The 2013

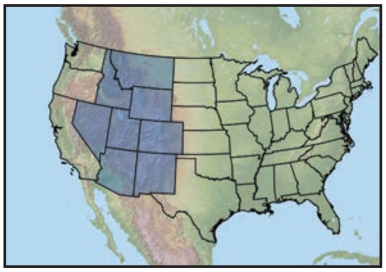
COLORADO COLLEGE

STATE OF THE ROCKIES REPORT CARD

Water Friendly Futures for the Colorado River Basin

An Outreach Initiative of Colorado College

Colorado College's Rocky Mountain Study Region



COLORADO COLLEGE
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The Colorado College State of the Rockies Project is designed to provide a thoughtful, objective voice on regional issues by offering credible research on problems faced by the Rocky Mountain West, and by convening citizens and experts to discuss the future of our region. Each year, the State of the Rockies provides:

- Opportunities for collaborative student-faculty research partnerships;
- An annual *State of the Rockies Report Card*;
- A companion State of the Rockies Speaker Series and Conference.

Taken together, these arms of the State of the Rockies Project offer the tools, forum, and accessibility needed for Colorado College to foster a strong sense of citizenship for both our graduates and the broader regional community.

The Colorado College
State of the Rockies Project
An Outreach Initiative of
Colorado College

Cover Photo by:
Stephen G. Weaver

The 2013

Colorado College State of the Rockies Report Card

Water Friendly Futures for the Colorado River Basin

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Will Stauffer-Norris

The Rockies Project Down the Colorado Expedition on their solar raft at Glen Canyon Dam on Lake Powell.

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The Colorado College State of the Rockies Project

Research, Report, Engage!

An Introduction from the President of Colorado College

The 2013 Colorado College State of the Rockies Report Card

Brendan Boepple

This 2013 Colorado College State of the Rockies *Report Card* is being published during the tenth year of the Project. Over the past decade our college has continued to celebrate the astounding region that shaped our beginnings and continues to be a distinctive aspect of what makes Colorado College unique. Since its inception, the Project and its annual cadre of stellar student researchers have done in-depth research on over 45 challenges that confront the Rockies region, roughly defined as the eight Mountain states, though for the past two years defined as the hydrologic boundary of the Colorado River Basin. Beyond CC, these "Rockies alumni" have already started to make their mark through initial jobs and internships, as well as advanced study at some of the nation's best graduate institutions such as Columbia, Yale, and Duke. The earliest of these Rockies' researchers are now in key conservation positions in places ranging from the Department of Interior and the U.S. Forest Service to non-profits like the Denver-based Center for Western Priorities.

Stimulated by our surroundings and 139-year history at the base of Pikes Peak, independent-minded students, sharp in the classroom and active in the outdoors, have helped us explore the region. Each year, summer research by students, supplemented by research completed during field trips around the Rockies, results in *Report Card* sections, which are often peer-reviewed. Monthly speakers connect the broader campus and community to current issues. An annual April Conference brings renowned experts to campus as the *Report Card* is unveiled, topics are discussed, and conclusions are drawn.

For the last two years, several new dimensions have broadened the Project and its outreach. During the 2011-2012 school year, CC student researchers served as field explorers, carrying out a 1,700-mile "source to sea" kayak trip from the origins of the Green River in Wyoming down the Colorado and to the delta. In 2012, four field explorers traced the origins of the Colorado River near Rocky Mountain National Park to the end of the Grand Canyon National Park, conducting water quality studies and interviewing stakeholders along the way. Social media have been incorporated into these new dimensions. Original videos, blogs, Facebook posts, and speaking tours, such as a Fall 2012 lecture tour among the northeast Ivy League universities, immensely broaden our outreach in ways that speak to other age groups and constituencies.

A common thread runs through this decade-long stretch of Project activity. We have "kept our eye on the ball" with bright students as the centerpiece of topics selected, places studied, speakers brought to campus, and now social media outreach to youth who will quickly be the next generation of users and managers in the spectacular but fragile Rocky Mountain region. Proof of this strategy's importance rests in the astounding students participating, the quality of their research and writing, and the growing recognition Colorado College now has as a key player in the environmental and socio-economic health of the Rockies Region. Eight years into the Rockies Project the Hewlett Foundation reached out to the

About the author: **Jill Tiefenthaler** is the President of Colorado College.

college, asking that we be organizer and host of a first-ever annual Colorado College State of the Rockies Conservation in the West Survey. Now in its third year, this survey brings widespread regional and national attention to key challenges in the Rockies and registered voter attitudes about what matters in the region. We welcome both the recognition hosting this survey brings to CC and the fresh knowledge each year about attitudes towards conservation in the West.

The 2012-13 Rockies Project focus, for a second year, is the Colorado River Basin. This year's student researchers look at prospects for a "water friendly future" in the basin. Last year's basin investigation looked at an "agenda for use, restoration, and sustainability for the next generation." Those students briefed, in person, Colorado Governor John Hickenlooper and Secretary of Interior Ken Salazar on five steps youth recommend in management of the basin. This year's student researchers led off from those five steps, studying how water can be managed wisely for agriculture, municipal and industrial, and energy uses. A recent major Bureau of Reclamation study of the demand-supply relationship in the basin until 2060 identifies a potential 3.2 million acre-foot per year shortage, indicating that "water friendly futures" are vital. Our students' work is current, relevant to major discussions in the water-scarce Rockies, and brings the voices of youth to the table.

The 2013 State of the Rockies Conference unveils this *Report Card* and once again brings to campus renowned individuals with a focus on "Conservation in the Rockies: Issues of Citizen Science, Water Friendly Futures, and Winter Recreation." And for the fifth time we recognize an individual of immense importance to the Rockies, naming Former Governor Richard D. Lamm as the 2012-13 Champion of the Rockies. He joins a renowned roster of earlier "champions": Ted Turner, Ed and Betsy Marston, Terry Tempest Williams, and CC graduate Ken Salazar.

Colorado College President Jill Tiefenthaler.

Our college mission statement continues to guide us in our goals and highlights the importance of the Rockies region so important to our character:

> *At Colorado College our goal is to provide the finest liberal arts education in the country. Drawing upon the adventurous spirit of the Rocky Mountain West, we challenge students, one course at a time, to develop those habits of intellect and imagination that will prepare them for learning and leadership throughout their lives.*

Even as we celebrate ten years of Rockies Project accomplishments, Colorado College is in the midst of a strategic planning effort driven by a mandate from our Trustees:

- *elevate the college's identity as a highly-selective liberal arts institution*
- *strengthen the academic program with an emphasis on engaged teaching and learning*
- *explore how our unique location, character, and community can be leveraged to support the academic venture and promote a collective sense of place*
- *evaluate and enhance institutional effectiveness and efficiency to better position the institution for evolving changes in higher education*

Two of the goals identified in the strategic planning process speak to the importance of our location in the Rockies:

Goal #6 - Strengthen connections to the local community and greater Rocky Mountain region by acting as a confluence of ideas, perspectives and actions.

Goal #9 - Establish Colorado College as the center for critical and civic engagement at the intersection of the Southwest and Rocky Mountain region by integrating and building upon existing programs and our location.

We are dedicated to keeping the Rockies region central to our identity and activities in coming years and decades.

I encourage you to join us as we recognize and celebrate the Rockies Project in its tenth year by looking through the rich student-written materials in this latest *Report Card*. I am confident that you will understand more of the immense and complex Colorado River Basin and its enormous challenges and that you will learn from the recommendations our students are making for a "water friendly future" in the Basin. Thank you for caring enough to learn more about and contribute to protecting the unique features and character that make the Rockies region everyone's special backyard.

Jill Tiefenthaler
President
Colorado College

Colorado College, the Rocky Mountain West, and

The State of the Rockies Project

By Dr. Walter E. Hecox

The 2013 Colorado College State of the Rockies Report Card

Ryan Schumacher

Colorado College today, as for the past 139 years, is strongly defined by location and events of the 1800s. Pikes Peak abruptly rises out of the high plains that extend from the Mississippi and Missouri Rivers towards the west. Peaking at 14,000 feet, this eastern-most sentinel of the Rocky Mountain chain first attracted early explorers and was later the focus of President Jefferson's call for the southern portion of the Louisiana Purchase to be mapped by Zebulon Pike in 1806. Gold seekers in 1858 spawned the start of the "Pikes Peak or Bust Gold Rush" of prospectors and all manner of suppliers to the mining towns. General William Jackson Palmer, while extending a rail line from Kansas City to Denver, in 1869 camped near what is now Old Colorado City and fell in love with the view of Pikes Peak and red rock formations now called the Garden of the Gods. An entrepreneur and adventurer, Palmer selected that site to found a new town with the dream that it would be a famous resort—complete with a college to bring education and culture to the region. Within five years, both Colorado Springs and Colorado College came into being in the Colorado Territory, preceding Colorado statehood in 1876.

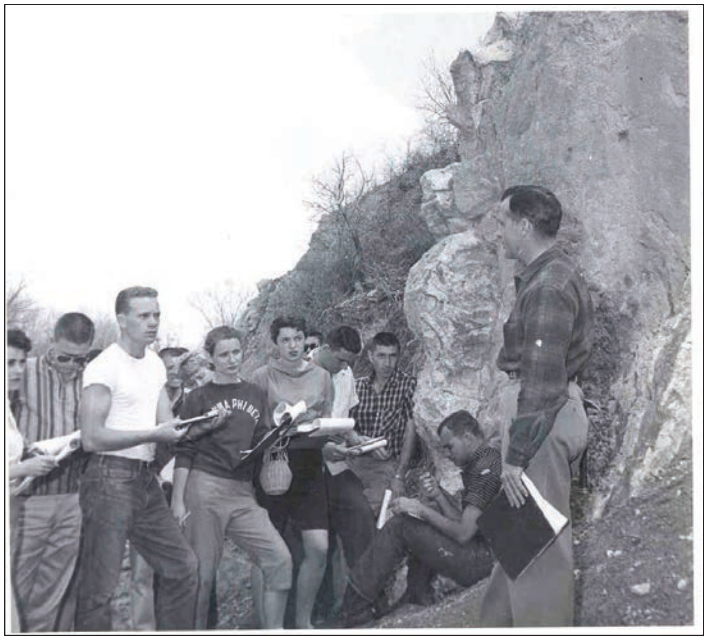
Early pictures of present-day Cutler Hall, the first permanent building on campus that was completed in 1882, speak volumes to the magnificent scenery of Pikes Peak and the lonely plains. Katherine Lee Bates added an indelible image of the region. In 1893, she spent a summer teaching in Colorado Springs at a Colorado College summer program and on a trip up Pikes Peak was inspired to write her famous "America the Beautiful" poem. Her poem helped spread a celebration of the magnificent vistas and grandeur of Pikes Peak and the surrounding region, and provided bragging rights for Colorado College as "The America the Beautiful College."

The last quarter of the eighteenth century was challenging both for Colorado Springs and Colorado College. Attempts to locate financial support in the east and ease the travails of a struggling college were grounded on the unique role of Colorado College in then President Tenney's "New West" that encompassed the general Rocky Mountain region. His promotion of this small college spoke of Colorado

College Building as seen from Cascade Avenue.
Vide p. 72.

An early depiction of the college in President Tenney's *New West*.

About the author: **Walter E. Hecox** is professor of economics in the Colorado College Environmental Program and Project Director for the State of the Rockies Project.



A Colorado College geology field trip circa 1950.

College being on the "very verge of the frontier" with a mission to bring education and culture to a rugged land. Even then, Tenney saw the college as an ideal place to study anthropology and archeology, use the geology of the region as a natural laboratory, and serve the mining industry by teaching the science of mineralogy and metallurgy. In the early 1900s, a School of Engineering was established that offered degrees in electrical, mining, and civil engineering. General Palmer gave the college 13,000 acres of forest land at the top of Ute Pass, upon which a forestry school was built, the fifth forestry school created in the U.S. and the only one with a private forest.

Subsequent decades brought expansion of the institution, wider recognition as a liberal arts college of regional and national distinction, and creation of innovative courses, majors, and programs. The unique Block Plan, implemented in the 1970s, consists of one-at-a-time courses lasting three and one-half weeks each that facilitate extended course field study, ranging across the Rockies and throughout the Southwest. Thus, CC has a rich history indelibly linked to the Rockies.

Today is no different: CC has new programs that meet evolving challenges in the Rockies, including environmental science and Southwest studies programs, the Rockies Project, and exciting fieldwork offered by a variety of disciplines. Students can thoroughly explore the Rockies through the Block Plan and block-break recreation.

The State of the Rockies Project

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- **Research:** offering opportunities for collaborative student–faculty research partnerships
- **Report:** publishing an annual Colorado College State of the Rockies *Report Card*
- **Engage:** convening a companion State of the Rockies Conference and other sessions.

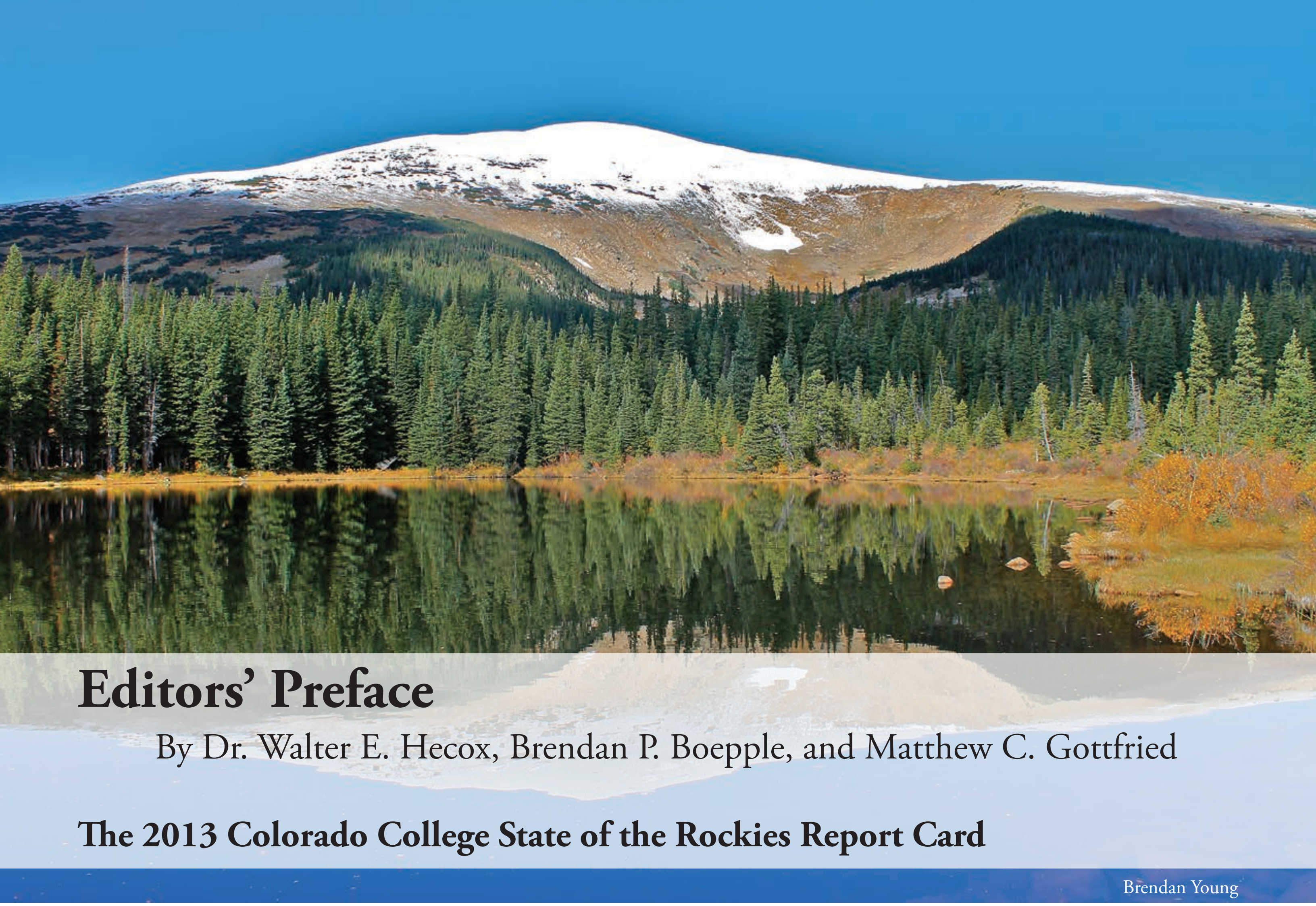
Taken together, these three arms of the State of the Rockies Project offer the tools, forum, and accessibility needed for Colorado College to foster a strong sense of citizenship among our students, graduates, and the broader regional community.

"An institution, like a person, is the product of a total environment. The whole setting of a college or university – climate, topography, material resources and the people – contribute to the formation of its character. Colorado College can best be understood through a knowledge of the West, of Colorado, and of Colorado Springs."

--Charlie Brown Hershey,
Colorado College president during World War II

Walt Hecox

A Colorado College environmental synthesis field trip, 2011.



Brendan Young

Editors' Preface

By Dr. Walter E. Hecox, Brendan P. Boepple, and Matthew C. Gottfried

The 2013 Colorado College State of the Rockies Report Card

Celebrating Ten Years of Focus on the Rockies

Colorado College President Jill Tiefenthaler's Introduction to this *Report Card* describes the decade-long effort of the college to create its Rockies Project. We appreciate the guidance and support of the college over these years as teams of student researchers have explored key challenges, written reports published in the annual *Report Cards*, and brought to campus experts able to help the campus and community engage in dialogue. Our-two-year long focus on the Colorado River Basin has brought new dimensions to traditional efforts of the Project.

This shared topic covering 2011-12 and 2012-13 has made possible new dimensions to our work and has broadened the project and its outreach. Recent CC graduates have served as field explorers, during 2011-12 carrying out a 1,700 mile "source to sea" kayak trip from the origins of the Green River in Wyoming down the Colorado and to the delta. During 2012, four field explorers traced the origins of the Colorado River near Rocky Mountain National Park to the end of the Grand Canyon National Park, doing water quality studies and interviews with stakeholders. Social media have accompanied these new dimensions to what some call "citizen science" and others describe as "adventurers assisting science." Original videos, blogs, Facebook posts, and speaking tours, such as a Fall 2012 lecture tour among the northeast Ivy League universities, immensely broaden our outreach in ways that speak to other age groups and constituencies.

The Colorado River Basin: A Second Year of Focus

The Colorado River Basin, covering a major portion of the eight-state Rockies region and extending into Mexico, has been the unified focus for all parts to the State of the Rockies Project during summer 2011 and the 2011-12 academic year and again for summer 2012 and 2012-13 attention. This basin encompasses portions of seven states in the American Southwest and continues into Mexico, supplying water to households, communities, businesses and farms, as well as natural ecosystems. Roughly 40 million people rely on the river for water, energy, food, and healthy ecosystems. Climate studies indicate the potential for inadequate water supplies throughout the 1,700-mile river system from the origins of the Green River high in Wyoming's Wind River Range to its historic outlet over the Colorado River Delta, emptying into the Sea of Cortez. Along its twisted path arise majestic mountains, deep canyons, tributaries, and a wealth of flora

About the co-editors: **Walter E. Hecox** is professor of economics in the Colorado College Environmental Program and Project Director for the State of the Rockies Project.
Brendan P. Boepple is the 2012-13 Rockies Project Program Coordinator.
Matthew C. Gottfried is the college's GIS Technical Director and the 2012-13 Technical Liaison for the Rockies Project.

and fauna. The basin is indeed a natural treasure of world-class caliber, but heavily threatened. We have dedicated two years of focus on the Colorado River Basin in order to help assure that the next generation inherits a natural and economic system as spectacular, diverse, and bountiful as has existed in the past, but is in transition today. The changes currently underway and those needed for the future must have new voices, especially those of today's youth, for they will live with the results.

A driving force behind our attention to the basin has been a parallel major two-year study conducted by the Bureau of Reclamation (BOR) of the water demand-supply imbalances that exist. We have used their studies and preliminary reports along the way and this year's focus on "water friendly futures" is well timed to supplement the BOR study's final conclusions released December 12, 2012. Thus, some of these conclusions have formed the foundation for our work and are worth our attention:

> *Secretary of the Interior Ken Salazar today announced the release of a study – authorized by Congress and jointly funded and prepared by the Bureau of Reclamation and the seven Colorado River Basin states – that projects water supply and demand imbalances throughout the Colorado River Basin and adjacent areas over the next 50 years. The Colorado River Basin Water Supply and Demand Study, the first of its kind, also includes a wide array of adaptation and mitigation strategies proposed by stakeholders and the public to address the projected imbalances.*
>
> *The average imbalance in future supply and demand is projected to be greater than 3.2 million acre-feet by 2060, according to the study. One acre-foot of water is approximately the amount of water used by a single household in a year. The study projects that the largest increase in demand will come from municipal and industrial users, owing to population growth. The Colorado River Basin currently provides water to some 40 million people, and the study estimates that this number could nearly double to approximately 76.5 million people by 2060, under a rapid growth scenario.*
>
> *"There's no silver bullet to solve the imbalance between the demand for water and the supply in the Colorado River Basin over the next 50 years – rather, it's going to take diligent planning and collaboration from all stakeholders to identify and move forward with practical solutions," said Secretary Salazar. "Water is the lifeblood of our communities, and this study provides a solid platform to explore actions we can take toward a sustainable water future. While not all of the proposals included in the study are feasible, they underscore the broad interest in finding a comprehensive set of solutions."*
>
> *U.S. Dept. of Interior, Office of the Secretary, News Release: "Secretary Salazar Releases Colorado River Basin Study Projecting Major Imbalances in Water Supply and Demand" Dec. 12, 2012.*

Secretary of the Interior Ken Salazar speaking at the 2012 State of the Rockies Conference.

Since we have built on last year's student researcher findings about the basin, the launching pad for exploring in more detail where water uses can be managed in a more "friendly" manner are key conclusions from the April, 2012 *Report Card's* section: Dear Colorado River Basin Water Users, Experts, and Enthusiasts:

> *We represent that "future generation" and through intensive research and observation we have earned "standing" in discussions about the Colorado River's future. In this letter we present Five Actions we find are essential if this national, even global, natural wonder is to stand tall and remain dynamic throughout our lives and those of our children. We are convinced that exciting changes are underway "at the margins" of these immense problems and challenges. Aggressive water conservation measures in the West's urban areas are proof we can meet the "frugal" needs of growing urban areas, but not the "frivolous" wants. Experiments with water banking and rotational crops in agriculture convince us that the "old" techniques of flood irrigation in a "use it or lose it" legal structure can be replaced with conservation that does not threaten our ability to grow crops in sustainable agricultural areas of the Rockies. All of these actions will take changes in legal structure and administration, as well as large amounts of new capital. However, if we once found literally billions of dollars in the "age of construction" then we know with immense will and perseverance we can fund the "age of conservation." And the outcome will gradually result in the Colorado River and its tributaries, as well as the delta, having a reasonable but essential "share" of nature's bounty in*

the form of sustainable flows all the way to the sea.

Here are the five actions we recommend so that a viable, living Colorado River Basin exists, even thrives for our children:

*•**Action 1:** Recognize the finite limits of the river's supplies and pursue a "crash course" in conservation and water redistribution that sustains current users while leaving water in the river.*

*•**Action 2:** Modify and amend the "Law of the River" to build in cooperation and flexibility.*

*•**Action 3:** Embrace and enshrine basin-wide "systems thinking" in the region's management of water, land, flora and fauna, agriculture, and human settlements.*

*•**Action 4:** Give "nature" a firm standing in law, administration, and use of water in the basin.*

*•**Action 5:** Adopt a flexible and adaptive management approach on a decades-long basis to deal with past, present, and projected future variability of climate and hydrology.*

2012 Colorado College State of the Rockies Report Card: "The Colorado River Basin: Agenda for Use, Restoration, and Sustainability for the Next Generation," p. 129.

These recommended actions were presented directly to Governor John Hickenlooper and Secretary of Interior Ken Salazar during the April 9-10, 2012 Rockies Conference.

Using A Proven Approach: Research-Report-Engage

Central to the 2012-13 year's activities, as in the past, are the three goals of the Colorado College State of the Rockies Project:

•RESEARCH: To involve Colorado College students as the main contributors to the *Report Card* and conferences.
•REPORT: To produce an annual research document on critical issues of community and environment in the Rocky Mountain West (the *Report Card*).
•ENGAGE: To host annual monthly speakers' series and conferences at Colorado College, bringing regional experts together with concerned citizens.

Research

Summer 2012 Field Trip Perspectives

Six student researchers engaged in field research about water use in the basin for 10 days: July 17-27, 2012. Their field visits included energy operations and related water use in the Glenwood Springs, Colo., area; meetings with the Colorado River Water Conservation District; Grand Junction, Colo., visits to orchards and meetings with the USDA Natural Resource Conservation Service; meetings with the Water Conservancy District in St. George, Utah; review of Las Vegas' water issues/projects and meeting with the Conservation Manager of the Southern Nevada Water Authority; Boulder City, Nevada. tour of the Nevada Solar One Concentrated Solar Plant; and tour of Glen Canyon Dam in Page, Arizona.

In addition, these six researchers spent a week on the Colorado River, going through Cataract Canyon. They joined a Rockies Project sponsored second research trip on the Colorado River. This entailed four adventurers exploring parts of the Colorado River from both scientific and "stakeholder" perspectives. The Down the Colorado Expedition started in

Rockies researchers exploring the Dollhouse area of Cataract Canyon in Canyonlands National Park, Utah.

Rockies researchers rafting through Cataract Canyon in Canyonlands National Park, Utah.

June, 2012 at the headwaters of the Upper Colorado River in Rocky Mountain National Park and headed downstream for three months. While on the river, they took video and photographs, interviewed basin stakeholders, and recorded water quality data. Working with partners in the Marine Ventures Foundation, the Colorado College State of the Rockies Project, and the river conservation group, Below the Surface (Outside Magazine's 2012 "readers of the year"), they have created a robust, interactive internet-based geographical overview of the Colorado River Basin. The goal of the expedition was to make the voices of various stakeholders and "river experts" heard, as well as provide a virtual tour of the Colorado River through narratives, photographs, videos, and scientific research.

Report

The results of the summer 2012 student research, illuminated by the above field trips, form sections of this *2013 State of the Rockies Report Card:*

- •Lake Powell to Lake Powell: Portraits of the Upper Colorado River
- •Overview: Colorado River Basin Water Demand and Supply Imbalance
- •Agricultural Water Use in the Colorado River Basin: Conservation and Efficiency Tools for a Water Friendly Future
- •Municipal and Industrial Water Use in the Colorado River Basin: Moving Towards a Paradigm Shift in Water Reclamation
- •Water and Watts: How Electrical Generation Has and Will Continue to Shape the Colorado River and Can Renewable Energy Lead the Colorado River Basin into a Water Friendly Future?

The results of each 2012-13 Rockies student researcher reflect a summer of intensive research, the two-week field trip, fall 2012 re-writes, peer reviews, and editing in preparation for the publication of the following sections in this *Report Card*. For this, our tenth *Report Card*, students worked in groups of two to tackle the issues surrounding the three main uses of Colorado River water: Agriculture, Municipal and Industrial Use, and Energy. In addition to these core sections, this year's *Report Card* is also supplemented with additional sections. The first, a section written by one of our expedition managers, Zak Podmore, covers the Rockies Project's Down the Colorado Expedition conducted during the summer of 2012. Next, a summary of the Bureau of Reclamation's recently released Colorado River Supply and Demand Study outlines the context for much of our work over the last year and the premise for much of the conservation and efficiency strategies highlighted in all three major sections of this report.

Zak Podmore: "Lake Powell to Lake Powell: Portraits of the Upper Colorado River"

Developing off the successes of the Rockies Project's 2011-2012 Source to Sea Expedition, the Project once again set out to explore the Colorado River Basin up close and personal. This time our expedition, led by Will Stauffer-Norris and Zak Podmore, accompanied by Carson McMurray and David Spiegel, began their journey at the headwaters of the Colorado River in Rocky Mountain National Park. Beginning in June, the team spent the next three months paddling the length of the river from the snowcapped peaks of the Rockies, down through Colorado's West Slope, and into Utah's desert canyons, winding their way through the Colorado Plateau. In August, the expedition ended its journey in unconventional fashion by solar rafting across the river system's second largest reservoir, Lake Powell. Throughout their expedition, the team interviewed various basin stakeholders from county commissioners to West Slope farmers in an attempt to piece together a personal narrative of the basin's many dependents. This section of the *Report Card* and a video series set to be released in the spring of 2013 attempt to do just that by examining the perspectives and opinions of the many who live near the river and depend on a water friendly future for their way of life.

Shannon Thomas and Walter E. Hecox: "Overview: Colorado River Basin Water Demand and Supply Imbalance"

This year's summer research and the focus of the Project's other initiatives were loosely based around the work that the Bureau of Reclamation has been conducting over the last two years on the Colorado River Basin Supply and Demand Study. The multiyear study has focused on the trends of growing demand and diminishing supply for the river basin. Basing much of our investigation into the river's future off of the results of this study, we began the *Report Card* by outlining the findings from the Bureau. As many of the following sections repeatedly use the data and assumptions covered in the overview, we have chosen to lay out the applicable information regarding the study in this initial, central location.

Nathan Lee and Alice Plant: "Agricultural Water Use in the Colorado River Basin: Conservation and Efficiency Tools for a Water Friendly Future"

Water use by the agricultural sector consumes the vast majority of the Colorado River's supply. While this share is projected to diminish in the coming years, agriculture will still continue to be the dominant user of water in the basin. Many posit that in a world of increasing demand and diminishing supply, the agricultural sector will be the source of "new" supplies as its share diminishes due to conservation practices and economic trends. However, the truth about water use and conservation in the sector is far from simple. From an investigation of irrigation efficiencies to an examination of the detriments of "buy and dry" tactics to increase municipal supply, this section takes a number of different perspectives at how the region's robust agricultural community might approach a water friendly future.

Rockies researchers touring a gas rig near Parachute, Colorado.

Matthew McNerney and Shannon Thomas: "Municipal and Industrial Water Use in the Colorado River Basin: Moving Towards a Paradigm Shift in Water Reclamation"

While currently a small share of the river's use, the M&I sector is rapidly growing, fueled by the expanding populations of the Rockies region. From the Colorado Front Range to the metropolises of southern California, municipalities rely on a consistent flow of water from the river to provide residents with their needs and a way of life to which they've grown accustomed. With data showing that the basin's demand may have already grown beyond its limited supply, many argue that there is no longer room for additional water use in the already stressed region. However, as the economy draws people from the rest of the country and beyond, a business-as-usual approach will not suffice to resolve the supply and demand conundrum. Many of the traditional conservation measures still present the opportunity to save water through changes in indoor and outdoor water use for homes and businesses, but additional measures must be taken to reduce per capita daily water use in many of the West's fastest growing cities. Additionally, new conservation techniques and practices must be implemented as well in order to help bridge the growing divide between the supply and demand of the river. In addition to taking a basin-wide approach to examining the necessary routes for municipal and industrial users to achieve a water friendly future, the section also examines some of the current conservation techniques being implemented on a smaller scale with a case study on the Colorado Front Range.

Henry Madsen: "Water and Watts: How Electrical Generation Has and Will Continue to Shape the Colorado River" and Audrey Burns: "Can

A view of the Colorado River and the Henry Mountains in Utah.

Renewable Energy Lead the Colorado River Basin into a Water Friendly Future?"

The energy sector consumes a small share of the Colorado River's supply, but with the current gap between the river's supply and demand projected to widen, every small use of water in the basin must be scrutinized. In the same manner that municipal and industrial demand for water is expected to grow in the coming years, demand for energy in homes and businesses will increase as well. Focusing on the different manners by which utilities might meet these increasing energy demands and shift pre-existing generation towards less water-intensive technologies, this section displays the growing share energy will represent in the expanding water deficit. By suggesting different solutions to help mitigate water use for energy, while also addressing the issues of cost and carbon emissions, this section aims to guide the basin's energy generation sector towards a more sustainable, water friendly future.

Engagement

April Rockies Conference

The April 8-9, 2013 Rockies Conference unveils this *Report Card* and once again brings to campus renowned individuals, around a focus of "Conservation in the Rockies: Issues of citizen science, water friendly futures, and winter recreation." And for the fifth time we recognize an individual of immense importance to the Rockies: Former Governor Richard D. Lamm as the 2012-13 Champion of the Rockies; he joins a renowned roster of earlier "champions"-- Ted Turner, Ed and Betsy Marston, Terry Tempest William, and CC graduate Ken Salazar.

"Citizen Science in the Rockies" is the focus of the Monday, April 8, 2013 Conference session. This brings to campus three renowned experts in the field. J. Thomas McMurray, co-founder of several nonprofits working to promote "citizen science" and the natural beauty of the Rockies region including the Marine Venture Foundation and the Ocean Foundation. Scott Loarie of the Carnegie Institution for Science and Brendan Weiner of Adventurers and Scientists for Conservation will share their field approach and activities pursuing "citizen science." This session will be prefaced by Carson McMurray, one of the summer 2012 Expedition Down the Colorado and 2012 Rockies Student Researcher, demonstrating our Project's use of GIS to depict "citizen science."

"Outdoor Recreation and the Winter Olympics: Companion or Threat to the Rockies" will be the focus of the Tuesday, April 9, 2013 Conference session, which will include the unveiling of the 2013 *Report Card* and student recommendations for water friendly futures in the Colorado River Basin. Former Governor Lamm, being honored as the 2012-13 Rockies Project Champion of the Rockies, will talk about his opposition to Colorado hosting the 1976 Winter Olympics from the perspective of early Colorado environmental movements. Ceil Folz of the Vail Valley Foundation will then discuss the current work to bring the February 2015 World Cup Ski Championships to Colorado and Vail, again from the perspective of environmental impacts.

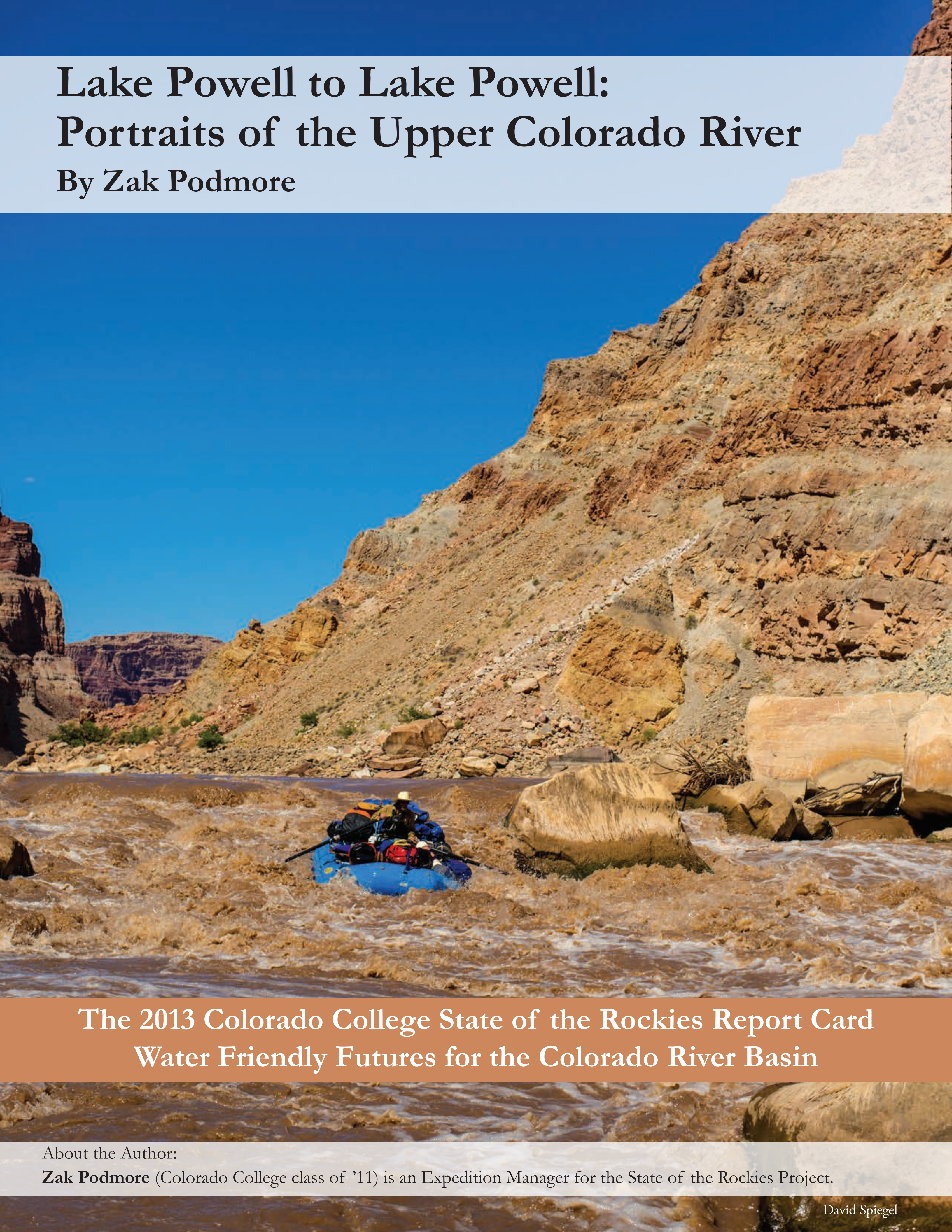
Saving the Colorado River Basin: Join In

This year, similar to the last nine years, the Rockies Project has sought to take our motto "research-report-engage" to new heights, mixing traditional dimensions with new social media, speaking to younger audiences in more visual and interactive ways. We have also supplemented last year's efforts to "take a stand" when we presented "Five Actions" that will help save the Colorado River Basin for the next generation. This year's recommendations for changes to achieve a "water friendly future" for the Colorado River Basin again emphasize what youth believe must happen to manage the basin, a vital part of the Rockies Region we continue to use as a focus of our Project's efforts.

In celebrating our tenth year, we once again urge you to be "active" in learning about, enjoying, and helping to protect the spectacular vistas and regions Colorado College is blessed to call "our backyard." Get out there and join in as each new class of CC Rockies Project student researchers and many of our alumni and friends work to protect the solitude, recreation, and enrichment we all gain from these spectacular, but fragile, Rockies environments. Help us advocate for a Rockies region that can and must be managed properly as a regional economy and environment. Your children and their children will thank you!

Lake Powell to Lake Powell: Portraits of the Upper Colorado River

By Zak Podmore



David Spiegel

The 2013 Colorado College State of the Rockies Report Card
Water Friendly Futures for the Colorado River Basin

About the Author:

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I
John Wesley Powell: The Man of Two Lakes

Lake Powell. You may have heard of it. It's a picturesque, alpine lake nestled in the craggy peaks of Rocky Mountain National Park. Fed by snowmelt and seated in a bowl of exposed granite, the lake lies cold and clear well above 11,000 feet. Lake Powell is the Rocky Mountains at their best: rugged, wild, and remote. No trail makes its way down from the lake-- but a creek does. It flows out of Powell over a series of waterfalls, which pour down a giant staircase of rock ledges. In the alpine meadows below, the stream meanders through swampy grass where moose abound.

If you follow that creek 500 miles and nearly 8,000 vertical feet downstream, you'll end up in the middle of another, more famous Lake Powell that stretches across much of southern Utah. The two lakes don't have much in common save the name and their shared waters. One Powell is the second largest reservoir in the country, filling the sandstone walls of Glen Canyon; the other is about as close to a perfect source of the Colorado River as you can get. Situated well above tree line, this Powell marks the beginning of the North Inlet Creek, which feeds Grand Lake below. Both the lakes take their name from John Wesley Powell, the one-armed civil war veteran who was the first known explorer to climb Longs Peak in Colorado and to navigate much of the Colorado River, including Glen Canyon and the Grand Canyon.

Expedition members Zak and Carson at Lake Powell in Rocky Mountain National Park, Colorado.

Anyone who does an extended raft trip on the Green or Colorado Rivers is compelled to look on J.W. Powell's harrowing first descent of the river with awe. His bags of moldy flour, 50-pound sacks of bacon and coffee, as well as his crew's back-breaking portages, find their way into the imaginations of many river runners to this day. As does the image of Powell himself, riding the desert rapids in a chair nailed to the deck of his wooden boat. To follow the Colorado River is to follow in the tracks of this man, or, in the case of the Down the Colorado (DTC) Expedition, it was to float over 500 miles of river from one Lake Powell to the other.

But as our team of four field researchers for the State of the Rockies Project hiked into the headwaters region of the Colorado River in June of 2012, we were aware that Powell was relevant to our expedition not only because we were about to attempt a nonmotorized crossing of the lands he spent much of his early career exploring, but we were also planning to spend the next few months investigating the topic that became Powell's obsession, a topic that is at least as pertinent today as it was in Powell's time: water in the American West.

The previous winter, Will Stauffer-Norris and I, half of the DTC crew, traced all of Powell's initial 1869 river route as we followed the Green and Colorado Rivers from Wyoming to Mexico. That trip's primary goal was getting from point A to point B without freezing. By the time we arrived at the Gulf of California, however, we'd discovered the ways in which the Colorado River connects the Southwest and we'd seen some of the effects of 30 million people relying on one desert river for water- among other problems- it dries up. In the late 1800s, Powell spent more time in Washington, D.C. than Utah or Colorado, arguing for a responsible settlement of the West and a careful development of its water. He argued for drawing political boundaries along watersheds and against the over-allocation of water rights. Needless to say, not much of his advice was heeded, and water remains such a contested topic in the Colorado River Basin and surrounding areas that the phrase, "Whiskey's for drinking, water's for fighting," has become something of a cliche. As Powell predicted, all too often water in what he called "the arid lands" is synonymous with conflict.

Now, less than six months after Will and I trekked through the Colorado's delta and received a firsthand picture of one of the biggest losers in that conflict --the environment--we're returning to find another source of the river, this time on the Colorado side of the basin. The goal of this trip is not simply to document the river corridor, but to learn about the straws taking the water elsewhere and the politics behind the basin-wide water shuffling. Instead of the sea kayaks, frozen water bottles, and summer sausage that defined our first trip, we opted this time for rafts, coolers full of fresh food, and summer the season, as opposed to the meat. In addition, we arranged over 40 interviews with basin stakeholders along the way and added daily water quality observations to our continued collection of videos, photos, and stories.

We also added two new members to our crew, Carson McMurray and David Spiegel, both of the Colorado College class of 2012. Carson's job--besides surviving his first exposure to whitewater and keeping the group in good spirits with his much-appreciated antics--is to create an interactive map of the Colorado River. Working with our expedition partners at Blue Cloud Spatial, Carson is using Geographic Information Systems (GIS) technology to post our videos, blogs, photos, and pertinent spatial information to an online map with the goal of creating a powerful educational tool for learning about water issues geographically. David was hired for his exceptional whitewater kayaking abilities and his keen photographic eye. He helped film the video series following the trip, which Will edited. And, of course, the ghost of John Wesley Powell was with us too, making us all the more grateful for our backpacks and dryboxes full of (mostly) mold-free food.

As we hiked up to Lake Powell to begin our expedition, the first major observation we made was of the yellowed hillsides and bare peaks, clear indications of drought. Though the lack of snow the preceding winter would lead to widespread impacts throughout the entire Colorado River Basin, our observation and tentative conclusion could probably have been made by most six-year-old skiers or rafters in the state--little snow means little water. And in a river system that's already diverted to depletion, a drought is a very serious event. Even as we climbed to 9,000 then 10,000 feet, we passed only a few scattered patches of dirty snow, about two percent of the local average for June. That was compared to the previous year's snowpack of over 200 percent. We hauled our small inflatable packrafts high into the park, not knowing when we'd see enough water to float them.

If we didn't pick the best year to go rafting for 500 miles, it was certainly a good year to discuss water. As we pushed our way through brush and climbed over downed trees, we talked about the drought and its implications for our trip. Would the many diversions leave enough water in the river for us to paddle? What would this mean for the state of Colorado and for the river? We didn't have many answers and eventually our talk of diversions, dams, and the threat of water shortages began to dwindle as we became distracted by clear pools and falls of North Inlet Creek. By the time we'd bushwhacked our way through the five miles from our camp to Lake Powell, we'd quieted down completely. We dipped our hats in the lake, waved our flags in Powell's honor, and tried to imagine what lay in store for us between the mountains and the desert Lake Powell.

In 1869, Powell famously wrote, "We have an unknown distance yet to run, an unknown river to explore. What falls there are, we know not; what rocks beset the channel, we know not; what walls ride over the river, we know not. Ah, well! we may conjecture many things." Despite our GPS technology, our proximity to supermarkets, and our planned schedule, this quote found some resonance with us. We may have had some idea of what to expect downstream, but we too faced the same uncertain future, the same thrill of walking towards the unknown. And for the communities that rely on the Colorado River, global climate change makes the idea of heading into uncharted territory an unsettlingly apt metaphor. Much has changed since Powell's ragtag group of mountain men set off onto the waters of the Colorado, not following a map, but making one. But although there is an abyss of sorts between the West of the 19th century and the West of the 21st, what Powell predicted would be the bottom line in defining any westward expansion--water--has proved to be quite prophetic. Water has worked its way into most aspects of western life, even when it's not readily apparent. As we traveled downstream between the Lake Powells, we met with people who painted many different portraits of the Colorado River. They told us how the same water finds its way under mountain ranges, shapes our politics, and floats local economies; we learned about how it grows our food, helps heat our homes, and gives us a place to play. We were also reminded time and again that these connections are tenuous--a growing population in the region and the difficult-to-predict effects of a changing climate make the need to find creative solutions, which protect our environment and our communities more urgent than ever.

But beyond all the strains and all the uncertainty, the river still provided our crew with a line of adventure, a chance to explore land while learning about its many issues. As we took our first steps down from our source, we looked out on a landscape


Will Stauffer-Norris

Headwaters of North Inlet Creek in Rocky Mountain National Park, Colorado.

The expedition members, Carson, David, Zak, and Will at the Grand Ditch in the Never Summer Mountain Range in Colorado.

almost as wild as it was in Powell's day. The thrill of the journey ahead and the thin mountain air left us exhilarated. That night, we unrolled our sleeping bags beneath a spread of stars. While I waited for sleep, I listened to the wind whisper in the pines, and to the creek as it plunged down the nearby cascades. It flowed onward into the night, anticipating our own journey just begun.

II
Why You Should Question Your Continental Divide

Water is normally forced to obey a few laws; namely, flowing downhill and joining other streams, creeks, and rivers until reaching an inland lake or the sea. Enforcing these rules is the continental divide, the Supreme Court of precipitation, which interprets the gravitational constitution and directs water to the most direct course down. This system is quite efficient, and for millions of years there have been few infractions--until recently. Today, the Colorado River is perhaps the number one offender in the world. The continental divide hasn't held the Colorado to the rules for more than a century. It constantly jumps its bed, moves uphill, disregards divides and cuts under mountains. Worst of all, it accepts bribes. As they say in Colorado, "Water flows uphill towards money."

Ask a ranger in Rocky Mountain National Park where the Colorado starts, and she'll most likely point to La Poudre Pass, just west of Estes Park. The continental divide once supposedly traversed the top of the Never Summer Range through which Poudre Pass passes and where the North Fork of the Colorado originates. But if you hike up to this pass with the intention of following the river to the Pacific, you'll quickly find yourself heading towards the Mississippi. This is thanks to the Grand Ditch, a water diversion project built between 1890 and 1930 to support farmers on the Front Range. The Grand Ditch, as the name suggests, is an earthen ditch dug into the slopes of the Never Summers above 10,000 feet that captures melting snow and funnels it from one side of the divide to the other.

This is just the first of many anomalies in the watershed, which make finding the official source of the Colorado less straightforward than might be imagined. We arrived in Grand Lake with five days budgeted to spend on foot in the headwaters. Our intention was to find the source and, if we had extra time, to do some further exploring. But finding the source was not easy. The locals we talked to pointed us in at least three different directions, and all spoke about the "East Fork" of the Colorado, which takes about 60% of the headwaters flow under the Rockies to the Front Range cities via the Colorado Big Thompson Project and its less ambitious cousins such as the Grand Ditch. Uncertain of what to make of this and after much debate, we decided to visit two sources to cover our bases. We hiked to the pass, saw the Grand Ditch, and checked it off our list in case any by-the-books expedition critics wanted to accuse us of going to the wrong source. Then we headed to the less complicated, more pristine source at Lake Powell.

But after a few days along the diversion-free North Inlet Creek, we returned to Grand Lake, where we met with John Stahl and Steve Paul of the Three Lakes Water and Sanitation District. Both Paul and Stahl recited the classic 80/20 problem, which is known by heart for most residents of Grand County. Eighty percent of the population of Colorado lives on the east side of the Rockies. Eighty percent of the precipitation falls on the west side. In order for Denver and other high desert Front Range cities to grow as much as they have over the last century, considerable divide manipulation has been necessary. Nearly every major tributary of the Upper Colorado River is diverted under the Rockies to the east through a number of gravity defying feats.

If the Grand Ditch is really nothing more than an ambitious, high alpine irrigation project, the Colorado near Grand Lake is the world's largest Lazy River: it flows in a circle which, of course, isn't very lazy at all. The laws of the divide, which most rivers obey, save them from exerting unnecessary energy, but circular rivers do not acknowledge these rules. The water that we followed out of North Inlet Creek can take two routes out of Grand Lake. Sometimes it flows out the historic outlet of the lake and down the Colorado. But when the pumps of the Colorado-Big Thompson Project are turned on, the flow out of Grand Lake is reversed and up to 550 cubic feet per second (CFS) of water is taken through Adams Tunnel to the Front Range. Since Grand Lake is only naturally filled by several small creeks which rarely run at 550 CFS, other sources of water are diverted into the lake through the manmade Shadow Mountain Reservoir.

Nearby, Shadow Mountain spills water down several miles of flowing river to Lake Granby, the next reservoir on the Colorado. After paddling across the lake and reservoir, our hopeful kayak expedition bumped down the rocky channel in this section amidst osprey nests with the intention of following the river. But little did we know, most of the water that flowed between these reservoirs made a lazy loop back uphill from Granby to Shadow Mountain via pump station and canal. We found this out when we made it to the dam that plugs the Colorado at Lake Granby to see a nearly dry riverbed below. Where did our river go? Back up to Grand Lake and under the divide.

Paul and Stahl explained the effects of this complicated circuit in the river. The artificial lake of Shadow Mountain is an average of eight feet deep and is connected to Grand Lake, Colorado's largest and deepest natural lake, which is 270 feet deep on average. After being brought up out of Lake Granby, water is drawn through Shadow Mountain and across Grand Lake. Paul summed up his issue when he said, "Moving water backward against Mother Nature's flow is never a good idea." The water from Shadow Mountain comes with the algae and other pollutants, which thrive in the shallow reservoir, murking up the once crystal clear Grand Lake. The water is then pumped under Rocky Mountain National Park through 13 miles of tunnel and passed on to the 800,000 people and lawns living between Boulder and Fort Collins.

Paul and Stahl are advocating for a bypass tunnel that will keep the polluting water out of Grand Lake, but they have yet to strike a deal with the Northern Colorado Water Conservancy District, the operator of the Lazy River at Grand Lake.

This same complication of the divide takes place down the whole spine of the Rockies, in over 20 west to east diversion projects. What's more, there are plans in the works to expand several of these tunnels. The population of Denver and the rest of the Front Range is expected to double in the next 50 years, and without extreme conservation measures or an extreme engineering project, such as building a pipeline from Wyoming or the Missouri River (both have been seriously proposed), the Colorado River will be further depleted.

III
The Hole in the Colorado

The day after we paddled across Shadow Mountain Reservoir and Lake Granby, we found ourselves walking along the highway. Soaring temperatures and widespread droughts were setting records around the country. Half the state of Colorado was up in flames and the river we were supposed to be following was nowhere in sight. We walked along the asphalt shoulder, looking to where the sagebrush and yellowing grass on the hillsides met the rich green and purple of the irrigated alfalfa fields below. The only relief from the sun's relentlessness came from the quick blasts of breeze riding on the tails of each passing semi-truck.

We were heading towards the town of Hot Sulphur Springs about 15 miles downstream of where we left the river at Lake Granby. Why trade floating the cool Colorado for walking on burning pavement? There were several reasons. First, we'd reached what's known locally as the "hole in the river." With this season's low runoff, most of the water flowing into Lake Granby, Shadow Mountain, and Grand Lake

The expedition members crossing Lake Granby in Grand County, Colorado.

Zak, Carson, and David walking along Highway 40 towards Hot Sulphur Springs, Colorado.

was being taken through the Adams Tunnel. The remaining water was incapable of floating our tiny inflatable rafts.

We also didn't want to be caught trespassing. Unlike other states, such as Idaho where both the river and its bed belong to the public, Colorado's law dictates that only the river's water is fair game for kayakers. Property owners can't persecute boaters who float past their land, but if you so much as scrape a submerged rock or get out to portage around a barbed wire fence, you enter an intimidating gray area in the law. Kayaking lore is rich with stories of boaters being driven away from some menacing rapid by an armed and irate landowner, but, like fishermen, kayakers are well-known for their tendency to exaggerate.

Nevertheless, when given the choice between a possible run in with a shotgun or sheriff on the river and the eating of exhaust on the highway, we leaned towards the latter, although our fears are probably as exaggerated as the stories. All the landowners we actually met along the way were very supportive of our journey and their generosity was exceptional. At Grand Lake, for example, we received not only the permission to float a section of river through private property, but we were invited to spend the night as well. All we had to do was ask. But below Granby we don't know who to ask; so we end up walking.

After eight miles, we reached Windy Gap Reservoir where we met up with Rob Firth, the Colorado River Headwaters Project Coordinator for Trout Unlimited. He informed us that the full-fledged "hole in the river" begins at Windy Gap and ends where Troublesome Creek reinvigorates the river's flow 21 miles downriver. According to Firth, this stretch is "a terribly dewatered section that puts this river in a very perilous state." He explains the situation to us as we head downstream to see more.

At Windy Gap, another Northern Water pump station further reduces the river's flow. Denver Water has already diverted much of the Fraser River, which joins the Colorado just upstream of Windy Gap. Although Denver and Northern are required to provide a certain amount of flow to senior water rights holders on the mainstem of the Colorado -- namely the Shoshone hydropower plant near Glenwood Springs and the canals that irrigate the Grand Junction area -- the two water suppliers can do a lot of shuffling in where they release the water to meet these deliveries. Drawing from a system of reservoirs on the Blue River, Williams Fork and other tributaries, Denver and Northern can pump much of the Upper Colorado across the continental divide and then return the required flows lower down on the river. The section between the last major pumping station and where water is put back into the river is considered the "hole."

When we crossed the Colorado River a few miles down from Windy Gap, it looked as if it should be called the Colorado Creek instead. It was clear, warm, and very shallow. Dewatering is threatening this Gold Medal trout stream and the broader riparian habitat.

We watched as a black bear crossed the stream several times, perhaps trying to find some relief from the day's heat. Firth, a former game warden, speculated on the bear's curious behavior and told us that Trout Unlimited's goal isn't simply to maintain quality fishing in the area; it's also to protect the ecosystem as a whole, from the insects to the bears.

Rob Firth, Colorado River Headwaters Project Coordinator for Trout Unlimited, holding an example of the river's macroinvertebrates.

"If you can keep trout at a healthy level, being the top of the food chain, then everything beneath them has to exist in harmony." Unfortunately, the "hole" is experiencing an unnatural warming of the shallow water, threatening the insect populations that trout and other fish depend on. According to Firth, "38 percent of the macroinvertebrates species have disappeared from this river since they've turned on Windy Gap Dam in 1985."

Firth is concerned with the Windy Gap and Moffat firming projects, proposals from Denver and Northern that would divert as much as 80 percent of the river's flow out of the Colorado. "The river reaches a tipping point," Firth said, "where it no longer means one more bucket out means one more bug out. You may reach a point where one more bucket out means everything crashes and you may no longer have a viable trout fishery."

An expedition member paddling down Gore Canyon in Grand County, Colorado.

When we reached Hot Sulphur Springs, we were able to get back in our boats. The river was still too shallow to float without scraping ground, but Firth kindly called every landowner between Hot Sulphur and Kremmling, securing permission for our safe passage. We spent two more days bumping along before we passed the Williams Fork and Blue Rivers. For the first time since the river's source, we found enough water to attract other boaters, people with a less insane idea of what constituted a floatable river. We were happy to have made it out of the "hole."

An expedition member in the rapids of Gore Canyon in Grand County, Colorado.

That night, we camped near the gates of Gore Canyon where the Colorado moves out of a wide valley and cuts directly into the jagged Gore Range. The mosquitoes were so thick we ate dinner in the tents. Smoke from wildfires to the west enriched the red haze at sunset. Red light lingered over the menacing notch in the mountains, looking like something out of Middle Earth. In the middle of that range lie what are arguably the highest quality Class IV-V rapids on the entire mainstem of the Colorado River.

IV
Gore Canyon: Why Recreate? A Kayaker's Perspective

The next morning, we slid our kayaks into the Colorado River and paddled towards the rapids of Gore Canyon. The surface of the river, slowly meandering its way through flat ranch lands near the town of Kremmling, was alive in the early light. A few strands of spiderweb flew by on an otherwise undetectable breeze. The bows of our boats cut through the water quietly.

After nearly two weeks spent following the Colorado River by hiking on mountain trails, paddling across reservoirs, and floating the mostly flat upper river, we were looking forward to the eight-mile stretch that several locals referred to as "Big Gore Canyon." Of our four expedition members, three of us are paddling kayaks and had been down Gore many times before. Carson, still new to river running, was paddling a packraft. He did well on the few riffles we'd encountered so far, but his plan was to hike around the bigger rapids.

All of us were a little anxious, but the Colorado, even with its increased volume, was in no rush to reach the notch in the mountains that marks the beginning of the canyon. It moved back and forth in lazy turns, flowing over sandbars, past flocks of pelicans and between more fragments of web. One strand in particular caught my eye. It was moving directly towards my boat as lazily as the river was moving towards the Gore Range. As it floated closer, I saw there was something attached to the end -- an airborne spider dangling from its homemade sail of silk. It began losing altitude quickly, headed for the water a few feet ahead of my kayak. I instinctively took a few strokes towards it, thinking I could catch it on my bow and save it from a watery grave. But I miscalculated and it sailed right over me, landing on the surface of the river. Amazingly, the web didn't settle onto the water but remained in the air, still being slowly propelled by the wind. The spider, seemingly unperturbed, skated across the surface of the water with its paraglider-turned-kite doing the work.

I watched the spider cruise away until I could no longer make it out against the grassy riverbank. Then I paddled on. I didn't wake that morning expecting to watch spiders, and as the current finally began to quicken, my thoughts moved elsewhere. The low grass banks turned to sheer rock walls towering 1,000 feet above us and soon the rapids began.

A few hours later, we emerged from the other end of the canyon, our hair still dripping from under our helmets and the adrenaline subsiding. The three of us in kayaks had found mostly what was expected: rapids forcing us to maneuver quickly between offset boulders, a few waterfall-like drops where our boats catch several feet of freefall before landing in the churning pockets of foam below, plus a few missed paddle strokes, several moments of terror, and a whole lot of hootin' and hollerin'.

For the packrafter, Carson, it may have been a little less fun but more action packed. After piloting several Class III rapids (no small feat for a river novice in craft designed for crossing flatwater in the backcountry), Carson made more than one mad sprint through the train tunnels along the riverbank. He found it easier than portaging the larger rapids over steep rocky slopes, though he had to pray the roar of the river wouldn't be enough to muffle the roar of an oncoming freight train. We all emerged unscathed. But even after all the excitement, even after weeks of hyping up Gore, the moment that stands out most clearly from the day is the sailing spider, bolder in my memory than any of the Gore's other rewards.

I think this is a fairly common experience for people who participate in any sport labeled as "outdoor recreation." Whatever it is that draws people to our public lands -- be it a scenic mountain trail, a prime fishing hole, a slope of fresh snow, or a series of rapids -- isn't always what stays with us when we return to civilization. Sometimes it's the unexpected encounters with a living landscape that bring us back out the next time and not to the trophy catch or finding the best powder turns. Sometimes the sport may serve more as a way to discover that sudden revelation of color, a coyote's gaze, some remarkable geometry of tree branches, or a floating arachnid than anything else. But for the addicted outdoors enthusiast, the sport of choice just happens to be the most interesting way to arrive at that exceptional moment that cannot be planned or pursued. Playing out of doors and away from asphalt differs from recreating in an amusement park or a basketball court in that it takes us away from our homes and business. It takes us beyond the right-angled world we attempt to make useful and allows us to visit, however briefly, the more-than-human world living and dying beyond our control.


Will Stauffer-Norris

David paddling in the surf of Gore Canyon in Grand County, Colorado.

