

RESEARCH NEEDS IN THE COLORADO RIVER BASIN:

A SUMMARY OF POLICY-RELATED TOPICS TO EXPLORE FURTHER IN SUPPORT OF SOLUTION-ORIENTED DECISION-MAKING

June 2014

Colorado River Governance Initiative, University of Colorado

Executive Summary

Over the past nine months, a diverse variety of Colorado River experts and reports have been consulted to assess the state of research in the basin, with the goal of identifying those areas where additional progress is most needed to aid the policy discussions. Embedded in this effort was an attempt to assess the knowledge base post Basin Study, and to identify the role, if any, that the academic community could play going forward in addressing any shortcomings.

Overall, the individuals and documents consulted in this project suggest that recent investigations, most prominently the Basin Study, have been largely successful in moving the policy discussion forward on several issues. Specifically, we found that:

- (1) Although the Basin Study was almost universally considered a good effort, there are several topics that need more attention, and a lot of agreement about what those items are.
- (2) Many of the issues/questions that need additional research are items that interviewees flagged as being poorly suited to the stakeholder-based research model featured in the Basin Study (and the Working Groups). Exploring the ignored and underrepresented research topics are believed to be important to maximizing future progress.
- (3) Several items identified for additional research are areas where the traditional “framing” of the challenge/issue is seen as problematic, and thus are areas where new thinking, methodologies, and viewpoints are pressing needs.

Moving forward, a variety of specific areas are identified herein that will require additional research. These are items that either improve the level of detail (granularity) or the framing of existing research threads, or that address areas that are currently omitted from most investigations due frequently to political sensitivities. Topic areas include:

- the characterization of the supply/demand gap, and the desire for more dynamic vulnerability analyses;
- the quantification (and characterization) of demands;
- the future of agriculture in the basin;
- the broader consideration of environmental flow needs;
- the role of tribes and tribal water rights in addressing basin issues;
- issues of law and governance; and,
- the role of economic analyses in understanding problems and solutions.

I. Introduction

In the past decade, water managers in the Colorado River Basin have been unusually busy in terms of negotiating new agreements and implementing new programs. However, to meet the challenges facing the basin much more will need to occur. In the search for solutions going forward, a key tool will be research. While the recently completed Basin Study¹ shined a light on many important concerns in the basin, it also helped to illuminate the wealth of issues where additional data and analysis may be useful. The search for answers has spawned a new inventory of questions; such is the nature of research.

This paper summarizes an effort over the past 9 months to identify the research agenda going forward, focused on “policy oriented” topics that are most critical to inform and support solution-oriented decision-making. This work entailed reviewing a variety of reports and attending numerous meetings; however, it is primarily the product of interviews, loosely scripted and informal, and using the Basin Study as the jumping off point to identify what questions remain unanswered. In that sense, interviewees were free to offer a critique (or defense) of the Basin Study if desired, or were free to frame their remarks in different terms. The first round of interviewees included stakeholders from both the Upper and Lower Basins, primarily in government and NGO positions, with personal experience with the Basin Study effort and related investigations and discussions. Material from those interviews was then summarized in a draft report and shared with a core group of prominent Colorado River academics convened as part of this project to help provide an organized academic voice on Colorado River matters.

Our goal in the interviews and literature reviews was to capture the range of ideas regarding valuable future research. In that spirit, all interviews featured a rule of absolute anonymity—that is, not only is there no effort to link ideas to particular interviewees, but a list of those interviewed is not provided. Why? The reason is that determining what is and is not studied, like most other facets of the Colorado River Basin, is a sensitive and politically charged issue. Our interview subjects are people directly immersed in efforts, such as the Basin Study (and the Next Steps efforts), where political and cultural sensitivities are important and, potentially, constraining. But we wanted to know: If every relevant subject and idea were on the table, what subjects would be most useful to study?

