

# The San Diego Foundation Regional Focus 2050 Study

## *Climate Change Related Impacts in the San Diego Region by 2050*

Working Papers compiled by The San Diego Foundation  
for the 2008 Climate Change Impacts Assessment,  
Second Biennial Science Report to the California Climate  
Action Team



nderstanding  
The San Diego Region

The San Diego Foundation

*We must understand. Then we can act.*

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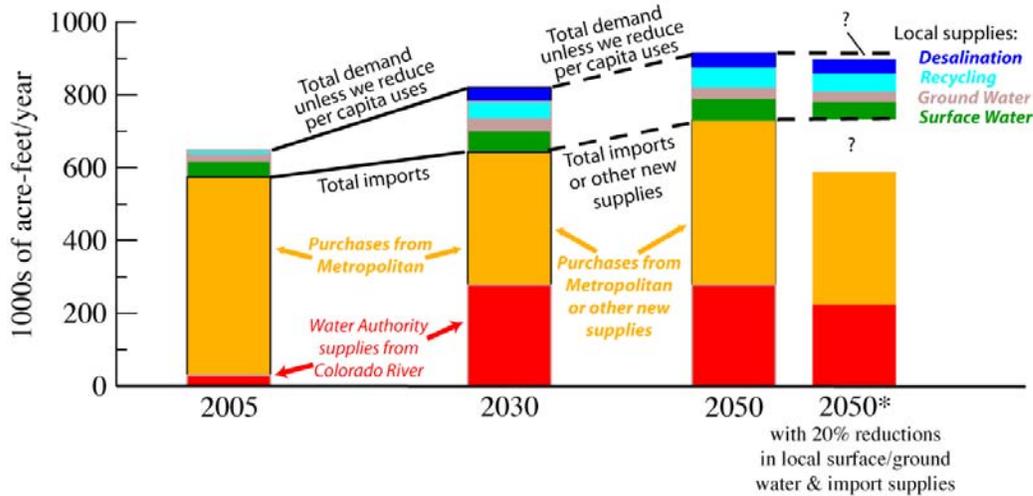
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## CHAPTER 4: WATER

### Introduction

San Diego is a major urban area built by importing water from hundreds of miles away into what is essentially a desert environment. Continuing population and economic growth in San Diego will result in increasing demands for water, and climate change is expected only to exacerbate those demands. **Climate change could yield more instances of drought and reduce the chances that existing water sources will be able to meet projected demands.** Water supply and demand are driven by many factors, some controlled at the local and regional level, others outside the control of decision-makers and citizens of San Diego.

This chapter summarizes recent local and regional syntheses of water planning information to 2030,<sup>1</sup> makes informed projections to 2050, and provides some possible outcomes for consideration. Figure 4-1 summarizes recent projections of future demands for, and supplies of, water for the San Diego region under several 2050 scenarios (with and without severe climate-induced supply reductions). Challenges illustrated in the figure are discussed, with background, in the remainder of this chapter. **There is much reason for concern that even with creative and innovative arrangements among competing water interests, with concerted conservation measures, and with enhancement of identified supply sources, the combined effects of regional growth, water-use practices, and climate change will expose the region to greater risk of water shortfalls even before 2050.**



**Figure 4-1. Projected water demands and supplies in 2005, 2030 and 2050, under “normal year” climate change conditions.**

<sup>1</sup> San Diego County Water Authority (SDCWA) 2005 Urban Water Management Plan and Water Resources Department staff.

In Figure 4-1, projected demands (assuming approximately 12% reductions in per capita demand), local water supplies, supplies of Colorado River water from recent Imperial County water county agricultural water transfers (red), and remaining projected demands for imported water from the Metropolitan Water District or other new sources of water are shown. For the future periods, these latter (orange) supplies were estimated solely by determining how much projected demands exceed projected supplies from other sources. The simple 2050 scenario shown assumes “normal climate” (neither climate change nor drought conditions) and is a direct extension of current 2030 predictions; the other 2050 scenario makes the severe assumption that climate limitations could reduce the availability of imported water and local surface and ground water by about 20%. Blank areas with question marks in the final bar indicate the shortfalls that would need to be accommodated under such a scenario.