V

Why Recreate? An Economic Perspective

A swarm of yellow life jackets poured out of a barge of rafts and moved upward, single file, to the top of a small cliff. One by one they jumped, letting out a quarter-second, midair yelp before disappearing into the water below. We'd moved a few miles below Gore and had finally switched our kayaks for a 16-foot NRS raft complete with cooler, two burner stove, and a set of chairs. We sat in camp late past noon, watching the yellow lemmings hurl themselves into the river. Although this particular cliff is more than an hour's drive from any significant population center and nearly three hours from Denver, the commercial rafts floated by our camp in an almost unbroken procession throughout the morning. And as our expedition floated downstream towards Glenwood Springs, we saw this scene repeated again and again in various forms -- tubers, rafters, fishermen, and picnickers flocking to the river to find some relief from the heat and to enjoy a day beside moving water.

Unlike municipal, industrial, or agricultural water diversions, recreation is one of the few legally recognized uses of water that doesn't require pumping water out of our rivers. Instead, it encourages making our rivers as accessible, clean, and as naturally beautiful as possible.

The stump speeches of numerous politicians in western Colorado suggest that to be pro-economy you have to be pro-growth, pro-drilling and in favor of new water projects, such as reservoirs and diversions. According to this mentality, anything that's going to protect the state's natural resources is going to kill jobs and hurt wallets. But there are other voices speaking up to say the direct opposite: that a strong, stable economy in western Colorado is going to be built not on the booming and busting cycles of resource extraction, but on the seasonal, sustainable cycles of resource preservation. People who come to enjoy the Colorado Rockies to raft, fish, hunt, bike, camp, or simply to sightsee are drawn by the recreational opportunities the mountains and rivers have to offer as intact mountains and rivers.

A commercial rafting group cliff jumping near Glenwood Springs, Colorado.

As our expedition team floated down the length of the Colorado, we met with many river experts who are interested in quantifying the value of river recreation. First, Molly Mugglestone, the project coordinator for the river advocacy group Protect the Flows, explained the river's contribution to the regional economy. Mugglestone has spent the last year creating a coalition of over 500 businesses in the Colorado River Basin who rely on a healthy river for their livelihoods. Coalition members range from the obvious rafting and fishing companies to small businesses in tourist towns who need the yearly influx of people to stay in business. Together Protect the Flows and the businesses they represent have been speaking up for the needs of a recreation economy.

"Policy makers have been really receptive to our message," Mugglestone said, "because we represent economic vitality. We represent jobs. We represent small businesses trying to survive with the economy and also with the drought." Helping to quantify the value of a healthy river system is a recently released Protect the Flows study, which estimates the Colorado River generates an economic output of $26 billion annually and employs a quarter of a million Americans. In the state of Colorado alone, $9.6 billion is thought to be produced from river-related business.

During summer months, Glenwood Springs, Colorado, is a convincing case study of the report's findings. Not only do independent businesses survive on river recreation, but the local government has also invested over one million dollars in a public whitewater park in town. When we floated through, we broke out our own kayaks and spent the day on the artificial wave. The park, which was constructed in 2008, consists of several river features that kayakers of all ages play in, surfing the waves and practicing tricks in the holes. During high water, even surf boarders come to ride the artificial hydraulics. Crowds of spectators form on hot summer days, sometimes outnumbering the number of boaters in the water. Glenwood's park is just one of over 20 new Colorado whitewater parks built in the last decade.

Whitewater parks hold a unique place in the Colorado legal system. According to state law, water rights can only be obtained if the water is put to "beneficial use." Traditionally, beneficial has meant agriculture, municipal and industrial uses, or hydropower. But, as the Protect the Flows report demonstrates, recreation makes a considerable contribution to the economy, and today it is possible to obtain water rights for recreational purposes such as a whitewater park.

We met with Nathan Fey, the Colorado Stewardship Director for American Whitewater (AW), to learn more about this issue. Recently Fey has been working with a number of West Slope entities to negotiate with diverters to the Front Range. AW helps represent the recreation community and their needs in these talks. "One of the few tools we have in Colorado to help protect recreational flows is a whitewater park," Fey reported. "A water right for paddling through a whitewater park is being explored all over the state." Such a right is known as a Recreational In Channel Diversion (RICD). As this oxymoronic name indicates, water rights can


David Spiegel
Zak reading under the moonlight on the Colorado River in Colorado.

still only be filed if they can be considered "diversions," which in the case of a whitewater park requires no diverting whatsoever. The beneficial use is found in the flowing river itself, which does more than draw crowds of tourists. "River-based recreation is a huge driver for our economy," Fey explained. "The other piece of that though is that flows which are great for recreation are also really good for the environment." Adequate flows for boaters mean better spawning grounds for fish, a healthier riparian habitat, and countless other benefits for the river's ecology.

VI
Fracking Along the Colorado River

A tangle of pipes, pumps, and green natural gas structures came into view as we rounded a bend in the river a few days later. To make miles, we traded our raft for sea kayaks where Glenwood's tourist-based economy gave way to western Colorado's gas country in Garfield County. All morning, we'd been seeing the telltale signs of the industry as we paddled under pipelines, past drilling rigs, and even by several well pads poised on artificial rock banks a stone's throw from the water. Although we were warned about the heavy gas development along this section of the river, it was strange to see active gas wells within the historic floodplain of the Colorado.

Our flotilla began growing more curious by the minute and when we passed another intriguing looking center of activity, we couldn't help ourselves. We pulled our boats out of the water and struggled up through the thick riverside brush to the top of the bank, not knowing if we were on public land or not. The hillside was cut by a thick metal pipe running down to a holding tank where four white pickups were idling. A door opened and a worker came out to greet us. We asked permission to look around, and he said it was fine. The worker, who looked to be in his early twenties, was in a collared company shirt and jeans. After asking a few questions about our plan to follow the Colorado River from source to sea, he explained that the assortment of pipes, valves, and tanks around us were part of a pumping station, which has been set up to transport used fluid from one drilling site to another.

"Like fracking fluid?" we asked.

"Yeah. They're recycling it for use in a new set of wells," he said pointing up the way towards the scaffolding of a drilling rig a few miles away.

Before floating through this section, we tried to do a little research about the oil and gas industry's use of water. Along with the millions of Americans living near areas of heavy gas development, we were particularly interested in the topic of hydraulic fracturing where a mixture of chemicals and water is sent thousands of feet underground to break up the rock and release trapped gas reserves. But finding reputable information is not easy.

Fracking, like any truly controversial topic, has developed the tendency to repel stable facts with magnetic force. Seemingly simple questions produce wildly different answers depending on whom you ask. For example, how much water does the natural gas industry use in Colorado? According to the Colorado Oil and Gas Association, 0.13 percent of the state's water use went to natural gas production in 2012. Their Water Use Report states: "Colorado's oil and gas industry is committed to minimizing our water use and maximizing our recycling," which sounds reasonable and relatively low impact. And then we hear the other side. According to an independent study from Western Resource Advocates, each new well takes five million gallons of water. Fracking uses enough water annually to supply up to 296,000 people for an entire year. Citing a range of figures for possible


Will Stauffer-Norris
A natural gas rig in Garfield County, Colorado.

water consumption, the report translates the industry's use to its municipal equivalent. "On the low end, that's slightly more than the population of the city of Lakewood (Colorado's fourth largest city). On the high end, that's similar to the entire population of either Douglas, Boulder, Larimer or Weld counties." When the situation is described that way, the impact of gas development no longer appears to be so benign.

Or how about the risk fracking poses to the quality of our rivers, streams, and drinking water? A typical answer from the oil and gas industry will emphasize safety, explaining that current technology is capable of completely sealing off well casings from any contact with underground water supplies. But when homeowners living near drill sites find that their wells have been contaminated or, in some instances, that their tap water is suddenly flammable, the industry's constant assurances seem less comforting.

There is one thing that's agreed upon, however. Any water used for drilling or fracking, even if it's recycled a few times, is eventually taken out of the water cycle for good. While much of the water used in cities or for agriculture is capable of being returned to the rivers and reused downstream, water used for fracking is far too polluted. The only safe way to dispose of it is by pumping it deep underground. Fracking is a 100 percent consumptive use of water.

It was just this used, polluted water that we saw being pumped to the new drill site alongside the Colorado River. The friendly worker explained that the four running pickup trucks, each with one or two men inside, were posted to this site on 12-hour shifts. Their assignment: to watch the pumping facilities and to make sure everything was working properly. A spill of the toxic fracking fluid here, on the banks of the river, could mean a devastated fish and insect population, poisoned crops, and problems with municipal water systems supplying 25 million people between Garfield County and San Diego. The added precautions made sense, but the parked trucks raised the question of why there were pipelines and wells so close to the river in the first place. As it turns out, fracking was exempted from the Safe Drinking Water Act in 2005, and there are few regulations in place for riverside gas development in Colorado. Wells are being built on riverbanks because there are no rules to prohibit it.

The photographers on our crew took out their cameras to begin documenting the site. We'd been talking with the pumping station attendant for over five minutes, but as soon as we began photographing, another man came out from his truck and informed us we were on private property being leased to Halliburton. One photo was snapped covertly before we got back in our kayaks and paddled down past more drilling rigs and well pads.

A few days before, we'd met with Tresi Houpt, the former Garfield County Commissioner and Colorado Oil and Gas Conservation Commissioner. Houpt, who has had over 10 years of experience working with energy policy on the county and state levels, told us that for most of these controversial questions, both sides are probably telling truths. While drilling only uses a small percentage of the state's water, the figures are quite large when they're put in the context of a river system that's already over-allocated (the Colorado River has not connected with the sea for well over a decade, for example). Current technology is indeed capable of making the drilling process safe, she explained, but that doesn't mean it's always implemented correctly. Houpt cited a number of situations where residential wells or streams were polluted by oil and gas activity, stating that, "the water contamination issues that we've seen throughout Colorado have been as a result of human error, not technological error."


David Spiegel

Carson near a well pad along the Colorado River.

While the industry constantly refers to an ideal situation that is safe on paper, Houpt pointed out that:

> "There's a great deal of human error that goes along with any industry or anything we do in this world; we're imperfect beings. I think we need to be very aware of where and how we allow oil and gas development to proceed because of the likelihood of some kind of contamination that could occur. There just aren't guarantees."

Natural gas has been hailed as a "clean bridge fuel" and, although it releases less greenhouse gas emissions than other fossil fuels, Houpt is wary of letting the industry regulations remain so lax. "It's important to recognize that we have this tremendous resource available to us in Colorado," she said, "but we should only develop it if we can protect public health, safety, welfare, the environment, and wildlife. If we fall short on that, then we really can't call natural gas a clean fuel."

VII
Agriculture

A man appeared on the porch of the dam keeper's house and began speaking into a radio. He eyed us as we pulled the last of our four sea kayaks onto the shore and started walking our way. It was a little after 8 a.m. and we'd just arrived at the Cameo Dam east of Grand Junction two days after the pipeline visit. A large portion of the Colorado River was being diverted beneath floodgates to Grand Valley agriculture. When the man arrived, he informed us, as indifferently as a cashier wishing us a nice day, that the sheriff has been notified of our arrival. If he'd never seen portaging boaters before, he was already bored with the situation. He told us the sheriff would be there in thirty minutes to give us a trespassing ticket.

Cameo Dam near Grand Junction, Colorado.

Weighing our options, we attempted to bargain: "Can we just portage the dam and get back in the river?" We could see a launch point not far downstream. The dam keeper radioed his boss but access was denied. We asked how much the ticket will be. He pondered the question for a moment before replying cheerily, "Probably not more than $1,000 each." We went back to the drawing board.

Twenty minutes later, we'd convinced the man to call off the sheriff. We paddled across the river, fought our way through a thick patch of poison ivy, and began dragging our boats down the shoulder of Interstate 70. This dam is far too important to grant access to any group of scruffy kayakers who comes along. We understood. It has provided a livelihood to farmers and fruit growers in the otherwise desolate lowlands of the Grand Valley since 1918. But besides being one of the most productive growing regions in the state, we'd been reaping the benefits of the Grand Valley's long-standing irrigation rights since we left the "hole in the river." The Cameo Dam is able to "call" down over 3,000 cfs of water during the growing season from anybody upstream who has a junior water right, ensuring that a certain amount of water will makes it down to the dam even in drought years. As kayakers, we could appreciate the role the dam plays in statewide water games, even if they didn't tolerate portaging.

But the dam is there to put the water to use. Cameo and the other irrigation structures just downstream can sometimes divert the entire flow of the river, leaving a few hundred yards of near-stagnant pools. This area, once a prime endangered fish habitat, is known as the "15-mile reach." The dewatered section extends from Palisade through Grand Junction before agricultural return flows and the Gunnison River replenish it. When we passed through, the flow dropped from 3,000 cfs above Cameo to less than 400 cfs through the reach.

Agriculture consumes about 80% of the Colorado River. If you've ever eaten a salad in the winter, there's a good chance it was grown thanks to the Colorado's water. Colorado water law operates under a policy known as "use it or lose it." Jeff Houpt, an attorney in Glenwood Springs who specializes in water law, told us that "there is a provision in Colorado law which says if you don't use your water rights, eventually they can be abandoned." Losing a water right to irrigate is, in the vast majority of the Southwest, synonymous with being bankrupted as a farmer. Understandably, farmers will often do what they can to use their full allotment, even if it's not going to actual crop production. There are stories of farmers irrigating weeds in unused fields simply out of fear of losing their right to that water in the future.

Fortunately, water in the West has become far too valuable to the environment and to other users to allow such waste to continue, and there are numerous alternatives being explored. In the summer of 2012, the Colorado Water Trust (CWT) implemented a program to help farmers keep their water rights during drought years while at the same time keeping water in the stream. CWT's water leasing program will actually pay participating farmers to turn off their ditch and keep their fields dry. The water that would have been used for irrigation is left in the river and the estimated

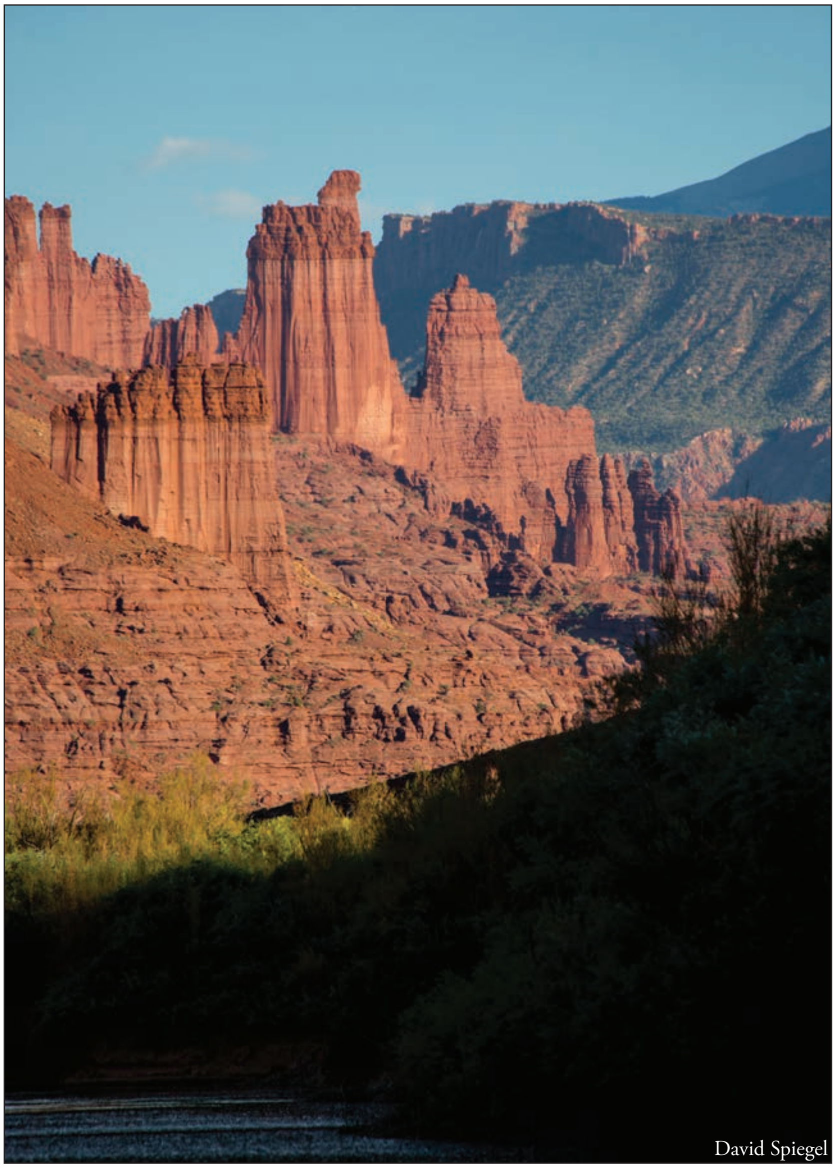
The expeditioners portaging Cameo Dam.

value of their crop (plus a small bonus) is paid to the farmers.

For farmers and fruit growers irrigating with water from the Cameo system, the "use it or lose it" rule doesn't apply in the same way as the rest of the state. Bruce Talbot, a fifth generation fruit grower in Palisade, told us about technological innovation and subsequent local cutbacks in water consumption. "In our own canal company, the Orchard Mesa Canal Company, we've been able to release more water than in the past, a lot of that has to do with sprinkler and drip systems that are more efficient with the use of water as well as the lining of canals." Installing these systems is sometimes against the best interest of farmers who fear losing their water rights by becoming more efficient. Talbot's orchard, however, is part of a cooperative canal company that holds the water right, so individual growers have an incentive to install modern irrigation technology and to save water.

Finding solutions that are good for farmers and for the river isn't as impossible as it once seemed, but there is still considerable animosity between the two sides. We visited a farmer in Fruita who brandished a copy of a Patagonia clothing catalogue with a story on dam removal at us and asked us if we wanted to "read some fiction." "I think it's important we understand our basic needs, which are food and water," he said. "Recreation and maintaining the balance of the environment should be considered, but we have to consider our primary needs first."

Hopefully with new laws that allow water leasing, more efficient irrigation technology, and a willingness to cooperate, we can find ways to grow the food we need without further degrading the river that makes desert farming possible.


David Spiegel

The iconic landscape of the Colorado Plateau.

VIII
Into the Colorado Plateau

After paralleling I-70 for more than a hundred miles, the Colorado River leaves the Grand Valley for iconic desert geology that the Southwest is famous for. The landscape makes a prompt transition from arable valley to sandstone canyon. Redrock walls rise on either side and guide the snowmelt of the Rockies into the Colorado Plateau. From where the river enters that uplift near the Utah-Colorado border to where it finally exits at the end of the Grand Canyon some 500 miles later, the string of wind-swept, water-sculpted cliffs tower over the river in almost unbroken procession. In that interval of rock, the Colorado has spent countless seasons working, cutting into the earth, opening unfathomable time to the desert sun. From shaping ancient round backs of breaching sand dune whales; to sharpening the sheer blocks of limestone that can shred through new hiking boots in hours; to roaring through black core of billion-year-old mountain ranges; the Colorado's protean waters--now flowing red, now chalk white, now gray--mark the continuation of that labor. It's a place like no other.

At the edge of the plateau, we were glad for the chance to get out of the sea kayaks, inflate our rafts for the second time, stretch out, and let the current take us into Horsethief and Ruby Canyons. But we weren't the only people who thought that sounded like a nice way to spend the weekend. There were barges of families, canoeists, kayakers, floating frat houses, bachelorette parties, and overworked rangers also out drifting down the same 26 miles of beautiful flatwater. Ruby/Horsethief provides a good picture of what the desert canyons have become as rafting has exploded in popularity over the last quarter century. Most overnight desert floats now require permits from the presiding public lands office in order to limit the impacts of recreational users. Ruby/Horsethief has, for years, been the exception to that rule, but now the BLM is phasing in a permitting program.

Steve Trimble, a writer and photographer who has spent the last 40 years exploring canyon country, explained the summer crowds we were witnessing in terms of the phenomenon of what he called the "urban pilgrim."

"Many of us have a place we just connect with, that

At the confluence of the Colorado and Paria Rivers.

becomes our spiritual landscape, our spiritual home. People who live in big cities use these places as their refuge, and every chance they get they come down to explore and to just be here. It feels very much like a pilgrimage. I think a lot of people say they're not religious in a normal, conventional way, but they find their spirituality in landscapes like the Colorado Plateau."

Although some of the groups we passed seemed to be on their pilgrimage primarily to propitiate Dionysius with sacrifices of Coors Light to parched gullets, visitors to the canyons do enact different roles from anywhere else upstream on the river. Instead of the fishermen of the headwaters, the adrenaline junkies of Gore, the assembly line tourism of Pumphouse, the gas well operators of Garfield County, or the farmers of the Grand Valley, people often come to the canyons to escape even the slight economic productivity of catching a fresh trout. Those who joined our trip through the canyonlands repeatedly echoed Trimble's statement that this is a place where people come "just to be."

Trimble met us on the section of river below Ruby Canyon along with ten other seemingly civilized folks eager to tag along for our pilgrimage through Westwater Canyon below. In all, we had a geologist, a few educators, two Ph.D. students, a teenage kayaker, a river restorer, a rock star, and a bandit along for what were two of the most flat-out fun days of the trip. Each of the many rapids in Westwater Canyon knocked at least one member of this unsinkable crew from their various rafts, duckies, open canoes, or kayaks into the river for a swim. One by one they were fished out, warmed in the sun, and sent off into the next rapid for more carnage. When the rapids were finished, we hiked to petroglyphs, jumped off cliffs, played games on the beach in camp, and sat by the fire while the swirling stars counted off the dwindling hours until dawn. In the morning, we fried up ungodly portions of bacon, hash browns, and eggs before floating down to the boat ramp where the cars of our short-lived posse were waiting.

An eclectic mix of fellow boaters continued to cycle in and out of our expedition for the next few weeks. We learned about the threats to the plateau in the form of invasive tamarisk trees, further water depletions, uranium mining, and commercial development. But it was hard to visualize the possible impacts of these problems in a landscape so powerfully empty of civilized scars. Trimble told us that spending time in the place itself was a crucial component of any attempt to preserve it. He claimed that both locals and urban pilgrims, though sometimes blaming the other for a place's ills, need to find ways to work together to keep corporate interests from degrading our remaining wild landscapes.

"How do we come together as a community and save the places that all kinds of different people love?" he asked. "The key, I think, is to keep talking, to bring everybody to the table, and then to take the table outdoors. We need to be with each other in a place to find common ground."

Below the town of Moab, the six student researchers for the State of the Rockies Project and the program coordinator met us for a week in Cataract Canyon. After having spent the first few months of summer preparing the research articles that form the rest of this *Report Card*, they were eager to explore the river they'd been learning about.

We met up with the Green River where John Wesley Powell arrived on the first official exploration into this part of the Colorado Plateau. When his expedition arrived at the Colorado River, it was two months into their journey and they'd only seen other people at one tiny outpost far upstream of the confluence. We'd seen a few other boaters, though for the most part, the landscape seemed as deserted as 1869. Where Powell "sifted through musty flour with mosquito netting,"[1] our crew again prepared various Costco-fueled feasts. Where Powell climbed the canyon walls with barometer and notebook, we climbed with cameras and polypropylene. Our crew floated and swam our way through the namesake rapids of the canyon in a single day--it took Powell and his men over a week to portage the same distance.

On our final night in the canyon we prepared our beds on the rafts. Our paddle boat was flipped upside down and the researchers laid their sleeping bags on the floor. The rest of us found spots among the baggage of the other raft or in the packrafts tied onto the boat. We slept as the mirror-smooth current of the Colorado slowed and finally stopped. When we awoke in the morning, we found ourselves between the walls of a mini canyon of stinking, reservoir-deposited silt. We'd finally made it to the second Lake Powell of the trip.

IX
Lake Powell Again: Reservoir by Solar Raft

At Hite Marina, the furthest up-stream boat ramp in Lake Powell, we switched crafts again. Leaving behind the rafts, kayaks, and packrafts that had accompanied us in varying combinations since the first Lake Powell, we'd decided to tackle the 160 miles of reservoir before us in something a little less current dependent.

Crossing Lake Powell with the solar powered raft.

Jack Kloepfer of Jack's Plastic Welding in Aztec, New Mexico, had recently teamed up with Solar Works, a Durango, Colorado, renewable energy company, to build an entirely solar powered raft, probably among the first of its kind. He met us at Hite Marina, hauling the recently designed craft behind his truck. Consisting of four solar panels mounted on aluminum poles and doubling as a shade roof, two 22-foot plastic cataraft tubes Jack himself welded together, and a German made electric motor, Jack told us this baby could crank out six whole horsepower. But not often. Given the contingencies of solar angle, cloud cover, and wind (which all too often blows up-lake), he explained the average cruising speed would probably be close to five miles per hour. Nonetheless, we excitedly helped rig the boat.

The expedition team preparing to embark on their solar raft journey.

Jack made his name in the rafting world with the invention of the "Paco Pad," a piece of foam enclosed in the heavy-duty plastic he uses to build rafts. The result is a nearly indestructible, very luxurious camp mattress, which doubles as a raft seat. He outfitted our craft with four of these pads, encircling our cooler of supplies in a sleep-inducing ring of waterproof opulence. When we got the boat into the water, he gave us a few pointers on how to work the motor as well as a very quick definition of watts, volts, and amps. He answered our flood of questions by concluding that it was really all "subjective." He thought it would be better to demonstrate instead of explaining. The trial run ended in a broken propeller, so that when we waved goodbye to Jack an hour later, we were already riding on our only spare prop. The sole alternative to the motor was a set of oars, and the Glen Canyon Dam was still at least six days away.

Soon, we'd learned what Jack meant by "subjective." With careful attention paid to the watts, speed (measured by GPS), and volts on the motor's readout screen, along with multiple attempts to charge the batteries during the high noon sunlight and to ride them into the windy afternoon, we'd formulated more opinions about maximum efficiency than we had people on the raft. A few days into the trip, we eventually found common ground: no matter what combination of tricks we tried, we remained the slowest boat on the reservoir by about 15 miles per hour. All day, every day we ate wakes. We were passed by powerboats pulling wakeboarders, trolling boats pulling fishing lines, and houseboats pulling up to two other motorboats with a string of five jet skis like ducklings behind their mothership.

Luckily, the pads gave us a place to sprawl and the panels gave us some shade. We spent our days studying the map, doing crosswords, and reading. Sara Porterfield, a Ph.D. candidate at the University of Colorado studying river history, was our sole guest for Lake Powell. She brought with her a small library of books on Glen Canyon, the name for the

Crossing Lake Powell.

walls that contain the reservoir. We delved into the stories of what is one of the most controversial environmental struggles in the Southwest. Built at the height of the Bureau of Reclamation's power in the 1960s, the Glen Canyon Dam was fiercely opposed by conservationists such as David Brower of the Sierra Club. Brower had successfully defeated the proposed Echo Park Dam in Dinosaur National Monument at the confluence of the Green and Yampa Rivers, and went on to help stop five more proposed dams in the Grand Canyon. Nevertheless, Brower never ceased mourning the loss of Glen Canyon, which was widely considered to be the most beautiful stretch of the Colorado by the few people who saw it before it was drowned. Writer Edward Abbey famously dreamed of piloting a houseboat of explosives towards the river's resurrection, while many fellow writers have lamented the loss of its slow current, sweeping curves, and towering walls. An array of accounts of the pre-dam canyon speaks with the same soft reverence of the winding side canyons with their hidden waterfalls and hanging gardens. Allies in this fight argue for the dam's decommissioning to this day.

On the other side of the spectrum, over two million people come to motor around on the reservoir's clear waters each year, fishing, jet skiing, and camping on its ever-fluctuating shores. The town of Page, Arizona, was founded to support the dam's building. But the debate between the canyon's aesthetic qualities as a river and its recreational opportunities as a reservoir pale in comparison to the argument about Powell's loss of water--at least politically speaking. Sitting exposed in the desert sun, the reservoir loses about six percent of the Colorado's total annual flow to evaporation, more than the state of Nevada's entire annual allotment. Lake Mead has been below 50 percent of its capacity for years and could currently store all of Powell's waters as well. If the population in the Southwest continues to grow, and precipitation continues to decline thanks to global warming, people will have to decide at what point water becomes more valuable than hydropower and houseboating.

For now, however, the reservoir remains. Our aluminum frame creaked endlessly as we rocked back and forth in the wakes of passing houseboats with names like "What a Sunset!" "Livin' R Dream," and "Sotally Tober." After four days of silent stares, we finally made contact with another group on the reservoir. Three jet skiers pulled up and asked, "Do you know how far it is to the Escalante Arm?"

"About a mile," I replied thinking of the scenes in Sara's books depicting a breathtaking Escalante Canyon.

"Are we in the San Juan arm now? We're trying to get to mile marker 51."

"No, you're on the Colorado," I told their blank stares.

"The Colorado?" They pondered the information for a moment before exclaiming, "Oh, you mean the main channel! Thanks." They took off in a cloud of exhaust towards the red buoy marked 51.

Our first interaction with other Powell goers only left us feeling more out of place. The river we'd followed for 500 miles was gone, sunk deep below our pontoons. Distances were no longer measured by landmarks or river miles, but by Park Service buoys. Tributaries--the San Juan River, the Escalante River--still flowing beyond the reaches of Lake Powell, had now become "arms." We plodded on, the sun propelling us along at the same glacial pace that the Colorado River flowed at for six million years to carve this canyon. We moved at about the same speed John Wesley Powell had moved as his wooden boats floated him past the "curious ensemble of wonderful features - carved walls, royal arches, glens, alcove gulches, mounds, and monuments," that he would describe in his journal from 1869. "From which of these features shall we select a name? We decide to call it Glen Canyon." Those features of the canyon Powell named are now buried beneath waters named after Powell. From dories to combustion engines, much has changed since the West was first fenced and dammed. But beneath our solar panels, we could imagine the beginnings of a new way forward.

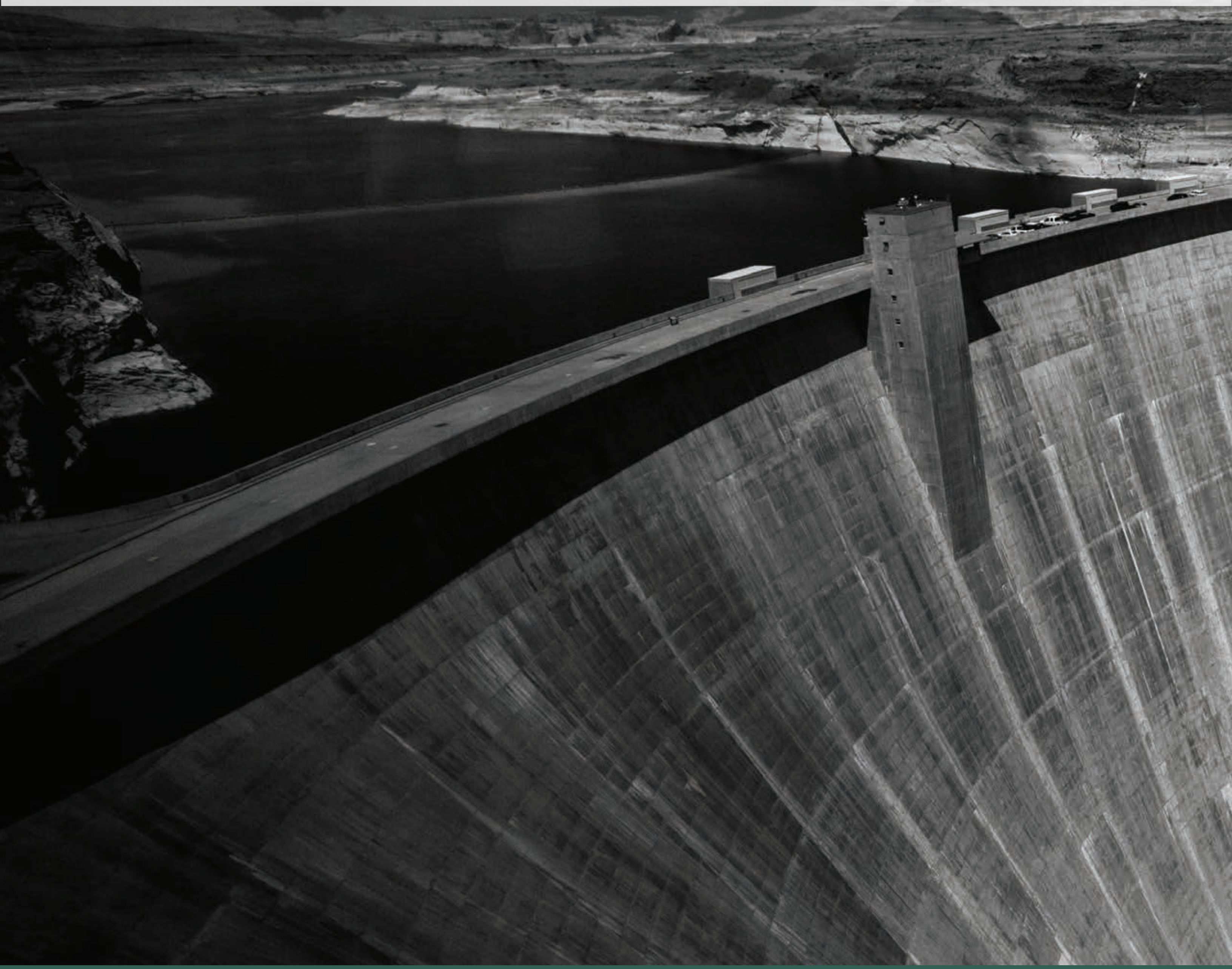
On the very first day of our trip, we met with Lurline Underbrink Curran, the County Manager for Grand County. After working for 30 years on Colorado River issues, her tone was firm when she told us that finding "common ground on water issues is the only thing that's going to keep the river whole in the future," the only thing that's going to help us "save ourselves from ourselves in the future." Our 50 days on the river had given us a new understanding of what that common ground might look like. The river is not just what is visible between the banks; it overflows into virtually all facets of southwestern life. The same water can go from filling a creek to running a shower to watering crops to creating a desert rapid. The common ground is what's beneath both communities and canyons, both cities and farms, both industry and wildlife. Common ground is what allows us to see the value of sharing water between multiple needs at the same time, of not choosing one at the expense of the others. "A finite resource can have more than one function," Underbrink Curran concluded. "Why not?"

Citation:

[1]Wallace Stegner, *Beyond the Hundredth Meridian: John Wesley Powell and the Second Opening of the West,* Penguin Books (New York, NY:1953), p. 85.

Overview: Colorado River Basin Water Demand and Supply Imbalance

By Shannon Thomas and Walter E. Hecox



The 2013 Colorado College State of the Rockies Report Card
Water Friendly Futures for the Colorado River Basin

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Will Stauffer-Norris

Introduction

Today the Colorado River and its tributaries provide water to more than 30 million people, irrigate approximately four million acres of land, and operate hydroelectric facilities that generate more than 4,200 megawatts (MW) in the seven basin states of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming. The Colorado River also supports 15 Native American tribes, seven national wildlife refuges, four national recreation areas, and five national parks.[1] Initiated in 2010, the U.S. Bureau of Reclamation (BOR) conducted the Colorado River Basin Water and Supply Demand Study for the basin states in order to predict possible imbalances in future supply and demand of the Colorado River Basin and the adjacent areas (**see Figure 1**) over the next 50 years. They deal with three geographic areas:

- the Colorado River hydrologic boundary (called the basin), which historically is divided into the Upper Basin and Lower Basin;
- Adjacent areas exporting water from the basin;
- Study Area that includes the two areas above.

The State of the Rockies Project has analyzed this study's results and built upon its findings regarding current and projected future water uses by agriculture, municipal and industrial (M&I), and energy. **Figure 2** provides a list of terms used in reference to the Colorado River Basin and its adjacent areas.

Figure 1: Map of the Colorado River Basin Study Area

Source: Bureau of Reclamation

Figure 2: Key Terms Used in the Colorado River Basin Supply and Demand Study

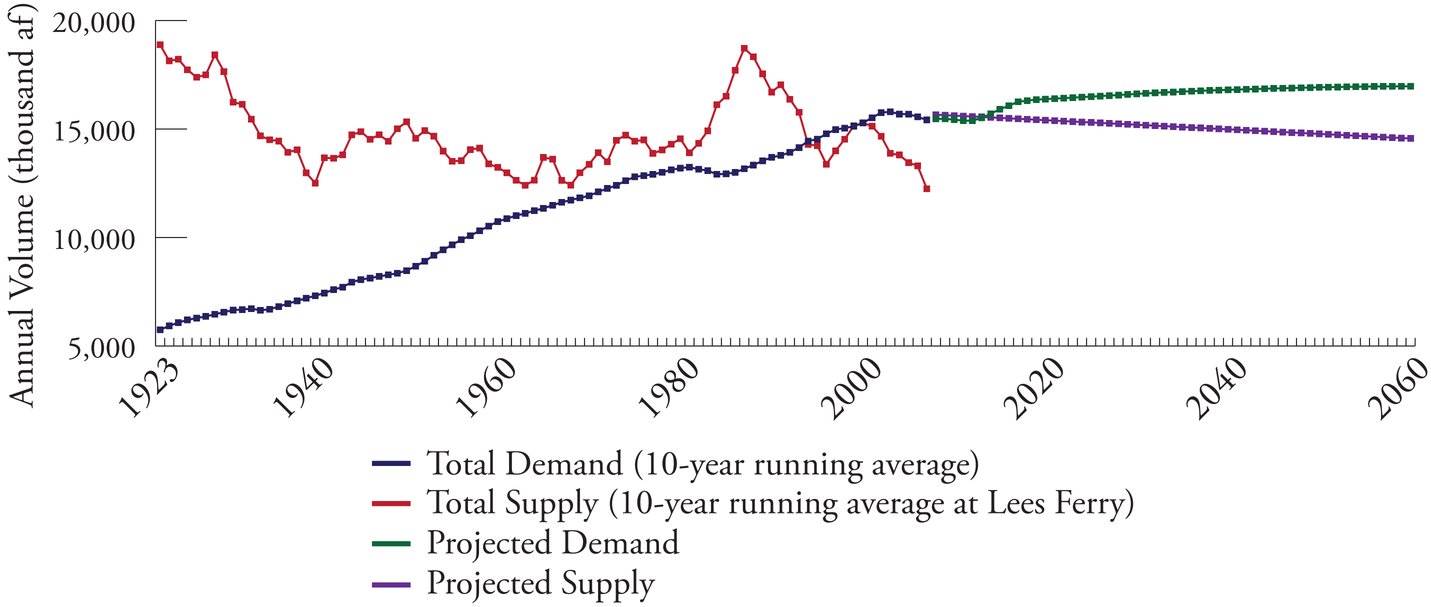
Hydrologic Basin	The geographic region naturally draining to the Colorado River.
Adjacent Area	Geographic regions outside the Colorado River hydrologic basin that receive Colorado River water.
Study Area	The hydrologic boundaries of the Colorado River Basin, plus the adjacent areas of the basin states that receive Colorado River water.
Demand	Water needed to meet identified uses.
Diversion	Water withdrawn from the river system.
Return Flow	Water diverted from and returned to the river system.
Consumptive Use	Water used, diminishing the available supply.
Non-consumptive Use	Water used without diminishing the available supply.
Loss	Water unavailable for identified uses due to reservoir/channel evaporation, phreatophyte use, and operational inefficiencies.
Other Supplies	Water supplies other than Colorado River Simulation System (CRSS) simulated Colorado River water supplies that may meet demand.
Parameter	A variable which impacts a demand category (for example, population).
Colorado River Demand	Potential Colorado River demand as computed by Study Area demand minus other supplies.

Source: Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." Reclamation Managing Water in the West (2012): 1.

Historic Colorado River Basin Water Use

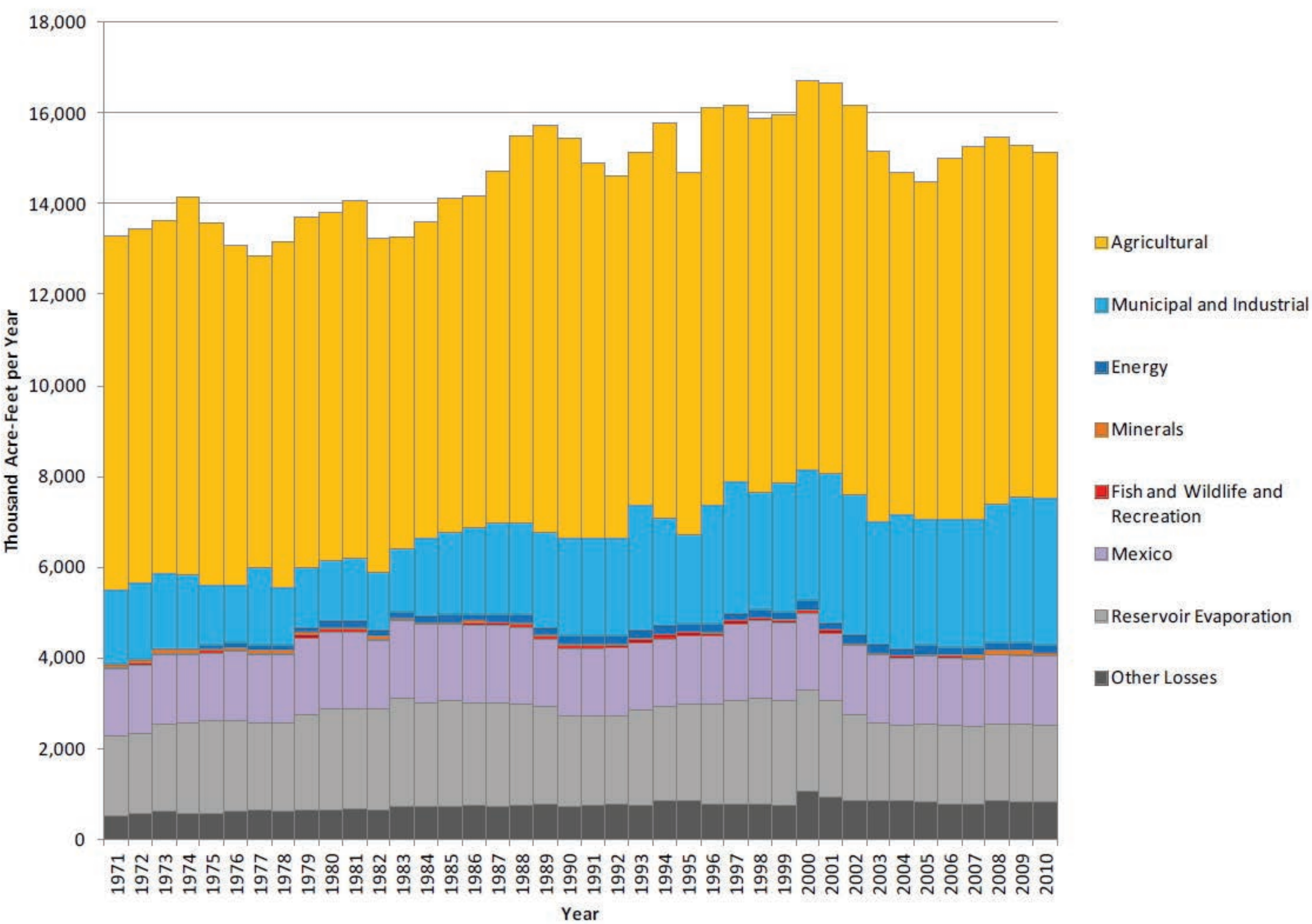
There already exists imbalances between water supply and demand in the basin and this imbalance is projected to increase in both magnitude and spatial extent over the next 50 years (**see Figure 3**). While for several decades storage capacity has been able to mask this imbalance in the current system, future drought and climate variation coupled with population growth in urban and industrial areas are projected to create more strain on the hydrologic basin and its resources. Colorado River water use has increased overall in the past century, primarily from increases in M&I water use despite a decrease in agricultural use. This increase in M&I use has primarily been caused by population growth in the basin states. These states have some of the fastest growing populations in the entire country. Improvements

Figure 3: Total Colorado River System Water Use and Required Deliveries to Mexico vs. Flow at Lees Ferry



Source: Bureau of Reclamation.

Figure 4: Historic Colorado River Water Use by Category (1971-2010)



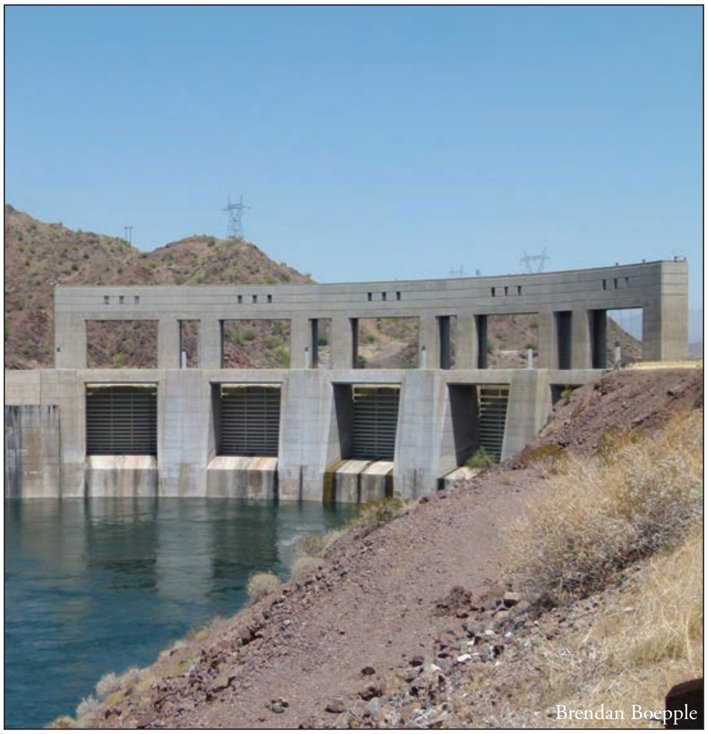
Source: Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." Reclamation Managing Water in the West (2012): 5.

Figure 5: Synopsis of Scenarios to Predict Future Supply and Demand of the Colorado River	
Current Projected (A)	Continuation of growth, development patterns, and institutions follow long-term trends.
Slow Growth (B)	Slow growth with emphasis on economic efficiency.
Rapid Growth (C1 and C2)	Economic resurgence (population and energy) and current preferences toward human and environmental values.
Enhanced Environment (D1 and D2)	Expanded environmental awareness and stewardship with growing economy.
Source: Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." Reclamation Managing Water in the West (2012): 6.	

from indoor fixtures and appliances, such as toilets and washers to outdoor xeriscaping, have led to a decrease in per capita water use and partially offset water demands from population growth; however, these water savings per capita are not significant enough to decrease overall water demand of growing total populations. In recent years, agricultural water use has been somewhat stable with drought causing variance in this pattern. Irrigated acres of land have also decreased in the basin, most likely due to economic conditions, supply limitations, and pressure from municipalities for land change and water transfers.[2] This trend is expected to continue due to population growth in the basin. Water demand for energy use has also increased over time, congruent with population growth in the West. **Figure 4** shows the historic water use of the Colorado River Basin by category. The categories include agricultural, M&I, energy, minerals, tribal, minerals, and fish, wildlife, and recreation.

The BOR's Water Demand-Supply Study analyzed six scenarios to examine possible future water supply and demand conditions related to the Colorado River Basin. **Figure 5** provides a brief synopsis of the BOR scenarios generated by reviewing key driving forces that may affect each scenario in the basin.

For each scenario, the categories of agriculture, M&I, energy, fish, wildlife, recreation, minerals and tribal were analyzed. **Figure 6** provides an overview of the definitions and parameters for each category.



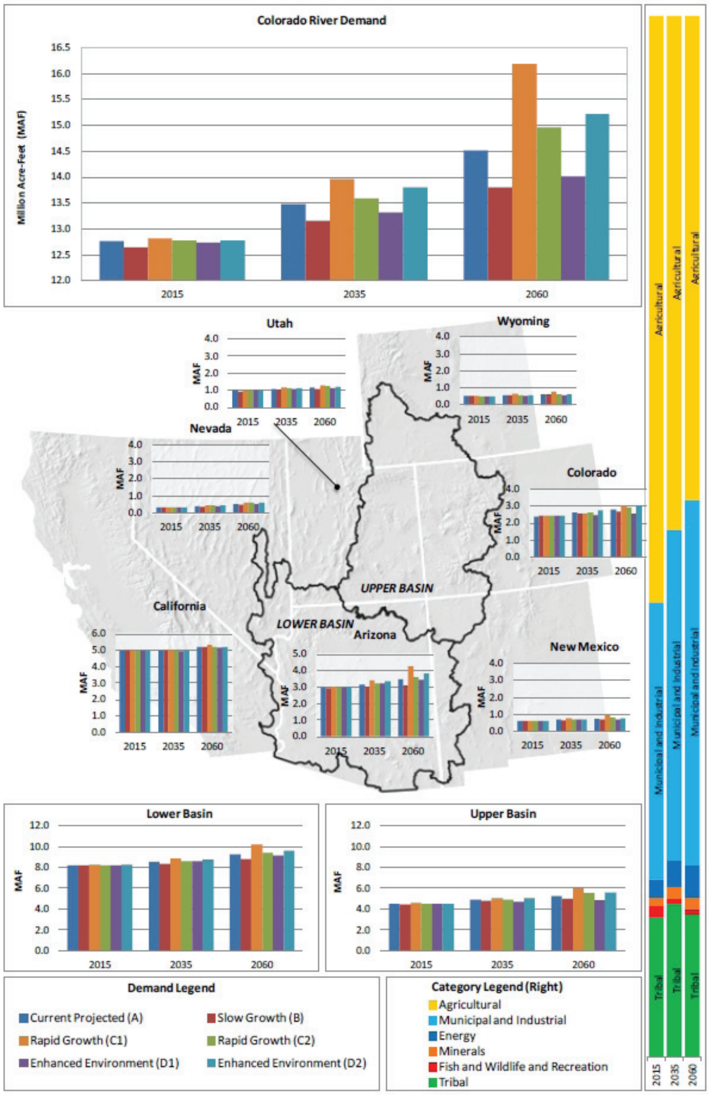
Parker Dam on the California-Arizona border.

Figure 6: Overview of Demand Categories

Demand Category	**Definition**	**Parameters**
Agriculture	Water used to meet irrigation requirements of agricultural crops, maintain stock ponds, and sustain livestock	Irrigated acreage, irrigation efficiency
Municipal and Industrial	Water used to meet urban and rural population needs, and industrial needs within urban areas	Population, population distribution, M&I water use efficiency, consumptive use factor
Energy	Water used for energy services and development	Water needs for energy generation
Minerals	Water used for mineral extraction not related to energy services	Water needs for mineral extraction
Fish, Wildlife, Recreation	Water used to meet National Wildlife Refuge, National Recreation Area, state park, and off-stream wetland habitat needs	Institutional and regulatory conditions, social values affecting water use, Endangered Species Act-listed species needs, and ecosystem needs
Tribal	Water used to meet tribal needs and settlement of tribal water rights claims	Tribal use and settlements

Source: Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." Reclamation Managing Water in the West (2012): 6.

Figure 7: Colorado River Water Demand by State



Source: Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." Reclamation Managing Water in the West (2012): 21.

Note: Demands do not include Mexico's allotment and losses such as reservoir evaporation. These factors will be included in the modeling supporting the system reliability analysis. Tribal demand within Colorado is not reflected in the tribal category but is included in other categories.

The Colorado River demand was analyzed by BOR at three geographic levels that are shown in **Figures 7, 8, and 9.** These figures show the Study Area, both the Upper and Lower Basin, and individual state demands for each scenario. The bars on the right side in these figures show the "relative contribution of each demand category to the total Colorado River demand at a point in time (2015, 2035, or 2060) in the Current Projected (A) scenario. In general, the category proportions remain relatively consistent across the scenarios."[3]

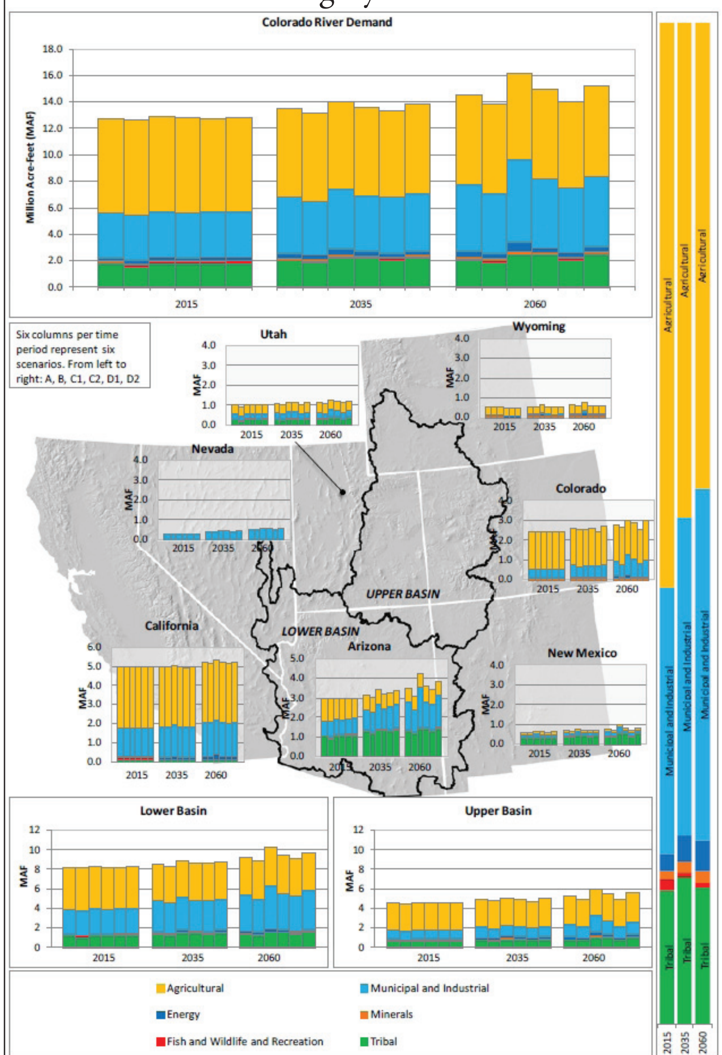
Figure 7 shows that change in Colorado River demand varies substantially across the basin states in both magnitude and percentage with Colorado and Arizona showing the greatest growth in demand in the next 50 years. The varied levels are due to different population growth and M&I demand. Tribal demand is also significant in growth for Arizona.

Figure 8 displays varied levels of demand across the Upper and Lower Basin. There is, however, almost equal demand in agriculture and M&I use in the Lower Basin. The Upper Basin's demand is comprised of two-thirds agriculture.

Figure 9 demonstrates the change in demand by category from 2015 for each scenario with increases in M&I leading to the majority of future growth in demand. Only in the Enhanced Environment (D1) scenario does M&I demand show an insignificant increase to demand, namely because per capita use decreases so substantially. Tribal, energy, and mineral demand are also expected to increase in all scenarios while agricultural demand is projected to decrease.

Figure 10 shows the percent change for each category in relation to the varying scenarios. In all scenarios, agriculture and M&I show the greatest change in demand, with agricultural decreasing and M&I use increasing. Energy also increases in all scenarios while the other categories show variance in the different scenarios.

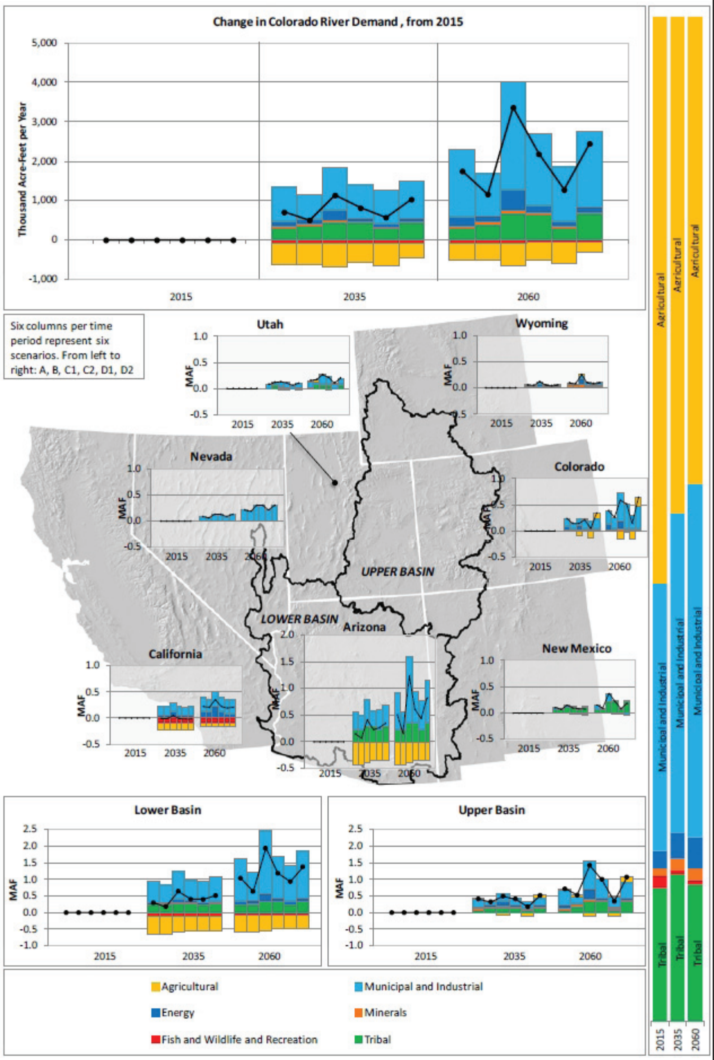
Figure 8: Colorado River Water Demand by Category of Use



Source: Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." Reclamation Managing Water in the West (2012): 22.

Note: Demands do not include Mexico's allotment and losses such as reservoir evaporation. These factors will be included in the modeling supporting the system reliability analysis. Tribal demand within Colorado is not reflected in the tribal category but is included in other categories.

Figure 9: Colorado River Water Changes in Demand 2015-2060 by Category



Source: Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." Reclamation Managing Water in the West (2012): 22.
Note: Demands do not include Mexico's allotment and losses such as reservoir evaporation. These factors will be included in the modeling supporting the system reliability analysis. Tribal demand within Colorado is not reflected in the tribal category but is included in other categories.

Rockies researchers at the Imperial Dam in southern California.

Figure 10: Total Colorado River Changes in Sector Demand- Total and Shares

Total Colorado River Demand	2015	2035	2060
Current Trends (A)	100.00%	100.00%	100.00%
Economic Slowdown (B)	99.16%	97.58%	95.11%
Expansive Growth (C1)	100.62%	103.60%	111.53%
Expansive Growth (C2)	100.20%	100.83%	103.05%
Enh Envir Healthy Econ (D1)	100.48%	99.01%	96.88%
Enh Envir Healthy Econ (D2)	100.53%	102.54%	104.88%
Current Trends (A)	100.00%	100.00%	100.00%
Agricultural	56.42%	49.36%	46.47%
Municipal and Industrial	26.14%	31.36%	34.66%
Energy	1.75%	2.58%	3.04%
Minerals	0.79%	1.15%	1.19%
Fish, Wildlife, and Recreation	1.16%	0.42%	0.45%
Tribal	13.36%	14.71%	13.67%
Other	0.38%	0.43%	0.51%
Economic Slowdown (B)	100.00%	100.00%	100.00%
Agricultural	57.08%	50.80%	49.12%
Municipal and Industrial	26.95%	30.62%	32.28%
Energy	1.77%	2.44%	2.76%
Minerals	0.79%	1.21%	1.28%
Fish, Wildlife, and Recreation	1.18%	0.44%	0.47%
Tribal	11.85%	14.06%	13.54%
Other	0.38%	0.44%	0.54%
Rapid Growth (C1)	100.00%	100.00%	100.00%
Agricultural	55.93%	47.01%	40.69%
Municipal and Industrial	26.40%	32.09%	37.89%
Energy	1.81%	3.39%	4.58%
Minerals	0.82%	1.25%	1.31%
Fish, Wildlife, and Recreation	1.16%	0.41%	0.40%
Tribal	13.51%	15.44%	14.67%
Other	0.37%	0.41%	0.46%
Rapid Growth (C2)	100.00%	100.00%	100.00%
Agricultural	56.37%	49.25%	45.08%
Municipal and Industrial	26.12%	30.81%	34.59%
Energy	1.67%	2.23%	2.46%
Minerals	0.71%	0.95%	0.94%
Fish, Wildlife, and Recreation	1.19%	0.48%	0.57%

Continued on following page.
Source: Bureau of Reclamation

Figure 10: Total Colorado River Changes in Sector Demand- Total and Shares (cont.)

Total Colorado River Demand	2015	2035	2060
Rapid Growth (C2)	100.00%	100.00%	100.00%
Tribal	13.57%	15.85%	15.87%
Other	0.37%	0.43%	0.53%
Enhanced Environment (D1)	100.00%	100.00%	100.00%
Agricultural	56.13%	48.85%	46.80%
Municipal and Industrial	26.20%	31.77%	34.10%
Energy	1.65%	2.15%	2.41%
Minerals	0.71%	1.00%	1.01%
Fish, Wildlife, and Recreation	1.65%	0.95%	0.96%
Tribal	13.30%	14.86%	14.12%
Other	0.37%	0.43%	0.53%
Enhanced Environment (D2)	100.00%	100.00%	100.00%
Agricultural	55.66%	48.47%	44.90%
Municipal and Industrial	26.43%	31.51%	34.81%
Energy	1.65%	2.12%	2.29%
Minerals	0.71%	0.97%	0.94%
Fish, Wildlife, and Recreation	1.66%	0.92%	0.96%
Tribal	13.52%	15.59%	15.61%
Other	6.57%	0.42%	0.49%

Source: Bureau of Reclamation.

