Planning for Climate Change in the Inland Empire, Southern California

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1 Climate Change Presents a Novel Challenge to Water Managers

Water managers across the United States are currently grappling with how to address climate change in their near- and long-term plans. Traditionally, water planners have assumed that historical weather patterns will persist into the future. With growing recognition of climate change, however, water managers are beginning to seek methods for incorporating such changes in their planning processes. Warmer temperatures are likely to increase water demand as farmers and homeowners resort to more irrigation to keep their crops healthy and lawns green. Changing precipitation patterns may lead already arid regions, such as Southern California, to face even drier conditions and reduced local river and stream flows. The reliability of imported supplies also is likely to be threatened due to hydrologic changes in source regions. Finally, changes in weather patterns may impact local aquifer budgets and reduce the amount of groundwater that may be sustainably extracted to meet water needs.

There are many water management options available to water planners that could reduce the impacts of climate change. Examples include increasing groundwater yields through replenishment; developing recycled wastewater systems to reuse supplies; reducing demand through water use efficiency programs and pricing strategies; constructing new surface storage and conveyance facilities; and facilitating inter- and intra-basin transfers. Each option has its own set of advantages, disadvantages, and costs that will depend importantly on uncertain future conditions. How should planners choose among the many options when the nature of local and regional changes is so uncertain?

The RAND Corporation, as part of a multi-year National Science Foundation project, has been developing and evaluating new analytic methods to incorporate uncertainty about climate change in long-term water planning (see http://rand.org/ise/projects/improvingdecisions/ for project information). Building on earlier work with the California Department of Water Resources on the California Water Plan Update 2005 and on scenario planning with the University of California, Santa Barbara, RAND partnered with the Inland Empire Utilities Agency (IEUA), a water and wastewater wholesaler in Riverside County, California, to evaluate the region’s vulnerabilities to and options for addressing climate change.

2 Identifying Water Management Vulnerabilities and Robust Strategies in the Inland Empire Utilities Agency

2.1 Methodology

Our analysis focused initially on the region's most recent published management plan—the 2005 Regional Urban Water Management Plan, or UWMP. The UWMP anticipates significant growth in water demand as the population increases from 800 thousand to over 1.2 million people, as currently estimated, over the next three decades. Although some improvements in water-use efficiency is anticipated, the plan proposes that most of the growth be accommodated through the aggressive development of local resources. Specifically, it calls for (a) the reuse of most of its treated wastewater for outdoor use and groundwater replenishment (up to 70 thousand acre-feet per year) and (b) a 75% increase in the sustainable use of its groundwater resources through aggressive recharge using recycled wastewater, captured storm-water, and imports when available.

We developed a water management simulation model using the Water Evaluation and Planning (WEAP) system, developed by the Stockholm Environment Institute, to evaluate how various water management programs for the IEUA region would perform under different scenarios of climate and other management conditions.[4] WEAP integrates a range of physical hydrologic processes, including rainfall-runoff and snow physics, with the management of demands and installed infrastructure by simulating the water mass balance for a user-constructed link-and-node representation of a water management system. Of particular interest to this study, WEAP evaluates the impact of alternative sequences of local weather conditions (e.g. temperature, precipitation, humidity, and wind speed) on soil moisture and irrigation requirements, surface and subsurface rainfall runoff, and percolation of precipitation and irrigation into aquifers. This capability thus enables the assessment of impacts of climate change upon the IEUA service area.

We evaluated the IEUA UWMP using WEAP under many scenarios reflecting a wide range of uncertain conditions. Each scenario reflected uncertainty about (1) natural processes, such as future temperature and precipitation and groundwater infiltration rates, (2) the effectiveness of specific management actions, such as the ability to implement ambitious

[4] The WEAP IWRM has been applied to numerous watersheds and districts throughout the world, including the Sacramento Valley, in California (see www.weap21.org for information).

recycling and groundwater replenishment goals, and (3) the costs of future supplies and management actions. Our project team worked with climate scientists at the National Center for Atmospheric Research (NCAR) to develop local sequences of temperature and precipitation for the IEUA region reflective of the climate changes predicted by the scientific community's global climate models. They first used the results of 21 atmosphere-ocean general circulation models (AOGCMs) to define plausible ranges of temperature and precipitation changes in the Southern California region (Table 1) (Tebaldi et al. 2005). They next used a bootstrapping technique (Yates et al. 2003) to develop individual sequences of weather parameters (e.g. temperature and precipitation) that retained the statistical properties of the historical weather in the IEUA region but also reflected the ranges of trends suggested by the AOGCMs.

