EVALUATING CALIFORNIA WATER SUPPLY
COST-EFFECTIVENESS ANALYSIS

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EVALUATING CALIFORNIA WATER SUPPLY
COST-EFFECTIVENESS ANALYSIS

A Thesis

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Abstract

of

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The debate over how to address California's future water needs has generally split people into two main camps: those that think the state should move forward with new supply projects, including surface storage (dams) and desalination and those that believe the state should invest in conservation and efficiency measures first before we consider any other alternatives. State policymakers remain convinced of the need for new water supplies but are unsure of how to proceed given budget constraints related to the economic downturn. This thesis will analyze the existing body of economic and cost-effectiveness analysis for the three leading alternatives: water use efficiency, seawater desalination and surface storage. After evaluating the best available data on each alternative and case studies, I found that efficiency measures and surface storage are more cost-effective than desalination proposals which remain expensive relative to other alternatives.

_______________________, Committee Chair
Robert Wassmer, Ph.D.

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Date

DEDICATION

I would like to thank Professors Rob Wassmer and William Leach whose patience and encouragement helped me finish this thesis.

I would also like to thank my mother, Violet Gray, and Professor Daniel Montello who have instilled in me a respect for the importance of continuous learning throughout life and whose support made this possible.

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Chapter 1

INTRODUCTION

Projected population growth in California, and other pressures on demand for water, makes improving access to water a top priority for state policymakers. The question facing state policymakers is: how can the state make the most of its limited water resources when confronted with choices between capturing additional water for use and conserving that water already in use? Debates over this question revolve around three key policy alternatives: conservation and improvement in efficiency, surface storage in new or expanded dam reservoirs, and desalination of ocean saltwater, a high-tech solution with unrealized potential and an uncertain future.

As late as 2010, the State of California faced serious drought conditions that earned a Declaration of Emergency in 2009 by Governor Schwarzenegger and designation of 21 counties as eligible for Federal Disaster Assistance. Despite a wet fall and winter in 2010, the state experienced three consecutive years of below average precipitation, depleting reserves and creating shortages around the state (Schwarzenegger, 2009). The trend accompanied a severe global recession and a deluge of serious environmental problems related to water shortage that prompted state officials to reduce allocations of state water for the state's major water users (Gorman, 2009).

Severe water shortages often exacerbate recessionary economies, which is especially the case in Central Valley agricultural counties hit hardest by water shortages and recent court decisions reducing water exports from the Delta (Stahl, 2009). In these counties millions of dollars of revenue was lost from the economy and tens of thousands of acres of farmland are fallow. Unproductive agricultural land also faces growing competition from suburban land development. Public revenue is also down, partly as a result of water shortage, contributing to the state budget deficit and creating ripple effects in communities around the state. Other sectors of the economy are also constrained by water shortage. Thousands of jobs have been lost as a result - in some agricultural communities at the height of the shortage, unemployment has reached 40% or more (The Economist, 2009). These are just a few examples of the harm of water shortage.

Shortages can quickly lead to emergency when unreliable or insecure water systems are poorly maintained or go unimproved to meet demand. To illustrate the costs of a water emergency, in the summer of 2008, the Spanish Government was forced to import emergency water rations, by tanker, for three months, to augment Barcelona's drinking water supply for its 1.7 million residents (Keeley, 2008). It did this at a cost of about $34 million for 18 shiploads, each carrying about 180,000 liters. On a marginal cost basis that comes to a staggering $100,000/acre-foot. An acre-foot (af) of water is the volume of water required to inundate one acre, equal to about 325,853 gallons. Typical California municipal water costs vary between under $100/af and up to around $1000/af. A few months of emergency water importation to the Los Angeles-Long Beach-Riverside Combined Statistical Area serving 17.8 million residents could cost hundreds of millions of dollars.

To confront the state's growing water crisis, the California State Legislature in 2010 approved a water bond and policy package that could dramatically reshape water operations in the state (California Department of Water Resources, 2009). California voters would have to grant final approval to the $11.14 billion bond package, a large portion of which would go to finance improvements to the state's water supply system, and complete ongoing water projects in the Central Valley (p. 7). Before ballots were printed, key water bond supporters decided to withdraw the proposal in favor of gaining more time to develop their campaign and win public support (BizFed, 2010).

Financing large water supply projects will challenge state policymakers to identify and pursue those projects that maximize beneficial uses of water at the lowest cost. The demand for additional water supply is high, yet only $11.14 billion would become available for diverse water-related projects under the water bond – only a portion of that would be available for supply improvements and grants for demand reduction. Inevitably, major California water policy changes must be weighed against consideration of federal policy and broader questions of appropriateness of water use.

A large part of California's water problem stems from the fact that agricultural water is not priced appropriately in California, frequently falling far below other types of water, resulting in overconsumption by agricultural water users. Instead of a water market, wherein all water users compete for access to water by sending and receiving price signals, most California water is obtained and earmarked for specific uses in government programs. This includes the Central Valley Project (CVP), operated by the US Bureau of Reclamation (BoR), which provides federally subsidized water to agriculture for irrigation under fixed-rate contracts for up to 40 years. Today, this well-intentioned policy devised in 1933 has resulted in artificially low water prices for agricultural water users (US General Accounting Office, 1994).

This is especially problematic because the CVP is the single largest owner of water rights in California, holding approximately 38% – water rights are the legal entitlement to a share of useable water and are usually attached to a source like a watershed, reservoir or river (Legislative Analyst's Office, 2008). The General Accounting Office (renamed the Government Accountability Office in 2004) found that the fixed-rates were no longer working and that the revenue from the contracts do not cover the operation and maintenance costs and are insufficient to cover the repayment costs of the $1 billion capital costs of the project (p. 13). In fact, the vast majority of the capital cost remains unpaid today, highlighting the historical divergence between the price of the water delivered and the cost of production.

Historically, fixed water rates, those charged by the CVP to water districts and wholesalers, have ranged between $2-$10/af (p. 14). After the cost of conveyance and delivery is factored in by the district or wholesaler, the final price paid by farmers may rise substantially. Yet the final prices still remain below the actual cost of production and the price paid by other water users around the state – Central Valley retail agricultural water users frequently contract for water at prices of only $7-$150/af (p. 14).

This eventually resulted in the Reclamation Reform Act of 1982 which created new rate structures that reflect the operation and maintenance costs and the repayment of capital costs (p. 13). This has partially addressed the problem, but hundreds of millions of dollars remain unpaid, both for the capital cost, interest on that cost serviced by the federal government and operation and maintenance debt. The 1982 legislation requires new terms for fixed-rate contracts (upon renewal), chiefly that the cost of repayment of the capital cost costs be incorporated into the rates going forward and that the capital cost be completely repaid (without interest) by 2030 (p. 14). Operation and maintenance deficit costs are also to be included in the new “cost-of-service” rates. In 1997, it is estimated that “over one-fourth” of the original 40-year contracts will have become subject to the new rates.

Progress on federal water finance policy for the CVP only addresses part of the problem with agricultural water pricing relative to shortages. Because farmers are locked into actual contracts with the federal government, any modification could result in successful litigation based on claims that the United States breached its contracts – these lawsuits could even subject the federal government to claims for damages (p. 43). Therefore, many aspects of CVP policy are unalterable in the near future to the extent that a large portion of 40-year fixed rate contracts remain on the books. As some costs were left out of the new rate structures provided for under the 1982 legislation, it is hard to imagine that CVP water will come into perfect market price parity in the next several decades. Still, the tremendous demand for water for other non-agricultural uses makes long-term planning around the potential for bringing more agricultural water into a market an important consideration for state policymakers.

The remaining fact that about 75% of California's water is underpriced, about half of which is dramatically underpriced by the CVP, has spawned a growing chorus of critics that prominently include fiscal conservatives and environmentalists. Aileen Roder with Taxpayers for Common Sense calls the contracts a "raw deal" while Barry Nelson with the Natural Resources Defense Council suggested that farmers should, "get off the welfare rolls" (Carlton, 2004). Chris Edwards with the Cato Institute (2007), that primarily advocates for "free markets" and reduction of federal spending, also suggests that "water should be moved into the free market and allow prices to rise to efficient and environmentally sound levels."

Farmers argue that agriculture in California must compete in a global market against farmers with lower costs, leaving little room to raise prices to compensate for more expensive water (Carlton, 2004). Furthermore, they argue, agriculture in California has been hit hard by water allocation reductions and the weak economy; many are already using drip irrigation and other water efficient practices that leave little additional room for improvement. If farmers' rates for water go up substantially, they would lose profits, be forced to change crops or lay off workers.

The General Accounting Office (1994) report looked at model farm budgets representing farm operations in the Central Valley which showed how profits decline as water rates rise to meet the market under a variety of scenarios (p. 7). Those models showed that farms were likely remain profitable and that while some farms would be hit hard, the overall effect of increasing water prices "is not likely to be severe" (p. 41). The report also notes that additional water could be freed up for alternate uses and that federal revenues would increase more quickly, allowing accelerated retirement of CVP debt.

Having so much of California's water being tied to long-term fixed-rate contracts that are so cheap relative to the cost of production is a major element of California's overall water problem. If federal and state policymakers acted quickly to bring agricultural water prices more into line with the prices paid by other water users, the effects would still not be realized for several decades. The vast majority of California's water will probably not be priced appropriately for some time, suggesting the importance of considering these policy changes now while also ensuring that the remaining water portfolio is managed cost-effectively to harness limited resources at minimal cost.

While agricultural water use reform may be a bright source of long term progress in the state, the effects of climate change on California's water portfolio will probably grow over time and are not well understood today. While the possible range of effects of climate change are diverse, we know that saltwater intrusion into the San Francisco Bay-Delta estuary from even minor sea level changes or the possibility of persistent reductions of precipitation in California pose serious threats to California's long-term water security.

In 2009, the California Climate Adaptation Strategy report (California Natural Resources Agency, 2009) was released as a response to Governor Schwarzenegger's Executive Order S-13-08 (2008). As the report points out, 75% of California's water originates in the northern third of the state, mainly from snowpack (p. 81). About 80% of the demand for this water comes from the southern two-thirds of the state.

The report states suggests that drought conditions are likely to become more frequent and persistent in the next century, creating additional reliance on the state's storage and conveyance projects to manage limited resources. However, because much of the state's water physically travels through the Sacramento River into the Delta where it is picked up by the California Aqueduct, the threat of sea level rise poses a serious risk the state's entire water conveyance system which relies completely on the Delta (p. 80). Meanwhile, demand is likely to increase during dry years, exacerbating the problem for state policymakers.

A number of historical policy challenges and new emerging problems face state policymakers and water managers. By limiting the state's flexibility and eliminating some of the state's water resources altogether these challenges make cost-effective decision making all the more important. The limited financial and water resources available to California must be used to the maximum potential going forward. Investments in less cost-effective projects will inappropriately divert resources away from other state priorities, while leaving inappropriately used water unavailable for other uses. Cost-effectiveness analysis is an important tool to use to ensure that tax dollars are well spent and that California's water is appropriately managed (Levin & Henry, 2000).

Overview of Report

This report will examine the three most important alternatives for the state to address the perceived need for more water. The alternatives evaluated here are limited to efficiency measures, desalination and surface storage projects. Efficiency measures involve evaluating how water is used and attempting to achieve the same or similar results while using less water overall. Desalination involves withdrawing ocean water and passing it through high pressure filters to remove salt, sediments and other impurities, preparing it for a variety of uses. Surface storage projects in the context of this report refer to large reservoirs, usually involving the construction of concrete dams that hold back river water, forming a reservoir.

These three alternatives may be described as "important" for two reasons. First, these happen to be the most realistic options that California has at its disposal to increase our access to water. Second, these three alternatives have caught the attention of major segments of the California public, each having gained major factions of political support – effectively the debate over water supply in California today is a competition between efficiency measures, desalination and surface storage. Other alternatives exist, but they are either unrealistic, incapable of large scale deployment or lacking for the cost-effectiveness data needed to consider them.

Cloud seeding is a classic example of a water supply approach that is known to work but that only delivers small and diminishing marginal returns and lacks sufficient reliability. The 2009 Water Plan Update (California Department of Water Resources, 2009) discusses many alternatives to improve access to water. The Water Plan Update suggests that many of these alternatives may be valuable in the future but lack specificity today and require further study. Of the strategies excluded from this report, water recycling remains the most developed alternatives. The Water Plan Update, states that, “Without a systematic inventory and reporting system, it is impossible to quantify water recycling efforts, characterize success and/or failures, or make informed decisions as to future endeavors and funding priorities” (p. 243). The remaining alternatives that need further development, brackish groundwater desalination, wastewater desalination and meadow restoration, also come with extremely limited data and are inappropriate for cost-effectiveness evaluation in this report.

