

RECLAMATION

Managing Water in the West

Interim Report No. 1

Colorado River Basin Water Supply and Demand Study

Technical Report A – Scenario Development



U.S. Department of the Interior
Bureau of Reclamation

June 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.

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Colorado River Basin Water Supply and Demand Study

Technical Report A – Scenario Development

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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Appendix

A1 Driving Forces Survey

Scenario Development

1.0 Introduction

The *Plan of Study*, provided in Appendix 1 of the *Status Report*, states that the purpose of the Colorado River Basin Water Supply and Demand Study (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 seven Colorado River Basin States¹ (Basin States) that receive Colorado River water over the next 50 years, and to develop and analyze adaptation and mitigation strategies to resolve those imbalances. The Study contains four major phases to accomplish this goal: Water Supply Assessment, Water Demand Assessment, System Reliability Analysis, and Development and Evaluation of Opportunities for Balancing Supply and Demand.

The amount of water available and the progression of demand for water in the basin (and the adjacent areas of the Basin States that receive Colorado River water) over the next 50 years are highly uncertain and dependent upon a number of socioeconomic and other factors. The potential impacts of future climate variability and climate change further contribute to these uncertainties. To analyze the future reliability of the Colorado River system, with and without adaptation and mitigation strategies, projections of water supply and demand are necessary. These projections must be sufficiently broad to capture the plausible ranges of uncertainty in future water supply and water demand to ensure that the reliability of the Colorado River system is adequately analyzed.

A scenario planning process has been used to guide the development of scenarios that provide a broad range of projections of future water supply and demand. The process involves the identification of the key forces that will likely drive future water supply and water demand, ranking of the driving forces as to their relative importance and uncertainty, and use of the highly uncertain and highly important driving forces to identify various themes and storylines (narrative descriptions of scenarios) that describe how water supply and water demand may evolve in the future. Quantification of the storylines results in water supply and water demand scenarios that will be used to assess future system reliability and inform the development of options and strategies.

This report provides background on scenario planning, describes the scenario development approach used in the Study, and summarizes the progress as of January 31, 2011, on the development of water supply and demand scenarios. Four water supply scenarios have been identified and quantified; four water demand scenarios have been identified and are in the process of being quantified. Details regarding the quantification and analysis of the water supply and water demand scenarios are presented in the respective technical reports (*Technical Report B – Water Supply Assessment, and Technical Report C – Water Demand Assessment*).

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

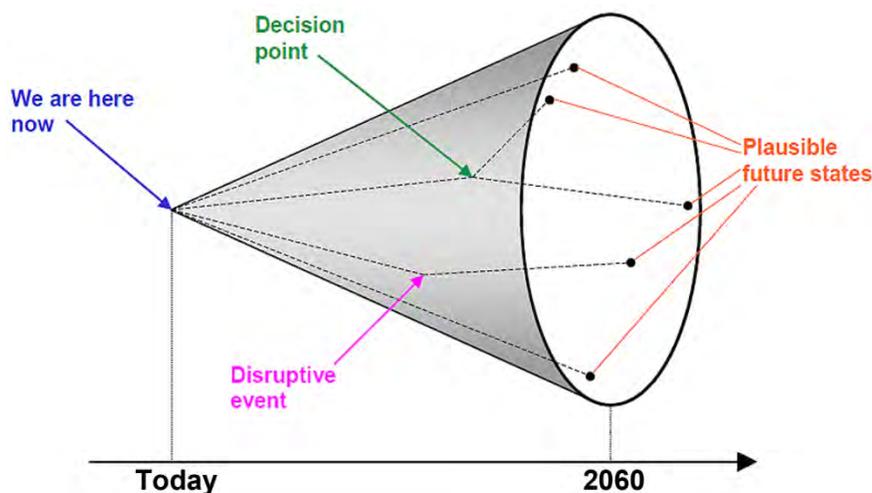
2.0 Incorporating Uncertainty in Water Resources Planning

Management of water resources, and particularly those of the Colorado River, is a complex interplay between natural and human systems, driven by forces such as climatic, demographic, economic, social, institutional, political, and technological factors. The precise trajectory of this interplay over time, and the resulting state of the physical system over time, are uncertain and cannot be represented by a single view of the future. In light of this broad uncertainty, scenario planning can be used to consider and portray the broad range of plausible futures in a manageable number of scenarios. Scenario approaches have been widely applied in water planning and management, from global to regional scales, although specific methodologies have varied considerably (Alcamo and Gallopin, 2003; Mara and Thomure, 2009; Water Utility Climate Alliance, 2010).

Scenarios are alternative views of how the future might unfold. Scenarios are not predictions or forecasts of the future. Rather, a set of well-constructed scenarios represents a range of plausible futures that assists in the assessment of future risks and the development of mitigation and adaptation options and strategies. Figure A-1 shows this concept. At the present time, an understanding of the current state of the Colorado River system exists. For the future, a range of plausible futures, represented by the funnel, can be identified. The suite of scenarios used in the planning effort should be sufficiently broad to span the plausible range.

FIGURE A-1

Conceptual Representation of the Uncertain Future of a System, also known as “The Scenario Funnel” (adapted from Timpe and Scheepers, 2003)



3.0 Overview of Scenario Planning Process

Figure A-2 presents the general steps involved in the scenario planning process as applied to a water resources planning study, from the initial point of framing the focal question(s) being addressed by the study, through the development and analysis of options and strategies to improve system performance.

The shaded area within Figure A-2 encapsulates the steps that are typically part of the development of scenarios, and is the focus of this report. Future phases of the Study will address the steps of system analysis, performance evaluation, and development of options and strategies to resolve water supply and water demand imbalances.

Input from a broad sampling of stakeholders, experts, and others interested in the management of the system is crucial throughout the development of scenarios. This input ensures that the resulting scenarios are representative of the plausible range of futures in the view of those who best know the system.

FIGURE A-2
General Steps Involved in the Scenario Planning Process



The five steps shown in Figure A-2 for scenario development are described below.

3.1 Frame the Question

The scenario planning process begins with a clear understanding of the purpose and objectives of the planning study. Defining the focal question of the study is crucial to the development of scenarios and options and strategies. The focal question (or questions) is the

key question or issue that the study wishes to address, and provides the framework for the consideration of the key forces that influence future uncertainty.

3.2 Identify and Rank Driving Forces

Driving forces are the factors that will likely have the greatest influence on the future state of the system and thereby the performance of the system over time. While the driving forces that have been considered in water management studies have varied, driving forces within the following categories have generally been considered:

- Natural Systems
- Demographic
- Economic
- Technological
- Social
- Governance

Not all driving forces influence the system to the same degree or contribute the same level of uncertainty. In the development of scenarios, it is useful to rank each driving force based on its relative importance to the focal questions of the study and the relative degree of uncertainty of that driving force over time.