### **Water Demands**

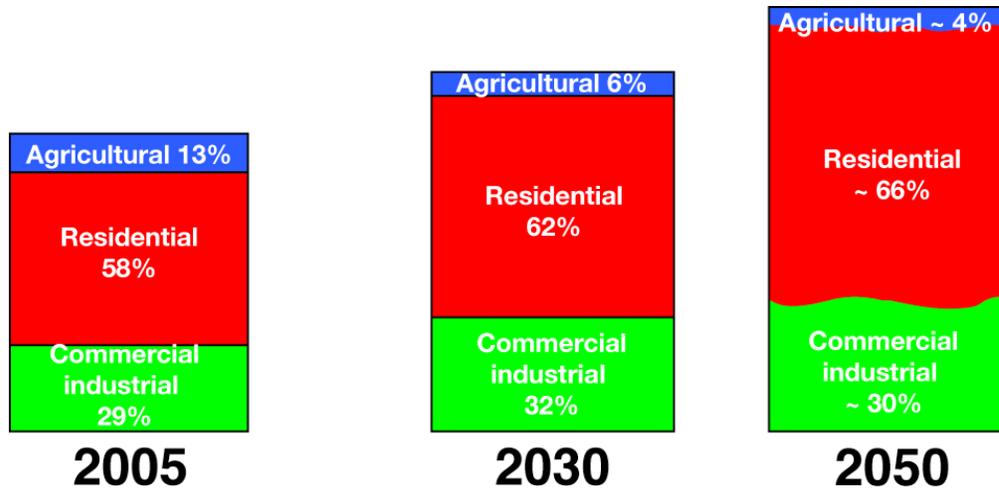
Water demands in San Diego County are dominated by residential, commercial and industrial uses, with a diminishing share devoted to agriculture. As these demands grow in the future, San Diego’s water supplies are likely to be challenged, especially in the context of (probable) adverse climate changes. By far, most of San Diego’s demands are—and will continue to be—supplied by water imported from hundreds of miles away in the Colorado River and the rivers of northern California. Demands for this imported water by some jurisdictions are expected to decline as a result of new supply sources (e.g., Carlsbad with its seawater-desalination plant) and expanded uses of local water supplies including recycled water. Demands by other agencies—most notably the City of San Diego and Otay Water District—are projected to continue growing rapidly, until at least 2030. Official predictions of water demands between 2030 and 2050 have not yet been made due to the lack of post-2030 demographic and economic projections from local jurisdictions.

For the purposes of this report, rough estimates of the growth of demands were made based on assessments and continuations of agency-by-agency trends around 2030.<sup>2</sup> The Water Authority officially predicts that overall water demands (for imports plus local water supplies) will rise by about 24%, from a five-year average demand of 668,000 acre-feet/yr between 2001 and 2005 to about 830,000 acre-feet/yr in 2030 (Figure 4-1). Our estimate of demands in 2050 is about 915,000 acre-feet/yr, of which about 730,000 acre-feet/yr would need to come from imports (under current demand projections and planned local supplies). ***If this 2050 water demand and use is realized, it will amount to about a 37% increase over five-year average demands from between 2001 and 2005.***

Taken together, the predictions of water use by sector are shown in Figure 4-2. Most of the future growth in water demands is expected to be for municipal and industrial uses (M&I), with declines in agricultural water uses. By 2030, 94% of demands are expected to be for M&I, with agricultural demands shrinking from 13% of total demands in 2005 to 6% in 2030. Agriculture water use not only fails to grow as quickly as the M&I demands, but it is predicted to decline in absolute terms (a decline of about 40% by 2030).

<sup>2</sup> These straight-line extensions were then scaled down to reflect the expectation that population growth in San Diego will slow by about 25% after 2030.

The Water Authority is working to offset predictions of 30% growth in water demands for M&I (which is a faster growth rate than the 26% population increase) through increased conservation measures, including residential surveys and retrofits, landscaping changes, efficiency standards, and expanded uses of efficiency measures by commercial/industrial operations. However, in its current predictions and plans (summarized here), the Water Authority only includes about 12% reductions in demand (as in Figure 4-1) from such increased conservation and efficiency measures. This target falls well below the State's current calls for 20% cuts in water use by 2020.