Our analysis used a new decision analysis methodology designed to support decisionmaking under deeply uncertain conditions called Robust Decisionmaking (RDM) (Groves and Lempert 2007; Lempert et al. 2003). RDM is an iterative, analytic method for decisionmaking and consists of three main steps: (1) evaluate the performance of various plans against hundreds or thousands of plausible scenarios of future conditions, (2) identify those scenarios that lead the various plans to perform poorly (i.e. identify the vulnerabilities of promising plans), and (3) develop improved plans that are more robust to the vulnerabilities and present the key tradeoffs inherent in the choice among plans.

In order to assess the value of this new analytic approach to water managers and elected officials from the IEUA region, we presented the analysis in a series of workshops held at the IEUA headquarters in Chino, California in 2006 and 2007. We surveyed the participants before and after each workshop to evaluate how the methodology impacted their views about the climate threat, the region's vulnerabilities, and the region's ability to respond to the possible climate change challenges. Groves et al. (2008a; 2008b) details the analysis and workshop findings summarized below.

2.2 Results

Our first workshop presented an evaluation of the current UWMP under four scenarios of water management conditions that reflected uncertainty about the future climate and uncertainty about the ability of the region to successfully implement all of it ambitious management goals. We found that under generally-benign climate change conditions—those that are warmer but rainier than the present—the region would not experience shortages through the simulation period (2005 – 2030). This result holds even if the region misses some of its management goals (left column in Table 2). However, under more significant warming and drying trends, the region experiences shortages in 19% of the years—even if the UWMP is successfully implemented (upper right cell in Table 2). If the region also misses its goals for its recycling and replenishment programs, then shortages become even more frequent (more than 40% of years) (lower right cell in Table 2). Although the IEUA workshop participants were intrigued by these findings, they reported that such a simple scenario analysis did not provide them enough information to understand the climate threat or to develop alternatives. In summary, the simple scenarios highlighted the importance of the region meeting its goals outlined in the UWMP and suggested some vulnerability to climate change.

In subsequent workshops, we presented an RDM analysis in which we evaluated the performance of the UWMP under a much larger set of scenarios reflecting different assumptions about the natural, management, and cost uncertainties described above. For this analysis, each WEAP simulation produced estimates of the annual cost of supplying water to the region's end-users and the costs of incurring any shortages. Water supply costs are higher, for example, under simulations in which the region uses more of the relatively expensive imports. Shortage costs are higher for simulations in which there is not adequate water supply to reliably meet the region's demand.

Figure 1 shows the performance of the IEUA UWMP in terms of the present value (PV) cost of providing supply to the region for each year (vertical axis) and the PV cost of incurring shortages for each year (horizontal axis) for 200 different scenarios in which precipitation declines. Note that in our analysis, to reflect the entire range of plausible conditions, we sample quasi-uniformly across the entire range of uncertain model parameters. The sampling scheme does not imply probability of occurring. The total cost of each scenario is the sum of the x-axis value and y-axis value. Total costs, thus, increase from the lower-left to upper-right of the figure. The lightly-shaded region indicates those scenarios in which the IEUA region incurs total costs that are more than 20% greater than what would be expected under historical conditions and the UWMP planning assumptions. The plot shows that about 120 out of the 200 scenarios evaluated exhibit costs greater than this threshold.

As a part of our RDM methodology, we performed a statistical analysis to identify the characteristics of the scenarios that lead to high-cost outcomes (Groves and Lempert 2007). We found that the IEUA UWMP is especially vulnerable to future conditions in which the following three conditions are met:

1. precipitation declines significantly
2. reliability of imports declines significantly in response to climate change
3. natural percolation of the groundwater basin declines (due, perhaps, to urbanization and increasing intensity of precipitation received in the region)

To evaluate options for addressing these key vulnerabilities of the IEUA UWMP, we considered eight additional management strategies that include additional management responses beyond those in the UWMP, such as more aggressively increasing water use efficiency, capturing more storm-water for groundwater replenishment, and more quickly developing the region's recycling program. For some strategies, these additional responses were specified to occur in the near-term, for others, they were part of an adaptive strategy and would occur only in response to deteriorating conditions (called updating).