3.3 Prioritize and Select Critical Uncertainties

Critical uncertainties are the key driving forces that are identified as both highly uncertain and highly important. Stakeholder and other expert input is crucial for identifying these critical uncertainties to gauge the relative “importance” and “uncertainty” of each of the driving forces. This input can be gathered in various ways, such as holding workshops, conducting surveys, or using other outreach methods. The critical uncertainties can be identified from the expert input and other outreach, and a number of critical uncertainties are selected to form the basis for storyline development.

3.4 Develop Storylines

A storyline is the narrative description of a scenario, based on the critical uncertainties; the storyline provides the “plot” of the scenario. Development of storylines is a qualitative process, requiring the involvement of subject matter experts who have the best understanding of the system and of the critical uncertainties.

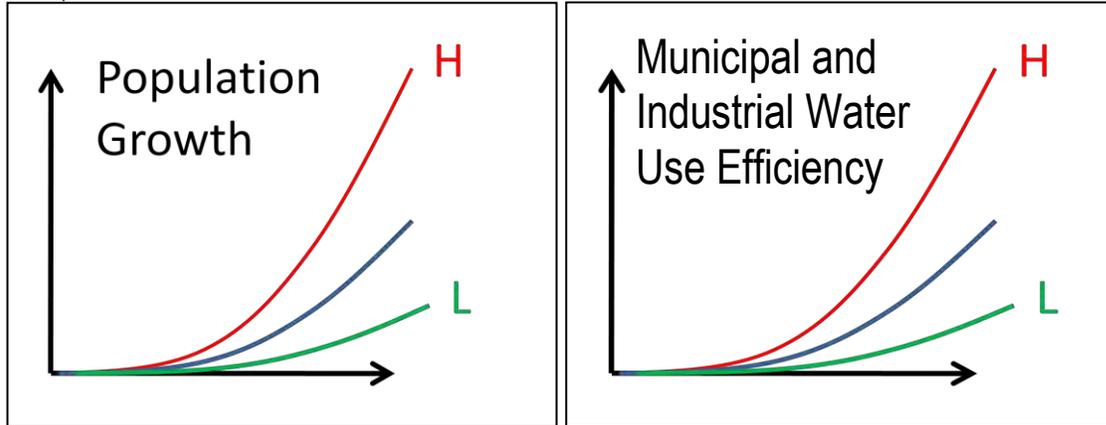
The process of developing the storylines requires identifying parameters that describe each critical uncertainty, characterizing the evolution of those parameters over time, and combining the characteristics of various parameters into descriptions of plausible futures.

Parameters are the variables that describe the behavior of a critical uncertainty. For example, for the critical uncertainty “changes in population and distribution”, parameters include “population” and “population distribution”. Once the parameters have been identified, the plausible range of each parameter over time is described.

Figure A-3 shows a hypothetical high-, low-, and medium-growth curve for the key parameter, “population” on the left, and a similar hypothetical plot for the parameter, “municipal and industrial water use efficiency” parameter on the right. For each parameter,

the curves represent qualitative characteristics describing plausible future trajectories. The two parameters in Figure A-3 are descriptors of two separate critical uncertainties identified in the Study, “changes in population growth and distribution” and “changes in municipal and industrial water use efficiency”, respectively.

FIGURE A-3
Example of the Qualitative Characterization of Critical Uncertainties



In the development of the storylines, the critical uncertainties and associated parameter characteristics are combined based on logical, coherent descriptions of how the future may unfold. For example, high population growth may be envisioned with modest or large increases in water use efficiency as part of a particular storyline. As a result of this process, the storyline and its logic should be understandable to a broad range of stakeholders. Furthermore, an understanding of the combination of parameter characteristics in a given storyline assists in the subsequent step of quantifying the scenario.

3.5 Develop Quantitative Scenarios

Scenarios are the result of quantifying the parameter characteristics that are described in the storylines. As is the case with other steps in the scenario development process, stakeholder and other expert input is important to ensure that the resulting scenario depicts the appropriate range of each parameter as described in the storyline.

For example, in the case of population growth, there may be differing views as to what constitutes high, medium, and low growth. Appropriate dialog is necessary to ensure a common understanding of the storyline’s meaning and its subsequent quantification.

In some cases, scenarios make use of quantitative information previously developed to address uncertainties. In these cases, the existing information is reviewed and checked for consistency with the assumptions and storyline process.

Well-understood and well-documented scenarios are critical to implementing the process depicted in Figure A-2.

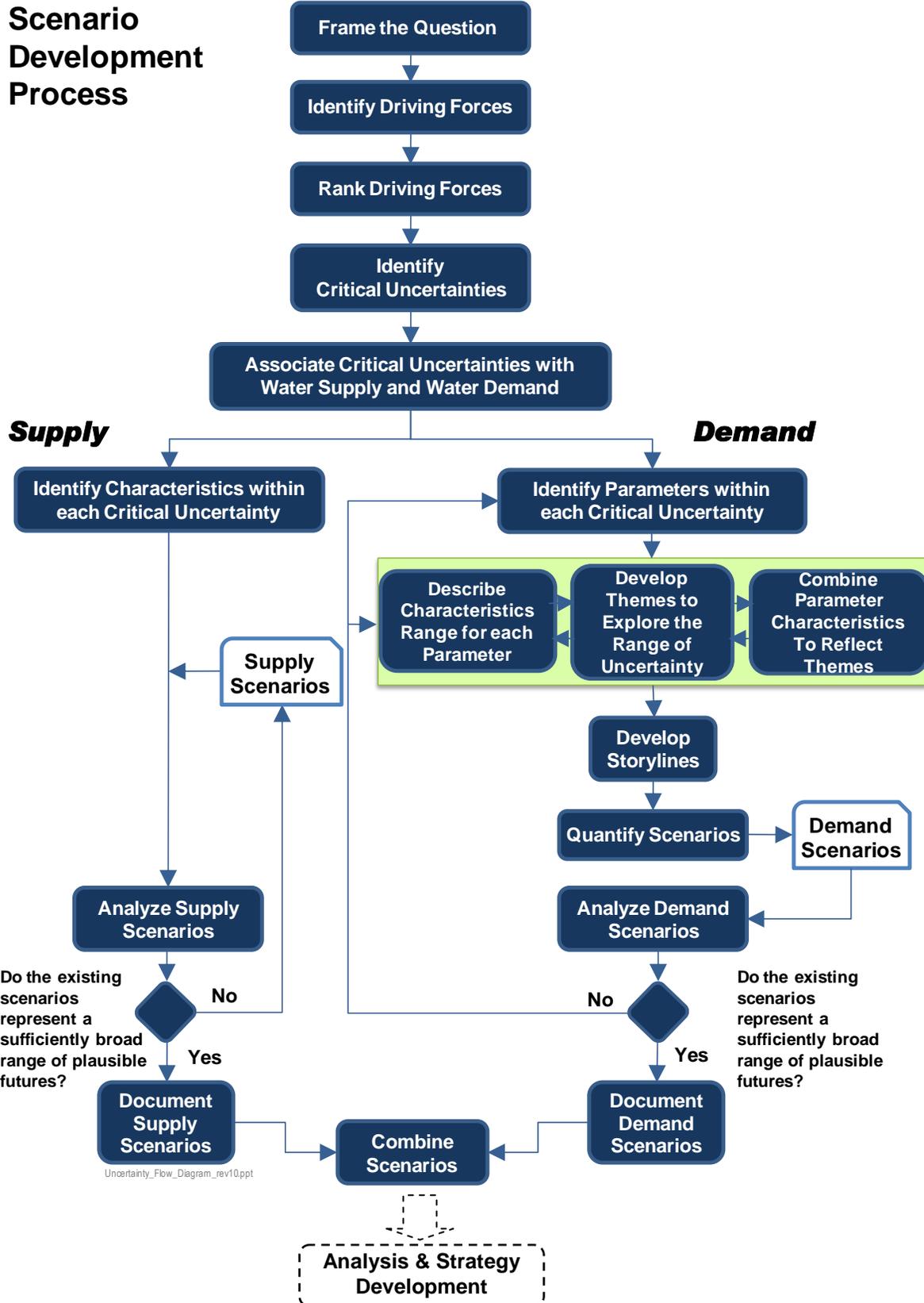
4.0 Implementation of Scenario Development Process