In part, our motivation for identifying a politically “unconstrained” research agenda was that there is a largely untapped resource in the Basin available to investigate such issues: the academic community. One of the most striking features of the decision environment in the

¹ U.S. Department of the Interior, Bureau of Reclamation. 2012 (December). Colorado River Basin Water Supply and Demand Study. <http://www.usbr.gov/lc/region/programs/crbstudy.html>

Colorado River Basin is the limited involvement of academics, not a surprising feature in terms of policy negotiations, but also in terms of research.² The Basin Study, for example, was primarily conducted by consulting firms (CH2MHILL and RAND) and managed by stakeholder teams. Likewise, the post Basin Study “Next Steps” process is similarly a stakeholder-based effort, supported again by consultants (CH2M HILL), and overseen by a 27 member Coordination Team without any academic members.³ While there are obvious and legitimate reasons for convening stakeholder-based research teams, we wished to explore if this approach imposes constraints on the issues that receive attention, and thus, if that suggests a need for an expanded academic role, as there is no reason for academics to limit their focus to issues which are politically innocuous. Addressing the more sensitive issues might, in fact, be the obvious role for the academic community. That possibility is one we wished to explore.

² Many places have found an independent academic voice to be a useful supplement to governmental-led initiatives. A prominent example is the role played by the Wentworth Group of Concerned Scientists in the Murray-Darling Basin in Australia (<http://wentworthgroup.org/>).

³ The *Next Steps* process features several research teams, most notably the three “Work Groups”: (1) Municipal and Industrial Conservation and Reuse; (2) Agricultural Water Conservation, Productivity and Transfers; and (3) Environmental and Recreational Flows. Additionally, three state-led projects have been established to examine Water Banking, Water Supply Augmentation, and Watershed Management. Finally, new Reclamation-led efforts focus on Climate Science Research, Data and Tool Development, and Tribal Water. The Work Groups, and to a lesser extent the state-led and Reclamation-led efforts, are overseen by a Coordination Team. Of the 65 organizations represented by Coordination Team and Work Group members, only one is an academic institution (Colorado State University). The represented organizations are: Albuquerque-Bernalillo County Water Utility Authority, American Rivers, American Whitewater, Arizona Department of Water Resources, Arizona Municipal Water Users Association, Arizona Public Service, Bureau of Reclamation, California Department of Water Resources, Central Arizona Project, City of Cheyenne Board of Public Utilities, City of Flagstaff, City of Santa Fe, Coachella Valley Water District, Colorado River Board of California, Colorado River Commission of Nevada, Colorado River Energy Distributors Association, Colorado River Indian Tribes, Colorado River Water Conservation District, Colorado Springs Utilities, Colorado State University, Colorado Water Conservation Board, Colorado Water Users, Denver Water, Eastern Municipal Water District, Environmental Defense Fund, Family Farm Alliance, Front Range Water Council, Green River - Rock Springs - Sweetwater County Joint Powers Water Board, Imperial Irrigation District, Jordan Valley Water Conservancy District, Los Angeles Department of Water & Power, Maricopa-Stanfield Irrigation & Drainage District, National Park Service, National Parks Conservation Association, National Young Farmers Coalition, Natural Resources Conservation Service, New Mexico Interstate Stream Commission, New Mexico Office of the State Engineer, Northern Colorado Water Conservancy District, Palo Verde Irrigation District, Public Service Company of New Mexico, Salt River Project, San Diego County Water Authority, San Diego County Water Authority, San Juan Water Commission, Southeastern Colorado Water Conservancy District, Southern Nevada Water Authority, Squire, Sanders & Dempsey LLP, Ten Tribes Partnership, The Metropolitan Water District of Southern California, The Nature Conservancy, Theodore Roosevelt Conservation Partnership, Trout Unlimited, U.S. Fish and Wildlife Service, U.S. Forest Service, U.S. Geological Survey, Upper Colorado River Commission, Utah Associated Municipal Power Systems, Utah Department of Natural Resources, Utah Division of Water Resources, Wellton-Mohawk Irrigation & Drainage District, Western Area Power Administration, Western Governors' Association, Wyoming State Engineer's Office, and the Zebre Law Offices. (*Source*: U.S. Department of the Interior, Bureau of Reclamation. 2014. Moving Forward to Address Challenges Identified in the Colorado River Basin Water Supply and Demand Study: Phase 1 Work Plan. February.)