In order to understand the projected changes in demand more clearly, the Current Projected Scenario (A) was used in the BOR Study as a baseline against which other scenarios can be compared. In other words, "general relationships were used to relate the expected changes in parameters for each scenario in comparison to the Current Projected (A) scenario consistent with each storyline."[4] **Figure 11** shows these relationships amongst the scenarios.

Comparison of Demand Scenarios

The section below shows a broad comparison of how the scenarios vary over time by focusing on the key "determinant" forces in the basin. The driving forces for each scenario were categorized and include: Demographics and Land Use, Technological and Economics, and Social and Governance.

Demographics and Land Use: Variations in demographics and land use were driven by different rates of economic growth, agricultural water supply projects, conversion of agricultural land to urban land, and phasing out lower economic-value crops. The Current Projected (A) and Enhanced Environment (D1) scenarios reflect a "best estimate" for population projects while Rapid Growth (C1 and C2) and Enhanced Environment (D2) reflect high-end population projections and the Slow Growth (B) model reflects low-end population projections. Agricultural land decreases in all scenarios with the greatest decrease in Rapid Growth (C1 and C2) models; however, irrigated acreage increases in Upper Basin areas in the Current Projected (A) and Slow Growth (B) models by 2060.[5]

Technology and Economics: Different rates of advancement of technology and conservation in the basin will result in reduced levels of water demands for agriculture, M&I and energy with regards to shifts in social values, economic forces, and resource restrictions. Although M&I water use is expected to become more efficient under all scenarios, this greater per capita efficiency varies for each scenario depending upon the changes in social values that will lead to increases in investment for water conserving programs at the local, state, and federal level. For example, Slow Growth (B) contains the lowest efficiency increase because it is expected that there is a slower rate for societal support for conservation programs and a shortage of resources to advance these initiatives. The largest increase in efficiency is in the Enhanced Environment (D1 and D2) scenarios where changes in social values, federal investment, and future conservation efforts are largest.[6]

Agricultural per acre water delivery ranges from a modest increase under the Rapid Growth (C2) scenario to a modest decrease under the Enhanced Environment (D1) scenario. The primary reason for the small decrease under this scenario is favorable economic conditions coupled with changing social values that create a willingness and incentives to invest in agricultural water conservation. This leads to rapid adoption of new technologies, resulting in decreased agricultural demands due to increased agricultural water use efficiency.[7]

Water needs for energy development increase across all scenarios and range from the most modest increase under the Enhanced Environment (D1 and D2) scenarios to the greatest increase under the Rapid Growth (C1 and C2) scenarios. Water needs for energy expand relative to population growth and results in the highest demand under the Rapid Growth (C1) scenario. Under the Enhanced Environment (D1 and D2) scenarios, an emphasis on renewable energy requirements and investments in technologies that reduce water consumption associated with energy production and new development decreases projected water demands for energy production despite a rapidly growing population featured under the Enhanced Environment (D2) scenario.[8]

Social and Governance: Changes in agricultural and M&I water use efficiency and the advancement of ecological and recreational programs have influenced institutional and regulatory changes. Water use efficiency changes vary from no meaningful changes in current practices (shown in Current Trends and Slow Growth scenarios) to increased efficiency from social values (Enhanced Environment). As a result of changing social values, the Enhanced Environment (D1 and D2) scenarios show increases in the following: investments for programs that support the recovery of endangered species, ecological and river recovery, and recreational use;

Figure 11: Scenario Matrix of Typical Changes in Parameters Compared to the Current Projected (A) Scenario

	Population	M&I Per Capita Use	Self-Served Industrial Demand*	Agriculture Irrigated Acreage	Agriculture Efficiency	Energy Demand	Minerals Demand	Fish, Wildlife, Recreation Demand	Tribal Demand
Slow Growth (B)	Slower Growth	No Change	No Change	No Change	Decreased Efficiency	No Change	No Change	No Change	Slower Growth
Rapid Growth (C1)	Rapid Growth	No Change	No Change	Increased Ag Land Use	Decreased Efficiency	Increased Demand	Increased Demand	No Change	Faster Growth
Rapid Growth (C2)	Rapid Growth	Increased Efficiency	Increased Efficiency	Increased Ag Land Use	Increased Efficiency	Decreased Demand	Decreased Demand	Increased Demand	Faster Growth
Enhanced Environment (D1)	No Change	Increased Efficiency	Increased Efficiency	No Change	No Change	Decreased Demand	Decreased Demand	Increased Demand	No Change
Enhanced Environment (D2)	Rapid Growth	Increased Efficiency	Increased Efficiency	No Change	Increased Efficiency	Decreased Demand	Decreased Demand	Increased Demand	Faster Growth

Notes: Blue represents a decrease and red represents an increase in the parameter value when compared to the Current Projected (A) scenario. *Self-served industrial demand represents the demand of industries in a given area that have water supply systems independent of municipal systems.

Source: Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." Reclamation Managing Water in the West (2012): 10.

government regulations for increasing supply and reducing demand; additional incentive programs for renewable energy use; and the implementation of further conservation programs.[9]

Comparing Demand Scenarios

The largest factor for the increase in demand is due to population growth in the basin states. It is estimated that there will be approximately 40 million in the study area by 2015. This figure is expected to increase to between 49 million (low-end population growth) and 77 million (high-end population growth) by 2060.[10] The low-end population growth is modeled in the Slow Growth (B) scenario while the high-end population growth is modeled in the two Rapid Growth (C1 and C2) scenarios and one of the Enhanced Environment (D2) scenarios. As mentioned previously, this growth in demand due to the municipal population will be partially offset by more efficiency in per capita water use. Based on passive and existing conservation measures, per capita water use is already expected to decrease by 7% to 19% by 2060, varying in both the scenarios and basin states.[11] However, this decrease in per capita water use is not enough to offset the increase in total demand of Colorado River water caused by the large influx in population that is predicted in all scenarios.

Irrigated acreage is expected to decrease in all scenarios through 2060. More specifically, irrigated acreage is projected to decrease more than 830,000 acres in the Rapid Growth (C1 and C2) scenarios and decrease about 300,000 to 550,000 in all other scenarios.[12]

Water demand for both energy and mineral use is expected to increase in all scenarios due to the growing demand for energy and mineral extraction. Arizona, California, and Colorado are projected to have the largest increase for energy demand while Arizona, Colorado, and Wyoming are expected to have the largest increase for water use for mineral extraction.

Under all scenarios, tribal demand is projected to increase over time as Native American Treaty water rights become "quantified rights."[13]

Figure 12 provides a brief summary of results for both the Study Area demand and the Colorado River demand with regard to the six scenarios. The first section discusses the changes in population growth, per capita water use, and irrigated acreage as explained above. The next two sections show the changes in the Study Area demand and Colorado River demand in relation to both the categories and the different scenarios. Demand in the Study Area ranges between 28.7 and 32.5 million acre feet (maf) by 2060 while Colorado River demand ranges between 13.8 and 16.2 maf; however, the increase in Study Area demand is expected to be partially met by other supplies. It is projected that Colorado River demand from 2015 to 2060 will increase between 1.1 and 3.4 maf with the Lower Basin contributing to about 60% of the increase.[14]

Figure 12: Summary of the Results for Water Demand Scenario Quantification by 2060

Key Study Area Demand Scenario Parameters							
	2015	2060 Scenario Parameters					
		A	B	C1	C2	D1	D2
Population (millions)	40.0	62.4	49.3	76.5	76.5	62.4	76.5
Change in per capita water usage (%) from 2015	--	-9%	-7%	-9%	-16%	-19%	-17%
Irrigated acreage (millions of acres)	5.5	5.1	5.2	4.6	4.6	4.9	5.0
Change in per-acre water delivery (%), from 2015	--	+1%	+2%	+1%	+3%	0%	+3%
Study Area Demand (maf)							
Agricultural Demand	16.5	15.2	15.7	13.7	13.8	14.9	14.9
Municipal and Industrial Demand	8.6	12.5	10.2	15.1	13.9	11.0	13.7
Energy Demand	0.35	0.66	0.57	1.01	0.58	0.53	0.56
Minerals Demand	0.1-0.11	0.18	0.18	0.22	0.15	0.15	0.15
Fish, Wildlife, and Recreation Demand	0.16-0.23	0.08	0.08	0.08	0.10	0.16	0.16
Tribal Demand[1]	1.6-1.8	2.0	2.0	2.5	2.4	2.1	2.4
Total Study Area Demand[2]	**27.6**	**30.7**	**28.7**	**32.5**	**30.9**	**28.7**	**31.9**
Colorado River Demand (maf)							
Agricultural Demand	7.2	6.7	6.8	6.6	6.7	6.5	6.8
Municipal and Industrial Demand	3.4	5.1	4.5	6.2	5.2	4.9	5.4
Energy Demand	0.22	0.44	0.38	0.74	0.37	0.34	0.35
Minerals Demand	0.09-0.11	0.17	0.18	0.21	0.14	0.14	0.14
Fish, Wildlife, and Recreation Demand	0.15-0.21	0.06	0.07	0.06	0.08	0.15	0.15
Tribal Demand[1]	1.5-1.7	2.0	1.9	2.4	2.4	2.0	2.4
Total Colorado River Demand[2]	**12.8**	**14.5**	**13.8**	**16.2**	**15.0**	**14.0**	**15.2**

Notes: [1] Tribal demand within the state of Colorado is included in other demand categories.
[2] Excludes Mexico's allotment and losses (reservoir evaporation, phreatophytes, and operational inefficiencies).
Source: Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." Reclamation Managing Water in the West (2012): 15.

Figure 13 displays historical Colorado River use coupled with the projected demand scenarios. The figure takes into account past and future losses due to reservoir evaporation and other factors and shows the historical Colorado River use and projected future Colorado River demand by scenario. This figure includes historical and future projected losses (comprised of reservoir evaporation and other losses) and deliveries to Mexico in order to provide a more accurate view of total demand.

Figure 14 shows the percent increase in demand by category with 2008 as the baseline. Expansive Growth (C1) shows the largest increase in overall demand with a total percent increase of 25.06% while Economic Slowdown (B) shows only an increase of 10.74%.

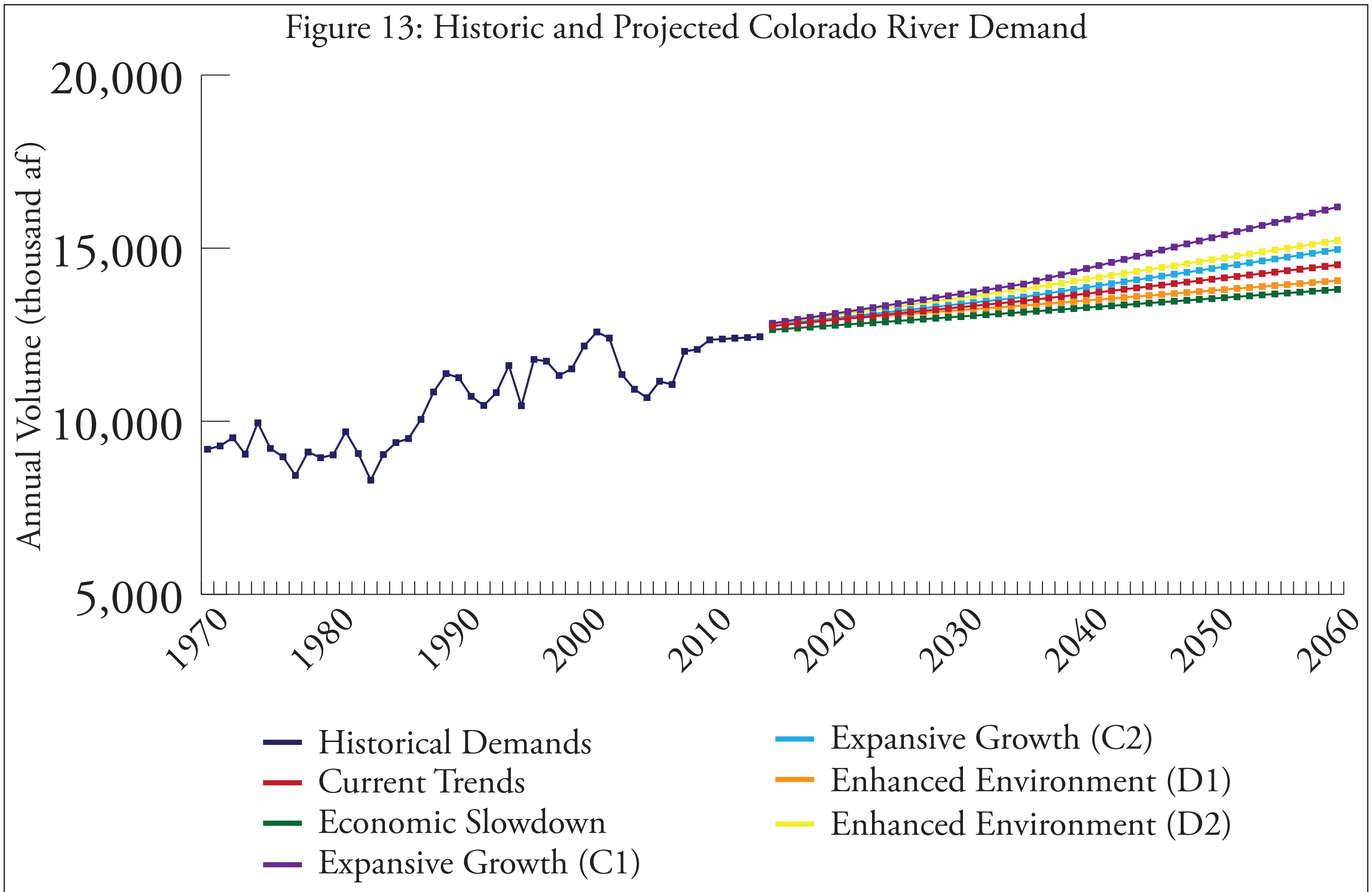
Major Demands for Colorado River Water

Agriculture Water Demand

Agriculture water demand is the largest component of total demand for the Colorado River and is determined by irrigated acreage and per-acre water delivery – the amount of water diverted per acre taking into account losses from evaporation, delivery, farm losses, etc. Under all scenarios, agricultural demand is expected to decrease as a result of reduction in irrigated acreage. Per-acre delivery, however, is expected to increase slightly in all scenarios.

Although demand overall decreases under all scenarios, Upper Basin states show increases in agricultural demand under several scenarios with demand in Colorado showing the largest increase under the Enhanced Environment (D2) scenario. Colorado, however, also shows decreases in demand in several scenarios due to predicted future irrigated acreage. Both Utah and Wyoming show small increases in most scenarios while New Mexico demand varies from no change to a notable decrease. The most significant decreases in demand in the Lower Basin are located in Arizona with small decreases also occurring in California under all scenarios. Nevada has no agricultural demand to report. The main factor behind the decrease in agricultural acreage is increased urbanization, which also causes pressure for water transfers that will greatly affect Colorado and Arizona.[15]

Figure 15 shows the percent change in agricultural demand for each scenario from 2015 to 2060. All scenarios show a significant decrease in demand, with the Expansive Growth (C1) scenario showing the largest decrease with agricultural making up nearly 56% of total demand in 2015, down to 45% in 2060. Economic Slowdown shows the smallest decrease with only about an 8% decrease over the period. **Figure 16** shows the changes in agricultural demand for the scenarios. For each of the scenarios, agricultural decreases significantly until 2035 in which there is then a slight increase for the remaining years.

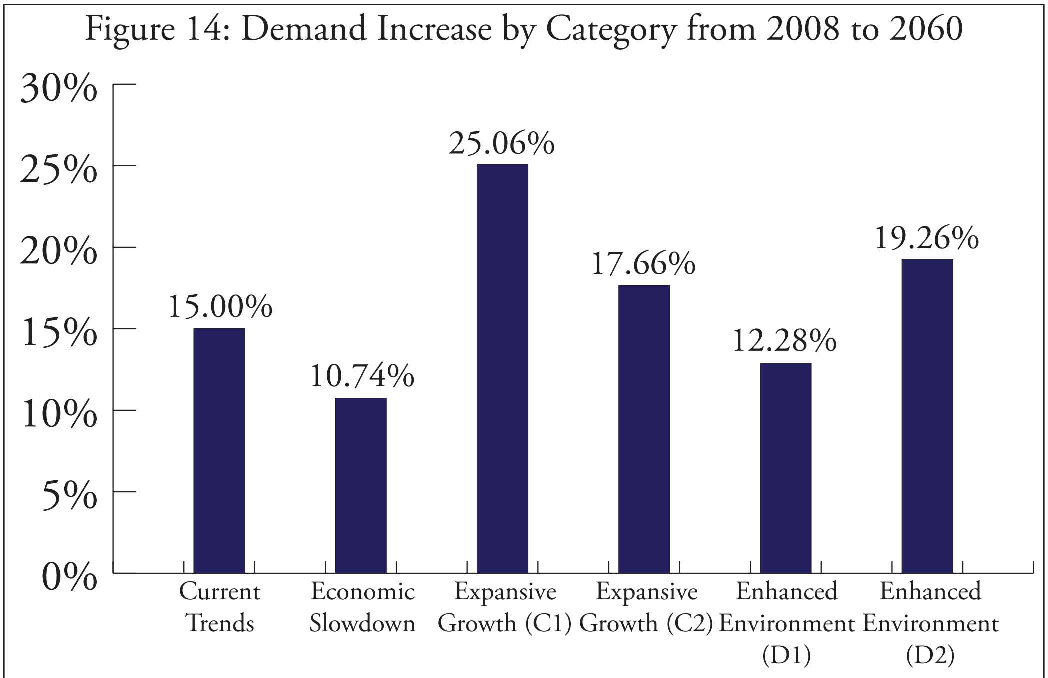


Source: Bureau of Reclamation.

Municipal and Industrial (M&I) Water Demand

M&I demand is the second largest component of total Colorado River demand and is calculated through population, per capita water use, and self-served industrial (SSI) demand. Per capita water use is measured by the amount of water used per person in a given service area that includes industrial, commercial, institutional, and residential demand. SSI demand is a measure of demand by industries that have an independent supply system for water. Since SSI demand is independent, it is not directly correlated to "population and per capita water use rates that are assumed for M&I demand projections" and only makes up less than 10% of M&I demand. Comparing M&I demand is quite difficult because of the many factors that influence it such as climate, number of industries, demographics, economy, number of visitors, etc.[16]

M&I demand is projected to increase in all scenarios. This demand is expected to increase from 27% of total demand in 2015 to between 33-38% by 2060, depending on the scenario. The main catalyst behind this increase is population growth within the basin states. For the Upper Basin, the increase in M&I demand is expected to increase between 19% and 32 %, with Colorado having the most significant impact and Utah and New Mexico contributing as well, while the Lower Basin shows a staggering



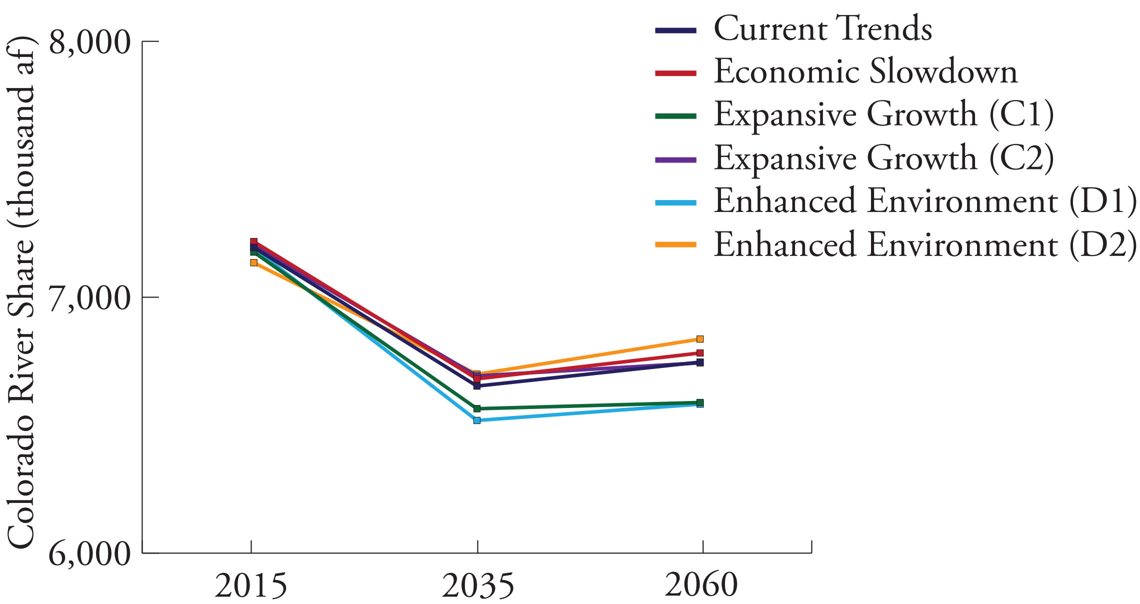
Source: Bureau of Reclamation.

Figure 15: Change in Percent Share of Agricultural Demand from 2015-2060

Agricultural Total Demand	2015	2035	2060
Current Trends	56.42%	49.36%	46.47%
Economic Slowdown	57.08%	50.80%	49.12%
Expansive Growth (C1)	55.93%	47.01%	40.69%
Expansive Growth (C2)	56.37%	49.25%	45.08%
Enhanced Environment (D1)	56.13%	48.85%	46.80%
Enhanced Environment (D2)	55.66%	48.47%	44.90%

Source: Bureau of Reclamation

Figure 16: Change in Share of Agricultural Demand for All Scenarios from 2015-2060



Source: Bureau of Reclamation.

scenarios. Each scenario shows a steady increase from 2015 to 2060.

Energy Water Demand

Water demand for energy is only a small percent of total demand and is comprised of expected growth in the different types of power generation including solar, geothermal, thermoelectric, and oil shale. The water demand for energy is determined by known plans for future power plants and by incorporating a per capita energy water use factor. Because energy can be imported and exported in the Study Area, the relationship between population and energy demand alone cannot determine the actual water demand for energy.[19]

Energy demand is expected to increase from only 1.7% of total demand in 2015, to 2.3% to 4.6% in 2060. All scenarios show an increase in energy demand with the most significant increase shown in the Expansive Growth (C1) scenario. Both the Upper Basin and Lower Basin states all show increases in energy demand with the Upper Basin showing an increase between 31% and 56% primarily due to Colorado, and the Lower Basin showing an increase between 44% and 69% almost entirely from energy growth in California. The Upper Basin shows increases in energy demand from the expansion of thermoelectric power plants and oil shale production while the Lower Basin shows increases in geothermal and solar projects, mainly in California.[20]

increase between 68 and 81% with Arizona alone making up half of the increase. The other half is due to increases in California and Nevada.[17]

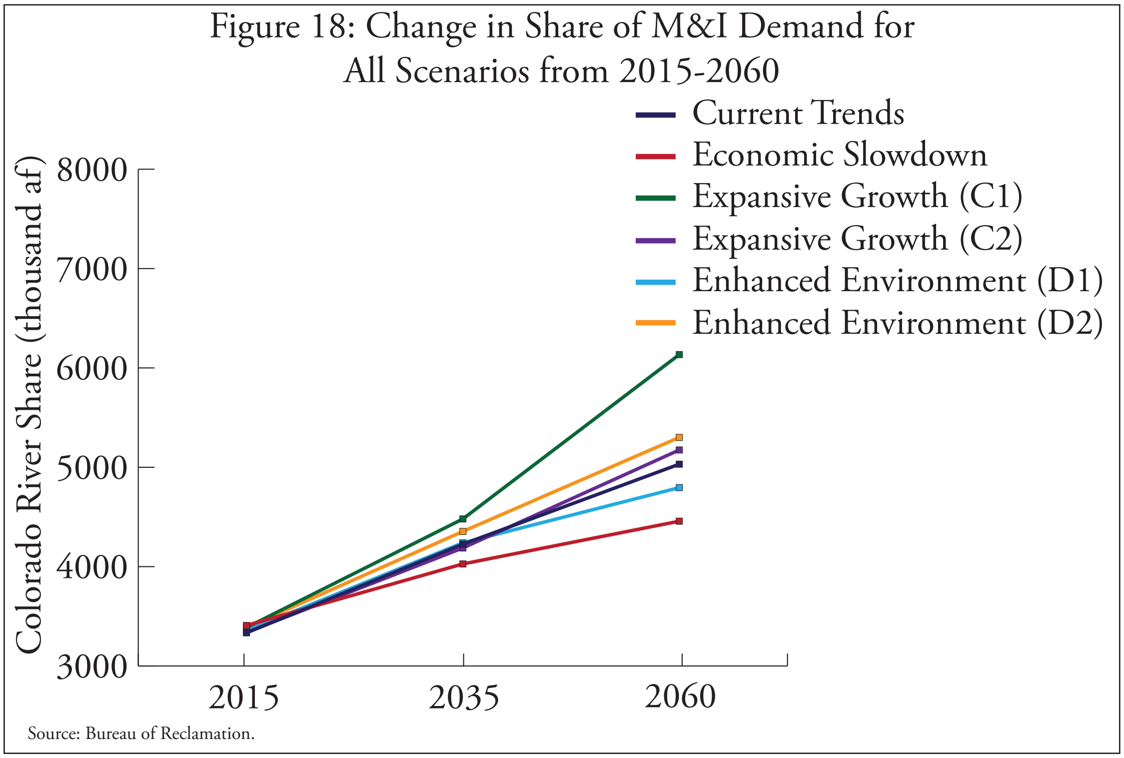
Per capita water use is expected to decrease in six out of the seven basin states in the scenarios. Wyoming is the only state where per capita rates slightly increase due to increased urbanization.[18]

Figure 17 shows the percent change in M&I demand for each scenario from 2015 to 2060. All scenarios show a significant increase in demand, with the Expansive Growth (C1) scenario showing the largest increase with M&I demand making up around 26% of total demand in 2015 to 37% in 2060. Economic Slowdown shows the smallest increase with a percent change of only approximately 5%. The remaining scenarios increase from around 26% to 34-35%. **Figure 18** shows the changes in M&I demand for all

Figure 17: Change in Percent Share of M&I Demand from 2015-2060

M&I Total Demand	2015	2035	2060
Current Trends	26.14%	31.36%	34.66%
Economic Slowdown	26.95%	30.62%	32.28%
Expansive Growth (C1)	26.40%	32.09%	37.89%
Expansive Growth (C2)	26.12%	30.81%	34.59%
Enhanced Environment (D1)	26.20%	31.77%	34.10%
Enhanced Environment (D2)	26.43%	31.51%	34.81%

Source: Bureau of Reclamation



A Study of Colorado River Basin Water Demand by the Colorado College State of the Rockies Project

For the purpose of this report, we focused on agriculture, M&I, and energy uses as they constitute more than 80% of water usage in the Colorado River Basin. We also excluded Expansive Growth (C2) and Enhanced Environment and Healthy Economy (D2) from our analysis for simplicity's sake as our research has determined that these scenarios will be the least likely to reflect conditions in the future.

The scenarios were determined by differentiated factors in population, efficiency, institutional and regulatory ordinances, and social values. **Appendix A-C** lists the descriptions for each scenario for agricultural, M&I, and energy demand.

Figure 19: Change in Percent Share of Energy Demand from 2015-2060

Energy Total Demand	2015	2035	2060
Current Trends	1.75%	2.58%	3.04%
Economic Slowdown	1.77%	2.44%	2.76%
Expansive Growth (C1)	1.81%	3.39%	4.58%
Expansive Growth (C2)	1.67%	2.23%	2.46%
Enhanced Environment (D1)	1.65%	2.15%	2.41%
Enhanced Environment (D2)	1.65%	2.12%	2.29%

Source: Bureau of Reclamation

Figure 19 shows the percent change in energy demand for all scenarios from 2015 to 2060. All scenarios show an increase, but Expansive Growth (C1) shows the largest percent change, increasing from 1.8% to 4.6%. The other scenarios range from an increase of 1.7-1.8% to 2.4-3.0%. **Figure 20** shows the change in energy demand for all scenarios. Each scenario displays a steady increase in demand over the time span. The Expansive Growth (C1) scenario shows a significant increase in demand compared to the remaining scenarios.

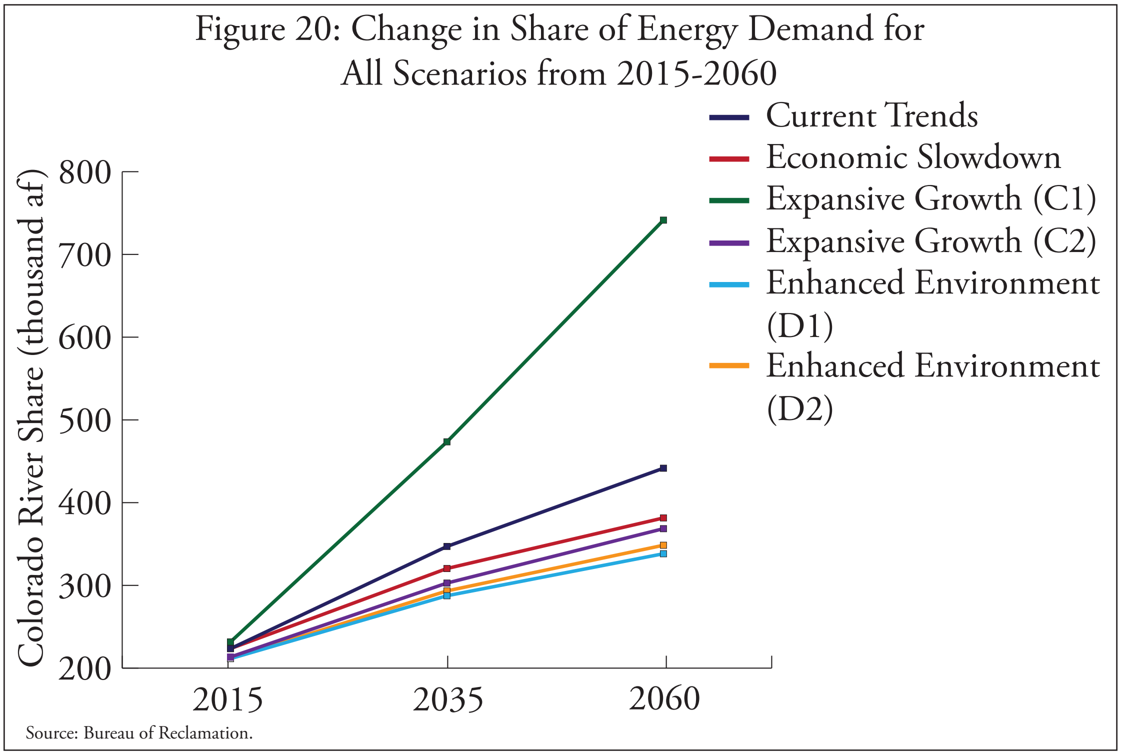
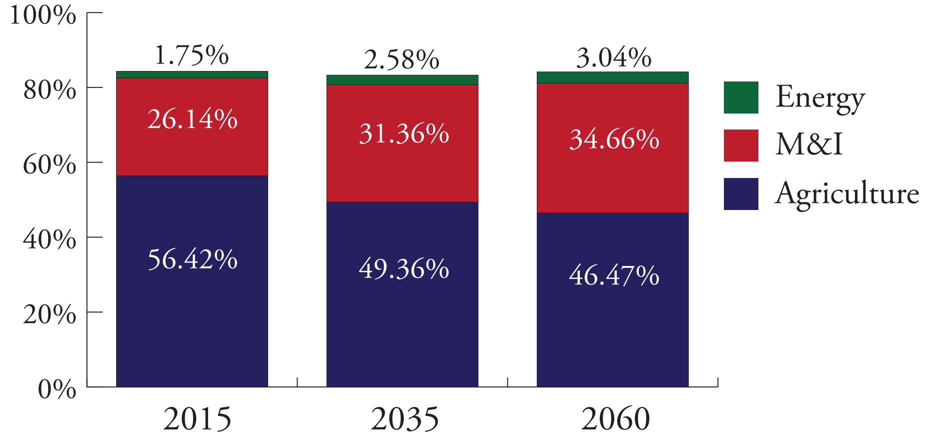
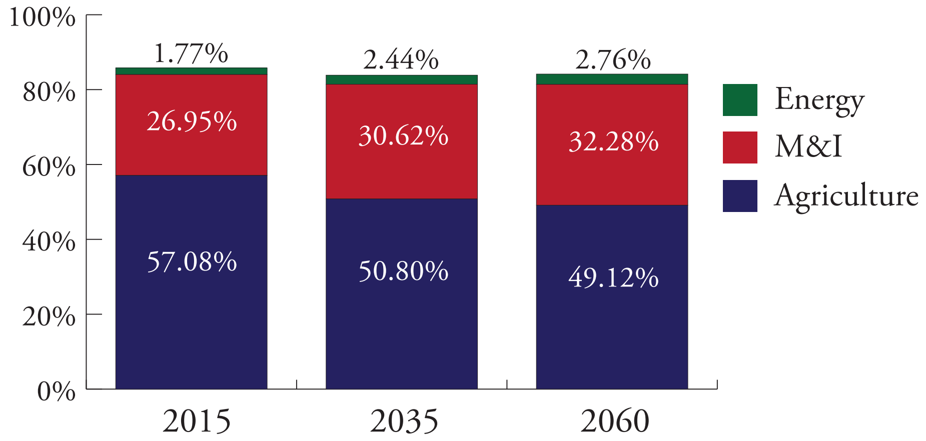


Figure 21: Percent Change in Agricultural, M&I, and Energy Demand for Current Trends Scenario



Source: Bureau of Reclamation.

Figure 22: Percent Change in Agricultural, M&I, and Energy Demand for Economic Slowdown Scenario



Source: Bureau of Reclamation.

provide a total quantity not to exceed 1,700,000 acre-feet a year. In such cases Mexico does not acquire additional permanent water rights beyond the guaranteed 1.5 million acre feet annually. Finally, in the event of extraordinary drought or serious accident to the irrigation system in the United States, thereby making it difficult for the United States to deliver the guaranteed quantity of 1,500,000 acre-feet a year, the water allotted to Mexico will be reduced in the same proportion as consumptive uses in the United States are reduced.[21]

Native Americans

Water demand for Native Americans is based on quantified entitlements and rights; however, numerous tribes in the basin have unquantified rights. Projections for tribal demand are based on quantified rights and future use and development.[22]

Climate Change Effects on Demands

The BOR study expected that future water demand may be affected by climate change in the coming years, specifically with regards to stream flow and climate (temperature and precipitation). The BOR addresses the effects of expected future climate change, namely temperature and precipitation, on evapotranspiration (which affects agriculture), outdoor M&I use, phreatophyte, and reservoir evaporation losses. Changes not addressed by the BOR study that could be caused by climate change include changes in demand for energy, environmental flow regulations, and changes in crop type.[23]

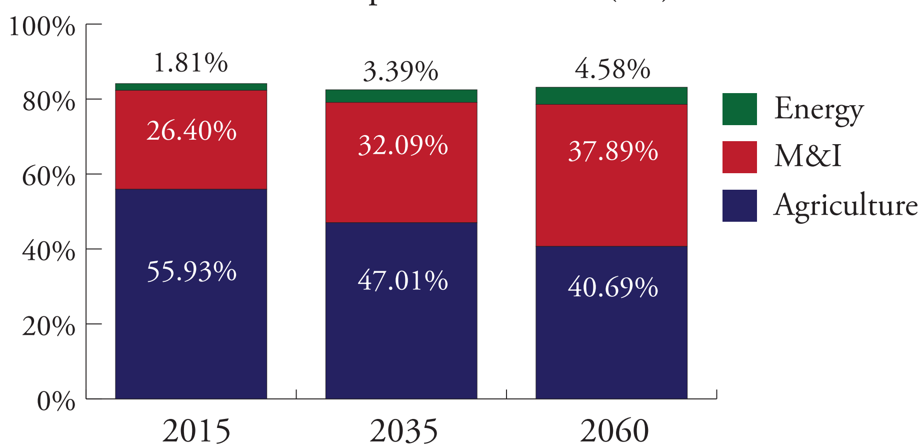
Figures 21-26 show a comparison in the percent change in demand for agricultural, M&I, and energy demand for each scenario. Each scenario shows a decrease in agriculture and an increase in M&I and energy demand.

Other Demand Sectors

Mexico

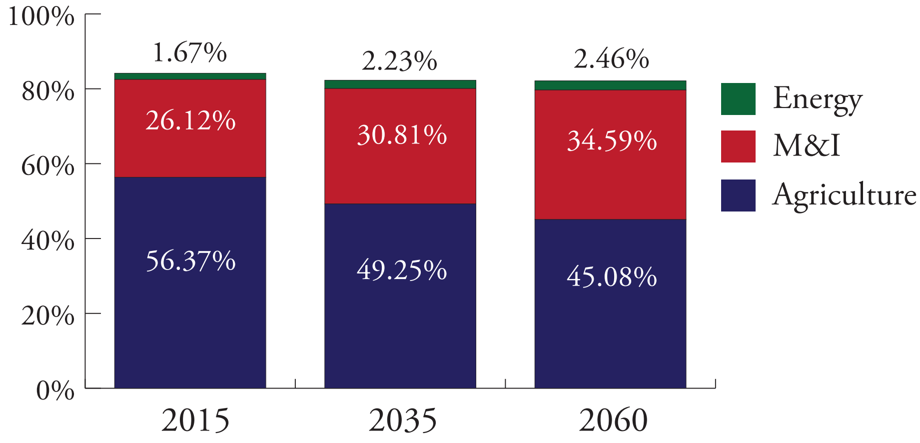
Mexico was awarded access to Colorado River water under a 1944 treaty that specifies: "Of the waters of the Colorado River, from any and all sources, there are allotted to Mexico: A guaranteed annual quantity of 1,500,000 acre-feet." Plus when it is determined that there exists a surplus of waters of the Colorado River in excess of the amount necessary to supply uses in the United States and the guaranteed quantity of 1,500,000 acre-feet annually to Mexico, the United States will undertake to deliver to Mexico additional waters of the Colorado River system to

Figure 23: Percent Change in Agricultural, M&I, and Energy Demand for Expansive Growth (C1) Scenario



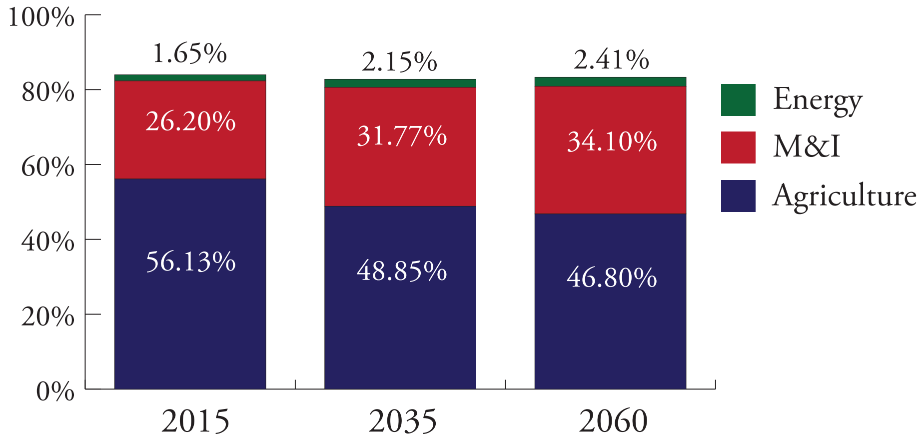
Source: Bureau of Reclamation.

Figure 24: Percent Change in Agricultural, M&I, and Energy Demand for Expansive Growth (C2) Scenario



Source: Bureau of Reclamation.

Figure 25: Percent Change in Agricultural, M&I, and Energy Demand for Enhanced Environment (D1) Scenario



Source: Bureau of Reclamation.

Reservoir Evaporation

Reservoir evaporation varies depending on the surface area of a reservoir and the climate of the region. The evaporation from large basin reservoirs, including Lake Mead, Lake Mohave, and Lake Havasu in the Lower Basin and Morrow Point, Blue Mesa, Crystal, Fontenelle, Flaming Gorge, Navajo, and Lake Powell in the Upper Basin, was calculated on a monthly basis through a modeling simulation in the BOR study. Calculations for smaller reservoirs are estimated from historical losses that are calculated monthly through model simulation. Evaporation from other reservoirs in the basin states is estimated from historical losses.[24]

Limitations

The BOR study demand scenarios for the Colorado River are by no means concrete and many factors can influence demand for each of the categories including population growth, efficiency, agricultural markets, government regulations, social values, availability of supplies and resources, and a variety of other forces that will continue to change in the future. The scenarios do not include programs by water management companies that may alter demand. Actual demand in the future will be compromised of both external factors (that the BOR uses to predict their scenarios) and direct, active management. The quantification of the scenarios was based on information provided by the basin states. Because the information was state-provided, there are differences in the treatment of data, reference points, assumptions, methods, etc.[25] Regardless, the BOR study still represents a comprehensive evaluation of Colorado River demand.

Citations:

[1] "Colorado River Basin Water Supply and Demand Study: Basin Study Program." Bureau of Reclamation press release, September 2011, on the Bureau of Reclamation's website, http://www.usbr.gov/lc/region/programs/crbstudy/FactSheet_May2011.pdf, accessed September 19, 2012.

[2] Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." *Reclamation Managing Water in the West* (2012): 4-5.

[3] Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." *Reclamation Managing Water in the West* (2012): 8.

[4] Ibid.

[5] Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." *Reclamation Managing Water in the West* (2012): 13.

[6] Ibid.

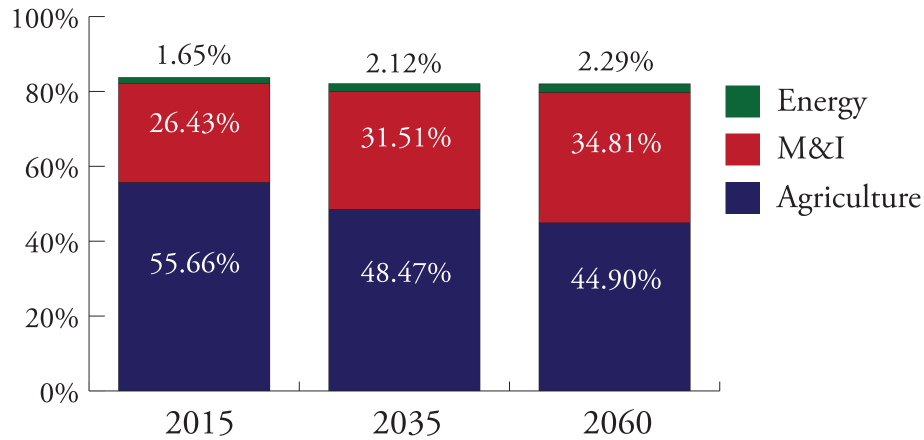
[7] Ibid.

[8] Ibid.

[9] Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." *Reclamation Managing Water in the West* (2012): 14.

Citations continue on page 45.

Figure 26: Percent Change in Agricultural, M&I, and Energy Demand for Enhanced Environment (D2) Scenario



Source: Bureau of Reclamation.

Appendix A: Agriculture Demand Scenario Descriptions

Agriculture Scenarios	Land Use	Water Use Efficiency	Institutional and Regulatory	Social Values
Current Trends	There are nominal increases in irrigated agricultural lands primarily due to the build out of currently planned agricultural water supply projects. Agricultural land use growth varies by location with some agriculture to urban land conversion occurring and lower economic-value crops being phased out in some areas.	Current trends in agricultural water use efficiency continue making modest improvements to on-farm and system efficiency through projects such as those supported under the Salinity Control Program. These improvements result in little change to Colorado River Basin consumptive use. No radical changes in technology are anticipated. Agricultural uses are generally consistent with today's practices (e.g., no major changes in techniques, crops, or practices).	Federal and state laws and regulations affecting the basin continue in a similar manner as today. Despite the potential for sunsetting of future regulations and agreements, the operations of the Colorado River are relatively unchanged.	Social values that affect water use in all categories remain consistent with the recent past. These values include continued support for ongoing planned M&I and agricultural conservation efforts as well as support for the ESA and its implementation.
Economic Slowdown	There are nominal increases in irrigated agricultural lands primarily due to the build out of currently planned agricultural water supply projects. Agricultural land use growth varies by location with some agriculture to urban land transfer occurring and lower economic-value crops being phased out in some areas.	Lack of economic growth results in decreased revenues and reduced capital investment for routine and long-term maintenance. Reduced maintenance results in an overall decline in on-farm and delivery efficiency. These efficiency reductions require greater diversions to meet consumptive use requirements. However, Colorado River Basin consumption changes little as additional losses are returned to the Colorado River system.	Economic slowdown and focus on economic efficiency lead to no significant change in institutional and regulatory requirements. Existing federal and state laws and regulations affecting the basin continue.	Economic efficiency is the overwhelming driver affecting social values. Social values that affect water use in all categories trend toward preferences for human water use and systems over other concerns. This focus is driven largely by a lack of funds for capital outlay and a lack of societal willingness to take on new programs.
Expansive Growth (C1)	Agricultural land use increases at a slightly faster rate than current trends due primarily to economic growth resulting in faster development of currently planned projects. Agricultural land use growth varies by location with some agriculture to urban land transfer occurring and lower economic-value crops being phased out in some areas.	Lack of economic growth results in decreased revenues and reduced capital investment for routine and long-term maintenance. Reduced maintenance results in an overall decline in on-farm and delivery efficiency. These efficiency reductions require greater diversions to meet consumptive use requirements. However, Colorado River Basin consumption changes little as additional losses are returned to the Colorado River system.	Federal and state laws and regulations affecting the basin continue in a similar manner as today. Despite the potential for sunsetting of future regulations and agreements, the operations of the Colorado River are relatively unchanged.	Social values that affect water use in all categories remain consistent with the recent past. These values include continued support for ongoing planned M&I and agricultural conservation efforts as well as support for the ESA and its implementation.
Expansive Growth (C2)	Agricultural land use increases at a slightly faster rate than current trends due primarily to economic growth resulting in faster development of currently planned projects. Agricultural land use growth varies by location with some agriculture to urban land transfer occurring and lower economic-value crops being phased out in some areas.	Economic conditions result in investment and rapid adoption of new technologies resulting in significant increases in agricultural water use efficiency. These technologies result in denser cropping patterns and higher yields with subsequent greater overall consumptive use demand. Irrigation techniques and delivery system water control are significantly improved over current trends. Gains in distribution efficiency partially offset the increased consumptive use.	Changing social values leads to increased governmental regulation including the enactment of climate change and greenhouse gas mitigation measures. These measures primarily manifest themselves in more integrated management of water and energy (water use efficiency).	Slight increase in social values and subsequent pressure focused on conservation efforts results in management of the basin with increased flexibility for multiple water uses (e.g., recreational). Trends continue toward M&I conservation adoption.
Enh Envir Healthy Econ (D1)	There are nominal increases in irrigated agricultural lands primarily due to the build-out of currently planned agricultural water supply projects. Agricultural land use growth varies by location, with some agriculture to urban land conversion occurring and lower economic-value crops being phased out in some areas.	Current trends in agricultural water use efficiency continue making modest improvements to on-farm and system efficiency through projects such as those supported under the Salinity Control Program. These improvements result in little change to Colorado River Basin consumptive use. No radical changes in technology are anticipated. Agricultural uses are generally consistent with today's practices (e.g., no major changes in techniques, crops, or practices).	Changing social values leads to increased governmental regulation including the enactment of climate change and greenhouse gas mitigation measures. These measures primarily manifest themselves in more integrated management of water and energy (water use efficiency).	Increase in social values and subsequent pressure focused on conservation efforts results in management of the basin with increased flexibility for multiple water uses (e.g., recreational). Trends continue toward M&I conservation adoption and public demand for in-stream flows (tourism, Wild and Scenic Rivers).
Enh Envir Healthy Econ (D2)	There are nominal increases in irrigated agricultural lands primarily due to the build-out of currently planned agricultural water supply projects. Agricultural land use growth varies by location, with some agriculture to urban land conversion occurring and lower economic-value crops being phased out in some areas.	Economic conditions result in investment and rapid adoption of new technologies, resulting in significant increases in agricultural water use efficiency. These technologies result in denser cropping patterns and higher yields with subsequent greater overall consumptive use demand. Irrigation techniques and delivery system water control are significantly improved over current trends. Gains in distribution efficiency partially offset the increased consumptive use.	Changing social values leads to increased governmental regulation including the enactment of climate change and greenhouse gas mitigation measures. These measures primarily manifest themselves in more integrated management of water and energy (water use efficiency).	Increase in social values and subsequent pressure focused on conservation efforts results in management of the basin with increased flexibility for multiple water uses (e.g., recreational). Trends continue toward M&I conservation adoption and public demand for in-stream flows (tourism, Wild and Scenic Rivers).

Source: Bureau of Reclamation

Appendix B: M&I Scenario Descriptions

M&I Scenarios	Population	M&I Water Use Efficiency	Institutional and Regulatory	Social Values
Current Trends	Populations in the basin, the adjacent water-dependent basins, and the southwestern U.S. grow at rates commensurate with the "best estimate" demographic projections. Population growth generally occurs centered in existing urban areas.	Increases according to current basin water provided policies and technology. External factors, beyond the control of basin water providers, that limit the water use of fixtures and appliances (e.g., federal statutes) continue resulting in "natural" increases in in-home efficiency. Water use efficiency changes vary by location according to local goals and mix of water use categories. No radical changes in technology are anticipated.	Federal and state laws and regulations affecting the basin continue in a similar manner as today. Despite the potential for sunsetting of future regulations and agreements, the operations of the Colorado River are relatively unchanged.	Social values that affect water use in all categories remain consistent with the recent past. These values include continued support for ongoing planned M&I and agricultural conservation efforts as well as support for the ESA and its implementation.
Economic Slowdown	Economic efficiency is the overwhelming driver affecting social values. Social values that affect water use in all categories trend toward preferences for human water use and systems over other concerns. This focus is driven largely by a lack of funds for capital outlay and a lack of societal willingness to take on new programs.	Water use efficiency increases according to current policies (e.g., SNWA's current gpcd planning goals) and technology. External factors that limit the water use of fixtures and appliances (e.g., federal statutes) continue resulting in "natural" increases in in-home efficiency. Water use efficiency changes vary by location according to local goals and mix of water use categories. No radical changes in technology are anticipated. Aging infrastructure and lack of capital investment due to economic slowdown result in some acute water loss events. However, these events are generally absorbed by the long-term natural trends toward greater efficiency.	Economic slowdown and focus on economic efficiency lead to no significant change in institutional and regulatory requirements. Existing federal and state laws and regulations affecting the basin continue.	Economic efficiency is the overwhelming driver affecting social values. Social values that affect water use in all categories trend toward preferences for human water use and systems over other concerns. This focus is driven largely by a lack of funds for capital outlay and a lack of societal willingness to take on new programs.
Expansive Growth (C1)	Rapid population growth focused around urban centers with sprawl to outlying areas is driven by rapid economic recovery followed by a period of prolonged growth. This population growth is similar to typical "High" demographic projections for the southwest basin states.	Water use efficiency increases according to current policies (e.g., SNWA's current gpcd planning goals) and technology. External factors that limit the water use of fixtures and appliances (e.g., federal statutes) continue, resulting in "natural" increases in in-home efficiency. Water use efficiency changes vary by location according to local goals and mix of water use categories. No radical changes in technology are anticipated.	Federal and state laws and regulations affecting the basin continue in a similar manner as today. Despite the potential for sunsetting of future regulations and agreements, the operations of the Colorado River are relatively unchanged.	Social values that affect water use in all categories remain consistent with the recent past. These values include continued support for ongoing planned M&I and agricultural conservation efforts as well as support for the ESA and its implementation.
Expansive Growth (C2)	Rapid population growth focused around urban centers with sprawl to outlying areas is driven by rapid economic recovery followed by a period of prolonged growth. This population growth is similar to typical "High" demographic projections for the southwest basin states.	Increased federal investment in water-saving technology and conservation programs results in a substantive increase in water-saving technology (e.g., WaterSmart, EnergyStar, landscape technology). These technologies are applied basin-wide, resulting in reduced demand and consumptive use.	Changing social values lead to increased governmental regulation including the enactment of climate change and greenhouse gas mitigation measures. These measures primarily manifest themselves in more integrated management of water and energy (water use efficiency).	Slight increase in social values and subsequent pressure focused on conservation efforts results in management of the basin with increased flexibility for multiple water uses (e.g., recreational). Trends continue toward M&I conservation adoption.
Enh Envir Healthy Econ (D1)	Populations in the Basin, the adjacent water-dependent basins, and the Southwestern United States grow at rates commensurate with the "best estimate" demographic projections. Population growth generally occurs centered in existing urban areas.	Increased federal investment in water-saving technology and conservation programs results in a substantive increase in water-saving technology (e.g., WaterSmart, EnergyStar, landscape technology). These technologies are applied basin-wide, resulting in reduced demand and consumptive use.	Changing social values lead to increased governmental regulation including the enactment of climate change and greenhouse gas mitigation measures. These measures primarily manifest themselves in more integrated management of water and energy (water use efficiency).	Increase in social values and subsequent pressure focused on conservation efforts results in management of the basin with increased flexibility for multiple water uses (e.g., recreational). Trends continue toward M&I conservation adoption and public demand for in-stream flows (tourism, Wild and Scenic Rivers).
Enh Envir Healthy Econ (D2)	Rapid population growth focused around urban centers driven by rapid economic recovery, followed by a period of prolonged growth. This population growth is similar to typical "High" demographic projections for the southwest basin states.	Increased federal investment in water-saving technology and conservation programs results in a substantive increase in water-saving technology (e.g., WaterSmart, EnergyStar, landscape technology). These technologies are applied basin-wide, resulting in reduced demand and consumptive use.	Changing social values lead to increased governmental regulation including the enactment of climate change and greenhouse gas mitigation measures. These measures primarily manifest themselves in more integrated management of water and energy (water use efficiency).	Increase in social values and subsequent pressure focused on conservation efforts results in management of the basin with increased flexibility for multiple water uses (e.g., recreational). Trends continue toward M&I conservation adoption and public demand for in-stream flows (tourism, Wild and Scenic Rivers).

Source: Bureau of Reclamation

Appendix C: Energy Demand Scenario Descriptions

Energy Scenarios	Water Needs	Institutional and Regulatory	Social Values
Current Trends	Water needs for energy expand relative to population growth and current regulations, policies, and planning for the energy industry. Current requirements for renewables are met according to current schedules. Fossil fuel development and, in particular, oil-shale development occur according to current plans. No dramatic changes to global economies or energy demand that would spur additional consideration occur (e.g., increased fossil fuel prices.)	Federal and state laws and regulations affecting the basin continue in a similar manner as today. Despite the potential for sunsetting of future regulations and agreements, the operations of the Colorado River are relatively unchanged.	Social values that affect water use in all categories remain consistent with the recent past. These values include continued support for ongoing planned M&I and agricultural conservation efforts as well as support for the ESA and its implementation.
Economic Slowdown	Water needs for energy expand relative to population growth and current regulations, policies, and planning for the energy industry. Current requirements for renewables are met according to current schedules. Despite the regional economic slowdown, global energy demand and in particular fossil fuel development (including oil-shale development) occur according to current plans. No dramatic changes to global economies or energy demand that would spur additional consideration occur (e.g., increased fossil fuel prices.)	Economic slowdown and focus on economic efficiency lead to no significant change in institutional and regulatory requirements. Existing federal and state laws and regulations affecting the basin continue.	Economic efficiency is the overwhelming driver affecting social values. Social values that affect water use in all categories trend toward preferences for human water use and systems over other concerns. This focus is driven largely by a lack of funds for capital outlay and a lack of societal willingness to take on new programs.
Expansive Growth (C1)	Water needs for energy expand relative to population growth and current regulations, policies, and planning for the energy industry. Current requirements for renewables are met according to schedules. Fossil fuel development and, in particular, oil-shale development, occur at a faster rate due to economic drivers spurring growth in energy production.	Federal and state laws and regulations affecting the basin continue in a similar manner as today. Despite the potential for sunsetting of future regulations and agreements, the operations of the Colorado River are relatively unchanged.	Social values that affect water use in all categories remain consistent with the recent past. These values include continued support for ongoing planned M&I and agricultural conservation efforts as well as support for the ESA and its implementation.
Expansive Growth (C2)	Water needs for energy expand relative to population growth and current regulations, policies, and planning for the energy industry. However, investment in technology results in adoption of water-saving techniques (e.g., dry cooling). Renewable energy requirements continue, with an emphasis on dry cooling due to an increase in social considerations related to carbon production. World economic conditions do not favor new fossil fuel development in the southwest.	Changing social values lead to increased governmental regulation including the enactment of climate change and greenhouse gas mitigation measures. These measures primarily manifest themselves in more integrated management of water and energy (water use efficiency).	Slight increase in social values and subsequent pressure focused on conservation efforts result in management of the basin with increased flexibility for multiple water uses (e.g., recreational). Trends continue toward M&I conservation adoption.
Enh Envir Healthy Econ (D1 & D2)	There are nominal increases in irrigated agricultural lands primarily due to the build-out of currently planned agricultural water supply projects. Agricultural land use growth varies by location, with some agriculture to urban land conversion occurring and lower economic-value crops being phased out in some areas.	Changing social values leads to increased governmental regulation including the enactment of climate change and greenhouse gas mitigation measures. These measures primarily manifest themselves in more integrated management of water and energy (water use efficiency).	Increase in social values and subsequent pressure focused on conservation efforts result in management of the basin with increased flexibility for multiple water uses (e.g., recreational). Trends continue toward M&I conservation adoption and public demand for in-stream flows (tourism, Wild and Scenic Rivers).

Source: Bureau of Reclamation

Citations (cont.):

[10] Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." *Reclamation Managing Water in the West* (2012): 15.

[11] Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." *Reclamation Managing Water in the West* (2012): 16.

[12] Ibid.

[13] Ibid.

[14] Ibid.

[15] Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." *Reclamation Managing Water in the West* (2012): 24.

[16] Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." *Reclamation Managing Water in the West* (2012): 26.

[17] Ibid.

[18] Ibid.

[19] Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." *Reclamation Managing Water in the West* (2012): 28.

[20] Ibid.

[21] Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." *Reclamation Managing Water in the West* (2012): 41.

[22] Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." *Reclamation Managing Water in the West* (2012): 34.

[23] Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." *Reclamation Managing Water in the West* (2012): 41-42.

[24] Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." *Reclamation Managing Water in the West* (2012): 44-45.

[25] Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." *Reclamation Managing Water in the West* (2012): 47-48.

Agricultural Water Use in the Colorado River Basin: Conservation and Efficiency Tools for a Water Friendly Future

By Nathan Lee and Alice Plant

Key Findings:

-Irrigation efficiency strategies are often cost-prohibitive for farmers and fail to offer a silver bullet for water conservation in agriculture.

-Buy-and-dry methods of water transfers from agricultural to varying uses are short sighted solutions and can have devastating impacts on rural economies and communities.

-Alternative transfer methods must play a crucial role in meeting the competitive needs of urban, environmental, energy, and recreational uses.

-Only through water law that is more flexible, as well as a social shift from conflict to collaboration, will water efficient irrigation technologies and alternative agricultural transfer methods aid in allocating Colorado River water for future generations.

The 2013 Colorado College State of the Rockies Report Card
Water Friendly Futures for the Colorado River Basin

About the Authors:
Nathan Lee (Colorado College class of '13) and **Alice Plant** (Colorado College class of '13) are 2012-13 Student Researchers for the State of the Rockies Project.

Introduction

Agriculture in the Colorado River Basin has historically represented the essence of the West. Initiated by the Homestead Act of 1862 and the settlement of the West, agriculture has facilitated, either directly or indirectly, the existence of each inhabitant in the Colorado River Basin while providing the nation with vital agricultural products. Whether agriculture will continue to support the basin's agricultural demand, or whether the basin becomes a region of largely imported agricultural goods with dwindling rural areas will largely be determined by the path of the water discourse in the next decade. As these issues unravel, finding creative ways to balance agricultural, municipal, and energy interests is paramount in the context of total water demand increasingly dwarfing a variable and stressed water supply.

By far the largest sector of use in the region, agriculture, utilizes approximately 56-80% of the water in the Colorado River Basin.[1] Several sources, including the Bureau of Reclamation (BOR), have cited current agricultural water use as consuming as high as 70-80% of Colorado River water.[2] However, there remains a discrepancy between this figure and the predicted decrease in agriculture water demand under the BOR's Current Trends scenario of 56.42% in 2015. This is likely due to the baseline data that was used for the demand scenarios and possibly due to different methods of measurement.