Chapter 2 begins with a brief literature review designed to help orient readers towards the subject matter by describing past attempts to compare sources of water on a marginal cost basis. The review will begin with state (CA Department of Water Resources) and federal (US Department of the Interior, Bureau of Reclamation) reports as produced by lead agencies evaluating the major water supply projects. It will then discuss reports by analytical and interest groups that have contributed to the discussion of cost-effectiveness of water projects.

Chapter 3 will discuss the methodology used in this report to gather and compare data on cost-effectiveness. It begins with a discussion of the reasons for using this approach when compared to other approaches. Next, the units of measurement used in this study will be explained. Finally, a brief summary of the demand reduction approaches and the supply project proposals will be laid out.

Chapter 4 provides an overview of the major water supply project alternatives presently receiving serious consideration by state and federal policymakers for which estimable price ranges per unit of water exist. The section is broken up by alternative, beginning with efficiency measures (agricultural and then urban), desalination and surface storage. For each alternative, the discussion includes a legislative and policy background, a discussion of the best available cost information from relevant studies, and a discussion of the methodology used to reconcile the available data used for comparison. Finally, case studies will be discussed where available to demonstrate a range of results that has actually been achieved.

Chapter 5 discusses the cost-effectiveness data for the selected alternatives. The section begins with a presentation of the costs of the projects on an acre-foot basis. It will discuss appropriate decision criteria for cost-effectiveness analysis, including least cost and others. I will then make recommendations based upon the data and the decision criteria which will provide a basis of choosing which investments in water supply or demand to prioritize first, given limited resources for investment.

Chapter 2

LITERATURE REVIEW

This section briefly discusses the two important contributors to a comprehensive discussion about cost-effectiveness of water projects. It outlines the major contributions of two organizations, the Department of Water Resources and the Pacific Institute. The goals, methods and impacts of those reports will be explained in this chapter. The findings of those reports will be discussed in greater detail in Chapter 4 and supplemented by other works.

The 2009 California Water Plan Update

The California Department of Water Resources (DWR) has performed extensive research on many supply enhancement and conservation strategies, including some approaches that are new, experimental, unready for mainstream use, or lacking specific data. Volume 2 of the 2009 Water Plan Update (WPU) includes detailed information on resource management strategies for use around the state in a variety of contexts. The report is updated every five years by DWR to help state policymakers choose alternatives that maximize beneficial uses of water.

The two elements of the WPU relevant to this report are the sections on reducing water demand and increasing water supply. The basic goals of those sections are to provide state policymakers with options to increase California's total access to water, both in terms of adding additional water supply to the state's water portfolio and by reducing demand through efficiency and conservation measures.

The supply section of Volume 2 includes six alternatives that include conjunctive management and groundwater, desalination, precipitation enhancement, recycled municipal water, surface storage operated by CALFED and surface storage operated by regional and local authorities. Because of extreme variance in those six approaches, only desalination and surface storage operated by have fairly well-developed estimates of cost associated with each alternative. The other four are subject to extreme variance and lack estimates of marginal cost.

The desalination portion of the WPU makes estimates of the costs associated with each potential project based on known costs of construction and making comparisons to existing projects. These estimates are based upon known cost drivers for construction, maintenance, operation and finance of a desalination plant. These variables most frequently include construction capital costs, discount rates, energy costs, labor costs, parts and maintenance, chemicals, membranes (the filters used that must be replaced), seawater salinity, operation cycle and citing and permitting. Based on these variables, the WPU produced an estimate for seawater desalination of about $1,000-$2,500/af for future projects.

The surface storage projects operated by CALFED section uses a combination of econometric modeling, benefit-cost analysis and cost-effectiveness analysis to produce estimates of the desirability of four major proposed dam projects in the state. Those projects are the Shasta enlargement, the Sites reservoir, the Los Vaqueros enlargement and the Temperance Flat reservoir. Each of the projects are dramatically different from one another, but share a similar and comparable set of variables that include capital construction cost, finance cost, discount rates, maintenance costs and operation costs. After costs were calculated, the WPU used econometric models unique to each project to develop an estimate of the relative desirability of each project in a benefit-cost ratio. Based on estimates of average annual water yield, the WPU produced benefit-cost ratios of 1.61 (Shasta), 1.14 (Sites Reservoir), 1.29 (Los Vaqueros) and 1.06 (Temperance Flat).

Based on these estimates, DWR is recommending that the state move forward with investigations of potential desalination facilities and surface storage projects. These estimates have been influential in moving state policymakers towards supporting the implementation of those projects but funding remains seemingly unavailable without the passage of a major bond measure of an agreement to pass on all costs to ratepayers. Still, the development of estimates of cost has had dramatic impact on the public discussion of these projects both by allowing proponents to think more seriously about the projects and by inviting additional criticism of the projects from environmentalists and advocates for fiscal restraint and austerity.

The WPU also developed estimates of cost for conservation and efficiency measures for both urban and agricultural use. One approach for reducing water use common to urban and agricultural water use is the potential for long term water savings obtainable by installing more efficiency hardware, including sprinkler heads, faucets, showerheads, washing machines, just to name a few. In most cases, this approach involves the local water authority giving grants, rebates and other incentives to private entities to encourage them to install more efficient hardware. In the agricultural context, this approach also involves large scale infrastructure improvements like lining of canals or upgrading conveyance to save water loss. Another common but controversial approach is water pricing. Water pricing schemes involve artificially setting the price of water for certain usage levels in order to compel reductions in use.

These efficiency and conservation alternatives were evaluated using econometric models that compared the estimates of the costs of each alternative to the potential savings from reduced water use. Based on the available information the WPU estimated that these measures would save water (the functional equivalent of increasing supply) at a rate of $233-$522/af (2004 dollars).

The Pacific Institute

The Pacific Institute has performed a great deal of research on efficiency programs and desalination. It has produced several reports looking at different aspects of California's water program. Each report aims to discuss the cost-effectiveness of water projects or contains major sections dealing with the topic (Pacific Institute, 2011).

The Pacific Institute has played a major role in raising awareness about the affordability of conservation and efficiency programs relative to other alternatives. It frequently plays the role of advocate for these approaches, expressing concern about new surface storage projects and desalination of ocean water. None of the Pacific Institute's policy reports directly discuss the role of surface storage projects in addressing California's water needs, instead proposing increased use of underground storage (Gleick, 2011).

The institute's report on desalination expresses a great deal of skepticism, suggesting that it remains uncompetitive with other approaches to water supply (Cooley, H., Gleick, P. H., Wolff, G., 2006). The report uses several economic valuation models to determine the cost of water produced from desalination in different scenarios (p. 39). It also includes a willingness-to-pay model that estimates the value of reliability that may be a factored into deciding to go forward (p. 47). The report concludes that the basic cost of production is about $977-$1,140/af range (2005 US Dollars) (p. 45). However, the report also suggests that given a wide range of factors, the cost of production could rise to as high as $2,932-$3,259/af (2005 US Dollars) (p. 39).

The institute urges policymakers to consider the costs of desalination relative to other approaches (p. 82). It recommends developing a better sense of how to judge these projects and emphasizes the potential environmental impacts. It suggests that, "California should pursue less costly, less environmentally damaging water-supply alternatives first." Finally it urges comprehensive, transparent public scrutiny of these projects.

The institute suggests that agricultural water use efficiency approaches are preferable to surface storage projects and other supply approaches based on cost-effectiveness analysis (Cooley, H., Gleick, P. H., Christian-Smith, J., 2008). It does not discuss many specific details about specific measures or their cost-effectiveness, largely due to the fact that little good data exists on agricultural water use beyond large-scale estimates (p. 50). This is discussed later in Chapter 4 in section 4.1.0 dealing with agricultural water use efficiency. Gathering additional data on agricultural water use and developing best management practices is heavily emphasized in the report (p. 49).

The Pacific Institute also prepared a report that urges policymakers to invest in urban water use efficiency (Gleick, P. H., Haasz, D., Henges-Jeck, C., Srinivasan, V., Wolff, G., Cushing, K. K., Mann, A., 2003). The institute employed a peer reviewed comprehensive study using a number of scenarios and efficiency measures to estimate the potentials savings from reduced urban water use. This increased a full range of measures from water pricing schemes to replacement of home appliances. The study focuses on deployment of existing technologies and modest changes to existing water use.

This report suggests that a large volume of urban water can be saved at a cost of $50-$600/af. More specifically, the report suggests that a volume of 663,000 af of water can be saved for $50/af, 147,000 af for $103/af and more than 2,000,000 af for $600/af (p. 115). All in all, this represents a total savings of 2,810,000 af/year representing an investment of $1,248,291,000 (2002 US currency). The weighted mean average of these savings is $444/af.

As a policy institute and as an advocacy organization, the Pacific Institute strongly supports the prioritization of public dollars for urban water use efficiency investment. This is partly an analytical conclusion based upon cost-effectiveness analysis and partly driven by the desire to pursue policy alternatives that minimize environmental impacts.

The Pacific Institute commands significant authority over discussions about water policy. Based out of Oakland, California, the institute and its staff routinely publish editorials and policy briefs that make their way into the hands of policymakers. It both pushes and is pushed by California's significant environmental movement, a process that doubtless impacts the decisions of policymakers at all levels of government. This influence probably extends to weak support for the current water bond proposal under consideration by the California State Legislature in part due to the perception that it will go to fund "big dams" at high cost (The Field Poll, 2010).

Other Contributors

Two major California policy research organizations, the Legislative Analyst's Office (LAO) and the Public Policy Institute of California (PPIC) have performed extensive analysis of water projects over the years. Those organizations take different approaches in their analysis, rarely mentioning cost-effectiveness or delving deeply into the economics of competing approaches to solving California's water supply. These groups highly respected for the quality of their research and hold sway over the attitudes of policymakers and the public at large. Unfortunately cost-effectiveness analysis is not a major component of their research to date. The PPIC has suggested that reallocation of water in the market could be a major improvement but faces "institutional hurdles" consistent with those described above in the discussion of agricultural water pricing (Hanak, 2005, p. 27).

The Residents for Responsible Desalination (R4RD) is a growing policy research organization that has chosen to focus its attention towards raising concerns about desalination of seawater. The R4RD marginal cost investigation explores the various cost drivers of desalination and applies different scenarios to four case studies in California (Fryer, 2010). From study of four proposed desalination plants, the R4RD report produced a range of estimates of cost for ocean water desalination between $2,000-$3,000/af (2009 US Dollars) (p. 3). Like the Pacific Institute, R4RD maintains strong ties to environmental advocacy organizations, transmitting attitudes in a reciprocal fashion.

Cost-effectiveness analysis and the requisite data needed to perform it remains somewhat limited for California water supply alternatives. For the three major alternatives evaluated in this report, a fair amount of good data and analysis exists. Much of the analysis relies upon the extensive and ongoing research conducted by the California Department of Water Resources, but some substantial independent analysis has been performed by the Pacific Institute and the Residents for Responsible Desalination, especially for efficiency and desalination alternatives.

Enough information and analysis exists to reasonably conclude that large, cost-effective water savings can be realized by implementing greater efficiencies around the state by urban and agricultural users, while surface storage and desalination are less cost-effective alternatives. Going forward, it should be a priority to make cost-effectiveness analysis more comprehensive and incorporate more unmeasured costs (like environmental or equity costs). Additional data is also badly needed to support consideration of other less-well understood supply alternatives. The next section of the report describes how the existing cost information may be verified and compared to original data sources to gain a clearer picture of the cost-effectiveness of each alternative evaluated in this report.

Chapter 3

METHODOLOGY

3.0 Cost-Effectiveness Analysis

This report takes a meta-analytical approach to cost-effectiveness analysis (Levin & McEwan, 2000, p. 125). In the simplest terms, meta-analysis is an approach that looks at and combines the results of several related studies in order to compensate for limited data. By gathering and comparing information from reputable sources about the costs of water projects, checking their methods and in some cases, updating that information, a clearer picture of the cost-effectiveness is realized. Few reports compare the three major categories of water supply projects in reasonably accessible terms. The Water Plan Update attempts to do exactly that, but cites optimistic cases that are sometimes out of date. This report will survey and evaluate the three major supply types (efficiency, desalination and surface storage) to gain insight into cost-effectiveness of those approaches.

Cost-effectiveness analysis (CEA) is an approach designed to assess decisions that affect the use of scarce or limited resources. In simplest terms, CEA compares the costs and effects of a policy, without regards to benefits (Levin & McEwan, 2000, p. 108). Instead, the selected “effect” replaces the “benefit” as a non-monetized measure. The CEA measures and compares the cost per unit of the effect for different alternatives.