II. Findings

Information gathered through interviews, events, and written materials are summarized in the following pages. Given that a diversity of tools were utilized to gather information—including largely unstructured interviews/conversations—we found the best way to present findings was to qualitatively group responses into themes of two types: (1) broad, over-arching conclusions regarding the state of, and potential need for, solution-oriented research in the Colorado River Basin; and (2) more specific, substantive areas/questions where attention is most needed.

The State of Research in the Colorado River Basin

Three over-arching conclusions were identified that speak to the state of research in the Colorado River Basin:

(1) Although the Basin Study was almost universally considered a good effort, there are several topics that need more attention, and a lot of agreement about what those items are.

Very few individuals saw any need for, or value in, “tearing down” the Basin Study. While all interviewees could readily identify shortcomings and omissions in the Basin Study, most chose to do so in the spirit of building upon, rather than discrediting, what had already been accomplished. To the extent that pointed criticisms were offered, they were mostly directed at the design and structure of the Study—especially regarding how questions were framed and how participation was managed—rather than the technical “execution” of the research. The list of topics identified for further research—discussed later in this document—was extensive, but remarkably consistent. That there would be so much consistency in responses—both in tone and in content—from such a diverse group of interviewees was an unexpected result.

(2) Many of the issues/questions that need additional research are items that interviewees flagged as being poorly suited to the stakeholder-based research model featured in the Basin Study (and the Working Groups). Exploring the ignored and underrepresented research topics are believed to be important to maximizing future progress.

While many items offered for inclusion in the research agenda would build upon analyses begun in the Basin Study, many others were characterized as needed to address fundamental omissions attributable to the political confines of the Study’s management structure. This sentiment was most frequently associated with “omitted” research dealing with questions of law, governance, and/or significant policy reforms (e.g., many water marketing proposals), and in context to subjects including the future of agriculture, interbasin relations (e.g., compact-

related disputes), and to a lesser extent, the treatment of tribes. The list of items that are considered taboo or, at least, problematic to address in a stakeholder-consensus research structure is widely—although not universally—perceived as limiting the search for solutions.

Despite the aforementioned presence of ignored and underrepresented research topics, there is also broad (and impassioned) recognition that many issues exist for which the body of research and understanding is already extensive, and where solutions are likely to already feature sufficient political traction to move forward. Perhaps the best example is urban water conservation.⁴ In these areas, there is still a recognized need for knowledge regarding implementation options and experiences, although many interviewees are hesitant to characterize that type of inquiry as “research,” and are not convinced that such efforts require the involvement of the academic community. In fact, whether or not such efforts would be enhanced by the involvement of academics was an area of considerable disagreement.

(3) Several items identified for additional research are areas where the traditional “framing” of the challenge/issue is seen as problematic, and thus are areas where new thinking, methodologies, and viewpoints are the most pressing needs.

Most interviewees describe the majority of recent and ongoing research efforts—most notably the Basin Study—as a collection of good, productive (albeit incomplete) investigations, burdened by the inclusion of a few distracting and often counterproductive tangents⁵, sidebars, and/or ground rules. Frequently mentioned examples from the Basin Study included the focus on a given consumptive use supply/demand imbalance rather than a dynamic vulnerability analysis emphasizing a range of futures; the characterization of the environment as a management constraint rather than a first-order objective; and the perceived assumption that whole classes of solutions and evaluative frameworks are treated as being inherently superior to others—e.g., technological and management options trump governance and market-based solutions, delivery reliability criteria supersedes economic efficiency, and so on. Whether these particular sentiments are accurate, fair, or widely shared (beyond those interviewed) is certainly debatable; they are only relayed here as confirmation that many individuals see a need for research guided by a broader set of ideas and values than what has been traditionally

⁴ An excellent summary of these topics is found in the recent publication of Carpe Diem West and the University of Montana entitled “*Mapping the River Ahead: Priorities for Action Beyond the Colorado River Basin Study*” (2014). In addition to urban water conservation and reuse, the report highlights broad support for solutions focused on: voluntary and temporary water sharing transactions, broad water transfer mechanisms engaging water users over larger areas, physical approaches to augmenting and managing water supplies, and public education and related public awareness initiatives.