The general steps involved in scenario planning are shown in Figure A-2 and they provide the framework for the approach implemented in the Study. To specifically address the needs

of the Study, this approach was customized and is shown in Figure A-4. This section describes the specific steps undertaken in the Study.

A collaborative process that engages stakeholders is essential to the successful development of scenarios. For the Study, representatives of numerous organizations have participated, including the Bureau of Reclamation (Reclamation), the Basin States, U.S. Fish and Wildlife Service (FWS), National Park Service (NPS), Bureau of Land Management (BLM), Western Area Power Administration (Western), Native American tribes and communities, environmental organizations, water delivery contractors, contractors for the purchase of federal power, and others interested in the Basin. This collaboration was accomplished through a variety of means, including workshops, surveys, and participation in specific sub-teams.

FIGURE A-4
Scenario Development Process Used in the Study



Uncertainty_Flow_Diagram_rev10.ppt

4.1 Frame the Question

The purpose and objectives defined in the *Plan of Study* (Appendix 1 of the *Status Report*) were used to frame the focal questions that the Study must address. These questions are:

1. What is the future reliability of the Colorado River system to meet the needs of Basin resources through 2060?
2. What are the options and strategies to mitigate future risks to these resources?

The first question requires an understanding of the underlying components of future reliability: water supply and water demand. Specifically, what are the factors that will determine the future availability of water and what are the factors that will determine the future demand for water? The scenario development process addresses these questions and results in scenarios of the future that define a range of plausible water supply and water demand outcomes.

The second question relates to water management responses to mitigate and adapt to the potential impacts to Basin resources under scenarios of the future, and is the focus of the analysis and strategy development phases of the Study.

4.2 Identify Driving Forces

An initial list of 14 specific driving forces relevant to understanding potential future conditions was developed using the general categories previously described, based on experience managing the Colorado River system. Four stakeholder teleconferences were conducted seeking input on further refinement and additions to the initial list of driving forces. The stakeholder outreach was conducted by the Water Supply, Water Demand, and System Reliability Metrics Sub-Teams, and included an expanded set of stakeholders, including members from water management entities, federal resource management agencies (fishery, recreation, energy and land management), Native American tribes and communities, and environmental organizations. The input from these stakeholders expanded the initial list from 14 to 18 driving forces and resulted in greater clarity in the definition of some driving forces. Table A-1 lists the driving forces and numbers that were assigned to the 18 driving forces. The numbers were assigned for identification purposes only and do not imply a relative priority.

TABLE A-1
List of Driving Forces Influencing Future Colorado River System Reliability

No.	Driving Force
1	Changes in streamflow variability and trends
2	Changes in climate variability and trends (e.g., temperature, precipitation, etc.)
3	Changes in watershed conditions (e.g., diseases, species transitions, etc.)
4	Changes in population and distribution
5	Changes in agricultural land use (e.g., irrigated agricultural areas, crop mixes, etc.)
6	Changes in urban land use (e.g., conversion, density, urbanization, etc.)
7	Changes in public land use (e.g., forest practices, grazing, wilderness areas, etc.)

TABLE A-1
List of Driving Forces Influencing Future Colorado River System Reliability

No.	Driving Force
8	Changes in agricultural water use efficiency
9	Changes in municipal and industrial water use efficiency
10	Changes in institutional and regulatory conditions (e.g., laws, regulations, etc.)
11	Changes to organization or management structures (e.g., state, federal, bi-national institutions)
12	Changes in water needs for energy generation (e.g., solar, oil shale, thermal, nuclear, etc.)
13	Changes in flow-dependent ecosystem needs for Endangered Species Act (ESA)-listed species
14	Changes in other flow-dependent ecosystem needs
15	Changes in social values affecting water use
16	Changes in cost of energy affecting water availability and use
17	Changes in water availability due to tribal water use and settlement of tribal water rights claims
18	Changes in water quality including physical, biological, and chemical processes

4.3 Rank Driving Forces

Stakeholder and other expert input regarding the critical uncertainties was collected by conducting a survey (see Appendix A1). The survey included the list of 18 driving forces (Table A-1) and asked the respondents to independently rate (using a scale of 1 through 5, with 5 being the highest), the relative importance and relative uncertainty associated with each driving force. Specifically, the respondents were asked to provide ratings based on the following two characteristics:

- **Importance (1 through 5):** Rate the relative importance of the driving forces to the reliability of the Colorado River system to meet the needs of Basin resources through 2060
- **Uncertainty (1 through 5):** Rate the relative uncertainty of the driving forces in the Colorado River Basin through 2060

The respondents were encouraged to provide comments related to each response to aid in understanding the context of high or low responses. In addition, guidance was provided to the respondents relating to the first focal question and to the Study period (through 2060), consideration of current and evolving trends, and external versus internal factors.

The survey was sent to all who participated in the driving forces list review and refinement. Some entities sought further input from their respective technical staff and/or stakeholders. Respondents could respond to the survey anonymously, if desired, but their respective affiliation category was entered into the database. A total of 51 survey responses were received with the affiliation category distribution as shown in Table A-2. Water management entities comprised over half of the responses while environmental organizations, fishery

management entities, and recreation entities represented approximately one-third of the responses.

