraft, and limit pumping to the safe yield, defined by ADWR as "as a long-term balance between the annual amount of groundwater withdrawn in the AMA and the annual amount of natural and artificial recharge." As we have seen, this definition of safe yield does not consider other aquifer outflows to rivers, wetlands, and springs. It is not sufficient to protect surface water resources. In fact, none of the current AMAs are designed to protect surface water, as described by Boyd (2003, 1156)

> Unless fish and wildlife survival is determined to be a future need, little in the groundwater code enables the State to protect riparian habitat from degradation by the consumptive use of ground water. See generally ARIZ. REV. STAT §§ 45-401-45-704. Additionally, even where the state creates an AMA in basins where habitat is threatened by groundwater depletion, many of the rights causing the problem would probably be grandfathered and allowed to continue depleting the aquifer. See generally ARIZ. REV. STAT. §§ 45-461-45-482 (grandfathered groundwater rights in active management areas). Overall, mandatory compliance with the groundwater code does not significantly protect riparian areas from degradation by the consumptive use of ground water.

In order to protect surface water flows, the Verde AMA would require a declaration by voters or the director of ADWR that fish and wildlife survival is a future need, or that surface water flows need to be protected, or perhaps that it is necessary to protect the rights of downstream senior water users.

### 3.5.2. Create a Verde River Conservation District

In Arizona, Active Management Areas (AMAs) regulate groundwater use below the state's largest population centers. AMAs cover 80% of the state's population, but only 13% of its land area. While Arizona groundwater law contains several provisions that extend to the entire state, rural areas lack many of the regulatory tools available to AMAs. "As a result, rural areas are compromised in their ability to control groundwater pumping and effectively manage the effects of population growth" (Jonsson 2008).

When faced with shortages, water managers have two basic options, to limit demand or to increase supply. Active Management Areas exist to limit demand by restricting pumping and limiting the expansion of irrigated agriculture. The Upper San Pedro River Partnership was formed by a broad coalition of government, environmental, and development interests to protect the San Pedro River from overdraft. Interests on the Upper San Pedro elected to pursue the latter option, seeking to form a special district to pursue water supply augmentation. Because no local government had the authority or funding to pursue such projects, the partnership sought to form a special district to pursue these options.

#### *3.5.2.1. What is a Special District?*

Special districts are local government entities that often cross city or county boundaries, and usually provide a single service using public funds. The most common type are school districts, of which there are 245 in the state, but districts also exist to provide irrigation, drainage, electricity, wastewater, transit, and weed control services, among others (Cochise County 2011). The Census Bureau defines districts as "independent, limited purpose government units, which exist as separate entities with substantial administrative and fiscal independence from general purpose local governments." In Arizona, districts are governed by Title 48 of the Arizona Revised Statutes. Districts are legal entities with the power to own property, enter into property, sue and be sued. Districts can raise funds by charging for services, assessing and levying property taxes, or issuing bonds.

There are advantages to district formation. First, existing units of government lack the authority to provide the service requested. Second, special districts cover a limited service area, thus allowing for greater local control. There are also potential disadvantages. According to Cochise County, "special districts often are the result of promotion by special interests which feel that they can control a district better than a unit of general government." Districts can also "add to the political confusion in that they provide more units of government to compete for the interest of voters" (Cochise County 2011).

Recent experience on the Upper San Pedro River illustrates the difficulty of convincing voters to tax themselves to support water projects. In November 2010, voters narrowly defeated by 51% a ballot initiative to create the Upper San Pedro Water District. Advocates for district formation emphasized that it would allow the region to attract federal funding for water project. They had planned for a district with limited powers to allay potential voter concerns (Jonsson 2008, 21). For example, the Upper San Pedro Water District would have been prohibited to:

- Levy a tax unless approved by voters.
- Engage in the retail sale of water to customers.
- Require the use of a water-measuring device for any well, except as a condition in a contract agreed to by both parties.
- Impose mandatory conservation requirements on persons in the District.
- Regulate the acquisition, use or disposal of water or rights within the District.
- Exercise any right of eminent domain (property acquisition).

There are several reasons to support formation of a Verde River Conservation District or Water District. First, a district would provide an additional forum for discussing water issues. Modest improvements to the river might make it even more a focal point for area communities, increasing support for river restoration. For example, making the river navigable on more days of the year could bring more residents and visitors into contact with it, galvanizing support for further efforts. Most importantly, as groundwater overdraft is only one of several threats to the river, the district could engage in or fund projects that would improve the river's environment and increase water supply security, such as:

- Improve water intake structures
- Line or pipe earthen canals
- Provide technical assistance to farmers to support efficient irrigation practices
- Upgrade wastewater plant outfalls
- Remove invasive species
- Monitor streamflow and water quality in the basin
- Build projects to increase infiltration and aquifer recharge
- Extend municipal supplies to homes with wells close to the river
- Support water conservation through public education or grants

### 3.5.3. River Restoration Activities by Local Government

In the absence of a Verde AMA or District that would cover all or part of the Verde basin, as described above, local governments can take actions to protect the watershed. An example is provided in the Edwards Aquifer case study, where the city of San Antonio passed a 1/8 cent sales tax for aquifer protection. The city used these revenues to purchase land in the aquifer's recharge zone and converted it to parks. In other cases, the city purchased easements, where pumping restrictions are attached to a land title. This helps to maintain open space and protects the aquifer, while allowing rural land to remain in private hands and to support traditional land uses such as hunting, grazing, and fishing.

## 3.6. Arizona Water Management Timeline

Several entries are reprinted from the Layperson's Guide to Arizona Water (WEF 2007).

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| 300–1450 A.D. (circa) | The Hohokam ancient civilization flourishes in the Salt River Valley "with as many as 250,000 inhabitants at its peak. Some 200,000 acres were irrigated by a network of 185 miles of canals" (WEF 2007). |
| 1528 | Spanish explorers arrive in Arizona. |
| 1579–1600 | Drought in the Colorado River Basin reduces the river's flow by nearly a third. |
| 1821 | Mexico achieves independence from Spain; claims Arizona as its territory. |
| 1848 | The Treaty of Guadalupe Hidalgo ends U.S.-Mexican War. Texas, California and New Mexico—which then included Arizona north of the Gila River—are awarded to the United States. |
| 1852 | Americans begin navigating the Colorado River by steamer. |
| 1853 | Gadsden Purchase extends Arizona boundary from the Gila River to the present boundary. |
| 1863 | Congress declares Arizona a territory. |
| 1864 | Arizona Territory adopts principle of prior appropriation for surface water use or "first in time, first in right" under the Howell Code. |
| 1868 | Salt River Valley Canal built atop remnants of Hohokam canals. |
| 1869 | First rights to use Verde River water established. |
| 1869 | John Wesley Powell explores the Grand Canyon. |
| 1892 | The Kibbey Decision states that surface water belongs to the land and is not a separate commodity. |
| 1893 | Arizona's Territorial Legislature adopts the principle of prior appropriation for water rights, similar to other Western states. To establish a new surface water right, users would post a notice, file a claim with the county recorder, and put the water to beneficial use. |
| 1902 | Federal government passes the National Reclamation Act. |
| 1902 | U.S. Reclamation Service (later Bureau of Reclamation) established by the federal Reclamation Act. |
| 1903 | Salt River Valley Water Users Association formed to fund construction of Roosevelt Dam on the Salt River. It is the first multipurpose reclamation project started under the federal Reclamation Act. |

1904 Construction begins on Roosevelt Dam on the Salt River at confluence with Tonto Creek.

1909 Salt River Project established.

1910 Kent Decree establishes the basis for water rights in the Salt River Valley.

1911 Roosevelt Dam is completed.

1912 Arizona becomes the 48th state on February 14.

1917 Salt River Valley Water Users Association takes full control of the Salt River Project from the Bureau of Reclamation.

1919 Arizona enacts state water code. From now on, new surface water uses require a permit application to the state. At the time, the permitting agency was the State Water Commission; later it was the State Land Department, and today it is the Arizona Department of Water Resources.

1919 Grand Canyon National Park founded.

1922 Colorado River Compact, signed in Santa Fe, New Mexico, allocates 7.5 million acre-feet of water each to the upper and lower basins of the Colorado River.

1928 Boulder Canyon Project authorized by Congress allocates 2.8 million acre-feet of water to Arizona, 4.4 million acre-feet to California and 300,000 acre-feet to Nevada.

1933 Arizona creates laws governing groundwater use. In essence, "groundwater can be used by the person whose land covers it. This law, based on the common law doctrine of 'reasonable use,' perpetuated the assumption that groundwater and surface water were physically separate systems" (WEF 2007).

1935 Hoover Dam on the Colorado River dedicated by President Franklin D. Roosevelt. Arizona National Guard and militia units sent to Parker Dam construction site on the Colorado River to protest future diversions of water to California.

1936 Construction begins on the Bartlett Dam.

1944 Arizona Legislature ratifies the Colorado River Compact.

1946 Central Arizona Project Association formed.

1960s A number of retirement communities are established in Arizona catering to senior citizens wanting to escape the harsh winters of the Midwest and the Northeast.

1963 Arizona wins Supreme Court decision in contest with California over share of Colorado River water. The decision confirms Arizona's 2.8 million acre-feet allocation and clears the way for construction of the Central Arizona Project (CAP).The Supreme Court's decree ends 12 years of litigation between California and Arizona over the Colorado River.

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| 1963 | The Salt River Project, although it is exempt from paying property taxes like any municipality, begins making voluntary in-lieu payments equivalent to property taxes to impacted counties. |
| 1965 | Upper and Lower Basin states reach agreement on Colorado River legislation. |
| 1968 | Colorado River Basin Project Act authorizes construction of CAP. |
| 1969 | National Environmental Policy Act enacted. |
| 1971 | Central Arizona Water Conservation District formed. |
| 1973 | Construction begins on the Central Arizona Project (CAP), a $5 billion system of power plants, pumps, and canals that will allow Arizona to begin using its full allocation of Colorado River water for the first time. |
| 1973 | CAP construction begins. |
| 1973 | US Congress enacts the Endangered Species Act. |
| 1976 | Agricultural water use in Arizona peaks at 8 million acre-feet per year and steadily declines in the years following. |
| 1979 | Beginning of the Gila River Adjudication, a judicial process to resolve all the water rights on an entire river system. The process "encompasses the Gila River watershed, including the watersheds of the Salt, Verde, Agua Fria, San Pedro, and Santa Cruz rivers, where more than 85% of Arizona's population lives. It contains 83,500 claims by more than 24,000 claimants and has been ongoing since 1979. Because of the complexity and number of claims, resolution is not expected for many years" (WEF 2007, 5). |
| 1980 | Groundwater Management Act passed; Active Management Areas (AMA) formed. "AMAs encompass 80% of Arizona's population. However, only 13% of Arizona's total land area is included in an AMA. The remaining 87% of land is subject to minimal groundwater regulation" (Jonsson 2008, 1). |
| 1981 | Federal government scraps plans for the Orme Dam at the confluence of the Salt and Verde Rivers, originally intended for flood control and water supply for Phoenix. |
| 1982 | The US Congress modifies the Endangered Species Act, recognizing that the way water systems are operated is often a barrier to species survival. It incorporated a policy statement in the Act directing federal agencies "to cooperate with State and local agencies to resolve water resource issues in concert with conservation of endangered species." |
| 1983 | Arizona Department of Water Resources allocates Central Arizona Project water from Colorado River water to several communities in Yavapai County. Because of the expense of constructing a delivery network for this water, communities sell their allocation to cities in central Arizona which are already "plumbed." |

1984 A 40-mile reach of the Verde River is declared protected under the national Wild and Scenic Rivers Act. It becomes the first Arizona river to receive such a designation.

1985 "The State of Arizona attempted to take title on the riverbed to prevent Superior Companies and Valley Concrete from dredging material from the river" (Ayers 2008)

1985 First CAP water flows through the Hayden-Rhodes Aqueduct.

1986 Arizona Environmental Quality Act passed; Arizona Department of Environment Quality created.

1987 Construction on New Waddell Dam begins. CAP deliveries begin on Santa Rosa Canal section of project.

1988 Assured Water Supply program requires developers and water providers in AMAs to demonstrate a 100-year water supply.

1988 Congress passes the last major changes to the Endangered Species Act.

1989 The Arizona Supreme Court, in Arizona Public Service Co. v. Long, issued a decision of importance to cities or other wastewater plant operators desiring to sell their treated effluent. The court ruled that operators could "dispose of effluent in the most economically and environmentally sound manner," and were immune from claims of injury by junior appropriators (Bell and Taylor 2008, 101-102)

1990 Senator Carol Springer proposes bill to abolish AMAs.

1990 DWR issues its first "instream" flow permit, which grants the right to keep water in a stream to support fish and other wildlife habitat to The Nature Conservancy of Arizona for Ramsey and O'Donnell Creeks in Southeastern Arizona.

1992 CAP completed; water delivered to Tucson.

1993 Central Arizona Groundwater Replenishment District (CAGRD) created.

1994 Legislature establishes the Arizona Water Protection Fund (AWPF) with a goal of "restoring the state's rivers and streams and associated riparian habitats" and funded by the legislative appropriations and "in lieu fees" or surcharges on interstate transfers of water from the Central Arizona Project. From 1995 to 2000, the Fund pays for $26 million in restoration projects. after 2002, the legislature discontinues funding, but the fund continues paying for about 10 projects per year through CAP revenues (Arizona Water Atlas, Appendix F).

1995 "Yavapai County Planning and Zoning Commission sent out a survey asking what the locals felt about home densities and commercial development and golf. The locals responded that they wanted to keep their rural lifestyles, and golf was not part of that lifestyle" (Kiefer 1998).

1995 Roosevelt Dam expansion completed, raising the height of the dam to 357 feet and expanding the lake's storage capacity by 20%.

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| 1996 | Arizona Water Banking Authority authorized by the legislature and governor as a means to store unused Arizona Colorado River water. Unlike water banks established in some other Western states, “the main purpose of the AWBA is not to facilitate transfers among willing buyers and sellers, but rather to store unused water for future needs” (Bell and Taylor 2008, 124). |
| 1999 | Yavapai County Water Advisory Committee established to address long-term water supply issues in this fast-growing area. |
| 1999 | AZDWR issues a Groundwater Mining Declaration in the Prescott AMAs. Because data indicated that pumping exceeded replenishment for three consecutive years, the Department was required to make the groundwater mining declaration, forcing the Prescott AMA to follow Assured Water Supply (AWS) rules. This requires developers of new subdivisions to prove the availability of sufficient water supplies for at least 100 years, in effect forcing them to use renewable or imported supplies. |
| 1999 | The Rural Watershed Initiative Program was created by ADWR to assist with water resources planning (ADWR 2006). ADWR provides technical assistance, funding for hydrologic studies, and advice on water issues. As a result of the program, seventeen watershed groups have been formed, including the Yavapai Water Advisory Committee (WAC). Since 1999, when the legislature approved $1.2 million, funding has declined. |
| 2000 | Population of the Verde Valley reaches 132,000 in 2000. Yavapai county is named the fastest-growing in America. Official projections put the population in the valley at over 260,000 in 2050. |
| 2000 | Federal government and states adopt Colorado River Interim Surplus Guidelines. |
| 2001 | First year of extreme drought conditions in Upper and Lower Colorado River Basins. First water stored for Nevada in Arizona groundwater basins. |
| 2002 | Arizona courts, in the Gila River adjudication, define “subflow” as water in the “saturated flood plain Holocene alluvium.” The effect is that “subflow of a stream is treated the same as water flowing above ground, as far as state law is concerned. Which means, in order to legally use subflow, you must have a surface water right. In the Verde valley there are over 7,000 residential wells, the vast majority of which are pumping in or in close proximity to what is assumed to be the subflow zone of the Verde River and its tributaries” (Ayers 2011). Hydrologists do not recognize subflow as a distinct phenomenon. |
| 2003 | California signs Colorado River water delivery agreement. |
| 2003 | The Upper San Pedro Partnership is formerly recognized by the US Congress and directed it to achieve sustainable yield for the regional aquifer by 2011 (Jonsson 2008, 4). |

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| 2004 | Arizona Water Settlement Act passed by US Congress. The Act "finalizes an agreement between the United States and Arizona for Central Arizona Project repayment obligations, and settles water disputes between the Gila River Indian Community and all parties." |
| 2004 | On December 8, the Center for Biological Diversity (CBD) sends a Notice of Intent to Sue Prescott under the Endangered Species Act the planned Big Chino pipeline, which it believes will harm endangered species in the Verde River. To date, CBD has not filed suit, and in fact prefers to work with the city to develop a Habitat Conservation Plan to protect the river's species (Marder 2009, 200) |
| 2005 | The USGS publishes the first of several studies (Wirt, DeWitt, and Langenheim 2005) on the groundwater resources of the Verde Valley. The studies elucidate the geologic connection between the aquifer and the river and the connection between groundwater use and river flows. |
| 2005 | State law passed requiring all community water systems to develop plans for drought preparedness and water conservation. The plans are to include "specific water supply or water demand management measures for each stage of drought or water shortage" (Ariz. Rev. Stat. § 45-342, 2006). |
| 2005 | Lower Colorado River Multi-Species Conservation Plan is adopted and funded. |
| 2005 | On July 5, Arizona's San Pedro River goes dry for the first time in memory. The dry period of eight days is the result of decades of groundwater over use and has caused the disappearance of 11 of 13 of the river's endangered aquatic species. |
| 2006 | American Rivers names the Verde one of the country's top 10 most threatened rivers. |
| 2006 | Verde River Basin Partnership was created as part of a federally brokered land deal, in order to integrate water policy in the Verde Basin. The cities of Prescott and Prescott Valley immediately withdraw. |
| 2007 | Prescott-area cities form the "Upper Verde Watershed Protection Coalition" ostensibly to develop mitigation policy for the Big Chino Pipeline. The council specifically excludes membership of both civil society stakeholders and Verde River municipalities, thus reinforcing the already substantial geographic and ideological 'divide' between watershed protection and short-term growth" (Bolin, Collins, and Darby 2008, 1506). |
| July 2007 | Arizona legislature authorizes the establishment of the Upper San Pedro Water District, to "maintain the aquifer and base flow conditions needed to sustain the Upper San Pedro River and to assist in meeting the water supply needs … within the district" (Jonsson 2008). The district's continued existence depends on approval by the voters. |

2008 State declares the Verde River non-navigable. This is an important ruling on who controls the river bank and beds. According to state law, the state owns navigable rivers and streams, while "those with title to the land adjacent to and beneath non-navigable waterways own the riverbed and the land and have control over its use" (Ayers 2008).

2009 The first of Prescott's eight wells begin pumping water from the Big Chino aquifer in the headwaters of the Verde River. At full capacity, the project will pump 2.8 billion gallons per year (8,600 acre-feet/yr or 12 cfs).

Jan 2009 Arizona Supreme Court makes an important ruling stating that one cannot own groundwater rights separate from its overlying land (Davis v. Agua Sierra Resources).

Aug 2009 The Roundtail Chub (locally known as the Verde Trout) is considered by the U.S. Fish and Wildlife Service following a listing under the Endangered Species Act. This followed from a lawsuit filed by the Tucson-based environmental organization Center for Biological Diversity.

Nov 2010 Voters in the Upper San Pedro Basin narrowly reject a proposal to create a Water Conservation District. If approved, the District would have likely levied local taxes and initiated projects to replenish the area's rapidly declining aquifer through water conservation, reuse, recharge, and augmentation.

2025 Groundwater basins that are administered as "Active Management Areas" under the state's Groundwater Management Act must guarantee safe yield by 2025. Safe yield is narrowly defined by the law as balancing pumping with recharge, a definition that is insufficient for protecting surface water such as wetlands, springs, and rivers.

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# 4. Case Studies

In this section, we present three case studies of water management in Western states, examining how different regions have addressed the question of sustainable groundwater management to maintain instream flows. The study regions are: the Middle Rio Grande Basin, New Mexico; the Deschutes River, Oregon, and the Edwards Aquifer, in Texas.

Each of the case studies shares a few similarities. Each region is in the midst of a population boom, and water is being re-allocated from irrigation to municipal and residential use and to maintain environmental flows. In each, surface water bodies were threatened by excessive groundwater pumping. Water management reforms were prompted in whole or part in each of the three regions by the Endangered Species Act. Either a lawsuit and subsequent enforcement action, or the threat of a lawsuit gave a sense of urgency to river restoration efforts (and often helped finance them).

In response to over-allocated groundwater basins, regulators instituted basin closures, meaning that no net increase in groundwater pumping is allowed. In each of the regions, however, household wells are considered exempt from regulation and threaten to draw down aquifers. A cap on basin water use can be an onerous provision; states have alleviated this possible "growth killer" with legal and administrative reforms to permit water trading, which allows water use patterns to shift. In Oregon, water reforms have been underway for decades, whereas in Texas, prompt changes were precipitated by a court ruling in 1993. In every state, reformers faced stiff opposition, although some of this opposition has gradually given way to acceptance and collaboration.

## 4.1. Middle Rio Grande Basin, New Mexico

### 4.1.1. Introduction

The Middle Rio Grande Basin offers several valuable lessons for the management and protection of the threatened Verde River. The Middle Rio Grande suffers from groundwater overdraft and faces the challenge of growing water demands, primarily driven by rapid population growth. Ranchers, farmers, cities, and environmental organizations clash over the basin's limited water supplies. Unlike the Verde, the Middle Rio Grande is subject to international and interstate agreements, and enjoys significant augmentation from interbasin diversions. Also unlike in Arizona, where management of groundwater and surface water are disjointed, New Mexico has engaged in conjunctive management for decades, with the state requiring the acquisition of water rights for most new groundwater uses.

The Middle Rio Grande also has a joint federal/state environmental compliance program in place, though the program does not include any representation from environmental organizations. Due to a lack of record-keeping by the region's largest irrigation district and New Mexico's failure to demand required information, little is known about crop production or actual agricultural water use in the Middle Rio Grande basin.

Five key challenges confront the Middle Rio Grande: (1) long-term and short-term impacts resulting from groundwater overdraft, especially by the fast-growing City of Albuquerque; (2) inadequate regulation and enforcement of ground- and surface-water rights; (3) lack of record-keeping and reporting by the basin's largest water users; (4) the needs of two endangered species that depend on the river for critical habitat; and (5) the unquantified water rights of the six Middle Rio Grande pueblos and of the large irrigation district in the basin.

In 1996, a 45-mile reach of the river went completely dry due to drought and irrigation diversions, causing the death of 40% of the river's remaining endangered silvery minnows. In the last several years, agencies have begun cooperating around endangered species recovery, opening opportunities to receive federal funding for restoration activities. Total endangered-species-related program costs to date have exceeded $130 million; about 10% of this has come from a non-federal match. The federal government spent another $35 million in the late 1990s on groundwater research and related reports. These can be seen to have benefits beyond the target species: preserving and enhancing natural lands, enhancing a region's aesthetic and recreational value, and supporting regional economic activity. However, environmentalists question whether the funds are being put to good use or resulting in actual improvements to the river.

Despite the imposition of a cap on groundwater withdrawals by the state, program rules allow new water uses as long as the user promises to offset these in the future. Proponents praise this incremental approach, which has allowed continued development. Critics call it a giant loophole that allows environmental degradation to continue or even worsen, while putting off for several years the difficult decisions about land fallowing or the expense of securing alternative water supplies. One such critic (Jones 2002, 967) has written:

> New Mexicans do not want to dry up rural communities in support of urban growth. Surveys and regional water plans indicate that New Mexicans value preserving the rural lifestyle and economy and do not favor transferring water away from rural areas to meet urban demands… The original plan placed a large responsibility upon future administrators to balance regional water use, protect existing rights, and preserve cultural values held by many New Mexicans.

Direct and indirect costs associated with groundwater regulations and overdraft, such as increased pumping costs and damages related to subsidence, apparently have not been reported.

The population of Bernalillo County—home of Albuquerque and surrounding suburbs—rose by almost 250,000 people between 1990 and 2008, an increase of more than 40%. To reduce its reliance on groundwater, Albuquerque recently began diverting surface water. Albuquerque's so-called Drinking Water Project (drinking water constitutes less than 1% of total municipal water use) cost $400 million, for a diversion point on the Rio Grande, new water conveyance infrastructure, and a new treatment plant. According to the regional water authority, seven rate increases were implemented to finance the project. Yet this partial solution to the groundwater problem will reduce flows in the river itself, increasing pressure on endangered fish species.

Despite these investments, the long-term health and survival of the Middle Rio Grande is far from assured. Forces contributing to the river's decline include a politically powerful irrigation district intent on preserving historic land and water use, a burgeoning municipal population, and projected decreases in surface water flows due to climate change. Unless current efforts to protect the river are improved and expanded, the Middle Rio Grande will end up in even worse condition than it is now.

In the following sections of this case study, we describe the Middle Rio Grande's physical setting and land and water use, groundwater overdraft, institutional framework, and natural environment. We also discuss efforts by state regulators to limit groundwater pumping, or mitigate its effects, in order to protect surface water flows. We offer a frank appraisal of New Mexico's "deferred mitigation" approach to regulating water use, and conclude with a description of efforts to aid the recovery of endangered species and bring water management in line with federal environmental laws.