Agricultural users hold many water rights that are senior to municipal, industrial, and recreational users, as agriculture was one of the first sectors to put the water to "beneficial use." The Colorado River is one of the most dammed,

Nathan Lee

regulated, and diverted rivers in the world.[3] Its water is already over appropriated and current growth trends for the region predict that more than 30 million people reliant on Colorado River water will increase to 50 million people by 2035 and again rise to 62 million people by 2060.[4] Since 'new' water supplies have been exhausted or deemed impractical, a reallocation of water in the basin is inevitable; the majority of these transfers will be from agricultural to municipal uses.

Historically, municipal water providers have in the early decades made claim to water, and in the later decades permanently purchased and diverted water rights from farmers or irrigation ditch companies to cities. These sales ensure a more secure water supply for cities, but also have a largely negative impact on rural communities and agriculture production. To counter the growing concern over the adverse social, environmental, and economic impacts of these types of "buy-and-dry" purchases of water rights, numerous individuals and organizations have devoted time to creating alternative programs. Examples of these alternative agricultural transfer methods include temporary water leasing agreements between cities and irrigation ditch companies, rotational fallowing programs, and the creation of "water banks." Successful implementation of these programs has the potential to balance competing interests and moderate conflicts between rural and municipal communities.

Under the current regime of prior appropriation, many farmers have little incentive to practice water efficient irrigation techniques. The Law of the River functions on what is known as a "use it or lose it" system. Farmers can either use the water they are apportioned or "lose it" and allow it to flow to downstream users. Only water that is considered part of the historical crop consumptive use[5] can be transferred to other alternative water uses.[6] Practices that reduce historical consumptive uses are considered "water conservation" practices; alternatively, practices that decrease non-consumptive losses are considered "water-efficiency" (or irrigation efficiency) practices. Changing to more efficient on-farm irrigation techniques generally is not considered to decrease crop consumptive use; therefore, any water "saved" under those practices is nontransferable and must flow downstream to junior users.[7] Further, changing to more efficient techniques can cost $400-$1,000 per acre of land, a prohibitive cost for most farmers. Nevertheless, examples of more efficient irrigation techniques exist in the basin, largely thanks to research and support from the U.S. Department of Agriculture (USDA) and extension offices at the states' land grant universities.

Water is the limiting factor in the vitality of ecosystems, communities, and economies throughout the Colorado River Basin. Although agricultural use is often demonized as using water inefficiently, this is not the case. The Law of the River allows only a specified amount of water to be transferred out of agriculture. Beyond that, irrigation runoff eventually reappears in the river in the form of return flows, ultimately to be used multiple times over by downstream users. The notion that agriculture uses water inefficiently misses the inherent complexities of the system.

Before delving into the different water efficient strategies in agriculture and the potential of alternative agricultural transfer methods, it is imperative to consider both the relative importance of these practices and the complexities involved in implementation. Changing irrigation techniques or creating water sharing programs have costs that are often prohibitively high. Additionally, legal and administrative barriers exist. Adjudication processes can last years as state engineers must ensure that transfers are in compliance with the "No Harm Rule" and interstate compacts. The question remains to be answered whether or not we can develop societal mechanisms to transfer water in a way that is administratively and financially efficient.

What we have sketched in this introduction is the "necessary" element of water efficiencies and water sharing in the Colorado River Basin. In the following pages we show that the technology exists and the costs can be mediated for farmers to use more efficient irrigation techniques. We also provide examples of where water sharing programs have been successfully implemented. The "sufficient" part of the puzzle is highly dependent on the human ability to compromise and the flexibility or adaptability of the Law of the River. The history of water law in the basin has demonstrated instances of rigidity and flexibility; so too have the individuals representing divergent interest groups. Only through future water law that is more flexible and a social shift from conflict to collaboration will water efficient irrigation technologies and alternative agricultural transfer methods be able to fulfill the potential they promise. We owe nothing less to future generations!

Water Efficient Strategies in Agriculture

As population growth and a changing climate stress water availability in the Colorado River Basin, water efficiency strategies in agriculture are believed to have the potential to stretch existing supplies. However, due to prior appropriation and water use laws in the Colorado River Basin, the

Figure 1: Gated Pipe Irrigation System

Source: Alice Plant.

Figure 2: On-Farm Irrigation Systems

System	Method	Description
Surface (Gravity)	Flood	Water is diverted from ditches to fields or pastures.
	Furrow	Water is channeled down furrows for row crops or fruit trees.
	Border	Water is applied to sloping strips of fields bordered by ridges.
Sprinkler (Pressurized)	Pivot and Linear Systems	High Pressure.
		Medium Pressure.
		Low Pressure.
	Side Rolls	Mobile pipelines deliver water across fields using sprinklers.
	Solid Set	Pipes placed on fields deliver water from raised sprinkler heads.
Micro-irrigation (Pressurized)	Surface	Emitters along pipes or hoses deliver water directly to the soil surface.
	Subsurface	Emitters along pipes or hoses deliver water below the soil surface.
	Micro-sprinklers	Emitters on short risers or suspended by drop tubes sprinkle or spray water above the soil surface.

Source: Agriculture Water Conservation: Irrigation Water Use Management- Best Management Practices. Texas Water Development Board, Conservation Division, 2011.

"savings" from on-farm efficiency measures do not necessarily translate into transfers to other uses. Improved methods of water delivery and application generally require less labor, leech less water through the soil, improve soil and water quality, and increase crop yields by increasing the uniformity of water application. These methods do not decrease the necessary amount of water required by an individual plant; the improvements simply increase efficiency, that is, the amount of water consumed by a plant relative to the amount of water applied to a field.

The benefits of improved irrigation and water delivery methods in agriculture are widespread throughout the basin. Instream flows are essential to the health and livelihood of the Colorado River and have the potential to increase with water efficient irrigation methods. In addition to supplying water to downstream users, instream flows improve riparian health and help to maintain aquifer levels. Water quality and soil health also increase with improved irrigation methods. Water applied with more precision leads to decreased erosion, leeching, and runoff. Consequently, decreased runoff reduces the amount of beneficial nutrients removed from the topsoil. In addition, the amount of fertilizers, pesticides, and salts that are absorbed in the runoff decreases, thereby increasing water quality and salinity levels.

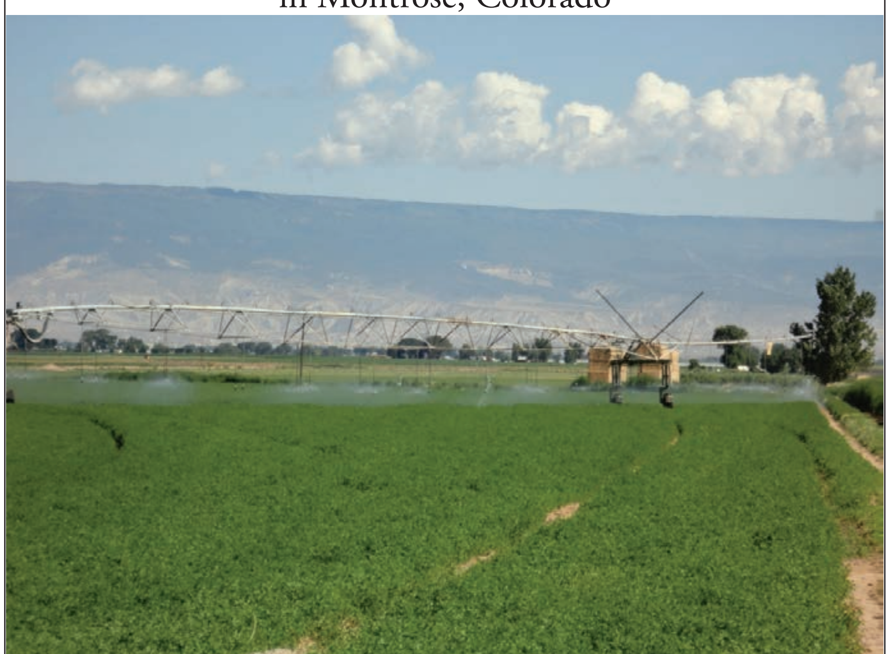
Irrigation Technologies

Converting to more efficient on-farm irrigation technologies is not the simple remedy that many may think. Although water efficiency[8] increases and the negative effects of runoff and seepage decrease with these methods, the success of an irrigation system is dependent upon the management of the system and the specific circumstances of each user. Flood irrigation is historically the most basic and low cost means of applying water to crops. Fed by gravity, furrows or gated pipe systems carry the water over the surface of the field (**Figure 1**). However, this system of irrigation has proven to result in low water efficiency, low uniformity of delivery, and high losses to evaporation.[9] To counter these effects, more efficient irrigation methods such as sprinkler, drip, and sub-irrigation are being implemented across the Colorado River Basin. Differences between irrigation systems are due to the amount of runoff, deep percolation, and evaporation. **Figure 2** offers a description of the most standard on-farm irrigation systems.

Sprinkler Irrigation

Sprinkler irrigation systems are a versatile but costly method of irrigating crops that can be utilized where surface irrigation is unsuitable and inefficient. There are several methods of water application, pressure, and movement of sprinklers depending on the type of crop being irrigated. **Figure 3** is an example of a center pivot unit. These systems carry with them the benefit

Figure 3: Center Pivot Sprinkler Irrigation in Montrose, Colorado



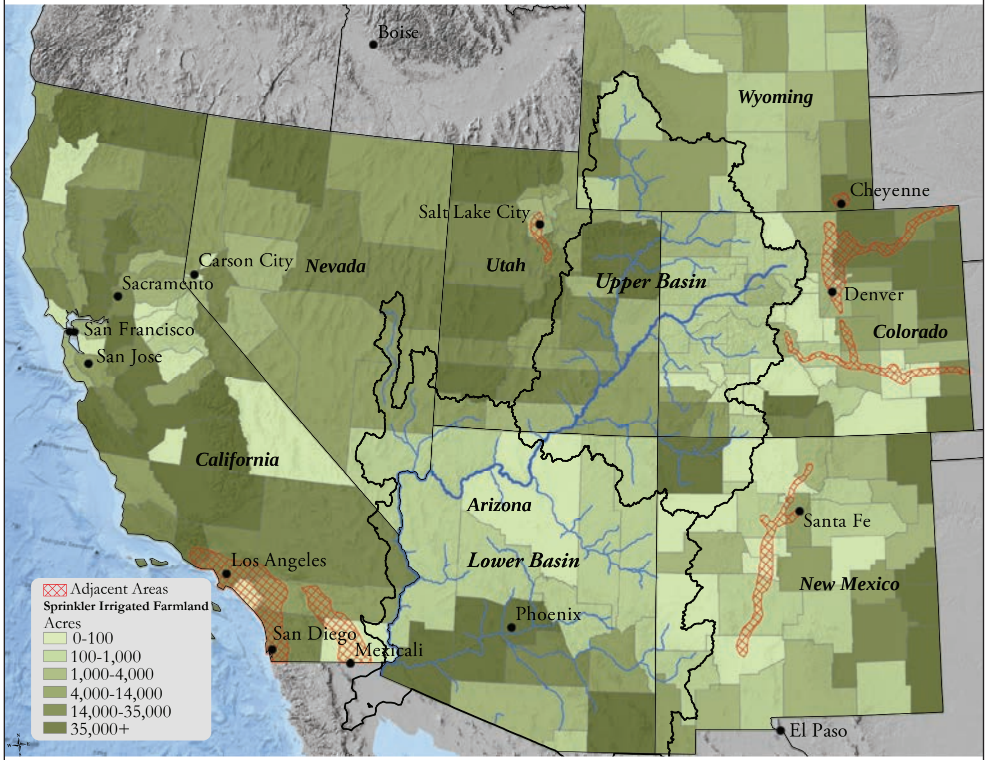
Source: Alice Plant.

of reduced losses to evaporation. Additionally, the increased uniformity of water application can lead to increased yields. As seen in **Figure 4**, there is extremely high variability in efficiencies and cost of implementation within each system and the benefits are dependent upon the management of the system and the selection of an appropriate sprinkler system that fits both the crop's and farm's needs.

An added cost of many sprinkler systems is the high-energy cost of pumping water into the raised system, whereas for a gravity-fed flood irrigation system the energy cost is extremely low or negligible. With a given diesel price of $2.20 per gallon (a low estimate for today's fuel prices), the cost for pumping water through a center pivot system on 130 acres is roughly $65/acre.[10] However, these costs have the potential to be offset by increased yields and productivity.

In 2005, twenty-five percent of the Colorado River Basin's irrigated land was covered by sprinkler irrigation.[11] **Figure 5** describes the distribution of sprinkler irrigated acres across the basin states as of 2005. However, over the last eight years there has been a substantial increase in sprinkler irrigated acres.

Figure 5: Sprinkler Irrigated Land



Source: Estimated use of water in the United States county-level data for 2005 in U.S. Geological Survey [database online]. 2005 [cited October 10, 2012]. Available from http://water.usgs.gov/watuse/data/2005/.

Much of the irrigation infrastructure development is due, in part, to Environmental Quality Incentives Programs (EQIP) run by the USDA Natural Resource Conservation Service (NRCS). EQIP was established under the 1996 Farm Bill and provides financial assistance to plan and implement conservation practices that address natural resource concerns.[12]

Figure 4: Estimated Efficiencies and Costs for Irrigation Methods

Type of Irrigation	Range of Application Efficiency	Average Capital Cost/ Acre	Average Annual Cost/ Acre
Flood	30-50%	--	--
Furrow	40-60%	$37	$30
Gated Pipe	~60%	$178	$51
Center Pivot Circle	~85%	$433	$64
Center Pivot with Corner	~85%	$568	$80
Subsurface Drip Irrigation	~90%	$1,000	$120

Source: Colorado Agricultural Water Alliance. Meeting Colorado's Future Water Supply Needs: Opportunities and Challenges Associated with Potential Agricultural Water Conservation Measures. 2008.

The 2008 Farm Bill prioritized surface water conservation as a national priority for EQIP. As a result, a concerted effort is underway in the Colorado River Basin to address those concerns. In 2010, 5.2 million acres were involved in EQIP projects throughout the basin states. The EQIP program has provided subsidies to many of those acres to offset the $430-$570 per acre cost of implementation of sprinkler irrigation systems.[13]

Micro-irrigation

Micro-irrigation systems are the most efficient and costly method of irrigation and include surface drip, subsurface drip (SDI), and micro-sprinklers or micro-sprayers. Micro-irrigation systems deliver water at a slow and frequent rate to the soil. These systems offer a high level of uniformity in water delivery, flexibility in applying water, and considerably decrease water losses. Under proper management of these systems, water is supplied only to the plant's root zone, decreasing water losses to evaporation, runoff, and water consumption by weeds. These systems' ability to create optimal growing conditions can result in up to 25% increases in crop productivity.[14]

A major disadvantage to micro-irrigation systems is the prohibitive initial costs of equipment. As **Figure 4** indicates, subsurface drip irrigation can cost upwards of $1,000/acre for initial implementation with an additional $120/acre in annual upkeep. In addition to high costs, there is a high potential threat of clogging in the equipment, often going unnoticed until signs of stress are shown through the plant. The state-of-the-art subsurface drip irrigation system shown in **Figure 6** costs $400,000 for 80 acres with the installation of

Figure 6: State-of-the-art Subsurface Drip Irrigation System and Settling Pond

Source: Alice Plant.

20 acres/year over a four-year period. However, the system has a 20-year life expectancy and the ability to irrigate up to 80 acres, double the capacity of most drip irrigation systems. In addition, with EQIP and other government programs covering up to 80% of the cost, the final fee borne by the individual farmer can drop as low as $80,000, or $1,000/acre.[15] **Figure 7** shows the economic advantage micro-irrigation systems offer over less efficient furrow irrigation.

Figure 7: Economic Comparison of Drip and Furrow Irrigation Methods

Economic Activity Evaluated for Each Scenario	Drip Irrigation Percentage as Compared to the Same Furrow-Irrigated Farm Model, 2000
Yield	+25%
Chemicals	-18%
Fertilizer	-26%
Capital	+47%
Fixed Costs	+19%
Seed Costs	-20%
Net Operating Profit	**+12%**

Source: Hawkes, Jerry. Drip Irrigation for Row Crops: Economic comparison of drip and furrow irrigation methods for Dona Ana and Sierra counties. New Mexico State University no. 573 (2001): 11.

Irrigation Scheduling

The ability to irrigate efficiently greatly depends on access to information. Peter Williams, Technology Chief of IBM's Big Green Innovations, stated at the 2011 Water Conference in Colorado, "Irrigation efficiency isn't just about water flow; it's about information flow too."[16] Programs like Colorado Agricultural Meteorological Network (CoAgMet) have been developed to increase that information flow to an expansive audience by offering real-time information from a wide-range of locations across various states. CoAgMet allows water users to access information via the internet, including hourly, daily, and monthly summaries of weather and crop water use data.[17] Public access to this data allows irrigators to better manage their water, decide when to irrigate, and at what level. **Figure 8** depicts a CoAgMet station located at the NRCS Limited Irrigation Research Farm in Greeley, Colorado. Irrigation scheduling offers the potential to decrease the amount of water diverted by senior users, leaving more water in the stream system for junior users and environmental stream health.

Deficit Irrigation

The era of agricultural production in a water abundant environment is quickly disappearing. As agricultural production under water scarcity will soon become the norm, agricultural producers must learn how to effectively manage their crops with a limited water supply. Understanding the physiological processes of crops and the amount of water needed to maximize "crop per drop" can help producers maximize profits in times of drought. Deficit irrigation refers to the practice of applying water below the plant's evapotranspiration (ET) requirements. The practice specifically times water application to critical growth stages to obtain maximum yields with limited water supplies.[18]

Figure 8: CoAgMet Station

Source: Alice Plant.

Case Study: Deficit Irrigation Helping Farmers Manage Crops in Times of Shortage

Tom Trout is the lead researcher at the Central Great Plains Limited Irrigation Research Farm (LIRF) in Fort Collins, Colorado. Currently, Trout and his associates are conducting a field study of four common Great Plains crops- field corn, sunflower (oil), drybeans (pinto) and winter wheat- to determine how to maximize productivity per unit of water consumed.[19]

The study takes place on a 50-acre plot with six different irrigation applications ranging from fully irrigated down to 40% of full irrigation. The crops are set up with drip irrigation that is monitored and regulated by real-time readings from a CoAgMet weather tower stationed at LIRF. Each plot is equipped with devices to measure soil moisture in addition to infrared thermometers that are placed throughout the rows to measure canopy temperature – one of the first indications of crop stress (**Figure 9**).

Initial findings indicate that yield per unit of consumptive use of water for corn tends to decrease with deficit irrigation, implying that in watersheds where return flows are depended upon by downstream users (such as the Colorado River Basin), deficit irrigation may not be economically viable.[20] Trout asserts that corn farmers may be more successful by irrigating a portion of their crops with full irrigation, fallowing another section, and leasing that water to other uses in times of shortage.[21] In addition, Trout's research will help farmers determine the price at which to lease water to nonagricultural uses based on projected water use and yields.

Figure 9: Deficit Irrigation Levels at the USDA ARS Water Management Research Unit, Fort Collins, Colorado

Source: Alice Plant.

Irrigation Delivery Systems

Canal Lining

Aging canal infrastructure is a serious problem facing the Colorado River Basin. As current infrastructure ages, water losses to seepage will continue to escalate. Due to the vast geographic scale of the Colorado River and wide distribution of water users, conveyance infrastructure in the basin is immense. Unlined, earthen canals can exhibit water losses to seepage at levels as high as 50%.[22] There is a wide range of strategies to diminish water losses to seepage and evaporation in canals. Compaction can be used in earthen canals and, in some cases, can improve efficiency to levels similar to concrete lined canals. However, compacted earthen canals require frequent maintenance. **Figure 10** describes average canal efficiencies for well-maintained canals for various soil types.

Figure 10: Conveyance Efficiencies for Adequately Maintained Canals

	Earthen Canals			Lined Canals
Soil Type	**Sand**	**Loam**	**Clay**	
Canal Length				
Long (>2000m)	60%	70%	80%	95%
Medium (200-2000m)	70%	75%	85%	95%
Short (<200m)	80%	85%	90%	95%

Source: C. Brouwer, K. Prins, and M. Heibloem. Irrigation Water Management: Irrigation Scheduling. FAO, 1989.

Lining canals with impermeable materials is another option; however, it is often cost-intensive and requires maintenance, although, less frequently. Additionally, in wet years seepage from canals may be relied upon to recharge groundwater resources and meet the demands of junior users.

Polyacrylamides

Water efficiency in earthen-lined canal systems can be enhanced with the addition of a soil conditioner called polyacrylamide (PAM). PAM was used in irrigation canals in the late 1990s to reduce soil erosion, enhance infiltration, and increase water quality in runoff. Erosion in furrow-irrigated canal systems is nearly eliminated with the addition of small amounts of the water-soluble PAM. PAM improves water quality by increasing soil adhesion and strengthening aggregates in the furrow (**Figure 11**).[23] On average, costs of implementing PAM treatments cost $37-88/ha per crop, a price that is easily compensated by reductions in erosion-related operations, increased infiltration, and water conservation.[24] The use of polyacrylamides has proven to be an appealing, low-cost alternative for many agricultural producers who oppose other irrigation efficiency measures.

Figure 11: Polyacrylamide (PAM) Increases Water Quality

Source: USDA ARS Northwest Irrigation and Soils Research Laboratory in Kimberly, Idaho.

Crop Management

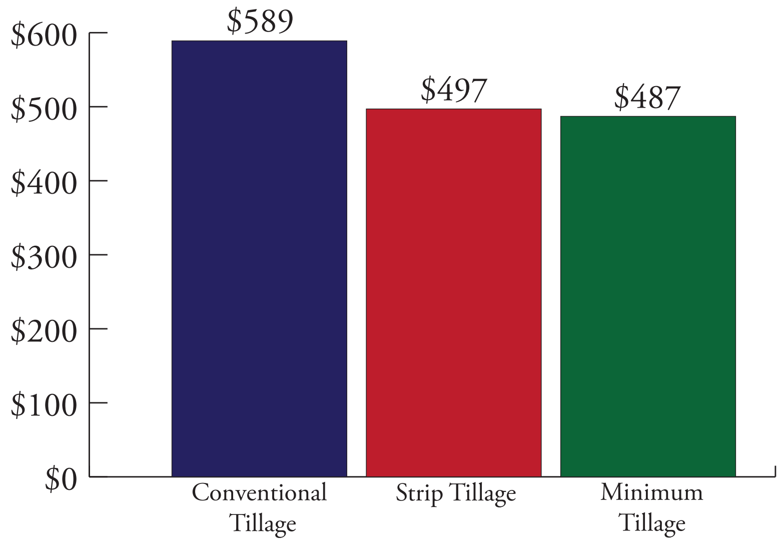
Conservation Tillage

Conventional tillage[25] methods leave soils susceptible to erosion by wind and water and can decrease soil productivity over time. Conservation tillage practices are commonly used in arid agricultural regions to retain soil moisture and better utilize water by leaving up to one third of the surface covered by crop residue at planting time (**Figure 12**).[26] Conservation tillage increases the ability of soil to store water due to reduced soil evaporation and increased infiltration of precipitation and irrigation water during the growing season and increased snow catch during the non-growing season.[27] During the growing season, the plant residue acts as a buffer against solar evaporation, much like canopy shading, and allows the soil to retain higher moisture levels. In addition, conservation tillage protects against losses of organic matter in the soil due to erosion by wind and water.

Tillage management practices are particularly effective when paired with sprinkler irrigation systems. Sprinkler systems often deliver water at a greater rate than the soil is able to infiltrate.[28] When these irrigation systems are paired with residue management, infiltration rates rise, thereby increasing the efficiency of the overall water delivery system. Further, changes in tillage management can allow growers to utilize a more intensive crop rotation, such as wheat-corn-fallow rather than a wheat-fallow rotation.[29]

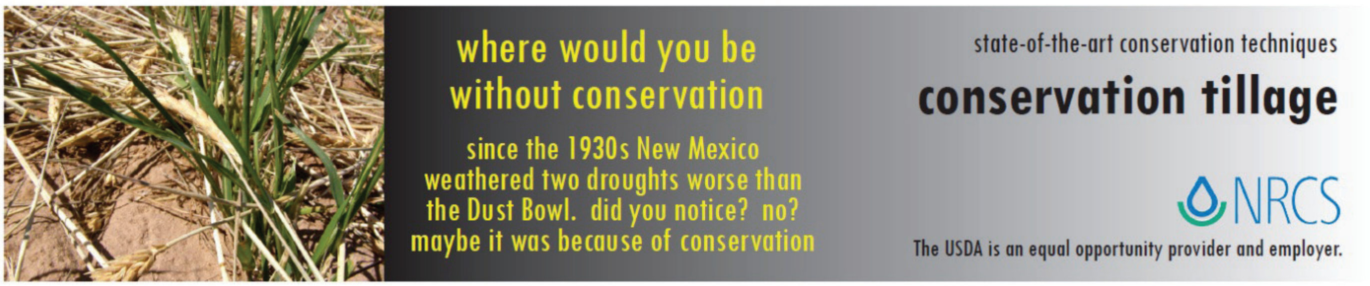
In a study conducted by New Mexico State University, conservation tillage was found to reduce fuel and oil use by up to 60% when compared to conventional tillage. In addition to fuel savings, labor, time, and machinery costs also decrease with conservation tillage practices. The study found that the conservation tillage system saved $27.71/acre in irrigation fuel and oil savings.[30] Colorado State University's Conservation Tillage Demonstration and Outreach Project found that these savings lead to an overall decrease in total cost per acre, as seen in **Figure 13**. Under minimum tillage, this can lead to a 17% reduction in cost per acre.[31]

Figure 13: Total Cost per acre Tillage Comparison



Source: Driscoll 2012.
Notes: Includes variable costs of seed, fertilizer, herbicides, fuel, crop insurance, and fixed cost of machinery ownership. Minimum tillage refers to the minimum amount of tillage required for crop production. Strip tillage refers to the practice of tilling only a narrow strip of land for the crop row.[32]

Figure 12: NRCS Conservation Tillage



Source: USDA, NRCS.

In a future where financial resources are stretched thin and farmers are in a constant battle to remain economically viable, the advantages of conservation tillage are great. Not only are soil, water, and organic matter resources conserved, but high cost inputs are also reduced, while concurrently improving crop productivity. For a farmer then, whose primary concern is to run an economical business, conservation tillage is an appealing way to conserve water, increase crop yields, and ultimately, increase profits. Although it may be an economically rational choice to implement conservation tillage practices, many farmers have yet to utilize the practice due to lack of information, inadequate resources, and a lack of confidence in the system.[33]

Crop Rotation

The sequencing of crops has the potential to increase yields and decrease irrigation water usage, leaving more water available for downstream users. Crop rotations spread the irrigation over a longer period of the season compared with a single crop while maintaining full irrigation levels.[34] Further, crop rotations are strategically designed to leave optimum levels of organic residue to improve soil quality. Due to the variability in soil quality, crops, compatibility of the land, and how the crops are managed, the results of a crop rotation program are dependent upon the appropriate selection of methods. However, with a well-designed rotation there is a great potential for decreased soil erosion, increased levels of organic matter, improved soil health, and improved crop yields.[35] According to agronomist Randy Anderson of the USDA Agriculture Research Service, rotations with winter wheat following dry peas increases the water use efficiency of winter wheat and increases yields by 10-15% with the same amount of water.[36]

Drought-tolerant Crops

Irrigation improvements can only take agriculture so far in terms of water use efficiency. One solution, which has been under investigation for several decades is the development of drought-tolerant crops that would allow producers to grow crops with limited water resources and retain high yields. Adaptive, drought-tolerant crops would allow the agriculture sector to respond to the mounting pressures brought on by a changing climate and a burgeoning population. Drought-resistant crops have been developed to maximize "crop per drop" as well as the ability to tolerate higher salinity levels, allowing the use of lower quality water for irrigation.[37] Currently, drought-tolerant crops are being pursued in many arid developing countries where the prospect of irrigation is nonexistent. However, this practice may come to play an important role in agriculture in the Colorado River Basin as water scarcity stresses the arid region.

Future of Water Efficient Strategies

As a sector that utilizes 56-80% of the water in the Colorado River Basin, pressures for agriculture to reduce usage are mounting. Projections for the Colorado River Basin are predicting a notable decrease in irrigated acres in agriculture moving toward 2060. To counter the impeding impact on rural agricultural communities, increased productivity, yields, and water use efficiency may have the potential to lessen the impact of decreasing irrigated acreage. Although the technologies to do so are available, often the costs of implementation are prohibitive. Water efficient strategies fall under two categories: improvements in irrigation and conveyance systems, and improvements in crop management and the crops themselves.

Case Study: Drought-tolerant Crops Around the World

Gebisa Ejeta, Distinguished Professor of Agronomy at Purdue University, received the World Food Prize for his work in developing a drought-resistant and Striga-resistant strain of sorghum. Striga, more commonly known as witchweed, infests the sorghum root system and parasitically removes nutrients from the plant; losses as high as 40% are common in non-resistant sorghum crops. Originally from Ethiopia, Dr. Ejeta understands the horrific devastation that drought and Striga can reap on a region.[38] Ejeta's early work took place in Sudan, researching drought-tolerance in sorghum and developing the first commercial drought-tolerant sorghum to hit markets in Africa. The hybrid, *Hageen Dura-1*, increased yields up to 150% over traditional sorghum cultivars. Today, nearly a million acres of the drought-tolerant sorghum are grown annually in Sudan. Ejeta's work was soon followed by his release of another drought-tolerant hybrid, NAD-1, that was developed for specific growing conditions in Nigeria and produced four to five times the national sorghum average.[39]

Although the Colorado River Basin is not faced with droughts and food shortages anywhere near the level of those experienced in eastern and western Africa, the potential for drought-tolerant hybrids to address concerns over future droughts in the region is great. Future water shortages in the basin states will undoubtedly limit the water available for agricultural growers; however, the use of drought-resistant crops has the ability to offset the expected losses associated with drought.

Source: Mugoya, Charles, and Wandui Masiga, Clet. Striga resistant sorghum due for release soon. in Asareca [database online]. 2012]. Available from http://www.asareca.org/taxonomy/term/4?page=1.

The lowest cost method of conservation is to improve crop management through specific crop selection, rotation, and tillage management. Although the cost of implementation for irrigation-efficient methods can be three to four times that of crop management methods, the results are considerable and programs to fund implementation of improved irrigation systems should remain a priority. Recent farm bills have made significant steps toward increasing funding for programs like EQIP, CRP and CTA, but more is needed.

The problem with incentivizing "agricultural water conservation" is that the increases in water efficiency, under the Law of the River, cannot be transferred to other uses unless the historical crop consumptive use is decreased. Improvements in irrigation systems do not offer the potential to transfer water to other uses. The only exception is the decrease in evaporative losses under the soil with drip irrigation systems. The conserved consumptive use water could, potentially, be transferred to other uses; however, the quantity of water would be relatively minimal. Therefore, the notion of seeking significant water savings in agriculture through irrigation improvements to meet urban demands is largely inaccurate. Drought-tolerant crops, deficit irrigation, and crop management practices such as conservation tillage are the best options for agriculture water conservation. It should be noted that deficit irrigation will result in saved water, but the individual farmers will lose productivity in crop yields as a result. Due to this outcome, the farmer has little incentive to bear the cost of lost productivity and we recommend that the farmer should be compensated for this water saving strategy.

Water Sharing Strategies

Water Sharing Overview

Because water supplies in the Colorado River are projected to continue to decline in the coming years, Colorado River Basin water users must find ways to utilize every drop of this precious resource. As outlined in the BOR Overview section of this *Report Card*, agricultural water demand is predicted to exhibit a prominent decrease by 2035 (**Figure 14**), and in some scenarios, continue to decrease through 2060. The decrease in agricultural demand is almost entirely due to a decrease in irrigated acres.[40] This decrease in irrigated acreage will largely be a result of water rights sales to urban or municipal uses. However, there is another option that would allow more agriculture land to remain in production and mediate the negative effects of buy-and-dry transfers. Agriculture alternative transfer methods are a means through which water can be leased to uses outside agriculture for temporary periods of time, meeting the needs of urban, environmental, and recreational uses, as well as sustaining the production of agricultural goods.

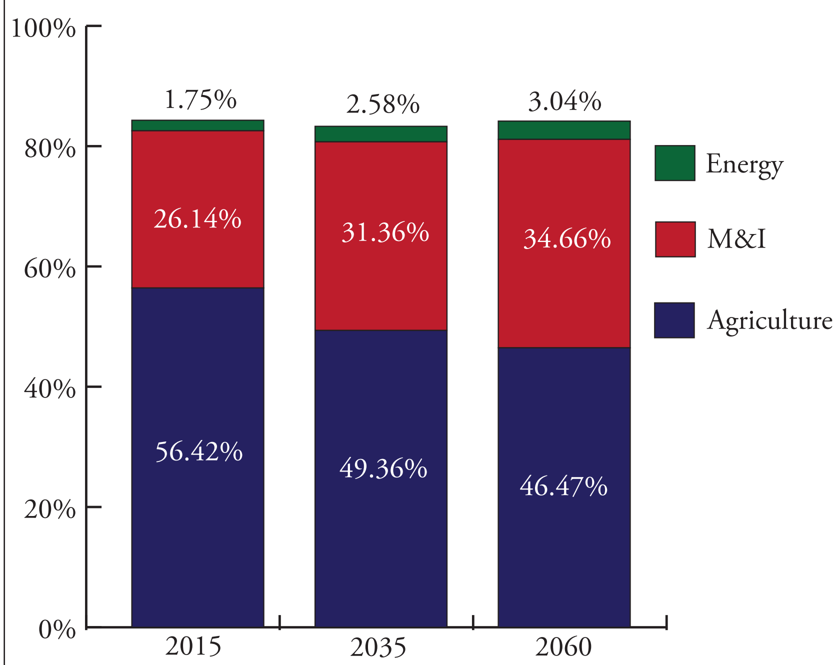
The transfer of water from agriculture to other uses can only occur when the water is part of the historical beneficial consumptive use. The water right holder must first obtain a court decree and prove that the transfer will not increase the water right or cause injury to any downstream or junior user.[41] Under prior appropriation, the "No Injury Rule" recognizes the right of junior users "in the continuation of stream conditions as they existed at the time of their respective appropriations" (*Farmers High Line Canal & Reservoir Co. v. City of Golden*).[42]

The laws governing the circumstances under which water can be transferred to uses outside of agriculture are complex and nuanced. The complexities of water sharing are rooted in a multifaceted interface between stakeholders of diverse backgrounds. However, for productive solutions to be achieved, stakeholders must come together through markets and collaboration, rather than continue to polarize the issue. Each choice carries with it third-party impacts and trade-offs; finding a balance between those choices is vital.

Alternative Agriculture Transfer Methods (ATMs)

Traditional transfers out of agriculture involve what have been coined "buy-and-dry" water transfers due to the drying up of agricultural land as a result of the permanent transfer of water rights. Although traditional buy-and-dry transfers will continue to be important in meeting future water demand, the adverse effects on agricultural rural economies and environmental effects beg for alternatives. To mediate these effects, policymakers are promoting alternative agriculture transfer methods (ATMs). The Colorado Statewide Water Supply Initiative report states, "The goal of the alternative transfer is to minimize the impact on the local economy, provide other funding sources to the agricultural user, and optimize both the agricultural and nonagricultural benefits of the remaining lands."[43]

Figure 14: Bureau of Reclamation Agriculture, Municipal and Energy Demand Projections



Source: Bureau of Reclamation. "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios." *Reclamation Managing Water in the West* (2012).

Interruptible Supply Agreements

Interruptible Supply Agreements (ISAs) involve the temporary, long-term, or permanent transfers of water to uses outside agriculture while on-farm irrigation is temporarily suspended. Current laws in Colorado allow the state engineer to approve up to three temporary ISAs over the course of a 10-year period; however, for long-term ISAs, the water user must obtain court approval.[44] ISAs are often utilized during drought years when farmers predict a low yield or as a means of drought recovery.

Rotational Fallowing

Long-term rotational fallowing programs are a type of interruptible agricultural transfer arrangement comprising several agricultural parties and one or more municipal/industrial, environmental or recreational users.[45]

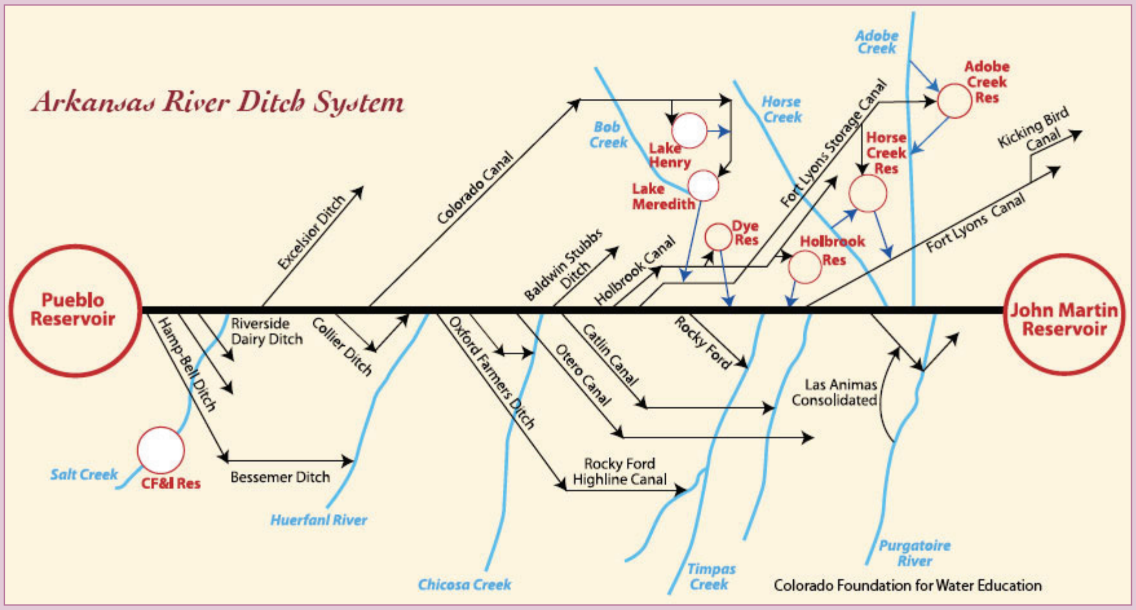
Case Study: The Arkansas Valley Super Ditch

The first example of a rotational fallowing project using Colorado River water started in 2003 between the Imperial Irrigation District and the San Diego County Water Authority. The Imperial Irrigation District is the largest irrigation district in the U.S. and diverts more than three million acre-feet per year of Colorado River water through the All American Canal.[46] The vast majority of diverted water is used to irrigate farmland in the Imperial Valley, which is one of the most productive agricultural regions in the United States. The agreement was negotiated as an alternative to large capital projects - such as the Central Arizona Project and Hoover Dam - that would bring water to urban areas. This was a response to California's limitation in 2003, for the first time, to its annual Colorado River apportionment of 4.4 million acre-feet.[47] Since the program's inception in 2003, more than 500,000 acre-feet have been transferred, with a plan to reallocate nearly 30 million acre-feet over the lifetime of the program.

Municipalities have responded to growing water demand by purchasing water from agricultural interests since the early 20th century. Southern Colorado's lower Arkansas Valley experienced this trend most significantly from 1971-1986, when the rights to 128,000 acre-feet annually were permanently transferred from agricultural to urban uses in eight sales.[48] Each of these sales was met with criticism from the local newspapers and Arkansas Valley citizens became increasingly concerned that the permanent removal of water from agricultural use would lead to degradation of both the quality of community life and economic vitality of the region.[49] In response to these concerns, citizens in five counties- Bent, Crowley, Otero, Prowers, and Pueblo- joined forces to form the Lower Arkansas Valley Water Conservancy District in 2002. This entity represents the interests of the five counties and eight mutual irrigation ditch companies. The Lower Arkansas Valley Water Conservancy District went on to form the "Super Ditch," which is not actually an irrigation ditch, but rather a collective bargaining agent for irrigators to negotiate a rotational fallowing agreement with nearby municipalities.

On May 2, 2012, after six years of planning and negotiation, the Colorado state engineer approved a pilot program for the Super Ditch to transfer 250 acre-feet annually to Fountain Public Utilities.[50] The Super Ditch is the only example of a rotational fallowing agreement being approved in our six-state region of interest. While it is not within the Colorado River Basin, it operates within the same legal and political structure as the regions of Colorado in the Colorado River Basin and thus can provide guidance for future in-basin projects. It is a unique example of collaboration and cooperation between agricultural and municipal interest groups.

Though promising, it is not a one-size-fits-all solution, nor do alternative transfer methods more generally serve as the only answer to the current and future conflicts over water in the Rockies region. Careful planning and cooperation are essential for programs like these to succeed; so too are studies that examine the actual impacts of implementation. Additionally, the fact that this program took six years to overcome legal and administrative barriers is disheartening; another legal complexity is that the Colorado state engineer's authority to allow such a program is being challenged in water court. A water friendly future for rotational fallowing programs and others yet to develop water sharing programs hinges on an expeditious authority granting process. The resolution of the legal disputes of the Super Ditch, it is hoped, will provide just that.



Case Study: Arizona Water Banking Authority: Banking Water Now for Arizona's Future

The Arizona Water Banking Authority (AWBA) was established in 1996 to utilize the state's full apportionment under the Colorado River Compact of 1922. The Compact allocates 2.8 million acre-feet (maf) of Colorado River water to Arizona, which the state has yet to fully utilize. Prior to the establishment of the AWBA, the portion of the 2.8 maf that was left unused remained in the river for downstream use by southern California. The ABWA allows for long-term storage of Colorado River water in existing underground aquifers or is used by irrigation districts in place of groundwater pumping. The program ensures long-term stability to Arizona's water supply and ensures supply during times of shortages or disruptions to the Central Arizona Project (CAP). In addition, the program seeks to assist in the settlement of Native American Indian water rights claims, exchange water with Colorado River communities, and meet the objectives of the Arizona Groundwater Code.[51]

In addition to meeting long-term supply needs, the AWBA is authorized to act on behalf of the state of Arizona in establishing interstate water agreements. In 2005, the AWBA entered into agreements with California and Nevada to store unused water in Arizona aquifers. Currently, Nevada and California pay to store their unused water in Arizona aquifers and in future years will be allowed to withdraw a comparable amount of water directly from the Colorado River. The AWBA is one of the largest and most successful water banking projects in the basin and serves as an example of the needed collaboration and cooperation among basin states that will become paramount in the coming years.

Arizona Water Banking Authority Agua Fria Basin

Source: Agua Fria, Arizona Water Banking Authority, accessed July 10, 2012, http://www.azwaterbank.gov/Photos/Aqua_Fria.htm.

Water Banks

Water banks are an institutional approach to water sharing, allowing free market forces to determine the course of water in the West. The banks serve as a legal mechanism for users who decide to forego their water use during a given year and lease those rights to water users who need it most.[52] Water users can voluntarily lease their water to water banks, which then act as a clearing house and temporarily lease water to other users without disrupting the water rights of the original holder.

Currently in Colorado, the Colorado Water Conservation Board is working with an assortment of agencies across the Front Range and Western Slope to determine the potential of the development of a Colorado water bank.[53] Faced with the potential for a Colorado River Compact curtailment, water banks offer a way to harness the incentives of free market forces to meet water needs across the Colorado River Basin.

Purchase and Lease-back

Purchase and lease-back programs are the most commonly used alternative transfer method in Colorado. Purchase and lease-back programs are a more permanent variation on ISAs and typically range from five to ten years. These agreements involve the purchase of water rights by M&I users with the option of leasing the water back to the agricultural irrigator under specified circumstances.[54]

Barriers to Implementation of ATMs

There are several factors that continue to plague the implementation of water sharing programs. Due to the temporary nature of ATMs, concern on behalf of municipalities regarding long-term supply and dependability of that supply acts as a hindrance to many programs. Certainly, ATMs must work within an overall municipal supply portfolio, but the degree and scope of those programs remain in question.

Perhaps the most serious barriers to implementation of ATMs are high transaction costs. Legal and engineering expenses quickly accumulate during negotiations of transfers and court fees plague the process. However, many of the expenditures are a requirement under the "No Harm Rule" to ensure that injury will not be caused by the transfer of water rights.[55] The court and legal processes required to acquire approval for transfers result in a time-intensive process, which has the potential to kill many projects before they can obtain approval. Other administrative issues also exist, such as state engineer approval to ensure that there are no expansion of water rights and increased transaction costs.

In addressing current barriers to effective agriculture-to-urban transfers, there is a general need for a more efficient water transfer process. If water users and policymakers could develop a more streamlined process, the potential for water transfers to play a larger role in municipal water supply portfolios would greatly increase. ATMs will not be the only means of meeting municipal demands in the coming years, but they will play an important and needed role. Partnerships between agricultural and municipal stakeholders will continue to be essential for the success of these programs.

Conclusion

In this section we have presented a brief list of water efficient irrigation strategies and water sharing programs; by no means is the list exhaustive. Although current technologies and strategies have been implemented in situations where the cost is non-prohibitive, the need for thoughtful and innovative solutions will continue in the coming years. It is important to remember the necessary, but insufficient, nature of the aforementioned strategies and programs. Whether or not the Law of the River can be used as a flexible doctrine may be the most important factor for widespread use of water efficient irrigation and water sharing. With this in mind, we have three recommendations that must be met in order to secure a water friendly future for agriculture in the Colorado River Basin:

1. *Transcend misconceptions of water use in agriculture.*
   One of the most common misconceptions of water use in agriculture is the idea that more efficient irrigation strategies can lead to farmers saving water and freeing it up for other users. Decreases in crop consumptive use generally do not result from improvements in irrigation technology. Another misconception is the notion that water right transfers only affect the buyer and the seller. Farm laborers, harvesters, suppliers, chemical providers, and equipment operators all stand to lose business or jobs when farmland is taken out of production, whether permanently or for a specified number of years.[56]

2. *Seek cooperation and collaboration among stakeholders.*
   Water disputes are often termed "fights" or "battles" over uses of water in the West. This rhetoric reflects the attitudes on both sides of the water issue, many of whom have been embittered by years of conflict and historical mistrust. Polarization of these issues has led to lengthy adjudication processes and counterproductive disputes. Instances of cooperation of habitually disparate groups to meet growing water needs have occurred on several occasions. The rotational fallowing agreement between Imperial Irrigation District and the San Diego County Water Authority that started in 2003[57] and the Agricultural/Urban/Environmental Water Sharing Work Group facilitated by the Colorado Water Institute in 2010[58] are exemplary examples of collaboration in the Colorado River Basin that should be replicated in the future.

3. *Make conscientious decisions, keeping in mind the needs of all stakeholders throughout the basin.*
   The Colorado River is a resource that will be stretched to its greatest limits in the coming decades. Population projections following current trends suggest that by 2060 more than 62 million people, twice the current number, will come to depend on the Colorado River. Agricultural stakeholders must take into account the growing needs of other sectors in the region, just as those sectors must understand the importance of continued agricultural production in the region. The Colorado River is the lifeblood of an arid region. Its inhabitants' adaption over thousands of years to changing conditions reflects its importance and offers hope that future inhabitants can respect the river's constraints. We recommend that the people of the basin follow suit in a serious and concerted way.

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Will Stauffer-Norris

The Down the Colorado Expedition paddling near agricultural diversions in Colorado's Grand Valley.

Municipal and Industrial Water Use in the Colorado River Basin: Moving Towards a Paradigm Shift in Water Reclamation

By Matthew McNerney and Shannon Thomas

Key Findings:

-M&I growth will contribute between 64-76% of the total increase in Colorado River demand over the next 60 years.

-The population of the Basin States is expected to approximately double in the year 2060.

-Supply enhancement, namely pipelines, will only continue to exceed the limits on the already diminished Colorado River.

-Conservation is a necessary aspect of meeting future water needs in the Basin.

-Both the Front Range and Las Vegas serve as case studies to show varying conservation strategies that can be used as lessons of effective and ineffective techniques for different water districts.

The 2013 Colorado College State of the Rockies Report Card
Water Friendly Futures for the Colorado River Basin

About the Authors:
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Introduction

Today, the Colorado River Basin supplies more than 30 million people with water in the seven basin states.[1] Currently, Municipal and Industrial (M&I) water use comprises between 22-26% of total demand for Colorado River water.[2] According to the Bureau of Reclamation (BOR), M&I growth will contribute between 64-76% of the total increase in Colorado River demand over the next 60 years. This large growth in the M&I sector is mostly attributed to booming populations in the basin. In a recent study, the BOR has produced population projections for several possible scenarios. Maintaining business as usual the Bureau projects we will have 19,840,000 water users in the basin alone by 2060 (not including water users from adjacent areas). When paired with the adjacent areas that also receive Colorado River water to meet their needs, the same projection rises to 62,435,000 water users by 2060.[3]

Meeting increasing water demands while facing a diminishing water supply has been the challenge posed to basin stakeholders in the last decade and has been a fervently debated issue by federal and state governments, water providers, and conservationists. Through this literature we see an increasingly necessary aspect of meeting future water needs in the basin is water conservation, especially in the domestic sector. Reclamation was historically used as a means to control free-flowing rivers with large scale infrastructure projects such as the Hoover Dam and Central Arizona Project, but has now taken the meaning of conserving water in various sectors. Due to drought, population booms, and over-apportionment of the Colorado River, there has recently been a

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resounding call across the basin to adopt new measures to minimize water use in order to save water for in-stream flows, recreation, and the possibility of continued posterity in the American Southwest. From ordinances and auditing programs to water reuse and storm water management programs, basin stakeholders are adopting a variety of measures to meet the growing demand for water. This section will take an in-depth look at the varying techniques of water conservation today for municipalities and provide examples of where different techniques are being implemented.

Focusing on the Colorado Front Range, we develop a snapshot of techniques used throughout the basin in the conservation programs of five water providers: Denver Water, Aurora Water, Colorado Springs Utilities, Pueblo Board of Water Works, and The City of Fort Collins Water Department. Based on demographics, location, and seniority of water rights, each water utility has a regionalized approach of how they promote domestic and commercial water conservation. These varying techniques can be used as lessons of effective and ineffective techniques for different water districts. This section will also provide a case-study on Southern Nevada Water Authority in Las Vegas to share another example of effective M&I water conservation measures in one of the basin's largest cities

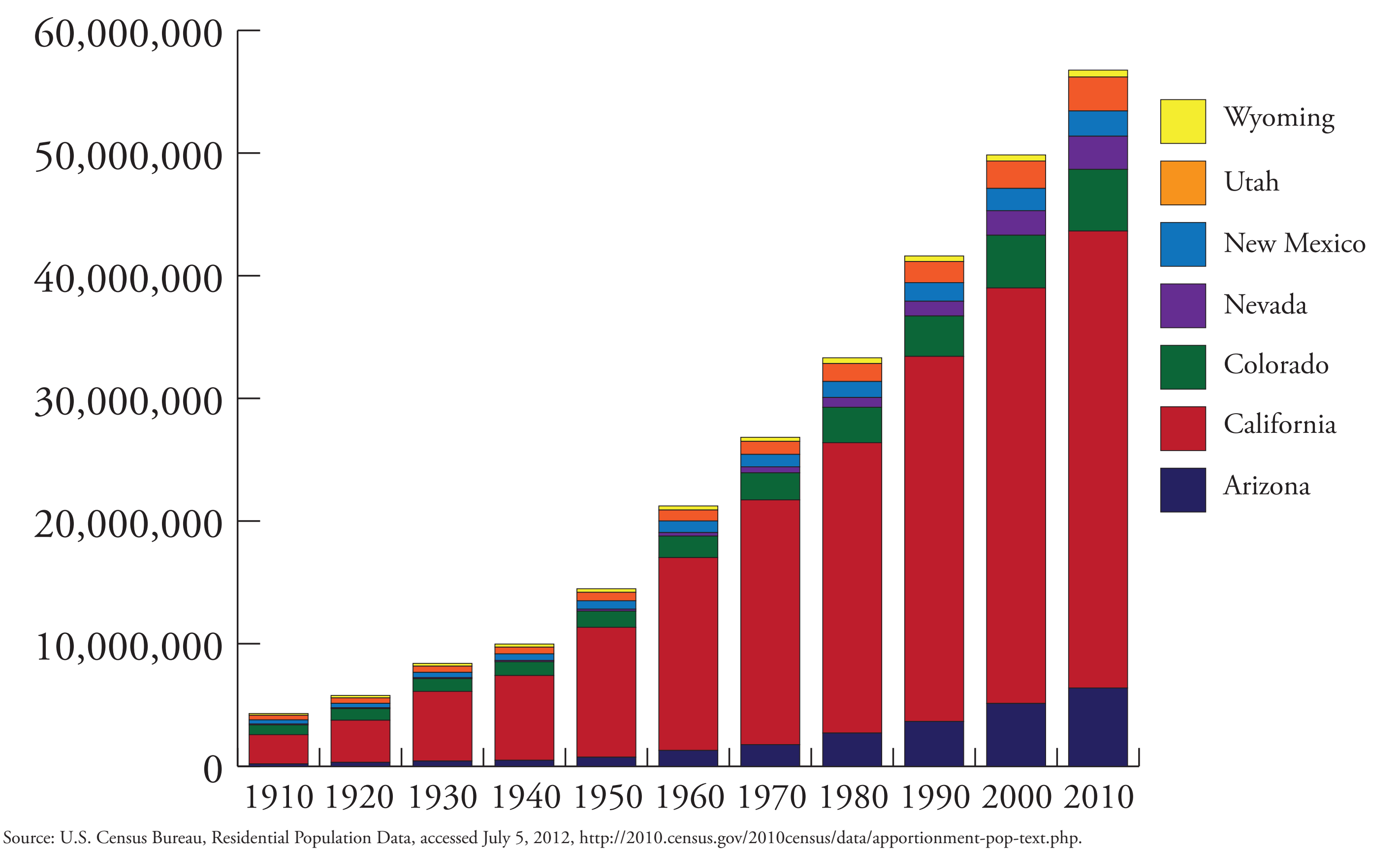
Water conservation can provide substantial results in decreasing M&I water usage, but for many water providers and their communities it is not enough. In order to meet the increasing demand, many are looking towards supply enhancement strategies, such as new large scale infrastructure projects - namely pipelines - to divert new water to major population hubs. One such example discussed below is the proposed Lake Powell Pipeline to St. George, Utah. Conservationists and concerned stakeholders fear that adding additional pipelines will drastically exceed the limits on the already diminished Colorado River.

BOR Supply and Demand

As mentioned in the BOR Overview, the Supply and Demand Study projects future growth of M&I water demand for the Colorado River Basin. M&I water use has increased consistently over the years mainly because of population growth in basin states. These states have contained some of the fastest growing areas in the United Sates and almost all exceed the national average. **Figure 1** shows historical population levels within the basin states while **Figure 2** displays the percent change in population for all seven basin states against the national average.[4]

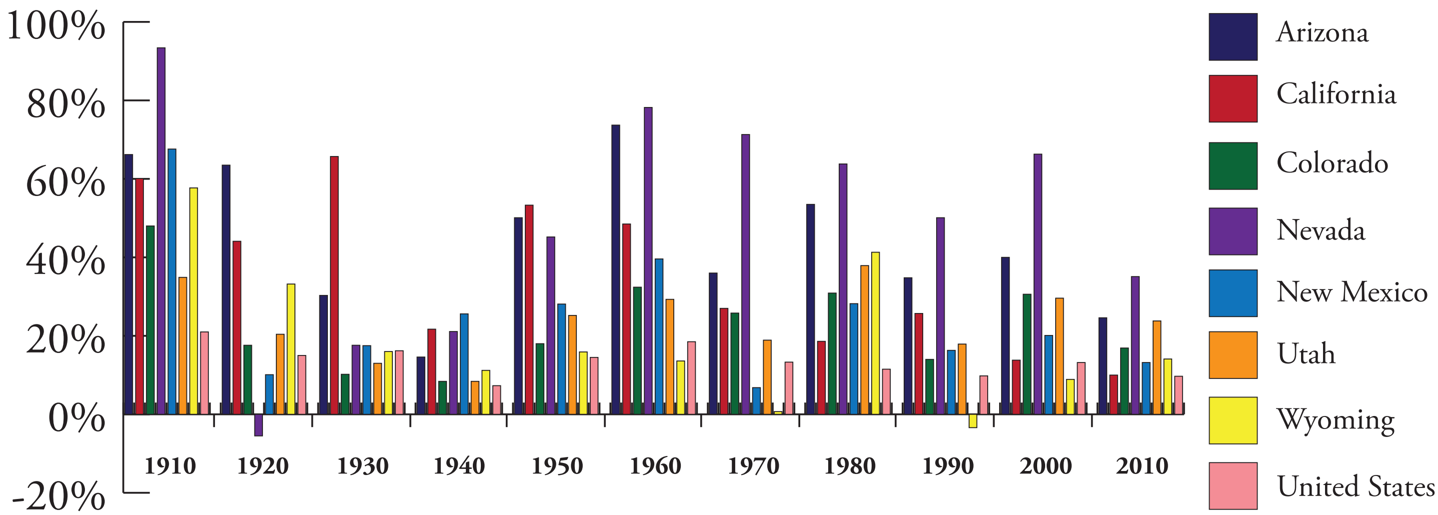
In **Figure 2** we see that all the basin states have exceeded the national average population growth rate from 1980-2010 with the exception of Wyoming in 1990. From 1960-2010, Nevada and Arizona have seen the highest growth in population. In fact, Nevada has maintained the highest percent change from 1960, with an average percent change of 60.80% per decade. In comparison, the U.S. average is shown to be among the lowest population percent changes throughout the 20th century and into the 21st century. From 1910 to 1950, the U.S. average was the lowest compared to all the basin states and continued to be the lowest in 1980 and 2010, with only Wyoming containing the lowest percent change

Figure 1: Historic Population Levels - Basin State Populations from 1910-2010



Source: U.S. Census Bureau, Residential Population Data, accessed July 5, 2012, http://2010.census.gov/2010census/data/apportionment-pop-text.php.

Figure 2: Percent Change in Historic Population Levels - 1910-2010



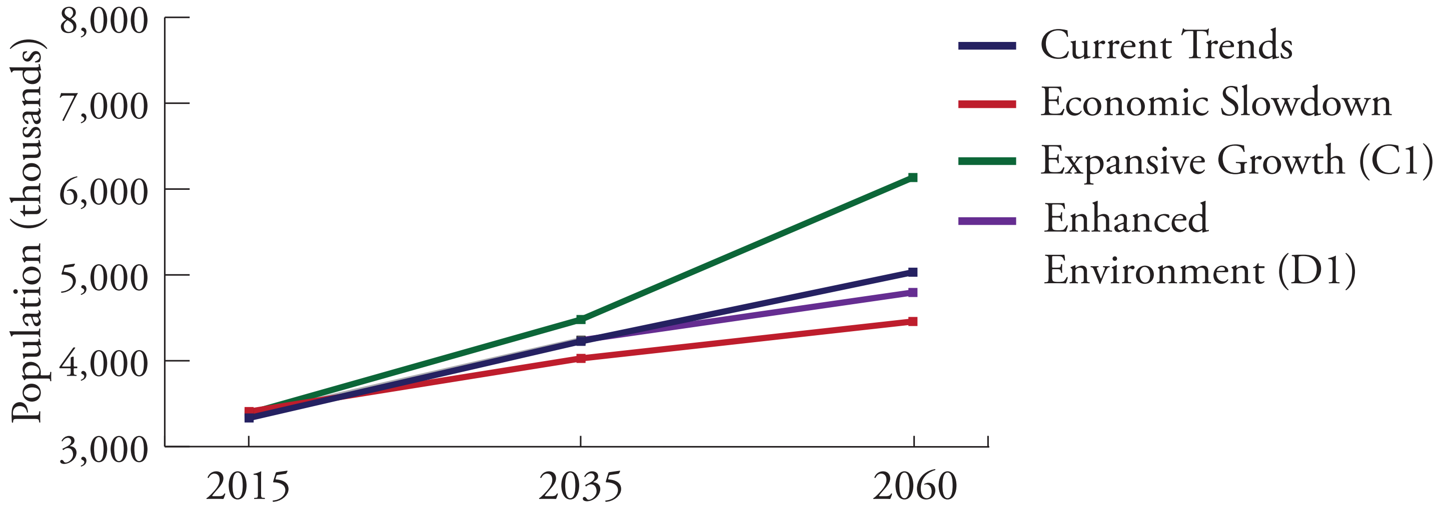
Source: U.S. Census Bureau, Residential Population Data, accessed July 5, 2012, http://2010.census.gov/2010census/data/apportionment-pop-text.php.

in 1960, 1970, 1990, and 2000. From these graphs, though population growth has slowed in recent decades, we can see that growing population has been and continues to be a problem for M&I uses of Colorado River water. With growing demands in M&I uses and an increasing population, future projections will only continue this distressing pattern.