While many forms of analysis are used to estimate the desirability of policy that effects water supply, CEA provides a great value as a compliment to other forms of analysis that are based upon complex valuation methods that tend to produce high estimation error generating extreme uncertainty in the final outcomes. The US Bureau of Reclamation and the Department of Water Resources use fairly sophisticated benefit-cost assessments which are used to rank bureau preference for the various policy alternatives under consideration.

With large dam-reservoir projects, or other capital intensive projects involving construction of large facilities over thousands of acres of land, many valuation techniques are used that may produce high levels of uncertainty. In the case of a large reservoir, the project may impact a large region, creating economic ripple effects that are not well understood or entirely estimable. These effects tend to range from more to less estimable, depending on their causal proximity to the policy effect.

For instance, new hydro-electric energy generation at a dam facility represents a benefit that is more accurately estimable, because of past experience with the technology, knowledge of energy prices on the wholesale energy market and by design of the dam features. Recreation benefits related to water-skiing, camping or other related benefits may be moderately estimable based upon past experience and knowledge of the physical geography. The effects on a local or regional economy of releasing discharge brine near a coastal community, in the case of desalination, are not well known and are less accurately estimable.

The controversy surrounding the use of certain valuation methods also remains a major drawback to over-reliance upon the more sophisticated forms of meta-analysis that often involve combining several forms of analysis, alternating between approaches at different phases of an analysis or using different forms of analysis inconsistently between project alternatives (US Department of the Interior, Bureau of Reclamation, 2007). In the case of the Shasta Lake Water Resources Investigation, the Bureau of Reclamation alternated between benefit-cost assessments involving many types of valuation techniques, variations of a criterion-alternatives matrix approach and environmental impacts estimations that are used differently for other similar project alternatives. While this may represent the best available approach to a complex policy decision, it is prone to uncertainty.

Stepping back and looking at one element of the policy, the annualized cost per unit of water provides a useful compliment to other forms of analysis. This report proceeds from the principle that it is beneficial to have a more reliable estimate of one element of an analysis than a comprehensive analysis that is prone to systematic uncertainty. It is also notable that this approach does not subtract from work completed by water agencies or interested groups. This report extracts cost information from prior works, updates and normalizes that information and presents it in a meta-analysis that will highlight the costs of water project alternatives.

By including only the direct cost data and reducing it to a common metric ($/af of water) this report provides a useful compliment to other policy reports designed to shed light on the problem of improving the state's access to water. While water is a monetizable commodity, uncertainty around pricing makes focusing on cost a preferable approach. Water pricing involves more complex market mechanisms and includes other cost drivers like conveyance, regional market variation and purification.

3.1 Cost Information

The literature for each alternative presents cost-effectiveness data in one consistent measure: dollars per acre-foot ($/af). For some of the data, cost-effectiveness information must be prepared by unit conversion. For the reservoir construction project alternatives, many of the initial alternatives reports contain cost estimates that rely on outdated assumptions, especially discount rates that reflect market conditions from the years in which the reports were prepared. In these cases, these cost estimates were reverse engineered and recalculated using updated discount rates and other updated assumptions to improve consistency, where appropriate.

Inflation Adjustment

All cost information is converted into 2010 US Dollars by adjusting for inflation using the Gross Domestic Product deflator, a comprehensive measure of inflation in the US economy (Officer, L., Williamson, S.H., 2011). The GDP deflator compares the average change in value of *all goods and services* in the US economy over time. Unlike the Consumer Price Index (CPI), a measure of the average change of value of a *selection of goods*, the GDP deflator accounts for changes in value of the total economy and is considered to be a better measure of inflation when evaluating large scale infrastructure projects whose constituent supplies and materials are purchased in large markets subject to national and international cost pressures.

Discount Rates and Discounting

Discount rates are the measure of the difference in the value of money over time. While sometimes confused with “interest rates,” interest rates are frequently based upon discount rates and other factors, causing them to vary slightly. Simply stated, discount rates reflect the various factors that cause money to change in value over time (Fuguitt & Wilcox, 1999, p. 101). Money is usually considered to be worth less in the future than in the present – discount rates provide a measure of that difference of value. Two important reasons for using discount rates are the declining value of money due to inflation and the social rate-of-time preference.

Economies tend to experience inflation, typically through rising prices, for a variety of macroeconomic reasons, including excess money in the economy and excess demand relative to limited supply. The social rate-of-time preference is a generally accepted phenomenon that reflects our many social, cultural and economic preferences for money to be available now, rather than later. Macroeconomists and financial institutions combine these factors to produce an estimate of the value of money today, relative to some moment in time in the future. The interest rates experienced by consumers and borrowers reflect the discount rates that are factored into the calculation of appropriate interest rates (p. 106).

Large scale capital intensive infrastructure projects may require capital finance mechanisms that provide for borrowing of large sums of cash now and repayment later. This form of borrowing often involves repayment periods of twenty, thirty or even one-hundred years. To determine the cost of this money over time, a discount rate is used to factor in the difference in value between money today and in the future. Similar to a monthly credit card payment, discount rates allow for the calculation of an annual repayment using the following formula:

$$\frac{\text{Capital Cost x Discount Rate}}{\text{1-(1+Discount Rate)\^{}-Repayment Period in Years}}$$

After inputting the capital cost, discount rate and the repayment period, an annual repayment cost is produced. The discount rate has a strong mathematical influence on the final outcome – a lower discount rate indicates that the total cost of the project is lower, requiring small annual repayments.

This report maintains a consistent discount rate to eliminate variance in marginal cost figures due to inconsistent application of this important financial variable. For all projects whose annuity payments were recalculated based upon known capital costs and amortization periods, the 2010 Discount Rate for Water Resources Planning was selected. This discount rate was 0.04375% and was based upon US Department of the Treasury borrowing rates, pursuant to the Water Resources Planning Act of 1965 and the Water Resources Development Act of 1974 (US Bureau of Reclamation, 2010).

3.2 Demand Reduction Alternatives

The two important demand shifters that are included in this report are agricultural efficiencies and urban efficiencies. These measures are thought to reduce demand making the excess water available for other uses (California Department of Water Resources, 2009, p. 26, p. 63). While these measures are not related to supply, they do decrease demand and reduce the potential for shortage. These measures help the state avoid alternative draconian rationing measures that occur during dry years and periods of persistent drought.

These measures are highly diverse and rely on implementation of new technologies and practices which are designed to reduce water usage and make water-using activities more efficient. These include installation of water efficient washing machines, replacing indoor fixtures that are known to leak or develop leaks, agricultural watering practices that involve computer control and specialized timing and other measures that are known to produce water savings at estimable cost. An important component of this effort is data collection, beginning with installation of water use meters to determine true levels of use in order to support further consideration of efficiency and conservation measures.

3.3 Supply Improvement Alternatives

This report includes analyses of the four most feasible surface storage (dam-reservoir) projects under consideration today by local governments, DWR and BoR. These are the Los Vaqueros Reservoir Expansion, the Sites Reservoir project, the River Mile 274 San Joaquin River Reservoir, and the Shasta Reservoir Expansion (p. 259). Each of these projects would increase supply by 100,000 af or more per year and are included due to their scale and the likelihood of their implementation.

Desalination alternative cost-effectiveness data remains somewhat hypothetical without more specific project alternatives to compare (p. 205). A number of existing facilities may be evaluated and planned projects with feasibility reports are being explored for projects in coastal communities. The picture of desalination is complicated by the divergent views on the feasibility of the technology, the divergent cost estimates for different project alternatives in recent years and the likelihood of volatility of energy prices in the future. Other concerns about long term environmental feasibility related to brine discharge create additional unknown costs.

This chapter built upon the literature review and summarized the methods and factors that go into determining estimates of cost-effectiveness in the next chapter. First, an overview of cost-effectiveness analysis and meta-analysis was provided. Next inflationary effects and discount rates were discussed. Finally, the alternatives under evaluation in the next chapter were described. The following chapter will examine the data and analyses available for each alternative, compare those to case studies and gather cost-effectiveness estimates that may be used to prioritize investments.

Chapter 4

COST-EFFECTIVENESS ANALYSIS

4.0 Demand Reduction & Supply Improvement Alternatives

This section of the report is organized by three major categories of project alternatives: efficiency measures, desalination projects and surface storage projects. Each have different bodies of research supporting their implementation. California water planners and their partners in the federal government know a lot about building dams. California also knows about desalination, but the technology involved is constantly evolving to the extent that the costs are probably more uncertain. We also know a great deal about improving efficiency, but we know more about some types of efficiency improvement than others. The approaches we take to storing water in large reservoirs, filtering salts out of water or using water more efficiently are each fundamentally different. The literature for these approaches, the methods for calculating costs and the cost structures themselves reflect these fundamental differences.

For each alternative, a brief summary introduces the alternative, followed by section on legislative and policy background. Next, cost information and the methodology are discussed - cost figures are updated or converted, producing cost-effectiveness estimates for each approach. Due to fundamental differences between each project alternative, consistent methodology is not available – the best available estimates of costs for each project alternative are collected and adjusted appropriately to demonstrate per unit cost in acre feet.

This section includes agricultural and urban water efficiency and conservation, desalination of ocean water and surface storage projects. These alternatives were selected because they are most credibly believed to have the largest potential for supply improvement. Other alternatives like precipitation enhancement (cloud seeding) or water transfers (market exchanges between users) were excluded because they lack data or are not practical on a large scale relative to surface storage, desalination and efficiency improvement (California Department of Water Resources, 2009, p. 13). A summary of the cost-effectiveness information for each project alternative or supply approach is found in the conclusion and displayed in Appendix A.

4.1 Water Use Efficiency

The Department of Water Resources estimates that 1.4 to 3.2 million af/year in increased water supply may be realized by state water planners from increases in efficient use of existing water supplies (CALFED, 2006). That includes high estimates of 1.137 million af/year from agricultural efficiencies alone. It is believed that this water can be captured inexpensively through implementation of cost-effective demand management measures.

4.1.0 Agricultural Water Use Efficiency

Agricultural water use efficiencies focus on adopting new irrigation practices like drip irrigation or spot (drip/micro) irrigation coupled with computer control to time water for optimal delivery to soil with minimal evaporation (California Department of Water Resources, 2009 p. 25). It also includes larger scale approaches like upgrades to conveyance structures (usually canals) that improve efficiency on a larger regional scale. DWR identified three major activities that represent the greatest achievable gains in agricultural water use efficiency - hardware upgrades, water management and crop water consumption targeted at reducing non-beneficial evapotranspiration.

Legislative & Policy Background

The Agricultural Water Suppliers Efficient Water Management Practices Act (AB 3616, 1990) established guidelines for improving agricultural efficiency and created advisory committee consisting of federal, state and local agencies, water users, academia and environmental groups to develop a list of potential efficiency measures. In 1996 the AB 3616 Advisory Committee adopted a memorandum of understanding between the environmental and agricultural communities and government agencies to focus on consensus based initiatives to cooperatively address water conservation measures (Agricultural Water Management Council, 1999).

That MOU established the Agricultural Water Management Council (AWMC) to continue the work set out under the terms of the MOU and "advance the efficiency of farm water management while benefiting the environment." The AWMC succeeded in uniting 79 water suppliers and four environmental organizations toward the goal of improving water use efficiency (California Department of Water Resources, 2009 p. 26). As of 2009, 66 of the water suppliers subject to the MOU submitted water management plans (WM Plans) that specified strategies to improve efficiency (p. 26).

SBX7 7 was part of a comprehensive water package adopted by state lawmakers and the governor in 2009 that included SBX7 1 (Delta Governance/Delta Plan), SBX7 2 (Water Bond), SBX7 6 (Groundwater Monitoring), SBX7 7 (Statewide Water

Conservation), SBX7 8 (Water Diversion and Use/Funding) and the proposed $11.14 billion water bond for voter approval under SBX7 2 (California Department of Water Resources, December 2009). SBX7 7 required water suppliers to submit WM Plans to DWR in a standardized process that satisfied the data needs of several state departments. It also requires suppliers to measure and record water deliveries accurately and to develop consistent pricing structures based in part on the quantity of water delivered. This effort remains in its early stages as agricultural water suppliers are not required to submit Agricultural Water Management Plans until December 31, 2012 (p. 5).

Unlike the provisions for urban water use, SBX7 7 did not specify an efficiency target or a target date for agricultural water use (p. 5). Environmental groups pushed for tougher efficiency policies including mandating and enforcing “Efficient Water Management Practices” (EWMPs) through the State Water Resources Control Board and reform of water rights, which they argued, “provides incentives for water conservation and efficiency improvements” (Cooley, H., Gleick, P. H., Christian-Smith, J., 2008, pg. 9). Agriculture representatives argued that agricultural water users had been improving efficiency for years and that most cost-effective measures had been taken. This produced "demand hardening" meaning that further reductions in demand would come with decreasing marginal returns. Additional gains in efficiency, it was argued, would be highly costly relative to progress already achieved.