⁵ In part this is attributed to poor media coverage, especially coverage focused on the potential 3.2 MAF water supply deficit (as discussed later in more detail) and the potential Missouri River pipeline.

featured. Again, this may speak more to the nature of the stakeholder-based research model featured in the basin than to the technical quality of the investigations conducted.

Specific (Interrelated) Thematic Areas Where More Work is Most Needed

The range of specific ideas regarding future research needs can be organized in a variety of ways, each with their own advantages and disadvantages. In the following pages, thoughts are organized in two overlapping categories. The first uses the “gap” (i.e., the supply/demand imbalance) as the organizing principle, as many interviewees found this to be the most useful jumping off point for identifying deficiencies in research conducted to date; while the second focuses primarily on items that have yet to be examined, or examined at a sufficient level of detail to evaluate or to provide the foundation for policy-making activities. Running throughout both categories are a few reoccurring themes, especially regarding the quantity of demands, the future of agriculture, the evaluation of options, and the need to broaden the scope of inquiry.

How the “Imbalance” is Characterized; Problem Definition

Many parties noted that the Basin Study utilized a familiar linear approach in terms of estimating supplies and demands, calculating the imbalance (or gap) among the two values, and evaluating projects/portfolios with respect to their ability to close the observed gap. Several interviewees found this “framing” to be antiquated, and argued for an approach more capable of exploring a fuller range of possible futures, risks and vulnerabilities, and similarly, a broader exploration of management regimes/options that are robust and resilient under a variety of possible future scenarios. Whether or not this is better characterized as an inherent limitation of the Basin Study framing, or rather, a problem in research execution is a question that most interviewees found difficult to answer. But on one point there was near unanimous agreement: the characterization of the 3.2 million acre-feet (MAF/year) gap by 2060 was (and is) problematic, and runs counter to most thinking about how to prepare for an uncertain future in a basin facing climate change pressures. The 3.2 MAF value is a single point, derived from a median supply and median demand projection evaluated with respect to static legal/policy assumptions selected largely on the grounds of political expediency (as discussed later). To most, the more useful—but much less publicized—finding is the range of the potential gap, which is shown in a figure, but not listed or discussed quantitatively.⁶

⁶ Figure 12 (page SR-34) suggests the range could be from zero to roughly 7 MAF/year. Obviously, the range of problems and potential solutions varies greatly based on what value one uses as the point of analysis. The Basin

Characterizing the problem in terms of a quantitative gap, whether presented as an average value or a range, places a great deal of pressure of getting credible supply and demand projections. Regarding supplies, the use of a GCM scenario (in addition to historic and paleo supply scenarios) was characterized as a notable Basin Study success. Whether or not the scenario selected (which assumes a roughly 9% decline in flows by 2060) was the best choice is debatable, and is an area where ongoing research is strongly desired.⁷ But again, the prevailing research need is probably best not characterized as simply striving for the “right” projection—that’s likely a fool’s errand—but to more extensively use and evaluate the range of plausible scenarios. Also of concern in the use of supply projections is the treatment of variability, especially with respect to decadal scale events (e.g., prolonged drought) and the recuperative powers of big flood events, and the salience of seasonal forecasts as reservoirs hover near key management thresholds.

Few subjects garnered as much comment as did the subject of demands. While a few interviewees noted the “storylines” approach to developing demand scenarios was a notable step forward from past (largely black box) efforts, the calculation of demands in the Basin Study is still considered by many to be an overly politicized topic where more independent research is warranted. Efforts to capture the effects of the recession (and related socioeconomic trends), the success (in many regions) of ongoing and scheduled conservation programs, and the relationship between demands and climate change are all areas where interviewees saw room for improvement.