TABLE A-2
Summary of Respondent Affiliation Category for the Driving Force Uncertainty Survey

Respondent Category	No. of Responses Received
Water Management Entities (including Reclamation)	28
Environmental Organizations	9
Fishery Management Entities	3
Native American Tribes and Communities	3
Water Resources Contractors	3
Recreation Management Entities	2
Energy Management Entities	2
Land Management Entity	1
Total	51

The individual survey responses were compiled into a database and the mean and standard deviation were computed for each driving force as shown in Table A-3. Driving forces that have the highest mean responses are highly important and highly uncertain. The driving forces, “changes in streamflow variability and trends” (No. 1), and “changes in climate variability and trends” (No. 2), consistently ranked high in both importance and uncertainty. Similarly, “changes in population and distribution” (No. 4), consistently ranked high in importance. While the sample size is relatively small for evaluating statistics, the standard deviation provides a measure of the differences in responses among the respondents. “changes in streamflow variability and trends” (No. 1), was considered important by most respondents as represented by a small standard deviation, while “changes in institutional and regulatory conditions” (No. 10), and “changes to organization or management Structures” (No. 11), had a wide range of responses in both importance and uncertainty.

TABLE A-3
Summary of Responses for the Driving Forces Survey¹

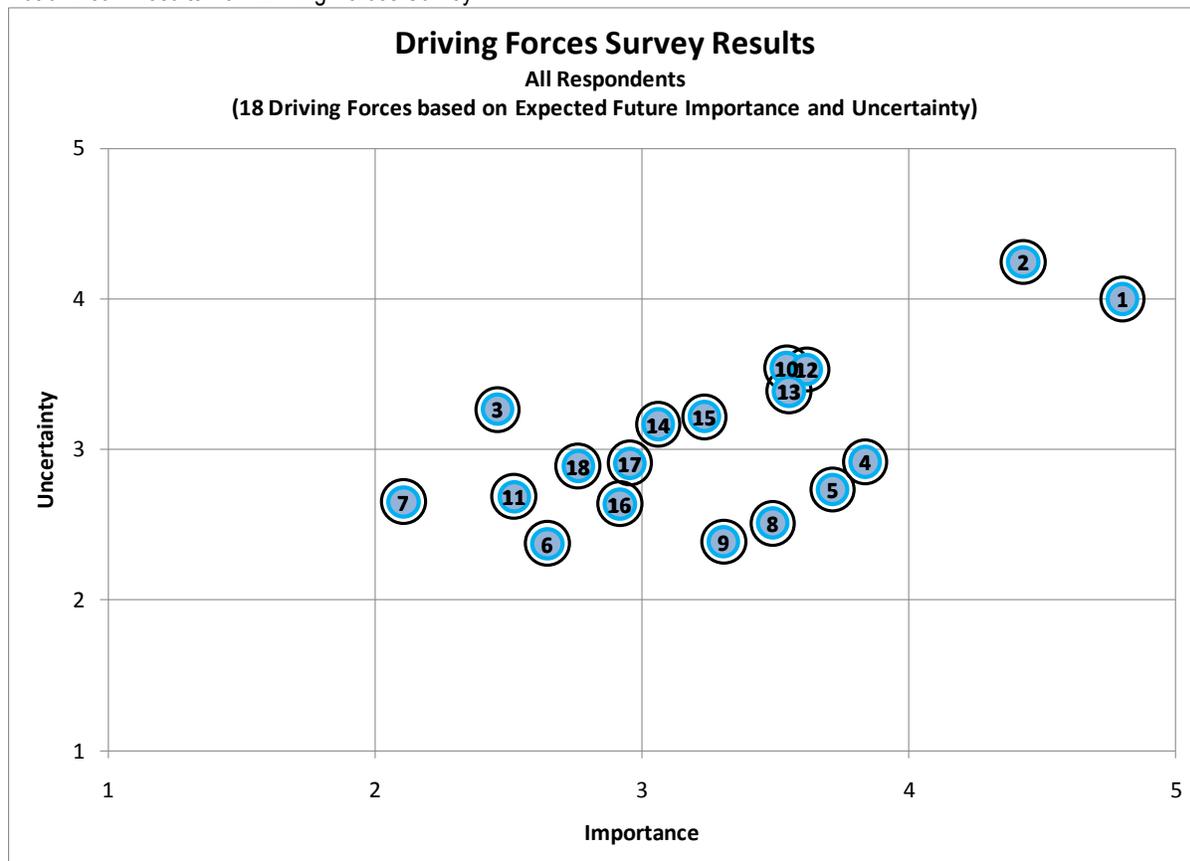
No.	Driving Force	Importance		Uncertainty	
		Mean	Std Dev	Mean	Std Dev
1	Changes in streamflow variability and trends	4.80	0.53	4.00	1.12
2	Changes in climate variability and trends (e.g., temperature, precipitation, etc.)	4.43	0.94	4.24	1.01
3	Changes in watershed conditions (e.g., diseases, species transitions, etc.)	2.46	1.10	3.27	0.88
4	Changes in population and distribution	3.84	0.96	2.92	1.08
5	Changes in agricultural land use (e.g., irrigated agricultural areas, crop mixes, etc.)	3.71	1.17	2.73	1.00
6	Changes in urban land use (e.g., conversion, density, urbanization, etc.)	2.65	0.96	2.38	1.02
7	Changes in public land use (e.g., forest practices, grazing, wilderness areas, etc.)	2.11	0.94	2.65	0.99
8	Changes in agricultural water use efficiency	3.49	1.19	2.51	0.87
9	Changes in municipal and industrial water use efficiency	3.31	1.12	2.39	0.84
10	Changes in institutional and regulatory conditions (e.g., laws, regulations, etc.)	3.54	1.24	3.54	1.25
11	Changes to organization or management structures (e.g., state, federal, bi-national institutions)	2.52	1.25	2.69	1.22
12	Changes in water needs for energy generation (e.g., solar, oil shale, thermal, nuclear, etc.)	3.62	1.11	3.53	1.08
13	Changes in flow-dependent ecosystem needs for Endangered Species Act (ESA)-listed species	3.55	1.00	3.39	1.11
14	Changes in other flow-dependent ecosystem needs	3.06	1.13	3.17	1.19
15	Changes in social values affecting water use	3.23	1.22	3.22	1.23
16	Changes in cost of energy affecting water availability and use	2.92	1.16	2.64	1.22
17	Changes in water availability due to tribal water use and settlement of tribal water rights claims	2.95	1.18	2.91	1.05
18	Changes in water quality including physical, biological, and chemical processes	2.76	1.25	2.89	1.27

NOTE:

¹ Respondent survey rating scale of 1 to 5, with 5 being the highest.

The results of the survey are also displayed in Figure A-5. In this figure the numbers are the driving forces listed in Table A-1 and the plotting position is determined by the relative importance and relative uncertainty based on the mean of all survey responses. Driving forces that plot to the upper right are believed to be highly important and highly uncertain, while those that plot to the lower left are perceived by the respondents to be of lesser importance and lower uncertainty. The driving forces that plot to the lower right are perceived to be of high importance, but have less uncertainty.