Instead, SBX7 7 authorized water suppliers to impose water use reduction targets or specific efficiency goals with majority votes from a governing board. Water suppliers like Thad Bettner, Glenn-Colusa Irrigation District general manager, stated that trying to calibrate a device to measure volume is difficult, expensive and time-consuming (Campbell, 2011). Last year, the district used 600,000 acre-feet of water, he said, "and I can tell you exactly what ran through our headgate, our laterals, where our losses were, where every drop of water went. I can tell you exactly what went onto the fields. If I have to spend time trying to get private landowners to figure out their water use, it will take three to five years to implement volumetric pricing."

Yet for state water policymakers to pursue efficiency policies, or corroborate the claims made by industry, additional data is needed. “The State lacks comprehensive statewide data on cropped area under various methods of irrigation, applied water, crop water use, irrigation efficiency, water savings, and the cost of irrigation improvements per unit of water saved,” DWR states (California Department of Water Resources, 2009, p. 43). It is acknowledged that installing and calibrating measurement equipment is potentially costly but is only the beginning of moving towards market-based reallocation policies in collaboration with the federal government – this is an issue for DWR to consider carefully from an equity and economic standpoint.

Cost-Effectiveness

Marginal cost estimates for agricultural water use efficiency improvements vary widely and few detailed efficiency-measure studies have been performed. The CALFED Record of Decision (ROD) (2000) estimates that irrecoverable flows could be reduced by 150 and 660 hm^3/year by 2030 at a cost of \$0.028-\$0.730/m^3. Irrecoverable flows are defined as that water that cannot be returned to re-application (recycled) following first use (California Department of Water Resources, 2009, p. 25).

When converted to acre-feet, that is the same as a range of 1,216 to 5,350 af/year at a cost of about $35-$900/af ($45-$1,150 in 2010 USD) (p. 33). While the lower range of marginal cost is quite attractive, no distribution was provided in this estimate to account for the wide range of the cost estimate in the ROD. This estimate was also limited to only 5,350 af/year although the marginal cost range for $35-$900/af is frequently attributed to larger potential gains, be it appropriate or not. The $35-$900/af is the most commonly occurring estimate in the literature and is based on the assumption of an 85% reduction of agricultural water use in all hydrologic regions using a number of inputs.

Specific agricultural use efficiency measures include proposals to line the All-American Canal (67,700 af/year) and the Coachella Branch Canal (26,000 af/year) to produce a net reduction of 93,700 af/year at a capital cost of $220,000,000 (1999 USD) (p. 33). When cost is adjusted (it rises to $281,000,000) using the GDP deflator and an annual repayment cost is calculated based upon a 100-year repayment period using the Fiscal Year 2010 Discount Rate for Water Resources (4.325%), that 93,700 af/year would cost only $133/af.

The proposal to line major sections of central valley canals is an example of a project that may have potential monetary and non-monetary costs that could also harm other supply projects in the long run (Dibble, Gardner, 2009). Among the positive unintended consequences of using large unlined canals, seepage has contributed to and sustained the formation of large wetlands. Over 70 years, seepage of Colorado River water from the All-American Canal has formed the Andrade Mesa Wetlands, an important life supporting ecosystem that covers over 15,500 acres (Hinojosa-Huerta, 2002). Seepage from canals around the state may also be contributing positively to groundwater recharge, restoring a source of water than may eventually be used to augment supply at cost to state taxpayers (Burt, 1999).

Since the ROD in 2000, other studies have suggested that much higher gains in total water use reduction are possible, but few specific marginal cost figures with which to compare to other significant proposals are offered that can be supported by specific methodologies for independent verification.

The Pacific Institute (2008) has explored the potential for water savings by comparing existing crops and water use intensity with the costs of installing new irrigation equipment. That report points to an online resource, the *Drip-Micro Irrigation Payback Wizard* (2008), that can use a number of inputs, assumptions and a national water database to calculate a repayment period - the period of time in which a farm owner can expect to realize sufficient savings to cover the cost of irrigation equipment installation.

For example a farmer in Central California with 50 acres of alfalfa that currently uses sprinklers and pays $25 per acre foot could install drip irrigation and save enough to cover the costs of installation in 2.28 years. Alternately, it could water an additional 14.71 acres for the same cost. If all other variables were the same but the price of water was $150 per acre foot, the payback period would drop to just 1.6 years. As the base price rises, the payback period falls. A full report is included with each estimate and explains each input of the calculation, offering the user a chance to adjust inputs based on experience and recalculate the payback period.

Without more specific data about existing and historical rates of agricultural water use, discussion of efficiency measures relative to agricultural use is limited. Still, some macro-scale estimates have been produced that warrant consideration while the state seeks to address the data gap, beginning with collection of existing baseline usage statistics. Some of the macro-scale estimates available include CALFED's 2006 estimate of $33-$416/af, the 2005 Water Plan Update's estimate of $44-$1,125/af and the 2009 Water Plan Update's estimate of $86-$683/af (See Appendix A.).

4.1.1 Urban Water Use Efficiency

Urban water use efficiencies focus on a comprehensive set of policy alternatives to reduce residential, municipal and industrial and other water use. The term efficiency is frequently used interchangeably with conservation. Usually conservation means changes in behavior designed to reduce use, whereas efficiency means changing behavior to get more from the resources that are available. These terms are frequently used interchangeably because both move the state towards closing projected water deficits; if we use less water or use water more efficiently— either act makes more water available for other purposes.

Efficiency efforts tend to revolve around technological retrofits and installation of new high-efficiency plumbing fixtures like toilets, showerheads, lawn sprinklers or appliances like washing machines (California Department of Water Resources, p. 76).

Policymakers can provide incentives for this behavior by giving rebates to water users that participate in the programs voluntarily. Free or low cost water use audits and consultations can also be provided to educate the public about ways to make water use more efficient. Conservation measures may also include tiered water pricing to provide incentives for reducing use or emergency measures like rationing or prohibitions against specific types of water use. Including all water in a market that allows consumers to determine their own level of use based upon price is one very efficient approach to achieving conservation, that is likely to raise revenue for investors in source water. Each approach is one tool available to policymakers that comes with different costs depending on the level of water use reduction being targeted.

Legislative & Policy Background

The severe drought of the late 1980s and early 1990s caused policymakers around the state to reexamine every aspect of water policy as part of a wide spread response to massive shortages affecting every part of the state. Over the course of the last twenty years, water policymakers have worked aggressively to develop strategies to change the way we use water to help to mitigate future shortages resulting from drought (p. 69).

Today, policymaking around efficiency measures is focused on development and adoption of best management practices (BMPs) or derivative model practices like EWMPs (p. 70) or urban best management practices (UBMPs) (p. 87). These practices, once developed are codified in urban water management plans (UWMPs) and adopted by the governing boards of public water agencies. BMP planning combined with specific efficiency measures, like replacing toilets, are at the core of the effort to reach targets established by the state legislature.

The Water Conservation in Landscaping Act (AB 325, 1990) directed the DWR to appoint an advisory task force to work with DWR to draft a model efficient landscape ordinance for local governments to adopt, replicate or provide good reasons for failure to comply (p. 69). This came as basic recognition of the fact that landscaping consumes a large portion of urban water use, 54% in 2005. Total urban water use hovers around 20% of the state's total water portfolio, falling in percentage terms during wet years and rising in dry years, largely because of increased outdoor use. AB 2717 (2004) created the California Urban Water Conservation Council (CUWCC) to develop model policies to update and expand on the provisions of AB 325. AB 1881 (2006) codified the work of the CUWCC by requiring local water entities to adopt model policies developed by the state or develop their own that are at least as effective.

The Urban Water Management Planning Act (AB 797, 1983 and updated in 2004) requires certain urban water suppliers to submit UWMPs to DWR every five years. Local agencies have reported substantial reductions per capita water use - the Los Angeles Department of Water and Power reports that it uses about the same amount of water as it did in the mid-1980s.

AB 1420 (2007) conditioned the disbursement of state funds upon successful adoption of demand management measures (DMM). It also directed DWR (contingent upon availability of resources) to form an Independent Technical Panel to develop new DMM. The technical panel was never formed due to lack of resources.

In 2004, the California Energy Commission adopted water efficiency standards for clothes washers, but because of federal preemption under the Energy Policy Act of 1992, California is seeking a state waiver that would allow the efficiency standard have force of law. The US Department of Energy denied the waiver - California is appealing before the Ninth Circuit US Court of Appeals.

In 2006, Governor Arnold Schwarzenegger signed Executive Order S-17-06, establishing the Delta Vision and Blue Ribbon Task Force to develop a long term management plan for the Delta. After about two years of work, the task force developed a long-term plan and a strategic plan for management of the Delta. Amongst its findings, it recommended legislation to reduce per capita water by 20% by 2020. It also suggested penalties for water suppliers that failed to implement BMPs.

SBX7 7 (2009), part of the comprehensive water package, focused on urban water use, mandated an ambitious reduction target for urban water suppliers of 20% by 2020. The law created several pathways for urban water suppliers to meet that goal, including setting a target of 80% of their baseline daily per capita water use, develop and implement performance standards for different types of use, meet the per capita water use goal for the specific hydrologic region (set by DWR) or use an alternate method developed by DWR. The law makes local water suppliers ineligible to receive state grants or other funding should they fail to comply.

Cost-Effectiveness

The startup costs and marginal costs of these water saving efforts vary widely. Water saving measures represent a vast universe of thinking about conservation and therefore often look different from others, making them difficult to compare or even measure. Some personal home improvement projects require home owners to voluntarily invest in their homes, sometimes gaining the benefit of a subsidy or incentive from state or local governments. Local governments and water districts around the state have offered incentives, including rebates, to property owners to replace their toilets with new water efficient "low flow" flush toilets that reduce water usage for toilets by about 70% at a one-time cost to local governments.

The City of Long Beach was the first city to impose mandatory water efficiency standards, including limits on certain types of activity (Long Beach Water Department, 2011). The program has contributed to 9-10% reduction of average use. This includes lawn watering is restricted to Tuesday, Thursdays and Saturdays before 9 am and after 4 pm, to reduce evaporation. As part of the program, the city issues educational letters to water users that are out of compliance. Repeated failure to comply can result in fines. The Long Beach Water Department also offers incentives for residential customers to replace water intensive lawns and other plants with drought resistant plants and landscaping at a rate of up to $2.50 per square foot, up to a maximum of $2,500 per resident. In terms of cost-effective water savings projects, retrofits are the classic example of an easily measured improvement. The experience of water suppliers around state demonstrates cost-effective water reduction from these types of efforts.

Goleta

The Goleta Water District provides water to about 85,000 customers in Santa Barbara County, primarily serving the city of Goleta (2011). Following the late 1980's, severe drought forced Goleta to seek new supplies and implement new efficiency measures. Its planners anticipated this and in 1972 established an efficiency program. Between 1987 and 1991, the district issued 15,000 rebates for plumbing retrofits, including high-efficiency toilets and showerheads.

As many as 2,000 new high-efficiency toilets and 15,000 new showerheads were installed, beginning in 1983. A comprehensive set of other measures were also taken that included education, free onsite water surveys and changes in metering and rate structure. Mandatory rationing was also imposed, directing water users to reduce use by 15%. The program cost the district about $1.5 million over several years (US Environmental Protection Agency, June 2002, p. 19).

The program is considered to be highly successful as the district experienced a 50% drop in per capita residential water use in just 1 year (between May 1989 and April 1990). The district reports that district water use fell from 125 to 90 gallons per capita per day. Multiplied by the number of users (about 75,000 during this period), the added 35 gallons per capita per day translates into about 2,940 af per year of new water that may be used for other purposes. This represents an 18.6% decrease in water use relative to existing supply at that time— about 15,800 af/year.

Theoretically, that additional 2,940 af/year will be realized in perpetuity with no additional cost. If the cost of this water were crudely divided by the new volume, it would produce a marginal cost of just $510/af. As the $1.5 million was spent over about eight years we could divide again by eight, bringing the marginal cost down to just about $64/af. This exercise is not methodologically precise but demonstrates the low cost of these one-time measures that could be replicated in other parts of the state.

Irvine Ranch Water District

The Irvine Ranch Water District (IRWD) provides water and sewage services to about 150,000 customers in the City of Irvine and the surrounding communities (p. 24). Following the drought of 1980s and early 1990s, Irvine chose a water conservation approach that involved a five-tiered rate structure to provide incentives to low volume water users and provide disincentives for higher volume water users.