But more often, comments about demands touched on more fundamental themes. At the heart of many comments is the observation that “demands” are indistinguishable from “wants” in the Basin Study and many other stakeholder-based investigations—i.e., a demand is merely how much water a given region, user or sector would like to have available, irrespective of practical availability, cost, apportionment, or public interest considerations. Given how salient the calculation of demands are in driving the traditional “gap based” water planning model, this approach is seen by many as inexcusably primitive. Individuals thinking along these lines saw the salient research questions as: What demands are critical, and which are discretionary? Are all demands of equal importance? How will (could) demands be shaped by prices? What solutions emerge from a consideration of the differences among demands? It is no surprise that the Basin Study did not ask these questions; in fact, water managers operating at almost

Study acknowledges the 3.2 MAF value as only a single point, explaining that it is merely a “median imbalance for a particular year and can either be more or less from year to year under any one of the projections” (page SR-35). This subtlety was largely lost in media coverage and in report outreach activities.

⁷ As noted by the Basin Study (page SR-6), “Recent studies have postulated that the average yield of the Colorado River could be reduced by as much as 20 percent due to climate change (Hoerling et al., 2009).” (Hoerling, M., D. Lettenmaier, D. Cayan, and B. Udall. 2009. “Reconciling Future Colorado River Flows.” *Southwest Hydrology*, 8(3).)

any scale dismiss these questions as outside their scope, and for good reason: these are politically and culturally sensitive questions, and questions that reach well beyond the technical aspects of water supply management.⁸ But these are questions that *someone* must ask.⁹ Before political leaders obligate the public to provide vast sums of money to implement portfolios of projects to satisfy these demands, these are questions that likely will require greater attention.¹⁰

For better or worse, the line of thinking that starts with demand calculations and runs through a discussion of values inevitably lands at the feet of agriculture. It's never been a secret that agriculture is the dominant water use in the Colorado River Basin, and similarly, that much of that agriculture generates only a small fraction of the economic returns (\$/acre-foot) as does water in municipal and industrial uses. Combine these two realities, and the conclusion emerges that it is impossible to seriously consider the future of the Colorado without explicitly focusing on the desired future of agriculture in the region.¹¹ *In fact, this is probably the most common observation across all the interviews.* The notion that agricultural water demand is a "problem to be solved" is a common one; however, more interviewees urged a broader framing of the issue focused on identifying ways to shave agricultural water consumption while simultaneously bolstering the strength of the sector. Without this framing, the topic is seen by many as threatening any hope of a socially sustainable solution to the basin's water issues.

Demand projections are also a particularly thorny issue with respect to the tribes. While the Basin Study did provide a limited compilation of existing uses and recognized tribal water rights, actually projecting future water demands was largely beyond the scope of analysis in two different respects. First, while 2.9 MAF of settled annual diversion rights were reported in the Basin, many unsettled claims remain¹², and the estimate provided was limited to tribes served

⁸ For many water managers, these questions may also be legally outside their scope; their mandate is to serve all demands. While that may be an appropriate practice at the municipal level, is it a reasonable working premise at a basinwide scale?

⁹ It's worth noting that a few interviewees felt efforts to refine demand calculations to be somewhat irrelevant. Why, the argument goes, is there any attempt to improve demand calculations when it's known that supply will be limiting? A sustainability framing would not treat demands as a modeling input, but as constraint to be managed. Stated differently, the challenge should not be described as finding ways to meet unsatisfied demands, but as finding strategies to live within available supplies. Arguably, the traditional planning approach utilized by the Basin Study, in the options and strategies phase, allowed people to think in these terms, defining demands (and not the gap) as the problem, and only considering solutions that focused on limiting demand.

¹⁰ Portfolio costs by 2060 range from \$2.5 to \$5.8 billion/year (in 2012 dollars) depending on which portfolio and which climate scenario is analyzed (page ES-21).

¹¹ The Agricultural Water Conservation, Productivity and Transfers Work Group established pursuant to the Basin Study is one vehicle for this discussion, but it is already apparent that the research questions may be bigger and, on some matters, more sensitive than what can be addressed therein.

¹² Federally recognized tribes in the basin with unsettled claims include the Hualapai, Havasupai, Kaibab Band of Paiutes, Ute Mountain Ute, Yavapai Apache, Tonto Apache, Pascua Yaqui, and Hopi Tribes. [For more information, see: Kenney, Douglas, et al. 2013. *Cross-Boundary Water Transfers in the Colorado River Basin: A Review of*

by Bureau projects. And second, while most current and projected water use in Indian Country is for agriculture, there is considerable interest among many tribes to broaden how water is used—including for non-consumptive uses. Neither of these issues are well suited to the Basin Study’s stakeholder-based and gap-based research model, and both may also stretch what is possible to investigate through the nascent tribal study. Consequently, these are areas where academic inquiries can potentially be beneficial.