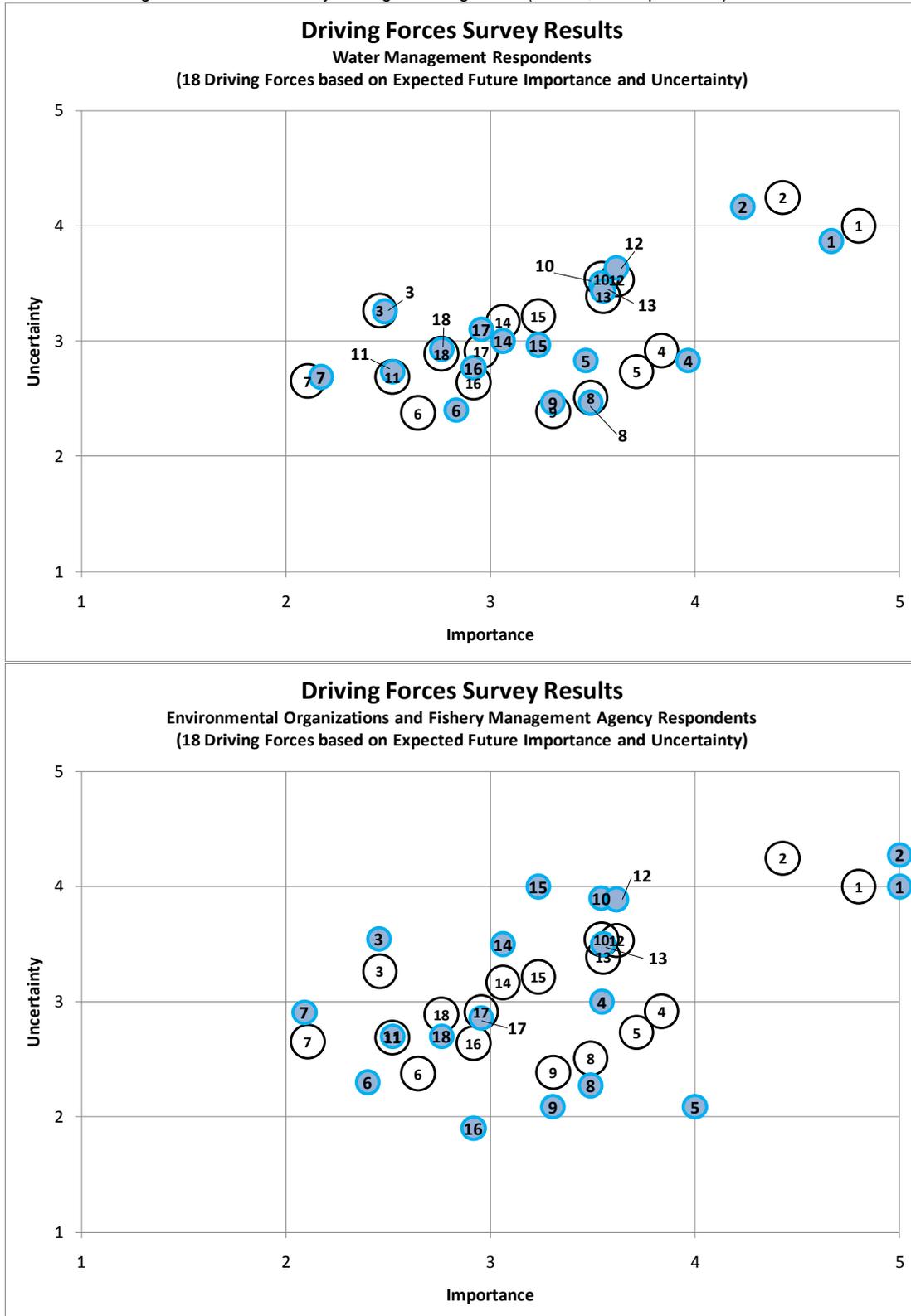
FIGURE A-5
Plot of Mean Results from Driving Forces Survey



Due to the differences in the number of respondents among groups, results based on particular respondent groups were evaluated. Figure A-6 represents the results from water management entity respondents (top) and the results from the environmental organizations and fishery management entities (bottom). In this figure the hollow circles represent the ranking based on all responses, while the shaded circles represent the responses from the particular respondent group.

While the sample sizes are small when partitioning in this fashion, there is a strong commonality of the results among these groups. For example, both respondent groups rated the streamflow variability (No. 1) and climate change (No. 2) driving forces as the highest, despite differences in absolute scores. Similarly, water needs for energy generation (No. 12) and flow-dependent needs for ESA-listed species (No. 13) were rated highly important and highly uncertain by both groups.

FIGURE A-6
 Plot of Mean Results from Driving Forces Survey, Water Management Respondents (top, 31 respondents), and Environmental Organizations and Fishery Management Agencies (bottom, 12 respondents)

