RECLAMATION

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Request for Ideas

Colorado River Basin Water Supply and Demand Study

Phase 4: Development and Evaluation of Opportunities for Balancing Water Supply and Demand

U.S. Department of the Interior
Bureau of Reclamation

November 2011

Mission Statements

Protecting America's Great Outdoors and Powering Our Future
The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Request for Ideas

Colorado River Basin Water Supply and Demand Study

Phase 4: Development and Evaluation of Opportunities for Balancing Water Supply and Demand

Prepared by:

Colorado River Basin Water Supply and Demand Study Study Team

U. S. Department of the Interior
Bureau of Reclamation

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1.0 Introduction

The Colorado River Basin Water Supply and Demand Study (Study), initiated in January 2010, is being conducted by the Bureau of Reclamation's (Reclamation) Upper Colorado (UC) and Lower Colorado (LC) regions, and agencies representing the seven Colorado River Basin States[1] (Basin States). The purpose of the Study is to define current and future imbalances in water supply and demand in the Colorado River Basin (Basin) and the adjacent areas of the Basin States that receive Colorado River water over the next 50 years (through 2060), and to develop and analyze options and strategies to resolve those imbalances. The Study is being conducted in collaboration with stakeholders throughout the Basin, and broad stakeholder input is paramount to the success of the Study.

The Study contains four major phases: 1) Water Supply Assessment, 2) Water Demand Assessment, 3) System Reliability Analysis, and 4) Development and Evaluation of Opportunities for Balancing Supply and Demand. Interim Report No. 1 was published in June 2011 and provided a snapshot of the work completed in the Study as of January 31, 2011. Since the publication of Interim Report No. 1, work has focused on 1) completing the Water Demand Assessment by quantifying the demand scenarios, 2) completing the Water Supply Assessment through further investigation into the supply scenario that considers a changing climate, and 3) identifying additional system reliability metrics to be used in the System Reliability Analysis. It is anticipated that important findings from this work on Phases 1, 2, and 3 will be published in January 2012.

As the other Study phases near completion, the last phase (Phase 4), Development and Evaluation of Opportunities for Balancing Supply and Demand, is being initiated. This phase consists of the identification, definition, and evaluation of options and strategies that can be implemented to address the imbalances between supplies and demands characterized in the Study. The Study will not result in the selection or funding of a particular proposed option or set of options. Rather, the Study is intended to explore a broad range of options to help address future imbalances and the performance of those options across a range of future conditions. The Study will also lay the foundation for future development and implementation of the options identified.

The purpose of this report is to provide relevant information to those interested in submitting input. This report provides a background of the past studies that have assessed future imbalances and explored options and strategies, and describes ongoing efforts for balancing supply and demand. Using preliminary information related to projections of future supply and demand, the projected range of future imbalances is presented. The Study approach for organizing the input received and the evaluation of options and strategies also is presented, followed by identification of the next steps in the Study.

Project participants and stakeholders are encouraged to submit ideas related to options and strategies that will help to resolve future supply and demand imbalances in the Basin. Options may be submitted by completing a submission form, which is attached to this report as Appendix 1 and is also available on the Study website. It is requested that input be

[1] Arizona, California, Colorado, New Mexico, Nevada, Utah, and Wyoming

provided by February 1, 2012, to allow sufficient time for its consideration. For additional information on submitting input, please contact the Study Team via:

1. The Study website at: http://www.usbr.gov/lc/region/programs/crbstudy.html
2. E-mail to: ColoradoRiverBasinStudy@usbr.gov
3. U.S. mail to: Bureau of Reclamation, Attention: Ms. Pam Adams, LC-2721, P.O. Box 61470, Boulder City, NV 89006-1470
4. Facsimile transmission to: 702-293-8418

2.0 Background

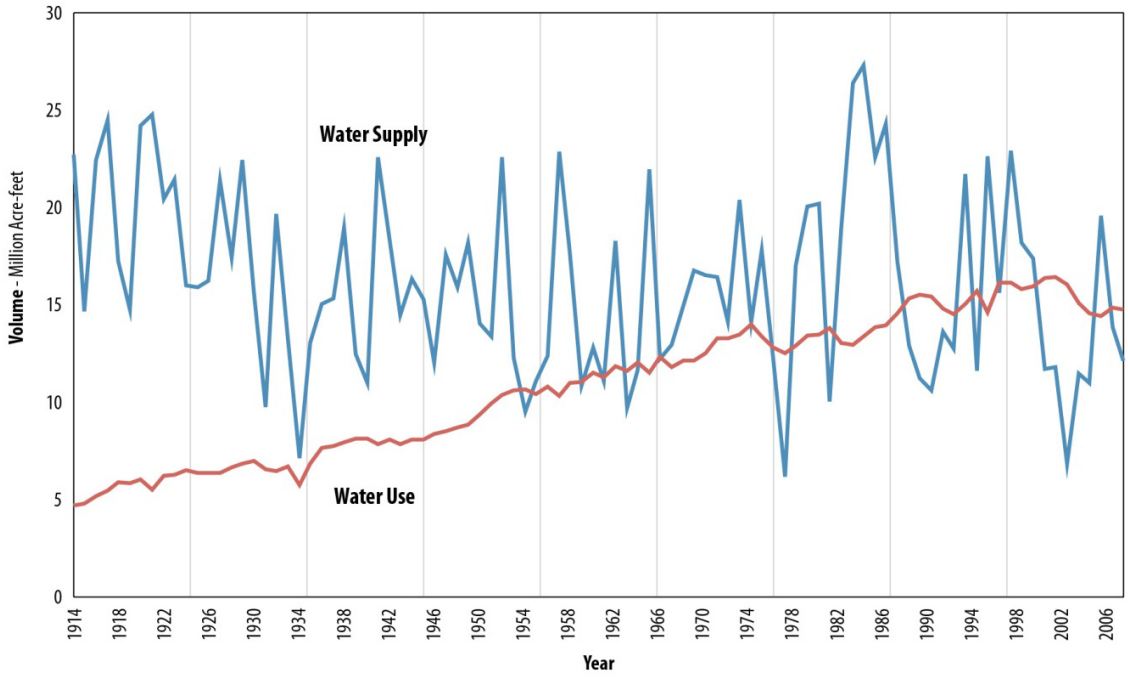
Spanning parts of the seven states of Arizona, California, Colorado, New Mexico, Nevada, Utah, and Wyoming, the Basin is one the most critical sources of water in the western United States. The Colorado River is also a vital resource to Mexico. It is widely known that the Colorado River, based on the inflows observed over the last century, is over-allocated and supply and demand imbalances are likely to be exacerbated in the future.