A water use model was developed to determine the water needs of district water customers. When customers used more water than was needed they were charged with progressively higher prices within the five tiers: 1) low-volume discount ($.64/1,000 gallons); 2) conservation base rate ($.85/1,000 gallons); 3) inefficient ($1.71/1,000 gallons); 4) excessive ($3.42/1,000 gallons); and 5) wasteful ($6.85/1,000 gallons) (p. 25). After the new rate structure was implemented in 1991, water use declined by 19%.

Water pricing schemes may be highly effective at reducing total water use but the cost of such schemes and the specific marginal cost of the water savings is are largely unknown. One method of calculating cost may be to begin by calculating the level of local economic harm (if any) caused by reducing the supply of cheap water and then discounting that value based on the percentage of lost productivity that would have come into the public revenue stream. As pricing schemes of the type used in IRWD are typically restricted to residential use, economic activity is probably isolated to complimentary services like lawn care or pool cleaning services, creating unknown low costs.

Efficiency oriented programs using plumbing fixture rebates, water audits and irrigation workshops constituted the other component of IRWD's efforts to conserve water and reduce costs. These were implemented between 1991 and 1997 at a cost of about $5 million. During that six year period, the district avoided purchasing about 77,030 af of water, valued at about $33.2 million. It has purchased this water from traditional sources at a marginal cost of $431/af.

From a water supply perspective, that 77,030 af of water became available over a six year period at a cost of just $65/af. If water savings continue to be realized, they could be considered like a stream of benefits realized in perpetuity, large compared to the one-time cost of $5 million, spent over six years. If the continued realization of benefits is taken into account the marginal cost of that water is much lower.

Metropolitan Water District of Southern California

The Metropolitan Water District of Southern California (Met) is the largest wholesale supplier of water in Southern California, serving 26 member water agencies and 19 million customers (2011). Starting in the late 1980s, Met initiated a large conservation effort at a cost of $155 million through direct customer rebates offered for installation of new highly efficient fixtures and indirectly through Met's 26 member water by offering subsidies to those members to implement conservation and efficiency measures.

One of the central elements of the program is the SoCal Water$mart program, a rebate offering to all customers of agencies that purchase from the Met. Rebates are offered for residential upgrades like high-efficiency clothes washers, high-efficiency toilets, high-efficiency shower heads, rotating sprinklers and weather-based controllers.

Indirect programs are supported by Met with payments to Met water purchasers by either paying for 50% of the water conservation project or paying for $154/af of conserved water. As was the case with other districts that tried conservation measures, installation of highly efficient toilets and other fixtures by providing rebates is the central element of the conservation effort.

Since initiated, more than 2 million toilets were installed, 3 million showerheads were installed, 200,000 new faucets were distributed and 20,000 high-efficiency clothes washer rebates were issued. In 2001, Met estimated that it was saving 66,000 af/year based on its entire portfolio. Given the size of Met and number of its end customers, this is a modest water savings relative to other those experienced by other districts. Roughly comparing the program cost to the water saved in one year, yields a marginal cost figure of $235/af in one year (US Environmental Protection Agency, 2002, p. 29).

The City of Santa Monica

Following the drought of the late 1980s and early 1990s, the City of Santa Monica quickly turned to reduce use (p. 36). The city took a comprehensive approach that included conservation, efficiency incentives and emergency measures to rapidly reduce use to conserve remaining resources. The Bay Saver Toilet Retrofit Program offered $75 rebates to residential customers that installed high-efficiency toilets at a total cost of $5.4 million (p. 37).

In 1990 the city set a goal of achieving a 20% reduction in water use by 2000 based on its level of use in 1991 of 14.3 million gallons per day, or about 16,018 af/year (p. 37). In just one year water use dropped to about 11.4 million gallons per day—about 12,769 af/year, slightly exceeding their goal in the first year. Emergency measures probably account for a large portion of this reduction. When emergency measures ceased in 1992, water use rose back up to 12.3 million gallons per day, or about 13,778 af/year, representing an average water use reduction of 14% from 1990 levels.

The city also made estimates of the percentages of plumbing fixtures that were replaced with high-efficiency fixtures. These are a useful indicator of the remaining benefits to be gained from efficiency policies, sometimes referred to as the "hardness" of demand. For instance, the Santa Monica estimated that between 1990 and 1995 about 53% of residential toilets were replaced while only 10% of commercial toilets were replaced. This information can be used to inform policymakers about the cost-effectiveness of pursuing further efficiency measures in places where some benefits are already being realized, bearing in mind that gains from efficiency are "one time" and not unlimited.

Like the other case studies in urban water use efficiency, accurately estimating marginal cost requires more data and models that can account for the diverse array of possible efficiency measures. In the short-term, we can compare the newly available

2,240 af/year to the "capital cost" of the program of $5.4 million. Even assuming that Santa Monica would only realize the new water for one year and use that money only for that new water, we still get a marginal cost of $2,411/af, in parity with the desalination marginal cost estimates. Assuming five years of this saved water, the marginal cost falls to $482/af - in the long term the program is a probably a cost saver.

4.2 Desalination

Desalination is a continuously developing process that involves removing salts and impurities from water. Ancient methods involved evaporating contaminated water and then capturing the water vapor, leaving contaminants behind. The Earth's hydrology desalinates water for us, evaporating ocean salt water and releasing desalinated water over land. Other methods involved filtering water through cloth or other permeable filter or membranes that capture contaminants, allowing this water to be consumed safely. Modern desalination usually involves reverse osmosis (RO) where pressurized salt water is exposed to a selective membrane, causing the water to pass through the membrane and leaving the salts behind to be flushed back out into the sea. This is the principle method used for seawater desalination in California (California Department of Water Resources, 2009, p. 205).

Legislative & Policy Background

The federal government began research into desalination technology when the U.S. Congress passed the Saline Water Conversion Act in 1952, creating the Office of Saline Water (OSW) within BoR (Bach, 2005). The OSW invested about $30 million per year into desalination technology research through the 1980s. The body of that research formed the basis of the technology in mainstream use today, especially membrane technology that responsible for separation of particles from water.

Large scale desalination of ocean water for supply augmentation purposes began in California in 1965 when it cost $10 or more to desalinate a cubic meter (m^3) of water, roughly the same as $12,335/af. California's experience with desalination for the next 20 years was mostly experimental, considered prohibitively expensive. That changed as prices rose and supply reliability was drawn into question. During a period of extended drought in the late 1980s, several localities "considered or built desalination facilities along the California coast" (California Department of Water Resources, 2003, p. 9).

As that drought ended, prices of water from traditional sources dropped, making the high cost of desalinated water difficult to justify, causing many localities to close their desalination facilities. The Charles Meyer Desalination Facility in Santa Barbara, once the largest reverse osmosis desalination facility in the United States capable of producing 7,500 af/year, sits idle, having been built in 1991-1992 as a temporary emergency response to the drought (City of Santa Barbara, 2008). It was later reclassified as a permanent facility but has never been used in 18 years, being placed on standby after initial testing.

In September 2002, AB 2717 (Hertzberg) was passed into law, creating Desalination Task Force under the DWR to “make recommendations related to potential opportunities for the use of seawater and brackish water desalination” (California Department of Water Resources, 2003, p. 9). DWR was then to report back to the legislature about opportunities for desalination, problems with implementation of the technology and what role the State should play in furthering its use.

It contained 41 key findings and 29 recommendations, many of which tended to indicate a large, successful role for desalination in augmenting the state water supply in the future (p. 10). The report claims in its key findings that existing desalination technology is cost-competitive with traditional water sources and that long-term, new desalination technology may bring the cost down to level sufficient to make increasing the application of desalination desirable.

Among the concerns mentioned in the report, are serious questions about environmental impacts and disposal of the concentrated toxic waste, or brine, which is water with a high concentration of soluble particles of salt and other contaminants. This is classified as a toxic waste product by the California Environmental Protection Agency and the US Environmental Protection Agency because of the important natural life-sustaining properties of salt water. Salt water of the right concentration can benefit and support life, but highly salted water can destroy life and upset delicate ecosystems.

Cost-Effectiveness

Desalination became a credible technology in the late-1980s as it was believed that cost-effectiveness was coming into parity with other sources. This view has been articulated mainly by state and federal government authorities and industry groups that tend to emphasize optimistic estimates of the costs of desalinated water. The DWR estimates the cost for desalination at $1,000-2,500/af (California Department of Water Resources, 2009, p. 211). One of the industry groups leading this effort is the

Affordable Desalination Collaboration that supports cost estimates in the lower end of the range (2011). Skepticism remains to this day about whether true parity with traditional sources has ever been achieved, most vocally from the Pacific Institute (2006) and the Residents for Responsible Desalination (2010) that tend to emphasize higher estimates of the cost estimates involved. Because local governments usually enter into long term contracts with desalination facilities or finance them themselves with bonds, significant concern remains about taxpayer equity for this unproven technology. California and the federal government have considered allowing grants to partially offset the cost of these projects, complicating the equity of investing in desalination before it is fully mature.

The two major cost drivers are capital costs related to technology (fixed) and electricity (variable). Mainstream desalination employs methods of constantly evolving reverse osmosis technology that tends to bear downward pressure on price as new systems become available - this includes more efficient membranes that filter water more efficiently at lower pressure. It is now argued that new “nano-tube” technology may unlock new potential for highly efficient RO methods. Researchers at the Lawrence Livermore National Laboratory claim that this technology could potentially reduce the cost of desalination by as much as 75% over existing costs (Aditi, 2006).

The source of mechanical energy required to produce pressure is electricity, a commodity whose price is steadily rising and subject to historical price volatility as unpredictable as the weather. The rising and sometimes unpredictable cost of electricity places strong upwards pressures on these new methods even as emergent technologies claim to reduce costs. The Task Force report points out that regional energy prices may make desalination unfeasible in communities with high energy costs (California Department of Water Resources, 2003, p. 12). Cogeneration facilities, desalination facilities with energy generation capability installed onsite, could be a partial answer to the problem of energy costs.

Long Beach has spent several years experimenting with a low pressure, nano-filtration system that promises to reduce energy costs by 20-30% over existing methods (California Department of Water Resources, 2009, p. 295). Reducing energy costs not only reduces the marginal cost of the water produced, but also reduces the total proportional cost of the unit of water that goes toward energy, improving the scalability of the technology, even in times when energy costs are high.

Most previous methods of desalination have relied on reverse osmosis technology (RO) or thermal distillation, both of which have shown continuous improvement. The San Leandro based company Energy Recovery, Inc. has designed a Pressure Exchanger system which recycles heat used in the desalination process (Mitra, 2008). They claim that this system is deployable, capable of producing water at a cost of only $\$.46/m^3$ or about \$567/af.

The International Desalination Association claims that desalinated water can be produced at a cost of \$0.75 to \$1.25 per cubic meter (about \$925 to \$1,541 per acre foot) (2011). Existing facilities overseas have demonstrated cost-effective desalination (Marlow, 2009). The Ashkelon Plant in Israel on the Mediterranean Coast employs highly efficient RO technology combined with an energy capture system that harnesses steam power from heat produced during the RO process, producing a co-benefit which may be directly monetized, reducing down (Net Resources International, 2011). The plant, having operated for several years, produces this water at about \$0.527/m^3 or about \$650/af. The Singapore-Tuas Seawater Desalination Project, developed by Black & Veatch Water, has been producing desalinated water since 2006 at a cost of only \$0.49/ m^3 or about \$604/af. It remains difficult to evaluate these claims because comparable cost drivers, including electricity, salinity of the source water, environmental regulation and capital construction costs are all likely to be higher in the United States, particularly in California.

Critics continue to suggest that conservation measures are the superior alternative. A June 2006 report from the Pacific Institute, entitled, “Desalination, with a Grain of Salt” describes efforts to expand water supply from desalination facilities as “overly expensive, inaccurately promoted, poorly designed, inappropriately sited, and ultimately useless.” The authors go on to state that, “water continues to be used wastefully in California and that substantial amounts of water can be conserved cost-effectively compared to almost all proposed supply expansions, including desalination” (p. 9).

A report sponsored by the Residents for Responsible Desalination (2010), also takes a critical view of recent efforts to implement desalination, citing three important case studies in the state. The report refers to claims made by advocates of desalination that suggest marginal costs for desalination of \$800-1,000/af – instead the authors of the report suggest that California’s actual experience with desalination has placed the cost in the $2,000-3,000/af range. Echoing the Pacific Institute, the report points to competition from water conservation measures that carry estimates from $300-1,300/af.

Carlsbad

Poseidon Resources' Carlsbad project is among latest attempts to construct a high capacity desalination plant in California. Poseidon projects a capital cost of $534 million for the 50 MGD facility that could produce about 56,000 af/year. Poseidon Resources claims the project will produce water at a cost of $1,000/af (Poseidon Resources, 2011). No specifics about the production cost or the business model were published for the facility because that information is propriety.

