

## CLIMATE CHANGE AND THE COLORADO RIVER: WHAT WE ALREADY KNOW

(OCTOBER, 2016)

The climate models used to predict future temperature and precipitation trends are among the most data and processor intensive computer programs in existence—a staggeringly complex amalgam of facts, theories, and assumptions. By comparing how well they explain past climatic trends for which we have real data—including paleoclimatic data about climate periods and events occurring long before the modern era—it's possible to get a good idea of what we can predict, and at what level of certainty. Perhaps more importantly, it's also possible to identify what we cannot accurately predict, and to establish the range of variability within which our infrastructure and management regimes should be designed to function. None of the climate models should be described as offering the "right answer" about what future temperatures, snowpack volumes, or runoff levels will be. That model doesn't exist, and it's foolish and futile to think that such a perfect model will ever be developed. But the existing models do have proven strengths, and Colorado River stakeholders should take heed. A key lesson from climate physics and one well evident in the models is that climate change is water change. The two are inextricably linked.

Yogi Berra had it right: "It's tough to make predictions, especially about the future." Translating the scientific knowledge gained from climate research into insights that can inform and aid individuals charged with making management decisions can be maddeningly difficult. Few topics generate as many questions, misunderstandings, and arguments as does climate change. Nonetheless, many points of clarity have already emerged, and perhaps more importantly, many "knowns" about climate change have been identified that have immediate value for those decision-makers with the difficult job of improving Colorado River management. In this paper, we highlight 4 findings that we believe every Colorado River stakeholder should understand.<sup>1</sup>

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### ***(1) It's Hot, and It's Getting Hotter***

The one finding that is unequivocal is that the world has gotten warmer in the past century—by roughly 2°F in the Colorado River Basin. Furthermore, this increase in temperature will persist and intensify, marching in step with increasing greenhouse gas concentrations in the atmosphere. The concentration

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<sup>1</sup> Since this is not intended to be a scientific paper for an academic audience, we have made no effort to include citations to the many statistics presented herein, nor to dwell on the specific assumptions and "error bars" associated with these numbers. Rather, we have selected values based on our careful synthesis of the leading studies, and have done so with the notion that it is the direction of change—rather than the magnitude—that is ultimately the key finding to be gleaned from the statistics. For those wanting more details, CRRG members (particularly Brad Udall and Jonathan Overpeck) are happy to provide such information.

of these heat-trapping greenhouse gases (GHG) has increased dramatically in recent centuries, and because heating lags GHG concentrations by several tens of years, additional decades of warming are “locked in” regardless of any behavioral changes that may or may not be implemented by the world’s governments. By 2050, this is likely to roughly translate to an additional 5°F of warming in the basin. Beyond that date, estimates of future warming levels are driven largely by assumptions about global emissions in coming years to decades—something that is highly uncertain. Depending on the climate model and the GHG emissions scenario used, the range of additional warming likely falls within the 6 to 10°F range by 2100. Whatever temperature is finally reached, that temperature will persist for millennia as natural processes take centuries to remove the excess GHGs and temperature from the climate system.

This is powerful information. Virtually every element of the hydrologic cycle and water management regimes respond to temperature changes. From a hydrologic standpoint, this includes the ratio of snow to rain, the location of storm tracks, the frequency and intensity of extreme events, the timing of snowmelt, and the rate of evaporation, among others. Likewise, from a water management perspective, temperature increases modify the start/end of the irrigation season, the scheduled operations of reservoirs balancing multiple benefits (and risks), the probability of shortages/floods, and many other salient factors, including most importantly the demand for water for all uses and by all users, including plant life. Inevitably, higher temperatures taken alone mean less supply and more demand.

## ***(2) Precipitation is a Wildcard***

Whereas the models and recent monitoring are clear in showing a clear warming trend, no obvious trend exists regarding precipitation. Compared to the 20<sup>th</sup> century, the 21<sup>st</sup> century has indeed been dryer, but only by about 2.5 percent. Whether or not this is the leading edge of a trend, or merely a part of normal variability, is unknown. Looking ahead, the climate models generate widely varied projections of future precipitation trends, with more than half showing a slight increase in total precipitation. Tremendous uncertainty surrounds these projections, however. Perhaps the only clear finding is that snowstorms will increasingly be transformed into rain events, a function of a warming atmosphere.