### 4.1.2. Background

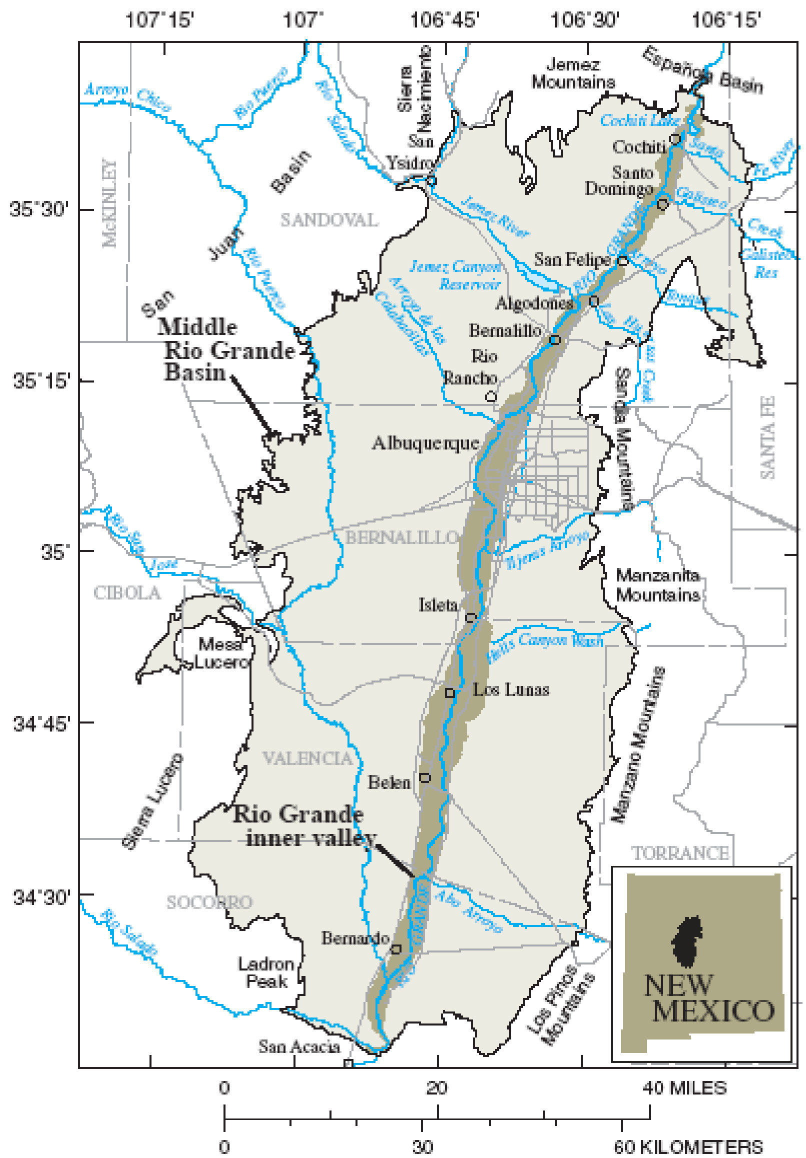


**Figure 22 The Middle Rio Grande Basin (From USGS 2002)**

The Middle Rio Grande is the largest, most populated, and most complex basin in the state of New Mexico. It is home to the largest city in the state, Albuquerque, as well as a number of smaller but rapidly growing cities and towns "competing for water with six Indian Pueblos and a variety of traditional irrigated agriculture interests" (Richards 2009). The Middle Rio Grande Basin covers roughly 3,060 square miles in central New Mexico, as shown in Figure 22. The Middle Rio Grande runs some 160 miles from Cochiti Dam to Elephant Butte Reservoir, gently falling from about 5,200' at the dam to 4,400' at the reservoir. The river's average annual flow from 1990–2010 was 900,000 acre-feet (1,300 cfs), though actual annual flows vary dramatically, as shown in Figure 23. Roughly 10% of the Rio Grande's flow through this reach comes from the San Juan-Chama project, an inter-basin transfer importing water from the Colorado River basin. Average annual precipitation in the valley is about eight inches, roughly half of which falls from July through September. Average monthly temperatures range from 36° F in January to 77° F in August.

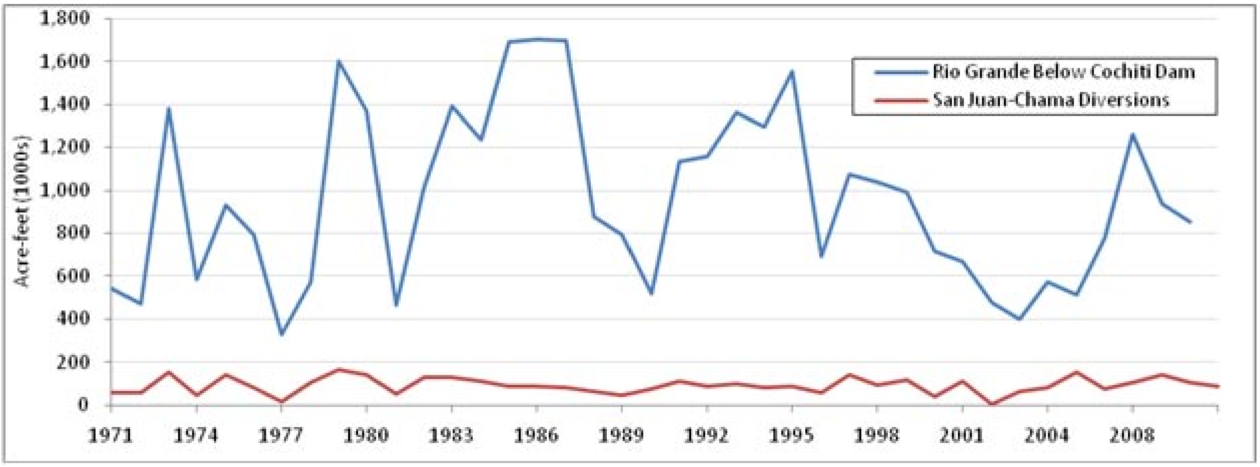


**Figure 23 Annual flow of the Middle Rio Grande, including interbasin transfers from the San Juan-Chama. (Data from USGS, USBR.)**

#### *4.1.2.1. Basin Water Use*

The river has been considered over-appropriated since the expansion of irrigated agriculture in the basin in the 1920s. That is, the volume claimed by water rights outstrips the river's flow in most years. Former State Engineer Thomas Turney estimated that paper water rights exceed "wet water" by a factor of four to one (Robert 2004).

The wooded areas in the river's floodplain, locally known as the *bosque* (Figure 24), have seen dramatic changes in the past 60 to 70 years. Scattered stands of cottonwood and willow have been replaced largely by invasive exotic plant species, predominantly saltcedar. These saltcedar thickets typically are much denser than the native bosque, decreasing biological diversity while increasing water loss from transpiration in the mid-basin. The river corridor has been dramatically altered over the past century due to the construction of bank stabilization and flood control structures, including dams and levees.

In the early 1900s, increasing upstream diversions decreased flow rates through the Middle Rio Grande, greatly increasing sedimentation rates and leading to local flooding, rendering vast areas un-irrigable. In 1923, is a conglomeration of 72 former *acequias* (self-governing community irrigation ditches), the six pueblos of the Middle Rio Grande Valley, and private lands came together to form the Middle Rio Grande Conservancy District (MRGCD). This mix of traditional Hispanic, Native American, and pioneer values and property-rights regimes has given rise to a large and unwieldy organization (Brown 2003).

The MRGCD is a subdivision of the state of New Mexico, is responsible for flood control and providing irrigation water to farmers. The district is funded through property taxes and water delivery charges and has an annual budget of $16 million (Rodriguez 2008, 2). MRGCD, with financial assistance from the Bureau of Reclamation, built the El Vado Dam 160 miles north of Albuquerque on the Rio Chama, a tributary upstream of the Middle Rio Grande. It also built four diversion dams through the middle basin, hundreds of miles of new irrigation and drainage ditches, and nearly 200 miles of levees constraining the river.

**Figure 24 Bosque of the Rio Grande at Bernalillo, New Mexico, and the Sandia Mountains.**

Although the geohydrology of the Middle Rio Grande has been studied extensively, little information exists on many critical factors affecting basin hydrology. The MRGCD, the major agricultural water supplier in the basin, does not compile records on total acreage irrigated, nor on crop types or acreage per crop. The MRGCD does not report total annual water deliveries as required by state law. The MRGCD estimates that there are more than 15,000 turn-outs in the district, but reportedly does not have an accurate count of the actual number of such turn-outs. MRGCD allots three acre-feet per acre in the district, but does not measure actual diversions; its newsletters report that irrigators in the district have been seen with more than their allotment on their fields. This is a very different approach to water management than that demonstrated by many irrigation districts in the lower Colorado River basin, where water deliveries are monitored carefully and crop production reports are readily available.

It is difficult to estimate the amount of water diverted or used by agriculture in the basin due to lack of reliable data on such basics as irrigated acreage. Estimates range from about 50,000 acres (Reclamation) to 70,000 acres (MRGCD) to 90,000 acres (also Reclamation); the Papadopulos (2000) investigation interprets a 1992 survey to estimate 63,500 irrigated acres, excluding fallow and idle lands. Crop types are also poorly known. Reclamation estimated in 2000 that more than 20,000 acres were planted in alfalfa and some 18,000 acres were planted in pasture hay. Corn, grains, fruit, and vegetables are also grown in the area, though actual acreages are not known. There are also extensive livestock operations in basin. MRGCD estimates that agricultural production in the district generates $35–$70 million annually.

The most recent water balance for the reach (Papadopulos 2000), modeling both surface and groundwater flows, relies on data that is now more than ten years old. From information presented in the Papadopulos report and an earlier groundwater model (McAda and Barroll 2002), we estimate total annual consumptive water use in the basin at about 590,000 acre-feet. Prior to 2009, annual groundwater extraction in the basin averaged about 156,000 acre-feet per year. Starting in 2009, as the new Albuquerque Drinking Water Project became operational, Albuquerque began to reduce its reliance on groundwater, so presumably total groundwater pumping has declined.

Total agricultural consumptive use has been estimated at roughly 186,000 acre-feet annually (Papadopulos 2000). However, diversions by irrigators are not known. Assuming that two-thirds of water diverted for irrigation is used consumptively suggests total annual agricultural water deliveries of about 280,000 acre-feet, or roughly half of the river's annual flow. Because most canals are unlined, and irrigators practice flood irrigation, much of this water seeps into the ground and some of it returns to the river.

Ownership of the facilities of the Middle Rio Grande Project is disputed, with the MRGCD claiming ownership and the federal government claiming ownership by the Bureau of Reclamation. The case is currently tied up in courts, so the ownership question is unresolved. It is contentious because ownership means authority and control over the facilities. In the 1950s, the Bureau of Reclamation constructed the Low-Flow Conveyance Channel (LFCC), a deep, wide, riprap-lined channel that runs parallel to the Rio Grande for 54 miles. The channel's purpose is to deliver irrigation water and convey floodwaters. However, the channel also drains shallow groundwater, depleting flows in the river's main channel. Environmental groups have raised concerns that the LFCC impacts vegetation, wildlife, and endangered species. The flood control projects have disconnected the river from its floodplain, preventing the periodic overbank flooding that recharged the local aquifer. The extensive drainage ditches and the LFCC further deplete the local aquifer, depriving the river of base flows. Reclamation issued a Draft Environmental Impact Statement proposing modifications to the LFCC in 2000, but to date, a final version has not been released.

Until 2009, nearly all domestic and municipal water use in the Middle Rio Grande came exclusively from groundwater. The human population of the basin has grown rapidly over the past twenty years. According to the Census Bureau, the population of the City of Albuquerque grew from 385,000 in 1990 to 449,000 in 2000, to 546,000 in 2010. Municipal water use totals for the basin as a whole could not be found, but total water deliveries by the Albuquerque Bernalillo County Water Utility Authority (ABCWUA) reportedly decreased from 117,000 acre-feet in 1990 to 98,000 acre-feet in 2008, despite a population increase of almost 150,000.

Per capita water consumption was 167 gallons per capita per day (gpcd) in 2007, a 32% reduction from 216 gpcd just 7 years earlier in 2000. The city has made substantial progress in improving water efficiency, and runs an aggressive conservation program (USEPA 2002). Conservation efforts are bolstered by a growing local recognition of limited water supplies, and are also being required by the state. As a condition for approval of the San Juan-Chama Drinking Water Project, the State Engineer required Albuquerque to reduce per capita consumption to 155 gpcd by 2024 (City of Albuquerque 2008).

#### 4.1.2.2. *Groundwater*

Studies in the 1960s led people to believe that there was a vast underground lake beneath Albuquerque, a falsehood that some held onto through the 1980s, justifying massive over-pumping. In the mid- and late-1990s, a series of USGS groundwater investigations noted that the aquifer was much smaller than originally thought and was being overdrawn. In eastern Albuquerque, aggressive groundwater pumping dropped the water table more than 120 feet between 1960 and 2002, altering groundwater flows and causing losses to the Rio Grande itself (Crilley 2009). Total groundwater overdraft in the Middle Rio Grande—the difference between natural recharge and extraction—has been variously estimated at 62,000 acre-feet/year (Crilley 2009) to 70,000 acre-feet/year (The Water Assembly 1999), at a time when total groundwater pumping in the area was an estimated 156,000 acre-feet per year. Groundwater overdraft has already had measurable impacts on the river. The pumping has been called a "debt deferred": the largest impacts of past pumping are expected to reach the river in coming years (Hathaway 2009).

#### 4.1.2.3. *Institutional Framework*

According to the US Geological Survey, 90% of New Mexico's population relies on groundwater for domestic use. Like Arizona, New Mexico's surface water has been fully appropriated for many decades. The most senior rights are held by Native American tribes, *acequias*, and agricultural water users. More junior rights are held by municipalities, as well as industrial, residential, and recreational water users.

The legal framework governing the Middle Rio Grande includes a treaty with Mexico, treaties with Native American pueblos, an interstate compact, various federal laws including the Clean Water Act and the Endangered Species Act, federal and state court decisions, and state regulations (Brown 2003). Key actors include the MRGCD, ABCWUA, the Bureau of Reclamation and the Army Corps of Engineers, the New Mexico State Engineer, the U.S. Fish and Wildlife Service (FWS), six different Pueblos, individual irrigators, and several environmental organizations, including Audubon, Defenders of Wildlife, and WildEarth Guardians.

Under the terms of a 1906 treaty, the US is required to deliver 60,000 acre-feet per year to Mexico, delivered at the Elephant Butte reservoir at the southern end of the Middle Rio Grande. According to one source, as of 1999 the U.S. had curtailed deliveries to Mexico 14 times under the Treaty's "extraordinary drought" provision (Hume 1999). Under the terms of the 1939 Rio Grande Compact, New Mexico agreed to deliver a certain amount of water to Texas, indexed to river flow measured at several gages. When native annual flow (which excludes water imported from outside the basin) at the upstream Otowi gage exceeds 1.5 million acre-feet, Middle Rio Grande users can deplete the flow of the river at Elephant Butte by a maximum of 405,000 acre-feet. When native annual flow at the Otowi gage is less than 1.5 million acre-feet, the amount available to Middle Rio Grande diverters decreases proportionately. Increased consumptive use and evaporation from reservoirs constructed on the river's mainstem in New Mexico have stressed supplies and interfered with New Mexico's obligations under the compact.

The New Mexico State Engineer is responsible for administering all water rights in the state. However, many of the water rights in the Middle Rio Grande have not been adjudicated; it is not clear how much of the water delivered by the MRGCD is quantified by right. In practice, the MRGCD continues to operate with less oversight and fewer reporting requirements than most irrigation districts delivering Colorado River water.

New Mexico was one of the first Western states to move beyond the "reasonable use" doctrine for the management of groundwater for the purpose of protecting threatened groundwater basins. Under this regime, groundwater and surface water are treated separately, and the only limit placed on groundwater is that it be used, usually on overlying land, for a productive purpose. New Mexico first regulated groundwater use in 1927, and in 1931 enacted legislation authorizing the State Engineer to administer groundwater, which was declared to belong to the public and subject to appropriation (Jones 2002). Unlike in many states, the law thereafter recognized the interaction between surface water and groundwater and outlined procedures for managing them as an interconnected resource. The emphasis was initially on preserving senior water rights and the state's ability to meet treaty and compact obligations to its downstream neighbors, but would later be modestly expanded to include public benefits such as recreation and fish habitat.

The 1931 act enabled the creation of groundwater management districts "to conserve, where necessary, the waters in any artesian basin or basins within the state, the boundaries of which have been scientifically determined by investigations, and where such waters have been beneficially appropriated for private, public, domestic, commercial or irrigation purposes, or otherwise." The law was designed specifically to solve the problems of a single area: the rapidly-declining Roswell Artesian basin. Under the new law, a district could be initiated by a petition of the owners of one third of the land in a region. Following public notice and resolution of any objections, a district court would appoint three commissioners, and elections would be held among residents for five directors. Districts were organized as "municipal corporations" with broad powers of taxation and control of local waters. Clark (Clark 1987, 238) states:

> Collectively they were vested with full authority to perform the actions necessary for carrying out the intent of the statute which basically was that of cooperating with the state engineer and the United States Geological Survey in determining what improvements should be made, then carrying them to completion. All wells wasting substantial amounts of water [broken or abandoned wells in an artesian basin can flow uncontrollably] were declared public nuisances, with directors authorized to abate them either by plugging or repairing.

In the next few years, amendments to the act clarified the role of the state and local district managers.

> All declared artesian-basin waters were under the control and supervision of the state engineer, but rules and regulations governing waters within an artesian conservancy district were to be made only after consultation with the district's directors, with concurrent power and authority in the district and the state engineer in enforcing regulatory provisions (Clark 1987, 239).

### 4.1.3. Water Management Reform

In November, 1956, in the face of increasing levels of extraction and failure to meet Compact delivery obligations, the New Mexico State Engineer declared his authority to administer groundwater use in the Middle Rio Grande basin, based on authorities' recognition that groundwater extraction was affecting surface water flows. This 1956 declaration stated that the Middle Rio Grande was fully appropriated and closed the basin to any additional surface water appropriations. New groundwater appropriations had to purchase and retire a like amount of surface water (less return flows from the groundwater extraction). The purpose of this declaration was to maintain surface flows, *not* to slow aquifer decline or preserve groundwater resources.

#### *4.1.3.1. Basin Closure*

Reaction to the declaration of basin closure was "swift and passionate" (Jones 2002). Several stakeholders, including the City of Albuquerque, the MRGCD, and the local farm bureau, immediately challenged the State Engineer's authority and declaration. Albuquerque submitted an application to pump 6,000 additional acre-feet of groundwater per year, explicitly refusing to retire any surface water rights, and then sued the State Engineer when he denied the permit. The case wound its way to the state Supreme Court, which held that the State Engineer acted within his authority to protect existing water rights. Stakeholders also prompted the introduction of state legislation to revoke the State Engineer's authority, but the governor vetoed the legislation.

The State Engineer's 1956 declaration meant that Albuquerque and other applicants had to commit to purchasing and retiring surface water rights in the future. This meant that large users (defined as those exceeding normal domestic consumption) seeking to drill new wells had to acquire and retire surface water rights for a similar volume of water (Turney 2000). In other words, the State Engineer created an early example of a "cap and trade" system, which has since become a more commonplace market-based mechanism for managing scarce resources. This was sure to be unpopular, and so a key provision was added to the rule to soften the blow, described in the following section.

#### *4.1.3.2. Groundwater Permitting Process*

Within designated groundwater basins, water users must apply for a permit to drill a new well or increase pumping from existing wells. According to a USGS publication (McGuire et al. 2003): "The State Engineer generally approves permits for livestock, lawn and garden irrigation, and other domestic purposes." For other types of water uses, there are several conditions for approval of new or revised permits:

(1) no objections are filed,

(2) unappropriated water exists in the basin,

(3) no infringement on the water rights of prior appropriators occurs, and

(4) it is not detrimental to the public welfare or the water conservation goals of the State.

All permits are provisional when they are issued. The State Engineer monitors the area around the new well for up to five years—if it causes excessive aquifer drawdown, it is deemed to be excessive, and the permit will not be approved. All appropriators, however, may appeal the decision of the State Engineer to a District Court. In this regard, the New Mexico system has been criticized as time-consuming, cumbersome, and prone to uncertainty and litigation: "Although New Mexico has a longstanding water market and many water transfers have occurred over the years, transaction costs, lead times, and increasing numbers of protests make the market highly inefficient in some circumstances" (Richards 2009, 2).

#### 4.1.3.3. Deferred Mitigation

Theoretically, basin closure marked a dramatic departure to the unrestrained access to groundwater and overconsumption of this common-pool resource. Because drawdown from pumping far from the stream might not have an effect on the stream for several years, pumpers were allowed to retire surface water rights gradually over time, as the impacts of groundwater reached the river.

Under the "deferred mitigation" approach, when a groundwater permit is issued, a well owner may begin pumping immediately, but may not have to offset that pumping with the same quantity of "mitigation water" for several years, or perhaps even decades. Rather than requiring the new groundwater user to mitigate their pumping immediately, pumpers are able to defer their debt to a future date. The timing of the effect of pumping on river flows is determined by the State Engineer's office using a simple mathematical model. In theory, one of the benefits to this approach is that it gives buyers time to search for willing sellers and initiate the paperwork for the transaction, a process that has been described as slow and cumbersome. In practice, people could begin pumping immediately and defer actions to offset the impacts of such impacts, confident that the state would not aggressively enforce mitigation requirements.

In September 2000, the State Engineer built upon the 1956 declaration, prohibiting new groundwater extraction in the populated portion of the Middle Rio Grande basin. Applications pending at that time had to demonstrate an equivalent volume of surface water rights in hand for the groundwater permit to be approved, though the State Engineer allowed portions of the surface water to be leased back to users until it is needed to offset the projected impacts of groundwater extraction (Jones 2002). The difference here is that a higher requirement is placed on pumpers. Rather than having years to purchase rights, they are required to purchase them upfront. Thus the financial requirement is greater, but because the water can be leased back, the hydrologic effect is no different than under the previous rules.

#### 4.1.3.4. Disadvantages and Critiques

Because of urban growth and the pumping cap, the long-term trend is one where water is transferred from agriculture to municipal and residential use. The deferred mitigation approach has allowed for continued rapid urban and suburban growth, without requiring the fallowing of irrigated lands, a change to the landscape that many view as undesirable and one that has far-reaching impacts on rural communities. Ultimately, New Mexico's approach has simply pushed these impacts off a decade or two into the future.

The State Engineer's decision not to require immediate offsetting of new water uses institutionalized groundwater mining and effectively guaranteed a large-scale, ongoing degradation of surface water flows in future years. The State Engineer also failed to determine or quantify surface water rights in the Middle Rio Grande, meaning that information did not (and still does not) exist to assess whether sufficient surface water rights exist to offset groundwater extraction, or where such surface water rights are in use.

Without adjudicated water rights in the Middle Rio Grande basin, the requirement that the impacts of groundwater extraction be offset by a like amount of retired surface water rights cannot be enforced. Anecdotally, there are allegations that some irrigators have "sold" their surface water rights but continue to irrigate at the same rate. This is possible because their water rights have not been quantified and because their actual diversions are not monitored or reported. Despite the State Engineer's declaration, groundwater extraction increased from less than 30,000 acre-feet in 1956 to almost 160,000 acre-feet in 2000—out of 217,600 acre-feet of total permitted extraction (Jones 2002). On paper, the declaration was a major step forward, linking groundwater and surface water use and denying additional surface water appropriations. On the ground, the declaration did nothing to prevent 45 miles of the Middle Rio Grande from going dry in 1996. This led Trout Unlimited to call New Mexico's system of groundwater management "really quite fragile" (Stillwell 2007).

On paper, the State Engineer's declarations created a clear and strict linkage between surface and groundwater use in the basin. In practice, "New Mexico is a state that rarely enforces its prior appropriation system, even during drought years" (Jones 2002, 968). That is, the State Engineer's office very rarely curtails surface water diversions or groundwater pumping, nor does it enforce beneficial use requirements. For example, in 1993, Rio Rancho, a city just northwest of Albuquerque, applied to double its groundwater extraction to 24,000 acre-feet per year. Because Rio Rancho residents reduced their per capita water use by 9% from 1995 to 1999, and because the city projected additional conservation at the very low rate of 0.75% *every five years*, the State Engineer approved the additional groundwater pumping, contingent upon the city obtaining sufficient surface water rights to offset the impacts of this pumping (Jones 2002).

#### *4.1.3.5. Water Trading*

Similar problems make it difficult to acquire water rights to offset pumping. Applicants are required to find and obtain surface water rights in the amount of their proposed withdrawal. The state acknowledges that this can be a lengthy, difficult, and expensive process (Turney 2000, 3):

> Any existing permittee requiring surface water rights for offset purposes is confronted with finding a seller of valid surface water rights and obtaining a permit from the State Engineer to transfer the surface water rights. The transfer of surface water rights within the Rio Grande stream system is a complicated and often lengthy process due to the complex interrelationship between the surface and ground waters, the numerous existing appropriations to be protected, and the diversity of the numerous interests having standing to participate in the administrative process for an application for permit. Because a transfer application can be denied or approved and the decision appealed to the district court, the court of appeals and the state supreme court, the final decision may be far removed from the time the application was filed.

In practice, this has meant that it is extremely difficult for water users larger than households to obtain a permit for a new well or increased pumping. As a necessary precondition to obtaining the permit, the applicant must find an existing water right holder willing to lease or sell a quantity of water to offset his pumping. At present, such leases or sales are bilateral exchanges: agreements are typically drawn up between the buyer and the seller, usually with the assistance of an attorney specializing in water. The Oregon case study demonstrates that the process can be made simpler when a mitigation bank serves as a clearinghouse for mitigation credits.

#### *4.1.3.6. Lack of Instream Flow Protections*

Analysts have called New Mexico the "blank slate state," highlighting the absence of a legal framework for securing instream flow rights (Boyd 2003). New Mexico does *not* have a strong record of protecting instream flows. State law does not protect the instream flow rights, nor is it recognized as a beneficial use. Executive-branch agencies, however, have taken steps to protect flows. For example, in 1945, in *State Game Commission v. Red River Valley Co*., the court ruled that recreation and fishing should be considered a beneficial use for otherwise un-appropriated water (BLM 2001).

The enhancement of instream flows has required the creative interpretation of existing laws that are not specific to rivers. There is no statute or regulation specifically providing for or authorizing instream flow. However, New Mexico law allows the State Engineer to provide legal protection to instream flows for fish, wildlife, or other ecological uses. *See Opinion of Tom Udall, Attorney General, Opinion No. 98-01* (March 27, 1998). The State Engineer has granted water right permits for instream flows on both the Pecos River (to increase water flows for the threatened Pecos bluntnose shiner) and the Rio Grande (to increase water flows for the endangered Rio Grande silvery minnow), though these have not been called "instream flow permits."