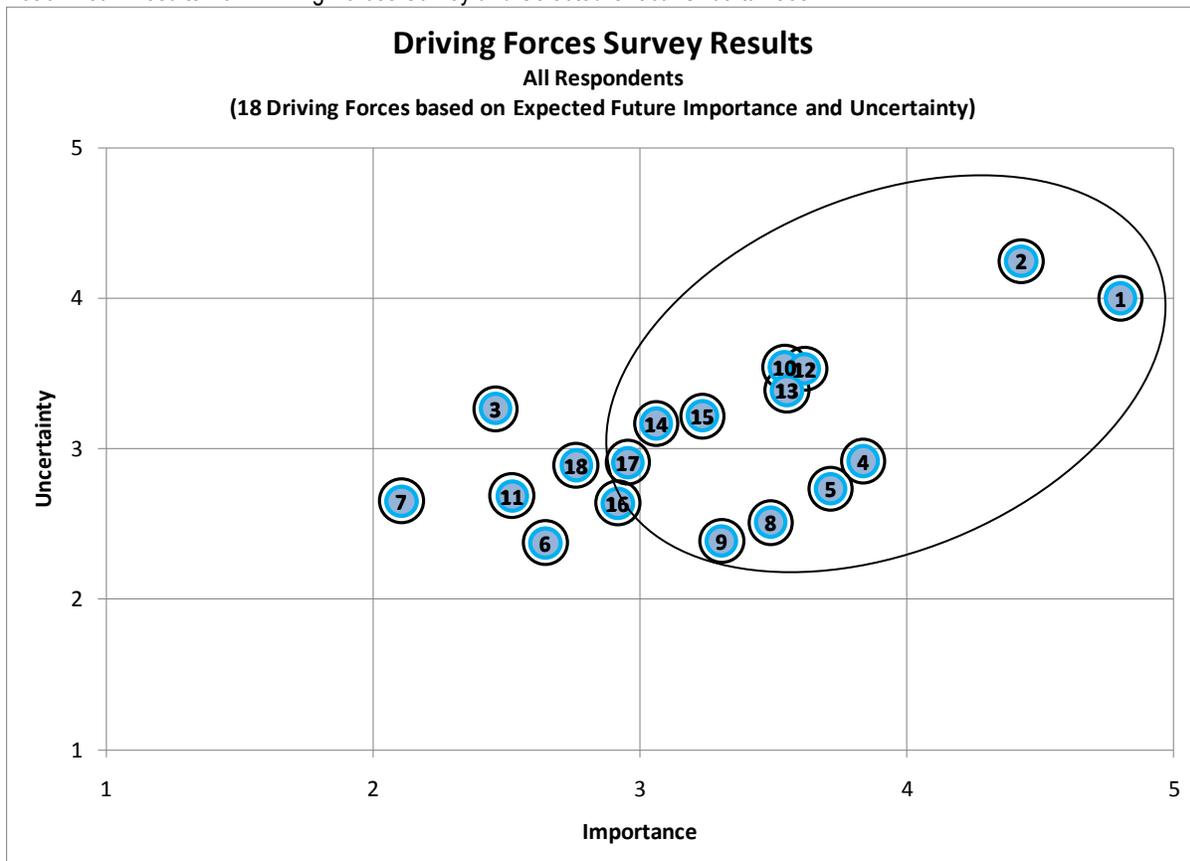


4.4 Identify Critical Uncertainties

Consideration of the relative rankings based on the survey responses led to identification of the critical uncertainties as shown in the oval in Figure A-7. The driving forces that were obviously located in the upper right in the figure were selected as critical uncertainties. For the driving forces near the middle of the graph, judgment and expertise were used to determine whether those should be considered as critical uncertainties.

The initial list of critical uncertainties was checked to see if the results would have been different based on responses of individual respondent groups. While there are some differences in terms of the relative magnitude of the ratings, it was concluded that the driving forces that represent the critical uncertainties would not be different based on subsets of the survey responses. In general, the decision was made to be more inclusive and the oval was expanded to include several of the driving forces in the middle range.

FIGURE A-7
Plot of Mean Results from Driving Forces Survey and Selected Critical Uncertainties



4.5 Associate Critical Uncertainties with Water Supply and Water Demand

Water supply and water demand are the key factors affecting the future reliability of the Colorado River system. Although critical uncertainties may affect both supply and demand, each critical uncertainty was associated with the factor thought to be most affected. For those critical uncertainties that have significant impact to both supply and demand, adjustments to parameters affecting both water supply and water demand will be made.

The critical uncertainties were first grouped by the broader categories of driving forces. Then each category of driving forces was aligned with either water supply or water demand, depending on its anticipated area of greatest influence. The resulting association of critical uncertainties is shown in Table A-4. The alignment of driving forces into water supply or water demand was performed to provide focus to its evaluation, but the subsequent quantification of scenarios will consider important linkages across water supply and water demand. For example, although changes in climate variability and trends will affect water demand (primarily through increased evapotranspiration due to increase in temperature), the potential influence is considered greater on water supply. For scenarios that explicitly include climate change, the associated demands will be adjusted based on temperature-related effects on evapotranspiration (see *Technical Report C – Water Demand Assessment*).

TABLE A-4
Association of Critical Uncertainties with Key Factors in System Reliability

Key Basin Study Driving Forces Identified in Survey	General Driving Force Category	Key Factor In System Reliability Most Affected
Changes in streamflow variability and trends [No. 1] Changes in climate variability and trends (e.g., temperature, precipitation, etc.) [No. 2]	Natural Systems (Hydroclimate)	Water Supply
Changes in population and distribution [No. 4] Changes in agricultural land use (e.g., irrigated agricultural areas, crop mixes, etc.) [No. 5]	Demographics and Land Use	Water Demand
Changes in agricultural water use efficiency [No. 8] Changes in municipal and industrial water use efficiency [No. 9] Changes in water needs for energy generation (e.g., solar, oil shale, thermal, nuclear, etc.) [No. 12]	Technology and Economics	Water Demand
Changes in institutional and regulatory conditions (e.g., laws, regulations, etc.) [No. 10] Changes in flow-dependent ecosystem needs for ESA-listed species [No. 13] Changes in other flow-dependent ecosystem needs [No. 14] Changes in social values affecting water use [No. 15] Changes in water availability due to tribal water use and settlement of tribal water rights claims [No. 17]	Social and Governance	Water Demand

4.6 Develop Water Supply and Water Demand Scenarios

After determining the associations of the critical uncertainties to the key factors of water supply and demand, additional stakeholder and subject matter expertise was sought to complete the scenario development process through the Water Supply and Water Demand Sub-Teams. Each sub-team had different requirements and therefore followed different steps as shown in Figure A-4. These steps are discussed in *Technical Report B – Water Supply Assessment* and *Technical Report C – Water Demand Assessment*, respectively.

As of January 31, 2011, the following scenarios are under consideration for the Study:

Water Supply Scenarios

- Observed Resampled
- Paleo Resampled
- Paleo Conditioned
- Downscaled Global Climate Model (GCM) Projected

Water Demand Scenarios

- Current Trends
- Economic Slowdown
- Expansive Growth
- Enhanced Environment and Healthy Economy

The themes associated with each scenario are described below.

The water supply scenarios are focused around the key driving forces in the “natural systems” category. These driving forces relate primarily to streamflow variability and trends, and climate variability and trends. Reclamation has previously conducted research and development relating to the uncertainty of future hydrologic conditions and these previous efforts were incorporated to the extent possible. The water supply scenarios utilize significant information from the observed record of streamflow, reconstructions of streamflow from tree-ring records, and projections of future hydroclimate conditions using downscaled global climate model results. The themes associated with the water supply scenarios are:

- **Observed Record Trends and Variability (Observed Resampled):** future hydrologic trends and variability are similar to the past approximately 100 years
- **Paleo Record Trends and Variability (Paleo Resampled):** future hydrologic trends and variability are represented by reconstructions of streamflow for a much longer period in the past (nearly 1,250 years) that show expanded variability
- **Observed Record Trends and Increased Variability (Paleo Conditioned):** future hydrologic trends and variability are represented by a blend of the wet-dry states of the longer paleo-reconstructed period (nearly 1,250 years), but magnitudes are more similar to the observed period (about 100 years)
- **Downscaled GCM Projected Trends and Variability (Downscaled GCM Projected):** future climate will continue to warm with regional precipitation and temperature trends represented through an ensemble of future downscaled GCM projections

The assumptions, methods, and results for each of the water supply scenarios are discussed in detail in *Technical Report B – Water Supply Assessment*.

The water demand scenarios are focused on the driving forces related to the general driving force categories, of “demographics and land use”, “technology and economics”, and “social

and governance”. The Water Demand Sub-Team identified the parameters which most significantly influence each critical uncertainty within the demand-focused categories. The range of parameter characteristics and the logical combinations of those characteristics were explored by the Water Demand Sub-Team, resulting in the following themes:

- **Current Trends:** growth, development patterns, and institutions continue along recent trends
- **Economic Slowdown:** low growth with emphasis on economic efficiency
- **Expansive Growth:** economic resurgence (population and energy) and current preferences toward human and environmental values
- **Enhanced Environment and Healthy Economy:** expanded environmental awareness and stewardship with growing economy

The assumptions, methods, and storylines for each of the water demand scenarios are discussed in detail in *Technical Report C – Water Demand Assessment*.