Imbalances that have occurred in the past are illustrated in figure 1, which shows the historical annual Basin water supply (estimated using natural flow[2]) and water use[3]. Historically, this imbalance has been managed, and demands have largely been met as a result of: 1) the considerable amount of reservoir storage capacity in the system (approximately 60 million acre-feet [MAF] of storage, or roughly four times the average annual natural inflow); 2) the fact that the Upper Basin States have not fully developed into their apportionments; and, 3) efforts the Basin States have made to reduce their demand for Colorado River water.

[2] Natural flow represents the flow that would have occurred at the location had depletions and reservoir regulation not been present upstream of that location.

[3] Historical use (as shown in Figure 1) does not necessarily reflect historical water demand, particularly for periods of drought. A decrease in reported use during a drought period may reflect the lack of available supply at the point of use rather than a decrease in the demand for water.

FIGURE 1
Historical Annual Colorado River Basin Water Supply and Use



NOTE:
Historical water use is the total use of water throughout the Basin for agricultural, municipal, and industrial, and other consumptive uses including Mexico, plus losses due to evaporation at mainstream reservoirs and use by native and non-native vegetation. In the current natural flow record, historical inflows based on USGS gaged records are used as estimates of natural flow for the Paria River, Little Colorado River, Virgin River, and Bill Williams River. Additionally, the Gila River is not included in the natural flow record. As such, the use reported here excludes consumptive uses on these tributaries. See *Interim Report No. 1 Technical Report C – Water Demand Assessment, Appendix C5 at* http://www.usbr.gov/lc/region/programs/crbstudy/Report1/TechRptC.pdf for additional detail regarding the treatment of these tributaries in the Study.

Throughout the 20th Century, the challenges and complexities of ensuring a sustainable water supply and meeting future demand have been recognized. These challenges have been documented in several studies conducted by Reclamation and the Basin States over the past 60 years. In particular, these studies discussed future water supply and demand imbalances and in some cases proposed solutions to dealing with these imbalances. The most recent of these studies was *The Westwide Study Report on Critical Water Problems Facing the Eleven Western United States* (Reclamation, 1975), a federal-state study conducted in 1975 which concluded that even with aggressive conservation efforts, the Basin faces future water shortages unless its natural flows are augmented or water-dependent Basin development is curtailed. Other relevant studies were referenced in Interim Report No. 1 and are listed in Appendix 2 to this report. Efforts by Reclamation to assess the potential impacts to Basin resources (e.g., hydropower generation, fish, and wildlife habitat)[4] from projected future

[4] Resources considered in the Study include water allocations and deliveries for municipal, industrial, and agricultural use; hydroelectric power generation; recreation; fish and wildlife, and their habitats (including candidate, threatened, and endangered species); water quality, including salinity; flow- and water-dependent ecological systems; and flood control.

supply and demand imbalances have largely been conducted through the National Environmental Policy Act process and have resulted in the issuance of several Environmental Impact Statements. These assessments primarily addressed impacts at specific geographical regions in the Basin.

Although many of the studies of Colorado River management have been led by federal agencies, agencies representing each of the Basin States have also conducted assessments of current and future Colorado River water needs. State-led efforts such as the Colorado Water Conservation Board's (CWCB) *Statewide Water Supply Initiative* (CWCB, 2010) and Arizona's *Water Atlas and Statewide Water Plan* (Arizona DWR, 2009) have documented water availability and use with a regional focus. These and other major state-led efforts are listed in Appendix 3 to this report. In a recent collaborative effort, the Basin States worked together to sponsor the *Study of Long-term Augmentation Options for the Water Supply of the Colorado River System* (Colorado River Water Consultants, 2008). That study examined water resource augmentation options and evaluated engineering feasibility, environmental viability, and potential for water resource yield.

2.1 Ongoing Efforts to Resolve Supply and Demand Imbalances

Water managers and water users in the Basin have long recognized the need to adapt to and mitigate the impacts of current and future shortfalls between water supply and demands. Historically, water planning efforts resulted in construction of significant infrastructure. Notable examples include the Hoover and Glen Canyon dams, the Central Arizona and Central Utah projects, Colorado's many headwaters transbasin diversions, California's Colorado River Aqueduct, the All-American Canal, and a wide range of other local and regional water infrastructure projects. In addition to these projects, Colorado River stakeholders have made significant investments in developing other water resources and implementing programs and policies to balance current and future supplies with existing and future demands. Many of these efforts have resulted in solutions to past water management challenges and will continue to provide benefit to the system in meeting the challenges that lie ahead. Examples of recent efforts include the following:

- ***Improving efficiency of operations***. Implementation of the Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations of Lakes Powell and Mead (2007 Interim Guidelines) is providing a more coordinated operation of Lake Powell and Lake Mead to minimize the risk of water supply shortages in the Lower Basin and reduce the risk of curtailment in the Upper Basin.