#### 4.1.3.7. Exempt Wells

Every year, the State Engineer issues several thousand permits for new domestic wells. Metering of these domestic wells is not required, so no records exist of the total pumping by the many thousands of such domestic wells. Such information is fundamental to developing an accurate water balance for the Middle Rio Grande basin.

> [Groundwater mitigation rules] apply only to large wells; domestic wells are considered *de minimus* depletions of groundwater and are exempt from the offset requirement, despite the fact that several thousand additional permits are issued by the state every year. The cumulative impact of domestic wells on the system may be anything but ancillary: No one knows how many are in use in the basin, or how much water they extract, because metering is not compulsory (Robert 2004, 2).

#### 4.1.3.8. Environmental Concerns

Like other desert rivers throughout the Southwest, the combination of extensive changes to the channel, multiple water diversions, changes to water quality, and colonization by non-native species have devastated the populations of native aquatic and riparian species. The listing of the Rio Grande Silvery Minnow in 1994 put local water managers on notice that water use practices in the basin would have to change.

The Bureau of Reclamation operated Rio Grande reservoirs primarily to fulfill treaty obligations for water deliveries to Texas, either cutting off flows or sending a surge down the channel. These flow conditions damaged fish habitat, threatening the survival of the silvery minnow (*Hybognathus amarus*). This fish species once occupied 2,400 miles of rivers in New Mexico and Texas, but is now confined to a 170-mile stretch of the Rio Grande, covering only 7% of its former range. The silvery minnow was federally listed as endangered in 1994 (Kelly and McKean 2011).

Along the Middle Rio Grande, extensive groundwater overdraft further depleted streamflows during low-flow periods, further jeopardizing the survival of at least two species. The following year, the designation of the southwestern willow flycatcher as endangered prompted initial discussions that eventually led to the formation of the Middle Rio Grande Endangered Species Collaborative Program (MRGESCP).

However, despite the presence of two endangered species, water practices did not change quickly. The year following the designation of the southwestern willow flycatcher saw very low native flow. Yet this low flow did not stop the MRGCD from delivering water as usual to its irrigators. That summer of 1996, a 45-mile long stretch of the Middle Rio Grande south of Albuquerque dried up, killing some 40 percent of the population of the endangered Rio Grande silvery minnow, and ultimately prompting litigation (Brown 2003).

The US Bureau of Reclamation began the Supplemental Water Program in 1996 to augment river flows and minimize impacts to listed species. The program consists of two elements: pumping from the Low Flow Conveyance Channel into the river channel, and purchasing or leasing water from willing sellers to be released from upper-basin reservoirs to maintain minimum instream flows. According to Leann Towne, Water Management Division Manager at the Bureau of Reclamation in Albuquerque, "Water management for endangered species… involves a multifaceted operation because of the complexity of the hydrology, the many entities involved, and ever-changing conditions." Because reservoir releases can take several days to flow to critical reaches, a proportion is lost due to transpiration by riparian vegetation and infiltration from the channel. These intervening factors mean that Reclamation lacks the ability to maintain base flows on a real-time basis, potentially leading to periods of hours or days when the channel could dry up and stress or kill fish.

The eventual creation of the Collaborative Program followed several years of false starts and disagreements about the best approach to species recovery. The MRGESCP (2006) provides the following history of species recovery efforts in the basin:

> In 1997, several federal agencies, which were later called the White Paper group, joined to outline alternatives to satisfy the water needs of the silvery minnow and accommodate the needs of the water users. The actions included water acquisition, water management, and water-use efficiencies. They also recommended the development of a plan of action.
>
> In 1998, the environmental community formed the Alliance for the Rio Grande Heritage and worked to develop a green paper because they felt the white paper lacked specific recommendations. It stated the long-term solution needs to include all the key players and interested participants, must assure adequate river flows, and share the responsibility among all who benefit from the river. The green paper proposed acquisition and storage of water for conservation purposes…
>
> In 1998, the two groups began meeting and exchanging information to evaluate and prioritize potential solutions and define future collaborative actions…. Despite their efforts, in 1999, environmental groups filed suit against Reclamation and the Corps for alleged ESA and National Environmental Policy Act violations. However, all parties remained active in the collaborative efforts….
>
> Court ordered mediation in 2000 led to an Agreed Order that provided additional supplemental water for both ESA and irrigation purposes. The mediation was also an impetus for increased pumping from the Low flow Conveyance Channel, the development of the City of Albuquerque's silvery minnow naturalized refugium, and improved metering and water transport efficiency of the Middle Rio Grande Conservancy District.

In 2003, the U.S. Fish and Wildlife Service (FWS) issued a Biological Opinion affecting water operations in the Middle Rio Grande. The FWS designated critical habitat for the silvery minnow in 2003 and for the flycatcher in 2005.

Five years after listing the silvery minnow and three years after nearly half the population of the listed fish was lost (and likely more, since many of the females found dead had not yet spawned), Reclamation and the Corps still had not completed ESA consultation with FWS, prompting the lawsuit. The non-environmental participants eventually formed the Middle Rio Grande Endangered Species Collaborative Program (MRGESCP), a partnership of 17 federal, state, and local agencies. The goal of the program is "to protect and improve the status of endangered species along the Middle Rio Grande (MRG) of New Mexico while simultaneously protecting existing and future regional water uses." The program has also attracted significant federal funding (MRGESCP 2010):

> Program activities include water acquisition and management, habitat restoration, endangered species monitoring, and silvery minnow propagation. Congress provided approximately $115.8 million to Reclamation from FY2001 to 2009 with an approximate non-federal match of $12.7 million to support Program activities. Reclamation serves the leadership role for the Program. Accomplishments include acquisition of over 158,290 acre-feet of supplemental water from willing lessors from FY2003-2009.

The 2003 Biological Opinion expires in March 2013 and the parties are in initial stages of re-initiating consultation. The environmental community's Alliance for Rio Grande Heritage is now defunct and there is no formal alliance of environmental groups working on the MRG. Former members, particularly Audubon, Defenders of Wildlife, and WildEarth Guardians, work on various issues of interest, with peaks and valleys in that engagement. There are no representatives of the environmental community in the Collaborative Program. The MRGESCP has gone through many formations, starting in 1998 when environmental groups and federal officials first sat down together. Now, the MRGESCP is largely an ESA compliance vehicle for federal agencies, the state and MRGCD, but according to local advocates it has made little-to-no progress on major issues like water acquisition and fish passage.

#### *4.1.3.9. Recent Restoration Activities*

Because of drawdown in the Middle Rio Grande aquifer, the river has become what hydrologists call a "losing stream" where water in the river seeps through the bed and down into the aquifer. While long-term efforts to restore instream flow and preserve the riparian corridor focus on raising groundwater levels, more immediate solutions during low flow periods involve releasing more water into the river, either by pumping it from the adjacent low flow conveyance channel or releasing it from upstream reservoirs.

Historically, there has been little scope for dam releases for environmental purposes, as rights to impounded water belonged to cities and irrigation districts. In 1999, environmental organizations brought suit against the Bureau of Reclamation and the US Army Corps of Engineers, in an effort to compel the government to release more water from upstream dams to support the endangered species in the Middle Rio Grande. after many years of appeals and counterclaims, at present "there continues to be uncertainty regarding both the discretion of the BOR to allocate Middle Rio Grande Project water to maintain stream flows for the continued survival of the Rio Grande silvery minnow" (Kelly and McKean 2011, 8).

At the time of the lawsuit, even if a conservation-minded group of citizens wished to spend millions of dollars to purchase water to preserve the river and protect wildlife, there were no administrative procedures for such a transaction or enabling laws or legal precedent to support it. This may have begun to change in 2005, when six environmental groups negotiated with Albuquerque water suppliers to create an “environmental pool” of 30,000 acre-feet in the Abuiqiu Reservoir on the Rio Chama. Environmental organizations planned to use this to store “water legally acquired from voluntary purchases, leases, and donations” and release it for instream flow during dry periods (Kelly and McKean 2011, 8). In exchange for this concession, they dropped legal claims against the city. To date, however, no releases from the environmental pool have occurred, and the environmental community is still in discussions with the Corps, the state, and the city of Albuquerque about obtaining federal and state permits. Backers acknowledge that “it is taking quite some time, mostly because it’s never been done before.”

In the 2005 settlement, ABCWUA agreed to donate $225,000 to the newly created Living Rivers Fund, to be used to acquire water for the environmental pool. They also agreed to put in place a “check-off program” on city water bills: beginning in 2007, water customers have the option to make a voluntary contribution to the Living Rivers Fund. The program has several shortcomings: water customers only have the option to contribute $1, there is ambiguity as to whether contributions are tax deductible, and even the project’s backers admit that it “largely symbolic,” but has the benefit of raising awareness of threats to the river (Horning 2007). Indeed, an increased awareness of river issues and an active conservation community have helped to guarantee that instream flows are protected from illicit diversions. According to an activist in the basin, today, unlike the mid-90s, there are lots of interested parties monitoring river flows on a daily if not hourly basis during the summer (when supplemental flows are most likely released), so illicit diversions are far less likely.

#### *4.1.3.10. San Juan-Chama Drinking Water Project*

For the past 40 years, the Rio Grande has had a cushion thanks to water imported from the Colorado River. Under the Upper Colorado River Basin Compact, “New Mexico is entitled to a little over 11% of the flow of the upper Colorado River because a tributary, the San Juan River, loops through the northwestern corner of the state” (Robert 2004, 2).

The San Juan-Chama project, completed in 1971, annually imports about 93,000 acre-feet of water from the Colorado River basin into the Rio Chama, a tributary that joins the Rio Grande above the Otowi gage. The project is part of the trend of the last few decades where upper-basin states in the Colorado River Compact have moved to use their legal allocation. Few contemporary observers would consider a large-scale interbasin transfer part of a sustainable water management portfolio, and this project was among the last to be built in the over-allocated Colorado River Basin. Water rights are held by the cities of Albuquerque and Santa Fe, who for decades resold the water to downstream users, and by the MRGCD and others. According to the Rio Grande Compact, the interbasin augmentations have to be consumptively used in the Middle Rio Grande, leading to some creative accounting. Albuquerque began to use its annual 48,200 acre-foot appropriation at the end of 2008; Santa Fe is scheduled to complete the infrastructure necessary to take its appropriation by 2014.

Albuquerque’s recently completed San Juan-Chama Drinking Water Project provides water for the metro area. It is intended to relieve pressure on overtaxed groundwater and avoid the need to treat the groundwater to meet the more stringent arsenic standards by mixing it with surface water. More than 50% of the water diverted from the Rio Grande will be returned downstream as treated wastewater, but the Project can dramatically diminish the flow of the river between the points of diversion and return (Price et al. 2009).

ABCWUA's historic reliance on mining groundwater devastated the underlying aquifers, but it supplemented the flow of the Middle Rio Grande by discharging extracted groundwater to the river channel. ABCWUA's new surface water diversion project relieves pressure on the aquifer, but in effect creates a double reduction for the Rio Grande, by depleting water from the river itself, and by reducing the volume of groundwater that is discharged to the river. The New Mexico State Engineer has limited ABCWUA's diversion to 130 cfs and limits the amount of "native" Rio Grande water (not imported by the San Juan-Chama Project) to 50% of the total instantaneous diversion. When native flows fall below 195 cfs immediately above the diversion point, ABCWUA may not divert any native water. These limitations provide some protection for instream flows, but do not alter the project's overall impact on the Rio Grande's water balance.

ABCWUA has implemented aggressive water conservation programs, with a goal of reducing per capita consumption. Total per-capita consumption has fallen from 252 to 161 gallons per day in ABCWUA's service area, with a target of 155. This is a noteworthy reduction in per capita water use. While their conservation program is considered by some experts to be among the most comprehensive in the nation, its gains may eventually be eroded by population growth (Hathaway and MacClune 2007).

### 4.1.4. Conclusions

Limited progress has been made on the challenges confronting the Middle Rio Grande. Perhaps the greatest success to date has been the dramatic reduction in per capita water use in the Albuquerque metropolitan area, a reduction that, despite a 34% increase in population, saw an absolute decrease of almost 19,000 acre-feet in total water deliveries between 1990 and 2008. Since population growth has been the largest factor driving the change in the region's water demand, this remarkable water conservation achievement stands out. Had per capita water demand remained at 1990 levels through 2008, ABCWUA's water demand would have been almost 60,000 acre-feet higher, putting additional pressure on already-stressed groundwater and surface water resources in the Middle Rio Grande.

But significant challenges remain. The lack of adequate record-keeping and reporting by the MRGCD frustrates efforts to realize real water savings through water efficiency and transfer programs. The MRGCD, despite being a political subdivision with significant power, such as to levy taxes and place liens on property, has operated largely without public scrutiny, keeping it always on the verge of litigation (or involved in litigation). The needs of the two endangered species that depend on the river for critical habitat have not been met. Worse yet, drought continues to grip the Middle Rio Grande, diminishing flows and likely signaling the basin's long-term supply prospects. New Mexico's policy of exempting domestic wells will lead to a time when those depletions impact the river to such an extent that Compact compliance is impaired. This happened on the Pecos and the state had to retire a lot of wells and fallow agricultural lands.

Important questions remain unanswered. The extent of the underlying brackish aquifer and its connectivity to the alluvial aquifer is not known, nor is its potential suitability as a source for desalination and distribution. Other water quality questions, such as the extent to which contamination from septic systems and other sources have polluted the aquifer and the river, need research. How will decades of groundwater overdraft affect the alluvial aquifer and the flow of the river in years to come? Can the river and the shallow and deep aquifers in the basin be managed conjunctively to meet the various human and ecological demands placed on them? The Middle Rio Grande retains options for long-term sustainability, but current agricultural practices and the host of unanswered questions suggest the river's future remains uncertain.

Of the three case study basins we examined, the Middle Rio Grande is perhaps the most similar to the Verde Valley. As each is in the arid southwest, they share several hydrologic and biological traits, and a direct connection between groundwater pumping and surface water flows. Like the Verde, the Middle Rio Grande is home to endemic aquatic species that are found in few other places. As American settlers arrived in the region, the rivers was prized for the water it provided to farm fields or homes. Recently, residents have placed greater value on the river's environment and begun efforts to protect it from exploitation. However, like most Westerners, residents do not generally welcome an expansion of government interference in their affairs.

In applying lessons learned to the Verde River, one should also be aware of the differences. Irrigated agriculture is a much larger presence in the Middle Rio Grande. The basin is also much more populous, with more than half a million in Albuquerque alone. When the State Engineer required that city's water supplier reduce per capita use, it showed dramatic results. Flows in the Middle Rio Grande are highly regulated by upstream dams, both on the river's mainstem and on its tributaries. Flows are also augmented via an interbasin transfer from the Colorado River system via the San Juan Chama project. Lawsuits and negotiations have frequently focused on compelling dam operators (i.e. the Bureau of Reclamation) or those who possess rights to use water stored behind dams to allow the water to be released and flow down the river for environmental purposes. The long-term health of the river depends on obtaining more secure rights for instream flows, restoring the condition of the river and its corridor, and reversing the long-term decline of the valley's aquifer.

### 4.1.5. New Mexico Water Management Timeline

| | |
|---|---|
| 1600s | Spanish settlers begin moving to the Rio Grande Valley, and begin constructing ditches or *acequias* near water sources. One thousand of these are still in use today. |
| 1608 | Settlement established at Santa Fe. |
| 1706 | Settlement established in Albuquerque. |
| 1821 | Following Mexican independence, trade routes open with the United States. Many American merchants move into the Rio Grande Basin. |
| 1848 | Following the Mexican-American war, the United States acquires the Rio Grande Valley in the Treaty of Guadalupe Hidalgo, opening the area to many more American settlers. |
| Early 1900s | Increasing upstream diversions cause a decrease in flow through the Middle Rio Grande, greatly increasing sedimentation, causing local flooding and rendering vast areas un-irrigable. |
| 1902 | Newlands Reclamation Act passed by Congress, funding irrigation projects in 20 Western states, including 155,000 acres in the Rio Grande. Similar acts in 1924 and 1939 will construct dams and irrigation infrastructure on the river and its tributaries. |
| 1906 | Treaty requires the United States to deliver of 60,000 acre-feet per year to Mexico. |
| 1908 | Important federal court decision in *Winters v. United States* upholds Indian water rights, reasoning that "the creation of a Federal reservation carries implicit rights of water to serve that reservation." |
| 1912 | New Mexico becomes a U.S, state. Its constitution, enacted in 1911, adopts the prior appropriation system of water rights, recognizing and confirming rights existing at the time of the statehood for "any useful or beneficial purpose" but declaring that water itself belongs to the public. |
| 1920s | Expansion of irrigated agriculture in the Rio Grande basin leads to "over-appropriation" where water demand exceeds the river flow in some years. |
| 1923 | The Middle Rio Grande Conservancy District, a large irrigation district, is formed to irrigate 120,000 acres in the basin. |
| 1927 | New Mexico passes groundwater law, making it among the first states to recognize the interaction between surface water and groundwater and to develop procedures for managing them as an interconnected resource. |
| 1928 | Report by the State Engineer on aquifer drawdown concludes that the solution requires "greater cooperation among water users." |
| 1931 | New Mexico Groundwater Code signed into law, providing for districts "to conserve, where necessary, the waters in any artesian basin or basins within the state…" The law |

replaces the 1927 law which was ruled unconstitutional.

1935 Rio Grande Compact signed in 1938 between the states of Colorado, New Mexico, and Texas, and later approved by Congress. The compact requires New Mexico to deliver a certain annual quantity of Rio Grande water to its downstream neighbor Texas.

1945 Drawdowns in the Roswell artesian basin (150 miles southeast of Albuquerque) emerge as a problem.

1945 State court rules that recreation and fishing should be considered a beneficial use for otherwise unappropriated water (Game Commission v. Red River Valley Co, cited in BLM 2001).

1948 Congress approves joint Corps-Bureau flood-control program for the Rio Grande, initiating construction of the Jemez Canyon Dam, Abiquiu Dam, and Cochiti Dam.

1950s Bureau of Reclamation constructs the Low-Flow Conveyance Channel, or LFCC, a deep, wide, riprap-lined channel that runs parallel to the Rio Grande for 54 miles.

1951 Texas files suit in federal court against New Mexico and the Middle Rio Grande Conservation District.

1950s Groundwater used to irrigate over half the 873,00 acres of irrigated land in the state. New Mexico not meeting treaty obligations to deliver Rio Grande water to Texas.

1956 State Engineer declares his authority to administer groundwater use in the Middle Rio Grande basin in order to meet the state's treaty requirements to deliver water downstream to Texas. He declared the basin "closed" to further groundwater development, a decision that was immediately challenged by agricultural and municipal interests. At the time, "many of the major basins in New Mexico had already been declared" (Jones 2002, 944).

1960 A district court rules for Albuquerque in its complaint against the State Engineer, ruling that the city has unlimited use of groundwater beneath its boundaries. The state Supreme Court overrules, granting that the state has the authority to regulate groundwater use to protect existing rights holders.

1960s Studies are released claiming an "underground Lake Superior" beneath Albuquerque, a false premise that justified years of over-pumping.

1971 San Juan Chama Project completed. The project collects water behind three dams on tributaries of the Colorado River, and pumps over the continental divide to the Rio Chama, a tributary of the Rio Grande. Water rights are held by the cities of Albuquerque and Santa Fe, who for decades resell the water to downstream users in Texas, and have only begin to use their appropriation in 2008.

1994 Rio Grande silvery minnow listed as endangered. The minnow was historically the most abundant fish in the river, but by 1994, it had disappeared from 95% of its historical habitat.

March 1995 — Southwestern Willow Flycatcher, a small migratory bird that nests along the Middle Rio Grande, listed as endangered.

1995 — Office of the State Engineer declares the Middle Rio Grande a “critical basin,” meaning there is not sufficient technical information about the groundwater basin to guide programs to protect it against rapid economic and population growth.

1996 — Bureau of Reclamation begins the Supplemental Water Program, with a goal to “advance the conservation and recovery of endangered species along the MRG Valley.” The program consists of two elements: pumping from the low-flow channel into the river channel, and purchasing or leasing water from willing sellers to be released from upper-basin reservoirs.

1996 — First significant drought in the Middle Valley in decades. The MRCG diverts the entire flow of the river, causing a 45-mile reach of the Middle Rio Grande to run dry. Biologists estimate that 40% of the endangered silvery minnow population dies. The drought lasts for three years.

1997 — Several federal agencies, which were later called the White Paper group, join to outline alternatives to satisfy the water needs of the silvery minnow and accommodate the needs of the water users.

1998 — The environmental community, disappointed by the federal process, form the Alliance for the Rio Grande Heritage and issues a “green paper” encouraging acquisition and storage of water for conservation purposes.

1998 — The federal “white paper” and environmental “green paper” groups begin meeting to discuss collaborative efforts.

1998 — New Mexico Attorney General Tom Udall issues an opinion stating that the State Engineer is allowed to provide legal protection to instream flows for fish, wildlife or other ecological uses. Subsequently, the state grants water right permits for instream flows on both the Pecos River (to increase water flows for the threatened Pecos Bluntnose Shiner) and the Rio Grande (to increase water flows for the endangered Rio Grande Silvery Minnow), though these have not been called “instream flow permits.”

1999 — Drought conditions worsen. The Department of the Interior issues the first Rio Grande Silvery Minnow Recovery Plan, designating 163 miles of the river as “critical habitat.” The MRGCD irrigation district will unsuccessfully sue twice over the next three years in an attempt to overturn the designation.

Nov 1999 — Environmental groups file suit against Reclamation and the Corps for alleged ESA and National Environmental Policy Act violations.

2000 — As a result of the 1999 lawsuit, the court-appointed mediator issues order requiring supplemental water for both ESA and irrigation purposes. This leads to increased pumping from the Low flow Conveyance Channel, the development of the City of Albuquerque's silvery minnow naturalized refugium, and improved metering and water transport efficiency of the Middle Rio Grande Conservancy District.

2000 State Engineer builds upon the 1956 basin closure decision by banning new groundwater extraction in the populated portion of the Middle Rio Grande basin. Applicants with pending permits have the option to purchase and retire existing surface water rights to offset their pumping, however, they may begin pumping immediately and may not have to provide the mitigation water to offset their extraction until several years or decades into the future.

2001 BuRec and the Corps consult with the U.S. Fish and Wildlife Service. The result is a provisional "take permit" that allows water deliveries to continue, even though they kill endangered fish, as long as the agencies participate in the newly created Middle Rio Grande Endangered Species Collaborative Program, which will focus on protecting endangered fish and rebuilding their populations.

2002 USGS Releases report *Ground-Water Resources of the Middle Rio Grande Basin, New Mexico,* greatly contributing the scientific understanding of the basin.

2003 The U.S. Fish and Wildlife Service issues a revised Biological Opinion on the survival of the endangered silvery minnow. The Opinion affects water operations in the Middle Rio Grande by declaring portions of the river "critical habitat" and focusing on keeping the river continuously wet. Preserving the species will require maintaining required flow and other activities, with a cost conservatively estimated at $233 million.

2003 New Mexico Congressmen introduce, and Congress passes, legislation that prevents the Bureau of Reclamation from releasing San Juan-Chama project water to the Rio Grande to meet minimum flow requirements of the ESA.

2004 New Mexico Interstate Stream Commission releases a study, again showing that groundwater use in the Middle Rio Grande Valley is unsustainable, with consumption exceeding natural replenishment.

2005 State water law amended to include regulation of private wells. Today, any applicant for a new well serving a residence or irrigating less than one acre must file a permit with the State Engineer's office for a fee of $125, but do not need to acquire a water right. To date, no effort has been made to catalog formerly exempt wells.

2005 Environmental organizations negotiate with Albuquerque water suppliers to create an "environmental pool" of 30,000 acre-feet in the Abuiqiu Reservoir on the Rio Chama. Environmental organizations planned to use this to store "water legally acquired from voluntary purchases, leases, and donations" and release it for instream flow during dry periods. In exchange for this concession, they dropped legal claims against the city.

2006 The Middle Rio Grande Endangered Species Collaborative, composed of state and federal agencies, cities, and tribes, is formally organized and approves a "Long Term Plan" covering 2005-2014.

2009 Albuquerque completes a $400 million project to begin using surface water from the Rio Grande, in order to reduce its dependency on groundwater.

2010 Congress's Water and Energy Appropriations bill includes a $2,994,000 earmark for the MRGESCP. This adds to the $115.8 million the federal government has spent from 2001–2009 to support endangered species recovery in the Middle Rio Grande.

2013 The U.S. Fish and Wildlife Service's 2003 Biological Opinion will expire, and they will issue a new BiOp that will set conditions for plans for the recovery of the endangered Rio Grande silvery minnow.

2024 Deadline for the city of Albuquerque to reduce its per-capita water consumption to 155 gallons per day. The State Engineer issued this condition for approval of the San Juan-Chama Drinking Water Project (City of Albuquerque 2008).

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## 4.2. Deschutes River Basin, Oregon

### 4.2.1. Introduction

In Oregon, as elsewhere in the Pacific Northwest, well-funded, highly-profile river restoration efforts have focused on supporting migratory fish habitat, often causing tradeoffs with historic land and water uses. In this case study, we look at how water management reforms have focused on restoring flows in the Deschutes River Basin in Oregon. Like the Verde, the Deschutes Basin is the site of a population boom, and has a semiarid climate and a groundwater connection with a river of significant value for the environment and local recreational as well as for water supply, irrigation, and hydropower. Additionally, stakeholder views in the Deschutes overlap with those in the Verde. Residents and decision-makers have said that they want water to be available for continued growth and economic development, while also preserving the rural character and agricultural heritage of the region (Lieberherr 2008).

The Deschutes River Basin in central Oregon (Figure 25) begins in the Cascade Range and flows north to the Columbia River; it is severely impacted by excessive withdrawals by cities and farms, especially during the summer. Irrigation accounts for up to 90% of water use in the basin, with up to 97% of the river's flow being diverted for irrigation in summer months. In addition to the decline of the river's environment, this has caused tension with other users, including the fast-growing cities of Redmond and Bend, the Warm Springs Tribe, recreational users, and fishermen. Because the surface water in the Deschutes Basin has been fully appropriated by agricultural users for the past century, beginning in the 1990s, new water users (both cities and irrigators) turned increasingly to groundwater, and the number of wells increased dramatically in the basin.