Figure 2 presents a summary of the key results. Each plan evaluated is listed along the vertical axis and each bar indicates the number of scenarios in which the specific management plan leads to costs above the threshold. The shorter the bar, the less vulnerable the plan. The top bar corresponds to the findings for the current UWMP, as shown in Table 2 (i.e. in 180 scenarios costs exceed the threshold). The other bars correspond to the results for the other plans. In all cases, augmenting the UWMP with additional management strategies leads to lower cost outcomes and less vulnerability. This result reflects favorable and changing economics in local resource development as discussed below. The best-performing plans are those that are adaptive (i.e. those with updates) and those that include the near-term implementation of more water use efficiency. For example, the region would experience fewer than 10 high cost outcomes (out of 200) if it aggressively increases water use efficiency and increases storm-water capture if conditions are more adverse than expected (i.e. the UWMP + efficiency with updates plan).

In summary, our analysis finds that the current IEUA UWMP, although very proactive in terms of accommodating significant expected demand growth, is likely to be vulnerable to plausible change in climate. Fortunately, the region has many options to manage demand and develop robust supply strategies to reduce these vulnerabilities. Specifically, extending IEUA's strategy of local development even further by increasing water use efficiency now, more quickly expanding the recycled water reuse program, and preparing to capture more storm-water for groundwater replenishment if conditions warrant, appears to provide for a considerable reduction in high-cost outcomes across a wide variety of plausible climate and management conditions. Adapting the region's response as conditions change will likely be a very favorable strategy for addressing climate change.

This analysis was presented to about 20 state, regional, and local water planners, and we administered surveys before and after the presentation. A comparison of the survey responses suggests that the briefing provided information that increased the participants' concerns about the effect of climate change—both the likelihood of significant effects and the severity of the effects. At the same time, water planners increased their belief that they could mitigate or manage these effects. This is a noteworthy finding, as a primary objective of an RDM analysis is to illustrate possible threats and then identify strategies that can be taken to address these threats without having a clear understanding of exactly how the future may evolve.

3 Broader Implications for Future Water Management

Water agencies across the United States face a common management challenge—to ensure reliability and avoid shortages within plausible scenarios of future climate and other changing management conditions. Historically, much of the west has relied upon large-scale surface storage and inter-basin transfer systems to capture water in the Colorado River and California watersheds and deliver it to rapidly growing populations in arid regions both near and far. Without a doubt, this approach has been extraordinarily successful, although not without its environmental and social impacts. Climate change and other ecologically-related challenges pose significant threats to the ability of these systems to continue to accommodate population growth in the west. In fact, Southern California is beginning to experience near-term challenges meeting water needs due to continued ecological decline in the San Francisco Bay-Delta and many municipalities face significant cutbacks in deliveries from the Colorado River if the current seven-year drought continues.

The research presented in this study has shown, however, that in the IEUA service area there are options to improve the region's resilience, or capability to cope with climate change, of the region while at the same time decreasing reliance on imported supplies. These options build upon the strategy of increasing local self-reliance articulated in the IEUA UWMP though expanded recycling, conjunctive use, and water use efficiency improvements, and adaptation over time in response to changing conditions. The added threat of climate change will require, perhaps, even greater investments in these options to compensate for more weather variability and declines in precipitation. Due to new cooperation among the region's cities, water, wastewater, and groundwater management agencies, and the supplier of imports (Metropolitan Water District of Southern California), as well as significant state and federal financial support for innovative management strategies, costs to the region of developing these local supplies will likely be lower than imported supplies in the future.

These favorable economic conditions are not present in all jurisdictions and significant cost versus climate resilience tradeoffs are likely to exist. Our analysis in the IEUA region, however, suggests some guiding principles that may be helpful for agencies when considering how to respond to climate change and other planning uncertainties. First, the threat should be analyzed head-on through the evaluation of many plausible future climate conditions using scenario analysis. RDM methods help managers interpret the significance of results and provide an analytical basis for action.[5] Second, managers should not overlook local solutions for increasing reliability, as these options may prove to be the most cost-effective and or feasible to implement in the future. Finally, consider all the benefits of local resource development. The IEUA region, for example, has been exploring the relationship between water use, energy consumption, and greenhouse gas emissions. For this region, increased reliance on local resources reduces the energy intensity of its water supply portfolio, thus paying an additional dividend in terms of reducing greenhouse gas emissions.

[5] For a discussion of how RDM methods compare to more traditional scenario analysis or probabilistically-based expected utility theory, see Groves and Lempert (2007) and Groves et al. (2008a).

4 Figures and Tables

Table 1: Ranges of 30-year trends (2000 – 2030) in temperature and precipitation over Southern California derived from weighting the results from 21 AOGCMs according to the criteria of bias and convergence (Tebaldi et al. 2005).