- ***Improving system water conservation and storage***. The 2007 Interim Guidelines also allow agencies in the Lower Basin to develop and store Colorado River system and non-system water in Lake Mead for future use. For example, Central Arizona Project (CAP), Metropolitan Water District of Southern California (MWD), and Southern Nevada Water Authority (SNWA) cooperatively funded the construction and operation through 2026 of Brock Reservoir near the All-American Canal to capture non-storable Colorado River water in excess of requirements to meet treaty obligations with Mexico. The project will provide long-term benefits to the system, with the funding partners receiving a portion of the water conserved as an interim water supply. In November 2011, the reservoir had conserved more than 110,000 acre-ft in 2011.

- ***Improving municipal water use efficiency***. A recent report by the Pacific Institute (Cohen, 2011) highlights the efforts of many Colorado River municipal and industrial water providers, including the cities of Phoenix, Las Vegas, and Denver, and cities in Southern California, to reduce per-capita water usage through education and water conservation programs. The data provided in the Pacific Institute report show reductions in per-capita water demands ranging from 24 percent to 31 percent for the period 1990 through 2008.

- ***Augmenting the Basin supply***. Since 2007, the Basin States have been working under cooperative agreements to extend, expand, and develop new projects to seed clouds to augment the supply of water available for use in the Colorado River Basin. In 2009, the Basin States completed the Colorado River Basin Tamarisk and Russian Olive Assessment (Tamarisk Coalition, 2009) which provides a comprehensive review of the state-of-the-science of tamarisk management and the potential for saving water to augment the flow of the Colorado River system.

- ***Voluntary water transfers***. Water transfer mechanisms have been used throughout the Basin on a voluntary basis to compensate water users to reduce water use and make the water available to another entity in the same state. In California, for example, up to 120,000 acre-feet of water per year is conserved and transferred from the Palo Verde Irrigation District (PVID) to MWD. In Colorado, more than 2,000 voluntary water transfers per year occurred on average between 1998 and 2008.

- ***Conjunctive use projects***. Storing Colorado River water supplies underground as an interim source and a means to reduce the impact of future water supply shortages or long-term droughts is being practiced by water agencies in Arizona, Nevada, and California, including the Arizona Water Banking Authority, CAP, SNWA, and MWD.

- ***Extending supplies through greater reuse of water***. Many municipal and industrial water users, in areas where Colorado River water does not return to the river, have developed water reuse projects to increase reliability or decrease water demands from the Colorado River. Examples include the Orange County Water District's Groundwater Replenishment Project, which uses highly treated effluent to replenish groundwater aquifers in coastal California, and Arizona Public Service's use of treated wastewater as cooling water for electrical generating plants.

The Study is another important chapter in this long history of water planning in the Basin. The Study is taking a comprehensive, Basin-wide view of supply and demand and assessing the reliability of the system in meeting the needs of Basin resources. Given the historical variability of Colorado River inflows and the potential for increased variability in the future, there is great uncertainty associated with future water supply throughout the Basin over the next 50 years. That uncertainty, coupled with the uncertainty in future demand for water Basin-wide, is being addressed using a scenario planning approach. Such an approach will lead to consideration of "robust" options and strategies that will perform well under a wide range of future conditions. Interest in the Study is broad, and interested parties include Native American tribes and communities, agricultural users, purveyors of municipal and industrial water, power users and providers, recreation groups, conservation groups, and the general

public. This continued broad stakeholder participation and input is critical as the Study enters the fourth and final phase.

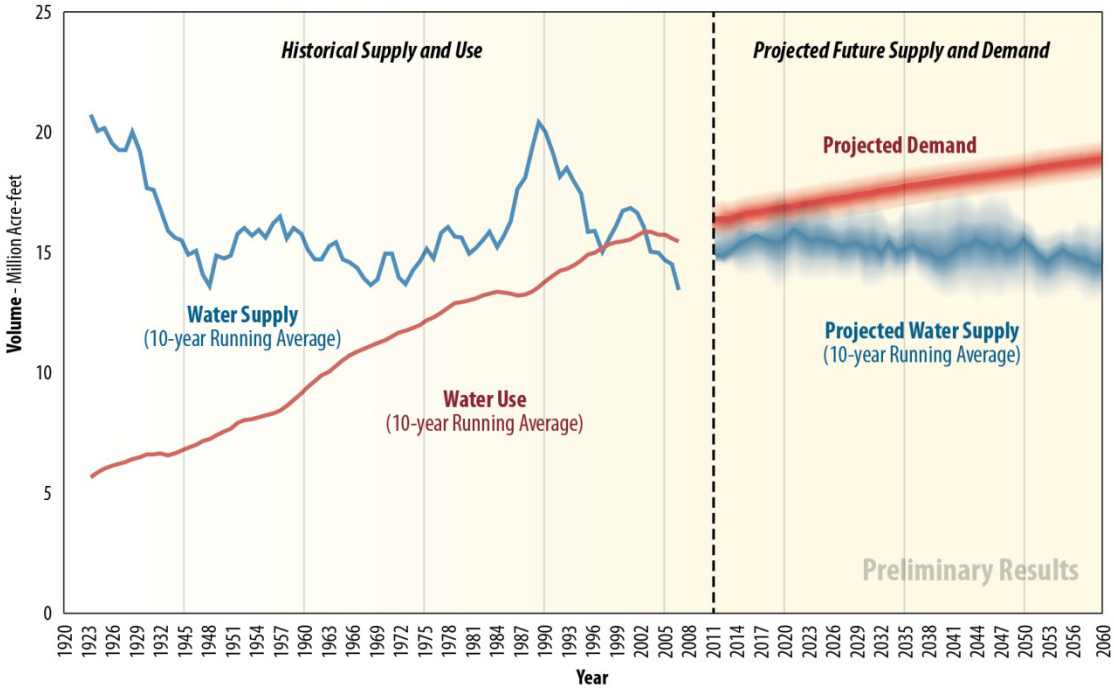
3.0 Projected Future Supply and Demand Imbalances