The Bureau of Reclamation study provides population projections depicting four varying scenarios. **Figure 3** displays the population projects for Current Trends, Economic Slowdown, Expansive Growth (C1), and Enhanced Environment (D1). In the graph, we see that through Current Trends, population will increase from approximately 39,953,000 in 2015 to 62,435,000 in 2060. Current trends for population are also used for the Enhanced Environment scenario. While Economic Slowdown predicts a population of 38,856,500 in 2015 to reach 49,262,800 in 2060, The Expansive Growth scenario predicts population levels of 41,141,700 in 2015 to reach an alarming 76,487,000 people in the basin states. From a percent change perspective, this means that for the Current Trends and Enhanced Environment models, population will have a percent change of 56% from 2015 to 2060, an Economic Slowdown model will only produce a 27% increase in 2060, and an Expansive Growth model will produce a disturbing 86% rise from 2015 to 2060.

Figures 4-7 show the percentage increase in M&I demand compared to agricultural demand. As mentioned previously, increases in population have been the primary cause for the increase in M&I demand. As the second largest component of overall demand, M&I demand is expected to increase from approximately 27% in 2015 to 33-38% in 2060 depending on the scenario.[5] Of this percentage, 19-32% of the increase is expected to occur in the Upper Basin, while the remaining 68-81% will occur in the Lower Basin.[6] When examining the Upper Basin, increases in M&I demand are

Figure 3: Total BOR Population Projections for the Basin States



Source: Bureau of Reclamation, "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios," Reclamation Managing Water in the West (2012).

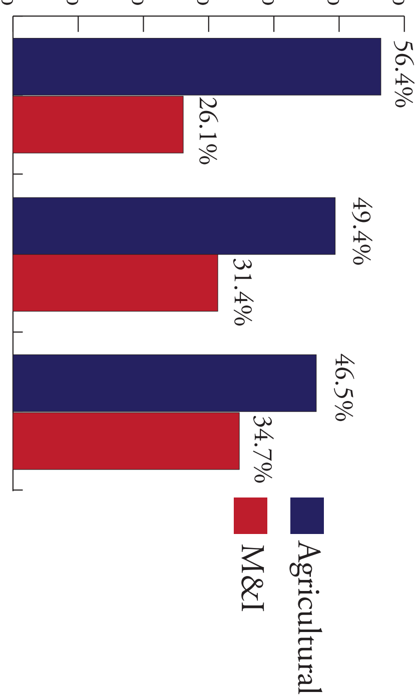


Figure 4: Percent of Total Potential Colorado River Demand for Current Trends

Source: Bureau of Reclamation, "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios," Reclamation Managing Water in the West (2012).

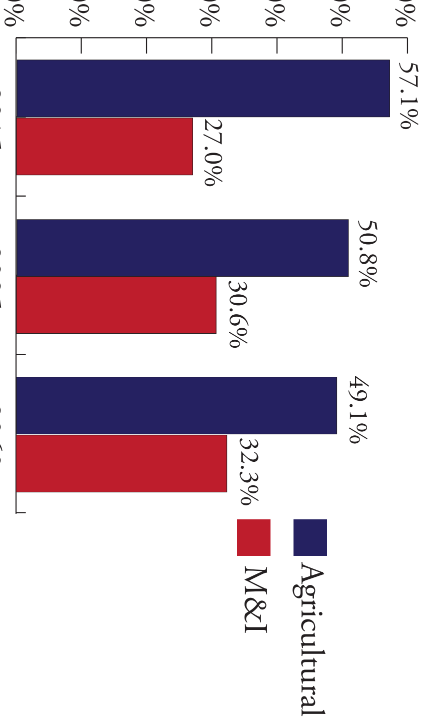


Figure 5: Percent of Total Potential Colorado River Demand for Economic Slowdown

Source: Bureau of Reclamation, "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios," Reclamation Managing Water in the West (2012).

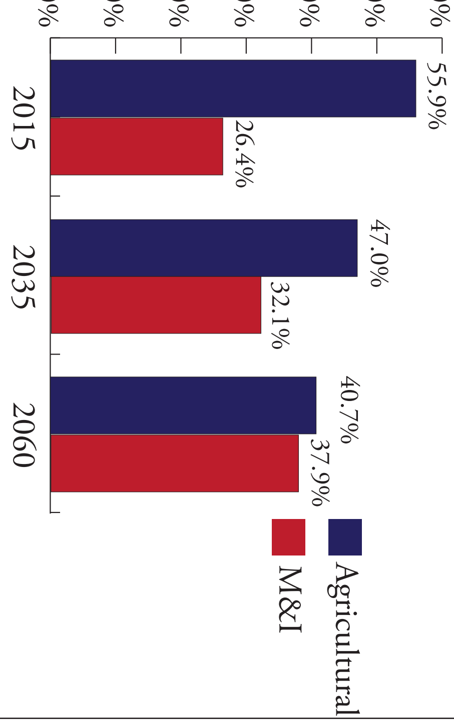


Figure 6: Percent of Total Potential Colorado River Demand for Rapid Growth

Source: Bureau of Reclamation, "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios," Reclamation Managing Water in the West (2012).

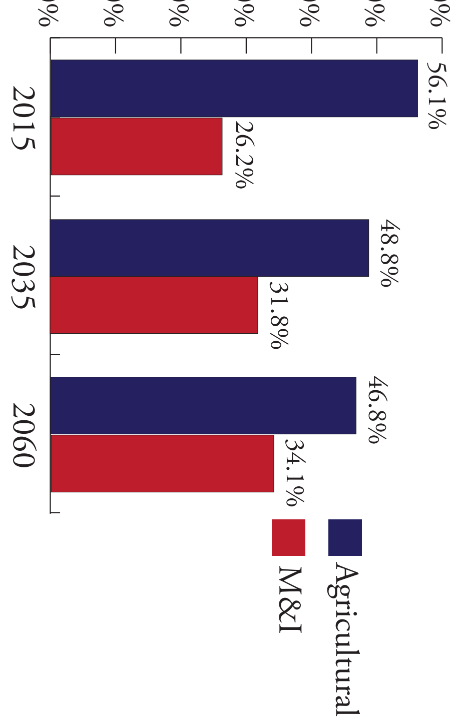


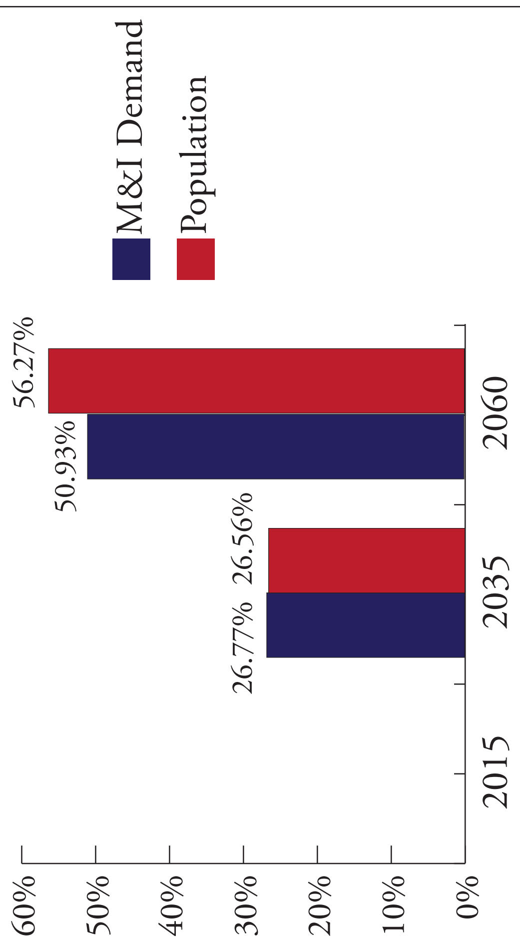
Figure 7: Percent of Total Potential Colorado River Demand for Enhanced Environment

Source: Bureau of Reclamation, "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios," Reclamation Managing Water in the West (2012).

mostly due to projected population growth in Colorado, with the remaining demand predicted in New Mexico and Utah, and a small increase in Wyoming. In the Lower Basin, Arizona is expected to have an increase in M&I demand of 50% while together California and Nevada will make up the other 50% in all scenarios.[7]

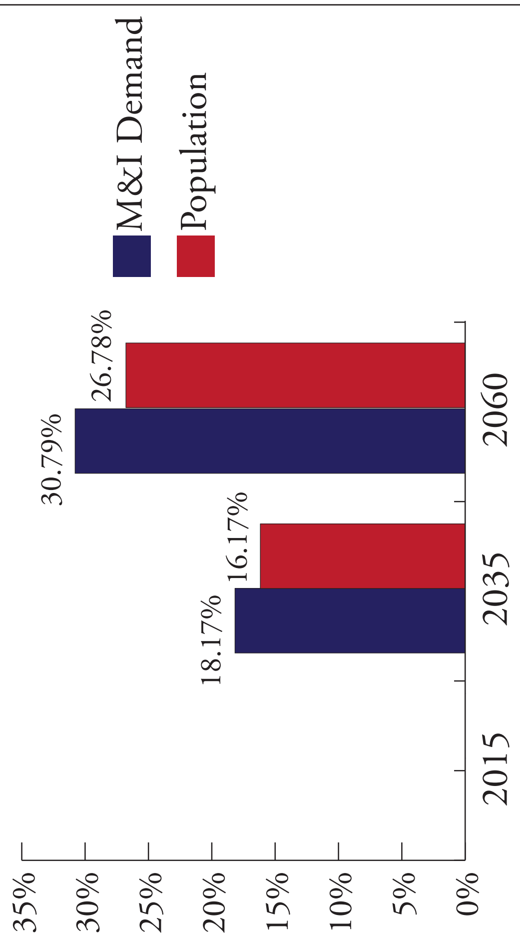
When viewing the percent changes in both population and M&I demand, both changes are similar and follow the same trend. **Figures 8-11** show the percent changes in population compared to M&I water use for each scenario. From these graphs, **Figure 11** shows the most idealistic scenario: Enhanced Environment. Even though population continues to increase for the "best estimate" predictions, M&I demand contains a significantly lower percent change. This is due to growing environmental consciousness and stewardship paired with a growing economy.[8] Increasing social values and awareness for the Colorado River Basin are essential, but also pose the greatest challenge. This change in values involves a paradigm shift in the public perception of future water supplies and necessitates a shift in understanding the need to conserve more water.

Figure 8: Population Percent Change versus M&I Demand Percent Change for Current Trends



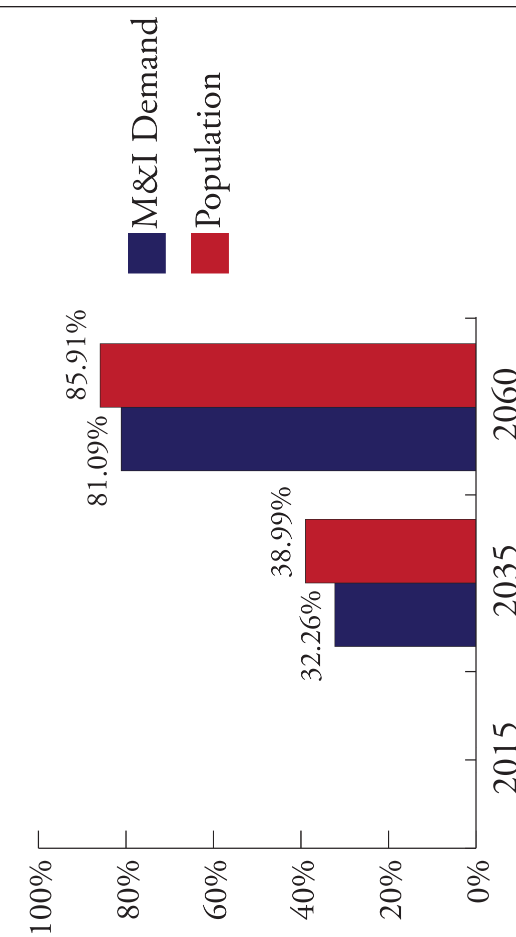
Source: Bureau of Reclamation, "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios," Reclamation Managing Water in the West (2012).

Figure 9: Population Percent Change versus M&I Demand Percent Change for Economic Slowdown



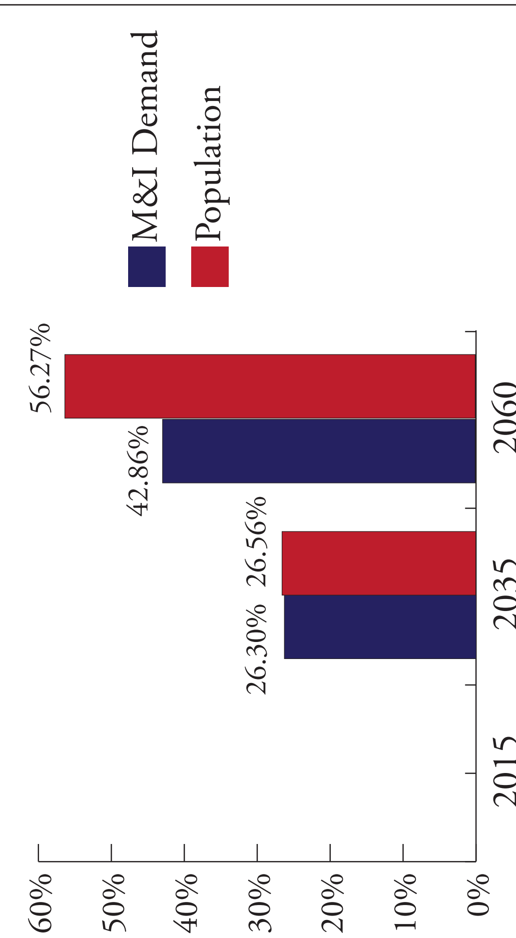
Source: Bureau of Reclamation, "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios," Reclamation Managing Water in the West (2012).

Figure 10: Population Percent Change versus M&I Demand Percent Change for Expansive Growth



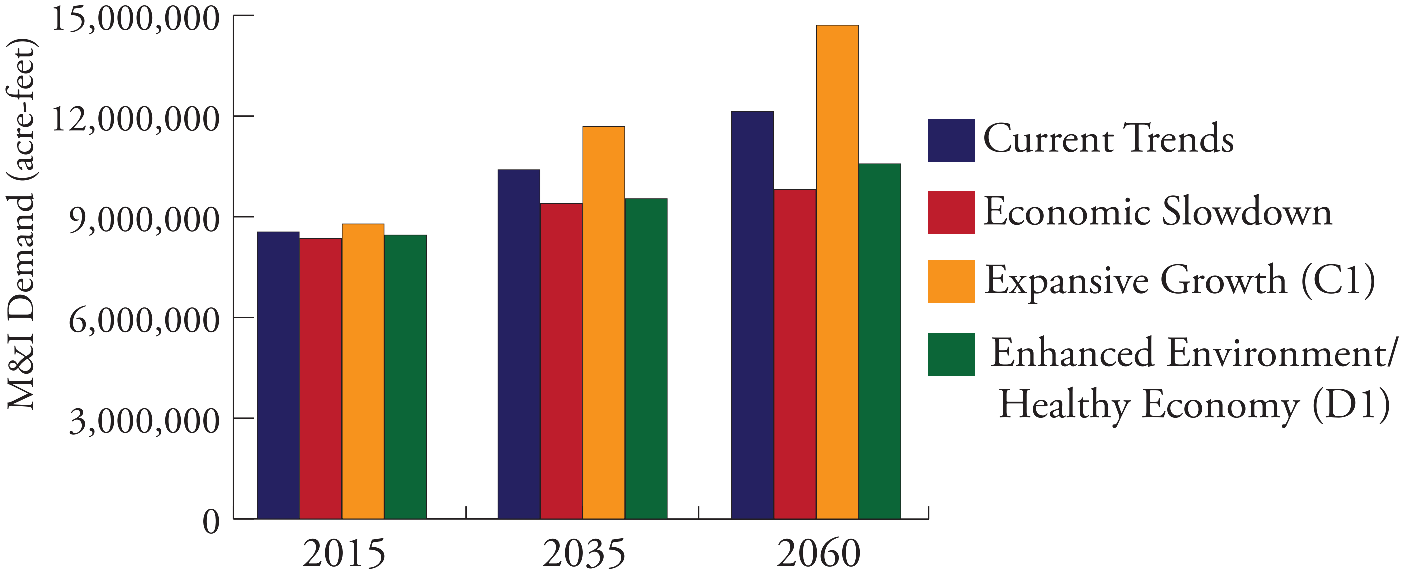
Source: Bureau of Reclamation, "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios," Reclamation Managing Water in the West (2012).

Figure 11: Population Percent Change versus M&I Demand Percent Change for Enhanced Environment



Source: Bureau of Reclamation, "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios," Reclamation Managing Water in the West (2012).

Figure 12: Total M&I Demand (acre-feet)



Source: Bureau of Reclamation, "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios," Reclamation Managing Water in the West (2012).

Figure 12 displays total M&I demand from 2015 to 2060. All scenarios show an increase in demand, but the Expansive Growth model continues to be the most alarming due to the large increase in population. The four models for M&I uses contain the following results:

-Current Trends model shows an increase in demand from 8,547,528 acre-feet in 2015 to 12,140,626 acre-feet, a percent change of 42%.

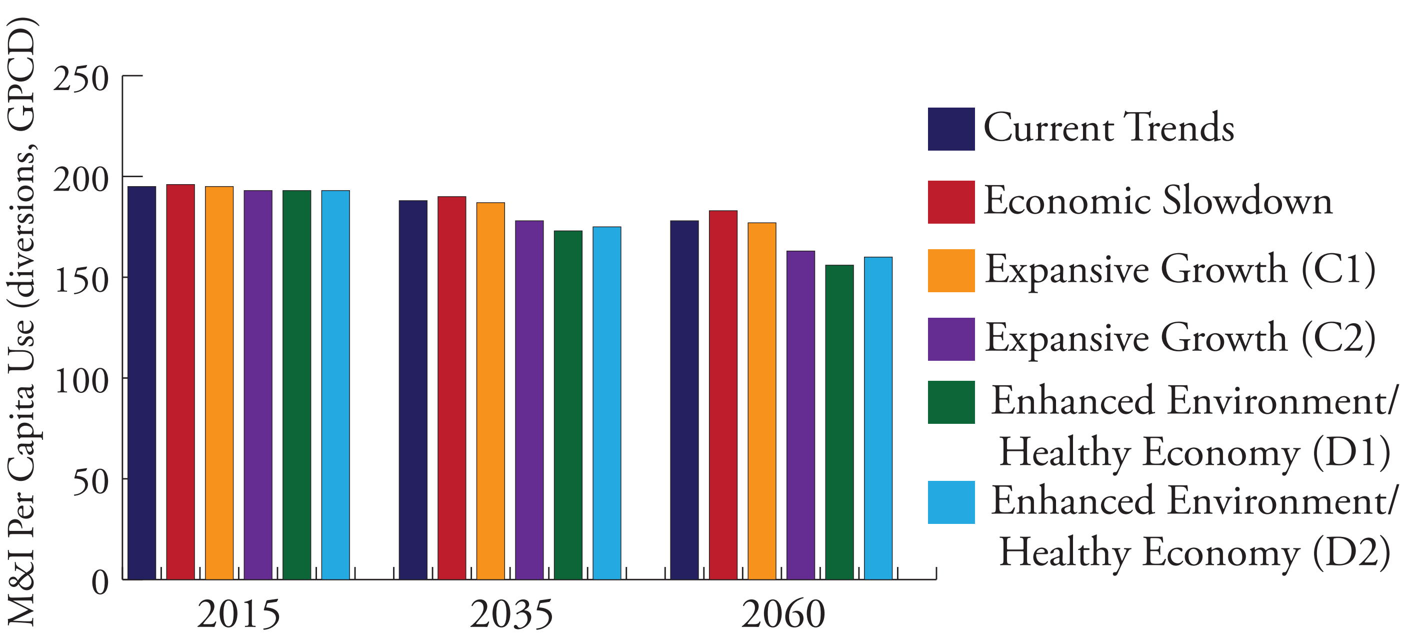
-Economic Slowdown shows that demand increases from 8,351,954 acre-feet to 9,809,819 acre-feet in 2060, a percent change of 17%.

-Expansive Growth demand increases from 8,785,467 acre-feet to 14,707,607 acre-feet in 2060, showing a percent change of 67%.

-Enhanced Environment demand starts out at 8,455,154 acre-feet and increases to 10,567,359 acre-feet by 2060, displaying a percent change of 25%.

Unlike M&I demand, per capita water use is projected to decrease in all four scenarios and in six out of the seven basin states. Wyoming is the only state where per capita rates increase partially due to expected urbanization of rural regions.[9] **Figure 13** displays each scenario with relation to

Figure 13: Total M&I Per Capita Use



Source: Bureau of Reclamation, "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios," Reclamation Managing Water in the West (2012).

M&I per capita use from 2015 to 2060. While total demand for M&I uses continues to increase over the next 50 years, M&I per capita use will actually decrease over the next half century. M&I per capita water use is measured by amount of water produced or diverted per person in a given municipality (industrial, commercial, and residential). From this graph, we see that the Enhanced Environment scenario shows the largest decrease in per capita consumption with a percent change of -19%, while an Economic Slowdown model shows the smallest decrease in usage with only a -7% change. When viewing the data state-by-state (**Figures 14-20**), the majority of states are predicted to decrease their per capita consumption with the exception of Arizona in the Economic Slowdown model and Wyoming in all models except Enhanced Environment. Decreases in per capita water use arise from improvements in indoor fixtures and appliances, which to some extent offset M&I demand from increases in population.[10] Due to current conservation plans, per capita water use in the Colorado River Basin and adjacent areas is expected to decrease by 7-19% from 2015 to 2060.[11]

Figure 14: M&I Per Capita Use for Arizona

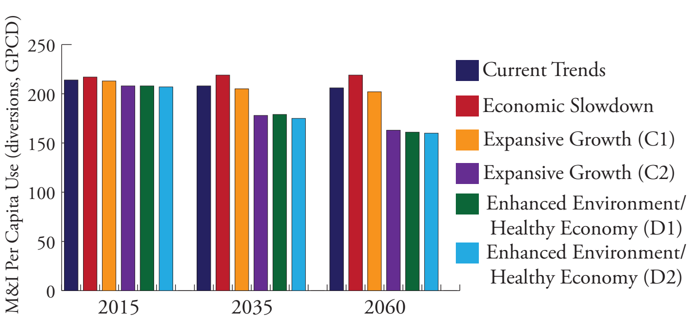


Figure 15: M&I Per Capita Use for California

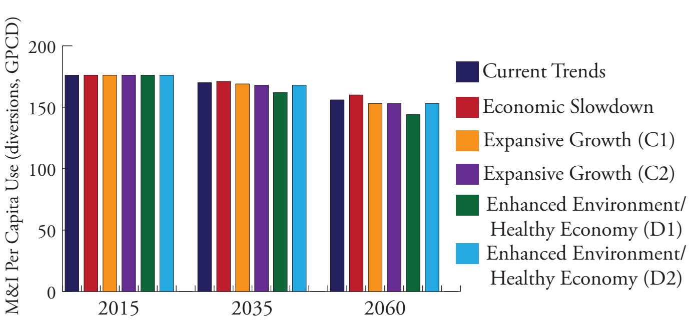


Figure 16: M&I Per Capita Use for Colorado

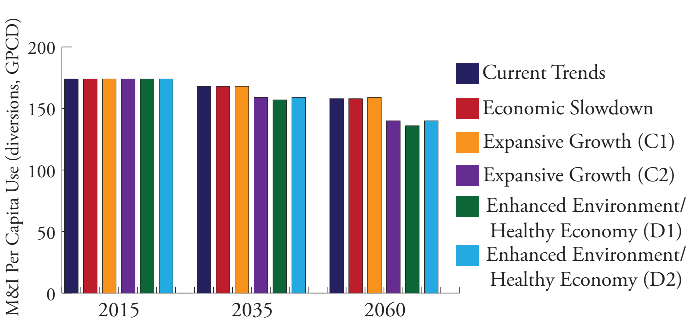


Figure 17: M&I Per Capita Use for Nevada

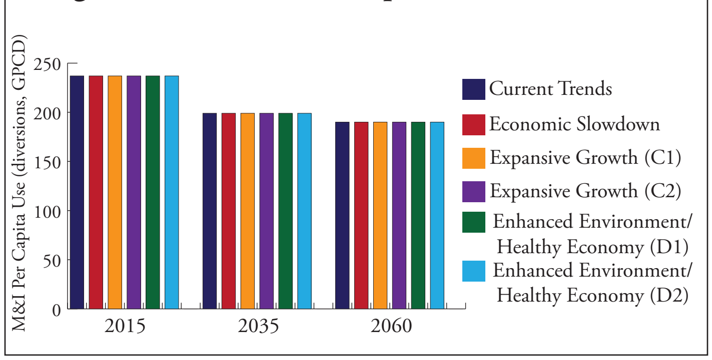


Figure 18: M&I Per Capita Use for New Mexico

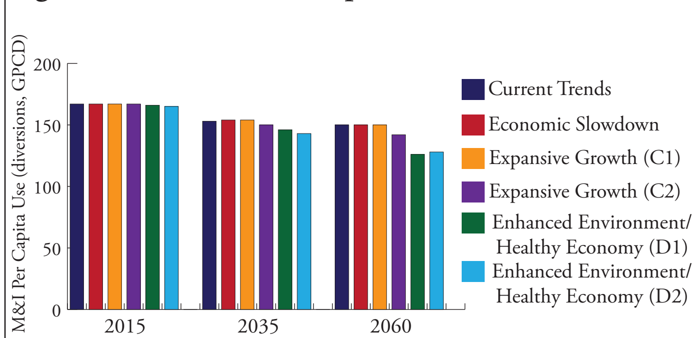


Figure 19: M&I Per Capita Use for Utah

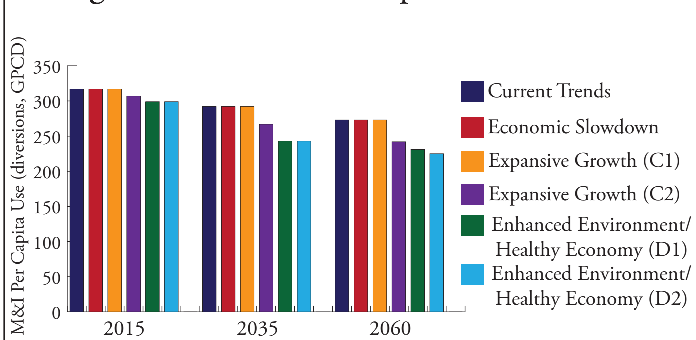
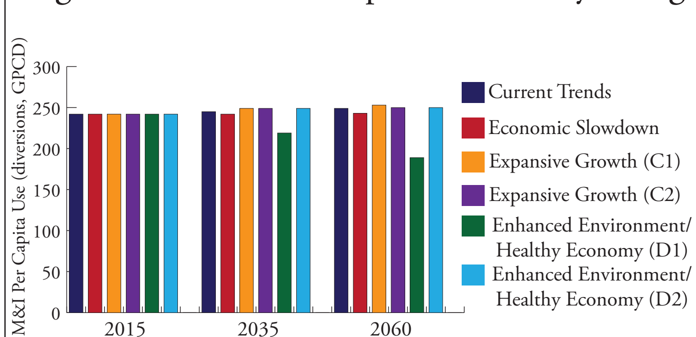


Figure 20: M&I Per Capita Use for Wyoming



Source for Figures 14-20: Bureau of Reclamation, "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios," Reclamation Managing Water in the West (2012).

Figure 21 provides an overview of the seven basin states with respect to change in population, per capita water use, and percent of total Colorado River demand. From this table, we can see the large variability in the expected population, per capita use, and demand for Colorado River water depending upon the scenario analyzed. Out of the scenarios examined above, the greatest water conserving scenario for the future of M&I demand would be Enhanced Environment (D1). Under this situation, population levels would remain consistent with the current "best estimate" projections along with increased federal investments in water conservation, government regulation, and social values.

Figure 21: Overview of Projected Population, Per Capita Water Use, and Colorado River Demand All Scenarios

	Approximate Populations for 2015	Expected Populations for 2060	Expected Change in Per Capita Water Use by 2060	Percent Growth of Colorado River Demand by 2060
Colorado	6 million	9-11 million	9-22% less	2-27% growth
New Mexico	1.5 million	2-3 million	11-24% less	14-63% growth
Utah	2.4 million	3.7-6.2 million	14-25% less	19-26% growth
Wyoming	.31 million	.37-.44 million	4% more-22% less	15-50% growth
California	20.4 million	19.8-34.6 million	9-18% less	4-7% growth
Arizona	7 million	9.8-16 million	1% more -23% less	5-41% growth
Nevada	2.3-2.6 million	4.2-5.1 million	20% less	63-100% growth

Source: Bureau of Reclamation, "Colorado River Basin Water Supply and Demand Study: Technical Memorandum C – Quantification of Water Demand Scenarios," Reclamation Managing Water in the West, 2012, Appendix C2 4-6, Appendix C3 4-6, Appendix C4 4-6, Appendix C5 4-6, Appendix C6 4-8, Appendix C7 6, Appendix C8 4.

Municipal and Industrial Water Conservation Techniques and Practices

Faced with current and projected conditions, in order to avoid the high end population and water use projections presented above, it is necessary to find new and innovative ways to satisfy water demand. Yes, agriculture accounts for 70-80% of the water in the Colorado River Basin, and 89% of the water for the state of Colorado, but over time agricultural water uses are decreasing, while M&I uses are increasing.[12, 13] Moving forward, the most substantial savings will not be in the fields and farms, but on the lawns and in the washrooms of our homes and businesses. Simply put, providing water for the projected populations in 2060 will require alternative strategies; continuing business as usual runs the risk of exacerbating basin-wide water scarcity.

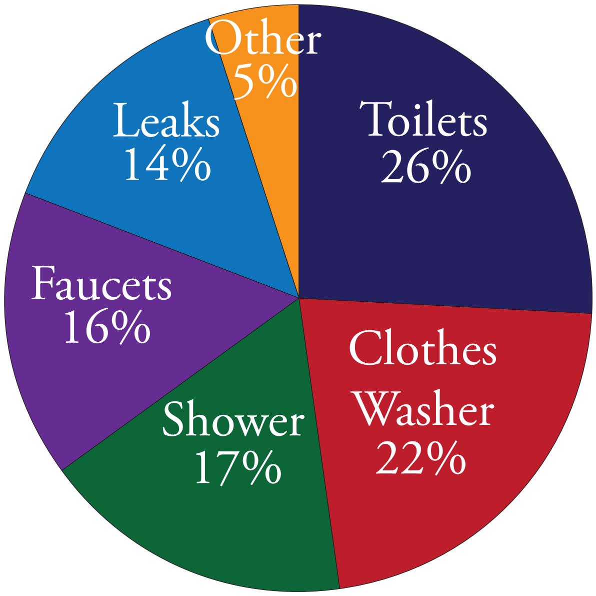
Water utilities in every major municipality have plans for meeting future water demands. Their plans include supply enhancement such as the construction of new infrastructure, and the revitalization of current infrastructure to improve efficiency, as well as demand management, such as conservation techniques. The following section focuses on conservation in the home and community, exploring the many water conservation techniques and practices in use today, and offering examples of where these techniques are being utilized around the basin.

Indoor Conservation

Water use in the home typically accounts for 30% of our monthly water bills, the other 70% being used outdoors.[14] Of this 30% the vast majority is from everyday fixtures and devices. One of the simplest ways to conserve water in the home is by replacing toilets, faucets, and other fixtures with more water efficient ones.

As seen in **Figure 22**, the single greatest use of water in the home is flushed down the toilet about five times a day. Toilets account for roughly 26% of indoor water use, about 18 gallons per day. Washing machines are a close second, compromising 22% of indoor use, followed by showers and faucets.[15] Besides just not flushing and washing, here are several ways to reduce these numbers. The availability of improved water use technology, along with top-down mandates, such as the national Energy Policy Act (EPAct) of 1992, are key forces at play to reduce the number of gallons per flush, gallons per load, and gallons per minute for indoor fixtures. Stricter state legislation is being proposed in Colorado today, and great strides are being made in California to bring these mandated numbers down as well.[16, 17] In the 1950s, a toilet could have used up to seven gallons per flush

Figure 22: Average Residential Water Use In Homes by Type



Source: Western Resource Advocates, "New House New Paradigm: A Model for How to Plan, Build, and Live Water-Smart" (Boulder, Colorado, 2009), accessed August 2012, http://www.westernresourceadvocates.org/water/newparadigm/NewParadigmReport.pdf.

Case Study: Lake Powell Pipeline

Large scale infrastructure projects, or supply enhancements, always have and always will draw controversy. From the construction of Hoover Dam in the early 20th century, to the proposal for the Flaming Gorge pipeline today, each is surrounded by controversy, and each comes with a long list of pros and cons. On the summer 2012 State of the Rockies research trip our team had the opportunity to take a closer look at the issues surrounding one such large project, while still on the drawing board. In St. George, Utah, student researchers met with a water conservancy in favor of, and a conservationist group opposed to the proposed Lake Powell Pipeline. The proposed pipeline would draw nearly 100,000 acre-feet of water from Lake Powell each year to Washington and Kane Counties, Utah. The water would be pumped through a 139-mile, 66-inch underground pipeline. Depending on whom you ask, the estimated cost of the pipeline ranges from $1.6 to $3.2 billion.

From our discussions we found the greatest argument in favor of the pipeline is the impending need for a more stable water source. As St. George and the surrounding counties continue growing, people are starting to realize they need alternatives for water sources, and for some the most practical of these alternatives is to build a pipeline.

The greatest argument against the pipeline is the high price tag: Washington County will bear the brunt of the costs. For those who doubt the necessity of such an expensive project, the question arises of whether funding could be better spent on different supply enhancement or demand management measures. Furthermore, since the pipeline will be financed through state bonds (which must be paid off at a later date), some citizens in the area are realizing the project could mean increases in both their taxes and their water bills.

Washington County has experienced some of the highest growth rates of any county in the basin. Between 2005 and 2006, Washington County experienced the highest growth rate of any county in the country, and the next year it ranked second. One of the biggest questions regarding the construction of the pipeline is whether this growth will continue.

As of now the pipeline is in the planning phase. The Lake Powell Pipeline Development Act was passed in 2006 and currently the Washington County Water Conservancy District (WCWCD) would like to see deliveries from the pipeline begin between 2020 and 2025. Pending legislation from the State of Utah Legislature, the project will get off the ground, but there is an army of dissenters. In the Lake Powell Pipeline Development Act of 2006, the state agreed to finance the pipeline through bonds, which the participating counties will have to repay over a 50- to 60- year period. The big question opponents of the pipeline are asking is: How can Washington and Kane counties repay these bonds? **Figure 23** examines some of the key issues surrounding the pipeline and discusses the pros and cons of each.

Figure 23: Pros and Cons of the Lake Powell Pipeline

Issues	Basics	For	Against
Costs	2006 Lake Powell Pipeline Act outlined financing for the project through the State of Utah, which will be repaid by Washington and Kane counties over a 50- to 60- year period. Estimated costs of the project vary and will not be truly realized until after completion.	Through block-by-block financing the two counties will be able to use a block of water and repay the state of Utah on a block-by-block basis, financed by impact fees, development fees, and property taxes.* Current costs estimates by WCWCD are $1.6 billion.	The burden of repaying the pipeline costs will be great for Washington and Kane counties. If the pipeline were to cost $2 billion, for example, the counties would have to repay an average of $45 million per year. Current costs estimates by Citizens for Dixie's Future (CDF) range from$1.8-$3.2 billion.**
Water Needs	Currently Washington County has a 75,088 AF total water allocation. The county currently uses 62,098 AF, leaving approximately 12,000 AF available. Currently per capita water usage for Washington County is around 270 gpcd.***	High end population projections estimate Washington County will be short of water by 2020, with conservation initiatives. The creation of the Lake Powell Pipeline is the only way to supply the increasing water needs of the county.	Increasing conservation, through such techniques as increasing water rates, and setting ordinances for landscape irrigation, along with Agriculture to Urban water transfers can supply the water needs to meet this impending gap.
Population Projections	2008 population projections from the Governor's Office of Planning and Budget estimated population of 279,864 by 2020 and 860,378 by 2060; recently revised estimates have dropped those numbers to 179,396 by 2020 and 498,239 by 2060.	Ron Thomson, the general manager of the WCWCD, argues that the new projections are a low-ball number and the new pipeline is still a necessity to meet incoming demand in his district.	The population estimates the pipeline was originally based on were set in a time of unprecedented growth, which has since decreased since the economic downturn. Recent estimates released show a decreased need for the pipeline.

Sources: [18, 19, 20, 21, 22]

Notes: * Washington County Water Conservancy District is one of few water providers who is able to collect revenue through property taxes levied on customers.
** High end cost estimates include an estimation of construction costs for Hurricane Cliffs Pump Storage Plant.
***Per capita water usage varies based on sources, 270 gpcd agrees both with literature supplied by WCWCD and numbers supplied by Paul Van Dam of Citizens for Dixie's Future (CDF).

(gpf); today, a high efficiency fixture can use one gpf or less. In the 1980s and 1990s, a washing machine could use up to 50 gallons per load (gpl); today, that number is halved.[23] The challenge is figuring out how to convince customers to replace outdated fixtures for modern, highly efficient ones. There are several ways to do this as previously mentioned; one option is through government mandates. This is known as passive conservation and occurs when producers and consumers are required to construct and purchase more water efficient devices. Another way to achieve this is through rebates, provided by water utilities or local governments, which incentivize consumers to replace their outdated fixtures through offering compensation for all or part of the cost.

An additional way to achieve conservation indoors is through educating and encouraging consumers to take matters into their own hands. Anyone can go to the local hardware store to purchase the most water efficient devices, or even adopt water efficient practices, such as only running full loads in the washing machine and turning faucets on only when needed. This topic of education will be discussed later in the paper, as it is arguably the most important means to achieving water conservation.

Besides replacing our fixtures, there are other ways to conserve. An individual toilet leak alone can waste more than 100 gallons per day (gpd). Although this is the exception rather than the rule, a 1999 AWWA study found that the average water lost for homes with toilet leaks is 21.9 gpd. Leaking toilets, faucets, and pipes are a huge waste and an easy fix. Identifying leaks can be as simple as listening for running water coming from fixtures, or in the case of toilets, by applying a line of dye along the inside of your toilet and looking to see if it runs. These simple measures can lead to great savings.[24]

These changes can take place in industrial and business settings as well. High efficiency urinals today are entirely waterless. Replacing water use fixtures in offices and homes reduces water bills and more importantly reduces the burden to the Colorado River.

An example of a successful toilet rebate program occurred in Los Angeles in the 1990s. Starting in 1990, the LA Department of Water helped to fund, through rebates and community involvement, the installation of more than 900,000 1.6 gpf toilets. The program saved an estimated 28.7 million gallons per day (mgd), and around 31.7 gpd per toilet replacement. From 1990 to 2000 the program spent around $107 million – that's about $3.70 per gallon saved. When the city surveyed their customers, they found that 80% said they would be likely or somewhat likely to participate in the program a second time.[25]

Outdoor Water Use

By far the largest use of residential water is spent outside the home, watering our lawns and landscaping our properties. A 25-by-40 foot area of lawn consumes around 10,000 gallons of water in one summer. Planted turf grass covers 25 million acres of U.S. soil, an area roughly the size of the state of Virginia.[26] To maintain this turf grass, Americans spend around $750 million a year on seeding lawns, and $25 billion for landscaping equipment and maintenance.[27] Here in the West where water sources are scarce and strained, it has reached a point of necessary self-reflection in which homeowners should ask themselves if the grass in their front yard is more important than the Colorado River reaching the Pacific Ocean as it once did. Curtailing our outdoor water use can be done in many ways, and as with indoor conservation, there are big and small steps to be taken, all leading in the right direction.

Simple water efficiency measures can be taken to reduce use. For starters, not watering during the heat of the day saves water by reducing losses to evaporation. It is generally accepted that the rate water lost through evaporation and transpiration is roughly 50-70% of the open pan evaporation rate.[28] Another crucial way to conserve is by discontinuing the practice of watering our sidewalks, driveways, and streets. Monitoring sprinkler systems and paying attention to their placement will greatly reduce water loss. Most importantly, however, is the use of water-efficient technologies: replacing sprinklers with more efficient systems, installing rain sensors, and using hose nozzles/shut-off devices are a few of the many tools that can be used.[29, 30]

These measures are reactive, but there is also a need for proactive measures in the planning and design of new and old landscapes. The use of native and adaptive plants is an important step forward to replace nonnative turf grass with vegetation more inclined to live in an arid or semiarid environment. The term xeriscaping was coined by Denver Water in 1981, combining "landscape" and "xeros," the Greek word for dry. This innovative term introduced a new idea of water efficient landscaping.[31] An all too common misconception is xeriscaping means rocks and cacti. This does not have to be the case. The American West contains a stunning variety of plant life. Water efficient landscaping utilizes plants adapted to flourish in this part of the country. Xeriscaping is not confined to the Colorado River Basin however; below are seven principles of xeriscaping as outline by a University of Georgia study:[32]

1. Proper planning and design

Before retrofitting a turf area or constructing a new landscape it is important to have a plan. Taking into consideration such things as water use zones, shade areas, and site characteristics are important aspects of a successful water efficient landscape.

2. Soil analysis

Soil can make or break a landscape. The higher quality the soil the more water it will retain, and the more efficient it will be. Before planting it is necessary to inspect the soil and see if it will meet the needs of whatever is being planted in it.

3. Appropriate plant selection

When choosing plants for your xeriscaping project there are many considerations involved. How much water is needed? What plants require what amounts of water? Choosing drought resistant plants and planting based on similar watering profiles will increase landscape efficiency.

4. Practical turf areas

Xeriscaping and water efficient landscaping does not mean a zero grass yard. As long as it is well planned and watered there can still be a place for practical turf areas. The important thing to recognize is that this should not be the entirety of a landscape. The going maxim states: if the only time you walk on your lawn is behind a lawn mower, take it out. Homeowners and businesses can also use water efficient grasses such as blue gramma and buffalo grass, which require 80% less water than Kentucky bluegrass.

5. Efficient irrigation

Irrigate different plants and areas differently. By smart planning and grouping plants of similar water needs together, one can save on irrigation. Using alternative techniques is also effective. Switching to drip irrigation systems, especially for plants with lower water needs, and avoiding sprinklers that cause misting or are improperly placed are essential.

6. Use of mulches

Mulch can reduce evaporative losses, cool soil, and control weeds. Mulching is an important part of water efficient landscaping. It keeps water in the soil. One can also top-dress a lawn by applying a thin layer of mulch on top of the grass. This will increase the organic content of the soil, protect grass roots, and decrease evaporation rates.

7. Appropriate maintenance

Too often watering systems operate without human involvement. A crucial aspect of water savings outside is maintenance. Inspecting fixtures, sprinkler heads, hoses, etc. is a simple and easy way to ensure not to incur water loss to leaks and inefficiencies.

Many water utilities promote xeriscaping and water efficient landscapes through demonstration gardens and rebates. These gardens allow customers to see what xeriscaping can look like in their own backyards and can be an important tool in the planning process of personal home gardens by offering examples of appropriate plants.

Rebates: Addressing Indoor and Outdoor Water Conservation

As mentioned in the previous two sections rebates are often offered by water utilities as a way of incentivizing customers to purchase more efficient water technologies, such as replacing indoor fixtures, irrigation and sprinkler systems, or turf grass for more efficient landscaping. Rebates can either cover the entire cost of replacement or a portion of the cost as incentive (often times 50%). A good example of successful rebate programs can be seen with the Southern Nevada Water Authority (SNWA). The SNWA offers a turf replacement program that pays participating customers between $1.00 and $1.50 per square foot of turf removed.[33, 34] The authority's Water Efficient Technologies program provides various rebates for both outdoor and indoor technologies such as a rebate of $200 or 50% of the purchase price for smart irrigation controllers.[35] The SNWA provides customers with a free device replacement and retrofit program where the authority will give faucet aerators, water efficient showerheads, toilet flappers, and leak detection tablets to homes built before 1989.[36]

An interesting criticism of rebate programs is they are not worthwhile because passive conservation (e.g., government legislation) will eventually require the replacement and use of the same efficient technologies. The EPAct of 1992, for example, set the standard for toilets at 1.6 gpf.[37] A similar argument is made based on market demand. As consumers become more informed about water savings, they will choose to purchase water efficient devices and appliances, thus the companies manufacturing such devices will be motivated to produce water efficient products. Although such arguments do have some grounding, rebates programs such as those offered by the SNWA have proven an effective way to reduce water demand in the short run.

Audits

Audits are another successful tool used by water providers to implement indoor and outdoor conservation measures. Water audits consist of trained technicians surveying homes and offices to evaluate water uses and offer suggestions to property owners on how to change watering practices, replace devices, and fix water leaks. These audits are meant to be education oriented as they offer a way for consumers to learn where there are inefficiencies in their water usage. This is often seen as the most successful way to implement many of the indoor and outdoor conservation measures discussed previously.

Water audits can be especially useful for promoting water savings in the commercial sector, as these are often the largest water users in a municipality. Commercial customers are concerned with meeting their bottom line – to produce and/or sell their products for the lowest feasible cost. Conducting water audits for business customers allows both the water provider and customer to recognize where the organization may be using more water than needed. Curtailing this use means lowering water bills and more efficient production.

Denver Water along with other water providers offer free water audits and replacement of inefficient devices to low income households. Lower income families are going to be less likely to pursue these changes on their own, but as with commercial customers, customers participating in such audits will reduce monthly water bills.[38]

Reuse

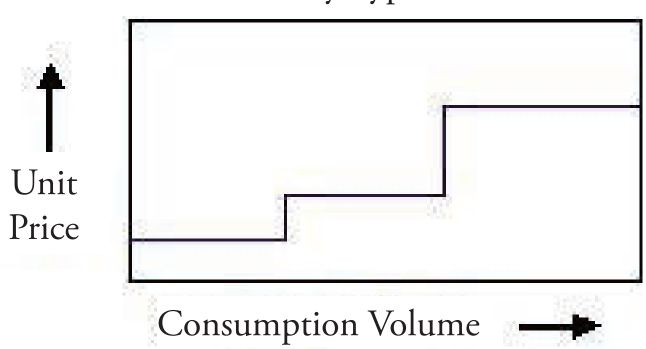
There are many ways to reuse water to increase water efficiency: from city wide infrastructure; to capture, treat, and return previously used water back into the system for non-potable uses; to collecting shower water to flush toilets and irrigate landscapes. On an individual scale, water reuse can be a cost effective way to increase water efficiency in the home, but there are arguments against it. Using reclaimed water can encourage excessive irrigating. Consumers may have the impression they are saving water and therefore will use more on irrigating than they otherwise would. While there is some validity to this argument, consumers who go out of their way to reuse water are likely to be more conscious of water usage and would not fall into such a conundrum. On a large scale, reclaimed and reused water can be taken through systems installed by municipalities for similar reuse, or to be sent through treatment facilities and reintroduced into the water source, either recharged into aquifers or simply sent back to the river or reservoir it initially came from.

Rate Structures

One of the most effective tools water providers use to incentivize efficient water use is billing structures. Consumers using excessive water can be charged a higher fee to disincentivize overuse. The most common form of this is known as increasing block rate pricing (**Figure 24**). This is a system in which water use is priced in blocks. Low water usage corresponds with low rates for essential uses while higher water usage corresponds with higher rates. Once a customer's water usage surpasses a certain level in a given month, a higher rate will be charged for subsequent use.

Research suggests block structures are most effective when blocks are properly sized and rate increases are large enough to get consumers attention. Ideally the first block of water use will be enough water for the average single family's indoor water use, the second block should allow for efficient irrigation, and the third and possibly fourth blocks should correspond with higher and potentially wasteful usage. It is suggested the most effective block should increase approximately 50% for each tier in order to properly inform customers.[39] Block rate pricing has been found to be more effective with lower and middle income customers than with the upper class customers, as price signals are weaker for the wealthy.[40] The responsiveness to change in prices is known as price elasticity of demand, a measurement of how demand will change when price is affected. A California study found price elasticity of demand for single family residences of -.2, meaning that a 100% increase in the price of water would lead to a 20% decrease in demand.[41]

Figure 24: Average Residential Water Use In Homes by Type



Source: Western Resource Advocates.

Other conservation oriented rate structures include budget based and seasonal rates. Both are more common for commercial customers, but some cities, such as Boulder, Colorado, use budget based rates for residential customers. Budget based rates are first determined by calculating historical averages and necessary/acceptable use. Every customer is assigned a specific, budgeted amount of water. Customers who abide by their budget see very low water bills, while those using more than the allotted amount experience high water bills as a penalty. Seasonal water rates function to disincentivize water usage during peak demand periods in the year. Under these rate structures, customers will pay more for water in the summer than the winter months.

Land Use

The population boom in the southwest since the end of World War II is not over. The Bureau of Reclamation demand projections expect population growth along the lines of 56% in the next 50 years with the current best estimate predictions.[42] This growth means new development and infrastructure, which translates to new opportunities to build water efficiency into homes, developments, and offices. Building with water efficient landscapes, fixtures and appliances, and modifying zoning regulations locks in water savings. Smart growth requires multiple layers of planning. Local governments have the greatest influence on smart growth, but both state and federal governments can influence as well through mandates, regulations, and funding. Water efficient growth necessitates cooperation between water providers and users. Smart growth can be promoted by utilities through offering discounts for efficient developments. This can be in the form of density bonuses (larger lots consume more water) or ordinances, such as the SNWA's banning of turf in front of homes.[43] There are many water efficient developments being lived in today: from Daybreak, Utah, to Sterling Ranch, Colorado, to Civano, Arizona, communities are beginning to learn to build homes suited to their surroundings.[44]

Civano Neighborhoods

The Civano Neighborhoods in Tucson, Arizona, started in the 1990s as the Tucson Solar Village Development with the goal of building an ecologically friendly and efficient community. The community was created as an antithesis to urban sprawl and inefficient resource management. It is one of the first communities to incorporate new-urbanism principles of community and anti-sprawl within an environmental and conservationist framework.[45] In a Memorandum of Understanding drawn up with the city of Tucson, Civano set standards for water use as 53 gallons per capita per day for indoor use, and 28 gallons per capita per day for outdoor use, roughly half the average gpcd for Tucson according to some estimates.[46, 47] The Civano developers put their focus on limiting outdoor water use as it is where the most water is wasted in nearby Tucson. The neighborhoods only use lower water use landscaping with the exception of a few practical turf areas. Outdoor community areas and many homes are irrigated with reclaimed water as well. Total water demands in the community are 20% lower than Tucson's during winter months and 40-50% lower during the high usage summer months.[48]

Ordinances/Mandates

Government legislation and mandates or restrictions by water providers are strong tools for implementing water savings. Legislation, such as the EPAct of 1992, and restrictions, such as the SNWA's no turf grass in front yards, are examples of top-down rules and regulations that prohibit water waste. There is a wide variety of these initiatives all with the guiding principle of telling people how they can and cannot use their water. A major benefit of such initiatives is their far reaching quality. A restriction on watering times affects an entire community, influencing consumer behavior. As stated previously, there is an array of mandates and restrictions of varying severity. A common example is days of the week watering restrictions (e.g., odd number home and business addresses can only water Tuesday, Thursday, and Saturday). Water providers inform their customers as to what days of the week they can and cannot water, followed up by enforcement, which can either be education or penalty based. Such programs can lead to inefficiency, however. For example, the Pueblo Board of Water Works previously implemented such a regulation, but the water provider noticed that by mandating customers to water on specific days, customers paid less attention to precipitation and irrigated more than previously. Now, as opposed to mandating restrictions, the Board of Water Works requests their customers only water their lawns three days a week. This allows customers to make informed decisions and account for rainfall in their irrigating.[49]

EPAct 1992

The Energy Policy Act of 1992, commonly known as the EPAct, addressed such issues as energy efficiency standards, energy conservation, and the use and acquisition of energy in many fields. In terms of municipal water conservation, the act established maximum use standards for toilets, urinals, faucets, and showerheads. The act stated that future production of such products was required to be under certain levels. Toilets were mandated to 1.6 gpf and urinals to 1.0 gpf. The act set maximum flow requirements for showerheads and faucets at no more than 80 pounds per square inch, which equates to 2.5 gallons per minute (gpm). The act also established labeling standards. This required all such products to bear clearly legible labels indicating flow rates.[50]

Social Norming

Social norming is a new idea in conservation that encourages users to save by sharing comparisons of individual water use to neighbors and the surrounding community. It relies on simple competition and the age old custom of getting ahead of one's neighbors. The practice has seen some success for energy utilities, which have been using the same idea but with electricity bills.

The Sacramento Municipal Utility District began sending out energy use report cards to various customers in 2008. The statements included a bar graph comparing individual energy use, the energy use of 100 additional houses of similar size, and 20 houses with exceptional energy use. The report cards also provided a smiley face rating of either two smiley faces for exceptional usage, one smiley face for good usage, or a frowning face for poor usage (the frowning face was eventually phased out due to too many complaints from customers). The first assessment of the program concluded that customers who received report cards reduced their energy consumption by 2% more than customers who received regular statements.[51]

A 2011 study was conducted in the greater Atlanta region to examine the effects of norm-based messages on water users. Different water users received different conservation messages. Some received water conservation tips with their water bills, while others received those tips along with a comparison of their water use to their neighbors' use. The study found that residents receiving only technical advice reduced their water use by around 1% while residents receiving norm-based messages reduced their usage by around 5%. The study also found high water users who are less influenced by price signals, such as increasing blocks rates, were the most responsive group to social norming.[52]

A potential way to introduce social norming on a large scale for water usage is through metering. Automated/Advanced Metering Infrastructure (AMI) is a new technology that can remotely meter household water use and then report water use to residents by request or on a scheduled basis.[53] With this technology it would be possible to implement social norming into water bills by simply gathering water use data for neighborhoods and supplying averages and efficient use data.

Education

Education is considered by many to be the most important resource for achieving water savings. Although education is the least quantifiable of the listed water conservation techniques and practices, it is how conservationists, utilities, and governments inform consumers about responsible water usage and the value of water itself. Homes and businesses can be told a thousand times over not to waste water, but if consumers do not understand the critical state of the basin and all of the resources going into producing the water supply they will not have the appreciation nor knowledge to pursue water savings and efficiency on their own. Passive conservation and locked-in savings can only go so far. As is the case with rebate programs, there will come a time when the market is fully saturated with high-efficiency devices. Moving forward from there requires informed water users. Helping people to understand the value of shorter showers, turning off faucets, fixing leaks, and minimizing outdoor watering is going to be critical in the coming years as the water supply in the basin becomes more stressed.

Education programs take many forms. From teaching children in schools, to offering adult water use classes, to performing water audits and pursuing informational advertising campaigns, these are all popular and important ways to educate the community at large. Reaching out to children either in school programs or water festivals, where kids can come together to celebrate and learn about water, are great ways to communicate with the youth about how they can save and appreciate their water. Working with the younger generation is a crucial step in long-term conservation as it will influence the next generation of home and business owners. Although adults are a more difficult population to reach, adult education classes are also important. Working with adults on such things as outdoor water use and water saving tips for inside the home can influence consumer behavior and reduce usage. Since the adult population is not already sitting in a class room as our students are, it is necessary to find alternative methods to educate adults. One technique for achieving this is to require

Case Study: Las Vegas: Southern Nevada Water Authority (SNWA)

When speaking of a city using its water resources poorly, more often than not one hears mention of Las Vegas: the opulent sin-city of America, right smack in the middle of the Nevada desert, slurping up the precious waters of Lake Mead and the Colorado River. Surprising as it may be to hear, Las Vegas is just the opposite. The growing desert metropolis has actually become one of the greatest examples for effective water conservation in the Colorado River Basin.

The state of Nevada was apportioned the smallest water allocation from the Colorado River out of the seven U.S. basin states, receiving 300,000 acre-feet annually, only 1.8% of the Colorado's allocated water. When the compact was written in the 1920s, Las Vegas was still a small town, agriculturally based, with little need for much water. Today, Las Vegas has more people per square mile than any city in the West besides Los Angeles. This combination of huge population and a relatively small apportionment of Colorado River water has necessitated the city to come up with creative and innovative solutions to using its water efficiently. The Southern Nevada Water Authority (SNWA) was created in 1991 as an agreement between seven regional water agencies with a goal of changing competition to cooperation and learning. The SNWA regulates the Las Vegas Valley's water resources and spearheads the valley's water conservation initiatives.

Approximately 90% of the valley's water comes from the Colorado River with the other 10% made up of ground water. Up until the 1970s, Las Vegas was a city almost entirely dependent on groundwater, with the majority of the downtown area based off wells. It was due to rapid growth in the 1980s that Las Vegas became reliant on the Colorado River.

Many people's first thought when they hear Las Vegas and water usage is of casinos, resorts, golf courses, and general excessive water usage for the entertainment of millions of tourists. However, the greatest water usage in the valley is not in these entertainment hubs, but rather in everyday residential homes.

As we can see from **Figure 25**, resorts and golf courses account for only 13.9% of metered water usage in the valley while residential single family use accounts for 45% of metered use. Thus, as with many other cities across the basin, the greatest area for water savings is in outdoor residential water use.

The SNWA has four principal demand management tools used in conjunction with each other to reducing water usage. The tools are: educating the public, regulating water use, pricing water to send conservation signals, and incentivizing efficient use. The authority attempts to interlink these four tools with the idea that in order for them to accomplish the greatest savings they will need a little bit of everything.

Education

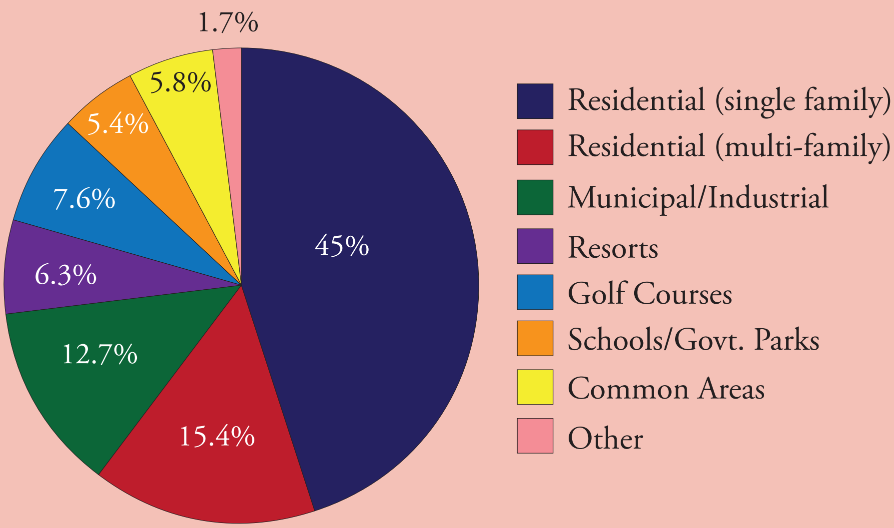
The SNWA education initiative is aimed at increasing consumer buy-in into various programs, as well as teaching the community how to use water responsibly in a desert environment. One of the more interesting programs is H20 University. This is a program designed to work with teachers, and provides lesson plans for teaching water conservation in the classroom. The idea behind the program is not directly sending utility personnel into schools, as many utilities are doing, but rather it can be more effective by educating teachers, thus enabling those who really understand how to reach out to the youth to share conservation ideas with the students. This allows fewer utility resources to be dedicated to the program, while increasing effectiveness.

The SNWA, as well as many other cities, has a public relations campaign, including billboards, television and radio commercials, and direct mail. This campaign is aimed at informing water users how and where they can save with simple messages. The SNWA also sponsors community outreach events, and runs demonstration gardens to further share ways in which the community can save water. But education is not limited to these programs alone. Looking at the authority's other demand management tools, education initiatives are implemented into many other programs, connecting the dots of the conservation nexus.

Partnerships

A crucial aspect of water conservation recognized by the SNWA is the ability to partner with private organizations in order to achieve a dispersal of knowledge and information for consumers. As opposed to consumers constantly being told how to save water and how they must save water, in the case of mandates, the SNWA sees the importance in linking their goals with other organizations around the community. This allows for multiple sources of water savings and water conservation ideas and practices to inundate water consumers with knowledge about smart practices. The SNWA has partnerships through the following programs to achieve this goal:

Figure 25: Average Residential Water Use in Homes by Type



Source: Southern Nevada Water Authority.

Water Conservation Coalition (WCC)

Created in 1995, the WCC is a coalition of local community leaders who work to spread the knowledge of water conservation throughout the community. Members of the WCC speak and work with individuals and businesses in the community to encourage participation in water savings programs offered by the SNWA. For example, in 2008 the WCC worked with Boys Town Nevada, homes for at-risk youth, to install water efficiency upgrades. The program is estimated to have save 2.2 million gallons of water a year.

Water Upon Request

The Nevada Restaurant Association, the WCC, and the SNWA have worked to implement a water savings initiative with local restaurants to only serve glasses of water when customers request them. For every glass of water that is not served, an estimated 1.5 to 3 gallons of water is saved. Currently over 300 restaurants are participating in the program.