5.0 Conclusions and Next Steps

To assess the future reliability of the Colorado River system, the water supply and water demand scenarios will be combined to yield scenarios for both supply and demand as depicted in Figure A-8. Each water supply scenario, relating primarily to the driving forces of streamflow and climate variability and trends, will be combined with each water demand scenario, relating to “demographics and land use”, “technology and economics”, and “social and governance” driving forces, to capture a more complete description of the range of future uncertainty influencing the Colorado River system. At present, all combinations of water supply and water demand scenarios appear plausible. However, not all combinations may provide distinctly informative results. Additional analysis will be performed to ensure that a manageable number of scenarios are used to assess system reliability for a sufficiently broad range of plausible futures.

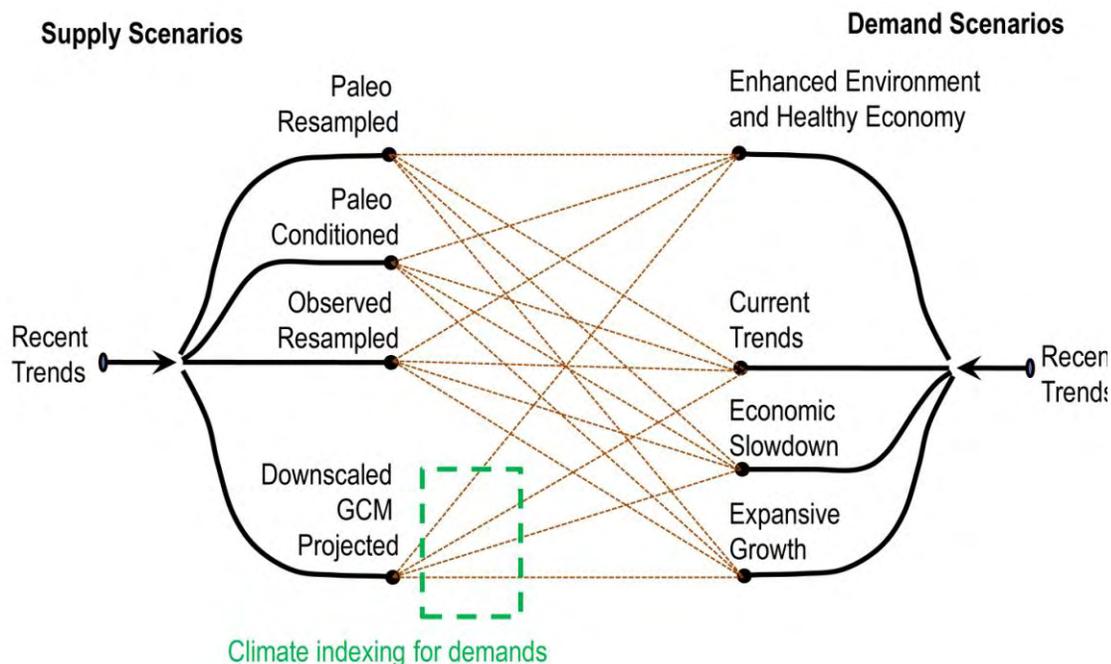
As discussed previously, when considering water demand scenarios combined with water supply scenarios that incorporate climate change, agricultural water demands will be modified to reflect estimates of changes in evapotranspiration rates consistent with the assumptions for water supply.

The combined scenarios will then provide the input to the Colorado River System Simulation (CRSS)² that simulates the future state of the Colorado River system, given the supply, demand, and other inputs. System reliability metrics will be used to compare the reliability of Basin resources under these plausible futures (see *Technical Report D – System Reliability Metrics*). The spatial and temporal representation of the Basin in CRSS, as well as other assumptions regarding how inputs are configured, influences the definition of metrics,

² CRSS simulates the operation of the major Colorado River system reservoirs on a monthly time step and provides information regarding the projected future state of the system. Major inputs to the model include projected natural flows at 29 locations throughout the Basin. Natural flow represents the flow that would have occurred at the location had depletions and reservoir regulation not been present upstream of that location. However, CRSS uses historical inflows based on U.S. Geological Survey streamflow records as estimates of natural flows for the Paria, Little Colorado, Virgin and Bill Williams Rivers. In addition, the Gila River is not included in CRSS. See Technical Report C – Water Demand Assessment Appendix C5 for more detail.

particularly whether a metric can be evaluated quantitatively or qualitatively, and the quantification of the supply and demand scenarios.

FIGURE A-8
Illustration of Combined Water Supply and Water Demand Scenarios



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Disclaimer

The Colorado River Basin Water Supply and Demand Study (Study) is funded jointly by the Bureau of Reclamation (Reclamation) and the seven Colorado River Basin States (Basin States). The purpose of the Study is to analyze water supply and demand imbalances throughout the Colorado River Basin and those adjacent areas of the Basin States that receive Colorado River water through 2060; and develop, assess and evaluate options and strategies to address the current and projected imbalances.

Reclamation and the Basin States intend that this Study will promote and facilitate cooperation and communication throughout the Basin regarding the reliability of the system to continue to meet Basin needs and the strategies that may be considered to ensure that reliability. Reclamation and the Basin States recognize the Study will have to be constrained by funding, timing and technological and other limitations, which may present specific policy questions and issues, particularly related to modeling and interpretation of the provisions of the Law of the River during the course of the Study. In such cases, Reclamation and the Basin States will develop and incorporate assumptions to further complete the Study. Where possible, a range of assumptions will typically be used to identify the sensitivity of the results to those assumptions.

Nothing in the Study, however, is intended for use against any Basin State, the Federal government or the Upper Colorado River Commission in administrative, judicial or other proceedings to evidence legal interpretations of the law of the river. As such, assumptions contained in the Study or any reports generated during the Study do not, and shall not, represent a legal position or interpretation by the Basin States, Federal government or Upper Colorado River Commission as it relates to the law of the river. Furthermore, nothing in this Study is intended to, nor shall this Study be construed so as to, interpret, diminish or modify the rights of any Basin State, the Federal government, or the Upper Colorado River Commission under federal or state law or administrative rule, regulation or guideline, including without limitation the Colorado River Compact, (45 Stat. 1057), the Upper Colorado River Basin Compact (63 Stat. 31), the Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, Treaty Between the United States of America and Mexico (Treaty Series 994, 59 Stat. 1219), the United States/Mexico agreement in Minute No. 242 of August 30, 1973, (Treaty Series 7708; 24 UST 1968) or Minute No. 314 of November 26, 2008, or Minute No. 318 of December 17, 2010, the Consolidated Decree entered by the Supreme Court of the United States in *Arizona v. California* (547 U.S. 150 (2006)), the Boulder Canyon Project Act (45 Stat. 1057), the Boulder Canyon Project Adjustment Act (54 Stat. 774; 43 U.S.C. 618a), the Colorado River Storage Project Act of 1956 (70 Stat. 105; 43 U.S.C. 620), the Colorado River Basin Project Act of 1968 (82 Stat. 885; 43 U.S.C. 1501), the Colorado River Basin Salinity Control Act (88 Stat. 266; 43 U.S.C. 1951), the Hoover Power Plant Act of 1984 (98 Stat. 1333), the Colorado River Floodway Protection Act (100 Stat. 1129; 43 U.S.C. 1600), or the Grand Canyon Protection Act of 1992 (Title XVIII of Public Law 102-575, 106 Stat. 4669). Reclamation and the Basin States continue to recognize the entitlement and right of each State under existing law to use and develop the water of the Colorado River system.³

³ Reclamation and the Basin States have exchanged letters and are in the process of amending the Contributors' funding agreement to, among other things, document and clarify the intent of the Parties consistent with the above disclaimer.