Options and strategies developed and evaluated in the Study will be shaped by the magnitude, timing, and location of future supply and demand imbalances in the Basin and the impacts to the Basin resources from those imbalances. The Study has taken a scenario planning approach to develop projections that are sufficiently broad to capture the plausible range of uncertainty in future water supply and demand. This approach has resulted in four water supply scenarios and six water demand scenarios that provide a broad range of future supply and demand. Work to finalize the supply scenarios and quantify all demand scenarios is ongoing; however, to date the quantification of one demand scenario is almost complete and can be used to provide a preliminary assessment of potential future imbalances.

Using the projections developed to date, the range of the projected total future supply and demand in the Basin is shown conceptually in figure 2. The historical data in figure 2 is the same data from figure 1 presented as 10-year running average to smooth out the annual variability so that trends are more visible. The lines in figure 2 over the Study period (2011 through 2060) have been shaded to indicate that there is a range associated with both the future supply and demand projections, but that range has either not been finalized (future supply) or has not been determined (future demand).

The water supply projections largely encompass the range of the four water supply scenarios that include historical observed, paleoclimate, and climate change approaches. The future demand is represented by one of six demand scenarios that contain specific assumptions related to factors such as changes in demographics and land use, changes in technology and economics, and changes in social and governance structures. The demand in figure 2 represents total Basin demand and includes water needs in the Basin States, the 1944 Treaty delivery to Mexico, reservoir evaporation, and other losses (phreatophyte and operational efficiency losses). Although not shown in figure 2, the Study is also considering non-consumptive demands (demand for water that will be used without diminishing the available supply) for resources such as fish and wildlife, recreation, water quality, and hydropower generation.

FIGURE 2
Historical Supply and Use and Projected Future Colorado River Basin Water Supply and Demand



NOTE:
Projected water supply delineated as the range of the 10th and 90th percentile (computed across all 112 projections for each year) from the water supply scenario titled Downscaled Global Climate Model (GCM) Projected. This scenario is based on climate projections from 112 unique GCM projections. An adjustment was applied for the purpose of this figure to bring the GCM projections over the historical period more closely in line with the observed historical long-term average. See *Interim Report No. 1 Technical Report B – Water Supply Assessment* at http://www.usbr.gov/lc/region/programs/crbstudy/Report1/TechRptB.pdf for more information. Projected demand is based on the information collected to date for one of the six scenarios and should be considered preliminary. A range of 10 percent was used to construct a range for illustration purposes only until the technical analysis is completed.

Under the demand scenario depicted in figure 2, consumptive use demand is projected to exceed 17 MAF by 2035 and 18 MAF in 50 years, or by 2060. Other demand scenarios will result in demands higher and lower than the line depicted here. The 10-year running average in supply is projected to range between 13.9 MAF and 16.8 MAF in 2035, with a median projection of 15.0 MAF in 2035. By 2060, these projections all demonstrate a reduction, with a median of 14.4 MAF. Comparing the median water supply projections to the water demand projection, the long-term imbalance in future supply and demand is preliminarily projected to be about 2.0 MAF in 2035 and greater than 3.5 MAF in 2060.[5]

Although the quantification of all future supply and demand scenarios is incomplete at this time, the preliminary information presented here can help frame the potential magnitude of the challenges that lie ahead and inform the shaping of various options and strategies. Ongoing work that will provide a broader view of the Basin-wide potential imbalances, detailed information regarding the specific timing and magnitude of potential imbalances,

[5] The supply projections reported here were computed by calculating the 10th, 50th (median), or 90th percentiles across the 112 values for each year. The imbalances reported here are based on the median imbalance for a particular year and can either be more or less year-to-year under any one of the 112 projections.

and the potential impacts to the Basin resources will be critical to the evaluation of options and strategies and can also effect the design of a particular option or strategy. The completion of this work is expected in early 2012.

4.0 Development and Evaluation of Opportunities for Balancing Supply and Demand

The *Plan of Study*[6] lays out specific objectives related to the development and evaluation of options and strategies that will be addressed through Phase 4 of the Study (Development and Evaluation of Opportunities for Balancing Supply and Demand), including:

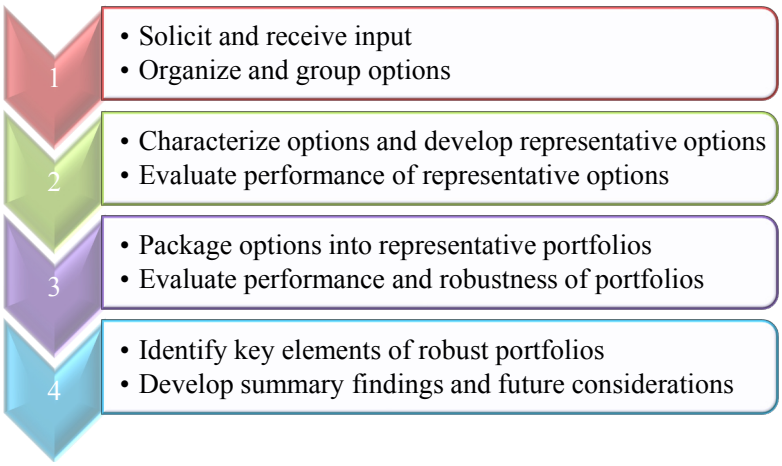
- Identification of potential strategies and options to resolve Basin-wide water supply and demand imbalances, including:
  - Modifications to the operating guidelines or procedures of water supply systems
  - Modifications to existing facilities and development of new facilities
  - Modifications to existing water conservation and management programs and development of new programs
  - Modifications to existing water supply enhancement programs and development of new programs
  - Other structural and non-structural solutions
- Identification of potential legal and regulatory constraints and analysis of potential impacts to water users and Basin resources for the strategies and options considered
- Prioritization (considering both the evaluation criteria described below and the level of increased reliability of the system to meet the needs of the Basin resources) of identified strategies and options and the recommendation for potential future actions, including feasibility studies, environmental compliance activities, demonstration programs, and/or implementation as appropriate

In initiating this phase, input is being sought across a broad range of stakeholders for ideas regarding potential options to resolve the projected supply and demand imbalances. The scale of the Basin, anticipated magnitude and timing of imbalances, regional differences, and the range of resources being considered require that a wide array of options be identified and evaluated. No single option, or type of project, will be adequate to meet all of the future demands of the Basin resources. Rather, a combination of options, including conservation and reuse, development of local supplies, augmentation, and new flexibilities in managing existing infrastructure will likely be needed. The Study will not result in the selection or funding of a particular proposed option or set of options. Rather, the Study is intended to explore a broad range of options to help address future imbalances and the performance of those options across a range of future conditions. The Study will also lay the foundation for future development and implementation of the options identified.

[6] The *Plan of Study* can be found in Appendix 1 of *Interim Report No. 1 – Summary and Status Report*, located at http://www.usbr.gov/lc/region/programs/crbstudy/Report1/StatusRpt.pdf

A process has been developed to help ensure that the objectives laid out in the *Plan of Study* are accomplished. This process consists of four key elements, depicted in figure 3: 1) solicit input and organize options, 2) characterize and evaluate representative options, 3) package options into representative portfolios and evaluate performance, and 4) identify key elements of robust portfolios and summarize findings.

FIGURE 3
Key Elements of the Development and Evaluation of Opportunities Process



Each option received will be characterized based on Study evaluation criteria, which may include, potential yield, timing of implementation, technical feasibility, cost, environmental effects, permitting requirements, legal and public policy considerations, and risk/uncertainty. The options will then be organized into categories based on similarities of option function (for example, desalination and reuse, banking and exchanges, importation, etc.).

To facilitate analysis, representative options will be developed that encompass the range of options within each category. The representative options will be analyzed to assess their performance in terms of improving the reliability of the system to meet the needs of Basin resources across a wide range of future water supply and demand scenarios. Representative option performance will be summarized for both the evaluation criteria indicated above and the impacts to Basin resources using the system reliability metrics.

Based on the results of the characterization and evaluation of representative options analyzed, various representative options will be packaged into portfolios for additional analysis. The portfolios will represent different potential adaptation strategies, each representing a plausible response pathway to an unfolding water supply and

Options and Strategies to Resolve Imbalances

No single option or project will be adequate to meet the needs of all resources, for all regions, and under each of the future scenarios. A combination of options addressing supply augmentation, demand management, and system operational efficiencies will likely be needed.

An **option** represents a specific action that could partially address the future imbalances (such as a desalination project, expanded reuse program, or river import project, etc).

Portfolios are collections of options developed to implement a particular **strategy.**

Strategies represent a particular plan of action to achieve a goal (for example, improve system reliability at a low cost).

demand imbalance. For example, a portfolio may be developed to enhance system reliability with low cost and high certainty in the near future and with increasing costs and less certainty over time. Each portfolio will be analyzed to assess the effects on Basin resources for each scenario. Robust portfolios, or elements of portfolios, will be identified. Finally, the findings of the options and strategies evaluation process will be summarized and future considerations will be identified.

5.0 Next Steps

This report provides a preliminary view of the potential future Basin-wide imbalances. Ongoing work will provide both a broader view of the potential future Basin-wide imbalances, a more detailed view of the timing and magnitude of those imbalances, and the potential impacts to the Basin resources.

The important findings from the ongoing work will be made available as the work is completed. It is anticipated that results related to: 1) the quantification of the demand scenarios, 2) further investigation into the supply scenario that considers a changing climate, and 3) the identification of additional system reliability metrics to be used in the System Reliability Analysis will be available in January 2012. These results will be published through technical updates made available on the Study website.

6.0 References

Arizona Department of Water Resources. 2009. *Arizona's Water Atlas and Statewide Water.*

Bureau of Reclamation. 1975. *Westwide Study Report on Critical Water Problems Facing the Eleven Western United States*. April.

Bureau of Reclamation. 2007. *Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead Final Environmental Impact Statement.*

Cohen, Michael. 2011. *Municipal Deliveries of Colorado River Water.* Pacific Institute.