Granularity

Many of the comments regarding research needs were prefaced by acknowledging the Basin Study’s limitations in terms of resources (time and money), tools (specifically CRSS limits), and a desire among the states to avoid sensitive issues. The focus, thus, was not on “casting blame” for work not yet completed (or even initiated), but simply to move forward, and to do so with the understanding that different issues lend themselves to different research approaches and venues. With this backdrop, many issues were identified that simply require greater attention.

Many of the research needs can be described in terms of “granularity,” a term offered to describe subjects where analyses have been conducted, but lack the detail or sophistication to provide a solid foundation for decision-making. Some examples have already been mentioned in the preceding discussion of problem definition and the 3.2 MAF gap; numerous others were also noted. Some examples include:

- *Environmental Flows*: Many problems are associated with the treatment of environmental considerations. Environmental water needs are inherently dynamic and site-based, suggesting a need for modeling with more precise time steps and greater regional specificity (especially in Upper Basin tributaries) than what is currently possible. While this is primarily a technical issue, thinking more broadly, an issue that might suggest more attention is the “treatment” of environmental flows in enhanced modeling efforts—i.e., are they a *metric* to be monitored, a *goal* to be pursued, a *constraint* to limit/shape management when pursuing other objectives, or an *objective* to maximize. While ESA issues and recovery programs point to specific river stretches, species, and management standards, many individuals see a need for research that takes a more comprehensive and holistic view toward the treatment of environmental resources.

Efforts and Issues Associated with Marketing Water Across State Lines or Reservation Boundaries. Boulder: Colorado River Governance Initiative; Getches-Wilkinson Center for Natural Resources, Energy, and the Environment. June. <http://www.waterpolicy.info/docs/CrossJurisdictionalWaterMarketingCRBJune2013.pdf>.]

- *Distribution of Shortages*: The Basin Study modeling has a strong focus on the quantification of shortages. As noted earlier, what constitutes a shortage can be an issue depending upon how demands are treated. But moving beyond that point, existing modeling has focused on defining shortages only in terms of Upper Basin and Lower Basin, and not in terms of states, sub-state regions, and sectors.¹³ Moving forward, it will be difficult to consider the viability or otherwise assess the merits of many solution strategies without a finer understanding of the distribution of shortage impacts.
- *Portfolios & Options*. The “portfolios” approach to considering solutions utilized in the Basin Study was a practical approach given time constraints, but moving forward, many interviewees expressed a desire to examine solutions individually or in different groupings, and believe there is a value in expressing the qualities of solution options in more detail.¹⁴ For example, the assumption that 1 MAF of conservation potential exists in both the M&I and agricultural sector is not tied to any specific research, and the location of said conservation is not identified in any detail. Similarly, in the evaluation of portfolio performance, the list of “reliability metrics” is acknowledged as an innovative way to evaluate system performance under current management regimes, but as such, may limit thinking about novel ways to address over-arching objectives such as economic growth, stability, and security.¹⁵ Likewise, practical qualities such as the “scalability” of solutions may deserve more attention than the current planning approach acknowledges.

Omissions and Simplifying Assumptions

While some issues call for a reframing and others call for additional granularity, many are best characterized as omissions—either likely unacknowledged, or defined away with simplifying assumptions. The best example of this category of research issues are topics of law and

¹³ As noted elsewhere, while this is partially a technical constraint, it also reflects an understandable hesitancy in the Study to address sensitive governance issues.

¹⁴ As noted in the Basin Study’s own peer review process, “not all stakeholders in the Study were in agreement with all characterization results, but it was recognized that future efforts beyond the Study should result in more in-depth assessments of the options and reduced uncertainty” (page ES-20).