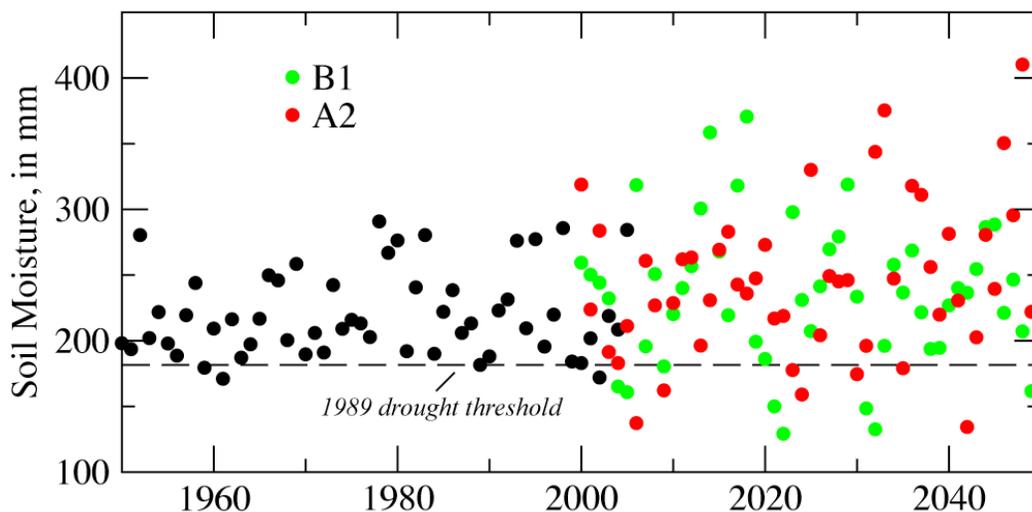
**Figure 4-2. Proportions of San Diego normal-year water demands for several sectors in 2005, 2030 and 2050. Height of bars indicates total expected (or observed) water demands under “normal climate” assumptions; colors indicate the proportions of each water use. Water use total in 2050 is a rough estimate based on slowing rates of growth, with distribution of demand quite uncertain (indicated by wavy edges of sectoral divisions).**

One use of water that is not discussed in plans for San Diego's future demands is the long-term need for environmental water. In other areas of the State and the Western US, water agencies have had to rethink many of their plans because “new” demands have been identified for keeping, or putting, water in rivers, wetlands, flood plains, and other areas for the protection or restoration of estuaries, beaches, ecosystems and landscapes. Often these new demands were identified long after best-laid plans for meeting all human needs were underway. In San Diego, every major river now has protection or restoration efforts under way. ***Under climate change conditions, just preserving the status quo on San Diego's rivers, wetlands, and riparian zones may require providing water to meet environmental goals, flows that have not figured into the very close fitting balances of supplies and demands that appear in the water agencies' projections.***

### ***Climate Change & Water Demands***

Weather and climate variations affect water demands in San Diego. The difference in total demand between a dry year (2004) and the subsequent wet years recently (2005) was 74,000 acre-feet, more than an 11% difference. The Water Authority analyzed past

dry year conditions and estimates a 7% increase, on average, in forecasting water demands during dry periods. As noted earlier, elevated greenhouse gas levels are expected to produce temperature increases of 1.5 to 4.5 degrees F (.83 to 2.5 degrees C) over San Diego by the mid-21<sup>st</sup> century.<sup>3</sup> The effects of climate change on San Diego's water demands are likely to reflect both warming and (likely) drying trends. However, the Water Authority's analyses of San Diego dry-year demands have looked only at "drought" as lack of precipitation, rather than as the combined effect of warming and drying. More frequent and much drier (20% drier) drought years are projected for San Diego in the early 21<sup>st</sup> century in some climate projections (e.g., Figure 4-3). To the extent that climate changes combine to increase San Diego's water demands in the same way as a prolonged and increasingly severe drought regime, even the "normal year" demand projections presented thus far will be underestimates. Perhaps this underestimation will be by as much as the 7% dry year adjustment used by the Water Authority, or perhaps by something closer to the 11% difference between wet and dry years witnessed in recent years, perhaps by much more. Including climate change in the projections will require recognition that ***San Diego is facing a new and more demanding "normal" between now and 2050.***



**Figure 4-3. Simulated annual-mean soil moisture, western San Diego County<sup>4</sup>. Note increased numbers of years (dots) below the 1989 drought threshold in the future 50 years compared to the historical 50 years, indicating increased numbers of significant droughts under climate change. Black dots are simulated soil moisture contents using historical observed meteorology; historical climate-model meteorology results in a somewhat broader range of highs and lows (not shown), with about 50% less lows than among the green (B1) and red (A2) projected soil moistures.**

<sup>3</sup> Cayan et al. 2008b.