Climate factor	Likely range (90%)	
	Low	High
Summertime temperature	+0.1ºC	+2.1ºC
Wintertime precipitation	-19%	+8%

Table 2: Percent of years with shortages for the IEUA UWMP under four scenarios of future conditions.

Recycling and Replenishment Goals	Trends in climate	
	Slightly warmer and wetter	Hotter and drier
Meet goals	0%	19%
Miss goals	0%	42%

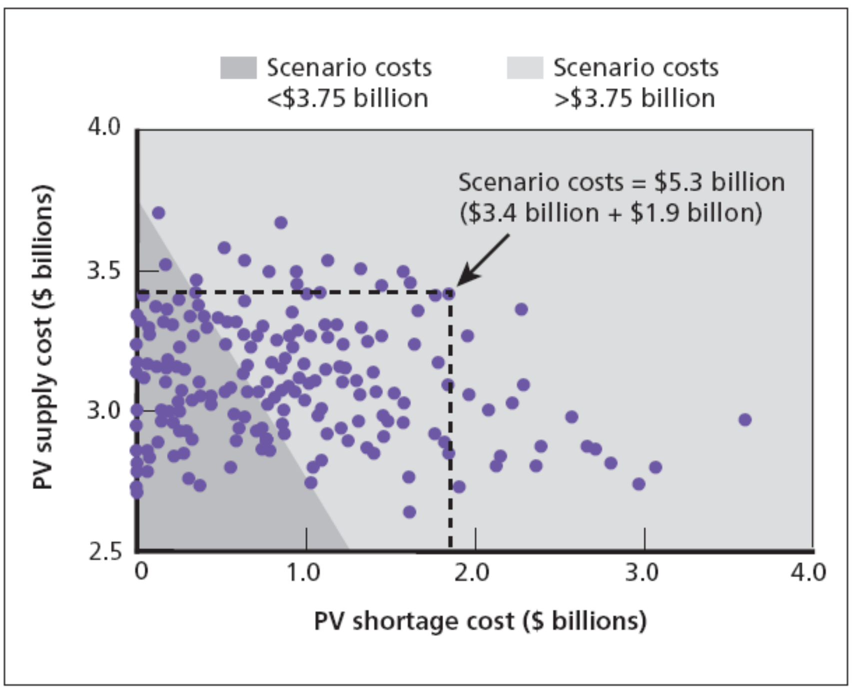

Figure 1: Performance of the 2005 UWMP under 200 different scenarios as measured by the present value (PV) of the supply costs (y-axis) and the present value(PV) of the shortage costs (x-axis).

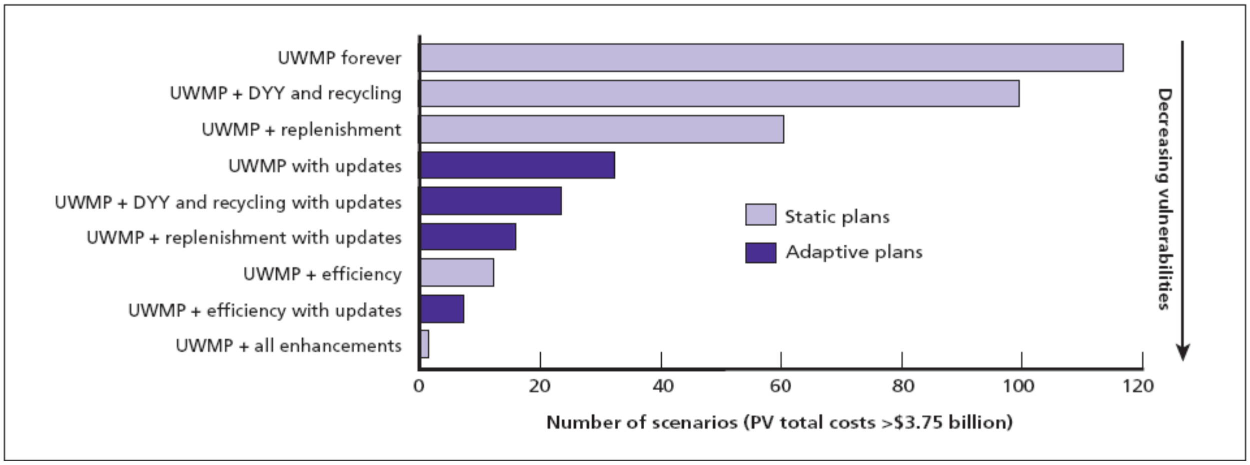

Figure 2: Number of scenarios (out of 200) that lead to costs above the $3.75 billion threshold for nine IEUA management strategies.

5 References

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