¹⁵ In some respects, measuring the performance of a portfolio against a “baseline” scenario is more difficult than measuring it against a hypothetical new management framework, as accurately defining the baseline requires making assumptions about several areas of currently contested law (as noted later). Simplifying assumptions, such as the use of “miracle water” in modeling (i.e., adding water into the system to compensate for any Lee Ferry deficit without assigning offsetting curtailments to particular water users) is a way to avoid that problem, but does nothing to shed light on the law and governance issues.

governance. The Basin Study's modeling of shortages, for example, assumes an Upper Basin delivery obligation of 75 MAF/10-years, an assumption consistent with Article III(d) of the Compact. However, many water managers in the basin assume the Upper Basin additionally has an obligation to provide half the Mexican Treaty obligation (0.75 MAF/year) (see Article III(c)), making the practical 10-year obligation 82.5 MAF. For many years, the "target" downstream release of 8.25 MAF has, presumably, reflected this line of thinking. Exploring this issue seems critically important, as an 8.25 MAF obligation is a full 10% higher than a 7.5 MAF obligation—more significant, quantitatively, than the roughly 9% supply difference between the historic climatology and the GCM scenario. This issue is closely tied to the issue of Lower Basin tributaries, an area where the key legal assumptions are largely taboo in stakeholder-based research, and where a basic understanding of hydrologic conditions is poor. Exploring many other governance-related omissions and assumption are also likely critical to conducting meaningful threshold-based vulnerability modeling exercises, including: the magnitude and limits on the exercise of tribal water rights, calculation of 602(a) storage, the ability to transfer water across state lines, the accounting of evaporation and other system loses, the "default" reservoir operation rules should the Interim Guidelines be allowed to expire in 2026, the "mechanics" of an interbasin Compact call, and so on.

Closely related to these issues are more general issues of governance—that is, an exploration of the who, what and where of decision-making in the basin. Just as stakeholder-based research models have inherent strengths and limitations, so too does the stakeholder-based governance model in the basin. In many river basins, critically examining the ways in which people can participate in decision-making is seen as an essential component of problem-solving—both in concept and in practice. But this line of inquiry has not taken root in the basin. As an example, the Basin Study invited all interested parties to submit proposed "options and strategies," but then choose not to examine those 41 of 160 options classified as "governance" related. This, in part, reflected the practical inability to integrate many such ideas into the quantitative gap-based modeling approach, but it also reflected a characterization of such topics as "destabilizing."¹⁶ One largely excluded segment traditionally viewed as "destabilizing" is tribal

¹⁶ As noted in the Study (SR-48): "Options were submitted that suggested modifications to Basin water management processes and changes in the distribution of water supply available in the Basin under the Law of the River. There are four representative options in this group: changes to apportionment of water supply, processes for expanded stakeholder involvement, population control, and conservation and trust funds. These options suggested modified methods for governing or managing water supply and demand in the Basin. Although these have been included in the Study for completeness and continued dialogue, mechanisms currently exist for flexible operations without destabilizing the Law of the River or triggering lengthy legal battles that would inevitably occur with any attempt to re-allocate the river." Equating options involving "expanded stakeholder engagement" and "modified methods for ... managing water supply and demand" to a wholesale and litigation-driven "re-allocation" of the river fails to acknowledge any difference between complete adherence to the *status quo* and a complete rejection of the Law of the River, a position many interviewees recognize as politically expedient but not necessarily desirable in the search for solutions. By this standard, the Interim Guidelines and Minute 319 would

interests. The Basin Study and the new tribal study are important acknowledgements that this is an area where additional work needs to occur, and furthermore, an acknowledgement that addressing some of the legal issues (and the associated modeling assumptions) cannot readily be divorced from issues of participation¹⁷ and governance.¹⁸

Another area where the practical and political limits on the Basin Study scope are problematic is the relationship between the Colorado River and neighboring basins. Many of the basin's water users, such as those in southern California, are served by a variety of sources of which the Colorado is only one component.¹⁹ Moving forward, it will important to investigate the interrelationships between the Colorado and neighboring basins, both in terms of exacerbating or remedying the supply/demand imbalance.