Colorado River Water Consultants. 2008. *Study of Long-term Augmentation Options for the Water Supply of the Colorado River System.*

Colorado Water Conservation Board. 2010. *Statewide Water Supply Initiative.*

Tamarisk Coalition. 2009. *Colorado River Basin Tamarisk and Russian Olive Assessment.*

Appendix 1
Form to Submit Options to Resolve Future Supply and Demand Imbalances

Form to Submit Options to Resolve Future Supply and Demand Imbalances

The Study is entering Phase 4 (Development and Evaluation of Opportunities to Balance Supply and Demand). A key task in this phase is to identify various options to help address the range of supply and demand imbalances projected to occur in the Basin over the next 50 years. The nature, magnitude, timing, and regional impacts of these imbalances mean that no one option will address all needs; rather, a combination of options will likely need to be considered. The Study will not result in the selection or funding of a particular proposed option or set of options. Rather, the Study is intended to explore a broad range of options to help address future imbalances and the performance of those options across a range of future conditions. The Study will also lay the foundation for future development and implementation of the options identified. The Study is seeking your input regarding ideas for potential options to address these projected imbalances. Please refer to the report titled *Development and Evaluation of Opportunities for Balancing Water Supply and Demand: Request for Ideas* for more information regarding this phase.

How to Submit an Option

Download or print the Option Submittal Form from the Study website. To allow sufficient time for its consideration, please complete and submit the form electronically (or in printed form) **by February 1, 2012** in one of the following ways:

1. Via the Study website at: http://www.usbr.gov/lc/region/programs/crbstudy.html
2. E-mail to: ColoradoRiverBasinStudy@usbr.gov
3. U.S. mail to: Bureau of Reclamation,
   Attention: Ms. Pam Adams, LC-2721, P.O. Box 61470, Boulder City, NV 89006-1470
4. Facsimile transmission to: 702-293-8418

How to Complete this Form

Complete this form to the best of your ability. Depending on the specific details of the option being submitted, some of the requested information may not be applicable or available. When this is the case, please enter "not applicable" or "not available" in the relevant data field. If the requested information is unknown, please enter "unknown." If there is additional information you would like to provide, please use the last field on the form titled "Other Information" to do so.

How Submitted Information Will be Used

The options received will be used to develop representative options to assess the impacts to Basin resources across a wide range of future water supply and demand scenarios. Representative options will be developed to encompass the full range of the options submitted, but in order to keep the analysis manageable not every submitted option will be analyzed. Representative options will then be used to develop portfolios to implement a particular management strategy to help resolve future supply and demand imbalances.

Providing Contact Information

Providing contact information is not required and options can be submitted anonymously. Anonymously submitted options will be treated in the same way as all other options. However, when attempting to properly characterize and evaluate the submitted options, it is possible that clarifying information may be needed. Therefore, although voluntary, you are encouraged to provide contact information. Before including your address, telephone number, electronic mail address, or other personal identifying information, you should be aware that while you can ask us to withhold your personal identifying information from public review by checking the box **"keep my contact information private,"** we cannot guarantee that we will be able to do so.

Option Submittal Form

To complete and submit electronically, click here

Contact Information (optional): ☐ **Keep my contact information private.**

Contact Name: _____ Title: _____

Affiliation: _____

Address: _____

Telephone: E-mail Address:

Date Option Submitted: _____

Option Name:

Description of Option:

Location: Describe location(s) where option could be implemented and other areas that the option would affect, if applicable. Attach a map, if applicable.

Quantity and Timing: Roughly quantify the range of the potential amount of water that the option could provide over the next 50 years and in what timeframe that amount could be available. If option could be implemented in phases, include quantity estimates associated with each phase. If known, specify any important seasonal (e.g., more water could be available in winter) and/or frequency (e.g., more water could likely be available during above-average hydrologic years) considerations. If known, describe any key assumptions made in order to quantify the potential amount.

Additional Information

Technical Feasibility: Describe the maturity and feasibility of the concept/technology being proposed, and what research and/or technological development might first be needed.

Costs: Provide cost and funding information, if available, including capital, operations, maintenance, repair, replacement, and any other costs and sources of funds (e.g., public, private, or both public and private). Identify what is and is not included in the provided cost numbers and provide references used for cost justification. Methodologies for calculating unit costs (e.g., $/acre-foot or $/million gallons) vary widely; therefore, do not provide unit costs without also providing the assumed capital and annual costs for the option, and the methodology used to calculate unit costs.

Permitting: List the permits and/or approvals required and status of any permits and/or approvals received.

Legal / Public Policy Considerations: Describe legal/public policy considerations associated with the option. Describe any agreements necessary for implementation and any potential water rights issues, if known.

Implementation Risk / Uncertainty: Describe any aspects of the option that involves risk or uncertainty related to implementing the option.

Reliability: Describe the anticipated reliability of the option and any known risks to supply or demand, such as: drought risk, water contamination risk, risk of infrastructure failure, etc.

Water Quality: Identify key water quality implications (salinity and other constituents) associated with the option in all of the locations the option may affect.

Energy Needs: Describe, and quantify if known, the energy needs associated with the option. Include any energy required to obtain, treat, and deliver the water to the defined location at the defined quality.

Energy Required	Source(s) of Energy

Hydroelectric Energy Generation: Describe, and quantify if known, any anticipated increases or decreases in hydroelectric energy generation as a result of the option.

Location of Generation	Impact to Generation

Recreation: Describe any anticipated positive or negative effects on recreation.

Location(s)	Anticipate Benefits or Impacts

Environment: Describe any anticipated positive or negative effects on ecosystems within or outside of the Colorado River Basin.

Location(s)	Anticipated Benefits or Impacts

Socioeconomics: Describe anticipated positive or negative socioeconomic (social and economic factors) effects.

Other Information: Provide other information as appropriate, including potential secondary benefits or considerations. Attach supporting documentation or references, if applicable.