Because of the facility's large size we have reason to believe the project should benefit from economies of scale, at least with regards to the portion of marginal costs related capital repayment. Using a range of discount rates from 4.375% to 10% (a private entity may not have access to low interest rates made available to governments) and calculating the portion of marginal cost devoted just to capital repayment over a 20 year period, the project would carry marginal capital repayment costs of $725-1,120/af.

R4RD (2010) performed a detailed (although speculative) marginal cost analysis of the Carlsbad Poseidon project that includes several different case scenarios for the facility and sensitivity analyses using a wide range of different variables as cost-drivers. He was careful to incorporate accurate energy costs and account for underestimates of capital costs, maintenance and operation costs, significant downtime and estimates of salinity of the source water. R4RD concludes that at best the Carlsbad plant could produce water at a cost of $1,897/af. That estimate climbs up to $3,507/af in the worst case scenario.

Marin County

The Marin Municipal Water District (MMWD) has approved a plan to build a 5 million gallon per day (MGD) in the San Rafael Bay at a cost of $111.2 million. That facility could produce about 5,600 af/year. An alternate proposal would construct a 10 MGD facility at a cost of $173.4 million that could produce 11,200 af/year. MMWD has discussed the possibility of expanding the facility to 15 MGD which could produce 16,800 af/year, but no capital cost estimate is available. Marginal cost analysis was not presented by MMWD for any of the project alternatives.

The Residents for Responsible Desalination estimate the cost per acre foot at about $3,009/af for the 5 MGD facility and $2,430/af for the 10 MGD facility. These marginal cost figures assume a rate of operation of about 54% of full capacity.

Using the 2010 Discount Rate for Water 0.04375% with a 20-year repayment period, the annual cost for repayment of the capital cost is about $8,441,075 per year (5 MGD) and $13,186,329 per year (10 MGD). The estimated operating costs for the facilities are $6.5 million and $12.4 million respectively. When the operating and capital repayment costs are added together and divided by total water production, the estimated marginal cost is $2,668/af (5 MGD) and $2,284/af (10 MGD), assuming either plant would operate at 100% capacity year round.

City of Santa Barbara

The City of Santa Barbara completed a 6.7 MGD facility in 1992 using bonds at a cost of $34 million (1991 USD)(City of Santa Barbara, 2008). That facility was designed to produce about 7,500 af/year at a cost of about $1,500/af. Operation costs for this facility at full capacity were approximately $1,100/af (1991 USD). Before the plant was ever used at normal capacity, it was mothballed at a cost of about $100,000 per year. As this facility was not used in 18 of the 20 repayment years, the facility's capital cost is now nearly paid off, meaning that, the city could produce water for only the operation cost plus a cost associated with bringing the plant back into production.

Rehabilitation of the plant would cost about $20.2 million. Annualized over a 20-year period, using the 2010 Discount Rate for Water, the repayment cost for rehabilitation is about $211 per year. Combined with the known operating costs, adjusted for inflation using the GDP deflator ($1,630/af), Santa Barbara could produce water for about $1,841/af. If a similar plant was built today using the original capital cost, adjusted for inflation, such a plant could produce water for $2,142/af, assuming it operated at 100% capacity year round.

4.3 Surface Storage

Surface storage projects refer to the construction of water reservoirs above the surface of the ground. Most commonly, reservoirs are built by constructing a dam in the natural course of a river or canyon, causing the water to inundate the land behind the dam up to the height of the dam or spillway - the device commonly used to release water. In lower laying, flat areas, a large earthen berm is constructed to create an artificial wall or embankment, causing a creek or river to form into a pond or lake. A levee may also be used to separate portions of water from within an existing body of water.

Surface Storage in History

In 1844, Daniel Webster is said to have addressed his colleagues in Congress on the subject of westward expansion into California, asking them, "To what use could we ever hope to put those great deserts and those endless mountain ranges, impenetrable and covered to their very base with eternal snow?" The circumstances of the speech are debated widely, but it is quoted frequently by experts on the period as an expression of the attitudes of the time towards westward expansion (Littleworth & Garner, p. 1). To many nineteenth century policymakers, California's intemperate and inhospitable climate made it undesirable for settlement. Development of water resources was a critical step for westward expansion into California.

For those living in California at the time, the problem was partially solved. Beginning in the 1700s, Spanish missions were established along the coast and inland and were frequently accompanied by a water conveyance system (p. 3). These were designed to support the irrigation needs of the settlement and irrigated lands that often sprung up adjacent to a mission, with most irrigation water coming directly from streams via diversion ditches. There were no reservoirs and the total supply was extremely limited. The ability to develop and move water was a great technology and a source of power for the Spanish military, helping to ensure that a mission was a center of commerce and a symbol authority throughout the region.

Construction of reservoirs began in the 1800s, which were often accompanied by rudimentary conveyance infrastructure. At Mission Santa Barbara in 1807 a small stone dam was constructed about a mile upstream in the foothills. Indian Dam captured excess water from Mission Creek and fed it into a long aqueduct structure that ran in a wooden suspension channel above the natural run of the creek and into a stone channel nearer to the mission that lead into a tank and a public fountain (SBMission.org, 2011). While not providing many of the modern benefits that large reservoirs do, like hydroelectric energy generation, flood mitigation, cold water regulation or recreation, the small Indian Dam provided a nearly steady flow of water, year round for a variety of purposes.

In the late 1800s, some of the first modern infrastructure was constructed, including dams and reservoirs to store large reserves of water, although they were simple in design and often supplied local rather than remote water needs (Littleworth & Garner, 1995, p. 3). Investigations began in 1873 when President Ulysses S. Grant directed the US Army Corps of Engineers to survey and evaluate water conditions in the Central Valley, in order to determine how best to develop the Sierra watersheds and irrigate the valley land for agriculture. The first California State Engineer, William Hammond Hall, also commissioned a comprehensive study in 1878. That study agreed with the findings of the federal study, that the waters of the Central Valley should be developed for statewide use.

These early investigations combined with a proposal raised in 1919 by the US Geological Survey suggested moving water from the Sacramento River, south to the

San Joaquin Valley for use in agriculture and then over the Tehachapi Mountains for use in Southern California. The idea of a comprehensive system designed to move water across the state became the state's first major modern water development which would manifest itself in the Central Valley Act of 1933. It was supported by a $170 million ($2.39 billion 2010 USD) bond measure that was used to finance the massive effort (p. 18). With federal government assistance during the Great Depression, construction began in 1935, laying the groundwork for the Central Valley Project.

The federally operated CVP was designed mainly to serve the agricultural water use needs of the Central Valley. The project, however, was composed of many elements that moved water in many directions within the state, and contained elements that overlapped those of the state operated State Water Project (SWP)(p. 21). While both water systems are separately administered, their impacts on water supplies in the state are complimentary and key features like the California Aqueduct are used in both systems and co-operated. As California's bourgeoning society expanded into predominantly arid Southern California, demand for water stressed existing supplies reliant upon the Colorado River and the Owens Valley.

This growing need for expansion throughout the 1940s and 1950s, culminated in a campaign to further improve water supply and construct the SWP. This included the relocation of the Lake Oroville dam facility, addition of East and West Branch connections to the California Aqueduct and numerous other improvements throughout the state. The California Water Resources Development Bond Act (Burns-Porter Act) was placed on the November 1960 ballot and narrowly approved by about a 3% margin in a hotly contested campaign (p. 23). The $1.75 billion bond ($10.4 billion 2010 USD) act supported construction of many key elements of the State Water Project. Other important elements were never completed, including several reservoir and conveyance projects in Northern California and the controversial peripheral canal, designed to transport water around the Delta. As discussed above in the Introduction, climate change could reduce over precipitation in the state, reducing snowpack, a major source of water for these reservoir projects.

Legislative & Policy Background

In California, the agency responsible for construction of surface storage projects is the Department of Water Resources. The BoR is the federal agency responsible for these projects. Due to the complex nature of water policy making, involving a balanced approach that observes diverse environmental, municipal and industrial and agricultural needs, the California Water Policy Council and Federal Ecosystem Directorate (CALFED) Bay-Delta Program was formed in 1994 under the San Francisco Bay Area-Delta Agreement.

CALFED's acronym is doubly useful by its reference to the California-federal collaboration, expressed most by the relationship between DWR and BoR, two of many state and federal agencies. The unique collaboration of 25 state and federal agencies seeks to improve California’s water supply and the ecological health of the San Francisco Bay/Sacramento-San Joaquin River Delta. Pursuing new surface storage projects is one of their main tasks.

One of CALFED's first acts was to identify five surface storage projects for further investigation from an initial screening list of 52 potential surface storage projects (California Department of Water Resources, 2010). Those projects are under investigation by the two lead agencies, DWR and BoR in partnership with local water entities, where appropriate. Each of the projects addresses three CALFED objectives: water supply reliability, water quality and ecosystem restoration. Reservoirs may achieves the objectives by storing excess water in rainy "wet years" and releasing that water, slowly, consistently and predictably over time during the "dry years" in combination with other management strategies.

Federal authorization for investigation of the five projects came from an omnibus appropriations bill in February 2003. This authorized BoR to study the storage projects identified in the CALFED ROD. The five projects identified included the Los Vaqueros Expansion, the Sites Reservoir (North-of-Delta Offstream Expansion), the Shasta Lake Dam Raise, the Temperance Flat River Mile 274 (Upper San Joaquin Basin Investigation) and the In Delta Storage project. The fifth project, involving storage of water on islands in the Delta was abandoned after it’s state funding was terminated in 2006 – it is excluded from this report (p. 12).

Each project is very different and involves different types of investigation. The investigation for each project also varies widely and remains in different stages of completion. Preliminary information is available for each project, but all four involve high costs that need to be examined further before a final project can move forward.

CALFED is working to develop a common analytical framework based on a team that shares the same assumptions for each study. While improving consistency in evaluation of these projects has been a major goal for CALFED, these estimates remain works-in-progress. The four projects detailed below, highlight information presented in the most recent project evaluations, demonstrating the diversity of surface storage project proposals and variance of expected costs associated with them.

Cost-Effectiveness

Traditionally surface storage projects have been a cheap way to create a reliable and abundant supply of water for the state. Like all water supply approaches, there are diminishing marginal returns as easily dammed rivers and canyons are not unlimited, nor is the total volume of water in the state. The modern approach to water management has also raised alarm about the serious environmental costs relative to damming rivers and inundating entire valleys to store water. There are also environmental benefits to consider and surface storage remains a key factor in the water supply strategy. Surface storage projects also come with easily estimable costs, relative to more complex or micro-scale efforts, subject to the threat of cost overruns that impact many modern infrastructure projects. The CALFED ROD recommended about 6 million acre feet of additional storage - the projects discussed below would bring about 3.9 million acre feet of water into the state's water portfolio and with specific marginal cost data that can be easily compared to other proposals.

Los Vaqueros Expansion

The Los Vaqueros Reservoir sits beneath the Mount Diablo State Park in Contra Costa County, five miles north of the 580 Freeway. The reservoir project, an effort of the Contra Costa Water District (CCWD) was completed on time in 1997 and on budget, costing $450 million. Today the reservoir holds 100,000 af of water which is used to augment environmental water management, supporting fish and wildlife in the delta region and augment the CCWD water supply, serving the San Francisco Bay Area (US Bureau of Reclamation, July 2006, p. 11). The reservoir also helps alleviate the effects of drought in the area or shortages that result from regulatory or environmental pumping restrictions.

The 275,000 af expansion had a preliminary capital cost projection equal to $596,889,000 (p. 15). The effectiveness measurement for this project is an estimated yearly average water yield of 104,200 af/year under normal non-drought conditions (p. 18). Based on the annual cost ($34,429,000/year) and annual effectiveness (104,200 af/year) of the project, the per-unit cost of this water is estimated to be $330/af.

To update this information, making it consistent with the other alternatives, I recalculated the annual cost by using the fixed cost (capital cost of $596,889,000) instead of their measure, the Capital Value of All Costs. I first adjusted the capital cost for inflation by multiplying $596,889,000 by 1.07, representing the GDP Inflator for 2006. The resulting capital cost estimate is $638,671,230.

Next that cost must be annualized to conform to the project's effectiveness measure which is a yearly average. To get the annualized cost a formula is used representing a stream of costs over a repayment period of 100 years, using a discount rate of 4.375 percent (%). This discount rate is the 2010 FY Plan Formulation Rate For Federal Water Projects, updated annually in early October of each year. The following formula is used for this calculation:

$$\frac{\text{Capital Cost x Discount Rate}}{\text{1-(1+Discount Rate)^-Repayment Period in Years}}$$

When the updated estimated cost and selected discount rate are entered into the formula, it appears as presented below:

$$\frac{\$638{,}671{,}230 \text{ x } .04375}{1-(1+.04375)\text{^-}100}$$

That calculation produces a result of $28,333,291 which represents the annual payment for this type of project with interest, excluding the average estimated cost of operation.