The first challenge faced by river restoration advocates and regulators has been how to re-allocate water from agriculture to instream uses while preserving traditional values and land aesthetics. The second challenge has been how to prevent rapid growth and development from causing further harm to the river. Over the last decade, regulators have capped groundwater pumping in order to preserve river flows, and a mandatory, market-based system of water trading has been put in place. This system is one means of exerting control over water resources while maintaining flexibility in water use and modest continued development. The decision-making process has been open to participants from all sides, which has helped, for the most part, to avoid costly legal challenges and a potentially onerous court ruling.

Oregon has put a series of policies into place over the last several decades that created legal standing for scenic waterways and instream water rights. The state has set numerical targets for instream flow rates. The state has legally recognized instream flow as a "beneficial use" for fish and wildlife, recreational use, and aesthetic values, affording river flows equal standing with traditional consumptive uses. Oregon granted some of the first water rights for instream flow, and created mechanisms that allow individuals or organizations to purchase water and dedicate it to instream uses. In the Deschutes, after excessive pumping emerged as a threat to river flows, the state took steps to regulate the use of groundwater. State regulators capped consumptive water use, essentially declaring that all new development must be "water neutral," i.e. that it must not increase overall water consumption in the basin. Today, new groundwater users in the Deschutes must purchase and retire an equivalent quantity of surface water or groundwater rights to mitigate the effects of that pumping. The state chartered “mitigation banks” to help facilitate such transactions.


**Figure 25 The Deschutes River in northern Oregon (from USGS)**

Analysts point out that many of the elements that foster water conflict are in place in the Deschutes (DWA 2009), yet the overall tone has been cooperative. Important actors in Oregon water policy include state and federal authorities; Portland General Electric, which co-operates hydroelectric dams in the basin with the Confederated Tribes of the Warm Springs Reservation; and several well established, active conservation organizations, such as the Oregon Water Trust, Oregon WaterWatch, the Deschutes River Conservancy; irrigation districts; and others. But battle lines have not been drawn between irrigators and environmentalists, because irrigators understand the potential downside if a lawsuit were brought under either the Clean Water Act or the Endangered Species Act and are motivated to prevent conflict and litigation. Further, because of the interest in restoring fish habitat in Oregon, “significant mitigation and restoration capital exists to invest in instream restoration, mitigation and efficiency projects” (DWA 2009).

Efforts to restore flows to the Deschutes have gained momentum in the last several years, and in a number of priority reaches are approaching the minimum instream flows targeted by the state. Many of the legal and administrative reforms, as well as institutional mechanisms, described in this case study were created in an effort to ensure an orderly transition from agriculture to municipal and residential water use, while ensuring that a portion of the water that is traded in each transaction is dedicated to the environment. Legal scholars from Oregon's Lewis and Clark University write that early results were mixed, and the state's "various experiments have not always achieved the goals of protecting and restoring flowing water. Recently, however, the experiments have begun to show tangible results" (Neuman, Squier, and Achterman 2006).

### 4.2.2. Background

Irrigated agriculture was an important part of the economy in central Oregon in the last century. Nearly two-thirds of the basin is dedicated to farming and ranching, covering 1.77 million of the basin's 2.9 million acres. About 10% of agricultural land, or 180,000 aces, is irrigated, with 9 irrigation districts serving a total of about 9,000 customers (Aylward and Newton 2006). The majority are family farms. The majority of farm operators work either part- or full-time off the farm, and so they are often referred to as "lifestyle" or "hobby" farms. As of 2006, in Deschutes County revenues from agriculture constituted only 1% of county income. Large-scale irrigation is more common in Jefferson and Crook Counties, where agriculture accounts for about 10% of county income. The most common crops are high value vegetable and grass seed crops, and specialty crops like peppermint for tea leaves, carrot seeds, and specialized potatoes (OSU Extension Service 2011).

The population of central Oregon has expanded greatly in the last three decades. Growth rates for basin counties averaged 44% per decade over the last century, well above the national rate of 14%. In 2006, the population was estimated at 202,000. Much of this growth has occurred in Bend and Redmond, but up to 40% of the population has settled in rural zones outside of incorporated areas (Aylward and Newton 2006). As the demographics and land use in the basin changed, so did patterns of water use. Because surface water has been fully appropriated since 1913, new water users have installed wells, greatly increasing the amount of groundwater used in the basin. When development encroaches on formerly irrigated land, it can cause financial difficulties for irrigation districts. When irrigated lands are retired, districts are left with a smaller assessment base and fewer customers paying water delivery charges. Residential and municipal use tends to consume less water than agriculture, leading to an overall decline in water use in the basin, as shown in Figure 26.

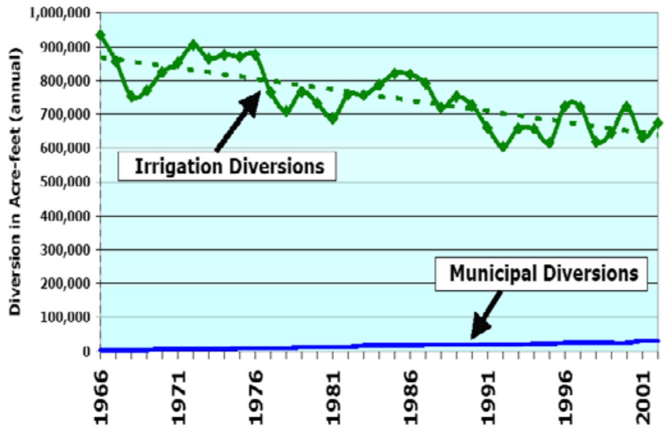


**Figure 26 Deschutes Basin irrigation and municipal diversions. Annual totals in acre-feet (from DWA 2009, 3)**

Municipal water use, while still small compared to agriculture, is the fastest-growing water use in the basin, driven largely by population growth. The area in and around Bend, the fifth-largest metropolitan area, grew by 47% over the last decade, reaching 171,000 in 2010. Per-person water use fell from 222 to 190 gallons per day over the same period. However, Bend does not seem to have yet made serious investments in water conservation, for example by implementing common measures, such as offering rebates or incentives for efficient appliances and fixtures. This may soon change, however, as the city recently commissioned a Water Management and Conservation Plan. The draft plan, released in January 2011, recommends a range of residential and commercial water conservation measures. Outdoor water use for landscaping is an area where significant efficiency gains are possible. Bend is in the rain shadow of the Cascade Mountain range and receives an average of only 10 inches of rain each year. Lawn watering consumes large quantities of water in the summer months, with peak monthly water use up to five times higher than in winter months (City of Bend, Oregon 2011).

River restoration efforts on the Deschutes have largely focused on restoring endangered and threatened fish populations. The decline of once-abundant salmon has played a central role in efforts to reform water management throughout the Columbia River basin:

> Salmon fisheries define the region's culture, ecologically and economically. Their precipitous decline from runs of 16 million in the early 20th century to about 1 million is caused by several interacting natural and human factors, culminating with the listing of 13 evolutionarily significant populations of salmon and steelhead as threatened or endangered under the Federal Endangered Species Act, triggering a range of biological studies and recovery actions. Habitat loss has occurred through the development of the hydropower system on the Columbia and Snake Rivers as well as irrigation diversions on tributaries where salmon return from the ocean to their natal grounds to spawn. These impacts led to the creation of a fish and wildlife recovery program with a $170 million annual expenditure funded by the Bonneville Power Administration—the Basin's state-owned hydropower utility. A portion of this program finances and coordinates market-based environmental water transfers to restore habitat in areas where other limiting factors are being addressed (Garrick et al. 2009, 10).

There were once native runs of summer steelhead, Chinook salmon, sockeye salmon, and Pacific lamprey in the upper Deschutes River, but they were wiped out by the construction of a hydroelectric dam at Pelton Round-Butte. In 2004, the Federal Energy Regulatory Commission relicensed the Pelton-Round Butte complex on the Deschutes River for another 50 years. The operator of the dams, Portland General Electric, put a new plan in place to restore flows and habitat for anadromous fish above the dams. This has reinvigorated efforts to restore upstream tributaries such as Whychus Creek and McKay Creek and guaranteed flows necessary to support healthy fish populations. Fish recovery advocates hope that conditions attached to the re-licensing of the dam, fish re-introduction programs, and a proposed multi-species Habitat Conservation Plan will play a role in restoring native fish. In addition, restoration activities also benefit resident, non-migratory fisheries. The movement to restore the river's flow has also been helped by its popularity as a rafting and fishing destination. A key challenge has been how to make additional water available for instream flow. The Deschutes suffers from low flows and poor water quality in some reaches, primarily due to surface water diversions for agriculture. Figure 27 shows a schematic that is well-known among basin stakeholders as the "whale diagram" (by OWRD, reprinted in Golden and Aylward 2006). Note that in the summer (b), middle reaches of the Deschutes drop very low. As the river is fully allocated, the only thing preventing it from being dewatered entirely is an informal agreement among irrigators to leave 30 cfs in the river at all times. During winter months (c), upstream reaches of the Deschutes suffer from low flows as upstream dams are refilled. Water quality in the lower reaches of the Deschutes is generally good, but smaller tributaries can suffer from low dissolved oxygen and excess nutrient and fertilizer inputs, particularly during summer months when irrigation withdrawals peak.

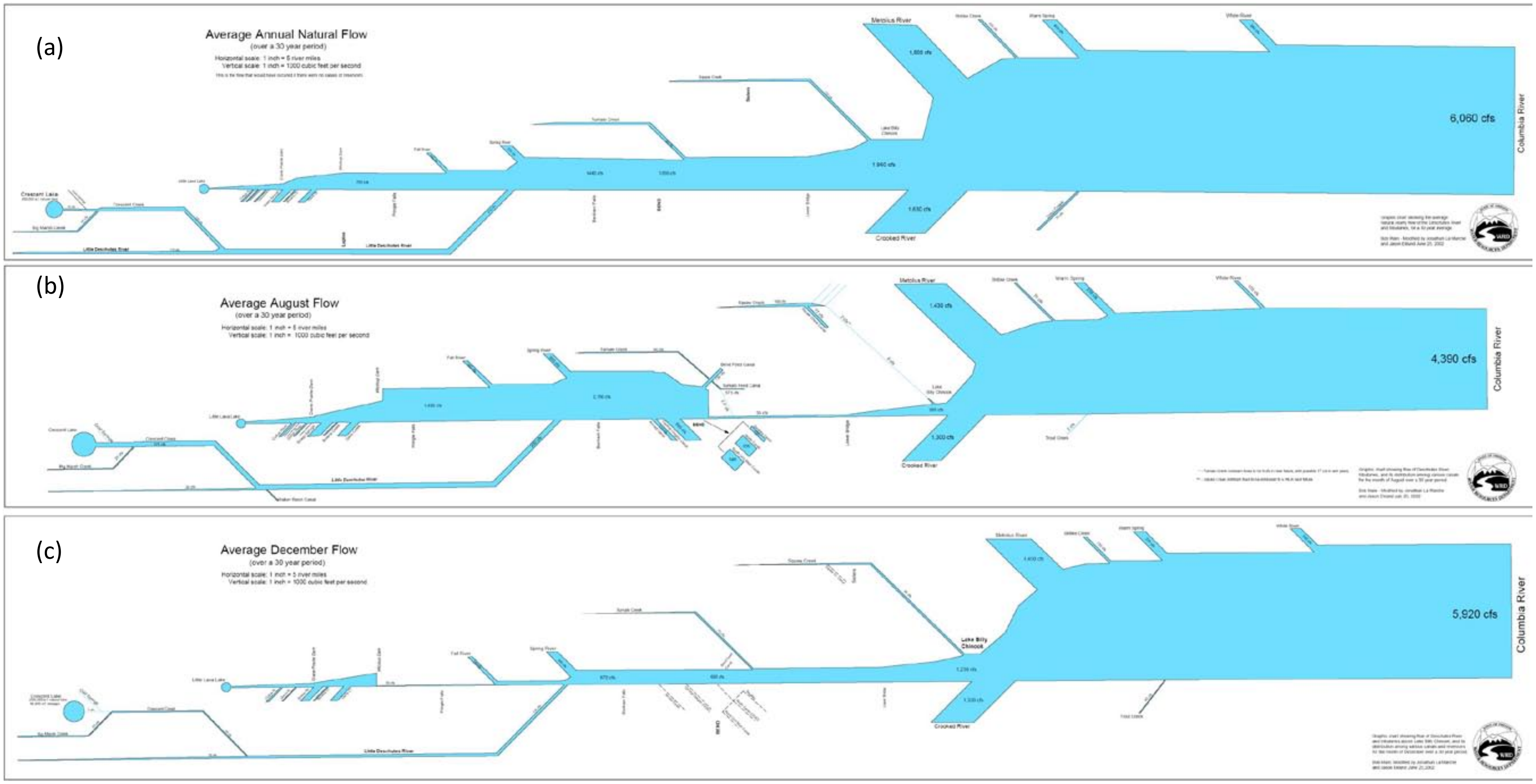


Figure 27 Schematic representing flows in the Deschutes River Basin under (a) average natural flow, (b) average summer flow, and (c) average winter flow.

### 4.2.3. Institutional Framework

Surface water rights in the Deschutes River were closed to further appropriation in 1913 when the federal government reserved all future rights (later developed as the North Unit Irrigation District). Because of this, municipalities, developers, and irrigators had to turn to groundwater to meet new needs, aided by significant advances in pumping and well-drilling technology that made it easier and cheaper to tap water at greater depths. The groundwater resources of the Deschutes are extensive, but pumping can diminish streamflows and dry up small tributaries during the summer. Before the 1950s, groundwater use did not require a water right; the only requirement was that the water be put to beneficial use and not be wasted. However, in the 1940s to 1950s, groundwater use began to diminish the flow of some Oregon's river, affecting senior water rights holders.

In response, the state passed the Groundwater Act in 1955, effectively extending the system of prior appropriation to groundwater in Oregon. Since that date, most well owners are required to apply for a well permit and a water right from the Oregon Water Resources Department (OWRD). As with any rights determination, OWRD must determine whether the application interferes with existing water rights, and the public may comment on whether it is "detrimental to the public interest." The following types of wells are exempt from the requirement of obtaining a water right:

- Group and single-family domestic use up to 15,000 gallons per day.
- Stock watering.
- Watering any lawn and/or non-commercial garden totaling one-half acre or less in area.
- Down-hole heat exchangers.
- Any single industrial or commercial development up to 5,000 gallons per day.

In 1996, the state expanded the permitting system to include most small, formerly exempt wells. While landowners must register these with the state, they are not required to obtain a water right or purchase mitigation credits to offset their pumping. Unpermitted wells need to be registered when the land they are on is sold. In the past, developers of subdivisions have flouted these rules by installing several small wells, but the state has revised the law to prevent such abuses.

### 4.2.4. Instream Water Rights

Water laws in Western states were designed to encourage the use of water. State laws promoted the diversion of rivers for "beneficial uses," which included irrigation, mining, hydroelectricity, and settlement. Oregon's earliest water rights derive from the time when the state's water code was enacted in 1909, when the state adopted the prior appropriation doctrine of "first in time, first in right." The state decreed in 1928 that water rights in the Deschutes basin be adjudicated, but it took until the 1950s for all the rights to be certified.

Lawmakers at the time did not consider water left in the stream to support navigation, fisheries, recreation, or aesthetics to be a reasonable use. There was historically no legal basis for an "instream water right." In other words, an individual or an organization could not legally dedicate water to the river—any water flowing in the channel was eligible for diversion. Contemporary values place more importance on free-flowing rivers—nowhere more so than the Pacific Northwest, with its iconic salmon runs and increasingly urban and environmentally-minded populace. Oregon has been a leader among the Northwest states in recognizing the value of its rivers and affording them legal protections. The challenge in the Deschutes river basin has been to re-allocate water from existing uses, primarily agricultural, to municipal and environmental purposes. As elsewhere, this is a difficult task, as historic "water rights are fiercely defended by the independent-minded Oregonians who hold them" (Neuman, Squier, and Achterman 2006).

Except in a few designated Critical Groundwater Basins, the state has not chosen to restrict existing water uses. In other words, there has been no effort to overhaul the rights system or reduce or invalidate historically permitted uses. Instead, the state has adopted two main strategies. First, it has established a set of laws and policies aimed to prevent further harm. New permits for ground- or surface-water use are no longer issued in over-allocated basins. According to OWRD "restrictions on new uses from streams and aquifers are adopted to assure sustained supplies for existing water users and to protect important natural resources" (2009b). The emphasis is two-fold: to prevent new water uses from causing harm to existing senior rights holders and to protect rivers and the environment.

In addition to giving legal status to instream flows, the state has chosen to allow a range of public, private, and nonprofit actors to participate in flow restoration through the use of market-based mechanisms. This generally takes one of two forms. Organizations can purchase or lease water from existing rights holders and designate it as instream flow. Other organizations, particularly state and federal agencies, fund water conservation projects and dedicate all or a portion of conserved water to the environment, for example by replacing leaky irrigation canals with pipes.

A few decades ago, there was no precedent for an environmental organization to buy water and "donate" it to the river. Laws governing water use simply did not have allowances for this type of transaction. The concepts of beneficial use, seniority, and appurtenancy are important to understanding this dilemma.

In order for a water rights claim to be verified by the state, or "perfected," the applicant must put the water to a beneficial use. This condition was designed to prevent waste; historically, instream use was not recognized by law or precedent as a beneficial use. Appurtenancy means that a water right is attached to the land described in the right. This means that the purchaser of a land or water right does not necessarily have the right put the water to use elsewhere. Another factor discouraging irrigators from selling or donating water is the so-called "use it or lose it" rule. In Oregon, in order to maintain a water right, it must be used at least once every five years, or it is "subject to forfeit and cancellation for non-use" (OWRD 2009b).

Over the last six decades, the state has incrementally passed laws and created procedures that give increased legal standing to instream flow, removing some of the legal and administrative barriers that prevented groups from purchasing water for instream use. Thus, the state has sought to protect existing rights holders and preserve historic water uses on one hand, while also passing a growing body of law aimed at restoring flows to degraded rivers. Some observers have noted the incompatibility of these "two impulses of consumption and protection" (Neuman, Squier, and Achterman 2006).

In 1955, Oregon overhauled its water laws after two years of debate and discussion. The law granted fish, wildlife, and water-dependent recreation legal status in the "use, management, development, and treatment of water" by various means (Neuman, Squier, and Achterman 2006). For the first time non-consumptive instream uses were to be considered a beneficial use under the laws of some Western states. The Act created the State Water Resources Control Board to develop management plans for each basin. This new state agency was instructed to create plans "to support the maintenance of minimum perennial stream flows sufficient to support aquatic life and to minimize pollution… if existing rights and priorities under existing laws will permit" (Act of May 26, 1955, quoted in Neuman, Squier, and Achterman 2006).

Further protections were accorded to rivers in the Deschutes basin in the 1960s, a time when the federal government became increasingly involved in water management with the passage of several landmark environmental laws. In 1968, the federal Wild and Scenic Rivers Act was passed, with the intention of protecting rivers from damming and development, for the enjoyment of future generations. Following the Act's passage, ten rivers in the Deschutes Basin were afforded some federal protections by being declared "Wild and Scenic." While administration of the designated rivers is left to the state, the law authorized the federal government to purchase land along rivers to maintain their character. Further, it prevents federal agencies from developing or licensing water resource development projects (e.g. dams or diversion works) on listed sections of river. The Act does not, however, authorize "federal regulation of water diversions, nor does it authorize federal acquisition of instream water rights" (Golden and Aylward 2006, 2–3).

#### *4.2.4.1. Scenic Waterway Act*

In 1972, the legislature passed its own version of the federal law, the Oregon Scenic Waterway Act, that granted protections to 496 miles of several rivers, including portions of the Deschutes. The Act prohibits the state from constructing dams or reservoirs on designated reaches, and prevents OWRD from authorizing new water uses upstream of a scenic waterway "unless that diversion is consistent with the free-flowing character of the streams and protective of recreation, fish, and wildlife" (Neuman, Squier, and Achterman 2006). The law prohibited OWRD from issuing groundwater permits that would diminish the flow in designated reaches by more than 1% of its pre-development flow, or 1 cfs, whichever is less.

Oregon's scenic waterway law far exceeded the federal act in its scope and powers. The federal law prevented the U.S. government from funding projects that would interfere with rivers. This set an important precedent, as large irrigation works have historically been built with government assistance. But Oregon's law essentially gave the state power to veto a whole range of activities that had previously been encouraged. In the following years, the "1% rule" turned out to be more restrictive than even its authors intended, especially in smaller headwater tributaries, and prevented projects such as a proposed resort from going forward (Aylward 2011). However, old ways die hard, and organizational cultures do not change overnight, and so "citizen activism and constant vigilance have been crucial to assuring compliance with the Scenic Waterways law" (Neuman, Squier, and Achterman 2006).

In the years following passage of the Oregon Scenic Waterway Act, the state of Oregon took several steps to improve instream flows. In 1987, Oregon passed the Instream Water Rights Act. Following its passage, the state created about 550 instream water rights based on previously designated minimum streamflows and given priority dates based on their date of adoption as minimum streamflows (Neuman, Squier, and Achterman 2006, 1148). The law gives instream water rights the same status as other water rights. Most, but not all, of these are junior rights, with a priority date after 1909 when the state created the water permitting system. The law allowed the Departments of Fish and Wildlife, Environmental Quality, and Parks and Recreation to apply for instream water rights, which are held in trust by the Oregon Water Resources Department (Boyd 2003). Further reforms in 1993 cleared the way for organizations or state agencies to free up water for instream flow by funding water efficiency projects, described in the next section on Oregon's Conserved Water Program.

Today, Oregon has what has been called "one of the most comprehensive (and comprehensible) systems for transferring water rights to instream use. The state has a clear regulatory scheme promulgated the OWRD and founded upon a large body of statutory law" (Boyd 2003).

Instream water rights are not guarantees that a certain quantity of water will be present in the stream. When the quantity of water in a stream is less than the instream water right, the Department will require junior water right holders to stop diverting water. However, an instream right cannot affect a use of water with a senior priority date. An exception is made in the event of a drought declared by the governor; in such a case, Oregon law instructs the Department to "give preference to human consumption and livestock watering over other uses, including instream uses" (OWRD 2009b).

In Oregon, there are three main methods used to put water back into rivers and streams, each of which will be discussed below. They are:

1. Instream leases;
2. Instream transfers, both time-limited and permanent;
3. Allocations of conserved water.

Oregon's water laws also allow right holders to sell, lease, or donate their water rights and have them converted, either temporarily or permanently, to an instream water right. Irrigators are now able to lease water on a short-term basis (e.g. for a season or during a critical low-flow period), and their right is protected from forfeiture. The Instream Water Rights Act sought to make leasing more attractive to irrigators by removing the threat of forfeiture for non-use.

Historically, many Western states have taken a conservative approach to allowing transfers based on impacts to other water users or rights holders. When water is removed from the land where it had formerly been used, it can cause negative side effects for other water users, often called "injury" (Neuman, Squier, and Achterman 2006). Courts have ruled that a water user has the right to expect the conditions in place at the time of his diversion to persist, and that water users may seek relief when others cause those conditions to change. Oregon's Instream Water Rights Act partially got over this hurdle by removing the appurtenancy requirement for instream transfers. While water rights may now be severed from the land they formerly irrigated and transferred to instream use, all transfers must still undergo an injury review by OWRD to ensure it does not cause undue harm, as will be discussed further below.

### 4.2.5. Oregon's Conserved Water Program

For decades, environmentalists and regulators have had reason to believe that improving the efficiency of irrigated agriculture could reduce withdrawals and contribute to flow restoration. "Original water rights issued in the early 1900s still allow over half of what is diverted from the Deschutes near Bend to be lost before it ever reaches the fields due to antiquated, leaky canals" (DWA 2009). To promote river restoration, Oregon has passed laws and promoted policies to expressly encourage water conservation and efficiency (Pagel 2002). Although there has been considerable debate over whether public funds should be used to fund the installation of irrigation infrastructure, it was clear that this was an area where significant water savings were available.

The Bureau of Reclamation has been studying the role that improved efficiency could play in restoring flows in the Columbia River basin since the 1960s. A 1997 study of irrigation in the Deschutes basin found that seepage accounts for 30% to 60% of water that is diverted by irrigation. The Bureau recommended canal lining and piping to save up to 327,000 acre-feet, or an equivalent flow of 700 cfs. Experience has also shown that conserved water projects are relatively cost-effective. In recent years, water rights could be purchased for $300 to $1,500 per acre-foot, while canal piping costs $300 to $1,200 per acre-foot conserved (DWA 2004).

Before 1987, however, the conserved water created by irrigation efficiency projects had a murky legal status. Normally, an adjudicated water right in Oregon takes the form of a permit to use water on specific parcels of land, and often only for a specific purpose. If an irrigator or a district frees up water, for example by piping or lining a canal, the permit holder does not necessarily have the right to "spread" water to new lands or uses not described in the original permit. Suppose a government agency with an interest in enhancing river flows funds a project that allows irrigators to reduce withdrawals from 8 acre-feet per acre to 4. Should irrigators be allowed to spread conserved water to additional lands? Or should that water be dedicated to instream flow? On the one hand, irrigation districts have little incentive to participate in projects if they do not share in the benefits. Rather than participating in an expensive and disruptive project, they may prefer the status quo. On the other hand, agencies may not be willing to fund efficiency projects unless there is a guarantee that conserved water will be protected instream (Aylward 2008).