Appendix 2
Examples of Past Studies Exploring Supply and Demand Imbalances

Appendix 2— Examples of Past Studies Exploring Supply and Demand Imbalances

1. **Colorado River Storage Project and Participating Projects; Upper Colorado River Basin (Reclamation, 1950).** This report combined various individual Upper Basin reservoir proposals into a comprehensive plan to increase long-term carryover water storage.
2. **Pacific Southwest Water Plan (Reclamation, 1964).** This report projected a Lower Basin water supply and demand imbalance and proposed a comprehensive plan to improve water supply and distribution, including the importation of water from the northern California coastal area.
3. **The Colorado River Basin Project Act of 1968,** which authorized the construction of the Central Arizona Project (CAP), the Southern Nevada Water Project, and other projects in the Lower Basin, further discussed the need for augmentation[7].
4. **Comprehensive Framework Study, Lower Colorado Region (Pacific Southwest Inter-agency Committee, 1971a).** This federal-state study projected a Lower Basin water supply and demand imbalance and concluded that a future water import program would be needed as part of a proposed framework program for the development and management of Lower Basin water resources to 2020.
5. **Comprehensive Framework Study, Upper Colorado Region (Pacific Southwest Inter-agency Committee, 1971b).** This federal-state study presented a framework program for the development and management of the water and related land resources of the Upper Basin to 2020, including alternative plans with emphases on differing water uses, some of which were dependent on water importation.
6. **Westwide Study Report on Critical Water Problems Facing the Eleven Western United States, (Reclamation, 1975).** This federal-state study described key factors affecting future water needs, formulated alternative future demand scenarios, and identified options for dealing with anticipated shortages. The study concluded that in spite of conservation, the Basin faces future water shortages unless its natural flows are augmented or water-dependent Basin development is curtailed.

In the latter part of the 20th Century, significant emphasis has been placed on improving the efficiency of the operation of Colorado River reservoirs and increasing the level of predictability needed by entities that receive Colorado River water, to better plan for and manage available water supplies. Two notable examples from this period are the *Operation of Glen Canyon Dam Final Environmental Impact Statement* (Reclamation, 1996) and the *Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations of Lake Powell and Lake Mead Final Environmental Impact Statement* (Reclamation, 2007). Both of these documents resulted in the adoption of new reservoir operating policies.

[7] Section 202 of the Colorado River Basin Project Act provides in part that "The satisfaction of the requirements of the Mexican Water Treaty, shall be from the waters of the Colorado River pursuant to the treaties, laws, and compacts presently relating thereto, until such time as a feasible plan showing the most economical means of augmenting the water supply available in the Colorado River below Lee Ferry by two and one-half million acre-feet shall be authorized by the Congress and is in operation as provided in this Act."

In addition to these studies, other Basin-wide assessments, such as the General Accounting Office report to Congress, *Colorado River Basin Water Problems: How to Reduce Their Impact* (GAO, 1979) and the more recent National Research Council report, *Colorado River Basin Management: How to Adjust to Hydroclimatic Variability* (NRC, 2007) have provided other independent perspectives on the Basin supply, demand, and opportunities to resolve imbalances.

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Appendix 3
Examples of State-Led Efforts Addressing Current and Future Supply and Demand Imbalances

Appendix 3— Examples of State-Led Efforts Addressing Current and Future Supply and Demand Imbalances

Arizona

Arizona has a long history of water resources planning and development of conservation and management programs and strategies within the State. In 1980, the Arizona Department of Water Resources (ADWR) was created to address surface water and groundwater issues. A major focus has been the development and implementation of management plans in critical groundwater basins (active management areas, or AMAs) to ensure the long-term viability of these supplies. These plans can be found at: http://www.azwater.gov/AzDWR/WaterManagement/AMAs/.

In 1996, the Arizona Water Banking Authority (AWBA) was created to ensure that Arizona fully uses its Colorado River apportionment of 2.8 million acre-feet by storing its unused apportionment in underground storage facilities. The AWBA provides municipal Colorado River water users a water supply to use during future shortages. Information about the AWBA can be found at: http://www.azwaterbank.gov/.

ADWR recently completed the Arizona Water Atlas, which compiles water resources related data throughout the State. The Atlas can assist local communities in their long-term water resources planning. Information about the Atlas can be found at: http://www.azwater.gov/AzDWR/StatewidePlanning/WaterAtlas/default.htm.

For areas outside the AMAs, ADWR actively participates in, or facilitates, 17 Rural Watershed Groups which address local water supply and demand issues. Additional information about these Rural Watershed Groups can be found at: http://www.azwater.gov/AzDWR/StatewidePlanning/RuralPrograms/default.htm.

Finally, the Arizona Legislature created the Water Resources Development Commission (WRDC). The WRDC identifies long-term water resources needs, identifies supply and demand imbalances, and recommends actions to mitigate these imbalances. The WRDC reports and information can found at: http://www.azwater.gov/AzDWR/WaterManagement/WRDC_HB2661/Meetings_Schedule.htm.

California

California agencies have implemented programs that address the water supply/demand imbalance within Southern California which have reduced the State's reliance on Colorado River supplies. These actions include development of California's Colorado River Water Use Plan prepared by the Colorado River Board of California. This Plan provides a framework by which programs, projects, and other activities are coordinated and cooperatively implemented to assist California in meeting its water supply needs from the Colorado River. California's Colorado River Water Use Plan is available at www.crb.ca.gov/reports.html. In addition, the California Water Plan Update 2009 prepared

by the California Department of Water Resources provides statewide and regional reports that contain a blueprint for sustainability and integrated water management in California. The California Water Plan Update 2009 is located at www.waterplan.water.ca.gov/cwpu2009/index.cfm.