To get the final annual cost, the operation cost is added. The report gave an estimated operation cost of $3,546,100 which was multiplied by the GDP Inflator for 2006 (1.07). The resulting $3,794,327 is added to the annualized capital repayment cost ($28,200,892), rendering a total annual cost of $32,127,618.

The cost-effectiveness is found by dividing cost ($32,127,618/year) by effectiveness (104,200 af/year). The resulting cost-effectiveness estimate is $308/af for the Los Vaqueros Reservoir Expansion project.

North-of-Delta Offstream Storage/Sites Reservoir

The North-of-the-Delta Offstream Storage (NODOS) project is an attempt to identify, plan and construct a reservoir in the North Sacramento Valley (US Bureau of

Reclamation, September 2008, p. 20). Initial examination of alternative reservoir sites included projects at Red Bank, Newville, Colusa and Sites locations. The site investigation area covers a large swath of Northern California watershed, running roughly parallel to the Sacramento River, 5-10 miles west of the river, beginning just south of the Red Bluff Diversion Dam. Current studies are focused on the Sites Reservoir site, following elimination of previous reservoir alternatives due to poor cost-effectiveness performance.

The Department of Water Resources Progress Report (2010) recommended discontinuing the Red Bank Reservoir and Colusa Reservoir alternatives (US Bureau of Reclamation, September 2008, p. 58). The Red Bank Reservoir alternative was estimated to only create about 250,000 af of gross storage compared to the other much larger (>1,800,000 af) reservoir alternatives that were considered. Because of the low expected returns, environmental concerns related to "considerable fishery and environmental impacts" and other problems, such as hydrologic leaking, the Red Bank Reservoir project was excluded from further review (p. 142).

The remaining sites, Newville, Colusa and (confusingly named) Sites Reservoir projects were evaluated further for cost. Initial evaluations of those remaining alternatives revealed total dam costs (in 2004 dollars) of $320,250,000 for the Sites Reservoir, $1,411,520,000 for the Colusa Reservoir and $235,134,000 for the Newville Reservoir (p. 144). These early cost estimates include only dam construction and exclude any costs related to land acquisitions, easements, rights-of-way, relocations, appurtenant structures, conveyances, road relocations, or recreation facilities. This was sufficient to recommend elimination of the Colusa Reservoir alternative from further evaluation on a unit cost basis as its water yield would be more than four times as expensive per acre foot, when including only dam construction costs alone.

A cost-effectiveness estimate comparing the alternatives states that the capital cost for the Colusa Reservoir is more than 4.4 times greater than the capital cost of Sites and 6 times greater Newville, but would yield only about 16 percent more water on average (p. 144). The preliminary capital estimates translated into cost-effectiveness estimates of $66/af (Sites), $50/af (Newville) and $222/af (Colusa), including only dam construction costs adjusted for inflation. This rough measure was admittedly excluding many costs associated with completion and operation of a reservoir project, but was justified by BoR because dam construction costs are a consistent and predictably large portion of reservoir total cost.

Between the remaining two alternatives, it appears that the Newville Reservoir alternative is slightly more attractive than the Sites Reservoir alternative as it produces a greater water yield, has a larger total storage capacity and has a slightly lower capital cost (p. 144). However, BoR performed a count of the environmental assets that would be jeopardized by the construction of both dams and found that construction of a reservoir at Newville would have a greater negative impact based upon all criteria used, except for bird species. As a result of the impacts counting exercise and a general lack of local support for the project, the Newville project alternative was not recommended for further consideration, although marginal cost estimates were similar (p. 170).

The 2008 report evaluated the Sites Reservoir alternative further for its economic impacts based on preliminary information available. Eight scenarios based on the 1,800,000 af Sites Reservoir alternative concept were compared, each suited to a different set of objectives and bearing different costs. The eight project concepts were compared using benefit-cost analysis with comparison to a no-project alternative. Expected increases in water supply were forecasted to have positive impacts on agriculture, municipalities, industry and the environment (p. 266).

Of the eight project concepts reviewed, all but one was shown to have net negative economic impacts, consuming more resources than they would produce in benefits (p. 266). Alternative “WSFQ” was predicted to carry an annual cost of about $189 million (2007 dollars) and produce annual benefits of about $215 million. This would yield a net benefit of $25 million annually, with a benefit-cost ratio of about 1.14. On a cost-effectiveness basis, initial estimates of about $189 million/year (2007 dollars) in annual costs and an average annual yield of 622,000 af/year resulted in an initial estimate of $304/af (2007 dollars). At this point, further evaluation of other alternatives was not recommended on a benefit-cost basis.

The initial cost information was updated for consistency. I recalculated the annual cost using the capital cost estimate of $3,624,400,000. I first adjusted the capital cost for inflation by multiplying $3,624,400,000 by 1.04, an index figure representing the GDP Inflator for 2007. The resulting current capital cost figure for the Los Sites Reservoir project is $3,769,376,000.

When the updated estimated capital cost and discount rate are entered into the formula, it appears as presented below:

$$\frac{\$3{,}769{,}376{,}000 \times .04375}{1-(1+.04375)^{-100}}$$

That calculation renders a result of $167,220,351 which represents the annual payment for this type of project with interest, excluding the average estimated cost of operation.

To get the final annual cost, the operation cost is added. The report gave an estimated annual operation cost of $10,800,000 which was multiplied by the GDP Inflator for 2007 (1.04). The resulting $11,232,000 is added to the annualized capital repayment cost ($167,220,351), producing a total annual cost of $178,452,351.

The cost-effectiveness is found by dividing cost ($178,452,351/year) by the long-term average water yield (560,000 af/year). The resulting cost-effectiveness estimate is $319/af for the Sites Reservoir project.

Shasta Lake-Reservoir Expansion/Dam Raise

The Shasta Lake Water Resources Investigation (SLWRI) project involves expanding the existing reservoir by raising the dam by 18.5 feet above its present height (US Bureau of Reclamation, 2007, p. 12). It's main purposes are to enlarge the state's reserve of cold water to improve environmental conditions for aquatic life in rivers and in the Delta and to improve the supply of water available for municipal and industrial use around the state.

In June of 2004, a report examined 12 “concept plans” each based upon a dam raise of 6.5 feet, 18.5 feet or 200 feet (US Bureau of Reclamation, p. 6). These alternatives were designed around achieving two coequal objectives to the maximum extent: Anadromous Fish Survival (AFS) and Water Supply Reliability (WSR). Three of the concept plans were oriented towards maximization of the AFS objective, and four of the concept plans were oriented towards Water Supply Reliability (WSR). Five additional concept plans were designed to achieve Combined Objectives (CO). These twelve plans were rated based upon four criteria: completeness, efficiency, effectiveness and acceptability (p. 11).

Based upon the June 2004 assessment, five plans (WSR-1, WSR-2, WSR-4, CO-2 and CO-5) were recommended for inclusion in further study (US Bureau of Reclamation, 2007, p. 128). Although none of these plans were taken up in future studies, it is important to note that in concept, any dam raise exceeding 18.5 feet was excluded from further study. While the benefits to humans and for fish produced by increased water supply reliability were projected to be enormous, the inundation of tens of thousands of acres and the resulting loss of environmental assets and important cultural sites was deemed unacceptable.

In addition to the criteria analysis used in the 2004 report, the 2007 report evaluates each of the comprehensive plans by the same criteria and for benefits and costs based upon preliminary economic impact information available (p. 128). The 2007 report expands the "efficiency" criterion from the 2004 report and incorporates the cost-benefit assessment information to determine efficiency. Of the five plans evaluated, CP-4 was shown to produce the greatest net economic benefits although it is noted that some refinement of CP-4 or a blend of elements of CP-4 and CP-5 may constitute the final plan formulation (p. 154).

The Shasta Lake Water Resources Investigation Plan Formulation Report (2007) and the Surface Storage Progress Report (2010) suggest that CP-5 will be ultimately be the design that is used. That project has an estimated cost of $941,900,000. Information was updated for consistency with information for the other alternatives. The capital cost was adjusted for inflation by multiplying $941,900,000 by the GDP Inflator for 2006 (1.07). The resulting current capital cost figure for the SLWRI project is $1,007,833,000.

To get the annualized capital repayment cost, the capital cost ($1,007,833,000) and the discount rate (4.375 percent), are entered into the formula as follows:

$$\frac{\$1{,}007{,}833{,}000\text{x } .04375}{1\text{-}(1\text{+}.04375)\text{^-}100}$$

That calculation produces a result of $44,710,368 per year, including only repayment of capital costs.

To get the final annual cost, the operation cost is added. The report gave an estimated annual operation cost of $1,700,000 which was multiplied by the GDP Inflator for 2006 (1.07). The resulting $1,819,000 is added to the annualized capital repayment cost ($44,710,368), producing a total annual cost of $46,529,368.

The cost-effectiveness is found by dividing cost ($46,529,368/year) by average annual yield. Plan Formulation Report (2007) estimated an average annual yield of 76,000 af/year. The Surface Storage Progress Report (2010, pg. 107) revised the average annual yield estimate to 74,000 af/year. The cost-effectiveness using the revised estimate is $629/af.

Temperance Flat

An October 2008 report outlines the Temperance Flat, River Mile 274 dam project, part of the Upper San Joaquin River Basin Storage Investigation, aimed at building a second large dam and reservoir above the existing Friant Dam and Millerton Lake (US Bureau of Reclamation, p. 3). The purpose of the new reservoir is to improve water supply reliability in the south Central Valley region and regulate fresh cold water flows into the badly environmentally degraded San Joaquin River (p. 7).

By combining the 520,000 af of water capacity in the Lake Millerton Reservoir (p. 74) with a new 1,260,000 af reservoir, it is believed that sufficient excess water can be captured in wet years to meet the environmental and human water user needs of the San Joaquin River and the Friant Water Authority (p. 11).

The alternative to enlarge Millerton Lake was abandoned because it would produce very limited additional water at high cost and do substantial harm to existing private property and recreational facilities that have emerged around the existing lake. The remaining five alternatives involved building a second dam upriver from the Friant Dam and Millerton Lake. Two of the alternatives involved construction of a Fine Gold Reservoir, northeast of Millerton Lake. Two of the alternatives involved construction of a Temperance Flat reservoir, east of Millerton Lake at River Mile 279. The fifth alternative that was eventually selected due to its large size, involves the construction of a dam at River Mile 274.

There is wide disagreement over the cost of the project. The DWR fact sheet from 2007 estimates the price per acre-foot at $350 (2007 USD). However, the Pacific Institute (2008, pg. 6) suggested much higher costs in the range of $760 to $1,400 per acre-foot. Given an expected annual water yield of about 180,000 af (2010) at a cost of $159,398,466 per year, this was the most expensive surface storage project evaluated in this report with an estimated cost of $886/af. This price rivals many of the other alternatives under consideration.

To get this estimate, the capital cost estimate of $3,358,000,000 from the 2008 PFR was used. To update the estimate, capital cost is adjusted for inflation by multiplying $3,358,000,000 by the GDP Inflator for 2006 (1.07). The resulting capital cost estimate is $3,593,060,000.

To get the annualized cost, capital cost ($3,593,060,000) and the discount rate (4.375 percent), are entered into the formula as follows:

$$\frac{\$3{,}593{,}060{,}000 \times .04375}{1-(1+.04375)^{\wedge}-100}$$

That calculation produces a result of $159,398,466 which represents the annual payment for this project with interest, excluding the estimated cost of operation.

No maintenance and operation cost was listed in this or any other report for the Temperance Flat project. Annual repayment costs and cost-effectiveness estimates that exclude maintenance and operations costs should be considered low estimates.

The cost-effectiveness is found by dividing cost ($159,398,466/year) by effectiveness (180,000 af/year). The resulting cost-effectiveness estimate is $886/af for the Temperance Flat River Mile 274 Reservoir project.

Conclusion

This exercise confirmed many of the cost-effectiveness estimates produced to date. Some project estimates were out of date and made the picture of cost-effectiveness for each alternative unclear. This exercise of probing into the raw data and recalculating the costs of each alternative was highly valuable in that it added consistency to the final cost estimates, in many cases causing them to rise significantly because of inflation, or fall due to use of a contemporary discount rate. Finally, comparing those estimates to case studies (where available) creates a better overall basis for comparison. All in all, a clear ranking has emerged from the data, indicating that efficiency and conservation measures are likely the most cost-effective, ocean water desalination proposals are the least cost-effective and surface storage projects fall in between, granted that these projects have considerably higher capital costs to begin construction.