Water Smart Home

The Southern Nevada Home Builders Association has partnered with the SNWA to develop a program that certifies new homes with a Water Smart label. These new homes are built with water efficient appliances and devices, as well as with water efficient landscaping. The Association is the nation's largest program for building new water efficient housing. The SNWA also works closely with WaterSense, the EPA program, which provides information on water efficient and environmentally friendly products. SNWA's Water Smart home program is now the model for WaterSense's New Homes Program.

Water Smart Car Wash

This program certifies water efficient car washes and encourages consumers to bring their cars to certified establishments through offering coupons. Certified car washes collect all of their waste water for it to be sent through treatment plants and returned into the system.

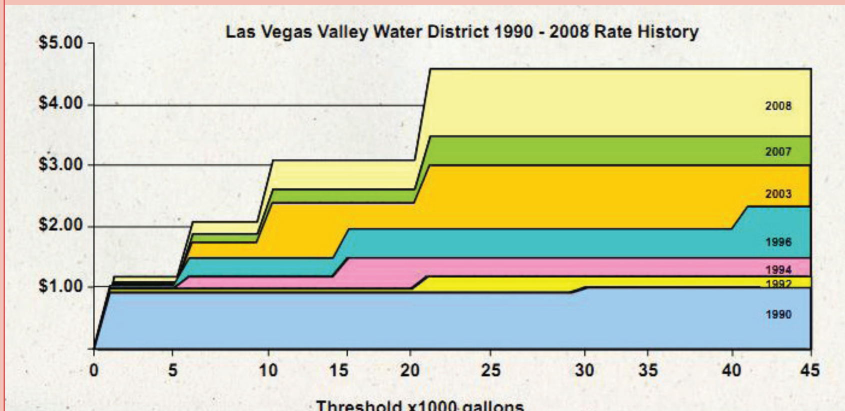
Regulation

One of the biggest differences between the SNWA and other water providers and authorities is the success of their regulation initiatives. The greatest one being turf grass restrictions. For residential homes, lawns are prohibited in front yards and cannot exceed 50% of the land area in new back yards. The idea of practical turf areas is strong here, with the notion if the only time you walk on your lawn is to mow it, it is unnecessary. For nonresidential developments, lawns are prohibited. Although many would at first balk at such stringent restrictions, through education meant to help people understand the reasons for such measures, these regulations have proven to be successful. The SNWA has also been working on regulations with the many golf courses in the valley. After placing a moratorium on the construction of new golf courses in 2003-2004, the authority began a water budgeting system for golf courses based on irrigated acreage. Each course is allotted a certain amount of water, and those exceeding their allotted use will pay high surcharges. This program was implemented in conjunction with water smart landscaping conversions, through which the authority helped golf courses convert unnecessary grass areas into more practical landscapes. Currently, over 35 million square feet of grass has been converted. From 2002-2003 to 2003-2004 alone, golf courses saw a 10% reduction in water use. The other major regulations implemented by the SNWA are their day-of-week and time-of-day watering restrictions. In the winter months, consumers are limited to watering one day a week, three days a week in the spring and fall months, and any day in the summer months. The reason for this delineation is because it was discovered that as opposed to the summer, it was actually the fringe seasons when consumers were over watering. Consumers are also limited to time-of-day restrictions where they can only water between 7 pm and 11 am from May 1st to October 1st. These restrictions are monitored and regulated by the member agencies that send out personnel to inspect water use. Those found not following the regulations are subject to increasing fines, the first being a warning and subsequent offenses carrying fines that double with each successive violation.

Water Pricing

The SNWA's member agencies utilize increasing block rate price structures to encourage efficient water use and penalize those consumers using excessive amounts. The rate structure is set up in a way that the first tier is subsidized by the higher tiers. The tiered rate system allows for growth while incentivizing smart water use. **Figure 26** shows the progression of the Las Vegas Valley Water District's rate history from 1990-2008.

Figure 26: Historical Las Vegas Valley Water Rate Structure



Source: Southern Nevada Water Authority.

Incentives

By far the best known incentive program implemented by the SNWA is their turf rebate program. This program offers consumers a rebate for every square foot of turf grass removed and replaced with water efficient landscaping. The program offers consumers $1.50 for every square foot of grass removed. Thus far the program has converted 160 million square feet and saved 59 billion gallons of water. Other incentives the SNWA offers are smart irrigation controllers and rain sensors, instant rebate coupons for water efficient car washes and pool covers, and indoor rebates for small scale retrofits, such as showerheads and faucet aerators. Along with these rebates the SNWA started their Water Efficient Technologies (WET) Program in 2001 to offer residential incentives to install approved water efficient devices that save more than 250,000 gallons per year.[54, 55]

In Summary

Las Vegas presents a strong example of a city that has identified a problem and is taking steps to fix it. A combination of a small legal apportionment, and its extreme desert climate, has led to serious and necessary changes in water usage and conservation in the Las Vegas Valley as it has grown. Many are quick to point out the city has a long way to go and that there are many measures yet to be taken, as there is always room for improvement. It is important to focus on the positive moving forward. Innovative conservation measures such as mandates on turf grass and partnerships with other conservationist organizations are strong examples of steps to take to reduce consumer demand.

classes in order to receive rebates; Aurora Water implements this technique.[56] Advertising campaigns are another important part of educating the population. Television commercials and billboards, like the one shown in **Figure 27**, receive constant viewership and can use simple messages to remind and inform consumers about water conservation. Residential and commercial water audits are additional ways water providers can work one-on-one with customers to inform them about water savings. These programs are successful because of their concreteness. As well as offering tips and techniques, technicians performing water audits can share examples with consumers as to where savings can be achieved. The combination of these and other water efficiency education programs will make a difference in the basin as we approach water scarcity in the coming years.

Water Loss and Metering

Ten percent water loss, either through system leaks or unaccounted for water, is the industry standard for acceptable water losses. This is a great quantity of wasted water that can be mitigated through monitoring. Water meters are the main tool used to account for this water loss, and as technology increases, water utilities are becoming more and more capable of recognizing losses. Automated Metering Systems (AMS) are increasingly common for Colorado River Basin water providers. AMS technology consists of individual water meters for homes and businesses, which report each property's water usage to the utility on a consistent basis. Utilities are then able to see when customers are using more water than usual, implying possible leaks or inefficiencies, and inform those customers of their increased usage. These systems can also be complemented by water audits. When a utility sees a customer has a potential leak, they can send a water technician to the property to address the problem.[57]

Agriculture/Urban Water Sharing

As urban areas increase in size and population, they are constantly pushing against land and water rights of long time agriculturalists. As opposed to this being a point of contention as it too often becomes, it presents an opportunity for compromise. Agriculture/urban water sharing refers to a practice whereby farmers are able to lease their water rights to municipalities for profit on long-term schedules, which work with farm planning and practices. There are a number of techniques through which this can be implemented, such as water banking, rotational fallowing, and interruptible supply agreements. The governing idea being a municipality pays a farmer not to use a portion of his or her water for a given season. The price paid by the municipality is assumed to cover the loss the farmer will incur from not growing crops for the season, and the water will be temporarily transferred to municipalities for urban needs. Some important considerations necessary for such agreements to work are: flexibility on the part of all parties involved; recognition that different amounts of water will be leased in different years based on factors such as reservoir levels and rainfall; willingness of both the buyer and seller to participate in the program; security of the water supply insofar as the water sharing does not affect nonparticipating farmers (i.e., beyond available consumptive use amounts); and protection from terms of forfeiture, (i.e., "use it or lose it" laws).[58, 59] A more thorough discussion of water sharing is presented in the Agriculture section of the *Report Card* on page 46.

Figure 27: Denver Water's Use Only What You Need Campaign

Source: Denver Water.

One of the largest scale examples of water sharing is currently taking place in California between the Metropolitan Water District (MWD), the water provider for much of Los Angeles, and the Palo Verde Irrigation District (PVID), an agricultural based water district in Southern California. The mid-1990s saw increasing pressure being placed on the MWD and the state of California to reduce Colorado River water usage. By 2004, the MWD and PVID came to an agreement whereby the MWD would pay farmers in Palo Verde to fallow up to 30% of their land and the MWD would receive up to 115,000 acre-feet (AF) of water each year. The program is based on voluntary participation. Participating farmers agree to fallow anywhere between 7% and 35% of their land (with the concession that no more than 30% of the district's land can be fallowed). Participating farmers received a one-time payment of $3,170 for each encumbered acre and are paid an additional $604 per nonirrigated acres (adjusted yearly). Ed Smith, the General Manager of the PVID, had this to say about the agreement in a statement for a Colorado State University Study, "I think the community as a whole understands that when times are tough our farmers are going to survive because of this program…. Some years farmers could make more if they weren't in the program, but overall you really can't go broke making money."[60]

One Less

Think about how many times a day you use a faucet. Now think about every second you leave a faucet running when not using it. Washing dishes, washing hands, brushing your teeth, taking a shower, think about every second in a day water is going down the drain when it is not entirely necessary. Does it add up to sixty seconds, to one minute? Everyone has different habits and practices, but we can all use less. What would happen if everyone used one less minute of water each day? The EPA act requirements for faucets is 2.5 gallons of water per minute. If one person used one less minute of water coming from 2.5 gpm faucets for one year they would save 912.5 gallons of water. Denver, Colorado, has a population of around 620,000 people.[61] If every Denver resident used one minute less of water for one year, assuming 2.5 gpm faucets, 565,750,000 gallons of water would be saved, the equivalent of roughly 1,736 AF of water a year, enough water for over 2,500 single family homes for one year. Over 30 million people rely on the Colorado River Basin for water. If all 30 million people used one less minute of water from 2.5 gpm faucets for one year 27,375,000,000 gallons would be saved each year, or roughly 84,010 AF of water a year, nearly 30% of Las Vegas yearly water allotment from the Colorado. Imagine if everyone used two minutes less.

Gallons per Capita per Day (GPCD)

GPCD has become the most common metric for measuring per capita water usage in cities, but interestingly enough, it is not standardized. Utilities, authorities, cities, and states measure this number differently and then attempt to compare numbers to demonstrate they are using more or less water than comparable entities. The term lends itself to what seems to be a clear definition, the number of gallons used per day per person in any given area, but it is not so simple. Some of the main areas of difference are centered on what portions of water use are taken into account: while some measurements account for total water used in a given area, others exclude water used for irrigation and agriculture, or tertiary uses, such as mining or small scale power generation. There is also a differentiation between residential GPCD and total GPCD, where the residential figure will only take into account water used in domestic settings. Furthermore, within these calculations there can arise the question of whether water used by second-home owners or vacationers should be included, as well as whether there should be a differentiation between single and multifamily residences. Another complication with the metric is how population is determined. Ideally total water use would simply be divided by total population, but similar to the aforementioned complication with second-home owners there is a question whether nonpermanent residents should be counted in an area's population. For residential calculations especially, agencies computing GPCD will often look at water usage by household and then divide by an average occupancy rate per household. Any variation in such number will have great effects on the final number. In short, it is important to look critically at such numbers and to realize, although one area may seem to have much higher per capita water usage, it may simply be they are taking more into account when computing their data.


Will Stauffer-Norris

Colorado River water in Las Vegas, Nevada.

Case Study: Australia

"The Big Dry" characterizes a more than decade long period of drought that began in Australia in 1997. Although the drought has been devastating to the Australian people it has also turned Australia into one of the world leaders in water conservation, and the techniques and strategies they have adopted can be lessons to us all. Between 2002 and 2008, per capita water usage in Australia dropped 37% with residential water usage estimated to be around 54-59 GPCD in 2009, nearly half of the per capita usage in the U.S.[62] Many of the changes in Australia's water usage have come from top down initiatives, chiefly originating in the form of legislation from the Council of Australian Governments (COAG). In 1994, the council agreed to the Water Reform Framework, which entailed promotion of market-based management systems for water use and water prices fully reflective of the resource costs. The National Water Initiative (NWI) of 2004 built upon the goals of the Water Reform Framework and sought to move towards "integrated management of water for environmental and public benefit." The National Water Commission (NWC) was instated in that same year to oversee the NWI.

One of the major programs these initiatives have promoted is water recycling. Implementation of systems to reuse once potable water for purposes such as flushing toilets, watering gardens, and washing cars has gained popularity on the Australian continent. In Geelong, Victoria, for example, there is currently a $90 million (U.S.) water recycling plant under construction, part of which is being funded by the COAG. The public is slow to use this reclaimed water for potable uses such as showering, but has adopted reclaimed water for nonpotable uses. The infrastructure in place differentiates the reclaimed water with purple pipes, signifying to all the source of the reclaimed water.

Another large scale initiative the country is pursuing is desalination. Between the country's five largest cities, a combined $13.2 billion (U.S.) is being spent on desalination operations that will eventually meet 30% of the five cities' water demand. This has proved an interesting and effective way to produce a sustainable drinking source, and may be a technique many countries will follow in the years to come; however innovative, it is important to recognize desalination is an energy intensive practice and is accompanied by high costs.

Water use restrictions have become increasingly common in Australia, both temporarily and permanently. Restrictions are typically mandated by local governments and authorities, ranging from such things as time of day watering schedules to the banning of sprinklers (only allowing consumers to water by hand). These restrictions have been met with mixed emotions by the Australian public, but for the short-term people have been pleased to comply. The one concern people seem to have is the time span of these restrictions and whether they will eventually phase out. Some states have even implemented water inspectors of varying authorities, some with the ability to handout fines (although typically not until a second or third offense) while others are tasked with educating consumers using excessive amounts of water. A key focus of the restrictions programs, along with the other initiatives in Australia, is educating the consumers. This is done through mailings, utilities websites, and public advertising. Using these mediums allows the Australian government to inform residents about restrictions affecting them while also spreading knowledge on water saving tips and rebate opportunities.

Water pricing has been another tool used by the Australian government to curtail water use. As opposed to the tiered rate systems we commonly see here in the Colorado River Basin, it is more common to see two-part tariffs in Australia where consumers are charged a connection fee and a volumetric charge for whatever their usage may be. A major aspect of water pricing that the Australian government is working to do away with is subsidies so customers are paying the actual price of water, and not a lower subsidized price. In some rural communities, however, this is impractical and subsidies are necessary, but such subsidies are also made transparent to the public. The main idea with these initiatives is customers are paying rates on a "rational footing" and the higher prices will discourage high water use.

As mentioned above, water education is a central feature of Australia's initiatives to reduce water uses. One of the main aspects of this program is labeling for appliances and fixtures. The labels include water usage for a particular product, as well as a six-star rating system. The more water efficient a product is, the more stars it receives. Included in the education and labeling program are rebates for many water efficient products and even direct installations of some devices such as toilets.[63]

Many of these programs seem similar to programs initiated here in the Colorado River Basin, leaving us with the question: why is Australian water usage nearly half of our water usage? The answer is consumer participation and buy-in to said initiatives. Through the drought, Australians were taught a quick and often times painful lesson about the scarcity of their water resources. In response the government, the people, and countless organizations reacted with an urgent message of conservation. The people have decided to work together and to make sacrifices with their water use, and thus they have seen per capita usage greatly reduced. For the U.S. and the Colorado River Basin to mimic such changes, societies must not only continue with the many programs and initiatives in place and being pursued, but the population must also consciously decide to use less water and work together to accomplish a set of goals.

Case Study: Front Range Comparison

This case study surveys five Colorado Front Range water provider's conservation programs to offer a vignette of conservation techniques adopted over the years in cities that are, while not in the geographic basin, reliant on Colorado River Basin water. Each city has its own unique approaches to conservation based on geographical location, availability of resources, and customer demographics. The five Front Range cities examined serve as a credible case study of conservation plans due to differences in population, seniority of water rights, demographics, and access to the Colorado River Basin and tributaries. **Figure 28** provides an overview of the urban water saving techniques that each provider has adopted in its conservation plan.

Inaugurated in 1937, The Colorado Water Conservation Board (CWCB), under the Colorado Department of Natural Resources, serves to conserve, protect, manage, and develop the waters of Colorado for current and future generations. In 2004, CWCB passed Colorado's Water Conservation Act requiring that all water providers who sell 2,000 acre feet or more of water submit an annual water conservation plan to the state to be approved by CWCB.[64] Each conservation plan must comply to meet the minimum requirements that are included in the act that are listed in **Figure 29**.

Figure 28: Comparison of Urban Water Saving Techniques Adopted by Front Range Water Providers

	Denver	Aurora	Fort Collins	Colorado Springs	Pueblo
1% Per Year Reduction	X	X	X		
Water Loss Tracking/Smart Metering	X	X	X	X	X
Water Audits	X	X	X	X	X
Education/Outreach	X	X	X	X	X
Youth Education	X	X	X	X	
Adult Education	X	X	X	X	X
Commercial Education	X	X	X		
Classes	X	X	X	X	
Land Use Planning/Smart Growth	X	X	X	X	
Residential Indoor Rebates					
Dish Washer			X	X	
Clothes Washer	X		X	X	
Toilet	X	X	X	X	
Residential Irrigation Rebates					
Weather-based irrigation controller	X		X	X	
Rain sensor shut-off device					
Soil Moisture Sensor	X		X	X	
Sprinkler heads with check valves			X		
Weather station for retrofit			X	X	
Pressure-reducing heads				X	
Rotating matched precipitation spray nozzles	X		X	X	
Commercial Indoor Rebates					
Toilets/Urinals	X	X	X	X	
Evaporative Cooling Systems				X	
Commercial Irrigation Rebates					
Weather-based (smart) irrigation controllers	X	X	X	X	
Xeriscape Rebate		X			
Xeriscape Demonstration Gardens	X	X	X	X	
Water Reuse	X	X	X	X	
Water Waste Ordinances	X	X	X	X	X
Revaluing Rate Structure: Increasing Block Rates	X	X	X	X	

Figure 29: Colorado Water Conservation Board's Minimum Requirements for Conservation Plans
As of July 1, 2005, the minimum water conservation plan elements defined in §37-60-126(4) C.R.S. are:
-Water efficient fixtures and appliances, including toilets, urinals, showerheads, and faucets
-Low water use landscapes, drought resistant vegetation, removal of phreatophytes, and efficient irrigation
-Water efficient industrial and commercial water using processes
-Water reuse systems
-Distribution system leak identification and repair
-Dissemination of information regarding water use efficiency measures, including by public education, customer water use audits, and water saving demonstrations
-Water rate structures and billing systems designed to encourage water use efficiency in a fiscally responsible manner
-Regulatory measures designed to encourage water conservation
-Incentives to implement water conservation techniques, including rebates to customers to encourage the installation of water conservation measures
-Statement of the covered entity's best judgment of the role of water conservation plans in the covered entity's water supply planning
-Steps to the covered entity used to develop, and will use to implement, monitor, review, and revise its water conservation plan
-Time period, not to exceed seven years, after which the covered entity will review and update its adopted plan
-Either as a percentage or in acre-foot increments, an estimate of the amount of water that has been saved through a previously implemented conservation plan and an estimate of the amount of water that will be saved through conservation when the plan is implemented
-A public review and comment process must take place. If the covered entity does not have rules, codes, or ordinances to make a draft plan available for a public planning process, then the covered entity shall publish a draft plan, give public notice of the plan, make such plan publicly available, and solicit comments from the public for a period of not less than 60 days after the date on which the draft plan is made publicly available.
Source: Colorado Water Conservation Board. 2004. Water Conservation Act of 2004, Other CWCB Related Bills - Passed, HB04-1365, accessed August 14, 2012. http://cwcb.state.co.us/watermanagement/conservation/Documents/MinReqWaterConservePlanElements.pdf.

Although water providers throughout the region are required to meet these efforts, Front Range agencies often exceed these guidelines and adopt exceptional programs aimed at decreasing demand while concurrently increasing productive use of the current water supply. The Front Range water providers included in this analysis are: Aurora Water, Denver Water, Colorado Springs Utilities, Fort Collins Utilities, and Pueblo Board of Water Works. The following case study shows how these agencies differ in their conservation techniques and practices depending on city demographics, population projections, and availability of water. **Figure 30** provides a basic outline of the demographics of the five Front Range cities.

Aurora Water

Overview

Aurora's conservation plan places a strong emphasis on education, technical and financial assistance, and management. The plan includes education and outreach campaigns, promotion of xeriscaping education and demonstration, innovative pricing structures, water audits, waste water ordinances, consumer rebates, and collaboration with peer agencies. As of 2007, Aurora Water served approximately 306,908 people in a 144-square mile area. The 2007 budget for Aurora's conservation department totaled $2.23 million, making Aurora's budget the second largest conservation program in Colorado, behind Denver Water.[65]

Rebates

Aurora Water offers toilet rebates: $75 for 1.28 gpf or $150 for 1.0 gpf or less. Aurora approximates from 2002 through 2006, 3,778 toilets were rebated, saving a cumulative 418 acre feet of water and making it one of the city's most successful programs in terms of quantifiable water savings.[66] The city previously offered clothes washer rebates, but the program was removed after finding it had little impact on the market. Aurora Water conducted a study, which showed nearly 80% of customers would still have bought a new washer without the rebate.[67] Aurora also offers outdoor rebates to both residential and commercial users for efficient irrigation systems and xeriscaping. For irrigation, Aurora offers a rebate to cover the cost of an irrigation system upgrade; this rebate maxes out at $300 for residential properties and $5,000 for commercial users. Aurora offers $1.00 per square foot of low water use plant material and an additional $.25 per square foot of hardscape material that replaces turf grass, with a maximum rebate of $10,000 for the residential sector and up to $25,000 for the commercial sector. Aurora is the only Front Range water provider of the five cities that gives rebates for turf replacement. The Front Range is notorious for using scarce Colorado River water to sustain water intensive Kentucky bluegrass. Incentivizing bluegrass removal in the arid West is an extremely beneficial conservation technique.

Education

Aurora Water has one of the most extensive and youth driven programs in the Front Range by actively engaging its community in water conservation programs. Their education program includes classroom presentations, field

Figure 30: Demographics of Front Range Cities

	Denver	Colorado Springs	Aurora	Ft Collins	Pueblo
Population, 2010	600,158	416,427	325,078	143,986	106,595
Population, percent change, 2000 to 2010	8.20%	15.40%	17.60%	21.40%	4.40%
Persons Under 18 years, percent	21.50%	25.00%	27.30%	19.90%	24.00%
Persons 65 years and over, percent	10.40%	10.90%	8.90%	8.80%	15.70%
Persons below poverty level, percent, 2006-2010	19.20%	11.80%	16.70%	18.00%	21.20%
Median household income, 2006-2010	$45,501	$53,074	$49,515	$49,589	$34,323
Housing Units	285,797	179,607	131,040	60,503	47,593
Households, 2006-2010	254,181	162,295	120,665	55,889	42,466
Land area in square miles, 2010	153	195	154.73	54.28	53.64
Persons per square mile, 2010	3,922.60	2,140.60	2,100.90	2,652.80	1,987.20

Source: US Census Bureau, State and County Quick Facts, accessed July 5, 2012, http://quickfacts.census.gov/qfd/states/08/0862000.html.

trips, and service learning projects for community schools. Classroom presenters provide water models, games, and activities to engage students and help them learn about the sources of their water, how to prevent water pollution, and the importance of conservation. Aurora Water also provides several fieldtrips and tours for students ranging from preschool to high school. Water treatment and wastewater treatment tours are available for grades 2-12 to learn about treatment facilities and the process of water reuse. Grades 6-12 can sign up for water quality testing fieldtrips in which students are accompanied to a waterway to conduct water quality testing, paired with lessons in the classroom both before and after the trip.

Aurora Water also provides the Aurora Water Quality Understanding and Appreciation (AWQUA) Lounge where water conservation initiatives and awareness are taught in a friendly, underwater environment. Aurora's education program has received and continues to receive high praise for their efforts, including the Silver Award in 2007 from the Denver Regional Council of Governments for their youth education programs, the Local Government Awards Program category of Community Outreach/Public Education, and the Colorado Alliance for Environmental Education Award in Excellence in 2006 for Aurora Water's Youth Water Festival.

The city's education program is not limited to the classroom. Aurora Water also requires customers who wish to participate in rebate programs to attend water efficiency classes. A similar initiative is in place for customers who violate water waste restrictions. This pairing of education with other programs offered by the utility allows for a greater dispersal of knowledge to the adult population.

Programs

Aurora Water provides numerous programs to its customers including free indoor and outdoor water audits, the Water Smart Neighborhood Program for homeowner associations, internship opportunities, and an Industrial, Commercial, and Institutional conservation program. For this program, Aurora Water came together with the Northern Colorado ICI Water Conservation Workgroup in 2005 to create a partnership to address water conservation on the regional level by gathering benchmark data on restaurants, hotels and motels, schools, and nursing homes. This program allows Aurora to further develop educational programs and initiatives aimed at the industrial sector.

Ordinances

Aurora Water maintains ordinances for new construction projects regarding lawn permits, irrigation standards, and car wash reclamation. The city also has water wasting ordinances prohibiting customers from allowing water to run across impervious surfaces, allowing customers to irrigate their landscapes only three days a week, and not allowing watering between the hours of 10 a.m. and 6 p.m.

Research

Aurora Water is one of the nine municipalities to participate in a new home efficiency study that analyzes water use in an average new home versus water use in a high-efficiency new home. Aurora water is also studying the relationship between price sensitivity and conservation measures. The city also actively conducts surveys to assess customer opinions and preferences. These surveys serve as a tool to see what conservation programs work well and what programs need improvements.

Conclusion

Aurora Water shows a strong conservation plan including several approaches to conservation, from rebates and incentives to ordinances and partnerships. Aurora Water is a leader in conservation among water providers and an example to be emulated throughout the Colorado River Basin. Aurora's education program is among the strongest in the Front Range, providing a broad range of opportunities for the residential and commercial sector alike.[68, 69]

Denver Water

Overview

In 2007, Denver launched its 10-year conservation plan with the goal to reduce water use and GPCD by 22% by 2016.[70] By 2011, customers were already using 20% less water, even with a population increase of 10%.[71] Denver Water services more than a million people in an area of 335 square miles.[72] The most successful aspect of Denver Water's conservation is its public outreach campaign: Use Only What You Need, and the ability of this campaign to create social changes in how we view water.

Education

Denver Water has an expansive education program. This includes a summer program, which hires temporary "Water Savers" who work to educate thousands of customers about water waste and enforce summer watering restrictions. Denver has made a serious effort to reach all of its customers with its Use Only What You Need Campaign. This lively campaign uses creative advertising, pictured in **Figure 31**, to capture the attention of the public, and encourage customers to reduce their water consumption. In the past six years alone, water consumption has decreased by 20%.[73] This campaign recognizes that different types of customers will be reached and affected in different ways; public outreach, media advertising, and a variety of water audit programs have led this program to great success. A recent study conducted by Denver Water found that 90% of its customers recognize the effect this initiative has had on their water consumption.

Figure 31: Denver Water's Use Only What You Need Campaign

Source: Denver Water.

Rebates

Denver's rebate program has seen great success in recent years with an increase of 62% on outdoor commercial rebates since 2009, a 19% increase for residential outdoor rebates, and a 45% increase for indoor residential rebates. Denver Water offers residential customers rebates for clothes washers, toilets, rotary nozzles for sprinklers, and smart irrigation controllers. Industrial rebates are farther reaching and include toilet and urinal replacement, cooling tower equipment, commercial warewashing equipment, and irrigation equipment (smart controllers and rotary nozzles).

Programs

Denver Water runs a large water recycling program, which was first initiated in 2004 and then revised in 2010. The Recycled Water Master Plan outlines and plans for future growth, recommends infrastructure, and analyzes effects of population growth. The water utility has set a goal of delivering 17,500 acre-feet of recycled water each year. Once completed, the system will free up enough drinking water for almost 43,000 homes. In 2011, Denver Water was about one-third of the way toward this goal. Denver Water also provides a variety of water audits. Low income audits allow for water technicians to evaluate lower-class housing where water conservation is less of a priority, and commercial audits are hugely effective in identifying large, hidden water uses in industrial facilities such as cooling towers. Denver implemented a soil amendment program requiring developers to till compost into soil prepped for landscaping, reducing future water needs for irrigation. In 2010 alone, employees performed 1,097 soil amendment inspections on more than five million square feet of land, with the potential to reduce water needs by more than 20 million gallons of water per year.[74]

Conclusion

Denver Water continues to make a great difference in water conservation and deserves every bit of praise it has received. Their public outreach not only affects the Denver population, but also carries over into other Front Range cities like Colorado Springs and Pueblo. With the largest conservation budget, coupled with the biggest service population in the Front Range, their influence is both vast and central for reducing water use in the West.

Pueblo

Overview

Since 2002, Pueblo has reduce per capita water usage by 19%.[75] Pueblo Board of Water Works has focused its conservation plan on education and outreach, and addressing water system water loss.

Education

Pueblo's water information initiative works to spread information to the utilities' customers about water conservation through mailings and public meetings. The city also has Water Wise programs, which are geared towards teaching the youth lessons about water conservation, water sources, and general appreciation of the resource.

Programs

One of Pueblo's most focused conservation initiatives is metering, specifically replacing existing meters with

Sports Authority Field at Mile High

Denver's acclaimed football stadium has undergone a water conservation renovation, saving millions of gallons of water each year. "When you have a big complex like we do, small changes make a very, very big difference," claims Andy Gorchov, general manager of Sports Authority Field at Mile High. "You can't be wasteful."[76] The renowned football stadium has saved millions of gallons of water through two water conservation initiatives. First, the toilet retrofit project replaced 142 toilets with high-efficiency models (1.28 gpf) with a toilet rebate of more than $17,000, saving the stadium thousands of gallons of water each time an event is hosted.[77] The second program is an irrigation contract that has almost halved the amount of water used for irrigating. In 2008, the stadium shifted towards a central control system that allows turf managers to change water schedules based on plant's needs in the 30 acres of land, factoring in weather data, precipitation rates, soil type, sun exposure, and additional factors. Since the installation of the project in 2008, Mile High Stadium has saved 6.8 million gallons of water per year in irrigation use, and received more than $55,000 in incentives from Denver Water. This saved water coupled with the savings of an average of $25,000 a year in water bills has been an extremely successful example of water conservation for commercial projects. "These things make very good business sense," explained Gorchov. "It's very expensive to waste."[78]

new meters that operate under Automated Meter Reading (AMR). AMR allows meter data to be sent to one of the 16 data collection units in the city of Pueblo, rather than the traditional process, which required employees to read meters individually and record the data. The solar powered collection units send the information to a central computer used for billing, customer service, and field services. Upgrading to AMRs began in 2008 and is estimated to be completed in a ten-year period in which all 40,191 meters in the system will be replaced. During the first three years, 18,078 meters were replaced and by the end of 2011, half of the meters had been replaced.[79]

The process is free for customers and promises to increase efficiency for operations. Instead of having employees travel across the city to read meters individually, employees can instantly access the information through a database. Additionally, if customers wish to inquire about a sudden change in their bill, Pueblo Board of Water Works can poll their specific meter and search for any changes which could result in a problem. Pueblo's effort to upgrade metering to prevent water loss and inform customers is a superb effort in water management and water conservation.

Conclusion

Although Pueblo does not include many of the water saving techniques listed in **Figure 32**, it is worth mentioning Pueblo is unique in its demographics compared to the other four Front Range cities. Pueblo has the largest percentage of senior citizens out of the cities, the highest percentage of population below the poverty line, and the lowest median income. Because Pueblo has an adequate supply of water with senior water rights over the Arkansas River, it is not necessary to take such an aggressive conservation stance like that of Denver and Aurora. Despite this, Pueblo has still adopted a conservation plan aimed at preserving their adequate supply for years to come.

Fort Collins

Overview

Serving 8.8 billion gallons of water to 128,000 people in 2007, Fort Collins views water conservation as an important, proactive response to supply variability and increased demand. The Fort Collins Water Utility has a stated goal of reaching 140 GPCD by 2020. Their conservation plan focuses on reducing both indoor and outdoor demand through leak reduction, behavioral change through education, improved technology, and efficient irrigation and landscaping.[80]

Education

Fort Collins Utilities operates a public information campaign in which all water conservation, water use, and billing are provided to customers upon request. The campaign also sponsors various community events, such as Sustainable Living Fair, a family-based event aimed at spreading information on water and energy efficiency. The utility also provides adult, school, and business education programs. Their school education program is comprised of a water conservation curriculum, which educates kids on the importance of using the resource wisely. Adults can participate in a variety of xeriscape programs to learn water conserving techniques and practices for landscaping. Each year the utility runs a Children's Water Festival, where approximately 1,700 third-grade students and teachers come to learn about issues such as wetlands and rivers, water conservation, the impacts of droughts, and the importance of water.[81]

Rebates

Fort Collins offers the most rebate opportunities to its customers of the five cities we examined. For indoor residential use, customers can claim $35 for a 1.28 gpf toilet and an additional $15 for recycling the old toilet, a $50 rebate for an approved clothes washer, and $25 for qualifying dishwashers. Approximately 900 rebates have been given each year for the clothes washer program, making this program one of the most successful.

Fort Collins Utilities offers rebates for weather-based irrigation controllers ($150), both wired and wireless rain sensor shut-off devices ($15 and $30 respectively), soil moisture sensors ($45), and weather stations for retrofit ($50). Fort Collins Utilities is the only water provider surveyed that includes a rebate for pressure reading heads with a $20 rebate for purchases between $40-$79, and a $40 rebate for purchase of $80+. Rebates are also offered for high efficiency nozzles with a $25 rebate for purchases between $50-$99, and $50 for purchases of $100+.[82]

Ordinances

Like many of the other water providers, Fort Collins maintains waste water ordinances. The utility prohibits homeowner associations from banning xeriscaping or requiring minimum turf areas. The city has a soil amendment ordinance for new properties requiring specific soils to promote landscape efficiency and landscape and irrigation standards for new developments. Under this ordinance, all new development landscape and irrigation plans must be in compliance with the Land Use Code's water conservation standards, which includes requiring a rain shut-off device for commercial sprinkler systems.

Conclusion

Fort Collins Utilities rebate program is one to be highlighted and emulated throughout the region. Because the market has not fully created a demand for water efficient appliances, especially for new efficient irrigation equipment, it is important for utility companies to incentivize such technologies, like Fort Collins has done, and educate their consumers. Similar to Aurora, Fort Collins also offers an impressive education program, aimed at not only adults and businesses, but also the youth.

Colorado Springs Utilities

Overview

Colorado Springs Utilities (CSU) is a community-owned utility with a service area of 184 square miles. In 2006, 26 billion gallons of water was delivered to 417,000 people. CSU emphasizes collaboration and cooperative relationships throughout the region to encourage water conservation and efficiency. In 1999, the city began pursuing a goal of reducing water usage by 30 billion gallons by 2017.[83]

Rebates

CSU offers rebates for toilets ($75), clothes washers ($75), and dishwashers ($50). CSU contains a wide array of outdoor irrigation rebates covering half the price of a weather-based irrigation controller up to $200, a $25 rebate for a wired rain sensor shut-off device, a $50 rebate for a wireless rain sensor shut-off device, and up to $4 for rotating matched precipitation spray nozzles. Colorado Springs is also the only water provider we interviewed to rebate sprinkler heads with check valves with a $50 rebate for purchases between $100-$199, $100 rebate for purchases between $200-$399, and a $200 rebate for purchases of $400+.

Education

CSU asserts that the historical emphasis on education has contributed to low residential per capita use. Their education programs include classes for adults on conservation and water efficiency in the home, public demonstrations such as their xeriscape demonstration garden, school partnerships and education in the classroom, public speakers, water tours, and public information initiatives.

Programs

Similar to the Pueblo Board of Water Works, CSU took a strong initiative to deploy AMRs to all customers by 2010. As mentioned previously, this allows water users to access daily and weekly consumption reports and information, making it a great educational tool. In addition to their AMR program to help customers with their water use, CSU's Peak Day Program will develop education programs aimed at reducing peak day use, specifically in areas with high residential per capita use and high peaking factors. CSU has commercial and residential audit programs to identify large, unnecessary water uses. CSU also launched a campaign specifically targeted at new residential construction. Colorado Springs Utilities developed landscape guidelines for distribution to home buyers, home builders, and realtors.

Ordinances

Colorado Springs Utilities conservation plan contains waste water ordinances, landscape establishment permits, and a Landscape Code and Policy. The Landscape Code and Policy requires water efficient landscaping for new commercial, industrial, and multifamily properties. For years, the landscape code in Colorado Springs has been cited as a model for other communities to follow. The utility recognizes, given recent advancements in irrigation technology and changing customer expectations, the existing code needs review. Elements under consideration include more stringent enforcement procedures and smart (ET) controller requirements. CSU will engage key stakeholders in the code review process. The water waste ordinance sets limitations on pooling or flowing of water across impervious surfaces, as well as time-of-day watering restrictions. The Utilities' landscape establishment permits require customers to install at least three cubic yards of organic material for every 1,000 square feet of planting area.[84, 85]

Conclusion

CSU's single family per capita use is a notable achievement compared to other Front Range water users. Similarly, their emphasis on education and metering programs has led to a strong conservation plan that will help curb the growing water demand of the city.

Comparison

Looking at the Colorado Front Range Case Study is an examination of five water providers meeting the needs of five distinctly different populations, and all possessing very different water rights. Looking at the prices customers pay for water in each of these cities alone speaks to the varying degrees of water rights. In Pueblo, for example, a recent study conducted by the Board of Water Works found that increase block rate pricing would be ineffective at decreasing demand for the city and other conservation initiatives would be better suited. Thus, in Pueblo there are starkly lower water prices than in any of the other Front Range cities studied. This difference in water price is closely associated with difference in water rights. Unlike any of the other four cities, Pueblo possesses highly senior water rights on the Arkansas River (taking much less from the Colorado), and therefore water supply is, for now, seemingly a non-issue. The city is able to charge lower rates. Conversely, the city of Aurora is one in possession of very inferior water rights on the South Platte River. Because of this, the city has a greater need to charge customers more in order to further discourage wasteful use. It is like looking at a puzzle slowly being pieced together, when

Figure 32: Indoor Rebate Programs

Rebates	Colorado Springs	Denver Water	Fort Collins Utilities	Aurora	Pueblo
Toilets/Urinals	$75 (1.28 gpf or less)	$75 (1.28 gpf or less)	$35 ($70 purchases made April through July 2012) 1.28 gpf or less, additional $15 for recycling old toilet	$75 (1.28 gpf), $150 (1.0 gpf or less)	
Clothes Washers	$75	$100	$50		
Dishwashers	$50		$25		

one corner is found the rest can start to work around it. The cities of Pueblo and Aurora have found different corners to work with, and not surprisingly they are fitting together their puzzles in different ways.

It is not all a story of differences, however. Among the five cities the popularity of rebates is nearly across the board. **Figure 32** displays various indoor rebate programs for the Front Range cities. While some rebates have been phased out in recent years, e.g., dishwasher rebates in Denver and Aurora, others are still going strong. Until the market is saturated and it no longer makes sense for water providers to facilitate such retrofits, these rebates, e.g., toilet replacements, will continue. Especially in more urban settings the prevalence of such initiatives is continuing, and likely will for years to come.

Outdoor rebates continue to be popular as well, although these tend to vary more based on city demographics and land use trends. Outdoor rebates, such as pressure reducing sprinkler heads and weather station retrofits, are granted by Fort Collins Utilities, but not Denver Water or Aurora Water. This is a case where higher density areas are putting less focus on initiatives utilized by lower density areas. Again the difference is based on the specifics of each city. The outdoor rebate program (shown in **Figure 33**) seems to be determined by the demographics and density of the city.

Different cities are responding to the different needs of their customer bases. Everyone understands conservation is necessary, but the tools utilized in order to pursue this goal will vary. In the city of Pueblo, where the very senior population places a high value on green lawns, xeriscaping programs are poorly received. Realizing this, the Pueblo Board of Water Works has focused its energies on installing smart metering systems to address water loss, something they know needs to be reduced. In Aurora, where water is scarcer, Aurora water has focused their efforts on education, both through teaching the youth the value of water, and educating adults about wasting water. Denver is a city with a huge population, and an even bigger audience. Knowing millions of people drive past or through their city all the time, Denver Water has initiated the Use Only What You Need campaign in an effort to inform the masses of water crisis and the simple notion of using less.

Each city goes about it in a different way, but the lesson to share from this case study is there are many right answers. Yes, the Colorado River Basin is approaching a crisis, water demand will exceed water supply for the basin in the not too distant future, but through education, through addressing waste on all levels, through incentives and mandates, the picture can be turned around. The different approaches of each city are meant to highlight the necessity of finding the conservation strategy that works best for the conditions presented. There is no one right answer; moving forward, the more viable possibilities the better.

Figure 33: Outdoor Rebate Programs

Outdoor Rebates	Colorado Springs	Denver Water	Fort Collins Utilities	Aurora	Pueblo
Xeriscaping				$1.00/sq. ft. low water use plant material + $.25/sq. ft. hardscape materials. Up to $10,000 residential, $25,000 commercial	
Weather-based irrigation controller	half of purchase price up to $200	$100 with rain sensor	$150		
WIRED rain sensor shut-off device	up to $25		$15		
WIRELESS rain sensor shut-off device	up to $50	$50	$30		
Rotating matched precipitation spray nozzles (qualifying equipment)	up to $4 each, minimum 5, limit 40	$2 per nozzle, minimum purchase 10, maximum 100	$25 (purchases of $50-$99) or $50 (purchases of $100+) (high efficiency nozzles)		
Pressure-reducing heads			$20 (purchases of $40-$79) or $40 (purchases of $80+)		
Weather station for retrofit			$50		

M&I Conclusion

From the Bureau of Reclamation supply and demand study we can see M&I water demand is expected to increase from approximately 27% in 2015 to 33-38% in 2060 depending on the scenario. From the scenarios analyzed, we determined the Enhanced Environment projection as the most beneficial outcome for the Colorado River Basin. For this scenario to come to fruition, it will take basin-wide social change, governmental regulation, and a greater understanding of what it means to use our water efficiently and responsibly.

In this section we discussed a multitude of conservation techniques and practices that can be pursued by both consumers and water providers. Programs that should be pursued throughout the basin include Las Vegas' mandated ordinances on turf grass, Denver Water's Use What You Need public outreach campaign, CSU and Pueblo's smart metering programs, and Aurora Water and Fort Collins Utilities' comprehensive education programs. These programs work to implement social change, but ultimately it comes down to the consumer's choices and preferences. Pursuing these measures will not only help meet the growing demand of Colorado River water, but also support a sustainable Colorado River Basin water future. We owe future generations nothing less!

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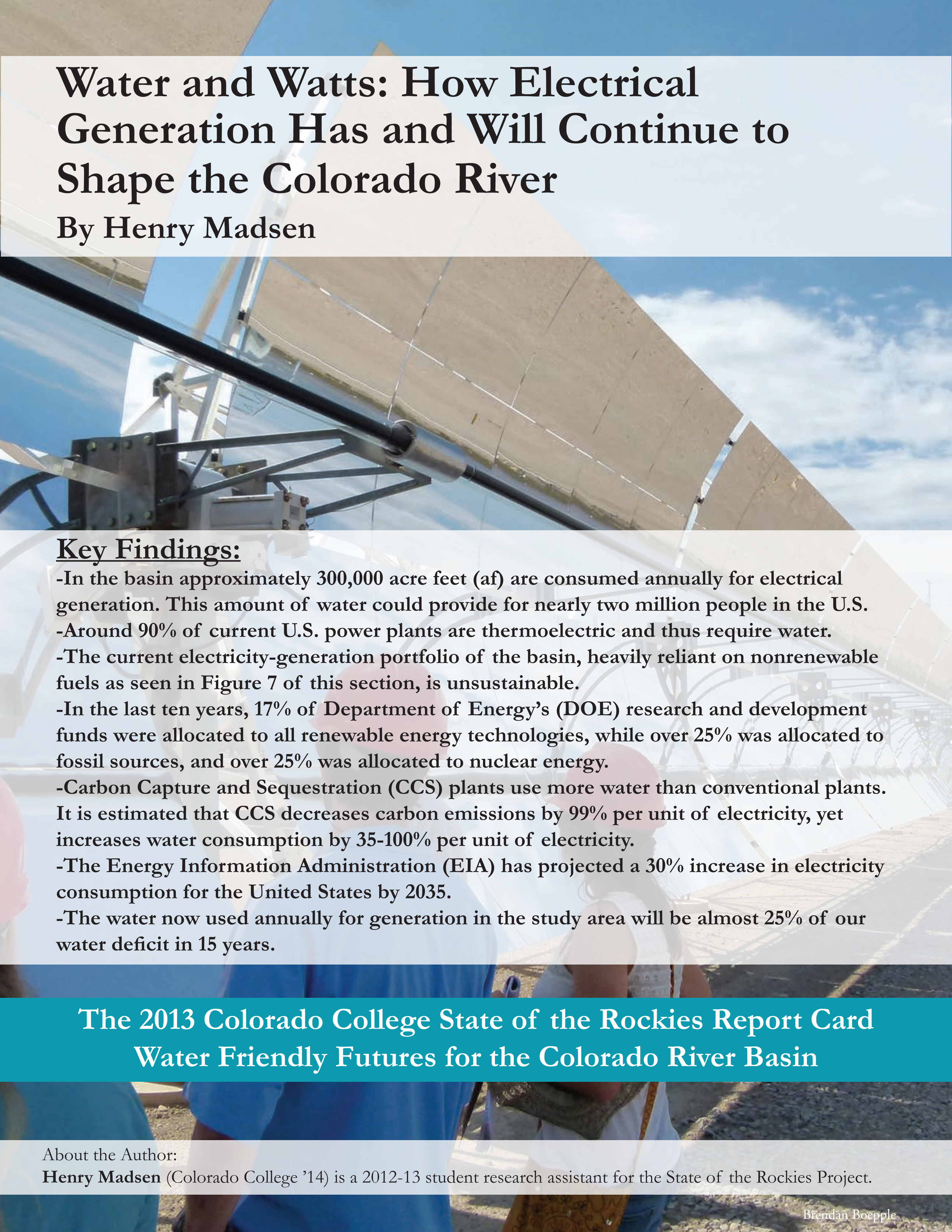
Will Stauffer-Norris

The Down the Colorado Expedition crossing Lake Powell on their solar raft.



Water and Watts: How Electrical Generation Has and Will Continue to Shape the Colorado River

By Henry Madsen

Key Findings:

-In the basin approximately 300,000 acre feet (af) are consumed annually for electrical generation. This amount of water could provide for nearly two million people in the U.S.

-Around 90% of current U.S. power plants are thermoelectric and thus require water.

-The current electricity-generation portfolio of the basin, heavily reliant on nonrenewable fuels as seen in Figure 7 of this section, is unsustainable.

-In the last ten years, 17% of Department of Energy's (DOE) research and development funds were allocated to all renewable energy technologies, while over 25% was allocated to fossil sources, and over 25% was allocated to nuclear energy.

-Carbon Capture and Sequestration (CCS) plants use more water than conventional plants. It is estimated that CCS decreases carbon emissions by 99% per unit of electricity, yet increases water consumption by 35-100% per unit of electricity.

-The Energy Information Administration (EIA) has projected a 30% increase in electricity consumption for the United States by 2035.

-The water now used annually for generation in the study area will be almost 25% of our water deficit in 15 years.

The 2013 Colorado College State of the Rockies Report Card
Water Friendly Futures for the Colorado River Basin

About the Author:
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Brendan Boepple

Introduction

It should come as no surprise to readers of this report that water will be in short supply in the future. Burgeoning populations will need water and electricity. These two needs are related. The prevailing methods that we use to generate electricity today could supply a population with water three times larger than Denver.[1] This amount of water will be very important as populations grow in the basin.

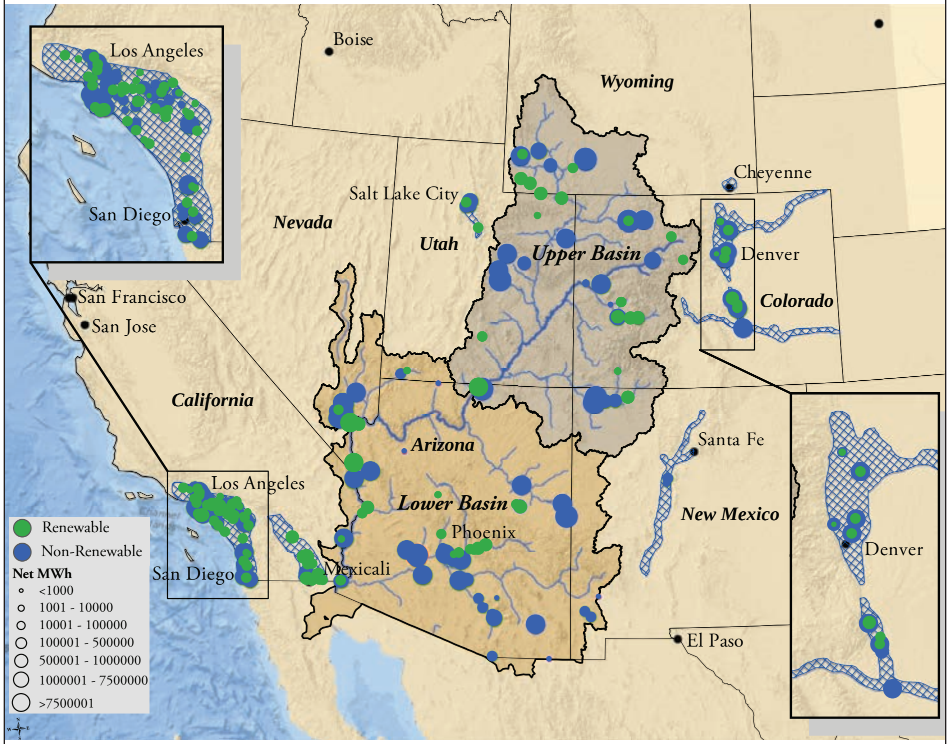
Figure 1: Map of the Colorado River Basin with Adjacent Areas

Source: Bureau of Reclamation

The seven states that encompass the Colorado River Basin (Arizona, Colorado, Nevada, New Mexico, Utah, and Wyoming) and trans-basin diversions to California include some of the fastest growing populations in the nation. For the purposes of this paper: a basin state qualifies by containing a portion of the Colorado River Basin as a hydrologic area and/or areas whose water is obtained from diversion out of the basin, as depicted in **Figure 1**. Historically, these states have primarily consumed energy in the form of nonrenewable fuels. Much of this energy comes as electricity generated with nonrenewable fossil fuels, and many states still rely heavily on fossil fuel electricity generation as seen by a majority of large blue markers in **Figure 2**. These plants generate the vast majority of the basin's electricity. The frequency of blue and green markers in **Figure 3** indicates the prevalence of coal and natural gas plants. With a recent push towards green energy, the electrical generation portfolio of the basin is changing. **Figure 4** depicts the growing number of diverse renewable generating plants in the basin states. Renewable plants represent good intentions, but they do not yet generate nearly as much electricity as the nonrenewable units (notice the discrepancy between legends). This means that the states have a long way to go to alter their electrical generation portfolios to become greener.

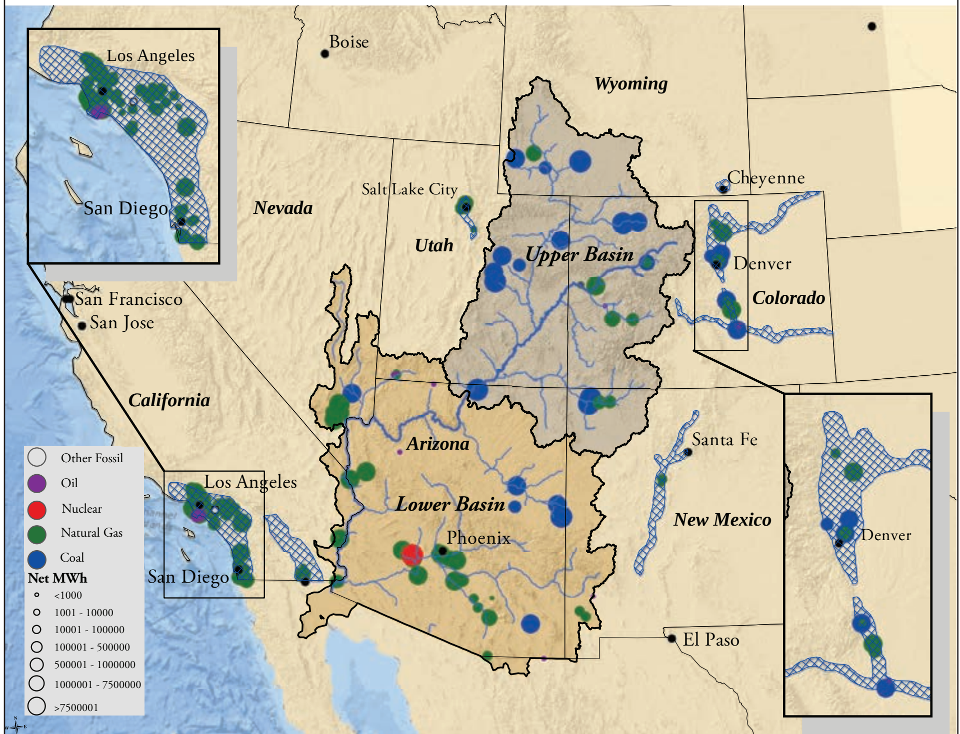
The manner by which the basin provides its future populations with electricity is important to the Colorado River. Water is necessary to produce electricity, some forms of generation requiring more than others. In the life cycle of a fossil fuel, from the ground to the furnace, water is consumed at every step. This water use is not explicitly stated to consumers of electricity. The amount of water consumed in the process of electrical generation is largely dictated by the cooling system used. Water is withdrawn from a source for cooling, and throughout the process of generation some evaporates. The amount of water withdrawn is much greater than that consumed. The withdrawal of water for power generation represents 49% of total water withdrawals in the country.[2] Only 2% to 3% is consumed (i.e., lost to evaporation), amounting to between 1.6 to 1.7 trillion gallons (4.9 to 5.2 million acre feet) of water annually for the country.[3] In the basin approximately 300,000 acre feet (af) are consumed annually for electrical generation.[4] This amount of water could

Figure 2: Power Plants by Fuel Type in the Basin



Source: United States Environmental Protection Agency. eGrid Survey. *Year 2009 eGRID2012 Boiler, Generator, Plant, State, PCA, eGRID Subregion, NERC Region, U.S., and Grid Gross Loss (%)* Data Files. eGRID plant year 2009 data (4/27/12). 2012.

Figure 3: Nonrenewable Power Plants by Fuel Type in the Basin



Source: United States Environmental Protection Agency. eGrid Survey. *Year 2009 eGRID2012 Boiler, Generator, Plant, State, PCA, eGRID Subregion, NERC Region, U.S., and Grid Gross Loss (%) Data Files*. eGRID plant year 2009 data (4/27/12). 2012.

provide for nearly two million people in the U.S.[5] Power plants affect water sources in more ways than consumption for cooling.

Traditional fossil-fuel plants indirectly pollute water sources with emissions of chemicals and particulate matter. These emissions affect water sources in the form of acid rain. Once emissions have entered the atmosphere they inevitably enter the water cycle and affect all niches of an ecosystem.[6] These contaminated water sources must be cleaned before human consumption. This energy and water-intensive process highlights an additional externality of our reliance on traditional sources of electrical generation. There are multiple options to simultaneously conserve water and lessen pollution.

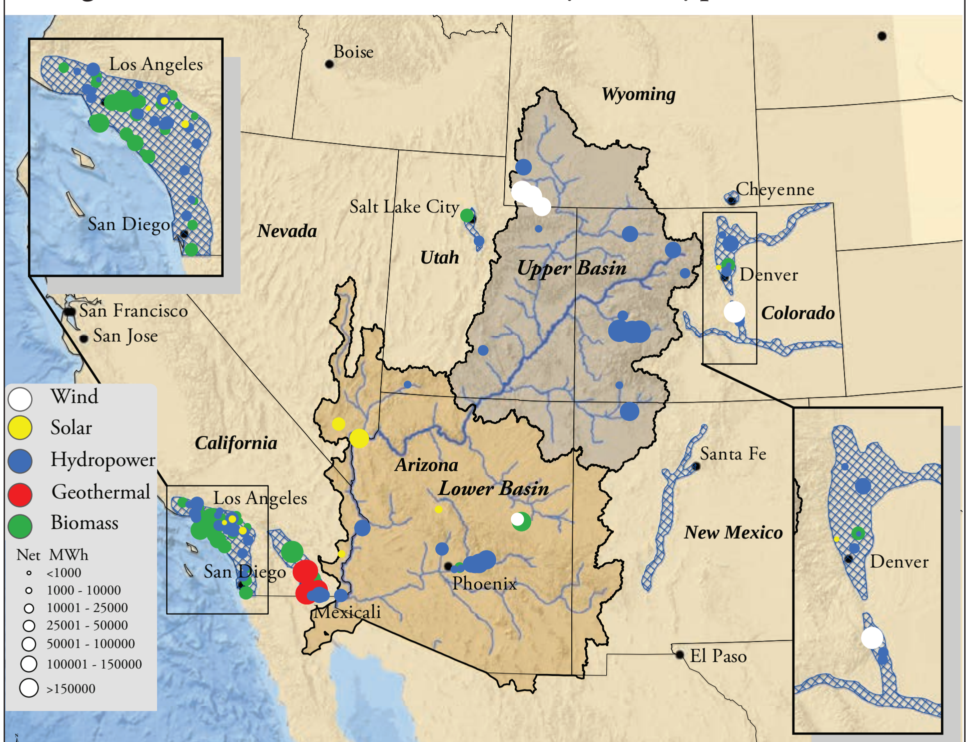
Technologies to limit emissions have arisen, but often consume more water. Traditional coal emits more pollution, yet consumes less water than coal generation with yet to be proven Carbon Capture and Sequestration (CCS) technology. These sorts of emission controls, resulting in less pollution but often additional externalities, are slowly becoming a more viable option for the future. Renewable fuels, such as wind and solar photovoltaic, are reliable water savers, only needing water to be cleaned, and they have no emissions while active. The emissions associated with these technologies occur during manufacturing. Choosing which option best suits our future requires an understanding of the current situation.

Understanding the water needs of our electricity generation sector and the electricity needs of the seven states will help us plan out a feasible and desirable water friendly future. The true cost of fossil fuels makes renewables seem more realistic; the market price of fossil fuels does not include the environmental impacts of their use, such as the water they require or pollution they emit. The country is beginning to understand these external costs, and incentives to change are being put in place. Renewable Portfolio Standards show the desire of the basin states to move away from fossil fuels. Many types of renewables are promising options that consume little water, produce little pollution, and generate moderate amounts of electricity. Fossil fuels are high water consuming, high pollution producing, and high electricity generating. We must make the correct decision in creating an energy portfolio that is at once low water consuming, low carbon producing, and high electricity generating.

Quantifying the Energy Portfolio of the Basin and the Water that Permits It

Whether we are aware or not, we use more water daily than what comes out of our faucets. Much of this water is hidden in energy intensive processes. How much water is consumed watching a movie? How much water is needed to

Figure 4: Renewable Power Plants by Fuel Type in the Basin



Source: United States Environmental Protection Agency. eGrid Survey. *Year 2009 eGRID2012 Boiler, Generator, Plant, State, PCA, eGRID Subregion, NERC Region, U.S., and Grid Gross Loss (%) Data Files*. eGRID plant year 2009 data (4/27/12). 2012.

manufacture a cell phone? How much water does a gas stove require? Water is used for nearly everything, even things that do not obviously require energy. For example, clothes constitute a significant input of water to produce their materials (a cotton T-shirt is estimated to require 718 gallons).[7] Earth is the water planet; life could not have evolved, as we know it, without water. Now the world is becoming increasingly dependent upon energy, a dependence that requires water. Much of this energy comes from generated electricity. In order to have water in the environment for necessities such as hydration, crop production, and healthy ecosystems, we must move towards minimal water use to obtain energy. For these reasons it is paramount to increase the water efficiency of all processes related to energy, especially electricity, while decreasing the amount of energy consumed.