Also, water agencies within Southern California have developed integrated water resource management plans. Two examples of such plans are discussed below and plans from other agencies can be found on their websites. The Metropolitan Water District of Southern California's (MWD) long-term Integrated Resources Plan offers an innovative strategy to protect the region from future supply shortages, with an emphasis on water-use efficiency through conservation and local supply development. The updated Integrated Resources Plan is MWD's strategic plan for water reliability through the year 2035, collaboratively developed with input from water districts, local governments, stakeholder groups, and the public. The Plan is available at http://www.mwdh2o.com/mwdh2o/pages/yourwater/irp/IRP2010Report.pdf.

The Coachella Valley Water District's (CVWD) Coachella Valley Water Management Plan, first adopted in 2002 and updated in 2010, is a 35-year plan with a long-term goal of eliminating basin overdraft through conservation, source substitution, recharge, and development of new imported and local water supplies. The Plan is available at www.cvwd.org. CVWD also formed the Coachella Valley Regional Water Management Group with other Coachella Valley water agencies to share information, develop a stakeholder group, and create the Coachella Valley Integrated Regional Water Management Plan, 2010, available at www.cvrwmg.org.

The San Diego County Water Authority adopted its 2010 Urban Water Management Plan in June 2011. This plan is prepared every 5 years to meet a California requirement for urban water suppliers to ensure there will be reliable water service during normal, dry, and multiple dry years. The 2010 Plan identifies a diverse mix of water resources projected to be developed over the next 25 years to ensure long-term water supply reliability for the region. It identifies measures to achieve per capita water use targets established by the state; analysis of potential climate change mitigation and adaptation strategies; and a scenario planning process to deal with future uncertainties in long-range water planning. The San Diego County Water Authority 2010 Urban Water Management Plan is available at: http://www.sdcwa.org/2010-urban-water-management-plan.

Colorado

The Colorado Water Conservation Board has led Colorado's water planning efforts for all of the water basins within the State of Colorado (including the Colorado River Basin) through the Statewide Water Supply Initiative (SWSI 1 and SWSI 2010) process. This process has provided a comprehensive examination of Colorado's projected water supplies and water demands for the year 2050, and is available at: http://cwcb.state.co.us/water-management/water-supply-planning/Pages/SWSI2010.aspx.

Nevada

The Southern Nevada Water Authority's (SNWA) main document related to long-term planning is the SNWA's Water Resource Plan, which provides a comprehensive overview of water resources available for use in southern Nevada, including Colorado River water resources. The SNWA's current Water Resource Plan is available at http://www.snwa.com/ws/resource_plan.html.

New Mexico

Assessment of current and future needs of Colorado River Basin water by agencies in New Mexico includes the San Juan Hydrologic Unit Regional Water Plan prepared by the San Juan Water Commission. This Plan identified existing and future water demands and the available water supply within the San Juan River Basin in New Mexico, and developed alternatives to meet the unmet demand. The alternatives included consideration of regional water resources management, water conservation, protection of the regional public welfare, and time lines for implementing the San Juan Hydrologic Unit Regional Water Plan. The Plan was accepted by the New Mexico Interstate Stream Commission as part of its state-wide regional water planning process in 2003. The San Juan Hydrologic Unit Regional Water Plan is currently available at http://www.ose.state.nm.us/isc_regional_plans2.html.

Additionally, in 2007, Reclamation completed an investigation of the amount of water available for use in New Mexico from New Mexico's Upper Colorado River Basin allocation and Navajo Reservoir (2007 Hydrologic Determination). This investigation was prepared in consultation with the Upper Colorado River Commission and included a schedule of anticipated depletions through 2060 from the Upper Basin in New Mexico prepared by the New Mexico Interstate Stream Commission. The purpose of the 2007 Hydrologic Determination was to determine the availability through 2060 of water to service a proposed contract for the Navajo Nation's consumptive uses in New Mexico under the Navajo-Gallup Water Supply Project and the Navajo Indian Irrigation Project. This contract is designed to be part of the settlement of the water rights claims of the Navajo Nation to waters of the Upper Colorado River Basin in New Mexico. The 2007 Hydrologic Determination is currently available at http://www.ose.state.nm.us/water-info/NavajoSettlement/Ltr-Richardson-HydrologicDetermination-2007-06-08.pdf.

Utah

The Division of Water Resources is responsible for comprehensive water planning in the State of Utah. Over the past decade and a half, the division has prepared a series of documents under the Utah State Water Plan. This included a statewide water plan and an individual water plan for each of the state's 11 major hydrologic river basins. The preparation of these plans involved several major data collection programs as well as extensive inter-agency and public outreach efforts. Much was learned through this process; state, local, and federal water planners and managers obtained valuable information for use in their programs and activities, and the public received the opportunity to provide meaningful input in improving the state's water resources stewardship. These and other reports prepared by the Utah Division of Water Resources are available at: http://www.water.utah.gov/Planning/Default.asp.

Wyoming

The State of Wyoming reinitiated river basin planning in 1997, when the State Legislature directed the Water Development Commission, the State Engineer's Office, and the University of Wyoming to develop a planning process to update Wyoming's 1973 Framework Water Plan. The 1999 Legislature approved the recommended planning process and authorized developing river basin water plans for the Bear and Green River Basins. The initial Green River Basin Plan was completed in 2001. In the following years the Legislature authorized funding for the five remaining river basin plans; thereafter a Wyoming Framework Water Plan (http://waterplan.state.wy.us/frameworkplan.html) was completed in 2007. In 2010, an updated version of the Green River Basin Water Plan (http://waterplan.state.wy.us/plan/green/green-plan.html) was published, reflecting changed circumstances during the decade and refinement of the results of the 2001 Plan. Wyoming's process will continue to move forward through updating of the plans in the other basins. In this manner, Wyoming intends to have current, up-to-date, and readily accessible planning information at hand as project-specific water development activities proceed in the State.