In response to this dilemma, Oregon created a clever program designed to "get the incentives right" so that efficiency projects will benefit both irrigators *and* the environment. Oregon's 1987 Instream Water Act created *instream water rights* that are equivalent to traditional diversion rights. With this law, the state signaled that it would not move to re-regulate existing water rights allocations (for example by canceling or modifying existing rights), but it would allow water to be re-allocated to instream use through market transactions (Aylward 2008). The 1987 law contained a "conserved water" provision that was subsequently strengthened through revisions in early 1993. The program is designed to reward water rights holders for investing in water conservation. The program took several years to begin bearing fruit, but is now considered a model for other states. A detailed overview of the program is given in a report from the University of Oregon School of Law (Amos 2009). A thorough overview and appraisal of the program at the 15-year mark is given in a report sponsored by National Fish and Wildlife

Foundation (Aylward 2008). A brief description of the program and some of its key provisions and accomplishments are given below.

The Conserved Water Program aims to create an incentive for existing water rights holders to retain a portion of the water saved through conservation, which they can then apply to additional land. They may also sell or lease the water or donate it as instream use (although there appears to be uncertainty about whether such donations are tax-deductible). According to the program's rules, at least 25% of the saved water must be dedicated to instream flow. If public funding pays for more than 25% of an efficiency project, then the same percentage of saved water must be dedicated to instream flow. However, the rest of the saved water (up to 75%) is available to the water right holder.

As of 2008, the state had received 53 applications under the conserved water program, all covering irrigation projects, other than one applicant from the forest products industry. Approximately half of the projects were for canal piping, and the other half for on-farm efficiency projects, for example to replace traditional furrow or "flood" irrigation with sprinklers that consume less water. Nearly half (21 of 53) of the applications for the statewide program were in the Deschutes River basin. This is attributable to two nonprofit organizations:

> The Oregon Water Trust (OWT) and the Deschutes River Conservancy (DRC) have played an important role in the program by motivating landowners and districts to engage in these projects by offering payments for the purchase of conserved water that is dedicated to instream use. The funds for these purchases come from a number of sources including Reclamation federal funds, Oregon Watershed Enhancement Board state funds, and hydropower mitigation funds from Bonneville Power Administration (through the Columbia Basin Water Transactions Program) and the Pelton-Round Butte partnership between Portland General Electric and the Confederated Tribes of the Warm Springs Reservation (through their Water Fund). OWT and DRC are therefore actively using the window opened by the conserved water statute that allows a water right holder to save water and then in effect sell the right to dedicate it to instream use to a third party. In addition, these organizations typically carry out the application intermediary role as well (Aylward 2008, 15).

In the past 15 years, nearly two-thirds of conserved water projects were funded with outside assistance. In about a third of these outside-funded projects, 100% of the conserved water is purchased by nonprofit environmental groups and dedicated to instream flow. In the remainder, a portion of the conserved water is retained by irrigators for other uses. In projects undertaken by landowners or irrigation districts, there were only a few instances (2 of 11) where conserved water was donated to instream use. Therefore, Aylward concluded, "irrigation districts or irrigators are using the program to meet their needs" (2008). In other words, landowners are responding to incentives as predicted by economists.

In his review of the conserved water program, Aylward (2008) goes on to identify a number of issues and concerns with the conserved water program. One concern is that spreading water to new consumptive uses could increase overall basin water use and be counter to restoration goals. There is concern that incentives may not be optimized to encourage participation in the program, and that participants run the risk of "forfeiting" their water right when applying water to instream use. Another issue is whether changes to water use are likely to affect junior rights holders and injure their interests. He concludes however, that while the program is 20 years old, it has really only gained momentum in the last several years. These issues and others that emerge in coming years are likely to be handled through minor changes to the statute and development of and clarification of how the program is administered. He notes that the program's largest participant, the Deschutes River Conservancy, is "extremely enthusiastic" and considers it both an "invaluable aid to instream flow restoration" and a model for other states.

There seems to be a broad consensus among those involved in Northwest water policy that supports reform over revolution in re-allocating water to the environment. Oregon's approach is an instructive model for how to work with existing laws and property regimes to incrementally increase environmental flows. The near-consensus is reflected in this statement, from an article evaluating Oregon's water markets:

> Allowing individual water rights holders to contribute to in-stream flow restoration when it is also in their own best economic interests, without being forced to do so by regulation or other government action, certainly seems like one of the least painful ways to accommodate the growing recognition that both in-stream and out-of-stream uses need to coexist in order to support sustainable agricultural economies over the long term (Neuman and Chapman 1999, 184).

### 4.2.6. The Groundwater Mitigation Program

In the late 1990s, Oregon's Water Resources Department convened the Deschutes Basin Ground Water Supply Work Group in an attempt to "seek a workable balance between development and environmental interests within the framework of strict surface water protection laws" (Pagel 2002, 30). In the following years, the Oregon legislature authorized the Water Resources Commission to take steps to control aquifer depletion where it was so severe that it threatened to harm the environment or economy. The Commission is a seven-member board appointed by the governor and confirmed by the state senate that is responsible for setting water policy and overseeing OWRD. The Commission may "close aquifers to new withdrawals where additional use is not sustainable."

To date, the Commission has only closed a single basin to new appropriations, in the area of Victor Point (OWRD 2009b). Basin closure is an extreme step that could severely limit the economic future of a region by locking in current patterns of water use. It is for this reason that "cap and trade" systems have attracted so much attention in managing scarce water resources. Mitigation programs are often designed around a "no net increase" approach where resource use is maintained at current levels and allows for trading to accommodate new water uses. When water rights are sold or leased, the permit is modified so that water may be used a different place and time, or for a different purpose. The standard program design is to cap resource use at current levels and decrease the cap gradually until resource use reaches sustainable levels.

The Oregon Water Resources Department (OWRD) issued rules for the Ground Water Mitigation Program in 2001. Following a period of public comment, they were adopted by the Water Resources Commission. In September 2002, the Oregon Water Resources Commission adopted the Deschutes Groundwater Mitigation Rules (OAR Chapter 690, Division 505).

The Oregon legislature passed House Bill 3494 in 2005, which stipulated that new groundwater permits could not be issued in the Deschutes unless the applicant could mitigate the impact of the withdrawal with a similar amount of water put instream. This is a similar requirement to those implemented in the other case studies considered in this report: in the Middle Rio Grande and in the Edwards Aquifer, regulators belatedly recognized that groundwater extraction affects surface water flows, with implications for surface water rights holders and instream flow targets.

Oregon has not taken any steps toward decreasing the entitlement of existing water rights holders. In some cases, it has placed the burden on new entrants to the water market to cross-subsidize flow restoration. The rules developed under the Groundwater Mitigation Program (GMP), require groundwater applicants who purchase temporary credits to lease *twice as much* as they will pump, and release this water instream. Thus, offsets must be obtained at a ratio of 2:1; each time a lease occurs, overall consumptive use in the basin is reduced. (If permanent credits are used, there is a 1:1 requirement. However, in the early year of the program, the majority of applicants leased water for mitigation rather than purchasing water rights, which proved to be more difficult to find. This situation is currently changing, and permanent transfers are becoming more common.) This approach makes sense from a political standpoint. While irrigated agriculture comprises an ever-decreasing part of the economy, the sector maintains outsize political influence and is likely to resist changes to historic entitlements. On the other hand, water is usually only a small part of the budget for municipalities and land developers, and they are less likely to balk at relatively modest charges required to move a project forward.

The mitigation process introduced through the GMP included important modifications of the water rights system in Oregon, introducing the concepts of mitigation credits and mitigation banking. The intent of the program is simply stated: “OWRD may not approve new ground water permits unless the impacts are mitigated with a similar amount of water being put instream” (OWRD 2009a). The objectives of the GMP are to:

1. maintain flows for Scenic Waterways and senior water rights, including instream flows;
2. facilitate restoration of flows in the middle reach of the Deschutes River and related tributaries; and
3. sustain existing water uses and accommodate growth through new groundwater development (Lieberherr 2008).

Under the groundwater mitigation program, OWRD was authorized by the legislature to authorize new groundwater use in the Deschutes Basin of up to 200 cubic feet per second (cfs). Between September 2002, when the rules were finalized, and the January 2009, when OWRD reported to the legislature, the department had issued 67 new groundwater permits with associated mitigation, totaling 52 cfs of water. The department has already received applications for the remaining 148 cfs under the 200 cfs cap. Once the cap is reached, OWRD will not be able to issue additional permits, unless the Water Resources Commission modifies its rules and adjusts the cap. Most of the new permit holders have leased water from irrigators to offset their pumping, although some outright purchases have also been made by permit holders.

#### *4.2.6.1. Mitigation Banking*

To make sure that water would be available to buyers who may have trouble finding willing sellers, the state authorized the creation of “mitigation banks.” When water trading is introduced, the expectation is that increased demand will drive up the cost of water, encouraging irrigators to use water efficiently and reduce waste. An irrigator holding a water right is motivated to trade when he believes he can make more money by selling his water entitlement rather than using it himself. And while water trading has existed in Oregon for many years, the Groundwater Mitigation Program was a new and additional element that is increasing demand and driving up water prices.

Mitigation banks can play an important role as a clearinghouse for buying and selling water rights and facilitating transfers. Banks are seen as a more stable and transparent alternative to individual buyers and brokers “wildcatting” for water. Suppose, for example, one of the several new destination resorts being built in the region makes a deal with an individual irrigator to purchase water and remove it from the district unilaterally. Irrigation districts consider this an “end run” that subverts their authority and threatens their stability. Instead of this situation, the resort developer has the option of purchasing mitigation credits from the Deschutes River Conservancy mitigation bank or the Deschutes Water Alliance Water Bank, both of which operate in cooperation with irrigation districts.

Banks also help increase confidence in the water market; developers and cities are assured that mitigation water is available. Another advantage of conducting transactions via a bank is that both buyers and sellers know in advance the price of mitigation credits, a function economists refer to as “price discovery.” Banks also help to keep transaction costs low by cutting out middlemen and profiteers.

Groundwater pumpers can purchase “mitigation credits” for their use of water which may impair the river. Revenues from the program are used to purchase water through leases or transfers and keep it flowing in the river. A seller may establish credits to be sold to the mitigation bank in one of four ways: (1) instream leases and transfers; (2) aquifer recharge; (3) storage release; and (4) conserved water projects. To date, only the first of these has occurred. The owner of a water right can create a mitigation credit by retiring an irrigation water right from surface water. The retired irrigation water right is left in the stream and accrues a credit for groundwater use.

Traditionally, when an irrigator diverted water in the Deschutes, it was transported to the field in unlined earthen channels. It is estimated that up to half of all water diverted infiltrated back to the ground, where it replenished the aquifer and eventually returned to surface water streams. Because of this, the rules for the mitigation program were drawn up so that an irrigator could only receive credit for the volume of water that is used consumptively (the amount that is lost to the atmosphere after being applied to crops a process hydrologists call evapotranspiration.) For example, a typical water right in the Deschutes grants 8–9 acre-feet of water per acre of irrigated land. Up to half of this water is lost before it reaches the field. Of the 4–5 acre-feet applied, approximately 1.8 acre-feet is consumed, or lost by evapotranspiration, with the remainder infiltrating back to the aquifer or draining to neighbors fields or a nearby stream. Thus, an irrigator that voluntarily fallows one acre receives 1.8 mitigation credits.

Urban water use, on the other hand, is largely non-consumptive: water used indoors is eventually treated and discharged back to surface water. The purchase of one credit by a municipality permits its user to pump 4.5 acre-feet or 1.5 million gallons of groundwater. For the last few years, credits have been valued at $100–$150 for a temporary lease, and $1,500–$2,000 for permanent transfers (lower than in many Western states with active water markets).

There are currently two banks in operation in the Deschutes. The first Bank is the Groundwater Mitigation Bank, which is run by the DRC and generates and sells temporary mitigation credits. This Bank was chartered by the State in 2003 and provided important initial liquidity to the mitigation market in the early years of the Program.

Second, the Deschutes Water Alliance (DWA) Bank is also run by the DRC. This bank deals exclusively in permanent mitigation credits and is the largest and most active bank. The Alliance was set up in 2004 with financial assistance from a Bureau of Reclamation Water 2025 grant. It was created by an alliance of four major groups in the basin representing urban, agricultural, environmental, and tribal interests: Deschutes Basin Board of Control, the Central Oregon Cities Organization, the Deschutes Resources Conservancy, and the Confederated Tribes of Warm Springs.

In most states, re-allocation of water rights is a complex and contentious process (Glennon 2005). Usually, applicants require the assistance of specialists, such as engineers and lawyers. Mitigation banking in the Deschutes was specifically designed to be straightforward for the applicant, with the bank helping to guide applicants through the process (Aylward 2011). The DWA bank supports the groundwater mitigation program by turning temporary leases and permanent instream transfers into mitigation credits. A third, private water bank has worked to provide a full set of services to smaller irrigators, seeking to develop new groundwater rights.

Water trading in the Deschutes is not a free market. For example, there are a number of conditions imposed regarding who may participate in the market. Initiating a trade is a lengthy process taking up to two years. The state has chosen to play a passive role in water markets, allowing intermediaries to facilitate transfers. However, the state exerts strong control over the transfer process, for example conducting lengthy and detailed "injury reviews" to ensure that the transfer will not adversely affect junior rights holders (Crammond 1996). Oregon's statutes are unusual among Western states, where water that is transferred for instream water use maintains its original priority date, protecting it from diversion by junior rights holders.

#### *4.2.6.2. Zones of Impact*

The Groundwater Mitigation Program is designed to allow for growth and new water uses without causing further aquifer declines or streamflow depletion. This policy won't restore streams, though, if a new water use is initiated in one area within a watershed, and a right is retired in a different area. Authorizing new uses could actually worsen conditions, especially in the vicinity of headwater tributaries where flow volumes are small, and modest pumping can have a large effect on flows. For this reason, OWRD has divided the basin into several "zones of impact." When a landowner submits an application for a new well permit, regulators determine "where the new use of ground water will have the most impact on surface water, and will require that the mitigation occur in that area" (City of Prineville, Oregon 2007).

There are seven zones of impact in the Deschutes basin. To define their boundaries,

> the OWRD considered sub-basin boundaries, locations where in-stream water rights or scenic waterway flows are not being met, general ground water flow information, and other hydrogeologic information, including identification of stream reaches influenced by groundwater discharge. By defining the

boundaries for each of the local zones of impact, mitigation may be targeted to areas where mitigation projects may provide the greatest in-stream benefits (Cooper 2008, 10).

#### *4.2.6.3. Criticisms of the GMP*

While the GMP enjoys wide support, some groups have critiqued this general approach to water management, while other stakeholders have critiqued specific areas where the program could be improved. In general, the concept of "mitigation" of a damaging environmental activity (such as groundwater pumping in a sensitive aquifer, filling wetlands, or destroying endangered species habitat) has been criticized on grounds that it fails to achieve conservation goals, and diverts attention from the seriousness of the issue by allowing developers to "buy their way out of" while continuing with harmful activities.

Some critics contend that the zone of impact approach does not adequately protect surface water flows. According to Kimberly Priestley of Oregon Water Watch, proposed resorts in the headwaters of the Metolius River "will likely affect the headwater springs, if mitigation water is returned to the bottom of the river system, the rules would 'call it good'" (Priestley 2008).

Another criticism is that mitigation does not necessarily replace water in the same place or at the same time as new withdrawals. To date, all mitigation water has come from leases from irrigators, and thus has been returned to the stream during the summer irrigation season. According to a program evaluation by the Oregon Water Resources Department (2009a), "While the additional flow to the system during the summer months is a positive effect, some have raised concerns about groundwater pumping impacts on streamflow during the non-irrigation season." Others argue that non-irrigation season instream flow needs could be met by releasing water from upstream reservoirs, something that the DRC is currently working on (Aylward 2011).

A significant drawback to Oregon's system of groundwater regulation is that it does not cover small wells used for domestic water supply or for livestock (OWRD 2009a, 24). With continued growth in the region, the proliferation of so-called "exempt wells" has the potential to draw down aquifers and deplete streamflows. There is some evidence that lawmakers are becoming aware of the exempt well issue. In 2009, Senate Bill 788 was passed, which requires landowners to record new water wells drilled for exempt use purposes. The landowner pays a $300 recording fee and is required to submit a map showing the location of the well on the tax lot, or he can use an online mapping tool to mark the location of the well. However, under the current GMP rules, exempt wells are still a source of "leakage" from the program.

Another limitation of the groundwater mitigation program is that it fails to address water quality concerns (OWRD 2009a, 38-42). Groundwater discharging to streams as base flow are cold, clean, and have a distinct chemical composition that may not be equivalent to surface water discharges (such as tailwater drained from irrigated fields). Restoration goals focus on rebuilding runs of anadromous fish like salmon and steelhead, which are especially sensitive to temperature and chemistry, and rely on specific conditions to spawn and lay their eggs. Fisheries biologists point out that there are a number of elements that contribute to healthy rivers that support salmon.

When the Groundwater Mitigation Program was launched, it was expected that developers, in addition to purchasing or leasing water rights, would fund conservation projects. To date, however, no mitigation projects utilizing Oregon's Conserved Water statute have been funded. Further, the majority of mitigation credits have been in the form of short-term leases. Cities have been very interested in using conserved water for mitigation. However OWRD ruled in 2010 that, although the mitigation rules allow it, this method fails the injury review standards because it would use non-consumptive water to back up a new consumptive use of groundwater.

Lack of financing may be another reason why irrigation efficiency projects, which are relatively low-cost, have not seen more widespread use to mitigate groundwater pumping. Researchers at Oregon State University's Institute for Natural Resource Studies (Hartwell et al. 2010) point out that irrigation districts normally deal with large public-sector entities, and that dealing with the private sector for such projects is simply too new and full of uncertainty, and that projects like replacing canals with pipes are simply too expensive for most private enterprises. "Some have insisted that, had the state financed early projects, the program might have developed more quickly."

Oregon's programs to restore instream flows through leases, transfers, and conserved water, and to mitigate for new groundwater uses through the Deschutes Groundwater Mitigation Program, were slow to develop. Early appraisals praised certain elements of the program but noted that they had not shown significant increases in instream flow. Reviews by Aylward (2008) and the Oregon Department of Water Resources (2008) have shown that interest in, and awareness of, these programs has grown in recent years. OWRD concluded (p. 49):

> Deschutes Basin Ground Water Mitigation program has been successful in meeting the key goals of the program: (1) to maintain flows for the Deschutes Scenic Waterway and instream water rights; (2) to facilitate restoration of flows in the middle reach of the Deschutes River below Bend; and (3) to accommodate growth through new ground water development. Since implementation of the program, the Department has issued new ground water permits while mitigating impacts to scenic waterway flows and instream water rights.
>
> In each year that the program has been in place, sufficient mitigation has been available to meet the needs of new ground water permits. And, the amount of mitigation available, overall, has increased annually. Through mitigation, scenic waterway and instream water right flows have been maintained and, in some areas, have been improved. The benefits of the program have been significant in some areas, such as the flows restored in the Deschutes River below Bend. Overall, as a result of the program, more than 39 cubic feet per second of instream flow has been restored to the Deschutes River and its tributaries.

Irrigators and cities in the Deschutes have chosen to participate in the Mitigation Program rather than fight it. This stands in stark contrast with the ongoing legal challenges faced by regulators in New Mexico and Texas described in this report. In fact, this seems to be the a common reaction by entities that are faced with a new regulatory regime that imposes new costs. A few explanations have been put forth to explain the cooperative attitude of most water users. Large water users understand potential liabilities from drawing down the river, based on the Clean Water Act and the Endangered Species Act. The state chose a moderate course of action that preserved historical water rights. A different approach was taken in Australia: in order to improve environmental flows in the Murray-Darling river system, regulators ordered cutbacks be shared evenly across the board. All irrigators' rights were reduced proportionally. It is likely that if Oregon lawmakers had chosen a similar course of action, there would have been a great deal of resistance.

Because transfers are the only type of mitigation that has occurred, it suggests that water for new development has occurred at the expense of irrigated land that is retired. This is something many basin stakeholders oppose, as they wish to prevent sprawl and preserve the rural character of the region. According to one manager, “If even one acre of land had to be fallowed as a result of the program, I would view it as a failure” (Tillman 2011). The DWA Bank focuses on urbanizing areas that are going out of agricultural production. As there is no significant new agricultural demand, water rights in the urbanizing acres are available for mitigation transfers. Thus the banks are helping to facilitate orderly transitions as land uses and the economy are changing.

The program also appears to suffer from a significant administrative backlog. Permit and transfer applications can take up to two years for OWRD to process. Part of this has to do with lack of staffing and resources at the agency, but is also because of the amount of analysis and number of factors that must be considered during “injury review” to ensure that other rights holders are not adversely affected. To date, experience has shown that transferring water permanently out of irrigated lands is subject to the most stringent review (Tillman 2011). The reviews for leases are much shorter and are typically processed in 30-45 days (Aylward 2011). The review process reflects a cautious approach by regulators. The barriers to trading, and the time it takes to conduct transactions stands in sharp contrast to the system set up by regulators of Australia’s Murray-Darling River Basin. While leases in Oregon can take over a month, Australian irrigators can buy and sell water in a few moments via their mobile phones (Cathcart 2010).

An open and transparent process has contributed to the acceptability of the GMP by stakeholders in the basin. Rather than crafting the rules in a highly top-down fashion by the legislature or bureaucrats, OWRD convened a wide range of stakeholders to develop and review the rules and implementation of the program (OWRD 2008). The Oregon Department of Water Resources concluded in a 2009 assessment of the program that the mitigation program is a small but important piece of overall Basin water management. They went on to caution that the basin’s problems have not yet been solved, but “will require continued commitment and effort locally and investments by the State in supporting these efforts.” The main advantage of this program has been to allow continued growth and evolution of water uses following basin closure.

### 4.2.7. Progress towards Restoration Goals

The success of the laws and programs must be measured by their ability to meet river restoration and regional economic goals. Over the past decade, Oregon has succeeded in putting more water back into rivers and streams through leases, transfers and conserved water than any other state in the Pacific Northwest. As of summer 2010, approximately 1,600 cubic feet per second (cfs) had been voluntarily restored to streams in Oregon. An informal survey by administrators showed that Washington had restored approximately 400 cfs, Idaho about 100 cfs, and Montana an unquantified but “substantial” amount (OWRD 2010).

One of the reasons for this success is that flow restoration has been a priority to the Oregon state government. Oregon's Department of Water Resources submits annual reports in which it reports its progress toward meeting certain "key performance measures" or KPMs. KPM #1 is Flow Restoration, and KPM #2 is Protection of Instream Water Rights (OWRD 2010).

However, many reaches of the Deschutes River and its tributaries are still impaired in terms of their ability to support resident and endangered anadromous fish. One of the main successes of the Groundwater Mitigation Program has been to allow for continued growth while preventing an increase in net water consumption. While cities and suburbs in the basin have continued to grow in the last few decades, overall groundwater use has declined slightly and the flows in the most impaired reaches have increased significantly towards meeting the instream targets, although they are still below the minimum target levels. Water for cities and instream flow has been transferred from agricultural water users. As shown in Figure 26, irrigation diversions have steadily declined due to changes in land use (less irrigated land); irrigation cessation (when an irrigator decides it is more profitable to sell or lease his or her water right); and efficiency gains (for example, a number of districts have replaced leaky earthen canals with pipes).

The rules established by the 2002 legislation "require that the Oregon Water Resources Department (OWRD) monitor and evaluate the effects of mitigation and groundwater allocation on streamflow throughout the basin. Specifically, the OWRD is required to "determine whether scenic waterway flows and in-stream water right flows in the Deschutes Basin continue to be met on at least an equivalent or more frequent basis as compared to long-term, representative base period flows established by the Department" (OAR 690-505-0500(3)).

A 2008 report by the Oregon Water Resources Department (Cooper 2008) summarizes the methods used to conduct evaluations of the impacts of groundwater withdrawals and mitigation projects on streamflow. Rather than using streamflow measurements, OWRD relies on a mathematical model to estimate the impacts of mitigation and projects on streamflows. The department states that modeling is preferable to monitoring because it is the only way to isolate the impacts of projects from other natural variation in the environment. For example, before mitigation began, in a historical dry year (1982), the Deschutes met the instream flow criteria just 28% of days; while two years later in 1984, wetter conditions prevailed and flow criteria were met 100% of the time. Analysts rely on model results also because the results of a conservation project may not be observed for many years.

On the most impaired reach of the Deschutes River, downstream of Bend, Oregon, where instream requirements are met only 23% of the time, OWRD estimates that mitigation has increased annual streamflow by 27.3 cfs and that minimum flow requirements are now met 2.3% more often (up to 25% of the time on average). While restoration activities other than the GMP have also increased the flow in the Deschutes, there is still progress to be made. The unimpaired flow averaged 1,350 cfs; reaches below Bend have plummeted as low as 30 cfs, the amount that irrigators agreed among themselves to leave in the river at all times.

Programmatically, a group of stakeholders convened to evaluate the program identified the following strengths (OWRD 2009a, 21-23). The group also raised a few concerns about the program, most of which have been summarized in the section above on Criticisms of the GMP. The summary of the groups conclusions are reprinted here in its entirety:

- Transactions are occurring—OWRD has issued credits and water has been put back into the Middle Deschutes reach.
- Cities support having the regulatory program because it provides definitions and sideboards.
- The program has allowed municipalities and quasi-municipalities to mitigate incrementally, which has been very helpful.
- All interests are aligned around an instream flow purpose. Everybody has to think about the river in terms of how new water rights can be acquired and what mitigation has to occur in order to provide for those new rights.
- The program has helped educate the public about water issues in the Basin. Everybody is more knowledgeable about this water issue.
- The program has helped create a roadmap for the mitigation process, which is useful to all water users.
- The program provides a pilot project and creative solutions for water management in other basins (though concerns were expressed that details of the program may not be transferrable and only the concept and approach may be transferable).
- Using instream leases as a bridge to permanent mitigation is working well.
- Instream leasing can provide a stable source of mitigation credits, but we need to be cautious to not rely too much on temporary leases.
- OWRD can track transactions well (in terms of what mitigation is occurring and where the uses are located).
- OWRD has started doing a more robust review of the applications (making sure speculation is not happening).
- There are now market-based (market pricing, supply and demand oriented) solutions in the basin, and the market can respond quickly to changes.
- Very few places in the West have capped consumptive use. Overall consumptive use in the Basin is neutral.
- There is more water instream in the Middle Deschutes River in the summertime.
- The water banks and mitigation credits are linked with flows.
- The program has made a good strong start in achieving the goals of mitigation in the Basin. People want to keep improving it, but don't the program eliminated or compromised.