<sup>4</sup> Simulated soil-moisture beneath western San Diego County under historical meteorology (black) and projected 2000-2050 climates from the Variable Infiltration Capacity water-balance model driven by the Geophysical Fluid Dynamics Laboratory's CM2.1 climate-model simulations of climate under B1 and A2 greenhouse-gas emissions scenarios.

By 2030, the Water Authority projects that a drought comparable to 1989 would increase overall demands by 6.5%. By 2050, overall demand (local plus imported) would increase from about 915,000 acre-feet/yr in a normal year to about 980,000 acre-feet/yr in 1989-style drought years, and ***drought years might happen as much as 50% more often (Figure 4-3). The drought years in the future might also yield larger demands than the 7% increase associated with 1989, because they are projected to be considerably drier than 1989.***

### ***Water Supplies***

To meet these various demands, water agencies in San Diego County currently depend on imported water from Metropolitan Water District of Southern California, local streamflow, ground water, and some recycled water. In the future, if growing demand is to be met, these supply types will have to be augmented by additional imported water, desalinated brackish or seawater, and increased supplies from other local sources. Climate change will affect all the possible sources of water supply. Some supplies may be reduced as a result of increased heat and changing precipitation patterns in our region and in other regions from which we import water; other supplies may be limited by costs and energy required to draw upon them. Because climate models do not yet reliably predict changes in precipitation, possible impacts on supply present a wide range of outcomes.

#### Imported Water

Prior to 2003, Metropolitan was the sole source of imported water for meeting San Diego's growing demands. In the future, Metropolitan will continue to play an important role, supplying over half of San Diego's imports from its supply sources in the Colorado River and Northern California. However in response to Metropolitan's delivery shortfalls during the droughts of the early 1990s, the Water Authority has developed additional, more secure sources of imported water. In 1998, the Water Authority negotiated an agreement with the Imperial Irrigation District for San Diego to acquire Colorado River water conserved by Imperial Valley farmers. Starting in 2003, San Diego also began receiving conserved Colorado River water from projects that reduce leakage from the All American and Coachella Canals. These new sources of imported water draw upon allocations of Colorado River water that are legally "senior" or ahead of Metropolitan in the order of water availability. Thus they should provide more secure, less expensive supply in drought periods, and do not count against San Diego's existing purchase agreements with Metropolitan. Together these new sources actually reduce the demands that San Diego will make on Metropolitan until about 2020, by which time the new sources will total about 268,000 acre-feet/yr, or about 45% of San Diego's projected demands for imported water. After about 2020, continued growth in demands and full ramp-up of current Water Authority transfer agreements will mean that San Diego's demands on Metropolitan or some other, as-yet-unidentified source of imports will begin to grow again. Purchases from Metropolitan (or other new imports) would need to increase to about 450,000 acre-feet/yr by 2050. Under the current Metropolitan tiered rate structure, rapid increases in deliveries can become quite costly.

#### Local Water Supplies

Although San Diego is a semi-arid to arid setting with limited precipitation, runoff and recharge, in addition to imported water, San Diego water agencies develop supplies

from local sources like surface- and ground water, as well as some reuse of water. Surface water is expected to be the largest local source of water through 2030, but is also the most variable from year to year. Under normal rainfall conditions, Water Authority member agencies can draw about 60,000 acre-feet/yr from local surface water, and no major increases in the region's local surface water supplies are anticipated in published water management plans. In 2005, local groundwater wells supplies totaled about 14,000 acre-feet. Production from ground-water supplies is anticipated to increase by 75% to about 31,000 acre-feet/yr by 2015. Thus by then, local surface and groundwater supplies will have reached their foreseeable limits, and additional less-traditional sources will be needed to meet most new demands beyond those that will be supplied by imported water.