Finally, for many interviewees, one of the most striking features of the Basin Study is the omission of economic analyses. While some cost-effectiveness (\$/acre-foot) analysis is provided in the review of options and strategies, economic analyses are absent from most remaining discussions, including the calculation and characterization of demands. Again, this is largely reflective of traditions that run deep in the water management community, where the role of economics is often confined to assessing the cost-effectiveness of projects selected on other criteria. But given that demands drive the traditional approach to problem analysis, and that demands in practice are largely a function of pricing and subsidy policies, there is a need to interject economic analyses into conversations normally shaped only by political, legal and cultural considerations. Additionally, it is difficult to imagine thoughtful research on the future of agriculture in the region that does not consider the spectrum of relevant economic issues,

both have been excluded from consideration in the Basin Study had they not already existed. This shortcoming was noted in the Basin Study's peer review process: "Due to the legal, regulatory, and sometime technical complexity of the options submitted, not all categories of options submitted underwent a quantitative assessment. ... The options modeled in CRSS do not necessarily reflect the entire range of innovative options and strategies that should continue to be explored in future efforts" (page ES-20).

¹⁷ At least one interviewee noted the "tradition" of defining the Gila River as outside the focus of Colorado River management has, as a byproduct, the effect of excluding some tribes from participation in the discussion of basin-scale problems and solutions.

¹⁸ As noted in the Study (SR-48): "Tribes hold quantified rights to a significant amount of water from the Colorado River and its tributaries (approximately 2.9 maf of annual diversion rights). In many cases, these rights are senior to other users. Options pertaining to water development and use were submitted by tribes for consideration in the Study and include concepts such as voluntary tribal water transfers, tribal water storage and ICS, convening of an inter-governmental forum, resolution of tribal claims, affordability of tribal water and removing barriers to tribal participation in federal programs, recognition limits to reduce demand, stabilization of soil, and development of non-tributary groundwater. Reclamation will work with tribes in future efforts regarding tribal water issues reflected in this report."

¹⁹ The current drought in California has highlighted this connection, as MWD prepares to withdrawal ICS water from Lake Mead as a way to cope with drought conditions in northern California, while most other activities in the Colorado are focused on protecting Lake Mead storage.

from the cost of water, the value of agricultural products, the contribution of agriculture to rural economies, and so on.

III. Summary and Conclusions

Overall, the individuals and documents consulted in this project suggest that recent investigations, most prominently the Basin Study, have been largely successful in moving the policy discussion forward on several issues. The integration of climate change concerns, for example, into analyses about the long-term future of the river is a notable accomplishment.²⁰ Water managers are rightly proud of the areas where significant progress has been—and continues to be—made, with the transition from the Basin Study to the Work Groups illustrating a viable model for not only conducting research, but for linking research efforts to the decision-making environment. However, the progress forward on some issues has highlighted the lack of movement on others, several of which are becoming increasingly critical. Many such items are identified herein.

Generally, two “threads” of remaining research questions have emerged: those that speak to the “nuts-and-bolts” of implementation, and that emphasize the strengths in expertise and political acceptance associated with the stakeholder-based research model; and those that challenge the existing scope, breadth and framing of research, and thus, the limitations of the stakeholder-driven model. Not surprisingly, some individuals focused more on one thread than the other, but the vast majority readily identified issues of both types. Perhaps more importantly, only a few interviewees offered anything to suggest that it was impossible or even undesirable to pursue both “threads” simultaneously as long as participants acknowledged their efforts as complementary. To the contrary, a sense of pragmatism was a dominant sentiment, and addressing issues of all types through a variety of mechanisms was seen as the obvious best path forward. In practice, this will undoubtedly present some tensions—for example, any thought of reframing the definition of the problem may undercut the logic for working out the implementation details of some solutions—but such is the nature of a complex challenge. In short, there is plenty of work to be done, and it will take a variety of individuals playing different roles to inform and support the difficult policy decisions that lie ahead.

²⁰ On this issue, Appendix U of the 2007 EIS was instrumental. (U.S. Bureau of Reclamation. 2007. *Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead*. Department of the Interior. <http://www.usbr.gov/lc/region/programs/strategies/FEIS/index.html>.)