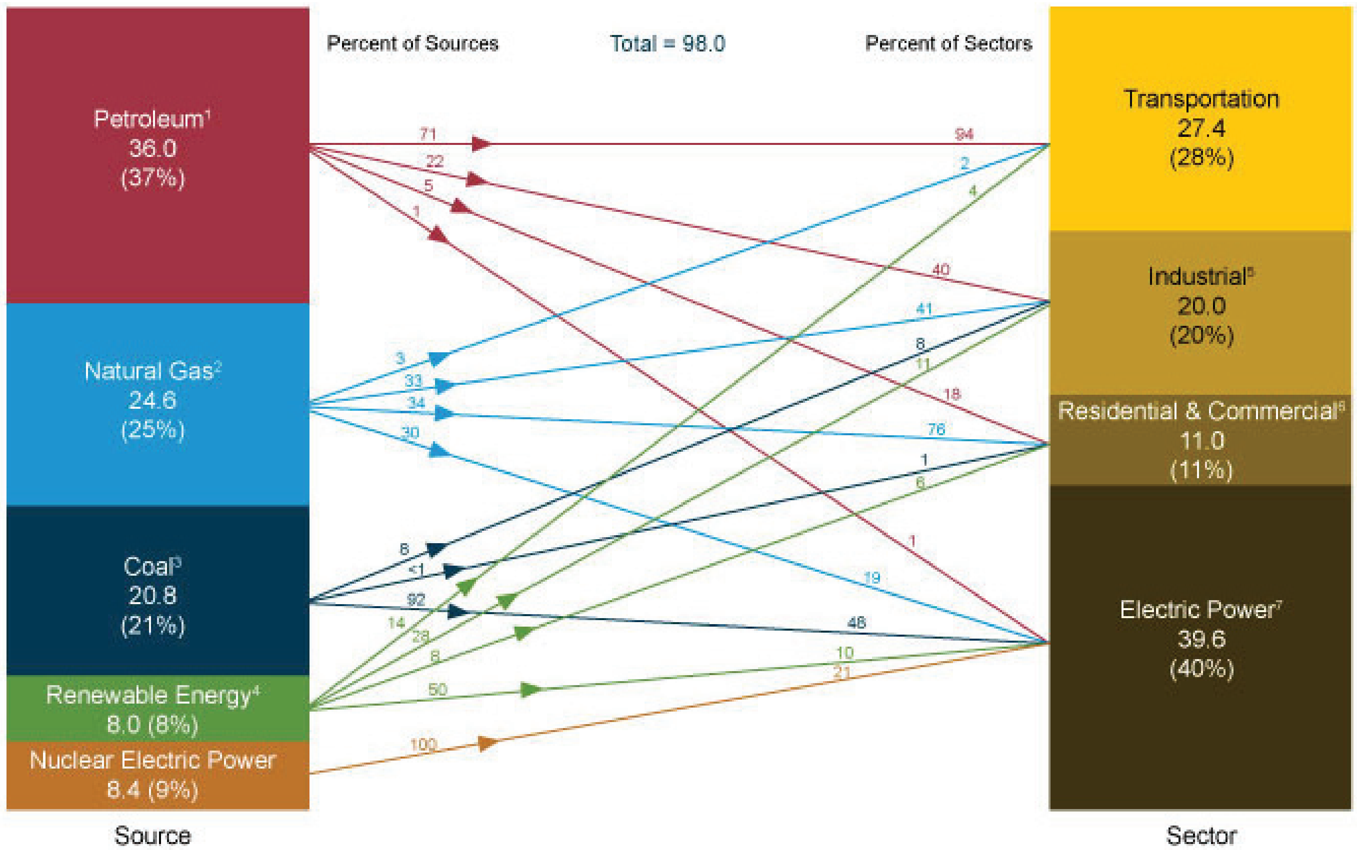
Energy consumption is broadly defined as the energy used per capita. It includes natural gas pumped to stoves, motor gasoline in cars, and electricity for appliances. Much of energy consumption is in the convenient form of electricity. Generation turns energy from fossil fuels into electricity, which is readily available for consumption. The electrical generation portfolio of the U.S. is still dominated by nonrenewable fuels, but renewable sources are making inroads. Nonrenewable fuels include: the fossil fuels coal, natural gas, and oil/petroleum fuels, as well as nuclear fuels.[8] Renewable fuels include: biomass, hydropower, geothermal, wind, and solar.[9] **Figure 5** illustrates the relationship between the total primary consumption of different fuels by sectors of the American economy, and the consumption of fuels for electrical generation. Electrical generation is of special concern because it comprises the majority of this breakdown.

Nonrenewable Fuels Are Embedded in Our History

The basin states have historically required fossil fuels in the proportions shown in **Figure 6**. This reliance has carried over to the modern day. A long history of these fuels has sometimes left brown smog over metropolises as its most blatant mark. Renewable sources were available in the past, much like today, but have faced implementation challenges. Hydroelectric power is an example. It has existed in the Colorado River Basin for many years, but cannot feasibly supply enough electricity on its own to meet the present and future demands of society. The demands of society, particularly in the West, have been for fast and cheap expansion. These demands mandated energy.

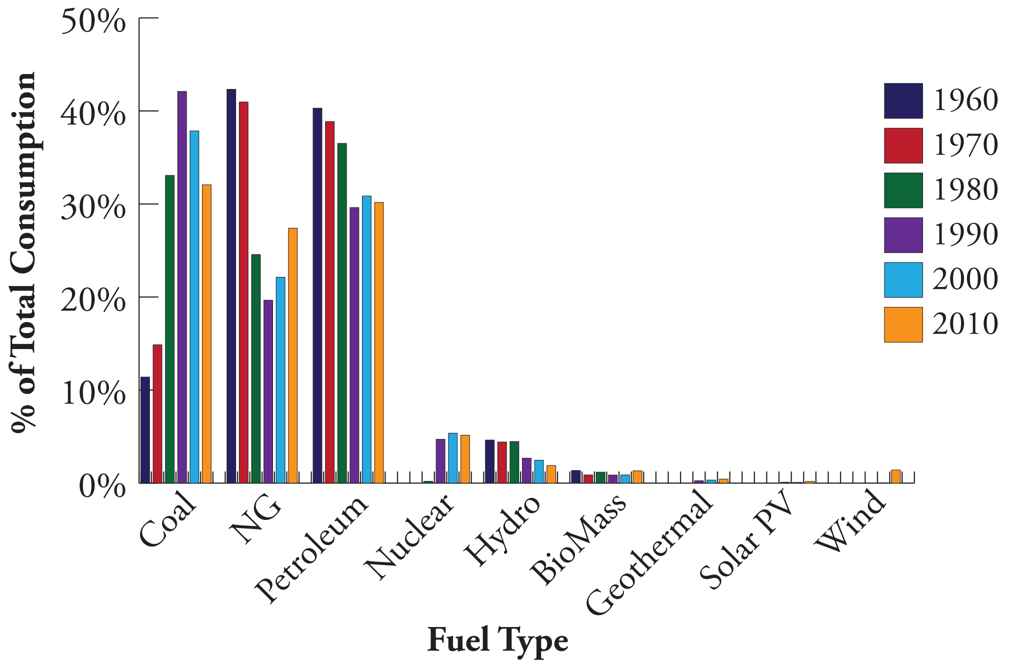
This development, expanding the bounds of society into the frontier of the Rocky Mountain West, was made possible with energy chiefly from utilities. The mission statement of 19th and 20th century utilities was "to deliver reliable, inexpensive electricity everywhere," a statement which could only be fulfilled by exploiting fossil fuels.[10] Fossil fuels have allowed life, as we know it, in the developed world. Now the crowding of the basin imposes limits on this traditional approach. The motto for 21st century utilities must be amended to include "at little or no cost to the environment." The path from the present to the desired future can be achieved multiple ways.

Figure 5: Primary Energy Consumption by Sector and Source



Source: U.S. Energy Information Administration, Total Energy, accessed July 31, 2012, http://www.eia.gov/totalenergy/data/annual/pecss_diagram.cfm.

Figure 6: Historical Primary Consumption in Study Area



Source: United States Energy Information Administration, *State Energy Consumption Estimates: 1960 through 2010*, accessed July 15, 2012, http://www.eia.gov/state/seds/sep_use/notes/use_print2010.pdf. AZ (p. 54-55); CO (p. 84-85); NV (p. 344-345); NM (p. 314-315); UT (p. 474-475); WY (p. 534-535), U.S. (p. 22-23).

The Prevalence of Nonrenewable Fuels Today

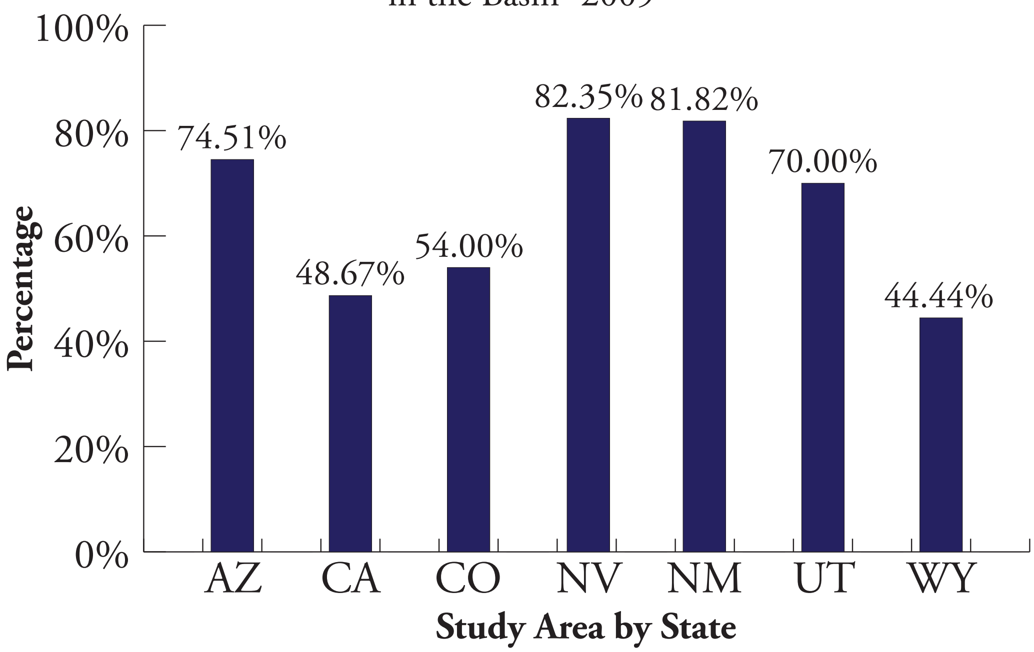
The values that shape our present situation will continue to contribute to the future of energy. Economic activity and the related need for energy sources are the driving factors behind energy portfolios around the globe. These factors make nonrenewable fuels an increasingly large part of the answer to utilities' mission statements. The immediate monetary advantages of nonrenewable fuels have not been overcome by concern about environmental issues. Renewable fuels have grown in prominence in past decades, but their role still remains minute because they are more expensive and receive fewer subsidies. **Figure 7** illustrates the ratio of power plants using nonrenewable fuels within the study area. See **Figure 8** for a more detailed breakdown of the major plants recognized within the basin and its adjacent areas by an EPA survey. The percentage of coal plants in this figure does not explain their popularity. **Figure 9** elaborates on the discrepancy between the percentage of plants from each fuel type and the amount of power provided by each. This is a measure of great importance. Coal is relatively more important than natural gas though there are four to five times more natural gas plants in the basin.

The External Costs of Cheap Energy

The current electricity generation portfolio of the basin, heavily reliant on nonrenewable fuels as seen in **Figure 7**, is unsustainable. Running out of coal, gas, and oil may be far in the future, but their use is unsustainable for other reasons. The emissions associated with these fuels are dangerous to life, and the quantity of water used by them is needed elsewhere. In this sense not all fuels are equal. Each fuel used today has characteristic advantages and disadvantages. The relationship between water, pollution, and energy for coal and natural gas is different from wind and solar as seen in **Figure 10**. From these statistics it is obvious that no fuel is perfect, but some are superior to others. As the costs of pollution and water use aggregate, the water-pollution-energy portfolio of our fuel sources will become more important. To tackle these issues requires comprehensive strategies; pollution and water use are associated by nature.

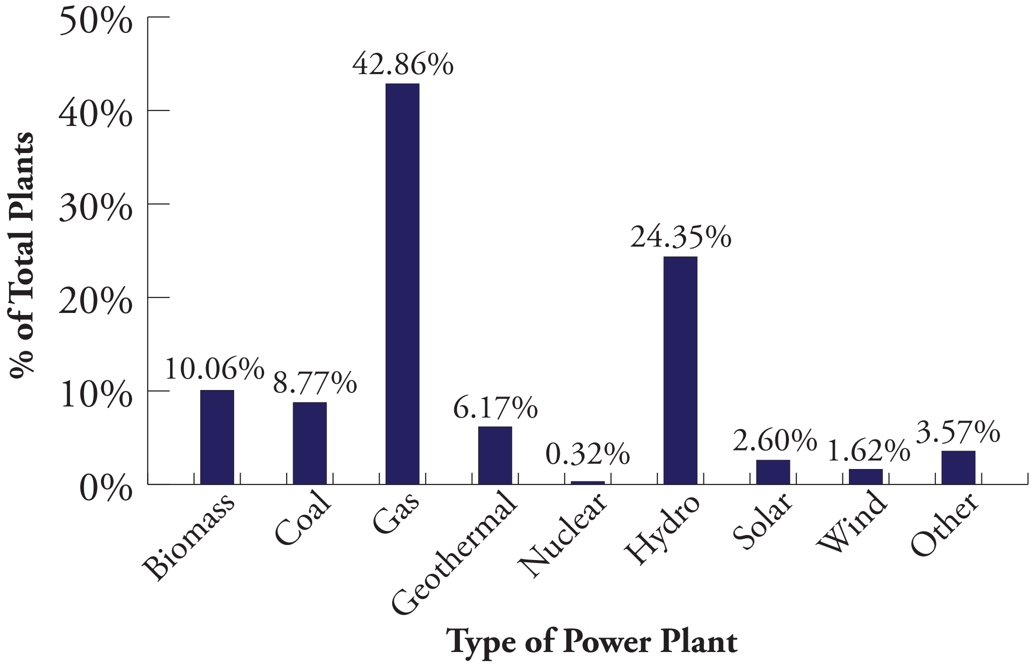
The control of pollution is important for reasons both obvious and obscure. Nitrous Dioxide (NO2) belongs to a family of chemicals called Nitrous Oxides (NOx) and is regulated by the EPA. Once emitted into the atmosphere, NO2 reacts to form Ozone (O3) and acid rain. Ozone is important in the stratosphere (upper atmosphere) because it blocks harmful radiation from

Figure 7: Percent of Power Plants Using Nonrenewables in the Basin- 2009



Source: United States Environmental Protection Agency. eGrid Survey. *Year 2009 eGRID2012 Boiler, Generator, Plant, State, PCA, eGRID Subregion, NERC Region, U.S., and Grid Gross Loss (%) Data Files*. eGRID plant year 2009 data (4/27/12). 2012.

Figure 8: Percent of Major Plants by Type in the Basin - 2009



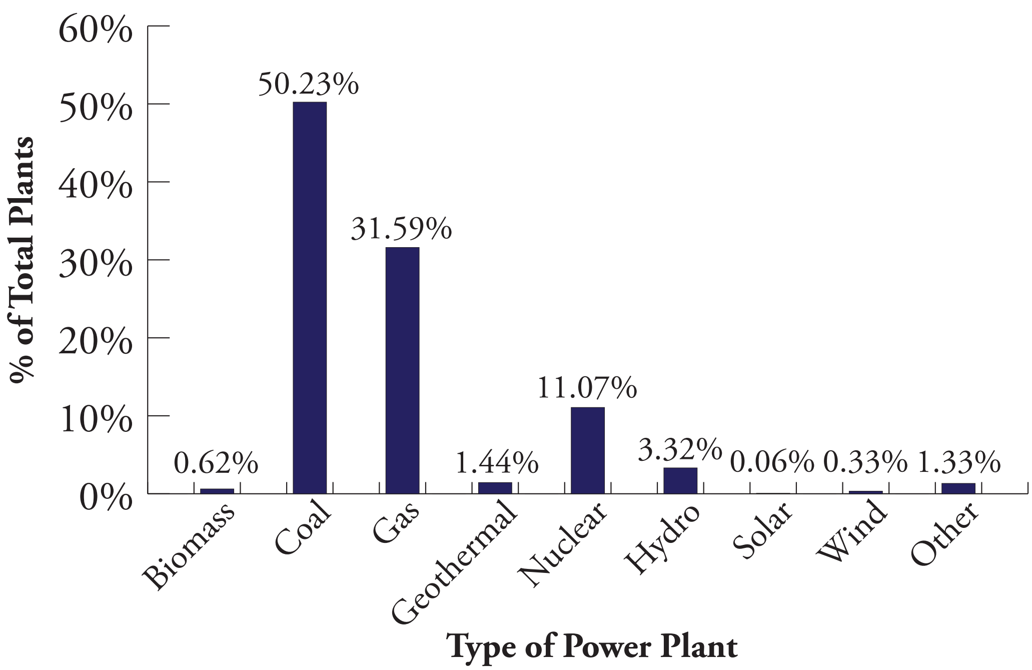
Source: United States Environmental Protection Agency. eGrid Survey. *Year 2009 eGRID2012 Boiler, Generator, Plant, State, PCA, eGRID Subregion, NERC Region, U.S., and Grid Gross Loss (%) Data Files*. eGRID plant year 2009 data (4/27/12). 2012.

reaching Earth. When emitted in excess by human activities, this harmful chemical spends time in the troposphere (lower atmosphere) where it may be inhaled and cause health problems. Ozone is also a major component of "smog," which is visually unappealing.[11] Sulfur Dioxide (SO2) is also a respiratory irritant present in fossil fuel emissions. In as little as five minutes of exposure it can lead to bronchoconstriction (constriction of the lungs' airways) and asthma attacks. In the atmosphere, SO2 can react to form particulate matter (PM), which may become lodged in the respiratory system and cause adverse effects to health, such as heart attacks and decreased lung function.[12] These emissions are also harmful to ecosystems.

Ecosystems are affected in subtle ways by our energy use. The effects of SO2, NOx, and their subsequent interactions with the environment manifest as acid rain and then alterations in soil composition. Higher levels of SO2 harm plants and trees and reduce crop productivity.[13] Increased levels of NOx can cause harm and/or death to plants, and lower the pH of the soil. These changes result in increased damages to agricultural production.[14] NOx can lower the pH (acidification) of soil beyond the range that ecosystems can tolerate; a low pH increases the solubility of toxic elements and decreases the solubility of essential nutrients.[15] Damage to the entire biological system is probable as a consequence of delicate changes like this. The effects of pollution on humans are easily quantifiable.

It is obvious to most that emissions from fossil fuels have an adverse effect on human health. The Clean Air Task Force, a non-profit public health and environmental advocacy group, estimates 24,000 deaths in the United States are attributable to power plant pollution each year. Each death represents a life cut short by an average of 14 years.[16] A study from Wharton and Stanford suggests that Americans value a year of life at approximately $129,090.[17] This number considers average medical expenses paid for a healthy quality year of life for the ill. Combining these numbers (24,000 deaths * 14 years/ death * $129,090 / year), Americans theoretically value reducing emissions from electrical generation at over $43 billion dollars. That statistic only considers how much we value human life. This is one example of the "external" costs of traditional energy production, demonstrating that society is far more impacted than what market prices depict and most of us suspect. The problem with our current energy situation has been so far easy to define. The solution to this problem will almost certainly prove difficult to discover and implement.

Figure 9: Percent of MWh Generated by Plant Type in the Basin - 2009



Source: United States Environmental Protection Agency. eGrid Survey. *Year 2009 eGRID2012 Boiler, Generator, Plant, State, PCA, eGRID Subregion, NERC Region, U.S., and Grid Gross Loss (%) Data Files*. eGRID plant year 2009 data (4/27/12). 2012.

Figure 10: The Pollution-Water Intensity of Fuel Sources					
Source	**Cooling System**	**Gallons of Water/ MWh[1]**	**CO2 (lbs)/MWh[2]**	**NOx/MWh[2]**	**SO2 (lbs)/MWh[2]**
Solar CSP	Cooling Tower	865	(uk)	(uk)	(uk)
	Dry	52	(uk)	(uk)	(uk)
	No Cooling Required	5	(uk)	(uk)	(uk)
Coal	Cooling Tower	687	2000	4.1	12
	Pond	545	2000	4.1	12
	Once-Through	250	2000	4.1	12
Natural Gas	Cooling Tower	198	1000	2.3	0.045
	Pond	240	1000	2.3	0.045
	Once-Through	100	1000	2.3	0.045
	Dry	2	1000	2.3	0.045
Solar PV*	No Cooling Required	0-26	44.09-396.83	0.0882- 0.3968	0.1102- 0.9921
Wind	No Cooling Required	0	(n/a)	(n/a)	(n/a)

Notes: *Solar PV projections include life-cycle analysis of panel creation.
(n/a) = negligible.
(uk) = unknown.
Sources: [1]HeadWaters, *Water Consumed to Generate Electricity*, Winter 2012, p. 15.
[2]National Research Council of the National Academies, *Hidden Costs of Energy: Unpriced Consequences of Energy Production and Use, Washington, D.C.*, National Academies Press, 2010, pp. 97, 99, 121, 123, 143, 151.

Power Plant Cooling Systems and Water Use[18]

Water is necessary for the operation of thermoelectric power plants. Around 90% of current U.S. power plants are thermoelectric and thus require water. To create electricity, a fuel is combusted and the heat from this is added to water to produce steam. The steam rises through a turbine, causing it to turn and generate electricity through a series of magnetic and conductive materials. This steam must be converted back to water so that the power plant can continue to utilize it. In order to turn the steam back into water, it is brought into contact with a cool water source. The cool water source heats up while it turns steam back into water; thus the cooling water source is now hot enough for some of it to be lost through evaporation. This is the main source of water consumption in these plants. This evaporated cooling water exits through a cooling tower, constituting the plume exiting the plant that looks like pollution but is, in fact, only water. There are three main types of cooling systems, listed here in order of descending popularity:

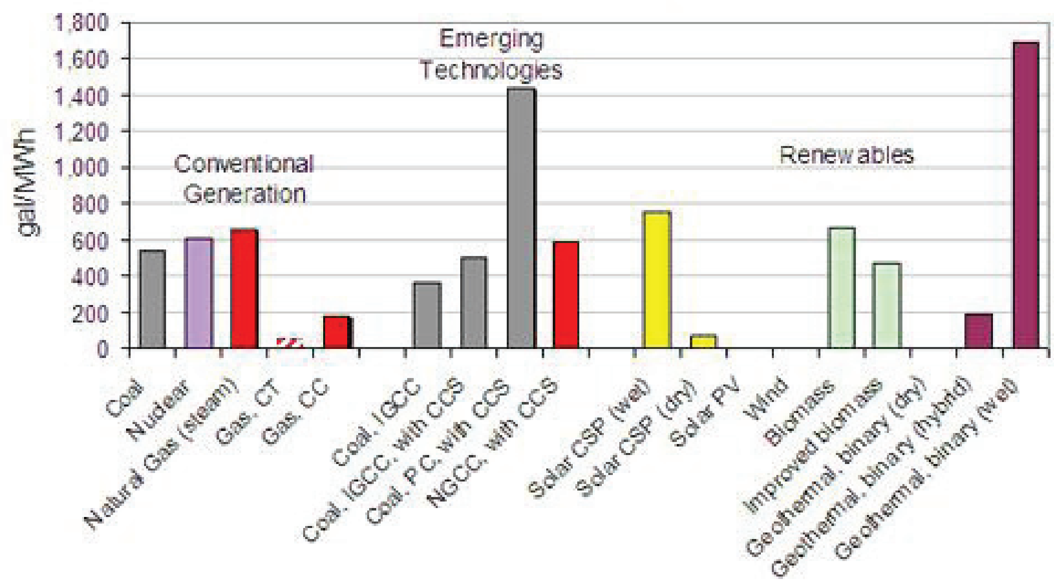
- **Once-Through Cooling:** This system requires a large nearby water source, and is most prevalent in the eastern U.S. Water from this source is circulated through the pipes to condense steam back into water, and then exits back into the water source at a higher temperature. Because of the close relation of these plants to large bodies of water, they tend to be the most environmentally disruptive. This system has the most adverse effects on the body of water it utilizes (thermal pollution, getting organisms caught in intake screens, etc.). Thermal pollution adds heat to a body of water. Warm water holds less dissolved oxygen than cold water. This alteration in the basic chemistry of the aquatic ecosystem affects what microscopic organisms (such as types of algae) occupy the lowest trophic system (the basis of the food chain). Some trout eggs do not hatch in warm waters, and some fish do not even spawn in warm waters.[19]
- **Closed-Loop Cooling:** These systems are more prevalent in the western U.S. Similar to a once-through system, water is used to absorb heat from steam and condense it back into water. This cooling water is not discharged like a once-through system, but exposed to ambient air to bring it back to a desirable temperature. Some of this cooling water evaporates and must be replaced. This system consumes the most water.
- **Dry Cooling:** These systems use air to cool the steam exiting from a turbine. Their efficiency is related to air temperature, making them less desirable; power demands peak in the summer when the air is warmest and dry cooling is least effective. This system is the least efficient and most variable in places like the arid west.

Suggested Methods for Solving the Problem

The problem with our situation is that the infrastructure of modern society in the U.S. requires large amounts of energy, most often produced through nonrenewable sources. This energy is provided in the form of electricity from power plants. These much needed plants will not be easily replaced. Efficiency measures for pre-existing plants are utilized as a quick fix to reduce human impacts. A recent push to limit impacts from power plants is due to the danger of pollutants and the ensuing governmental regulations to limit their emission. These regulations require implementation of efficiency measures. An example of these efficiency measures is emission capture. Emission capture technology mitigates the environmental effects of traditional electrical generation. This technology may also be referred to as emission sequestration. This solution introduces one problem by solving another.

Emerging sequestration technologies focus on inhibiting emissions. However, there is a trade-off; Carbon Capture and Sequestration (CCS) plants use more water than conventional plants. It is estimated that CCS decreases carbon emissions by 99% per unit of electricity, yet increases water consumption by 35-100% per unit of electricity. CCS is an expensive retrofit that requires incentives to install. Incentives exist in limited quantity outside of governmental regulations; i.e., using sequestered carbon to more efficiently recover oil from older wells and thus see a return on investment.[25] Incentives are necessary because the retrofits are expensive. A rough estimate for installing CCS equipment would be around $500 million per plant; it must also be noted that CCS reduces the efficiency of the plant thus requiring additional fuel purchases and an enlargement of combustion facilities to offer the same net generation.[26] Other options exist to reduce our net emissions.

Figure 11: Water Intensity by Fuel Source



Source: Western Resource Advocates, Water Use for Energy, accessed July 12, 2012, http://www.westernresourceadvocates.org/water/waterenergy.php.

Major Basin Power Plants and Water Use

To illustrate water consumption by power plants, consider the water use portfolio of four of the basin's major plants. Arizona's Navajo Generating Station (26,274 acre-feet/year), New Mexico's Four Corners (24,826 acre-feet/year) and San Juan plants (19,977 acre-feet/year), and Wyoming's Jim Bridger plant (25,333 acre-feet/year), aggregate over 94,000 consumed acre feet a year.[20] Assuming the average U.S. household consumes 127,400 gallons annually, or .391 acre feet, these four power plants consume water that could provide for over 246,570 homes for one year.[21] These four power plants generate over 58 million MWh annually.[22] An average home consumes 11.496 MWh of electricity annually,[23] so these plants provide well over five million homes with electricity. They consume a substantial amount of water relative to residential needs, yet supply about 1/6th of the basin's over 30 million dependents with power. Combined they emit (assuming the average two tons of CO2/MWh per coal plant) over 116 million tons of CO2 annually, an amount equal to the average annual emissions of 20,634,005 passenger vehicles, or the sequestration of carbon from 2,698,292,954 tree seedlings grown for ten years.[24] Yet a population the size of Colorado's relies on them for power. It is this reliance that makes the situation precarious and difficult to amend.

A number of large-scale options are available to limit emissions from electrical generation. Installing nuclear power is one option. Nuclear plants emit between 3.5 and 12 pounds of CO2 per Megawatt-hour (MWh),[27] a reduction of over 99.5% from coal plants. Investing in nuclear power and retrofitting fossil fuel plants with CCS do not require dismantling the current systems in place for generation. Installing renewable power and upgrading the country's energy efficiency (a cheaper and cleaner option)[28] breaks the trend from relying on large nonrenewable energy sources. Energy efficiency is cheaper because consumers can directly assume some of the costs of new appliances. Water can also be saved by some of these options.

Our traditional forms of generation are highly water consumptive. In contrast, the least water consumptive forms of generation are those of emerging technologies, such as wind and solar photovoltaic technologies. Greater efficiency in our use of electricity also saves water by lessening the amounts of electricity and the water they need. (See the following section on renewables for greater coverage of the implementation of emerging energy technologies in the Colorado River Basin).

Saving Water Is Not Simple

The relationship of water intensity for various types of electrical generation can be seen in **Figure 11**. This figure is a simplification of the solutions; it seems obvious which technologies are ideal. Economics drive decisions in reality. A wet solar CSP plant may exist in a desert because a dry solar CSP plant overheats in that climate. When the dry plant overheats, it is less efficient, and the investors receive less money. Water laws can change this; a heavier tax on water could make the less efficient, dry CSP plant the more economical option. Conundrums like this one illustrate the unique obstacles that proponents of a water and pollution friendly future face.

Impediments to a Green Future

The solar and wind potential in the U.S. could easily supply our electricity needs.[29] Then why have we not yet begun the transition from traditional sources of electrical generation? One issue facing renewables is unreliable base prices. When oil experiences a price spike, renewables get investments. Then oil sees a dip, and it is no longer economically feasible to invest in renewables. The U.S. government lowers the price of fossil fuels that consumers pay with various forms of subsidies (totaling $15 billion in 2010[30]), rendering the public unaware of their true cost. The percentage of money that the Department of Energy commits to research and development for each source matches these subsidies; in the last ten years 17% of DOE's research and development funds were allocated to all renewables, while over 25% was allocated to fossil sources and over 25% was allocated to nuclear energy.[31] There are also physical obstacles to a green future.

Renewable fuels face an issue with transmission. Areas with high solar and wind potential are often not proximate to our cities. Electricity generated in remote areas may need to be moved vast distances through regions without transmission corridors. Projects to install transmission lines face numerous natural and legal obstacles; from private land to mountaintops, it is costly and time-consuming to conquer nature and nimbyism (best described as a "not in my backyard" attitude).[32] The basin is an ideal place to tackle these challenges. All of the basin states have high potential for wind and solar energy. Wyoming has enough wind potential to meet the state's electricity needs 116 times over,[33] yet 93% of the state's electricity (nearly 43,000,000 MWh) comes from fossil fuels.[34] Coal has been the long time winner in the nonrenewable versus renewable debate. This is starting to change in favor of a new fossil fuel.

Natural gas generation has increased recently, largely due to declining production costs emanating from new efficient technologies. These include advancements in hydraulic fracturing and directional drilling that suggest a cheap future for gas. Natural gas plants emit half as much CO_2 and consume less than half the water per unit of electricity than coal plants with a comparable cooling system, as seen in **Figure 10**. Natural gas still emits significantly more pollution and uses more water than wind and solar photovoltaic. Natural gas is not the resource of the future, but one to supplement dirtier coal plants while legislation and investments allow renewables to come online. The supplementation of natural gas for coal may very well turn into natural gas market dominance. The key to avoiding a natural gas monopoly is to remember that its supply in the U.S. is estimated at 92 years,[35] it still emits 1,000 pounds of CO_2 per MWh, and its extraction from the earth raises a number of issues related to the protection of groundwater. The future demands more energy and we are at a critical tipping point as to how this energy is provided.

Future Expectations: Energy-Water Needs of Increasing Populations

The basin offers unique landscapes, abundant recreational opportunities, and the remainders of the pioneer frontier. The population is expected to double in the study area by 2060 as previously implied in **Figure 12** of the Overview. Each member of the new population will require some amount of electricity. This is an influx that our current electric generation infrastructure cannot manage.

Hidden Costs of Water in Daily Energy Use

The 11.496 MWh of electricity used annually by a household represents nearly 31.5 kWh per day. This is the energy the average home uses to watch television, heat water, charge phones, and other such things. In Colorado, one kWh of electricity takes about .46 gallons of water to produce.[36, 37] This essentially means that the average Colorado household consumes about 14.5 gallons of water daily just to power itself. In the United States, an average person consumes over 158 gallons of water a day. In most developing countries, a family uses 5.3 gallons of water per day.[38] Embedded in the electricity that one household in Colorado uses daily is the water a family in the developing world needs overall in a day. The food we consume throughout the day accounts for a surprising amount of water as well; the average American has a diet that directly and indirectly involves about 4,500 gallons daily (the production of one pound of beef requires approximately 1,799 gallons of water[39]).[40] Understanding these numbers is essential to making direct and easy changes to lifestyles.

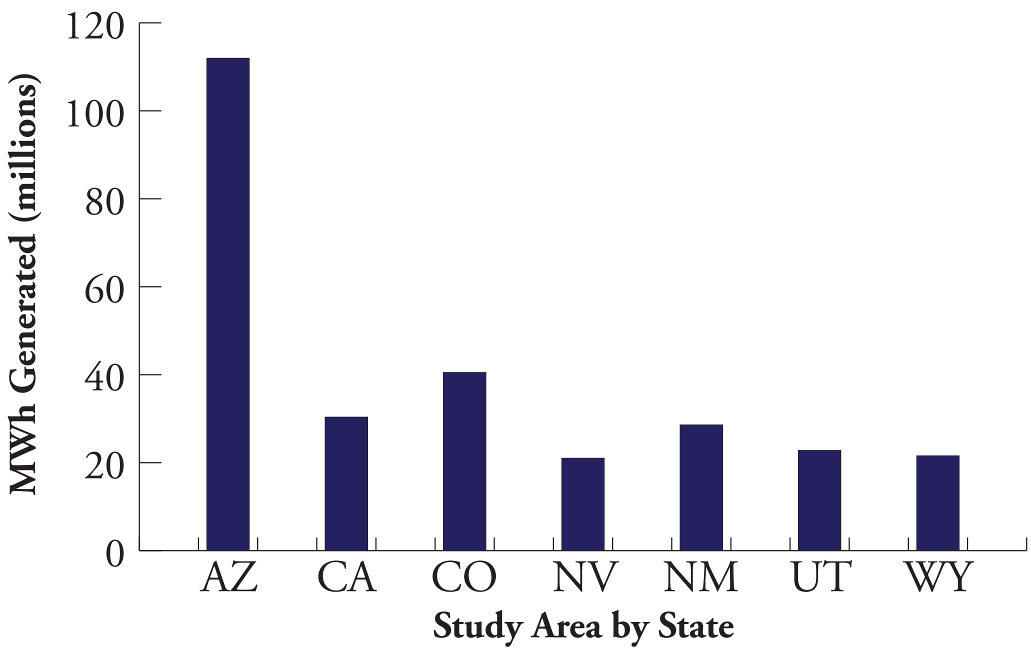
Electricity Needs

More electrical generating capacity will be needed in order to support needs of a growing population. The future will consume more electricity than the amount we now generate as shown in **Figure 12.** The EIA has projected a 30% increase in electricity consumption for the United States by 2035.[41] The manner in which we meet this blossoming demand is consequential to the basin. Air quality and water availability hinge on the nature of new electrical generators.

Water Needs

The water required by future populations will not be easily met by the Colorado River (see Municipal and Industrial Water Use section of this *Report Card*). Some of this water can be obtained from our electrical generation sector. Extending the use of our current electrical generation portfolio to a more demanding future gives the expected unsustainable result. The amount of water that is consumed by electrical

Figure 12: Total MWh Generated in the Basin- 2009



Source: United States Environmental Protection Agency. eGrid Survey. Year 2009 eGRID2012 Boiler, Generator, Plant, State, PCA, eGRID Subregion, NERC Region, U.S., and Grid Gross Loss (%) Data Files. eGRID plant year 2009 data (4/27/12). 2012.

generation within the study area currently exceeds 300,000 af annually. This amount is equivalent to the water needs of over 767,263 homes for a year (at .391 af per home per year).[42] In the 2011 census, there was an average of 2.59 people per home.[43] This means that the 767,263 homes represent almost 1.98 million people. The water that currently is used for electrical generation could supply approximately 6.6% of the basin's dependents. This deficit will increase drastically in the future if society continues to obtain electricity from a similar ratio of fuel sources.

In fact, the amount of water consumed for electrical generation in the basin will be over 335,000 af within two years. The water now used annually for generation in the study area will be almost 25% of our water deficit in 15 years. The amount of water used for electrical generation will accelerate to match population growth. It is estimated that the water needed for electrical generation in the study area will increase to over 452,000 af by 2035 and over 531,000 af by 2060.[44] The total deficit for the study area is predicted to be 2,405,640 af in 2060. The amount of water we are projected to use for energy will be over 22% of the deficit at that time. This could supply almost 1.36 million households (or 3.5 million people) with water.[45] **Figure 13** displays these numbers.

The projected increase in water needed for electrical generation will not be easily met in the future with a growing Study Area deficit. It is important for society to select fuels for electrical generation that are not water-intensive to achieve a sustainable, water friendly future. We may come to use only what we need and will be able to support the future with a high standard of living through this transition. Utilities are an interface between society and resources that can provide incentives to their customers, as Denver Water's motto displays in **Figure 14**.

Figure 14: Denver Water's Motto

Source: Denver Water, Campaign Overview, accessed July 13, 2012, http://denverwater.org/Conservation/UseOnlyWhatYouNeed/CampaignOverview/.

Figure 13: Projected Water Deficits and Use for Energy

Year	Projected Deficit (af)[1]	Projected Water Use for Energy (af)[2]	% of Deficit Used for Energy	Households this Energy Water Could Supply	People (at 2.59 people/household)[3]
2015	339,420	335,000	98.7%	856,777	2,219,054
2035	1,603,400	452,000	28.2%	1,156,010	2,994,066
2060	2,405,640	531,000	22.1%	1,358,056	3,517,366

[1] Doug Kenney, "CR Basin Historical and Future Depletion."
[2] Bureau of Reclamation, *Colorado River Basin Supply and Demand Study*, All State Demand, 2012.
[3] United States Census Bureau, *State & County Quickfacts*, accessed August 10, 2012, http://quickfacts.census.

Incentivizing a Green Future

Municipal utilities can only provide a portion of the needed push to a green future. Other interests are pushing for this future as well. The basin states have implemented Renewable Portfolio Standards (RPS) to ensure that the growing populations of the future are not left with clouds of haze and water-stressed ecosystems, but rather impressive wind turbines and water aplenty. The Renewable Portfolio Standards of the basin states are seen in **Figure 15**. They should reduce carbon emissions and water consumption once in effect. For example, Colorado's wind energy sector saves around 2.18 billion gallons, or 6,690 af of water a year[46] that would be consumed if the same power came from fossil fuels. The state's wind power only accounts for about 6% of its current generation portfolio.[47] A full 25% of the deficit expected in 2025 could be provided if the basin's entire generation portfolio was renewable. These good intentions will require hard work.

Figure 15: Percent of Electricity from Renewables in 2009 and RPS Goals by State

State	% of Generation from Renewables-2009	Target % of sales	Year
AZ	6%	15%	2025
CA	26%	33%	2020
CO	10%	30%	2020
NV	11%	25%	2025
NM	5%	10% to 20%	2020
UT	3%	20%	2025
WY	7%	n/a	n/a

Sources: Center for Climate and Energy Solutions, *State RPS Details*, accessed July 7, 2012, http://www.c2es.org/docUploads/state-rps-aeps-details.pdf. United States Environmental Protection Agency. eGrid Survey. Year 2009 eGRID2012 Boiler, Generator, Plant, State, PCA, eGRID Subregion, NERC Region, U.S., and Grid Gross Loss (%) Data Files. eGRID plant year 2009 data (4/27/12). 2012.

From **Figure 15** it is obvious that most states are not yet close to their RPS goals. Colorado must gain 20%, Arizona 9%, California 7%, New Mexico 15%, Nevada 14%, and Utah 17%. Many billions of gallons of water will be saved annually when these states begin generating this much power with renewables. The economic incentives to encourage this transition are slow in coming, though public opinion regarding a transition to a renewable energy economy is growing. According to the Colorado College State of the Rockies Project 2012 *Conservation in the West Poll*, western citizens already support the implementation of renewable energy over fossil fuel energy.[48]

Conclusion

As we move into a future of rising water demand and projected dwindling water supply in the Colorado River Basin, the electricity generated from nonrenewables must be weighed against their environmental effects and the cost of lowering their emissions to government mandated levels. This section ends with an example of what is afoot to modify existing energy facilities even as renewables gradually take on a larger role. Xcel Energy recently unveiled a third unit at its Front Range Comanche Station in Pueblo, CO, a coal-fired generating unit. With the addition of this third unit and conservation measures for the rest of the plant, Comanche will actually emit less pollution than it previously did. "The entire plant's mercury emissions are lower than they were prior to the addition of Comanche 3," says Xcel. Pollution isn't the only thing the plant is cutting back on; "The plant's new Unit 3 has a low-water use system (air cooled condenser) that provides additional cooling capability, reducing water use on the unit by half," says Xcel.[49] The utility claims that such "new plants are needed to meet future demand."[50] However, fossil fuel plants are getting more expensive to run as they must meet stricter EPA air regulations. Some public opposition claims the money would have been better spent on renewables; one environmental organization source claims, "Several local residents have criticized Xcel for investing in the $1.3 billion dirty coal plant and for not promoting cleaner, renewable energy sources, such as solar, effectively."[51] Due to Colorado's strict legislation regarding plant emissions, and the subsequent burdensome cost of retrofitting the plant to meet emission requirements and use less water, Xcel Energy may never build another coal plant. But economic conditions, mainly the growing demand for electricity on Colorado's Front Range, necessitated the building of Comanche 3. The Xcel chief executive claimed, "We (are building) Comanche 3 because we need the power. Even today, it is still the best thing we could have done for both the customers and the environment."[52] It may be the best thing at the moment, but as restrictions on emissions become more stringent and renewables become cheaper, it is likely that a coal plant will no longer be the best option for electrical generation. To paraphrase a panelist at the 2012 Clyde Martz Summer Conference: *A Low-Carbon Energy Blueprint for the American West* in Boulder, CO, "renewables have already won the fight, now it is just a matter of the speed of implementation."[53]

Bald eagle on Lake Powell and the Navajo Generating Station.

Case Study: Navajo Generating Station vs. Mohave Generating Station

Introduction

Fossil fuel power plants impact water sources: direct consumption is necessary for cooling and steam production, while air pollution contributes to acid rain and thus affects water sources.[54] This pollution alters basic ecosystem processes, affecting the organisms that rely on stable habitats, and on a human level, it can affect those residents who live in the ecosystems. The Navajo Generating Station (NGS), seen in **Figure CS1**, began full operation in 1976 in Page, Arizona, near the Grand Canyon and the Navajo Nation. A year later the Grand Canyon qualified for Class 1 Federal Air Quality Protection under the Environmental Protection Agency (EPA), and in 1990 the Clean Air Act was amended, allowing the Navajo Nation to create the Navajo Nation EPA (NNEPA) to control air quality.[55, 56] The plant was built to power the Central Arizona Project (CAP), as well as other interests for a reasonable cost; this lead to its reputation as one of the dirtiest coal-fired plants in the nation. Now, 42 years after the Clean Air Act and 35 years after Class 1 Federal Protection for the Grand Canyon, the NGS faces strict U.S. EPA and NNEPA regulations that are forcing it to invest in cleaner emissions regulations, or shut down. This is exactly the choice that faced the Mohave Generating Station, as seen in **Figure CS2**, once located nearby in Laughlin, Nevada. Under pressure to clean up the plant or close down, the owners opted to close down the plant in 2005, indicating that it was too expensive to retrofit (it would have cost nearly $1 billion to meet requirements).[57]

Figure CS1: The Navajo Generating Station

Source: Merchant Circle, *City Gallery*, accessed July 6, 2012, http://www.merchantcircle.com/directory/AZ-Page/cityphotos/4.

A closer examination of two of the nation's dirtiest coal plants helps to predict the future of electric generation in the basin; will "dirty" power continue to be "cheap?" Will social and environmental concerns lead to the demise of more fossil fuel powered generating stations?

In 2005, the NGS was declared the fifth dirtiest coal-fired plant in the U.S.[58] The installation of SO2 scrubbers in 1991 helped to mitigate emissions from the plant and more recently, the installation of low-NOx burners in 2009-2011 has reduced the NGS' emissions further.[59] The water footprint of the NGS is approximately twice as large as the closed Mohave; it consumes approximately 24,500 acre-feet of Lake Powell water annually (whereas the Mohave consumed 13,000 af annually[60]), but reviews to alter the water intake to increase its efficiency are underway.[61] The Navajo Nation currently trucks in 40% of its water from an array of other basins.[62] The water that the NGS consumes could supply twice-over the Nation's annual consumption of 12,000 acre-feet.[63] From a public health perspective, it is estimated that the 2,250-megawatt NGS contributes to 16 deaths, 25 heart attacks, and 300 asthma attacks annually.[64] The 1,580 megawatt Mohave Plant, which was forced to close down because of its emission rates, had similar emission rates to the Navajo, as seen in **Figure CS3**.

Figure CS2: The Mohave Generating Station

Source: Merchant Circle, *City Gallery*, accessed July 6, 2012, http://www.merchantcircle.com/directory/AZ-Page/cityphotos/4.

Figure CS3: Pollution and Water Intensity of the Mohave and the Navajo Stations		
Criteria	**Mohave**	**Navajo**
MWh annual	10,000,000	16,140,683
CO2 tons/1000MWh	986	1,178
NOx tons/1000MWh	1.92	1.89
SO2 tons/1000MWh	3.91	0.28
Acre Feet/1000MWh	1.30*	1.52

Note: * Estimated by comparing the capacities ((Mohave capacity/Navajo capacity) x Navajo water consumption).

Sources: United States Environmental Protection Agency. eGrid Survey. *Year 2009 eGRID2012 Boiler, Generator, Plant, State, PCA, eGRID Subregion, NERC Region, U.S., and Grid Gross Loss (%)* Data Files. eGRID plant year 2009 data (4/27/12). 2012. Las Vegas Review-Journal, *Laughlin Coal Fired Power Plant Going Away*, accessed August 8, 2012, http://www.lvrj.com/business/47761602.html. Center for Energy Efficiency and Renewable Technologies, *Clearing California's Coal Shadow from the American West*, accessed July 19, 2012, http://www.ceert.org/PDFs/reports/Coalreport.pdf.

The Navajo Generating Station Situation

The Navajo Generating Station is unique for many reasons. Controversial in its proximity to the Grand Canyon and Navajo Tribal Lands, it is nonetheless crucial for the Central Arizona Project and thus the ability for Arizona to use its full apportionment of the Colorado River Compact.[65] The employment of Navajo and Hopi tribal members at the Kayenta and Navajo Mines, which provide the plant with coal,[66] places the NGS in an additionally delicate situation. In 2007, the NGS began planning to meet the EPA's Best Available Retrofit Technology (BART) requirements.[67] BART requires plants to meet emission requirements with retrofits. To meet BART, the NGS has three options: 1) operate at a major financial deficit to meet the passage of the strictest (and most expensive) of EPA emission requirements; 2) to retrofit with fiscally feasible technologies that meet but do not surpass EPA minimum standards; 3) or to close down.[68] This is the choice which the Mohave Plant faced seven years ago, with the owners choosing option three. To analyze all options, the NGS hired EN3Professionals to plan the phasing-in of environmental controls to keep the plant open while considering all stakeholder interests.[69]

The choice preferred by NGS authorities is to retrofit with fiscally feasible technologies.[70] The Central Arizona Project, which receives most of its 2.8 million MWh energy requirement from the NGS, would see a 20% spike in energy prices with the passage of the strictest EPA requirements.[71] The major shareholders in the NGS are: 24% Bureau of Reclamation, 22% Arizona's Salt River Project utility, 21% L.A. Water and Power, and tribal and community groups.[72] In order to moderate the proceedings, the National Renewable Energy Laboratory (NREL) has begun research to quantify the technical and economic benefits of various scenarios of compliance and to analyze any alternatives.[73] Though by no means a final decision, an authority from the Salt River Project (SRP) (with 22% ownership in the NGS) has released a "strawman," or initial document meant to describe the desired evolution of the plant. Many groups have an interest in some aspect of the plant, whether it be employment, power, or income. No decision will make all groups happy, but it is important to consider all opinions when moving forwards. The SRP, political representatives from the Navajo Nation, EPA, and community representatives from the Navajo Nation each have a unique stance on the subject:

SRP Stance

The NGS is critical to the economies of Arizona and the Navajo and Hopi Tribes, and to the fulfillment of the CAP. The plant can be kept open by implementing emissions controls voluntarily in exchange for flexibility with future requirements, addressing community concerns, and considering a transition to renewable energy on the reservations. The SRP wishes to offset past pollution by investing in a Fish and Wildlife Conservation Program, and meeting standards for hazardous emissions. The SRP will analyze the cost of converting the NGS to a renewable unit. SRP has proposed to invest $6 million in a Community Benefit Fund for all communities within a 100-mile radius of the plant and the Kayenta mine. The SRP interests at the NGS support research of renewable options, aid to economic development on reservations, and support of public health research.[74]

NNEPA Stance

The Navajo Nation Environmental Protection Agency catalyzed the requirement of strict controls at the plant by issuing air control permits in 2009. These permits were subsequently challenged by the Peabody Coal Mine in 2010, and then upheld by the U.S. EPA in March of 2012. With the backing of a federal agency, the NNEPA is asking the NGS to undergo changes for the betterment of the Navajo Nation and to comply with a clean future.[75] The NNEPA is distinct from other Navajo Nation groups in that they have quantifiable U.S. government backing.

EPA Stance

The NGS has complied with Arizona emission guidelines. However, since the passing of the EPA's tribal authority rule, which declares that state guidelines do not carry over to plants on reservations, the EPA has had to create new guidelines for the NGS that are federally enforceable. The EPA finalized a Federal Implementation Plan in 2010 for the station to protect tribal air that will limit sulfur dioxides, total particulate matter, opacity, and dust. Though requirements may be stringent, they are necessary for the health of the surrounding area. Further requirements will be made in the future.[76]

Forgotten People Stance

The Forgotten People (FP) is a non-profit public charity with the goal of improving life and building communities for the Navajo People. The FP feel that the NGS is doing irreparable harm to their landscape, such as laying "coal dust over black mesa" and replacing "desecrated cemeteries" with coal mines. The FP will educate the NGS on its effect on Navajo communities. The Forgotten People have pulled out of the proceedings in deciding the future of the NGS because they see the continuation of NGS operations under stakeholder interests as stalling voluntary submission to EPA regulations. The opinion of the Forgotten People that they "cannot afford to be used to keep the NGS operating" is due to the fact that they see "water sources degraded and diminished like sacred Sagebrush Spring, people living without electricity and piped water, and impassable, ungraded dirt roads….”[77]

The Mohave Generating Station Situation

An example of a similar situation depicts the problem that the Navajo Nation faces with the continued operation of the NGS:

> “Because of EPA regulations, the Mohave Generating Station near Laughlin, Nevada, closed its operations. As this power plant was the sole buyer of coal from Black Mesa Mine, it had to close its operation on January 1, 2006. Closure of this mine has had very adverse economic impact not only on the 160 or so people laid-off from the mine, but also on the Navajo Nation coffers.”[78]

The Mohave Generating Station emitted much more SO2 per MWh than the NGS currently emits. SO2 is a pollutant measured by the EPA and its high concentrations in the plant's emissions likely contributed heavily to the closure of Mohave. The NGS emits similar amounts of CO2 and NOx per MWh, and uses more water per MWh than the Mohave required. The Mohave was under contract to receive 19,000 acre feet of water annually, but its use never exceeded 13,000 acre feet.[79] The NGS uses nearly twice this much water at 24,500 acre feet of annual use. Water use is not currently a concern for power plant operators as it is not restricted by government. In the foreseeable future this may change, and if the NGS is still open, it will have to face another choice; shut down or reduce water use.

If the EPA enforces its most stringent requirements, thus forcing the plant to install more expensive technologies, the NGS plant could be forced to close. This would cause both the Hopi Tribe and Navajo Nation considerable economic harm and stall the CAP. Stalling of the CAP would shift the demand of the area to local water sources, which cannot supply the desired amount for long.[80] Workers from the Navajo Nation provide coal for the NGS and are employed at the plant. These workers directly and indirectly provide much of the energy for the Southwest at the NGS and FCPP (Four Corners Power Plant), but many Navajo homes lack sanitation and piped water.[81] Revenue from the NGS provides at least one-third of the Navajo Nation's government operating costs.[82] Tribal leaders know power plants will provide their people with jobs and combat rampant unemployment, but they also are coming to realize that power plants have serious health-related side effects.[83] Therefore, it is paradoxically in the best interest of the plant and the tribal revenues to avoid installing unaffordable top-of-the-line pollution control. This will keep the power plant open and provide the tribes with jobs, yet emissions of pollution will continue unless the power can be provided from renewable sources or stringent emission regulations are met.

Conclusion

The industries surrounding coal, from its producers to those that work to generate electricity, have entrenched the fuel source in American society as a way of life. This traditional fuel source for electric generation continues to be popular due to its low cost and high energy per volume. However, the growing costs of inputs and the externalities it places on public health are beginning to overshadow the traditional equation that has made coal the solution to the nation's energy needs. The growing recognition of the need for a new energy portfolio for the nation, and particularly the West, is not without controversy.

The communities and the owners associated with coal power plants have differing opinions of coal's future. Communities surrounding the two previously discussed plants see investments in cleaning up coal plants as investments that should have gone to renewables. Though the owners of the NGS support clean energy, it is not yet an economically sound investment. More government mandates are needed to make renewables more profitable than fossil fuels before coal is pushed to the background of any energy portfolio. The profits from the NGS support more than just the owners of the plant. Surrounding Native American communities rely on the plant for economic security, and far away interests rely on the plant for energy security. If EPA regulations force the NGS to close for financial reasons, the Nation will need jobs and the CAP will need power. The cost of transmission for the CAP is over $8 billion annually,[84] and the NGS is currently the only way to provide the energy. The CAP is a good incentive for the plant to stay open, but the emissions from the plant are an incentive for surrounding communities to ask for change.

There are different modes that can create this change. It is more reasonable to expect some modes than others. The SRP has declared their intention to begin implementing renewables at the station. Nonetheless, the coal-fired portion of the plant will be necessary into the foreseeable future, as renewable plants capable of producing as much energy do not yet exist in reality. The cost of cleaning up the NGS' emissions is high, and the former Mohave Plant portrays the possibility of closure. The owners of the NGS will want the plant to remain profitable, and the importance of the plant to the CAP all but necessitates its existence. Though meeting regulations is expensive, emissions controls will likely be installed as the most viable option to continue to provide the needed power. Situations like this are often unforeseeable, but the NGS teaches us valuable lessons.

It is best to not rely heavily on any one source of power. It would be easier for a natural gas plant to comply with the regulations because they emit far less pollutants. Renewable energy can cover some, but not all, of the burden. Retrofitting is a solution to a problem that was not predicted when the plant was built. Outside forces, in the form of the EPA and NNEPA, are working with internal interests, in the form of stakeholders, to achieve an optimum solution.

This solution will be a compromise between communities. Some communities directly rely on the power, and some rely on jobs the power provides. Through increasing government regulations the Navajo Nation and Hopi Tribe will achieve the clean air that anyone, anywhere, deserves. Their communities will be stronger and healthier when the pollutants are lessened. The stakeholders will continue to profit from the plant if they follow regulations. Someday renewables may be the answer to help them profit more. The only way to reach a satisfactory solution is to give all concerned an equal say, and to deeply consider the repercussions of any decision.

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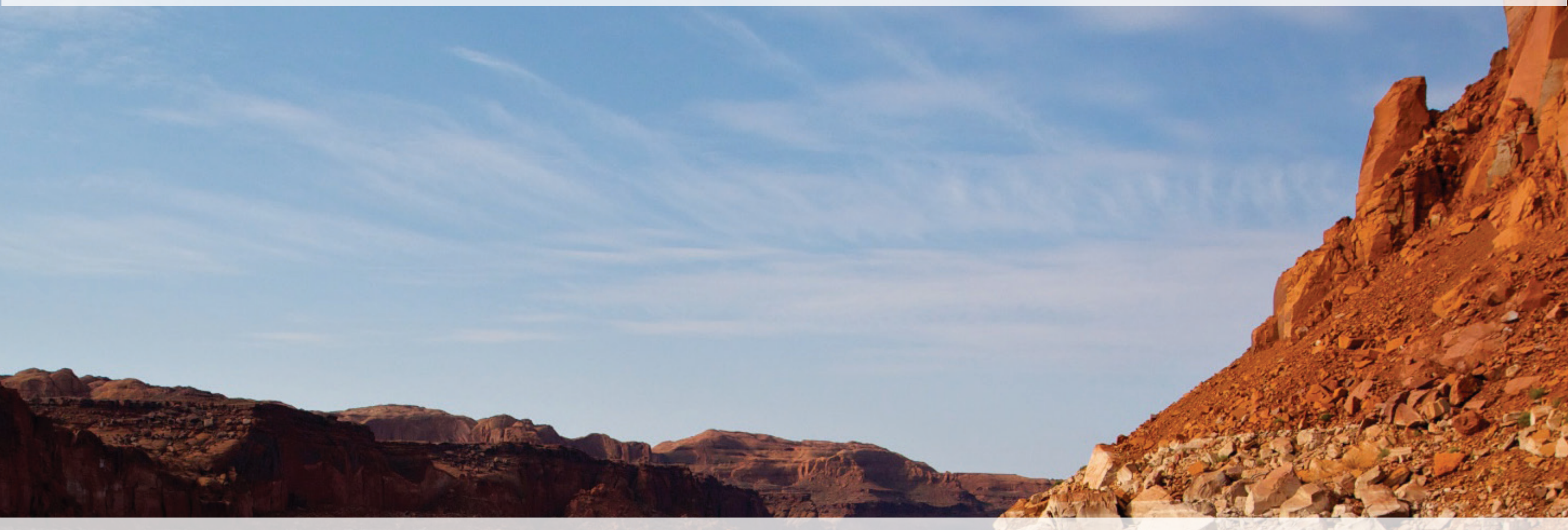
Will Stauffer-Norris

The Down the Colorado Expedition in the Grand Canyon.

Can Renewable Energy Lead the Colorado River Basin into a Water Friendly Future?

By Audrey Burns



Key Findings:

-The agricultural sector consumes about 39 times the amount of water as the electricity generation sector.

-Photovoltaic solar systems have a median emission of 43 grams of carbon dioxide per kilowatt hour vs. concentrating solar power systems- 26 grams and coal- 1,001 grams.

-Colorado wind saves around 2.18 billion gallons, or 6,690 acre feet (af) of water a year that would be consumed if this power came from fossil fuels.

-Biomass can substitute for up to 20% of the coal used in the coal-fired boilers.

-Natural gas, if implemented more widely in place of coal combustion, can be an effective method of simultaneously reducing carbon dioxide emissions in half and using half the amount of water for generation that coal requires.

-The average home in the United States uses 31.5 kilowatt hours of energy per day. For the state of Colorado, this amount of energy use translates to water consumption of 14.5 gallons of water per day.

-If the basin's entire generation portfolio were renewable, nearly 300,000 af could be saved each year, supplying a full 25% of the deficit the basin will be facing in a decade.

The 2013 Colorado College State of the Rockies Report Card
Water Friendly Futures for the Colorado River Basin

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Will Stauffer-Norris

Introduction

As population, water demand, and energy demand increase in the Colorado River Basin, water stress is becoming highly prevalent. Water for electricity generation comprises approximately three percent of consumptive water use in the Colorado River Basin. As water becomes scarcer, it becomes more expensive to generate electricity. The state of energy and water use as they stand will not allow for a water friendly future in the basin. While water for electricity generation comprises three percent of consumptive water use in the basin, water for agriculture constitutes about 80% of consumptive water use in the basin. Since water rights are appropriated toward senior holders first, agriculture will likely continue to receive the majority of water in the basin. If agriculture is the main water consumer, why is there a concern for water use for electricity generation?