Appendix A1
Driving Forces Survey

Appendix A1—Driving Forces Survey

1.0 Instructions/Guidance for Completing the Colorado River Basin Water Supply and Demand Study Driving Forces Survey

1.1 Survey Objectives

The Plan of Study, provided in Driving forces represent the key factors that affect the reliability of the Colorado River system over time. The attached survey is intended to receive input from representatives of water agencies, other federal and state agencies, Native American Tribes and communities, other stakeholders, and other experts on the relative importance and uncertainty of each of the driving forces over the next 50 years. The overall objective of the survey is to identify the critical uncertainties that will form the basis of storylines and scenarios for the Colorado River Basin Water Supply and Demand Study (Study). Critical uncertainties are key driving forces that are both highly important and highly uncertain.

The purpose and objectives for the Study can be expressed in two fundamental questions:

1. What is the future reliability of the Colorado River system to meet the needs of Basin resources through 2060?
2. What are the options and strategies to mitigate future risks to these resources?

The first question relates directly to incorporating uncertainty and is the focus of the scenario development process. This survey is an important element in that process. The second question relates to management responses to the potential impacts under uncertain futures and is the focus of the water management option and strategy development. This question will be addressed in the “options and strategies” phase of the Study.

1.2 Survey Format

The survey includes a list of driving forces that influence the future reliability of the Colorado River system. The respondent is requested to independently rate (using a scale of 1 through 5, with 5 being the highest) the relative “importance” and “uncertainty” associated with each driving force with respect to the key question or focal issue of the Study being addressed through the scenario development process:

- **Importance (1 through 5):** Rate the relative importance of the driving forces to the reliability of the Colorado River system to meet the needs of Basin resources through 2060
- **Uncertainty (1 through 5):** Rate the relative uncertainty of the driving forces in the Colorado River Basin through 2060

The respondent is encouraged to provide comments related to each response. Such comments will help the Study Team better analyze the data received, particularly for high and low ratings.

1.3 Guidance for Completing the Survey

The driving forces list is intended to be relatively broad to capture the large-scale mechanisms that influence the system reliability. Not every variation on a driving force category is necessary at this point in the scenario development process as details of the critical uncertainties will be explored in the next steps of the scenario development process. However, please provide any comments you have that may help us better understand your views regarding a particular driving force.

Some additional guidance may be helpful in the completion of the survey:

1. Relate all ratings to the key question/focal issue
 - a. What is the reliability of the Colorado River system to meet the needs of Basin resources through 2060?
2. Consider the current influence of the driving force in addition to evolving trends and the range of effects of the driving force through 2060
 - a. How important is the driving force on the system today? What are the current trends in these forces? Are the future trends likely to following the same trajectory? What is the magnitude of these influences?
3. Distinguish between “external” factors (i.e., those factors that are largely outside of the control of water management entities) and “internal” factors (i.e., those factors that are largely within the control of water management entities and will be addressed in the “options and strategies” phase of the Study)
 - a. Consider each factor in the context of the forces that are largely “external” to the control of water management entities.
4. Keep your ratings of importance and uncertainty separate
 - a. Importance is a relative measure of the magnitude of the influence of a driving force on system reliability.
 - b. Uncertainty is a relative measure of the likelihood of occurrence of the driving force over the planning horizon.
5. Keep in mind that the survey is a relative comparison
 - a. You may wish to make two passes through the survey—the first to gauge an initial baseline and the second to align the relative rating of all driving forces.

1.4 Complete and Return the Survey

Please complete the survey, indicating 1 through 5 in the “importance” and “uncertainty” columns for each driving force. Please add comments that will help to convey the reasons for and the intent of a specific rating.

The survey responses can either be typed directly into the form or filled out by hand.

Please return the survey to Amber Cunningham via email (AZCunningham@usbr.gov) or fax to (702) 293-8156 by 12:00 PM PDT on Thursday August 26.

Please call Amber at (702) 293-8472 if you have questions/problems.

TABLE A1-1
Table of Driving Forces and Survey Relating to Importance and Uncertainty

Name/Organization (optional):
Importance (1–5): Rate the relative importance of the driving forces to the reliability of the Colorado River system to meet the needs of Basin resources through 2060
Uncertainty (1–5): Rate the relative uncertainty of the driving forces in the Colorado River Basin through 2060
Importance Rating Guidance: 1=Relatively Unimportant, 3=Important, 5=Extremely Important
Uncertainty Rating Guidance: 1=Relatively Certain, 3=Uncertain, 5=Highly Uncertain
NA=Enter “NA” if you are unfamiliar with the driving force (Note: will not be included in final rating)

No.	Driving Forces	Importance	Uncertainty	Comment
1	Changes in streamflow variability and trends			
2	Changes in climate variability and trends (e.g., temperature, precipitation, etc.)			
3	Changes in watershed conditions (e.g., diseases, species transitions, etc.)			
4	Changes in population and distribution			
5	Changes in agricultural land use (e.g., irrigated agricultural areas, crop mixes, etc.)			

Table continued on next page

No.	Driving Forces	Importance	Uncertainty	Comment
6	Changes in urban land use (e.g., conversion, density, urbanization, etc.)			
7	Changes in public land use (e.g., forest practices, grazing, wilderness areas, etc.)			
8	Changes in agricultural water use efficiency			
9	Changes in municipal and industrial water use efficiency			
10	Changes in institutional and regulatory conditions (e.g., laws, regulations, etc.)			
11	Changes to organization or management structures (e.g., state, federal, bi-national institutions, etc.)			
12	Changes in water needs for energy generation (e.g., solar, oil shale, thermal, nuclear, etc.)			
13	Changes in flow-dependent ecosystem needs for ESA-listed species			
14	Changes in other flow-dependent ecosystem needs			

Table continued on next page

No.	Driving Forces	Importance	Uncertainty	Comment
15	Changes in social values affecting water use			
16	Changes in cost of energy affecting water availability and use			
17	Changes in water availability due to tribal water use and settlement of tribal water rights claims			
18	Changes in water quality including physical, biological, and chemical processes			