### 4.2.8. The Role of Nonprofit Organizations in Restoring the Deschutes

River restoration efforts in Oregon have been greatly advanced by several active nonprofit, nongovernmental organizations, including Oregon Trout, Oregon Water Trust, Oregon Environmental Council, Water Watch, the Deschutes River Conservancy, and the National Fish and Wildlife Foundation. Nonprofit groups have not only advocated for new and better laws and policies, but have also helped them to gain acceptance once they are passed. In the words of Bruce Aylward, former water bank manager at the Deschutes River Conservancy, "non-profit groups have worked tirelessly with water users to convince them of the merit of the conserved water program, and to improve their water management while simultaneously protecting saved water instream" (Aylward 2008).

The Oregon Water Trust is the nation's first water trust. It was created in 1993 in order to test out the recently enacted Instream Water Act of 1987. The initial seed money came from a grant from the Northwest Area Foundation, a grant-making organization founded in 1934 by Louis W. Hill, heir to the Great Northern Railway fortune. The Water Trust's four founders came from various walks of life: among them a cattle rancher, an environmentalist, an irrigation district director, and an attorney (Neuman and Chapman 1999, 135).

The Trust's board of directors includes a variety of agricultural, environmental, legal and tribal perspectives. This diverse board membership allows the organization to pursue the conservation of aquatic resources while "openly and effectively address the concerns of rural Oregonians regarding their livelihoods" (Anderson and Snyder 1997). The Oregon Water Trust, which merged with Oregon Trout in 2009 to form The Freshwater Trust, has grown into an organization with a staff of 29 and an annual budget of $4 million, with funding from state and federal grants, and donations by corporations, foundations, and individuals, and a number of other activities in addition to water transactions (Oregon Freshwater Trust 2009). The success of the Oregon Water Trust has spawned the creation of similar organizations in Washington, Idaho, and Montana.

In addition, traditional land trusts in the Northwest have focused land acquisition efforts in areas that support aquatic habitat, especially for restoring endangered salmon runs. While maintaining streamflows is critically important, restoration efforts must deal with other factors in order to be effective in restoring native fish populations. For example, in 2009, the Deschutes Land Trust finalized a $1.4 million deal to acquire 145 acres on Whychus Creek, a tributary of the Deschutes, with funding from Boeing and Portland General Electric. The project is part of an integrated the plan to reintroduce of salmon and trout. The project addresses both flow and habitat, making it more likely to succeed.

The Deschutes Land Trust and the Deschutes River Conservancy have worked together to purchase land and water rights to restore the creek's floodplain, re-create meanders, plant native vegetation, and re-introduce native fish to the stream. The project also includes a component of public education and volunteerism. In 2011, restoration of the Whychus will continue. A partnership among the Three Sister Irrigation District, the Upper Deschutes Watershed Council, the U.S. Forest Service, and the Deschutes Basin Land Trust will spend $2 million to modify intake structures and replace canals with pipes to reduce seepage losses and increase instream flow (Wright and Bell 2010).

The Deschutes River Conservancy (DRC) was created in 1996 following discussions among irrigators, the Environmental Defense Fund, and the Confederated Tribes of the Warm Springs Federation (made up of the Wasco, Warm Springs, and Paiute Indians). The DRC, a nonprofit, nongovernmental organization, has received Congressional authorizations of $2 million per year, although only a portion of these funds are appropriated each year. These authorizations were canceled during the second administration, but reinstated in 2007. The DRC has a large board, currently with 29 members representing a diverse range of interests, and 12 staff members. While the DRC has mainly focused on leasing and purchasing water rights to support instream flow, it also supports a range of restoration activities. For example, it has installed 40 miles of riparian fencing to protect streams from grazing animals and planted over 100,000 trees. Its approach of simultaneously working for conservation while allowing development has not pleased all environmental organizations, nor those in favor of reducing obstacles to development (Lieberherr 2008, 42).

In 2009, the DRC received $3.66 million to be spent over 24 months through the American Reinvestment and Recovery Act, or the so-called stimulus bill (DRC 2011). The funds, which include a 1:1 non-federal cost match, in addition to supporting temporary job creation, fund projects to conserve water and restore flows of about 26 cfs in Whychus Creek and the Deschutes River, mainly through limiting distribution losses at the irrigation district level. The Act included the following projects:

- Piping 3.7 miles of the Three Sisters Irrigation District Main Canal
- Piping 2.25 miles of an open canal managed by the Central Oregon Irrigation District
- Piping up to 10 miles of an open canal that compromises Crook County Improvement District's water delivery system
- Financing water acquisitions for the Deschutes Water Alliance Bank

### 4.2.9. Conclusion

The Deschutes has attracted a great deal of attention because water managers and policymakers have recognized the importance of dealing with groundwater to protect surface water flows. They have set up market-based strategies with the dual goal of providing for continued growth and maintaining a healthy river. Efforts were helped by access to funding to protect salmon habitat, both from the state and federal government and the electric utilities which operate hydroelectric dams in the basin, and are required to fund projects to mitigate the harmful effects of dams on fish runs.

Several of these strategies and "lessons learned" may be applied to the Verde River basin. Despite the Deschutes's distance from Arizona, the basins share several characteristics. Each is in the midst of a population boom. The Deschutes region, like the Verde, is becoming an increasingly popular resort destination. In each river basin, a productive aquifer is connected to surface water, and excess pumping can diminish river flows. And like in the Verde, basin stakeholders have expressed a strong desire to protect family farms and preserve the pastoral character of the landscape.

However, there are also several differences in both the legal and physical settings that may make it difficult to transfer programs and policies directly without modifying them to fit the local context. The first is the physical setting. The Deschutes river basin is larger (10,500 vs. 6,250 square miles) and has a much higher average discharge (5,000 vs. 550 cfs) due to higher precipitation and lower average temperature and evaporation. The most conspicuous difference is the movement of groundwater in the basin. The river's hydrology is somewhat different from the Verde's, as it is located in a highly permeable karst basin. Karst refers to highly soluble carbonate rock such as limestone, which dissolve to form underground fissures and channels. Thus, groundwater movement may be faster on average than in the Verde.

As seen by the assessment of the Deschutes Groundwater Mitigation Program, many stakeholders and a number of legal scholars and water policy experts consider Oregon's experiments at restoring instream flows to be successful. While the restoration goals have not yet been reached, the program is relatively young, and much progress has been made. Modest reforms to Oregon water law, and the creation of new institutions and procedures have allowed market-based transactions to occur that have allowed urban and suburban development to take place without putting irrigators out of business, while putting modest amounts of water back in streams. For the most part, expensive and time-consuming lawsuits have been avoided, cooperation has been enhanced, and basin organizations have succeeded in attracting a great deal of private, state, and federal funding to support river restoration and more efficient irrigation infrastructure.

The much heralded market-based approaches employed in the Deschutes have largely been a way to facilitate an orderly transition from agricultural to municipal and residential uses, while simultaneously restoring stream flow. They serve as an excellent example of the types of reforms and processes that can help ease this transition, giving cities the water they need to grow while allowing irrigation districts to “remain whole” and stay in business. In the Verde River Valley, there is significant potential to increase water use efficiency among irrigators and other surface water users. There is also the potential to mitigate for future groundwater pumping and its impact on the Verde River, as has been done in the Deschutes. Several components of water management in the Deschutes offer an excellent roadmap for allocating water to cities, agriculture, and the environment.

### 4.2.10. Timeline of Water Management in the Deschutes River Basin Oregon

1825 "Peter Skene Ogden and a party of Hudson Bay Company trappers embarked from the Columbia River, at the mouth of the Deschutes River ("River of the Falls") to survey the little known region of inland Oregon" (Tillman et al. 2011). Up until this time, the region was known to native Americans who hunted and fished there.

1863 First white settlers arrive in central Oregon.

1909 Oregon passes the Water Act, adopting the prior appropriation system of water rights used in other Western states.

1910 City of Bend incorporated.

1913 Oregon enacts law to protect the waterfalls at the Columbia gorge from development.

1913 In the same year, the state declares the Deschutes basin fully appropriated.

1922 The U.S. Congress passes the Carey Act authorizing Oregon irrigation districts and financing a dam at Crane Prairie that will irrigate 40,000 acres in central Oregon.

1928 State calls for adjudication of water rights in the Deschutes basin.

1935 A U.S. Supreme Court ruling affirms the 1877 Desert Lands Act, giving the states primary authority for water allocation.

1950s State completes adjudication of surface water rights in the basin. At the time, groundwater use is limited, and pumping is unregulated and does not require a permit or a water right.

1938 From 1938 to 1945, the US Bureau of Reclamation and the Civilian Conservation Corps embark on the ambitious Deschutes Project, designed to break central Oregon's "cycles of poverty and drought." Its dams, canals, and pump stations will eventually irrigate up to 100,000 acres.

1955 Oregon overhauls its water laws, creating the State Water Resources Control Board, tasked with developing management plans for each basin that would support a variety of goals, including maintenance of instream flow for fish and wildlife, recreation, and scenic values.

1955 Another important law passes. The Groundwater Act extends the system of prior appropriation to groundwater, requiring permits for groundwater uses. It also introduces laws requiring the state to establish targets for minimum instream flows.

1958 Pelton Dam completed on the Deschutes River. Two more major dams would be completed by 1965. In response to fierce opposition from the fishing community, the owners (Portland Gas & Electric) spend $1 million for fish ladders and a hatchery. These prove ineffective and are abandoned after three years. As a result, migrating fish are extirpated above the dams.

1960s Federal environmental laws is enacted, including the Endangered Species Act and the Clean Water Act, which will be important to water management in Oregon.

1968 Federal Wild and Scenic Rivers Act passes. Ten rivers in the Deschutes Basin are included in the system. The law prohibits federal assistance for water projects on listed rivers, but does not authorize federal regulation of water diversions, nor does it authorize federal acquisition of instream water rights.

1970s State Scenic Waterway Act passes. Portions of the Deschutes are declared a Scenic Waterway.

1980s-1990s Rapid population growth in the Deschutes basin. By mid-90s, much former large-scale irrigated land had been converted to small (<10 acre) "hobby farms."

1987 State passes Instream Water Rights Act which "enables high priority rights to be leased or transferred instream without losing their underlying priority and reliability in Oregon" (Garrick et al. 2009).

1991 State establishes minimum instream flow requirements for the Deschutes River to support wildlife and recreation. The summer flow requirement of 430 cfs is modest, representing only 5% of pre-development streamflow.

1993 Oregon Water Trust formed. It is the first trust formed in the United States to purchase water for the environment. The following year, it will initiate the first private lease of water for environmental purposes, paying $6,600 to a farmer not to irrigate his hay crop in order to protect spawning steelhead in Buck Hollow Creek.

1994 In November, Democrat John Kitzhaber is elected governor with 51% of vote. During his two terms, he makes water policy prominent, launching the *Oregon Plan for Salmon and Watersheds* and supporting the removal of several hydroelectric dams in order to restore endangered salmon runs.

1995 The state Scenic Waterway Act is amended, requiring a detailed assessment of new groundwater uses on scenic waterway reaches. Under the law, the state may not issue groundwater permits that would diminish the flow in designated reaches by more than 1% of pre-development flow, or 1 cfs, whichever is less.

1995 The City of Bend applies for a groundwater permit to meet the water supply needs of a growing population. The permit is contested by environmental organizations which claim it will adversely affect flows on the Deschutes River.

1996 The Deschutes River Conservancy is formed, bringing together environmental and agricultural interests in an effort to restore flows to the severely over-tapped Deschutes River. The DRC is set up as a nonprofit, nongovernmental organization, but receives a Congressional authorization of $2 million per year.

1997 A U.S. Bureau of Reclamation study of irrigation in the Deschutes basin finds that seepage losses in unlined canals consume up to 39% of water diverted by irrigation districts. The Bureau recommends canal lining and piping to save up to 327,000 acre-feet, or an equivalent flow of 700 cfs.

1998 USGS scientists release preliminary results from the Deschutes Basin Groundwater Study, co-financed by the Confederated Tribes of the Warm Springs Indian Reservation. The study shows that pumping causes a diminution in streamflows, violating the instream flow standards set by the state.

1998 Oregon's Water Resources Department begins convening the Deschutes Basin Ground Water Supply Work Group. They meet for three years in an attempt to "seek a workable balance between development and environmental interests within the framework of strict surface water protection laws" (Pagel 2002, 30).

1998 The state of Oregon establishes a water right for instream flow. Most instream rights are given a pre-1909 water right, making them senior rights with "first call." During times of low flow, the basin water master regulates junior rights holders to preserve the instream flow.

1999 Middle Columbia River steelhead listed as "threatened" by the National Marine Fisheries Service. NMFS launches a species recovery plan. It includes a number of actions such as limiting harvest and improving fish passages, but also "calls upon Federal, state, and tribal entities to manage land, hydropower" to support species recovery.

2000 Irrigators along the Deschutes institute a "gentleman's agreement" to leave at least 30 cfs in the river.

2000 Paul Cleary succeeds Martha Pagel as Director of OWRD. Rulemaking is taken away from the Working Group, which has been meeting for the three years to balance water use in the Deschutes, and moved to the OWRD Director's office.

2000 National Marine Fisheries Service (NMFS) issues "reasonable and prudent alternative" for salmon recovery efforts mandated by the Endangered Species Act. As a result, the Columbia Basin Water Transactions Program is created to encourage voluntary water transactions, with funding from the two major Northwestern hydroelectric utilities, the Bonneville Power Administration and the Northwest Power and Conservation Council. By 2010, it has funded $35 million in restoration activities.

Sept 2001 OWRD releases draft Groundwater Mitigation Strategy which states that new groundwater permits will require the applicant to offset their water use by purchasing and retiring an equivalent amount of surface water. It generates controversy and receives over 100 comments.

Feb 2002 OWRD issues revised rules for the Groundwater Mitigation Strategy.

2002 The Oregon Water Resources Commission places a moratorium on issuing new groundwater rights in the basin "unless mitigation counterbalances any extraction for additional water supply" (DWA 2004).

2001 House Bill 2184 authorizes the creation of the first water bank. The Deschutes Water Exchange is run by the nonprofit Deschutes River Conservancy, and is authorized to buy and sell temporary credits.

2002 Oregon WaterWatch sues the state over the Groundwater Mitigation Program (GMP), arguing that it is likely to be ineffective and shift the focus away from instream flow protection.

2004 The Federal Energy Regulatory Commission relicenses the Pelton-Round Butte complex on the Deschutes River for another 50 years. A new plan is put in place to restore anadromous fish above the dams, reinvigorating efforts to restore upstream tributaries such as Whychus Creek and Crooked Creek.

2004 The Deschutes Water Alliance is formed with initial funding from a Bureau of Reclamation Water 2025 grant. The DWA is tasked with "stabilizing water use in the basin in order to meet agricultural, municipal, and ecosystem requirements through collaborative efforts among water users." The grant also enables creation of the Central Oregon Water Bank to facilitate leases and transfers under the GMP (Lieberherr 2008, 55-56)

2005 Court rules against the GMP, finding it violates the Scenic Waterway Act. That same year, the legislature reinstates the program by passing House Bill 3494. Former OWRD Director Martha Pagel argues that the program is good for the environment because there is "more stream flow in the Deschutes River today than before…even though many new ground water rights have been issued" (quoted in Lieberherr 2008, 55).

2009 Senate Bill 788 passed, requiring landowners to record new water wells drilled for exempt use purposes.

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## 4.3. Edwards Aquifer, Texas

### 4.3.1. Introduction

The Edwards Aquifer in south central Texas is an important groundwater resource, supporting thousands of acres of irrigated agriculture and supplying water to San Antonio, the country's seventh-largest city. The region shares similarities with the Verde Valley, as the aquifer also feeds springs and rivers that are important for water supply, recreation, the regional economy, and as habitat for several endangered plant and animal species. Decades of increasing groundwater use culminated a crisis when the worst-ever drought occurred from 1947–1956. For five months in 1956, Comal Springs—fed by the aquifer—ceased flowing for the first time in recorded history. Up to this time, effective groundwater management in Texas had been hampered by outdated laws granting users almost unlimited use of groundwater, with little consideration of how it affected other water users or the environment.

A groundwater management district created for South Central Texas in the late 1950s did little to improve the situation, as it lacked the power to limit pumping. In response to a lawsuit by the Sierra Club and others, Texas created the Edwards Aquifer Authority (EAA) in 1993 for the express purpose of preserving the flow of artesian springs and maintaining endangered species habitat, and gave it the power to regulate water users. The EAA was tasked with capping pumping at specific levels and buying down existing water rights by 2008, at a potential cost of hundreds of millions of dollars. Today, all wells producing more than 17 gallons per minute tapping the Edwards Aquifer must be permitted, pumpers must hold rights for their water use, and they must pay fees for their water use.

The EAA is self-sustaining, with the majority of its revenues coming from permit fees. Because of the aquifer's karst hydrology, where recharge is high and groundwater moves quickly, pumping impacts can quickly diminish flows from artesian springs. This has enabled the Authority to put in place flexible pumping restrictions, with drought restrictions triggered when spring flows or monitoring well levels decline below certain levels. Withdrawals from the aquifer have been capped, and applicants for new water use permits are required to purchase or lease existing water rights so that overall pumping remains steady. A water market has been established in response to the cap, with frequent trades occurring among irrigators. Cities have also become major players in the water market. San Antonio has already spent $135 million to acquire land and water rights, and plans to spend even more in coming years.

Springs fed by the Edwards Aquifer support a number of unique aquatic species, several of which are listed as threatened or endangered species due to low flow conditions and other stresses. Current efforts to protect endangered species have focused on the multi-stakeholder Recovery Implementation Process, led by the U.S. Fish and Wildlife Service (FWS). To date, however, the program has not secured the funding necessary to carry out the $30 million in annual activities deemed necessary for species to recover. Anti-regulatory interests have mounted continuing legal and legislative challenges to the EAA over the years, with challenges continuing to this day.

Despite the many advances made in water management, threats to the region's springs and rivers remain. In response to pressure from water users, and lacking funds to buy down approximately 100,000 acre-feet of permits authorized over the initial cap given by the Legislature, the Texas legislature raised the pumping cap in 2007 rather than allowing it to diminish as originally required by the Act. Recent study by the EAA has forecast that a repeat of the 1950s drought of record, even with current rules in place, would cause Comal Springs to run dry for nearly 3 years.

### 4.3.2. Background

The Edwards Aquifer in south central Texas (Figure 28) is one of the world's most productive artesian aquifers. Several rivers flow across the recharge zone of the Edwards Aquifer; three of these are created by artesian springs: the perennial Comal and San Marcos Rivers that flow year-round; and the ephemeral San Antonio River, which flows only intermittently. The San Antonio River's abundance made it hard for early settlers to imagine that it could run dry (Glennon 2004). Today, the aquifer is home to San Antonio, a city with a metropolitan area of two million, and the largest city in the United States which relies almost entirely (98%) on groundwater for its water supply. The aquifer also supports 80,000 acres of irrigated agriculture and water-based recreation on the San Marcos and Comal Rivers (Schaible, McCarl, and Lacewell 1999).

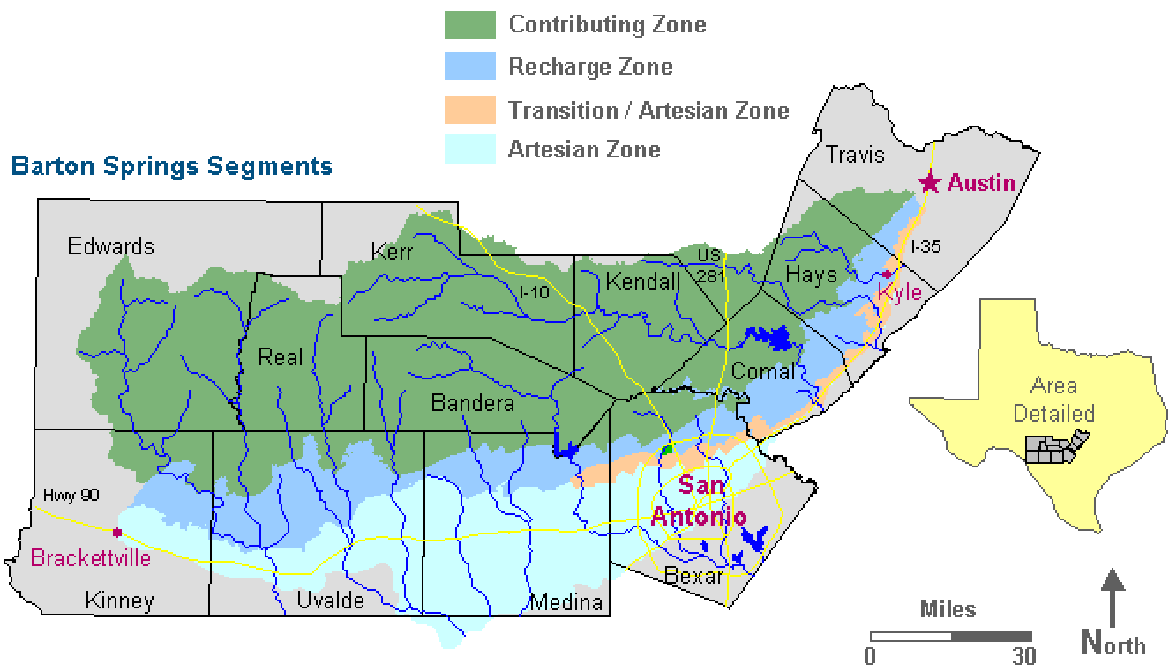


**Figure 28 The Edwards Aquifer system and surrounding area (from Eckhardt 2011)**

According to the U.S. Geological Survey (USGS), the annual volume of water pumped from the Edwards Aquifer in south central Texas increased 215% from the mid-1930s to the 1950s. For the last few decades, withdrawals have exceeded the aquifer's replenishment. The decrease in aquifer storage has caused springs to dry and threatened several endangered species, river recreation, downstream users, and the regional economy. At its peak in the late 1980s, annual withdrawals for agriculture, municipal, and industrial uses (542,000 acre-ft) consumed the majority of the annual recharge (628,000 acre-ft through 1989), causing a drastic reduction in spring flows, which formerly discharged 350,000 acre-ft per year (McCarl et al. 1993).

The aquifer contributes to flow in the Guadalupe River at Comal and San Marcos Springs, homes to several endangered aquatic species. Seven species in the Edwards Aquifer system are listed as endangered, and one is listed as threatened (Aquarena Aquarium undated; Eckhardt 2011a), including Texas Wild Rice, arthropods and salamanders, and two fish species, the Fountain Darter and the San Marcos gambusia (which has not been seen since 1982 and is likely already extinct).

The rivers that are fed by the Edwards aquifer draw people from across the state. Tubing on the Comal, San Marcos, and Guadalupe Rivers attracts thousands of visitors every day in the summer. The Schlitterbahn Waterpark, on 65 acres along the Comal River near the city of New Braunfels, is consistently rated one of the top water parks in the nation. Attendance at the park has grown consistently as the park has expanded, with 900,000 visiting in 2009. Estuaries on Texas' Gulf Coast depend on rivers fed by the Edwards, such as San Antonio Bay at the mouth of the Guadalupe River. The National Wildlife Federation (Johns et al. 2004) says the bay is in danger due to insufficient freshwater inflow to support wildlife such as oysters and migratory waters. (The Guadalupe is threatened by increased withdrawals from all aquifers that provide its base flow, not only the Edwards. Maintaining healthy estuaries is not only an environmental issue, but also an economic one that affects recreational and commercial fishermen. According to the National Wildlife Federation, "95% of the Gulf's recreationally and commercially important fish and other marine species rely on estuaries during some part of their life cycle" (Johns et al. 2004, 2).

Use of the aquifers' waters expanded greatly in the 1950s due to drought, and as irrigators took advantage of new technologies in well drilling and pumping. Until the 1990s, most of the irrigation on the Edwards relied on inefficient irrigation techniques. "Because the cost of water to the farmer has been only the cost of the well and the energy to pump water from the Aquifer, few incentives have existed to encourage farmers to adopt more efficient irrigation methods" (Votteler 1998, 5). It is estimated that pumping increased from 100,000 acre-ft in the 1930s to 321,000 acre-ft in 1956. In the 1950s, a serious drought brought attention to the need to manage the waters of the Edwards Aquifer. In 1968, the Texas Water Commission released a report that stated that withdrawals from the Edwards should not exceed 400,000 acre-ft/year, based on historical rates of recharge and discharge. By 1989, annual pumping peaked a 542,000 acre-ft, aquifer levels had dropped precipitously, and spring flows reached an all-time low.

### 4.3.3. Groundwater in Texas: "The Law of the Biggest Pump"

Outdated state laws and customs have stood in the way of better management of the aquifer's waters. Surface water in Texas has always been closely regulated under the prior appropriation doctrine: almost all diversions require a permit from the state and are determined by the doctrine of "first in time, first in right." The framers of water laws in the 1800s did not understand the hydrologic connections between surface water and groundwater. Underlying this "separation myth" was the belief that subterranean water was a limitless resource that bubbled up from the center of the earth or from caverns deep in the ocean.

Among the fifty states, Texas is among the most dependent on groundwater. Despite this, it persisted in upholding an outmoded legal doctrine that did not give the state authority to regulate its use, or to ensure that water is put to reasonable use. Under the “rule of capture,” groundwater is considered a private property right: any landowner could pump unlimited quantities of groundwater “provided the water is not willfully wasted, used maliciously to injure a third party, or pumped negligently” (Votteler 1998, 10). Unlike other Western states, there is no legal requirement that the water be used on overlying land or that it be used “reasonably,” merely that it is not willfully wasted.