By 2030, the Water Authority projects that the County's uses of recycled water will have quadrupled from about 13,000 in 2005 to about 48,000 acre-feet/yr. Planned growth in recycled water use is expected to reach its projected capacity by about 2020. However, the Water Authority anticipates that additional (as yet unidentified) opportunities for using recycled water may be available well beyond 2030.

Taken together, by 2030, the official projections show that San Diego's projected normal-year imported-water demands through 2030 can be met, if climate or other unanticipated changes do not restrict the water availabilities indicated (see Appendix H for details). Even so, San Diego will need to develop additional local supplies, additional exclusive-use import supplies, or else compete with other Metropolitan member agencies for additional deliveries as its demands continue to grow through 2050. New local supplies beyond about 2015 will likely be restricted to additional increments of recycled water or additional desalination of seawater (which has implications for energy use and greenhouse gas emissions). These options are expensive, as are imports of water, especially in competition with the other growing member agencies of the Metropolitan customer base. Additional local conservation efforts could slow the projected growth in water demand, thereby avoiding a portion of the need and costs of these additional supplies.

### ***Climate Change & Water Supplies***

#### Impact of Climate Change on Surface and Ground Water

Even as the region attempts to develop these local supplies to meet its burgeoning demands, climate change may reduce the amount of local surface and ground water available. The drying trends associated with warming may significantly decrease the availability of surface water, the largest current and projected local water supply. Studies of climate-change projections over the Southwestern United States conclude that ***runoff and ground water are expected to decline by an average of about 7 inches/yr over the entire Southwest by 2050.***<sup>5 6</sup> With San Diego's already dry conditions, such trends suggest that drying in the San Diego area could be quite extreme. Given the relatively limited extent and thickness of most of the County's aquifers, reductions in recharge would likely impact ground-water sources quickly. In addition to these projected impacts of warming, if future climate change includes significant declines in precipitation (which remains uncertain at present), ***surface and ground water resources in San Diego***

<sup>5</sup> Seager et al. 2007.

<sup>6</sup> Milly et al. 2005.

**(comprising fully half of the projected local supply sources) would be even more directly and severely challenged.**

#### Impact of Climate Change on Imported Water

**The sources of most of San Diego's imported water are also likely to be challenged under climate change.** By 2050, San Diego will need commitments for imported water equivalent to about 17% of California's current 4.4 million acre-feet/yr allocation of Colorado River water. However, climate change is expected to result in significant declines in Colorado River flows and thus in availability of these waters for import to San Diego. Recent projections have ranged from about a 6% decline to as much as a 45% decline in Colorado River flows.<sup>7</sup> In absolute terms, a 6% cut to California's allocation would amount to 264,000 acre-feet/yr less water availability; a 45% cut would amount to almost 2 million acre-feet/yr less water. In recent years, the states that draw water from the Colorado River have negotiated a shortage-sharing agreement that specifies how supply shortfalls from the River of as much as 8% might be shared. A new study<sup>8</sup> has estimated that, without this agreement, the major reservoirs of the Colorado River could be emptied within a few decades by the combination of large demands and climate change. However, additional calculations<sup>9</sup> indicate that overall demand for Colorado River water would have to be reduced by 20% to achieve a 90% chance of maintaining water in its reservoirs by 2050. These results suggest that (with or without climate change) **even more extreme reductions from the Colorado River may need to be accommodated in the next few decades than envisioned in the shortage-sharing agreements.** The possibility for water shortages is very real, given the relatively close fit between San Diego's projected demands and its currently projected sources of imported water (mostly from the Colorado River) in the face of currently projected climate-change effects on the Colorado River.

In this context, San Diegans also want to consider the fact that Tijuana, with a population approaching that of the City of San Diego, and just a few miles away, gets about 90% of its water supply from the Colorado River as well.<sup>10</sup> San Diego will feel water-demand pressures placed upon its nearest neighbor directly or indirectly,<sup>11</sup> because water shortfalls in Tijuana could result in greater pressures for emigration and economic stresses there. Options for addressing serious shortages across the border may be almost as important for San Diego as for Tijuana.