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## ***(3) Significant Declines in Runoff are Likely***

Ultimately, the question of greatest interest to most water managers is how will runoff values change in the future? While the difficulty of combining known temperature-induced losses with unknown precipitation changes makes this a difficult question, it is increasingly evident that the strong warming trend is likely to overwhelm any modest changes in precipitation. The climate change scenarios utilized in some of the Bureau of Reclamation’s Basin Study analyses suggest an average streamflow decline of roughly 9 percent by 2060. This value was compiled from a suite of 112 projections derived from 16 climate models driven by 3 greenhouse gas emissions scenarios (high, medium and low). Utilizing climate change hydrology in the Basin Study’s scenario planning was a major advance for Reclamation, and an invaluable first step in understanding the challenges of water management in an era of climate change. More recent, but not necessarily more accurate, climate models suggest the possibility of small

increases in flow. However, with 16 years of the 21<sup>st</sup> century already passed, there is now considerable evidence that a 9 percent decline is likely an optimistic scenario. Streamflows thus far in the 21<sup>st</sup> century are already down roughly 15% from the previous century, significantly more than the median decline projected in the Basin Study for 2060. Reductions in precipitation do not fully explain these losses, leaving higher temperatures as the likely culprit behind the remaining declines. With far warmer temperatures expected as the century unfolds, this does not bode well for future runoff.

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If there is a point of widespread agreement regarding future runoff volumes, it is that it is dangerous to focus too heavily on a mean estimate of flow changes—9 percent or otherwise; it is the range of plausible flow scenarios that is critically important. Likewise, the enhanced probability for extreme events, such as decades-long megadroughts, associated with a warming planet must be considered jointly along with any changes in the overall trajectory of runoff.

#### ***(4) Climate Adaptation and Climate Mitigation are Both Part of the Solution***

In the language of climate change policy, *adaptation* describes those actions that can be taken to deal with the known and expected impacts of a changing climate; *mitigation* refers to those actions that can be taken to deal with the root cause of the problem. Adaptation efforts in the basin take many forms, including the Interim Guidelines, the System Conservation Program, and many other emerging efforts, such as the drought contingency planning efforts underway in both the Upper and Lower Basins. This is where the majority of action is occurring, and for good reason. In this modern era of non-stationarity—that is, an era where historic patterns of weather and climate can no longer be assumed to repeat—adapting to climate change and variability is now a core task for every water manager. But the issue of mitigation deserves greater consideration.

The science community is united in its belief that global warming is primarily a result of human behavior—namely, activities that lead to enhanced atmospheric concentrations of carbon dioxide and other greenhouse gases. Efforts to mitigate climate change, therefore, hinge on reducing global emissions of greenhouse gases, a challenge that far exceeds the reach of even the most influential individual Colorado River decision-maker. Nonetheless, carbon emissions in the basin contribute to the global problem, and solving the global problem will benefit the basin. All stakeholders in the Colorado River Basin have much to gain from effective climate change mitigation, as even a modest 10 percent reduction in flow has potential economic impacts in the billions. And there are increasingly reasons to think that global mitigation is possible, including a recent persistent drop in U.S. emissions, the rise of inexpensive and reliable renewable energy systems (many being deployed in the basin states), and the latest global agreement emerging from the Paris talks. Climate mitigation is neither an easy nor short-term solution, but it is a lasting solution that deserves the support of the Colorado River community. After all, the rate of global greenhouse gas emissions translates directly into the rate of Colorado River flow reductions.

## Conclusion: Acting on What We Already Know

Based on this assessment of what is known and unknown, several policy lessons are immediately apparent. Some of the most important include:

- The science of climate change needs to be a central element of virtually all conversations and planning efforts regarding the river—and increasingly, this is already the reality. The Bureau of Reclamation has been a leader in this regard, although politics and the physical limits of the Colorado River Simulation System (CRSS) model can limit progress. To ensure further progress, the research and water management communities need to improve efforts in coordination and mutual understanding, bringing political leaders into the loop to speed the implementation of solutions that are beyond the capability of scientists and managers alone.
- Assuming the current drought will end, and that the supply/demand problems in the basin will thus fade away, is both naïve and dangerous. A return to “normal” (i.e., 20<sup>th</sup> century) precipitation patterns would be unlikely to result in a return to normal levels of runoff, as steady warming will continue to erode streamflows. The “new normal” is variability and change, likely in directions that further stress the basin’s water resources. A risk management philosophy that assumes continued climate variability and change is the correct way forward, rather than an approach that views current conditions as something calling for a temporary coping strategy until normal conditions resume.
- The research community will continue to make strides forward in understanding climate change. However, it is unlikely that any “breakthrough” is on the near-term horizon that will dramatically enhance our current understanding, or that will reduce the wisdom associated with integrating climate considerations into risk-based water planning and management. To the extent that breakthroughs are possible, they most likely involve novel ways to better apply scientific findings that already exist.

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