The rule of capture doctrine has also been called the “Law of the Biggest Pump,” and can lead to what one commentator has called “gross misallocations of resources” (Glennon 2004). In 1991, Living Waters Artesian Springs Ltd. began using as much as 40 million gallons per day (as much as 25% of San Antonio’s total water use) to raise catfish in flow-through raceways. This legal use of water threatened downstream uses, caused worry and outrage in downstream San Antonio ,and galvanized public opinion to protect the aquifer. Unlike several Western states, property owners in Texas can sell their water separately from the land above it. Texas water laws have also spawned a new industry some have called “water ranching” (Glennon 2004). In 1999, the oil billionaire T. Boone Pickens set up a company named Mesa Water to mine groundwater from the Ogallala Aquifer beneath his properties in Roberts County in north Texas and sell it to San Antonio, or to any other willing buyer. The San Antonio city council considered the offer, but decided it was too expensive to pursue at the time.

From 1947-1956, the most severe drought in recorded times struck Texas, causing Comal Springs to go dry for the first time in memory. At this point,

> Most politicians had come to recognize the rule of capture is basically an unworkable free-for-all, because it gives everyone unlimited rights to a finite resource. Even so, none had been willing to tackle the issue head on, and you can’t really blame them. In Texas, politicians who dare to suggest that private property rights are less than paramount are routinely placed on rails and escorted from town wearing tar and feathers (Eckhardt 2011b).

In response to decreasing water levels in the Ogallala Aquifer in the panhandle of Texas, in 1949 the legislature passed a law allowing for the creation of groundwater conservation districts (GCDs). Most of the 90+ existing districts formed along county boundaries. Many districts performed valuable research, improved understanding of the aquifer, and ran valuable education, outreach, and conservation programs, but they lacked the regulatory ability to limit pumping. Districts were given authority to regulate well spacing and set maximum pumping rates, giving them, in principle, the regulatory ability to limit pumping.

In 1999, the Texas Supreme Court re-affirmed the rule of capture. In the case before the court, a private well-owner unsuccessfully sought damages when pumping by the nearby Ozarka water bottling plant caused his well to go dry. In its opinion, the court did state, however, that the legislature could enable local groundwater districts to restrict pumping to protect landowners. Two years later, the Legislature passed laws making it easier for property owners to form groundwater conservation districts by petition. This demonstrated to some the legislature’s desire to avoid dealing with groundwater management comprehensively at the state level. Instead, it deferred the difficult and unpopular job of restricting pumping to local districts, which “allowed lawmakers to avoid certain political doom” (Eckhardt 2011b).

In the last ten years, the number of groundwater districts has more than doubled to nearly 100. In each district, meetings are being held where local residents determine the “Desired Future Conditions” (a statement of desired aquifer conditions 50 years in the future) for their aquifer. It is now expected that in most cases Desired Future Conditions (DFC) will involve pumping limits. The purpose of Texas' Groundwater Management Area process, of which Desired Future Conditions is part, is for groundwater districts to collectively make these decisions based on aquifer rather than county boundaries (Broad 2011). A more detailed overview of the groundwater management process is available at the website www.texaswatermatters.org.

### 4.3.4. The Edwards Aquifer Authority

The creation of the EAA by the Texas legislature in 1993 marked the beginning of the end of the era of unlimited and unregulated pumping. Ultimately, it was the Endangered Species Act that compelled the state to manage groundwater in the Edwards Aquifer (Votteler 1998). The Texas legislature acted in response to a court decree. In 1991, a coalition led by the Sierra Club filed a lawsuit over protection of endangered species at San Marcos and Comal springs. A federal circuit court judge ruled in 1993 that if the legislature (which only meets every two years) did not act during the current session, he would appoint a water master to regulate pumping to protect springs and endangered species.

In 1993, with only days left to act, the Texas legislature voted to create the Edwards Aquifer Authority (EAA), with a core goal of "ensuring that the continuous minimum springflows of the Comal and San Marcos Springs are maintained to protect endangered and threatened species to the extent required by federal law (Edwards Aquifer Authority Act, Texas Senate Bill 1477, 1993). The EAA's legality and constitutionality have been challenged repeatedly and upheld each time in state and federal courts.

The EAA was responsible for setting pumping limits and issuing pumping permits, which are essentially an allocation of groundwater rights. Therefore, in all areas under the EAA's jurisdiction, the rule of capture was severely constrained, and groundwater became governed by the prior appropriation doctrine. Rather than determining permit volume based on the user's current pumping levels, permits were based on documented use over a certain period. (This smart approach by the EAA avoided giving pumpers the perverse incentive to over-pump in order to receive a larger allocation.) In a state where access to the water beneath one's property had always been unfettered, the effort to limit pumping was sure to be unpopular. One EAA staffer who was there at the beginning said, "It had the potential to be the largest taking [confiscation of private property] in U.S. history" (Illgner 2011).

It took many years for the Authority to overcome legal and administrative challenges and commence operations. After that, it took several more years to request and validate permit applications, adjudicate and define water rights, issue pumping permits, and collect fees. Aside from its role as a regulator, the Authority has other water management responsibilities, including "conservation, drought management, reuse, enhanced recharge methods, new surface water sources and the transfer of water through market mechanisms" (Kaiser and Phillips 1998, 413).

The EAA eventually issued pumping permits for more than 450,000 acre-feet (based on documented use), with the intention of "buying down" the excess rights. Water availability varies dramatically from year-to-year based on the highly variable recharge of the aquifer: historical recharge has ranged from 44,000 to 2.5 million acre-feet per year. In a system with such a high variability, it is tempting to allow water use to increase proportionally with water availability. Therefore, establishing a set cap on extractions was sure to be controversial. The Act established an initial pumping cap of 450,000 acre-feet that was to decrease to 400,000 by 2008, but authorized raising the cap if evidence became available that it should be higher. A series of wet years from 2000–2009 caused springs to discharge at an average of 500,000 acre-ft, well above the long-term average of 384,000 acre-feet.

In 2007, the state Legislature raised the cap to 572,000 acre-feet. It also directed the EAA to develop recommendations on how to cut back pumping during droughts to protect endangered species. On the one hand, this was a pragmatic and money-saving move that prevented the EAA from having to spend hundreds of millions to purchase rights. However, did raising the cap make sense based on the aquifer's hydrology? One may also ask: Why are pumping caps are set by politicians and not by a credible authority? To what extent is the cap based on the best science versus politics and economics? The controversy over pumping limits reflects two different philosophies on water management: one favors a set cap based on sustainable levels of extraction, while the other favors allowing extractions to vary from year to year based on water availability at the time.

Traditionally, water managers are cautious about permitting water use above the "safe yield," the amount of water that can be reliably delivered, even during a drought. Such caution may be warranted for municipal supply, where demand is relatively constant. On the other hand, where water is used for the irrigation of annual crops, water managers may be able to exercise "real-time control" by imposing restrictions during a drought. This is especially true in central Texas, where water, rather than land, is the limiting factor for crop production. The main irrigated crops—cotton, corn, sorghum, peanuts, hay, and vegetables—are all annuals and fields can be readily fallowed (Schaible, McCarl, and Lacewell 1999). The legislature reasoned that restricting withdrawals in wet or average years did little to improve the situation for the endangered species. Rather, withdrawals during a severe drought create the most significant impacts, and therefore the EAA should focus its regulatory efforts (and spending) on drought-period restrictions. This approach will be described in more detail in the section on "Critical Period Management" below.

### 4.3.5. Regulation of Water Use

The EAA has several tools at its disposal to protect aquifer levels and spring flows. In its first few years of operation, during the period when the EAA was reviewing permit applications and adjudicating water rights, the EAA relied on public education campaigns encouraging conservation. At times, the EAA simply paid farmers not to irrigate. In 1996, the Edwards region was gripped by drought. Normally, this would trigger drought restrictions on pumping enforceable by the EAA, but board members were unwilling to adopt emergency drought rules. A Court Monitor was appointed in 1994 and developed an Emergency Withdrawal Reduction Plan in 1995. In 1997, the EAA implemented the Irrigation Suspension Plan, to pay farmers not to irrigate for the season. In its first year, irrigators were paid $2.35 million to suspend water use. That year, 37 individuals with 9,669 acres of irrigated land were enrolled for a median per-acre cost of $240, conserving an estimated 15,470 acre-feet of water (Keplinger and McCarl 2000, 8). Farmers were not compelled to fallow their fields, but competed based on bids; the limit was available funding and not willing bidders. An economic study done afterwards concluded that the program was a cheaper way to save water and raise aquifer levels than funding irrigation efficiency, but more expensive than simply purchasing irrigated land at market rates (Keplinger and McCarl 1998).

During the next short but sharp drought, which came in 1998, the EAA again failed to impose pumping restrictions, but instead implemented its "Critical Period Management Plan." The plan followed the same general protocol set forth in the 1995 by the Court Monitor. Restricted uses focused mainly on urban water users (for example, limiting car washing and lawn watering), giving a free ride to agriculture. The EAA further demonstrated its aversion to imposing restrictions by asking the legislature for a half million dollars for a cloud-seeding project. Flow at Comal Springs fell to 168 cubic feet per second (cfs) in August, below the "take level"[1] at which the Fish and Wildlife Service determined endangered species would begin to die. Thus, in its first major test, the EAA failed to take effective action, and crisis was only "averted by an unusually wet August" (Votteler 1998, 30).

In fairness to the EAA, enforcement of pumping limits would have been difficult if not impossible, as rights were not yet clearly defined and meters were not yet in place. It took the Edwards Authority several years to verify the thousands of claims to water rights in the basin. The EAA reached a major milestone on January 9, 2001 when it issued the first permanent Edwards Aquifer pumping permits. According to Edwards Aquifer historian Gregg Eckhardt (2011b), the Stein family, who drilled one of the first irrigation wells in Medina County, was handed the first permit to pump 224 acre-feet per year.

Following the resolution of water rights claims and the issuance of permits, the EAA has restricted pumping restrictions in response to dry conditions several times in the past ten years. The decision about when to impose restrictions is made in response to conditions in the aquifer, as described in the following section.

#### *4.3.5.1. Critical Period Management*

An important tool used by the EAA to protect spring flows is the imposition of mandatory pumping cutbacks during drought periods. During "critical periods," withdrawal reductions are triggered by water levels in a monitoring well, and flow from springs, as shown in Table 16 below (from Texas S. B. 1477, May 30, 1993). Reductions affect all water users under the EAA's jurisdiction: urban, industrial, and agricultural.

**Table 16 Critical period management triggers for the Edwards Aquifer Authority**

| Critical Period Stage | J-17 Index Well (feet above msl) | Comal Springs Flow (cfs) | San Marcos Springs Flow (cfs) | Withdrawal Reduction |
|---|---|---|---|---|
| I | < 660' msl | < 225 cfs | < 96 cfs | 20% |
| II | < 650' msl | < 200 cfs | < 80 cfs | 30% |
| III | < 640' msl | < 150 cfs | n/a | 35% |
| IV | < 630' msl | < 100 cfs | n/a | 40% |

[1] "Take" means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." Endangered Species Act of 1973, 16 U.S.C. s 1532(19) (1994). A take may apply to one or more individuals of the species. The more serious "jeopardy" refers the potential for permanent extinction of the species.

The drought-index method relies on the fact that there is a quick response between decreased pumping and flow conditions at the spring. Because of the high transmissivity of the aquifer, groundwater flows quickly, so imposing pumping reductions may provide some rapid relief, or at least slow the rate at which springflows decline. We believe that such a scheme would be much more difficult to implement for the Verde River basin; even if the right laws and institutions were created, the lag time between pumping and river flows makes it less feasible.

#### *4.3.5.2. Governance of the Edwards Aquifer Authority*

The Edwards Aquifer Authority was created as a political subdivision of the State of Texas and is governed by a 17-member board of directors. Fifteen of the board positions are elected by popular vote from single-member districts (thus representation is geographic, unlike with at-large representatives). An additional two members are appointed: one on an alternating basis by the commissioners' courts of Medina and Uvalde counties and the other by the South Central Texas Water Advisory Committee, which will be discussed further below. Board members do not draw a salary, meaning that most board members have other full-time jobs, potentially opening the door for conflicts of interest. It is left to individual board members' discretion to excuse themselves from a vote because of a conflict of interest.

The EAA board was set up with a "built-in watchdog," the South Central Texas Water Advisory Committee, comprised of downstream water users. The committee was established in the enabling Act to advise the board on downstream water rights and issues and is required to submit a report every two years (Illgner 2011). The committee does not have an environmental focus; rather, it represents the interests of downstream cities and petrochemical plants which rely on river flows for their water supply.

The EAA had an annual budget in 2010 of $13.1 million; the budget for 2011 is $15.4 million. The majority of the EAA's expenses (Figure 29) are either for staff (52%) or professional technical services (27%). The EAA does not receive any state appropriations but is funded entirely by management fees collected from aquifer users. EAA business is conducted in the open, with meetings subject to Texas' open meeting laws. In recent years, local environmental groups have become more active participants in the region's water management, frequently attending public meetings and providing comments on issues. These include the Save Our Springs Alliance, Aquifer Guardians in Urban Areas (AGUA), San Marcos River Foundation, the Lone Star Chapter of the Sierra Club, and the Guadalupe-Blanco River Trust, among others.

Today, all groundwater extraction is monitored with the exception of small, exempt wells for household use. Permits for groundwater use have been issued to every non-household well that accesses the aquifer (with permit allocations to a thousandth of an acre-foot, well beyond the accuracy of meters). In a testament to the strength of the agricultural lobby (irrigation water use represents about 25% of groundwater use on the Edwards), irrigators receive free meters, including installation, and free lifetime repairs and replacement. Meters can cost up to $500 each, and installation costs have been known to reach up to $4,000 (Illgner 2011). Permit fees are paid by water users; these are called "Aquifer Management Fees," and the amount of the fee is based on the quantity of extraction permitted. Municipal users pay $39 per acre-foot per year, while agricultural users (irrigation and livestock) pay $2/acre-foot, a cap which was set by lawmakers. As a result, the authority derives 98% of its revenues from non-agricultural users, and only 1% from agricultural users. The Authority derives less than 1% of its revenues from "Miscellaneous" sources.

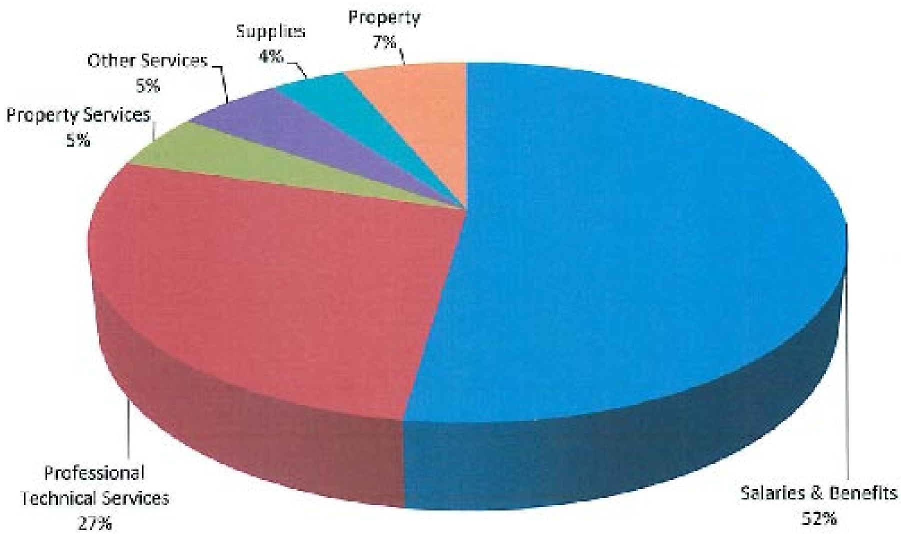


**Figure 29 Edwards Aquifer Authority's budget expenses by category for 2010 (EAA 2010a).**

Property owners also pay modest permit fees when applying to drill a new well or to re-condition or close an existing well. For example, applications for a new well or modification of an existing well cost $35. The permit is required even for exempt wells. The five-page application would normally be filled out by an engineer or driller.

Pumping permits and groundwater rights are not conditioned upon continual use. In other words, the "use it or lose it" doctrine does not apply.

Every water user is required to submit an annual water report, with beginning and ending meter readings. While annual reporting and billing has simplified administration by the EAA, collecting consumption data only once a year is also somewhat limiting, making it hard for regulators to gauge the current water use during a drought (Broad 2011). While annual water reporting is required during normal years, during critical periods the EAA requires monthly reporting. The EAA has begun installing smart meters on municipal and irrigation wells, but significant administrative changes will be needed to move to an automated data collection system.

At the end of the year, the EAA mails out "conservation rebates" to water users who consume less than their full allotment. Hence, billing is based on actual consumption, rather than on an entitlement. Fines are issued to those who exceed their allotment. Fine limits were set by the legislature "at an amount of not less than $100 or more than $1,000 for each violation and for each day of a continuing violation" (The Edwards Aquifer Act, Texas Senate Bill 1477, 1993). Failure to pay fines can result in suspension of permits; however, no permits have been suspended to date. This approach was, as expected, met with a great deal of resistance in the first few years of the Authority's existence, especially in rural districts. Revenue from fines does not enter the EAA's budget, but has been deposited in an Endangered Species

Mitigation Fund since 2005. The fund is expected to have a balance of $514,000 at the end of 2011 (EAA 2010a). The fund pays for EAA's participation in the Edwards Aquifer Recovery Implementation Plan discussed below ($25,000 in 2011), and variable flow monitoring during drought or flood conditions at Comal and San Marcos Springs ($50,000 per event, as needed). It is not clear why the EAA accumulates the bulk of the funds rather than spending them on projects to benefit endangered species recovery.

The Edwards Aquifer website describes an early enforcement effort against the embattled Bexar (pronounced Bear) Metropolitan Water District, which provides water in jurisdictions in and around San Antonio:

> In November 2000 the Edwards Aquifer Authority board authorized the agency to take enforcement against 43 pumpers who had exceeded their monthly water quotas during five months of drought restrictions. Fines and penalties were expected to be hefty, up to $10,000 per day per violation. Pumpage by the Bexar Metropolitan Water District accounted for almost half of all the excess water used by the 43 pumpers. Bexar Met argued that fines would take away resources necessary to develop non-Edwards sources, and that it had done more than any other utility to wean itself from the Edwards by focusing on delivering Medina River water from its new treatment plant. The Aquifer Authority countered that Bexar Met had simply ignored the law while other users had gone out and transferred water rights or cut back on pumpage to comply.

Following negotiations, Bexar paid $200,000 in fines and agreed to ramp up conservation efforts. There have been other instances where permittees have negotiated reductions in fines in exchange for promises to conserve (Parker 2011).

There are essentially four types of enforcement handled by the EAA, with responsibility falling on the enforcement division which has two field staff and four compliance staff based at the office in San Antonio. Actions subject to fines include:

- Using unpermitted wells
- Non-reporting (failure to submit year-end meter readings)
- Exceeding permitted pumping volume
- Failure to close abandoned wells

The EAA is committed to working with well owners to resolve problems, and has issued very few fines in recent years. The staff and board much prefer to work with violators to work out problems and bring them into compliance. According to Earl Parker, Program Manager for Compliance at the EAA, of the 300–400 cases he sees each year, only 10–15 are referred to the EAA's general counsel, and only 2–3 well owners end up faced with a lawsuit. Many of the water users who exceed their permitted use are small rural churches or schools, most of which are not aware that they have done something wrong. The EAA is authorized by the legislature to levy fines, as mentioned above, but according to Parker, "the penalties go away if they're willing to work with us."

As the EAA has moved more aggressively to protect water quality, one of the biggest challenges it faces is finding and closing abandoned wells, which pose a pollution risk. Permanently closing a well can cost $10,000–$15,000. In the past few years, the authority added $1 to the permit fees to finance an "Abandoned Well Closure Fund," and is currently developing a program to assist low-income homeowners with derelict wells. Well owners are usually responsible for reimbursing the Authority over time, making this a revolving fund (EAA 2010a).

Landowners that failed to file for a well permit in the 1990s when the EAA was created find themselves in an uncomfortable position when their pumping is eventually discovered. At the time, existing water users were "grandfathered in," and were entitled to a permit volume reflecting their past use. Under current rules, new permittees must acquire a water right, at an approximate cost of $200/af to lease for a year, or $5,000/af and up to purchase outright.

#### *4.3.5.3. Limitations of the EAA's Regulatory Approach*

Because the majority of the Authority's operating budget comes from pumping fees, there is a risk that its capabilities could be strained during a sustained drought. If severe pumping restrictions were put in place, its revenues would fall, potentially hampering its ability to manage the aquifer precisely when it is needed most. However, fees are set by the EAA, and not by the legislature in the Act. Therefore, if the revenue stability becomes an issue, it could be changed relatively quickly (Illgner 2011).

There is also growing concern about the effects of exempt wells. The combined effect of thousands of small wells on aquifers in the arid West has been likened by one journalist as "death by a thousand wells" (Carswell 2009). The EAA does not impose drought restrictions on small wells used at households or for livestock. In the Edwards, exemptions cover those wells capable of producing less than 25,000 gal/day or those exclusively for household use or watering livestock. The maximum flow rate is equivalent to 17 gpm, 28 acre-feet per year, or 0.04 cfs. In general, this covers developments of more than 5 acres. It is estimated that exempt uses may total 20,000 acre-ft per year, at present less than 5% of groundwater use, but a quantity that is likely to continue growing. Currently, the EAA includes estimates of exempt use in all modeling scenarios to provide the most accurate representation of aquifer water use (Illgner 2011).

A much more serious concern is that the current rules governing pumping would do little to preserve spring flows during a serious drought. In 2007, modeling by the EAA showed that with current pumping levels and management rules in place, a repeat of the 1950s drought of record would result in Comal Springs ceasing to flow for 33 months (Sierra Club Lone Star Chapter 2007). In other words, the Act, as currently written, has not yet undergone a serious test, and would be completely inadequate during a serious drought.

Climate change is another concern. Climate scientists expect that warming trends will cause a decrease in water availability in the arid southwestern United States. A 2001 study by Texas A&M concluded that, by the year 2090, pumping must be reduced in order to maintain spingflows at the currently desired levels and to protect endangered species. The authors estimated that pumping must be reduced by 9 - 20%, and would cause the loss of $3–$5 million in agricultural revenues (Chen, Gillig, and McCarl 2001).

#### *4.3.5.4. Water Markets*

Several analysts have pointed out the benefits of regulation to current users of the resource, especially when existing uses are "grandfathered" (e.g. Votteler 1998; Kaiser and Phillips 1998; Merrifield et al. 1993). Early on, opponents opponents of regulation claimed that pumping restrictions were an infringement of their private property rights. Rather, following quantification of water rights by the EAA, farmers found they had a marketable commodity. The system put in place under the EAA can be considered a form of “cap and trade.” Existing water users were granted rights equivalent to their historic use. Once the authority verified their claims, a water user had the right to continue using his or her allocation, or to sell it on the open market. New water users were required to purchase water from a willing seller, in the form of either a lease or a permanent transfer.

Supporters of such a system argue that allowing a market to operate is far better than centralized decision making or “command and control” by a water czar. Neoclassical economic theorists maintain (somewhat controversially) that markets are the most efficient means of allocating scarce resources. In this context, “efficient” means that resources go to those willing to pay the most for them, and resources are put to productive use where they will generate the most income and wealth. Indeed, a group of economists at Texas A&M’s Water Resources Institute found much to praise about the new institutional arrangements (Merrifield et al. 1993):

> A system of transferable groundwater rights is commendable for several reasons. It is flexible because it accommodates unforeseeable future shifts in demand. Transferable rights allow voluntary action on behalf of water users as opposed to requiring compliance with offensive regulations. The marketing of water complements regional competitiveness because water is not bound to inefficient uses, and overly expensive methods of water supply enhancement are avoided.

An economic analysis of proposed aquifer management plans by researchers from the Texas Water Resources Institute (McCarl et al. 1999) found that the imposition of pumping restrictions came at a cost to some users, for example, irrigators who had to take lands out of production, or pay to install efficient irrigation equipment. The economists concluded, however, that these costs were probably lower than that of a future crisis. Two years later, another economic analysis reported that reduced spring flows could cost the region $2–$7 million per year, compared to modest pumping reductions of 10%- 20% that would cost the region $0.5–$2 million (Chen, Gillig, and McCarl 2001).

The EAA has played a limited role in the water markets, for example, following directions in the Act that allow an irrigation permit holder to sever only up to one half of his water allotment from the land. The EAA imposes geographic conditions on transfers as well. Cibolo Creek forms a line of demarcation relating to proximity to the springs and is the boundary between Bexar and Comal counties. If a party wants to transfer water rights from west to east across Cibolo Creek, the buyer must purchase or lease more water than he needs because groundwater withdrawals closer to the springs have a more direct and immediate effect on spring flow. East of Cibolo Creek, water users must acquire 5 acre-ft of water in order to use 1 acre-foot if the water rights originate in Uvalde County and must acquire a 3:1 ratio of water rights if the water originates in Medina or Bexar counties.

Despite such restrictions, water trading has increased greatly, and available supply is currently the limiting factor preventing more trading. Today, with the groundwater basin considered fully allocated and closed to new appropriations, anyone needing new water must purchase or lease it from an existing permit holder. Anecdotes and available evidence suggest that water trading has risen significantly in the last few years. The Water Transfer Database maintained by University of California Santa Barbara (Donohew and Libecap 2011) records a number of transactions in Texas over the last decade. While there is not always sufficient information to locate the transactions that occurred in the Edwards, it appears that transactions are on the rise, as more areas around the state are restricting new diversions and wells. In fact, in the first four months of 2011, there have been more than 100 transactions whereby irrigators have installed more efficient technology so that they could market their saved water (Illgner 2011). Often transactions are performed with the assistance of a water broker, several of whom are in business in Texas.