Metropolitan also receives and distributes large amounts of water from Northern California by way of the State Water Project.<sup>12</sup> Currently Metropolitan has a contracted entitlement to about 2 million acre-feet/yr of this water, or almost half of the total volume carried through the Project as a whole. However, this amount has not, in fact, been

<sup>7</sup> Christiansen et al. 2004 -18%; Milly et al. 2005 -20%; Christiansen and Lettenmaier., 2007 -6%; Hoerling and Eischeid. 2007 - 45%.

<sup>8</sup> Barnett and Pierce. (In Press).

<sup>9</sup> D. Pierce, unpublished calculations, 2008.

<sup>10</sup> Ganster, 1999.

<sup>11</sup> Malinowski, 2004.

<sup>12</sup> This project stretches from the Feather River near the north end of the Central Valley to Perris Lake, southeast of Riverside, more than 600 miles. Water flows down the Feather River into the Sacramento River, into the Sacramento-San Joaquin Delta, and then is pumped into the California Aqueduct where it is conveyed to southern California.

delivered because of a variety of restrictions on the overall deliveries of water in the system.<sup>13</sup> In coming decades, the State Water Project also is expected to be impacted by climate change and other environmental challenges. Deliveries from Northern to Southern California are already being constrained by judicial restrictions to protect threatened fish species in the Delta, and nonetheless Delta ecosystems continue their decline.<sup>14</sup> Invasive species, aging and failing levees, and a poorly understood decline in the populations of key species all threaten the Delta, which is widely recognized as the weak link in the State's North-South water delivery systems. Efforts are underway by the CALFED Bay-Delta Program and by various other State commissions and agencies to develop policies and structures that aim to improve long-term State Water Project water-supply reliability for southern California while also restoring the Delta's ecosystems. The success of these efforts may well determine the extent to which the State Water Project continues to meet southern California's water needs in the future.

The State Water Project deliveries to southern California are also likely to be challenged by climate changes between now and 2050. Trends towards increasing amounts of rain vs. snow, less springtime snowpacks, and earlier snow-fed runoff from the Sierra Nevada have already been detected in California in response to modest warming over the past 30 years.<sup>15</sup> These changes are just the beginning if warming trends continue unabated. As warming grows more extreme, rain-fed and rain-on-snow flood risks may increase, summertime flows will dwindle, and ground-water recharge from California's mountain catchments may decline, making management of the State's water resources more difficult and potentially less productive.

Meanwhile, along with global warming comes sea-level rise, which poses unique threats to the Delta (which is mostly near or even below current sea level).<sup>16</sup> So far, engineering studies of the impacts of these changes on the ability of the State Water Project to continue to deliver water to southern California have yielded surprisingly optimistic results.<sup>17</sup> ***Nonetheless, estimates of reductions in water supplies from Northern California due to warming have ranged as high as 25%<sup>18</sup> but at present the most detailed studies have indicated that the ability of the State Water Project to continue to supply water hinges more on the extent to which precipitation rates in Northern California change<sup>19</sup> than on projected degrees of warming.*** That is, recent studies indicate that the water infrastructure of Northern California is adequate to accommodate many of the challenges of warming alone (in the absence of changes in precipitation). However, those studies have not yet addressed the increased tension between using our reservoirs to manage floods (in a time of growing flood risks) and using reservoir as warm-season water supplies (when summertime flows have declined). Because current projections of precipitation change over Northern California are highly uncertain, the capacity of the State Water Project to maintain its deliveries of water in the face of climate change remains likewise uncertain, but could easily increase or decrease by 10 to 15% depending on how precipitation eventually changes.

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<sup>13</sup> At times, the deliveries have been much smaller, e.g., during 1991 in the protracted drought of the early 1990s, Metropolitan received only 381,000 acre-feet or 20% of its "entitlement".

<sup>14</sup> Healey et al. 2008.

<sup>15</sup> Luers et al. 2006.

<sup>16</sup> Cayan et al. 2008a.

<sup>17</sup> Medellin-Azuara et al. 2008; Anderson et al. 2008.

<sup>18</sup> Luers et al. 2006.

<sup>19</sup> Anderson et al. 2008.