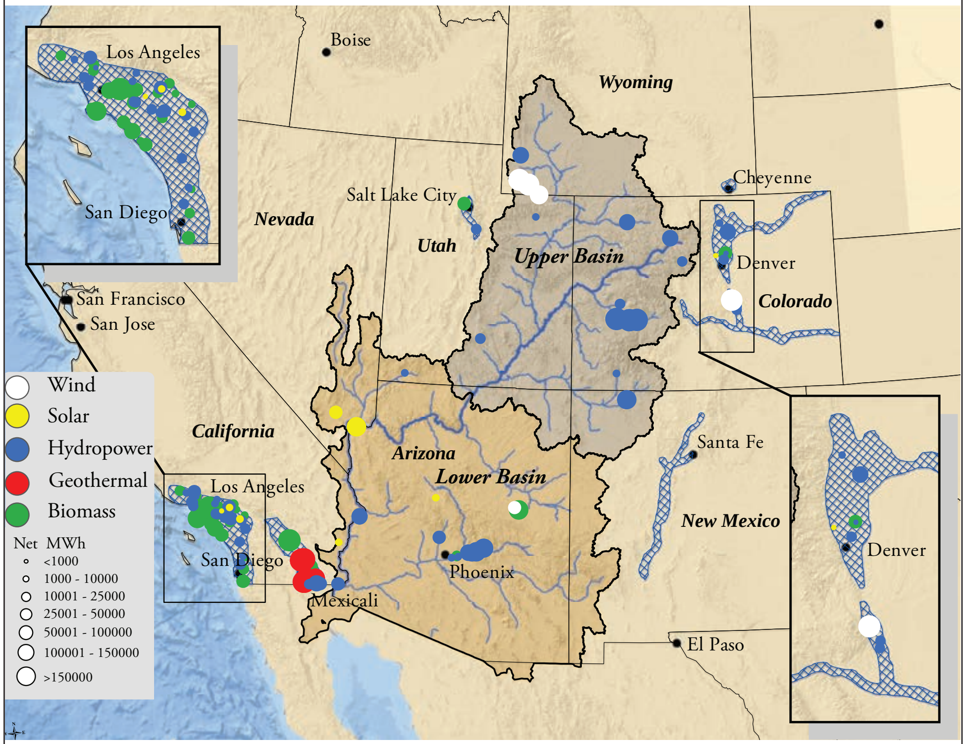
If demand patterns continue according to the Bureau of Reclamation's (BOR) current trends scenario, as population increases and water becomes scarcer, there will be less water available for energy, as well as less energy for water. The factors considered in this BOR study with respect to electricity and energy are oil shale development, photovoltaic solar power, concentrated solar power, wind, geothermal, and fossil fuels. The consumptive water demand for energy in the Colorado River Basin is projected to be at 271,849 acre feet in 2015, 363,369 acre feet in 2035, and 434,289 acre feet in 2060.[1] The increase in water consumptive demand from 2015 to 2060 is estimated to be 63%. While electricity production and generation are less water-consumptive than agriculture, there still needs to be water available for energy generation. Thus, implementation of a less water-consumptive method of electricity production is in order. The demand study indicates that using less water in the energy sector will help bridge the gap between water availability and water demand in the basin. Even though the agriculture sector consumes about 39 times the amount of water as the electricity sector, significant reduction of water consumption in the electricity sector will aid in alleviating the basin's water stress. As agriculture often holds senior water rights, it may be a less politically charged matter to reduce water consumption in the electricity sector.

Renewable Energy in Opposition to Fossil Fuels

Fossil fuels comprise a sizeable portion of the source for electricity production in the basin, thus consuming a sizeable amount of water in the basin. Many forms of renewable energy, namely wind and some forms of solar, use significantly less water than fossil fuels. Renewable forms of energy also have far fewer carbon emissions than nonrenewables. They do, however, have higher up-front costs than nonrenewables, and it is difficult to arrange for large-scale renewable projects. **Figure 1** displays the renewable plants in the Colorado River Basin and its adjacent areas.

There are several options for renewable energy in the Colorado River Basin. The irradiation in the southwest is more conducive to solar power generation than anywhere else in the United States. There is also high wind potential on the High Plains, making some wind energy for the Colorado River Basin and some of its adjacent trans-basin diversion areas a viable option. Geothermal potential also abounds in and around the Colorado River Basin, with plants currently in operation in Montana, Nevada, New Mexico, and Wyoming.[2] With respect to biomass potential, the Colorado River Basin has the smallest quantity in the U.S., although there is fairly high potential in southwest Arizona and in the southern tip of California.[3] Hydroelectricity is a renewable currently being implemented to a great extent in the basin, but it leads to massive loss of water by evaporation and is a risky choice for electricity in an area with an arid climate and water stress.

Figure 1: Renewable Power Plants by Fuel Type in the Basin



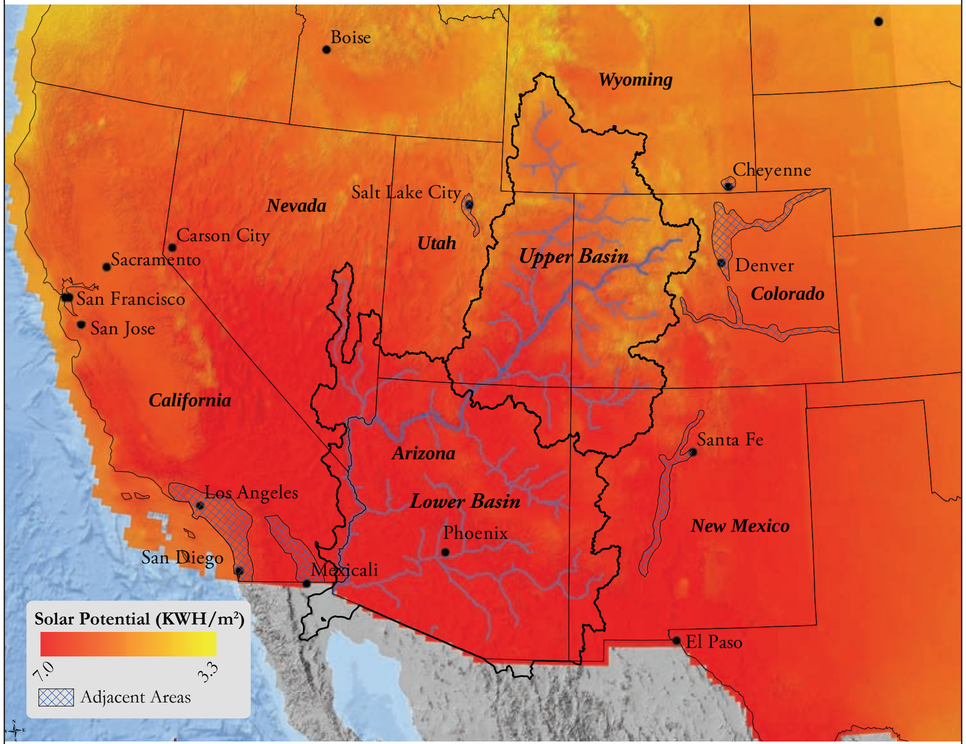
Source: United States Environmental Protection Agency. eGrid Survey. Y*ear 2009 eGRID2012 Boiler, Generator, Plant, State, PCA, eGRID Subregion, NERC Region, U.S., and Grid Gross Loss (%) Data Files*. eGRID plant year 2009 data (4/27/12). 2012.

Solar Potential in the Colorado River Basin

Solar irradiation would be able to deliver substantial amounts of energy to the Colorado River Basin, depending upon the type and scale of the solar energy projects. As displayed in **Figure 2,** there is high radiation potential in the Colorado River Basin, particularly in Arizona and New Mexico.

The two main categories of solar power are photovoltaic solar power and concentrating solar power. In 2011, silicon photovoltaic sales made up 90% of all PV product

Figure 2: Solar Radiation in the Colorado River Basin



Source: National Renewable Energy Lab, Department of Energy

sales in the U.S.[4] While solar panels are not terribly water-consumptive to operate at maximum capacity for electricity generation, they do need to be washed regularly. If they are not routinely cleansed with water, their efficiency can be reduced by 15-20%.[5] When put in the context of the Colorado River Basin's water stress, photovoltaic panels are a smart choice because their manufacturing, a highly water-intensive process, generally occurs outside of the basin and they require about four gallons of water per panel to wash. Solar panels should be washed about every six months.

Concentrating solar power (CSP) uses radiation from the sun to generate electricity without PV solar cells. CSP parabolic troughs concentrate solar radiation onto a small tube following tracking parabolic mirrors, or troughs. The transfer fluid in the tube is heated and stored, later to be used to generate steam and spin a turbine.[6] The CSP tower system uses a centrally located tower surrounded by a field of tracking mirrors, or heliostats. The heliostats reflect solar insolation to the top of the tower, and here the solar energy heats the fluid in the tower, and the heated fluid then turns the tower's steam turbine.[7] The engine system produces electricity without using steam or a turbine.[8] The four main types of CSP are parabolic troughs, linear Frensel, power towers, and dish/engine. CSP parabolic troughs are the most commercially available technology of the CSP types, and they will thus be the main CSP focus in this report.[9]

CSP plants must implement various cooling methods to disperse the heat via evaporation from the power plant. There are several different cooling methods for concentrating solar power—dry cooling, wet cooling, and a combination of the two. Wet cooling is frequently used over dry cooling because it is the cheaper and the more efficient method of the two.[10] Dry cooling, while far less water-consumptive than wet cooling, is more subject to temperature swings. Thus, when air temperature is at high levels, the dry cooling system has a compromised level of efficiency. As temperatures are often quite high in the Colorado River Basin, dry-cooling systems will often be compromised in the region. The hybrid system of wet-and-dry cooling utilizes less water than systems that are purely wet cooling while simultaneously alleviating the reaction to temperature upswings typical of the dry-cooling system.[11]

There are myriad benefits to solar energy, and if there were not impediments to implementing solar power, it would top the list of future energy options in the Colorado River Basin. Solar energy emits significantly less carbon dioxide when compared to nonrenewables, and is even less carbon intensive than some renewables. Photovoltaic systems have a median emission of 43 grams of carbon dioxide per kilowatt hour and concentrating solar power systems have a median emission of 26 grams of carbon dioxide per kilowatt hour, whereas coal has a median emission of 1,001 grams of carbon dioxide per kilowatt hour.[12]

While solar energy has relatively low carbon dioxide emissions, it does require significant amounts of water for maintenance of PV solar and for cooling systems in CSP plants. **Figure 3** displays the water use in gallons per megawatt hour of generation and consumption for washing the solar arrays for the most common forms of CSP and PV. Wet-cooling systems are water-intensive for parabolic trough systems, as they use up to 800 gallons of water per megawatt

Figure 3: Water use per MWh of all forms of CSP and PV

Solar Type	Water Consumed per MWh of Generation (gallons)
CSP-Parabolic trough, wet cooling	800-1000
CSP-Parabolic trough, hybrid cooling	100-450
CSP-Parabolic trough dry cooling	78
CSP-Tower recirculating cooling	500-750
CSP-Tower hybrid cooling system	90-250
CSP-Tower dry cooling	90
PV-thin-film cadium telluride (CdTe)	211
PV-multi-and mono-silicon PVs	528

Source: *The Water-Energy Nexus in the American West.*

Figure 4: Current Solar Generation Plants and Solar Projects

State	Plants in Operation	Plants Under Development	Plants Under Construction	Total Plants
Arizona	267	664	2,455	3,386
California	624	3,445	15,553	19,602
Colorado	81	30	267	379
Nevada	139	2	376	517
New Mexico	221	156	3,373	3,750
Utah	X	X	155	155
Wyoming	X	X	X	X

hour. Dry cooling, while not being nearly as water-consumptive (78 gallons of water per megawatt hour), is nonetheless much less efficient than wet cooling. The most water-consumptive form of concentrating solar power is the parabolic trough with a wet-cooling system. While these numbers give a good approximation of water use for PV and CSP, there is still a good deal of uncertainty about the impact of CSP on water use because how much water a CSP system requires depends upon its location, whether thermal storage is included, and whether wet cooling is used.[13]

CSP parabolic troughs are currently the most cost-effective forms of concentrating solar power. When compared to PV, however, CSP is more expensive.[14] Whereas solar thermal was formerly considered to not be a cost-effective option, the price of PV is coming down, and PV is becoming a more accessible form of renewable energy. **Figure 4** is a table of current solar generation plants and solar projects under development and construction in and around the Colorado River Basin. Concentrating solar power plants and photovoltaic solar power panels have a life expectancy of at least 20 years, which allows these electricity sources to effectively pay for themselves before the end of their lifespans.

Wind Energy Potential in the Colorado River Basin

When considering only the aspect of water stress in the Colorado River Basin, it seems that wind energy is the best option. Wind energy uses no water in generating power and wind power only requires water for washing of the turbines' blades. An individual wind turbine uses about one gallon of water for one megawatt of energy produced, assuming the blades are washed four times per year. This number varies slightly depending upon the size of the turbine. There are other aspects of wind energy that must be taken into consideration, such as the cost of wind turbine implementation and the feasibility of bringing a wind turbine online.

As there are drawbacks to solar energy, there are drawbacks to wind energy. Wind turbines come in varying sizes and scales of operation. Commercial-scale turbines currently tend to be 2 MW in generation capacity and cost $3.5 million to be installed, which is a steep up-front cost. Wind turbines operating under 100,000 kilowatts cost about $3,000 to $5,000 per kilowatt hour of electricity.[15] An average home operates at a 10kW capacity, and it would cost $32,000 to

Case Study: Concentrating Solar Power in a Semi-Arid Desert: Nevada Solar One

Nevada Solar One (NSO), owned by Acciona Energy, went online in June 2007, creating over 800 construction jobs during building and approximately 30 permanent operation jobs. Nevada Solar One is a 30-year project. One of the largest CSP systems in the world, it operates in Boulder City, Nevada, proximate to the Colorado River Basin. **Figure 5** is an image of the parabolic trough system in place at Nevada Solar One. This CSP plant uses parabolic troughs and a wet-cooling system. The full load capacity at the plant is 75 megawatts. All of the power generated was purchased by Nevada Power Company and Sierra Pacific Resources under long-term power purchase agreements (PPAs) prior to the plant's dedication. In powering 14,000 homes in Nevada annually, Nevada Solar One avoids the CO_2 emissions equivalent to 20,000 cars. NSO heats oil rather than salt because salts typically use more storage than oil. Nevada Solar One uses a closed-loop system. They use a wet-cooling system at the plant. Ninety percent of the water used at NSO goes toward operating the cooling system. Getting Nevada Solar online was made easier by the previously existing transmission lines. About one mile of transmission line was implemented to get NSO running.

Figure 5: Nevada Solar One Plant

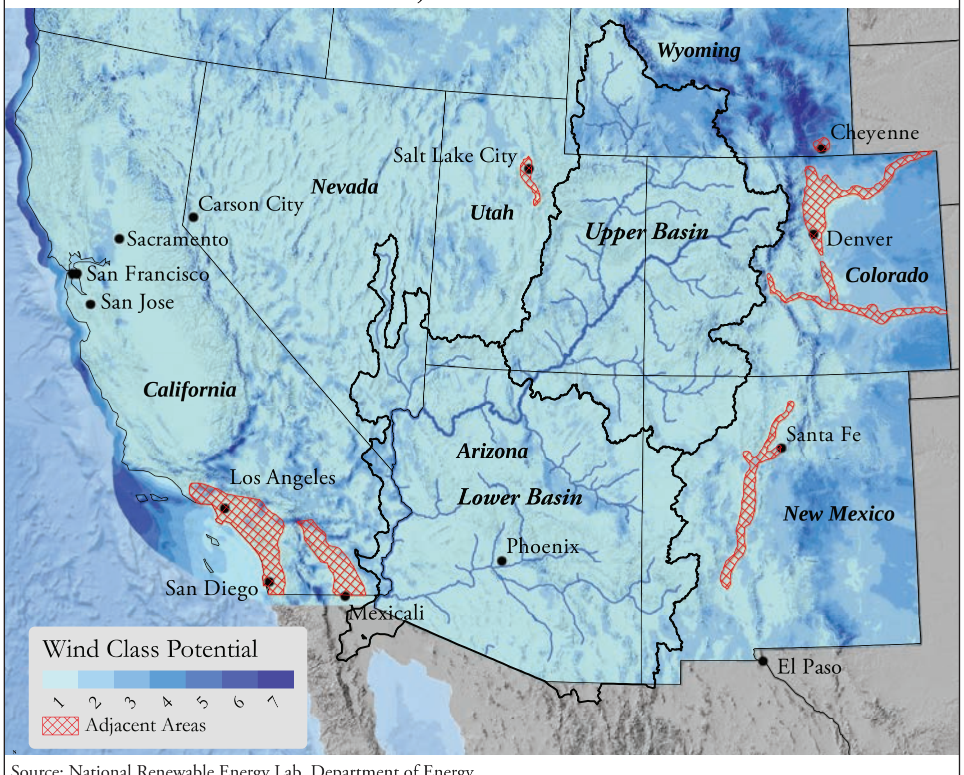
Source: Alice Plant.

install a wind turbine for such a home.[16] There are tax incentives and rebates in several states in the Colorado River Basin, which would help to offset the cost of turbine implementation.

There is high wind potential located in the High Plains, adjacent to the Colorado River Basin, and decent wind potential directly in the basin. While power generation on the plains will not be occurring within the basin, it would help to alleviate water use by fossil fuel plants that rely on transbasin diversions of Colorado River water. **Figure 6** displays the wind potential in the basin and its adjacent areas. This wind energy has the potential to assist in meeting the energy needs of the Colorado River Basin, given that there are the funds and resources available to create these transmission lines.[17]

Colorado wind saves around 2.18 billion gallons, or 6,690 acre feet (af) of water a year[18] that would be consumed if this power came from fossil fuels, and Colorado's wind power only accounts for about 6% of its generation portfolio.[19] If the basin's entire generation portfolio were renewable, nearly 300,000 af could be saved each year, supplying a full 25% of the deficit the basin will be facing in a decade.

Figure 6: Wind Potential in the Colorado River Basin and Adjacent Areas



Source: National Renewable Energy Lab, Department of Energy.

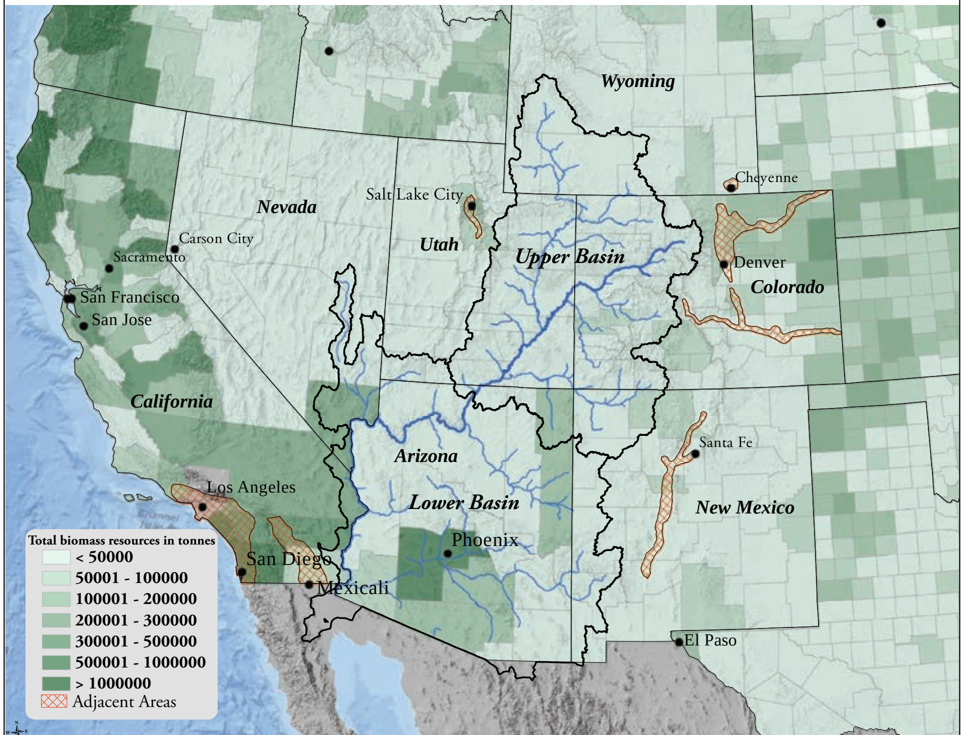
While wind is a positive option in the context of low water consumption, wind turbines are at the mercy of fluctuating wind conditions. Thus, the amount of electricity generated by the spinning turbines can vary day-to-day, and even hour-to-hour. This direct tie between favorable wind conditions for spinning the wind turbines suggests that wind could never be the only form of energy supplying customers.[20]

Other Renewables in the Colorado River Basin: Biomass, Geothermal, and Hydropower

There are several other forms of renewable energy options in the Colorado River Basin—namely biomass, geothermal, and hydropower. While biomass is an increasingly popular form of renewable energy in the region, there are impediments to implementing biomass as a significant energy resource in the West. A drawback to biomass is that it uses large quantities of water, both for the irrigation of biomass feedstocks and for converting of the feedstock into the form of biomass for electricity generation.[21] Water use for power generation using biomass feedstocks is on par with the water use of fossil fuel-fired plants for power generation.[22] An approach to avoiding water-consumptive biomass production is to utilize previously existing feedstocks. Woody biomass and agricultural waste do not require irrigation for their production. Woody biomass can be cofired with coal to generate electricity. This form of biomass is largely comprised of wood that would otherwise be unusable, such as trees felled because of beetle kill. Other forms of woody biomass include urban wood waste, pallets, sawdust, and forest products.[23]

Biomass feedstock can be processed by itself, or it can be cofired. The cofiring process involves combining biomass feedstock with coal in high-efficiency coal boilers. Biomass can substitute up to 20% of the coal used in the boiler.[24] The biomass and the coal are then burned simultaneously. There are several benefits of the cofiring process. Partially supplementing biomass for coal allows for lower fuel costs. Biomass substitution for coal also cuts greenhouse gas emissions as it facilitates avoidance of stowing biomass in landfills and the methane production following the decomposition of organic matter, as well as reducing the sulfur oxide, carbon dioxide, nitrous oxide, and other greenhouse gas emissions which come with coal combustion.[25] While cofiring plants do not reduce the plant's totally energy input requirement and the efficiency of a cofiring plant will be about equal to that of a solely coal-fired plant, they are a positive force in that they reduce the combustion of nonrenewable, greenhouse gas emitting fuel.[26] The payback period of changing a coal plant over to a cofiring plant is in the range of one to eight years. At larger-than-average facilities, as well as in the case of facilities with self-disposal options for their biomass, the payback period can be much shorter. For biomass cofiring to be economically attractive, the boilers must be able to produce 35,000 pounds of steam per hour.[27] Several coal power plants are using this form of electricity generation to meet their renewable portfolio standard requirements, such as the Martin Drake Power Plant in Colorado Springs.[28]

Figure 7: Biomass Potential in the Basin and Adjacent Areas



Source: National Renewable Energy Lab, Department of Energy.

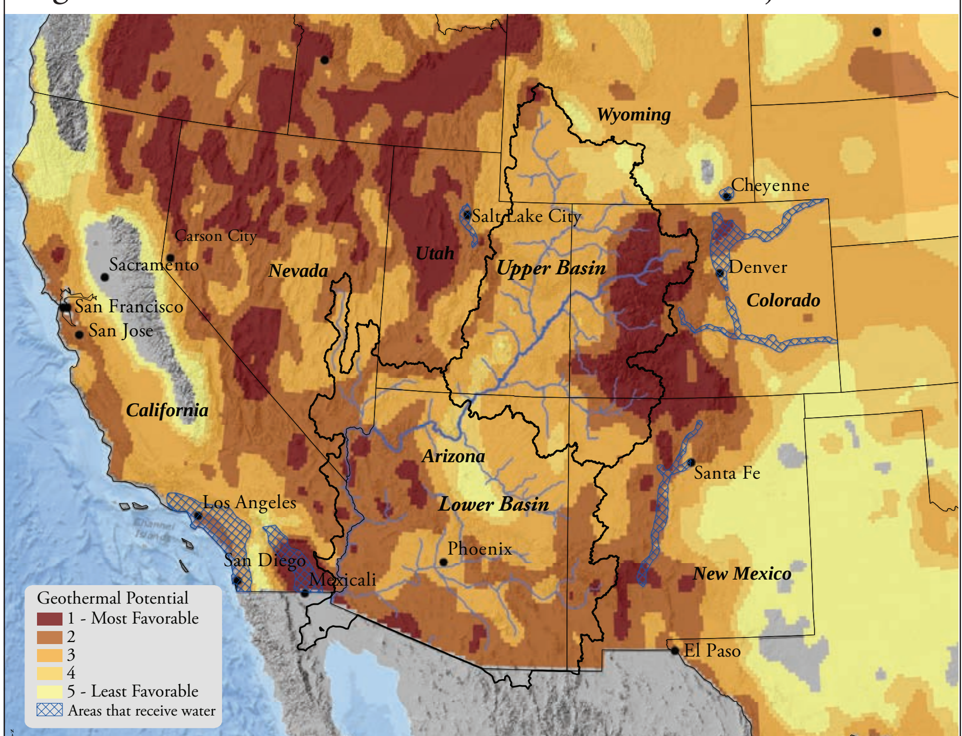
Biomass for electricity generation is gaining more of a presence in the Colorado River Basin. In addition to the change at the Martin Drake Plant, there is one large-scale, cofiring biomass operation underway in Nevada. The Nevada forest service collects woody biomass and sends it to the cogeneration plant at the Northern Nevada Correction Center. There are three biomass plants currently in operation in Arizona. The Western Renewable Plant is a direct-fire facility operating at 2.5 megawatts, the APS Biomass l Plant is a direct-fire facility operating at 2.85 megawatts, and the Snowflake White Mountain Plant is a direct-fire facility operating at 24 megawatts.[29] **Figure 7** is a map of the biomass potential in the Colorado River Basin.

Another important resource for renewable energy in the Colorado River Basin is geothermal energy. It harnesses energy from hot water or steam reservoirs buried deep in the earth. The water in the hot water reservoirs can be as hot as 700 degrees Fahrenheit. A geothermal well is drilled down to the water reservoir, and steam is brought to the surface to perform the classic process of spinning a turbine and generating electricity. This type of geothermal electricity production is known as flash production.[30] Some consider geothermal a good renewable energy source because it uses no petroleum in production and has few greenhouse gas emissions. Geothermal energy produces one sixth of the amount of carbon dioxide that a natural gas plant produces.[31] Less commonly known about geothermal energy, however, is that electricity production from a geothermal source uses an incredible amount of water.

The geothermal reserves in and around the Colorado River Basin are largely in Nevada, with other resources-rich areas peppered throughout California, Colorado, Arizona, New Mexico, and Utah. **Figure 8** portrays the geothermal potential in the Colorado River Basin.

A substantial amount of electricity in the Colorado River Basin comes from hydropower resources (**Figure 9**). The reservoirs feeding the dams are both costly and inefficient. They are costly in that much of their cost must be paid upfront, and they are inefficient in that much of the reservoir's water is lost to evaporation.[32] In the Colorado River Basin, hydropower is exacerbating the problem of water stress, even though it is a renewable source for electricity. Hydropower is not renewable in the sense of being able to replenish itself—once significant amounts of water from the reservoirs evaporate, it is incredibly difficult

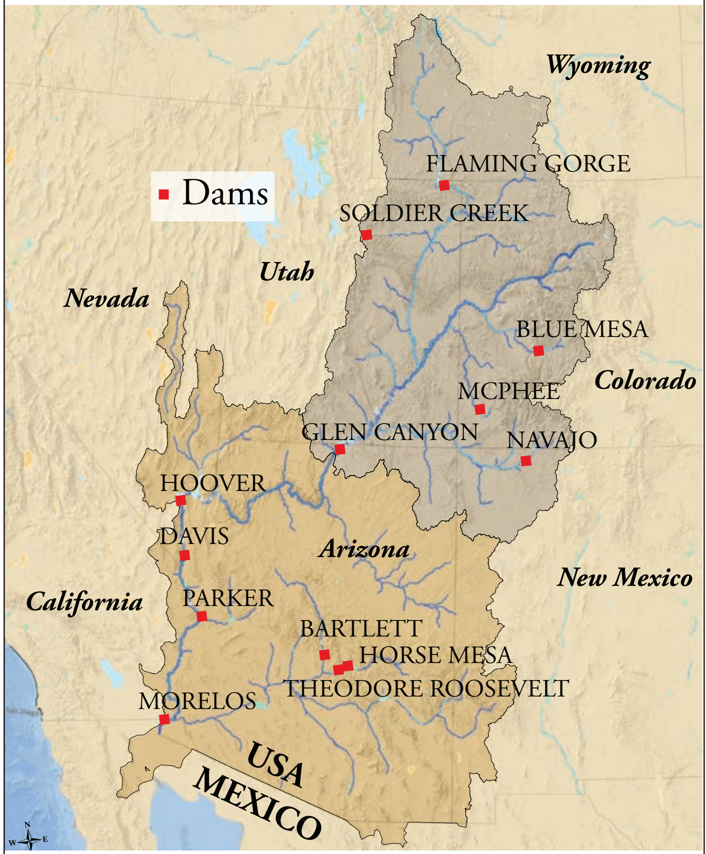
Figure 8: Geothermal Potential in the Basin and Adjacent Areas



Source: National Renewable Energy Lab, Department of Energy.

for those reservoirs to return to their former levels. The "bathtub rings" around Lakes Powell and Mead indicate the extensive water loss on these two reservoirs.

Figure 9: Map of Hydropower Plants in the Basin



Source: U.S. Geographic Names Information System.

The Big Three: Carbon, Water, and Cost

The comparison of the carbon emissions, water consumption, and cost of renewables compares renewables against one another regarding their overall effectiveness for the Colorado River Basin. **Figure 11** displays these comparisons among the forms of renewable energy described in this *Report Card*. Where wind turbines have relatively few cradle-to-grave carbon emissions and are hardly water-consumptive, they are fairly costly. In a water-stressed region such as the Colorado River Basin, the question arises as to what is most important—conserving water, reducing carbon emissions, or keeping costs low.

Out of the renewables presented in this report, photovoltaic solar power, concentrating solar power using dry cooling, and wind energy are the least water-consumptive. They also have relatively low carbon emissions.

If water and carbon emissions are two of the main issues with respect to implementing renewable energy, cost is the third. While they may pay for themselves in the long term, they are expensive up-front forms of energy. **Figure 12** displays the cost of renewable energy and conventional energy per megawatt hour of generation.

While electricity generated from renewables averages a higher cost per megawatt hour than electricity generated from fossil fuels, the price of the former is expected to decrease significantly by the year 2020. **Figure 13** depicts the predicted price drops in renewable energy.

Thus, solar energy is likely to become cost-competitive in the near future. Once solar energy is more accessible, it can become more prevalent in the Colorado River Basin.

Case Study: Evaporation from Reservoirs in the Colorado River Basin

Due to the low water levels in reservoirs in the Colorado River Basin, hydroelectric power generation is threatened. The Colorado River system is running at a deficit of 1 million acre feet per year.[33] Evaporation from the main reservoirs along the river partially contributes to this problem. The evaporation from Lake Mead totals 800,000 acre feet per year.[34] The yearly evaporation from Lake Powell is at about 370,000 acre feet.[35]

As of October 2012, the end of the water year, the Lake Powell inflow was 29 percent of the average inflow.[36] The total inflow for 2012 was at 5 million acre feet, which is 46 percent of the average.[37] Lake Mead hit an historic low in 2010 with a water level of 1,083 feet above sea level.[38] There is a 50 percent chance that the water levels in the reservoir will be too low by 2017 to power Lake Mead's Hoover Dam, which supplies electricity to Los Angeles and Las Vegas.[39] **Figure 10** depicts Lake Mead. The white "bathtub ring" above the water marks the difference between the current level of water in the lake and what level the lake would reach if it were full.

Figure 10: Lake Mead's "Bathtub Ring"

Source: The Resilient Earth.

Figure 11: Water Consumption and Carbon Emissions of Various Renewables		
Energy Type	**Water Usage in gallons per MWh-generation**	**Carbon Emissions per kWh**
Geothermal	1321-3963	40 g
CSP-Parabolic trough, wet cooling	800-1000	31.8 g
CSP-Parabolic trough, hybrid cooling	100-450	31.8 g
CSP-Parabolic trough dry cooling	78	31.8 g
CSP-Tower recirculating cooling	500-750	32.3 g
CSP-Tower hybrid cooling system	90-250	32.3 g
CSP-Tower air cooling	90	32.3 g
Mirrored Parabolic Dish	4	22 g
PV-thin-film cadium telluride (CdTe)	211	45 g
PV-multi-and mono-silicon PVs	528	45 g
Wind	1	11 g

Source: *The Water-Energy Nexus in the American West*. National Renewable Energy Laboratory, *Life Cycle Assessment (LCA) Harmonization Project.*

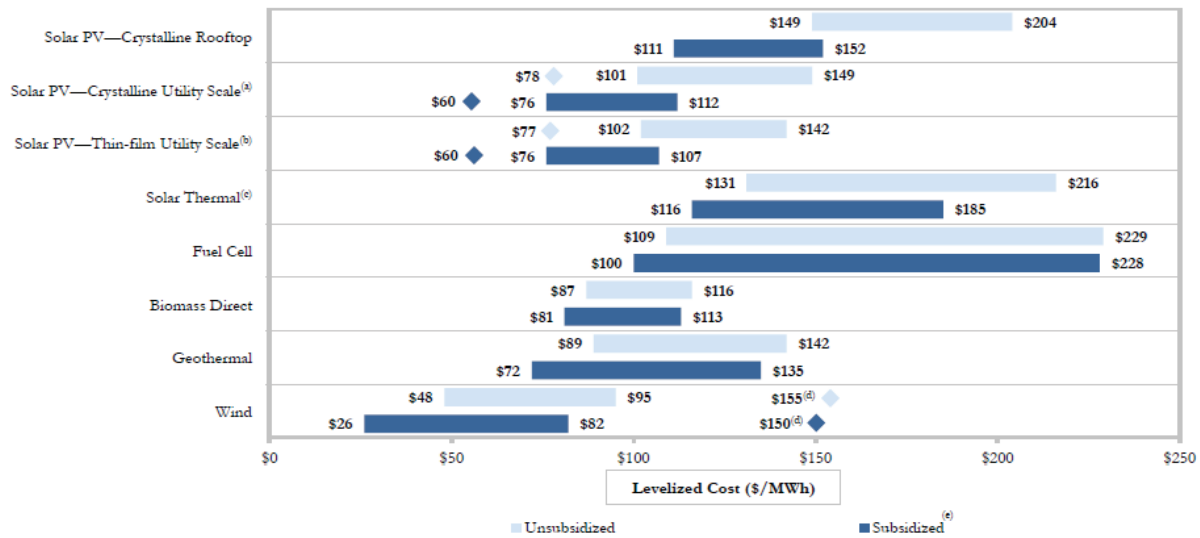
Navigating the Path to Renewable Energy in the Colorado River Basin

While there is potential to greatly reduce greenhouse gas emissions and reduce water for energy and energy for water use in the Colorado River Basin, there are myriad challenges lying in the way of implementing a renewable, clean energy system in the basin. Among these challenges is the glaring issue of cost. The up-front cost of renewables makes it difficult for many who want renewables implemented. Federal subsidies for renewable energy make renewable energy within the reach of more people. Hand-in-hand with the issue of cost is the issue of who the customers are for renewable energy. The main clientele for bulk renewable energy are electric utility companies trying to meet the renewable portfolio standards their states have set forth.[40]

The Obama Administration has continued to support subsidies for solar, wind, and biofuels.[41] The Senate Finance Committee voted on August 2, 2012 to renew a tax credit for wind power that would otherwise expire at the end of 2012.[42] On January 2, 2013, the Committee extended

Figure 12: Levelized Cost of Energy- Sensitivity to U.S. Federal Tax Subsidies

U.S. federal tax subsidies remain an important component of the economics of Alternative Energy generation technologies (and government incentives are, generally, currently important in all regions); future cost reductions in technologies such as solar PV have the potential to enable these technologies to approach "grid parity" without tax subsidies and wind currently reaches "grid parity" under certain conditions (albeit such observation does not take into account issues such as dispatch characteristics, the cost of incremental transmission and back-up generation/system reliability costs or other factors)



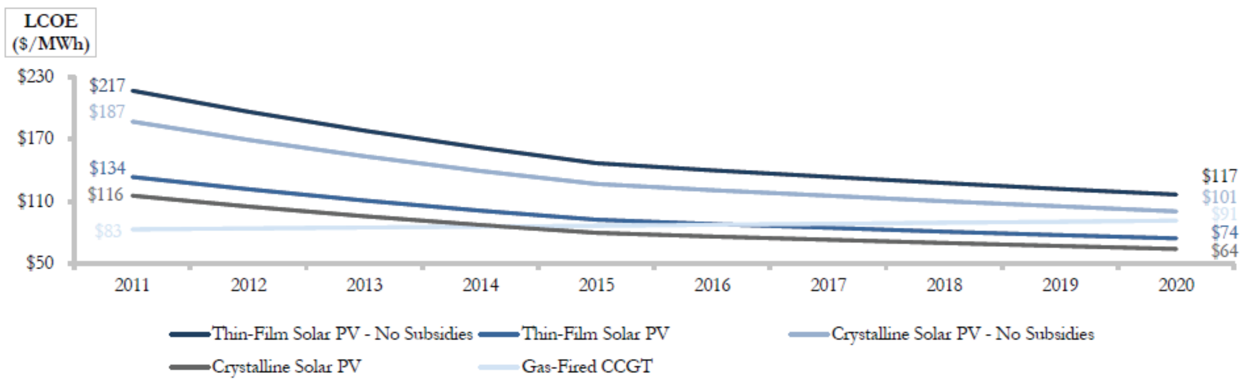
Source: Lazard estimates.
(a) Low end represents single-axis tracking. High end represents fixed-tilt installation. Diamonds represent estimated implied levelized cost of energy in 2015, assuming a total system cost of $1.75 per watt for a single-axis system.
(b) Assumes fixed-tilt installation. Diamonds represent estimated implied levelized cost of energy in 2015, assuming a total system cost of $1.50 per watt.
(c) Represents solar tower with and without 3 hour storage capability.
(d) Represents midpoint of levelized cost of energy for off-shore wind, assuming a range of total system cost of $3.10 – $5.00 per watt.
(e) Reflects Production Tax Credit or Investment Tax Credit, as applicable. Assumes 30% debt at 8.0% interest rate, 50% tax equity at 9.5% cost and 20% common equity at 12.0% cost.

Source: Lazard, Levelized Cost of Energy Analysis, Version 6.0, June 2012.

Figure 13: Levelized Cost of Energy- Sensitivity to Capital Costs

An important finding in respect of solar PV technologies is the potential for significant cost reductions over time as manufacturing scale along the entire production value chain increases; by contrast, conventional generation technologies are experiencing capital cost inflation, driven by long-term global demand for conventional generation equipment, where potentially cost-reducing manufacturing improvements for these mature technologies are largely incremental in nature

- **This assessment, however, does not take into account the intermittent nature of solar PV as compared with the dispatchable nature of conventional generation; the key finding in this regard is that solar PV technologies will play an increasingly *complementary* role in generation portfolios**



Source: *Lazard estimates.*
Note: Reflects investment tax credit and accelerated asset depreciation, as applicable. Assumes 2010 dollars, 20-year economic life and 40% tax rate. Assumes 30% debt at 8.0% interest rate, 50% tax equity at 8.5% cost and 20% common equity at 12% cost for Alternative Energy generation technologies. Assumes 60% debt at 8.0% interest rate and 40% equity at 12% cost for conventional generation technologies. Assumes natural gas price of $5.50 per MMBtu. Assumes midpoint of analysis conducted earlier.
(a) Assumes capital costs for thin-film and crystalline solar PV decline by 10% annually through 2014 and 5% annually thereafter. Assumes capital costs for gas-fired CCGT increase by 2.5% annually.

Source: Lazard, Levelized Cost of Energy Analysis, Version 6.0, June 2012.

the wind tax credit for another year. The credit is worth 2.2 cents per kilowatt hour of electricity produced by wind turbines still in their first ten years of operation. The wind industry considers this tax credit renewal vital to its becoming more competitive with coal and natural gas.[43] Similarly, on July 24, 2012, the Obama Administration opened up 285,000 acres of public lands in the states of Arizona, California, Colorado, Nevada, New Mexico, and Utah for development of solar projects.[44] This opening up of public lands to solar development is an increase from the nil solar projects on public lands at the beginning of Obama's first term in office. Since that time, there has been an increase of 17 major approved solar projects on public lands and an added generation of 6,000 megawatts of power.[45]

The Clean Energy Standard (CES) Act of 2012, proposed by former Senator Jeff Bingaman (D-NM), would increase the generation of renewable energy in the basin and throughout the United States.[46] The act would mandate that the amount of energy produced that is low carbon would stand at 80% by the year 2035. Utility companies would be the driving force in effecting these changes with clean energy credits. The act is one of, if not the most serious, federal propositions for major changes in the renewable energy sector. With the varied motivations and concerns of politicians, it will take time for the act to gain enough approval to be passed, if it is to be passed at all. Clearly, political tumult increases the tension in the field of renewable energy, and regardless of the position taken by either side, disagreements impede the facility with which renewables may be implemented.

While policy issues present a difficulty for implementing renewable energy in the Colorado River Basin, there is a lack of other resources that would be needed to get most large-scale renewable projects underway. Transmission lines are going to be incredibly difficult to implement in the Colorado River Basin. The Western Governors' Association cites access to electric transmission lines as one of the main barriers to implementing more renewable resources in the western states.[47] The WGA proposes the Regional Transmission Expansion Project as a means to get electric utilities, states, and other stakeholders to develop a regional transmission plan to utilize more of the renewable resources in the West.[48] The RTEP would implement water supply considerations into electric transmission planning. The project's plan is expected to come out in mid-2013 with its regional transmission plan. The water-energy assessment will include four components: a water availability assessment, a water-energy model, a scenario analysis, and a concluding section on policy development. The water availability assessment will bring together the current existing assessments of water supply availability, use, and projected demands throughout the West. The water-energy model will address water-energy planning and craft a decision-support framework for it.

Due to policy barriers, conflicting political interests, lack of resources, and other obstacles, the Colorado River Basin will likely not be able to run completely on renewable energy for quite some time. There are, however, steps residents and industries in the Colorado River Basin can take in their use of energy to conserve water and utilize water resources in a more efficient manner.

Steps Forward for a Water Friendly Future

Since renewable energy is not feasible as the only water-conserving measure for the time being, how can we solve the water for energy and energy for water issue in the Colorado River Basin? There are some immediate changes that we can implement to limit water consumption in the Colorado River Basin. Water conservation, recycling water, and leasing water allocated for agriculture to urban users are all "energy-smart" water resource strategies.[49] As mentioned in the M&I section, water conservation on the urban front can be particularly effective. The approach of end-use water conservation eliminates the energy use of pumping, treating, and distributing potable water supplies.[50] There are still many steps utilities in the basin can be taking to promote water conservation. The Basin Roundtables, which bring together 300 knowledgeable citizens around the state of Colorado to discuss issues surrounding the Colorado River Basin, similarly cite conservation as an important step to improving the flows in the Colorado River.[51]

Recycling water, which is also known as reclaimed or reuse water, has the potential to engender great energy savings in the Colorado River Basin. In the interior West, downstream water rights put a cap on the total amount of water utilities can recycle. Many cities in the region, however, have not yet tapped into the potential for recycling water, and there are still substantial water initiatives cities in the basin can take. An impediment to getting more water recycling programs running in the basin is the capital cost of implementing water recycling distribution systems. Recycling water uses energy, and generation of energy, of course, requires water. The western portion of the basin has been playing a part in recycling water. In Las Vegas, among other cities, where wastewater is treated to advanced tertiary standards, there is only incremental energy needed to distribute recycled water to customers. In other cities, there may be more energy needed to bring the wastewater up to higher standards. There is substantial potential for energy savings if reliance on recycled water programs were to become more of a staple in southern California. Large amounts of wastewater are discharged by treatment plants into the ocean in this region, and where fresh water is typically imported to the southern part of that state from the northern part, there would be substantial energy savings if the practice of recycling water were more prevalent.[52]

A third approach to ensuring there is enough water for energy is that of enacting more agricultural-to-urban water leases. This tactic has become increasingly prevalent by cities in the basin and in the adjacent areas. Dry-year leases and rotational fallowing agreements have benefits for both farmers and municipalities.[53] These leasing programs may have a positive effect in the energy sector as well. A rotational-fallowing program located in the Arkansas River Valley, which is in southeastern Colorado, would provide water to Colorado Springs, among other cities in the Front Range. Colorado Springs could use the Southern Delivery System to pump the leased water to the city, which would be an extremely energy-intensive process, or, in some places, the leased water could be transferred to cities by means of exchanges utilizing the river system. The latter scenario would have no extra energy demands.[54]

Boulder-based Western Resource Advocates cites natural gas as a good transition fuel from coal into renewables.[55] Natural gas generation emits half the amount of carbon dioxide that coal emits. As policy issues are worked out and the capital is raised to implement renewables in the basin, natural gas would partially relieve the water requirements for generation currently utilized by coal, as coal generation emits approximately 2,000 g of CO2 per MWh, while natural gas emits about 1,000 g of CO2 per MWh.[56]

According to Western Resource Advocates, there has recently been a decline in carbon emissions from power plants in the West. This decrease is due to several factors. A major coal-fired power plant was recently closed. The recession has also caused many electricity consumers to reduce their electricity use. State regulatory policies have led to an increase in renewables and energy efficiency, which have also helped reduce carbon emissions. The problem of carbon dioxide emissions, however, is not just an issue for the Colorado River Basin. While decreasing carbon emissions in the Colorado River Basin helps dissipate climate change, carbon emissions reduction needs to be enacted on a larger scale than that of the Colorado River Basin.

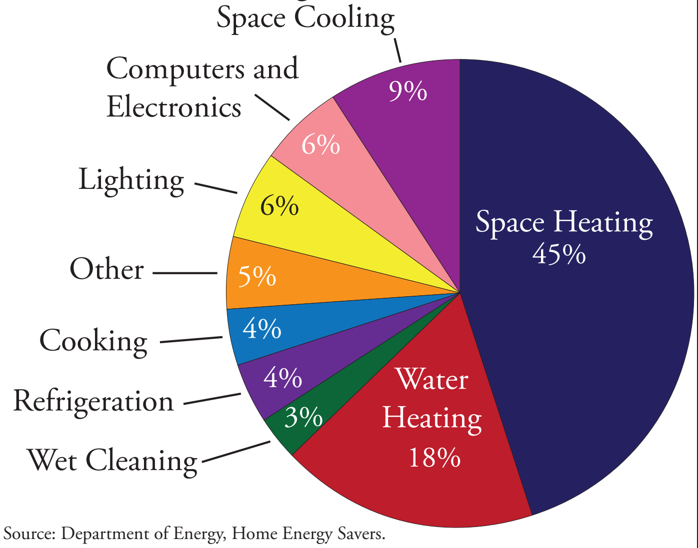
Is there, then, a role for water efficiency in the future? Renewables may not be the most accessible method of decreasing water use in the energy sector in the Colorado River Basin. While the Colorado River Basin still has a long way to go with respect to implementing renewables, most of the states in the basin have renewable portfolio standard (RPS). State-by-state renewable portfolio standards may also serve as a means by which to reduce water for energy consumption in the Colorado River Basin. A state's RPS requires the utilities companies within a state to supply a certain percentage of its electricity with renewable resources by a certain year. **Figure 14** displays the renewable energy standards by state in the Colorado River Basin. California has the highest renewable energy standard in the Colorado River Basin, with Colorado not far behind at a renewable energy standard of 30% by 2020. Utah has a renewable energy standard goal, while Wyoming does not have any renewable energy standard in the works. Renewable energy standards are a push in the right direction for getting a greater prevalence of renewable energy in the Colorado River Basin. According to the Western Governors' Association, state laws and policies put in place in the last decade are expected to "more than double the amount of renewable resources in the Western U.S." by 2022, compared to 2010.[57]

How can renewable energy become more of a staple in the Colorado River Basin? While many argue that renewable energy will just not have as big a presence as either natural gas or coal in the Colorado River Basin for many years, others contend there are steps legislators in the basin can take to make an equivalent renewable energy presence realized sooner. While having a renewable portfolio standard in almost every state in the Colorado River Basin is a positive step, the basin would benefit from having more stringent renewable portfolio standards.[58]

Figure 14: Renewable Portfolio Standards in the Colorado River Basin

	2015	2020	2025
Arizona		15%	
California		33%	
Colorado		30%	
Nevada			25%
New Mexico	15%	20%	
Utah	Renewable Energy Standard Goal		
Wyoming	X	X	X

Figure 15: Energy Consumption Distribution in the Average American Home



Source: Department of Energy, Home Energy Savers.

Energy Saving on a Day-to-Day Basis

As mentioned earlier in this section, the average home in the United States uses 31.5 kilowatt hours of energy per day. For the state of Colorado, this amount of energy use translates to water consumption of 14.5 gallons of water per diem. How can homes cut down on their energy use, and by extension, water consumption? **Figure 15** displays the average distribution of energy consumption in the American home.

Home energy audits, which homeowners can either do themselves or have their utility company do, are excellent means of determining a home's energy efficiency and where homeowners can make improvements in energy efficiency. There are five main components of the do-it-yourself home energy audit. See **Figure 16** for the steps involved in conducting the audit.

Once these areas have been examined, homeowners can make the appropriate changes in insulation, air leaks, lighting, and heating and cooling equipment.

The Ideal Situation in the Face of Increasing Demand for Energy and Water

Of the scenarios delineated in the Bureau of Reclamation's Demand Study, the Enhanced Environment and Healthy Economy scenario (EEHE) is the most ideal scenario from the energy-water nexus perspective. Where the Expansive Growth scenario (EG) anticipates increased fossil fuel development and increased oil shale development, the EEHE predicts the adoption of water-saving techniques, such as smarter fuel choices and cooling systems. This scenario is also the most positive for the energy sector because there is an increase in social and legal considerations for carbon emissions. The future economic conditions, enforced by emission mitigation legislation, would not favor fossil fuel development in the southwest.

The EEHE predicts enhanced governmental actions prioritizing the environment, including climate change and greenhouse gas mitigation measures. Greenhouse gas controls would dictate the substitution of polluting fossil fuels with renewables, and a focus on climate change would dictate the installation of only water friendly renewables. The best case scenario for the energy-water nexus would be to have a large reduction in the amount of water used for energy and the amount of energy produced; this scenario is effective in reducing water consumed for energy while reducing demands for energy with social values.

The predicted change in social values for this scenario is positive overall for the demand side of the water-energy nexus, and legislative changes would allow for "increased flexibility

Figure 16: Energy-Efficiency Changes Around the Home

Where to Make Energy-Efficiency Changes Around the Home	Fix
Check insulation in the attic, exterior and basement walls, ceilings, floors, and crawl spaces.	Seal any gaps with expanding foam caulk or other permanent sealant.
Check for air leaks around walls, ceilings, doors, light and plumbing fixtures, switches, and electrical outlets.	Plug and caulk holes and cracks that are discovered. Beware of indoor air pollution and combustion indoor "backdrafts."
Check for open fireplace dampers.	Close the open fireplace dampers.
Look into the status of home appliances and heating and cooling systems.	A professional should check and clean the equipment once a year. If the equipment is more than 15 years old, consider replacing it.
Examine the status of lighting in the home. Sensors, dimmers, and timers are available to reduce lighting use.	Consider replacing incandescent light bulbs with compact florescent (CFL) bulbs. They are more efficient and do not give off greenhouse gas emissions when in use.

Source: Department of Energy, *Energy Savers: Do-it-Yourself Home Energy Assessments.*

of water uses." While water for energy and recreation are inherently included under that category, changing values and legislation will improve the in-stream flows and health of the Colorado River. Thus, society will grasp the importance of water to ecosystems while legislation simultaneously pushes them to succumb to the betterment of water use practices, which is the ultimate goal of improving the status of the energy-water nexus in the Colorado River Basin.

Conclusion

Under current conditions it is difficult to initiate enough large-scale renewable energy projects going in the Colorado River Basin to power the entire basin in the near future. Solar energy is becoming increasingly cost-competitive, and wind energy is similarly becoming more popular. While renewable energy may initially sound like the ideal future for the basin, it is not representative of the most feasible one. There are promising policies helping to gradually increase the renewable energy generation in the Colorado River Basin. However, the rate at which renewable energy is being implemented cannot alone free up water use in energy production sufficient to solve the basin's projected supply shortages. Therefore, natural gas can act as a useful bridge fuel as we slowly transition away from coal and into a cleaner, less water-consumptive future. Water demand will soon surpass its supply, so we must start saving water immediately, through renewable energy options discussed here and through other tactics.

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David Spiegel

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Steve Weaver for his annual contribution of the cover photo.

Brendan Boepple is the Program Coordinator for Colorado College's State of the Rockies Project. Originally from Wilton, Connecticut, Brendan graduated from Colorado College in May of 2011 with a Political Science major and an Environmental Issues minor. While growing up Brendan developed a love for the outdoors and the environment, and he later worked with environmental organizations like Trout Unlimited and his local conservation land trust. He was a student researcher for the 2010-2011 State of the Rockies Project and researched the Eastern Plains region of the Rocky Mountain states. In the future, Brendan hopes to further his education in natural resource policy and management, and later pursue a career in that field. His interests include skiing and fly-fishing, two activities that drew him to the Rocky Mountain region.

Audrey Burns is a 2012-2013 student researcher from Bel Air, MD. She will graduate in the spring of 2013 with a degree in Environmental Science, along with a double minor in English and Philosophy. She co-chairs EnAct, interns for CC's Sustainability Office, leads service trips with BreakOut, and tutors peers at the Writing Center. In her free time, she enjoys running, baking bread, playing guitar, studying fungi, and identifying Rocky Mountain flora.

Matthew C. Gottfried is the GIS Technical Director at Colorado College and the 2012-13 technical liaison for the State of the Rockies Project, overseeing tasks including data assimilation, GIS analysis, and logistics management. He received his B.S. (1999) in Field Biology and Environmental Studies from Ohio Northern University and his M.A. (2005) in Geography and Planning from the University of Toledo where his focus was on land use planning and GIS. Matt's regional research focus includes studying the biogeography of critical species, land use planning, and conservation management practices of local natural resources.

Walter E. Hecox is professor of economics and environmental science, and project director for the State of the Rockies Project at Colorado College, Colorado Springs, Colorado. Walt received his B.A. degree from Colorado College (1964) and an M.A. (1967) and Ph.D. (1970) from Syracuse University, Syracuse, New York. He teaches courses in ecological economics and sustainable development. He has conducted research and taken leave to work for the World Bank, U.S. Agency for International Development, U.S. Department of Energy, and Colorado Department of Natural Resources. He is author of *Charting the Colorado Plateau: an Economic and Demographic Exploration* (The Grand Canyon Trust, 1996), co-author of *Beyond the Boundaries: the Human and Natural Communities of the Greater Grand Canyon* (Grand Canyon Trust, 1997), and co-editor of the Colorado College *State of the Rockies Report Cards*.

Nathan Lee hails from Spring Lake, Michigan and is a student researcher for 2012-2013. At CC, he majors in Economics with a minor in Environmental Issues and has a passion for food, ethics, and the natural world. He has made his home in the foothills of the Rocky Mountains for the past three years and is thrilled to be able to contribute to the 2013 *Report Card*. He draws inspiration from author Aldo Leopold, social and economic critic Wendell Berry, and singer-songwriter/humanitarian Harry Chapin. He hopes to live out his days gardening, reading, and writing.

Henry Madsen is a student research assistant for the 2012-13 Rockies Project. Originally from Denver, Colorado, Henry will graduate in 2014 with a degree in Biology and a minor in Physics. He hopes to use these degrees, and further education, to pursue a career in the natural world. His interest in nature began on long hikes, ski trips, and fishing trips with his father. His involvement in conservation and sustainability began when he visited a State of the Rockies speakers series event and subsequently became involved in the 2011-12 Rockies Project. Through the State of the Rockies Program, Henry hopes to learn more about the ecology of the Rocky Mountains.

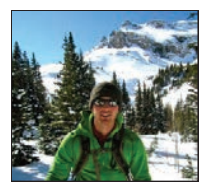
Carson McMurray is a 2012-2013 field researcher for the Rockies Project. Originally from Chapel Hill, North Carolina, Carson graduated in May 2012 with a degree in Environmental Science. His interests in environmental issues originate from his family's obsession with fishing and have grown during his time at Colorado College. Carson specializes in work with GIS mapping and has combined this specialization with his environmental studies to help people see environmental issues through a new perspective. In his spare time, he enjoys playing sports, mountain biking and of course fishing.

Matt McNerney is a student researcher for the 2012-2013 State of the Rockies project. Originally from Oakton, Virginia he will graduate this coming spring with a major in Economics and minor in English. His interest in environmental issues, especially rivers, developed at an early age as he spent most of his childhood summers on the Rappahannock River. He spent his previous summer as a conservation intern for the organization American Rivers where he received a topographical look at many of the issues surrounding the preservation and restoration of river systems. Matt's interests including rock climbing, snowboarding, and playing guitar and in the future he hopes to blend his love of the environment with his background in economics.

Alice Plant is a student researcher for the 2012-2013 State of the Rockies Project. Alice will graduate from Colorado College in May of 2013 with a degree in Environmental Policy. Originally from the Northern California, Alice spent much of her childhood exploring the Sierra Nevada Mountains and developing a love for the outdoors and an interest in environmental issues. In her spare time, Alice enjoys rugby, backpacking, snowboarding and horseback riding. It was these activities that drew her to the region and developed her love for the Rocky Mountains.

Zak Podmore is an expedition manager for the 2012-2013 State of the Rockies project. He grew up in Glenwood Springs, Colorado where he came to appreciate the waters of the Rocky Mountains over the course of a childhood shaped by winters skiing on mountain slopes and summers floating through the arid sandstone canyons of the San Juan, Dolores, Green, and Colorado Rivers. A long-time kayaker and rafter, Zak's love of wilderness rivers has taken him to Mexico, Canada, Ecuador, and throughout the American West. This winter he hopes to gain a deeper understanding of the Colorado River basin by researching the water issues currently facing Southwestern communities and by exploring the rivers that fuel them. He graduated from CC in May of 2011 with a degree in Philosophy and a minor in Psychoanalysis.

David Spiegel is a field researcher for the 2012-2013 State of the Rockies Project. He grew up in Woodinville, Washington and graduated from CC in 2012 with a degree in International Political Economy. David grew up in a family of river runners and experienced the rivers of the west coast from a young age. He first discovered his love for the Colorado River during a Grand Canyon expedition in 2007 and has since paddled many of the river's wilderness sections. David joined the 2012 expedition hoping to utilize his passion for photography and social media to share water related issues with the communities that depend on the river.



Will Stauffer-Norris is an expedition manager for the 2012-2013 State of the Rockies Project. He was born in Moscow, Idaho, grew up in Blacksburg, Virginia, and graduated from Colorado College in May 2011 with an Environmental Science degree. Starting from early childhood float trips in Idaho, Will has paddled rivers in the U.S., Canada, Chile, and Argentina. He intends to combine his passions for wild rivers, visual art, and adventure to document environmental issues surrounding the Colorado River for the 2012-13 Rockies Project.

Alex Suber is the State of the Rockies videographer and a member of the Colorado College class of 2015. He was born and raised in the hills of Northern California and later moved to Highland Park, Illinois. This past summer Alex interned for Bitter Jester Creative, a documentary film company, while also working on his own documentary. Alex has no idea what he will major in, but has a strong passion for environmentalism and cinematography. These two interests have led him to become involved with State of the Rockies. When he's not making a movie, Alex enjoys playing the banjo, hiking, and working at the farm.

Shannon Thomas is a student researcher for the 2012-2013 State of the Rockies Project. A native to Colorado Springs, she will graduate from Colorado College in May 2013 with a major in Integrated Environmental Science. She also participated in the Washington Semester Program where she traveled to Ghana for a three-week service learning program and interned for the Office of the Secretary at the Department of the Interior. After graduating, she hopes to pursue a career where she can combine her interests in development and the environment. In her spare time, she enjoys hiking, snowboarding, rock climbing, and playing the piano.

The Colorado College State of the Rockies Project

Students Researching, Reporting, and Engaging:

The Colorado College *State of the Rockies Report Card*, published annually since 2004, is the culmination of research and writing by a team of Colorado College student researchers. Each year a new team of students studies critical issues affecting the Rockies region of Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, and Wyoming.

Colorado College, a liberal arts college of national distinction, is indelibly linked to the Rockies. Through its Block Plan, students take one course at a time, and explore the Rockies and Southwest as classes embark in extended field study. Their sense of "place" runs deep, as they ford streams and explore acequias to study the cultural, environmental, and economic issues of water; as they camp in the Rocky Mountains to understand its geology; as they visit the West's oil fields to learn about energy concerns and hike through forests to experience the biology of pest-ridden trees and changing owl populations. CC encourages a spirit of intellectual adventure, critical thinking, and hands-on learning, where education and life intertwine.

The Colorado College State of the Rockies Project dovetails perfectly with that philosophy, providing research opportunities for CC students and a means for the college to "give back" to the region in a meaningful way. The *Report Card* fosters a sense of citizenship for Colorado College graduates and the broader regional community.

Research

During summer field work, the student researchers pack into a van and cover thousands of miles of the Rocky Mountain West as they study the landscape, interview stakeholders, and challenge assumptions. Back on campus, they mine data, crunch numbers, and analyze information.

Report

Working collaboratively with faculty, the student researchers write their reports, create charts and graphics, and work with editors to fine-tune each *Report Card* section. Their reports are subjected to external review before final publication.

Engage

Through a companion lecture series on campus, the naming of a Champion of the Rockies, and the annual State of the Rockies Conference, citizens and experts meet to discuss the future of our region.

Each *Report Card* has great impact: Media coverage of *Report Cards* has reached millions of readers, and the 2006 report section on climate change was included in a brief presented to the U.S. Supreme Court. Government leaders, scientists, ranchers, environmentalists, sociologists, journalists, and concerned citizens refer to the Colorado College *State of the Rockies Report Card* to understand the most pressing issues affecting the growing Rockies region.



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