### 4.3.6. San Antonio's Role

In the 1960s State Water Plan, the Texas Water Development Board outlined an ambitious program to construct surface water reservoirs around San Antonio to help end its reliance on the over-drafted Edwards Aquifer. City residents, whose votes were required to secure bond financing, did not share the state's enthusiasm for dam projects. In May 1991, the voters narrowly rejected a proposal to continue construction of the Applewhite reservoir. Two weeks later, the Sierra Club sued the Department of Interior for negligence because of its alleged failure to put forth a plan to protect the endangered species dependent on springflow from the Edwards Aquifer. In August 1994, San Antonio voters decided a second and final time in a referendum not to fund the completion of Applewhite Reservoir (Votteler 1998). As a consequence, San Antonio is almost entirely dependent on groundwater from the Edwards for its water supply. The city has taken efforts to protect the quality and quantity of water in the aquifer, to reduce its own pumping levels, and has moved to diversify its own water supplies. For example, a desalination plant has been proposed to treat brackish water in the nearby Carrizo-Wilcox Aquifer (Galbraith 2011).

The city of San Antonio, despite its laudable conservation efforts, continues to grow quickly, and is continuing to acquire water to meet its needs. In the late 1990s, San Antonio spent $9 million to purchase 10,000 acre-feet of water, and committed $200,000 per year to lease more, at an average cost of $700/acre-foot. Farmers typically pay only the direct costs of extracting the groundwater, typically less than $20/ acre-foot. Unsurprisingly, this has led to considerable outrage among city dwellers: one editorial writer characterized farmers' attitude as, "Stick 'em up! I've got a pump!" (Glennon 2004). Yet, programs to acquire water by the city enjoy the support of San Antonio's business community, who see expanding the water supply as a key to the region's economic growth. Today, water prices have risen, fetching up to $5,500/acre-foot on the market in 2010 (Illgner 2011).

#### *4.3.6.1. Conservation Efforts*

In response to drought restrictions, San Antonio has taken a number of steps to reduce pumping from the aquifer. Conservation and water efficiency programs run by San Antonio Water Services (SAWS) are considered among the best in the Texas (US EPA 2011a). The city's overall water use has remained level since the early 1980s; at the same time the region's population grew from 1 to 1.3 million people. Per-capita consumption over this time period decreased from 225 to 140 gallons per day. The water agency did this by offering vouchers and rebates for a range of efficient fixtures and appliances such as toilets, clothes washers, showerheads, and rain sensors for irrigation systems, and by encouraging the use of native, drought tolerant plants in landscaping and more efficient lawn watering. SAWS has imposed a year-round prohibition on outdoor watering from 10:00 am to 8:00 pm. The agency has stopped short, however, of offering "cash for grass" rebates like the ones offered in Las Vegas.

The utility also encourages conservation through pricing: customers pay “inclining block” rates designed to encourage conservation, with water becoming more expensive as consumption goes up. Residents are also subject to seasonal rates, where the price of water goes up in the summer when demand is highest and shortages are more likely to occur. The imposition of conservation rates marks a large shift from a decade ago when San Antonio’s water rates were among the lowest of any metropolitan area in Texas (Votteler 1998).

#### *4.3.6.2. Water Recycling*

San Antonio has emerged as a national leader in the reuse of recycled water. In 2000, SAWS completed a $140 million project to distribute treated wastewater. The city constructed a 110-miles pipeline that provides water mostly for landscaping, but also serving commercial and industrial users such as a battery manufacturer and a Microsoft data center. Today, every municipal golf course uses recycled water (Eckhardt 2011c). Treated water is also discharged to the San Antonio River upstream of the downtown area, providing continuous flow through the Riverwalk, an area along the river banks that has been revitalized with shops and restaurants and has become a major tourist draw. Currently, San Antonio has not been authorized by state water quality regulators to engage in “direct reuse,” where highly-treated wastewater is injected directly back into the water supply system.

#### *4.3.6.3. Enhancing Aquifer Recharge*

Because of the Edwards’ high infiltration rates, water managers have been tempted for many years by opportunities to build engineering projects to artificially enhance recharge of the aquifer. Aquifer Storage and Recovery (ASR) projects have been in use in Florida, Arizona, and Texas, and are especially valuable where there are few opportunities to build surface water reservoirs. Under Texas water quality laws, water injected into the ground must meet drinking water quality standards.

In 1996, SAWS began feasibility studies for the Twin Oaks Aquifer Storage and Recovery facility. Completed in 2004 at an estimated cost of $215 million, the facility treats Edwards Aquifer water that is in surplus in wet periods and stores it in the neighboring Carrizo-Wilcox Aquifer(SAWS 2011). As of January 2011, more than 90,000 acre-feet of water was stored underground (Illgner 2011). This water can be withdrawn for use during droughts when Edwards water is unavailable due to pumping restrictions. The facility “came in very handy during the drought [in 2006], when more than 6,400 acre-feet of stored water was produced, deferring Edwards pumping and protecting springflows and endangered species. When the rains returned, the facility went back into recharge mode and began storing excess Edwards waters throughout the very rainy year of 2007” (Eckhardt 2011d). Based on these numbers, one may question the cost effectiveness of this project. Doubtless, 6,400 acre-feet could be more cheaply obtained during a drought by imposing stronger drought restrictions or leasing water from farmers.

The EAA has also been interested in enhanced recharge for years. Prospects for this increased in 2007, when the legislature gave the EAA permission to use aquifer management fees for the design, construction, and operation of recharge facilities (EAA 2010b).

#### *4.3.6.4. Land and Water Purchases*

In 2000, San Antonio voters approved a landmark aquifer protection initiative, adding a 1/8 cent sales tax measure designed to protect open space and improve water supply. “So far, about $135 million has been spent to protect close to 97,000 acres. More easements will be bought starting this fall, with the help of $90 million in additional money that voters handily approved in November, despite the tough economic conditions” (Galbraith 2011).

With the first round of funds, beginning in 2000 the city focused on purchasing land and turning it into public natural areas. In recent years, they have focused more on purchasing *easements* within the aquifer’s recharge zone, rather than buying it outright. An easement places a permanent restriction on a property, and while each is different, the deals that San Antonio has brokered with the assistance of The Nature Conservancy typically limit the number and production of wells; allow for ranching, hunting, or fishing, and limit the amount of impervious cover. Easements typically cost $800–$1,200 per acre (Galbraith 2011).

The program has created partners out of rural residents that often oppose such programs. The fact that the program enjoys such popularity is astonishing, especially when contrasted with tales of Los Angeles’ desiccation of the Owens Valley around 1905, or the backlash against Las Vegas’ current “water grab” in the valleys north of the city. In fact, in recent years, “more ranchers wanted to sell easements to San Antonio than the city was able to accommodate” (Galbraith 2011). Ag-to-urban transfers are often accompanied by undesirable side effects, such as promoting sprawl, but some scholars have proposed means to mitigate these so-called externalities (e.g. Reisner and Bates 1990). On the other hand, placing easements on a parcel of land prevents it from being developed into a resort or subdivision, preserves open space and rural character, and allows the landowner to continue traditional activities such as cattle ranching.

### 4.3.7. Endangered Species Activities

The central goal of the EAA set out by the Texas legislature in 1993 was to preserve endangered species habitat at San Marcos and Comal Springs and the rivers they feed. Because of conditions found there (consistently flowing water surrounded by arid country), there is a high degree of endemism, or plants and animals that are found nowhere else (Aquarena Aquarium undated). There are currently eight listed species (two which are shown in Figure 30):

- Fountain darter (*Etheostoma fonticola*)
- San Marcos gambusia (*Gambusia georgei*)
- San Marcos salamander (*Eurycea nana*)
- Texas wild rice (*Zizania texana*)
- Texas blind salamander (*Typhlomolge rathbuni*)
- Peck’s cave amphipod (*Stygobromus pecki*)
- Comal Springs dryopid beetle (*Stygoparnus comalensis*)
- Comal Springs riffle beetle (*Heterelmis comalensis*)

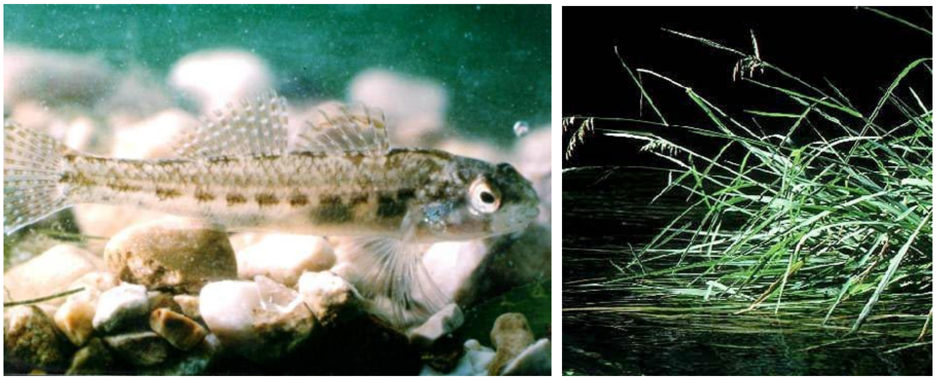

**Figure 30 The endangered Texas fountain darter, *Estheoma fonticola,* and Texas Wild Rice, *Zizania texana* (from Aquarena Aquarium, undated)**

Under the Endangered Species Act, any activity which results in killing or harming a species listed as endangered or threatened requires an Incidental Take Permit from the U.S. Fish and Wildlife Service. A permit requires the holder to have a Habitat Conservation Plan (HCP) in place. These plans are designed to minimize adverse effects on the species and to mitigate and offset negative impacts wherever possible.

Biologists agree that flow is a critical piece in maintaining these species, but by itself is not sufficient for their survival. Attention must also be paid to the quality of habitat, pollution prevention, and minimizing other disturbances (for example, most tubers floating down the San Marcos River and dragging their feet on the shallow bottom are probably not aware that they are tearing out some of the last remaining stands of Texas wild rice). Habitat modification to the river channel (such as bank stabilization, dams, and maintenance or construction activities along waterways and adjacent tracts of land) can also harm native plants and animals.

In 2005, the EAA released a Habitat Conservation Program on behalf of its permittees. Critics deemed it inadequate, and the plan was shelved by the U.S. Fish and Wildlife Service. A year later, the U.S. Fish & Wildlife Service brought stakeholders together in the Edwards Aquifer Recovery Implementation Program (EARIP) to develop a long-term solution for the protection of listed species. In 2007, when the state Legislature increased the EAA permit cap and added a drought plan into the Act, it also directed the EAA and other agencies to participate in the collaborative, consensus-based stakeholder process to develop a plan to protect endangered species dependent on the Edwards Aquifer, a plan which eventually became the EARIP.

The focus of the EARIP is on writing an effective plan to restore the species. A meaningful plan will have to include measures to preserve flows, most likely by instituting a scientifically-determined pumping cap and mandatory conservation during droughts. However, it is also likely to address problems of pollution and water quality and control of non-native species. For example, the giant ramshorn snail invaded Comal springs in the 1990s, threatening endemic species: it is “a voracious herbivore grazing to the point that there is insufficient cover for the fountain darter” (Aquarena Aquarium undated).

A comprehensive recovery plan is likely to be expensive. Participants hope that with a viable plan in place the group will be able to attract for federal support for the program. According the EARIP’s most recent estimate, an effective recovery plan would cost "about $30 million per year, about half of which would go to the San Antonio Water System to use a portion of the storage capacity at SAWS' Twin Oaks Aquifer Storage and Recovery facility to augment flows during dry times. Another $10 million would go to farmers not to irrigate, and the remaining $5 million would go to improving habitat, conservation programs, and scientific studies" (Eckhardt 2011e). It appears that the plan relies heavily on an engineering solution—pumping water to the springs to maintain their flow during droughts—rather than addressing the root of the problem, which is over-pumping. It remains to be seen whether federal authorities will accept a plan that depends on a technological plan to maintain wild nature, rather than reducing human activities that have thrown natural systems out of equilibrium.

### 4.3.8. Conclusion

Water management in the Edwards Aquifer is an example of regional regulation by a state-level agency with powers to restrict the installation of new wells and limit pumping from existing wells. As such, it marked a departure from Texas' historic "rule of capture." It is doubtful that either the legislature or an executive-branch agency would have acted to trump private property rights to protect common natural resources without the "stick" of the Endangered Species Act and a lawsuit by environmental organizations. The EAA faced numerous setbacks and legal challenges that continue to this day. Despite this, the creation of the EAA turned Texas water law on its head.

In the twenty years since the legislature moved to control over-pumping of the Edwards Aquifer, the region has seen a dramatic expansion of more efficient irrigation technology such as center-pivot systems (Illgner 2011). Today, the Edwards Aquifer Authority supports itself through aquifer management fees paid by all water users. It has done a great deal to raise awareness of water issues, promote conservation, and is taking on the difficult task of regulating water quality.

Yet, much more needs to be done. In its early years, EAA regulators did not always move quickly and decisively enough to limit pumping during droughts. And to date, the EAA has not faced a very serious test. Droughts in the late 1990s were short and followed by heavy rains which allowed aquifer levels to recover quickly. There is evidence that without a revision to its rules or major reductions in pumping, a major drought like the one that occurred in the 1950s would cause springs to dry up for months or years, causing great harm to wildlife, recreation, downstream communities, and the regional economy.

Comparing the Edwards Aquifer to the Verde River, there are both strong parallels and some differences. In both basins, downstream urban users rely on consistently available water from groundwater that infiltrates in the basin's headwaters. Before the creation of the EAA, groundwater pumping was *unregulated* and *undocumented*, as it is today in most of the Verde Valley. In this arid region of south central Texas, rivers that flow year-round are a focal point for communities as well as a major draw for tourists and recreational day users. The region's rivers are important for the communities along them and also to downstream cities and industry, and are of great importance to the region's economy.

There are some physical differences between the regions. Because of these, the EAA's management approach may not transfer directly to Arizona without some modifications. In the Edwards, where recharge is high during wet years and groundwater moves very quickly, there is a strong correlation between pumping and springflows. Rather than mandating cutbacks across the board to preserve water for the future, regulators have opted to allow pumping that may exceed the long-term safe yield, and to rely on restrictions during drought periods. In the Verde, where groundwater moves more slowly, it is unlikely that a "critical period" management approach would succeed in protecting surface flows. By the time that pumping has a visible effect on streamflow in 20 or 30 years, it may be too late to do anything about it. Even if cutbacks are ordered, streamflows may take many years to recover.

Groundwater extraction on the Edwards Aquifer is dominated by irrigators growing annual crops, and Texas regulators have reasoned that drought restrictions can be readily imposed on them. Residential water use cannot be as easily cancelled during a drought. Therefore, in a region where households count for a large fraction of water use, it is unwise to rely on drought water restrictions to keep groundwater pumping below sustainable levels.

There are also some similarities in politics and culture from Arizona to Texas. Private property rights are sacrosanct, and many oppose government intrusion into landowners' affairs. Yet, many of those previously opposed to regulation have found themselves as beneficiaries of the new system. For some, selling or leasing water has been an additional source of income. Other rural residents have sold easements on their property to San Antonio, allowing them to preserve their lands' rural character and continue ranching. And while efforts have largely been driven by compliance with federal environmental laws, steps to protect water courses have had numerous benefits for recreational users and downstream water users as far away as the Gulf Coast. However, the listed species of the Edwards Aquifer have demonstrated no measurable recovery since the new pumping restrictions have been implemented. Although driven by ESA requirements and litigation, the EAA seems designed more to protect water availability for irrigators and San Antonio than to promote real species recovery.

### 4.3.9. Timeline of Water Management in the Edwards Aquifer, Texas

ca. 1900 Pumping in the Edwards Aquifer is about 30,000 acre-feet, or about 7.5% of the long-term aquifer recharge. Population of San Antonio is 53,000. By 2010, San Antonio will be the 7$^{th}$-largest city in the country with 1.33 million people, and among the highest growth rates, at 16% per decade.

1913 The Irrigation Act creates the Texas Board of Water Engineers to establish procedures for determining surface water rights.

1949 The Texas legislature creates a law (Texas Underground Water Conservation Act) The law also allows for the creation of underground water conservation districts.

1956 Drought of Record in Texas causes Comal Springs to go dry for the first time in recorded history.

1959 Legislature creates the Edwards Underground Water District (EUWD), mostly along aquifer boundaries. The EUWD conducted valuable research, improved understanding of the aquifer, and promoted education, outreach, and conservation, but it lacked regulatory ability to limit pumping.

1961 State releases Texas Water Plan, discouraging over-reliance on Edwards Aquifer waters and encouraging the construction of several surface water reservoirs. A new version in 1968 details five potential sites around San Antonio. Only one of these is ultimately built.

1968 Texas Water Commission releases a report stating that Edwards withdrawals should not exceed the average annual recharge 400,000 acre-ft/year. Later study will show there is a huge variance from one year to the next, with actual recharge varying from 43,000 to 2.5 million acre-feet.

1970 First regulations to protect the Edwards Aquifer were issued by the Texas Water Quality Board. The rules, aimed at protecting water quality, applied to high recharge areas, and imposed regulations on underground storage tanks, above-ground storage tanks, and sewer lines.

1970s San Antonio begins planning a series of surface water reservoirs, most of which will never be built. Construction begins on the Applewhite Reservoir, which will come close to completion.

1975 The US Environmental Protection Agency designates the Edwards Aquifer a “sole source aquifer,” (the first in the nation) as it provides more than 50% of the water supply for many communities—up to 98% for San Antonio’s 1.3 million residents. “The intention of the program is to prevent federal funding of projects which might contaminate an aquifer which is the sole or principal source of drinking water for an area” (US EPA 2011b).

1982 Last sighting of the San Marcos gambusia, an endangered fish species endemic to Edwards Aquifer springs. It is now believed to be extinct.

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| 1984 | Texas Water Quality Board begins requiring Water Pollution Abatement Plans for residential, commercial, and industrial developments on the Edwards Aquifer recharge zone. Further, geologic assessments are required for housing developments with 100 or more units and non-residential developments greater than five acres. |
| 1988 | State water quality regulators begin requiring one-time fees for all types of development in the Edwards “Contributing Zone” (areas of high recharge). Fees cover the cost of reviewing protection plans, conducting inspections, and other program efforts. |
| 1989 | Withdrawals from the Edwards Aquifer peak at around 542,000 acre-feet, causing water tables to fall and springflows to decrease to all-time lows. |
| 1991 | Living Waters Artesian Springs Ltd. begins using as much as 40 million gallons of well water per day to raise catfish. This legal but wasteful water use galvanizes public opinion to protect the aquifer. |
| May 4, 1991 | San Antonio voters vote against completing the nearly-completed Applewhite Reservoir. As a result, the city will have to increase pumping from the Edwards Aquifer to accommodate its rapid growth. |
| May 19, 1991 | A coalition led by the Sierra Club Lone Star Chapter files a lawsuit over protection of endangered species at San Marcos and Comal Springs. |
| Feb 1, 1993 | A federal circuit court judge rules that if the legislature (which meets every two years) does not act during its current session, he will appoint a water master to regulate pumping to protect springs and endangered species. |
| 1993 | Edwards Aquifer Authority created by the Texas legislature. The core goal is “ensuring that the continuous minimum springflows of the Comal and San Marcos Springs are maintained to protect endangered and threatened species to the extent required by federal law.” Department of Justice prevents agency from moving forward because of concerns over the Voting Rights Act. |
| 1994 | San Antonio voters decide in a second referendum not to fund completion of the Applewhite Reservoir. |
| June 1996 | EAA begins operating. The EAA withstands the first of many legal challenges when the Texas Supreme Court unanimously upholds its legality and constitutionality. |
| Summer 1996 | Drought hands EAA its first test. Directors fail to adopt emergency drought pumping restrictions. |
| 1997 | EAA implements the Irrigation Suspension Plan, to pay farmers not to irrigate for the season. In its first year, irrigators were paid $2.35 million to suspend water use. An economic study done afterwards concluded that the program was a cheaper way to save water and raise aquifer levels than funding irrigation efficiency, but more expensive than simply purchasing irrigated land at market rates. |

1998 Second drought faced by the EAA.

1999 Texas Supreme Court ruling “muddies the waters” by re-affirming the rule of capture, also known as the “law of the biggest pump.” A private well-owner sought damages when pumping by the nearby Ozarka water bottling plant caused his well to go dry. The court opinion stated that it was merely upholding the law but that the state legislature could enable local groundwater districts to restrict pumping to protect landowners.

2000 EAA takes its first action against those violating pumping restrictions.

May 2000 San Antonio voters approve aquifer protection initiative, approving a 1/8 cent sales tax measure designed to protect open space and improve water supply.

Sept 2000 EAA initiates periodic and special event bio-monitoring activities in the Comal and San Marcos ecosystems to gather empirical data on the species and habitats. Through 2010, the EAA has spent more than $3 million on data gathering and special research.

2001 In the wake of the Ozarka decision (see 1999), the Legislature passed laws making it easy for property owners to form Groundwater Conservation Districts (GCDs) by petition. It gave Districts the authority to regulate spacing and production from wells. The laws reinforce Senate Bill 1 in 1997, which deemed GCDs to be the State’s preferred method of groundwater management.

2001 EAA issues its first pumping permits. It finally issues permits for more than 572,000 acre-feet, with the intention of “buying down” the excess rights above the legislatively-set 450,000 acre-ft cap. Staff estimates the cost to be more than $200 million.

2002 EAA makes its first rules relating to water quality (which had until then been left to another state agency, the Texas Commission on Environmental Quality). It requires businesses storing large amounts of hazardous materials to take spill containment measures. The rules were later amended in 2008.

2003 Faced with a volume of permits that exceeds the 450,000 acre-ft cap, the EAA votes to temporarily (through 2007) designate about 22% of pumping permits as junior rights which cannot be used if Aquifer levels drop below certain triggers. While the vote was contentious, this action was more expedient than buying down those rights.

2003 An EAA-sponsored study reports that with current pumping levels and management rules in place, a repeat of the 1950s drought of record would result in Comal Springs ceasing to flow for 33 months. In other words, the rules, as currently written, have not undergone a serious test, and would be completely inadequate during a serious drought.

2005 The EAA submits a Draft Habitat Conservation Program on behalf of its permittees. Critics deem it inadequate, and the plan is shelved by the U.S. Fish and Wildlife Service.

2006 The U.S. Fish & Wildlife Service brings stakeholders together in the Edwards Aquifer Recovery Implementation Program (RIP) to develop a long-term solution for the protection of federally listed endangered species.

2007 State Legislature directs the EAA and other agencies to participate in a collaborative, consensus-based stakeholder process to develop a plan to protect endangered species dependent on the Edwards Aquifer by 2012. This is known as the Edwards Aquifer Recovery Implementation Program (EARIP).

2007 In advance of the 2008 deadline to reduce the pumping cap to 450,000 acre-ft, legislators amend the Edwards Aquifer Authority Act, raising the cap to 572,000 acre-ft. Several new measures were added to the Act compensate for the higher cap, including enhanced critical period management stages, triggers, and reduction amounts.

2009 EAA board considers creating a program to artificially enhance aquifer recharge.

Aug 2009 The EAA board authorizes staff to develop proposed rules for future consideration that would establish a 20% impervious cover limit for all classes of development on the recharge zone. The proposed rule is based on scientific studies that show allowing impervious cover to exceed a threshold of 10%–20% can adversely impact water quality. In 2010, the Board will vote against proceeding, “fearing legislative retaliation and a property rights backlash” to the EAA getting into land use regulation; instead, the EAA decides to move forward with development of a Comprehensive Water Quality Protection Plan.

Nov 2010 San Antonio voters approve an additional 1/8 cent sales tax that will generate $90 million to acquire land or purchase water easements.

2011 Continued challenges to the EAA’s authority: in January, State Senator Troy Fraser filed Senate Bill 332, which would specifically affirm that landowners have “a vested ownership interest in and right to produce groundwater below the surface.”

2012 Deadline for the EARIP working group to prepare an approved Habitat Conservation Plan to protect endangered and threatened aquatic species of the Edwards.

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## 5. Conclusions

The Verde River is special, high-value resource for the region and for the State of Arizona. As with any shared resource, cooperation in water management can lead to significant gains. Consensus-driven management choices, based on shared information and shared vision, are likely to be useful for management of this important asset in the Verde Valley.

**Verde River near Clarkdale. Photo courtesy of Doug Von Gausig.**

The Verde River provides large economic value that is difficult to fully capture monetarily. Many resources and values in the Verde Valley would not exist without the Verde River. Documented economic values from use of the river and related water resources are greater than $150 to $161.5 million per year in direct revenues for the uses assessed here.

Under a mid-range growth scenario, increases in groundwater withdrawal are projected to cause annual flow volume in the Verde River to decrease by about 3,000 acre-feet by 2050. Under a high growth scenario, increases in groundwater withdrawal are projected to decrease annual flow volume in the Verde River by almost 8,000 acre-feet by 2050. For the mid-range growth scenario, increases in groundwater withdrawal are projected to cause median summer monthly flow to decrease by about 6% near Camp Verde by 2050, and under the high-growth scenario, increases in groundwater withdrawal are projected to decrease median summer monthly flow by 15% near Camp Verde by 2050.

Larger decreases in streamflow are likely to be observed in the future. Potential additional causes for streamflow depletion include reduced inflow to the Verde Valley due to groundwater extraction in the Big Chino and Little Chino basins, climate change, and the arrival of effects caused by the initiation of pumping in the Verde Valley prior the beginning of the study period. Without reduction of groundwater pumping, additional streamflow depletion in the years following 2050 may also be expected.

Due to relatively small projected declines in streamflows and groundwater levels, economic value at risk is also relatively small. Some instream uses are very sensitive to flow changes, but other uses have low sensitivity. The total economic value at risk was estimated to range from $7.4 to $16.3 million annually.

Management alternatives that cap groundwater extraction are shown to reduce projected streamflow depletion in the Verde River. The formation of a regional water management institution through cooperation by the Verde Valley governments could be a valuable tool in approaching water management problems in the future. One possible mandate for the institution could be to collect data on current and historic water use and to begin monitoring streamflow at ungaged locations in the Verde River to observe the efficacy of management techniques. In time, the information developed by the institution could serve as part of a transparent, consensus-driven, local water rights allocation process. The institution could also eventually serve as the forum for developing inclusive and cooperative approaches to water management in the Verde Valley. It will be important that individual parties in the Verde Valley organize and cooperate with each other to manage water not only for individual goals, but also for a collection of goals and values that will benefit the region as a whole.