Thus the amounts by which San Diego's crucial imported water supplies might decline due to climate change impacts on the Colorado River (which is generally predicted to decline, but by an uncertain amount) and on the rivers of Northern California (which may also decline) remain highly uncertain. Nonetheless, the risks of overall declines in the availability of imported water are high and merit detailed evaluations and inclusion in San Diego's long-term water supply plans. Figure 4-1 shows a 2050 "climate change" scenario that is quite severe, assuming that import-water supplies from the Colorado River and northern California might follow streamflow declines in those regions to result in 20% reductions in the anticipated import supplies. Meanwhile local surface-water and ground-water supplies are assumed to similarly decline whereas supplies of recycled and desalinated water are not so impacted. The blank areas in the final bar of Figure 4-1 represent the supply deficits that would need to be made up under such a scenario unless demands could be reduced substantially. This severe climate-impacts scenario does not include the potential for increased demands, which also could follow from warming, drying local conditions. ***The 2050 shortfalls that would need to be made up under this severe climate-impacts scenario total 164,000 acre-feet per year or about 18% of the total demands by then.***

Unfortunately, because of these uncertainties about the effects of climate change, precise estimates of the levels of depletion or shortfall that the region may face (like those in Figure 4-1) remain very uncertain. Even if a specific climate-change scenario was agreed upon, because of San Diego's strong dependence upon water imported from several distant sources through arrangements that are dictated by economic and institutional competition among many major political entities, the extent to which future supplies will be able to meet future demands in times of prolonged drought and adverse climate changes is almost impossible to quantify at present. ***San Diego's success in obtaining sufficient water by 2050 will depend more on our success in competition with other agencies that draw upon the Colorado River and Northern California than upon the net declines of those resources,*** at least until those resources decline to a much greater extent than is projected here for 2050.

San Diego's projected demands for "normal year" imports of water (to round out its supply portfolio and just meet demands extrapolated here) is about 730,000 acre-feet/yr by 2050. This represents an astonishing 228 billion gallons of water per year. However, even if all of this water were derived from the Colorado River, it would only represent about 5% of total allocations from the river. Meeting San Diego's projected demands in the face of a 20% reduction in the river's flows would only raise its purchases of this supply source to about 6%, assuming it is still-available. When a resource is such a modest part of the whole, even small concessions for the sake of regional economic and political stability would make a large difference locally, and could remain regionally feasible. Thus as priorities for the use and deliveries of water (say, between urban and agricultural users) are sorted out in the face of declining river flows, San Diego's future ability to meet its water demands is far from being strictly a function of the overall supply. Rather San Diego's fate in the coming competitions for imported water will depend much more on its ability to make the case for its continued survival in times of shortages and less on the precise amount of resource depletion from the climate changes themselves. In this context, ***the more San Diego is perceived to be using its water supplies wisely and, especially, efficiently, the more likely the region may be to fare well in the regional redistributions of water that climate changes may require.***

### ***Economic Implications***

The cost of water in San Diego County will be adversely impacted both by increases in the costs of water imports and increases in demand, anticipated as a result of climate change. Currently, the cost of supplying additional water to San Diego—which can be inferred from the cost of new desalination and reclamation projects—is between \$600-1800 acre-feet, depending on the water source. This cost may rise significantly by 2050 as less expensive ways to increase water supply are exhausted. Continued growth of the Los Angeles, Arizona, Las Vegas, and Central Valley is likely to increase competition for the same imported water supplies as San Diego, with the potential to drive up prices as purchase agreements are renegotiated in the future.

Additionally, San Diego County residents' water use responds less to price increases than do residents in other parts of the US and California. A 10% increase in price has been shown to reduce residential and commercial water demand by between roughly 2-4%.<sup>20</sup> This unresponsiveness could mean that San Diego residents and business already use water in an efficient and inelastic manner. However, some suggest that it reflects a low level of awareness of the importance of conservation. The Water Authority has done recent polling and conducted focus groups that indicate an increasing concern over water supply issues, but a current low level of behavioral change in response to this concern. Consequently the Water Authority has begun an aggressive public awareness campaign to address this public-response problem.<sup>21</sup>

A very conservative lower bound for expected yearly increased direct costs of water, with population growth effects removed, is \$100 million/year<sup>22</sup>. A more reasonable estimate, accounting for increased demand due to climate change in regions that compete with San Diego, is on the order of \$220 million/year, mostly due to lower expected supply. This represents yearly additional costs due to climate change. Under future climate changes, actual costs of water imports would be substantially more as more people in the Southwest compete for fewer water resources in more severe drought conditions. Methods to mitigate future increases in water costs due to climate change include; long-term water agreements (which guarantee set prices on imported water in drought years), more desalinization and wastewater research funded on the local and regional levels (to lower the costs of these water production sources), and statewide water pricing efficiency improvements on both urban and agricultural water users.

### ***Mitigation and Adaptation Options***

In recent years, the San Diego County Water Authority and its member agencies have developed and initiated far-reaching plans and projects to increase the amounts and reliability of water supplies that they can provide for San Diego's growing population and

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<sup>20</sup> Hanemann et. al. 2007; Nauges. 2005.

<sup>21</sup> Correspondence with Marty Eberhardt, Water Conservation Garden. 2008.

<sup>22</sup> Tanaka et. al. 2006.

economy. Projections of climate change add significant additional burdens to the problems of meeting San Diego's future needs for water. Not yet included in agency plans and outlooks for coming decades are very likely reductions in surface-water runoff and ground-water recharge to local water supplies in San Diego under increasingly warm and dry climates. Probable reductions in Colorado River flows and supplies have been addressed by major agencies with new shortage-sharing agreements, but probably not to the extent required by current projections of climate-change-driven declines on order of 20% by mid-century. ***Uncertainties and risks facing deliveries of Northern California to Southern California are large and potentially dire.***

Additional conservation may be possible and would serve to reduce overall water use and demands, but presumably would require more vigorous measures than pursued to date. Since over half of the residential water uses in San Diego are for outdoor uses,<sup>23</sup> reductions in outdoor demands are likely to bring the look of many San Diego neighborhoods more into alignment with the native dry-land setting in which we live. In 2006, the Water Authority began a retooling effort to expand its outdoor water savings measures. Effective measures have focused on "hardwired" conservation (i.e., changes that make conservation automatic) like xeriscaping and replacement of natural grass with artificial turf rather than requiring repeated actions by residents.

The prospects for acquiring additional sources of imported water, or more local surface and ground water, seem particularly challenging in the face of climate change, given the large regional footprint of water-supply reductions that are likely to be imposed on the whole of the southwestern US. ***Indeed, holding on to currently available rates of supply from these sources is likely to become increasingly difficult.***

Increased reservoir capacity is one adaptive measure to enhance water supply stability to San Diego County in the face of climate change. This measure would lessen the region's annual imported demand requirements and help offset some of the future yearly import costs (\$220 million/year as stated above) due to population growth *and* climate change. The Water Authority is currently pursuing a capital project to expand the City of San Diego's existing San Vicente Dam, motivated in part by just such benefits.

An important strategy for facing the potential effects of climate change on San Diego's water supplies is to remain adaptable and vigilant for developing impacts. Work by the RAND Corporation working with the Inland Empire Utilities Agency (IEUA), just north of San Diego, evaluated IEUA's plans in the face of 200 climate-change scenarios describing possible future climates of the next 35 years. The simple expedient of ***building more regular updates and chances for adapting the plan to unfolding future conditions reduced the chances of incurring large costs due to climate change by almost half*** compared to strict adherence to any of the augmentation options considered.

The lesson that San Diego can draw from this investigation is that, given the continuing large risks and uncertainties regarding climate change and how it will impact San Diego's water-supply sources, San Diego's water planning needs to incorporate climate change into its design and decision making, to provide for regular evaluations of whether the plan remains well adapted to developing conditions, and to focus even more on

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<sup>23</sup> Estimates range from 60-75% with the higher percentage in inland areas.

improving water-use efficiencies if it is going to avoid the worst risks from climate change by 2030 or 2050.

### **Summary**

San Diego's water supply plans through 2030 (the current planning horizon) are likely to be severely challenged by climate change, even as they balance supplies to address growing demands. The path to reliable water supplies in 2050 remains unclear. Options for meeting these challenges are likely to depend on much increased conservation and demand reduction (including water reuse), together with increased reliance on desalination where feasible. Moving forward on these options is a matter of political will and public commitment. Technological improvements in water efficiency and greenhouse emission reduction from energy use associated with desalination will help. Regular assessments of evolving climate knowledge incorporated into periodic evaluations of infrastructure and planning, will be important tools in moving government policy and public awareness. The critical factor will be forward-thinking public policy and leadership to change individual and collective behavior.

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