Chapter 5

CONCLUSIONS

Overall the data and analyses reviewed in this report confirmed the theory that efficiency measures should be among the first investments made. Agricultural water use, while showing signs of progress, has a long way to go towards achieving desired levels of efficiency and bringing price into parity with market conditions. Additional data is also needed to develop policy alternatives going forward. Surface storage and desalination projects generally appear to be less desirable on a cost-effectiveness basis, but should remain under consideration where appropriate.

The costs of water project alternatives available to California vary widely between types and within types. In the chart in Appendix A (below), low end estimates are shown in dark red and high end estimates are shown in light red. Generally, conservation and efficiency measures are similar to surface storage projects on the lower end of the range of costs. It is important to note that large surface storage projects require large investments of state taxpayer dollars or another costly mechanism to cover the large capital costs that could run into the billions of dollars.

Generally, desalination alternatives exceed the cost ranges presented for all other alternatives, with the exception of alternatives outside of the United States or alternatives involving technology that remains in the research stages of development. Because of the distribution of cost data, this section refers to “low” cost as falling under $1,000/af, “medium” (or mid-level) cost as falling between $1,000-$2,000/af and “high” cost as falling between \$2,000-\$3,000/af. “Very high” cost refers to any project that costs more \$3,000/af.

Demand Reduction Alternatives

Cost estimates for conservation and efficiency alternatives range widely from extremely low cost measures (approaching \$0) to cost estimates approaching \$3,000/af. Of those alternatives, most have one time capital costs that translate into the realization of very low cost water benefits over the long term. These long terms savings are highly attractive where available but carry two significant drawbacks. Firstly, these alternatives do not bring additional water into the state’s water portfolio but instead divert water into alternative uses, saving the adopters of conservation or efficiency measures the cost of the additional water. This water may also go towards higher value uses at higher prices, resulting in additional revenue for the state and economic stimulus in some circumstances. Secondly, conservation and efficiency measures suffer from increasing marginal costs resulting from hardening of demand.

No current estimates of California’s overall level of water use efficiency, in large part due to the agricultural water use problem and the lack of data for that type of use. As water delivery across the state approaches higher levels of efficiency, demand becomes more inflexible as water use approaches the minimal volume necessary for society. As efficiency rises, additional efficiency may become prohibitively expensive. This may cause some users to reduce their consumption, freeing up water for higher value uses.

Conservation and efficiency alternatives vary widely and represent a growing industry of constantly evolving innovation. These may include replacing leaky faucets, installing water efficient washing machines or replacing grass lawns with desert environment landscaping. These alternatives also include market mechanisms including pricing schemes and incentives designed to reduce consumption or encourage efficient water use.

Local governments have had some success with implementing water conservation and efficiency programs but levels of success vary by government and level of investment. Small jurisdictions like Goleta have had great successes at low cost. The largest water agency in the state, Met has invested a great deal and has produced huge water savings for the state but can probably achieve a great deal more with additional research and investment in new conservation and efficiency programs around its large customer base. Generally, development of and investment in new applications can produce very low cost water savings that continue to accrue in perpetuity after the one time investment is made. In the long term, the marginal cost of this water approaches zero, making these measures highly lucrative, however, as stated above, these measures are limited by existing conditions of inefficiency and harden demand to the extent that no further reduction in water use may be achieved.

Very large water savings have yet to be achieved in agricultural water use, both in water conveyance and delivery systems and in usage practices. Among efficiency and conservation measures, those in agriculture are the most uncertain relative to opportunities for water savings and the costs at which those savings may be realized.

Given some of the limited basic evidence available (unlined canals, flood irrigation, etc.) very high cost savings may likely be realized by adopting more efficient practices. Specific information about those opportunities remain largely unverified as water usage is measurement is just beginning for many parts of rural California, even though fairly accurate estimates exist in some cases. A significant amount of water may be cheaply captured and directed to alternate uses by making necessary conservation and efficiency improvements.

Desalination

Ocean water desalination remains a tempting, futuristic alternative that remains the only approach that involves adding new water to California's roughly 7 million acre-feet of annual rain and snow. The costs and uncertainly involved with desalination, probably make it a more futuristic than realistic, contemporary alternative. California's experience with desalination has cost between $2,000-3,500/af, adjusted for inflation. First and foremost, desalination is a technology driven alternative that is highly dependent on frequently occurring advances in the efficiency of the processes used to remove salt from ocean water. It is highly probable that innovation will press costs down, but how much farther down and how soon those downward cost pressures will be realized is a problematic unknown.

Many variables impact the final retail cost of desalinated water and emergent upward pressures on final costs are a certainty. The most important cost driver in desalination is the cost of energy, a commodity whose price will continue to rise as California moves towards its ambitious environmental and renewable energy goals.

Shortages of existing energy fuel sources also threaten to push energy costs up, resulting in higher desalination costs. Energy cost represents over 40% of desalination cost. Other variables include salinity of the ocean source water, building costs and materials, operations and maintenance costs, filter membrane replacement, environmental mitigation, siting and permitting, land prices and uncertainty about cheaper alternatives in the water markets make for daunting challenges for prospective planners and investors in desalination.

Despite the seeming immaturity of the technology, water agencies have succeeded in bringing these new supplies online without breaking budgets. Recent proposals have received fierce opposition and fallen short of the public’s demanding expectations of this new technology. MMWD has attempted to move forward with their desalination plant but court challenges and public objection to its high cost remain looming threats to implementation. This most recent proposal for a new site is expected to cost between $2,200-3,000/af. The Carlsbad Poseidon plant is an entirely private venture so the exact business model and cost information is not publicly available. The costs of that project range from $2,000/af (or less) all the way up to $3,500/af, depending on who is asked.

Existing mainstream use is limited and the state is largely operating from estimates of costs. Given the range of variables, desalinated water will probably continue to cost in the range of $2,000-3,000/af, at least until “the next big thing” in desalination technology revolutionizes the industry. Optimistic estimates may show prices in the $1,000-2,000/af range while pessimistic estimates (or bad project designs) may render prices in the range of $3,000-3,500/af or more. The Charles Meyer facility in Santa Barbara could probably reliably produce water for about $2,000/af if it were rehabilitated and operated at full capacity year round – this facility was never actually used.

The Santa Barbara experience is as fine an illustration as any of California's experience with desalination: a good deal of money was spent but future success relies upon technological advances that may never materialize and policymakers that may become risk averse during economic recession. The Poseidon Resources firm claims their Carlsbad facility will produce water for only $1,000/af – if this claim is true, it may go a long way to build support for other similar facilities along California's coast.

Surface Storage

Cost estimates for the four major surface storage project alternatives fall between $308/af and $886/af. The cost-effectiveness of these projects are competitive with the short-term cost estimates for conservation and efficiency measures and fall far below the estimated costs of desalination proposals. More than ten years of study of specific project sites have filtered a large set of proposals down to just four: Temperance Flat (in the Eastern San Joaquin watershed), Los Vaqueros Expansion (near Altamont), Sites Reservoir (Western Sacramento watershed) and the Shasta Reservoir expansion.

Each of these projects is technically feasible and may be built given the right funding mechanism. These projects are fairly cost-effective, falling in the low cost category of projects, in parity with most conservation projects. Current estimates for these large capital projects include the assumption of a 100-year amortization period. This keeps the price of marginal cost of water produced low and a wide variety of revenue approaches could apply to these projects, however they are completely dependent on the success of an unrealized bond measure and conditions of the bond market.

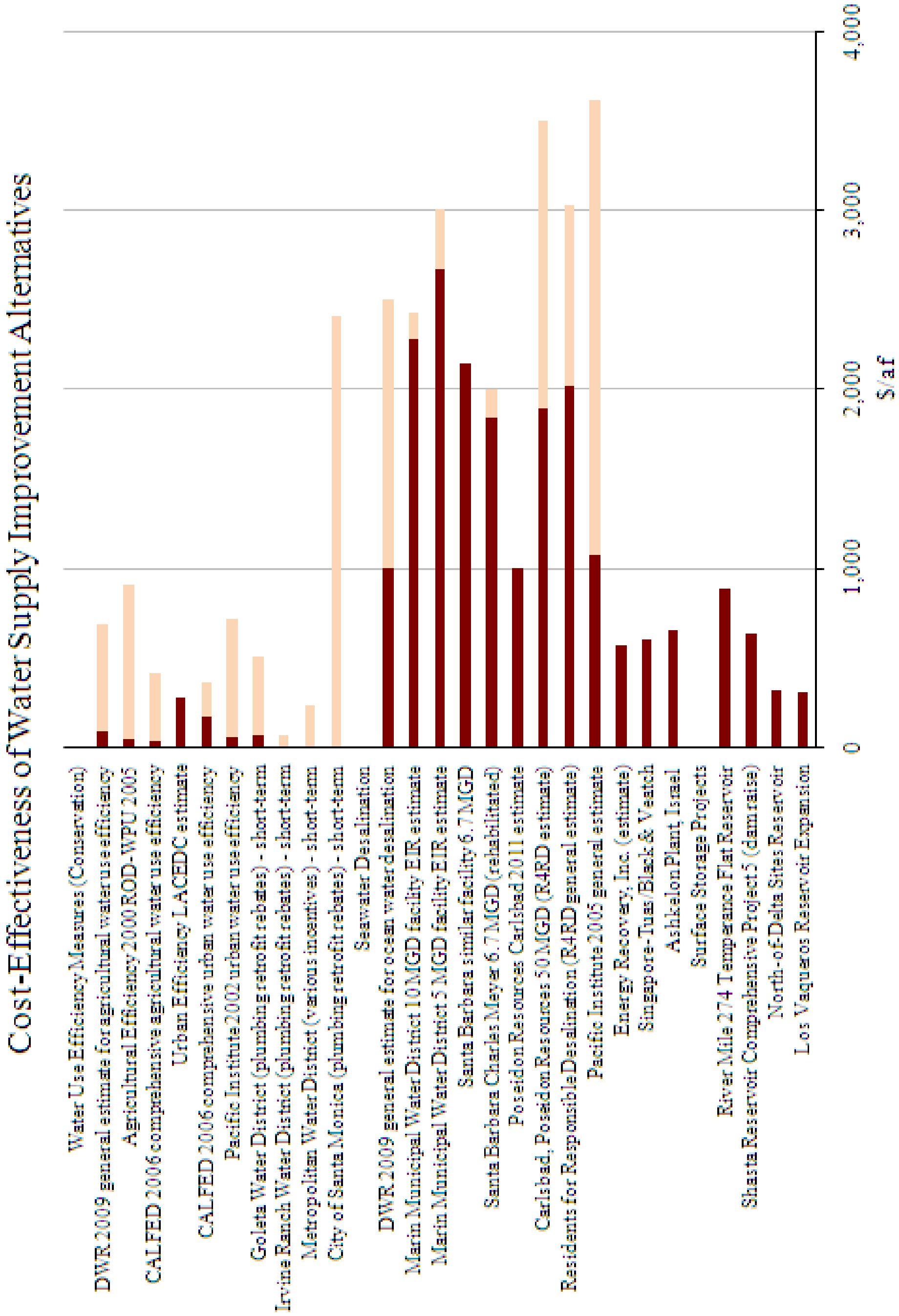
Of the approaches considered, surface storage projects are relatively simple, excluding the actual engineering and construction of the reservoir infrastructure. Still, environmental and equity concerns remain about these projects. Fierce opposition to construction of new “big dams” remains in the public and no bond financing will become available without public support. Still, if balanced against the right mix of financing for other water-related priorities, a deal on the bond measure is possible.

California’s entire complex water system is heavily controlled at far-away reservoir control stations that release or withhold water into the state’s colossal network of rivers, canals and pipes. Using reservoirs to manage the state’s water system is a complicated process that involves careful balance between the state’s economic and environmental priorities. Notwithstanding the problem of potentially harmful regional economic, environmental and equity impacts, the benefit of increased flexibility towards meeting statewide economic and environmental objectives is substantial. State policymakers should exercise care but continue to consider large scale surface storage projects as an important piece of California’s water puzzle.

A Note on Federal Water Policy

In addition to the lack of precise data for agricultural water use, federal water policies for the CVP continue to impede water use reform because of the ongoing practice of using long-term fixed-rate water service contracts that frequently do not reflect cost-of-production. Agriculture in California is among the most productive and highest quality in the world – it is also a point of pride for the state's economy. The continued prosperity of agriculture in California is also essential to reaching and maintaining California's environmental goals, relative to sprawl, greenhouse gas emissions and preservation of open spaces. Yet the current situation is out of balance. With about 75% of California's water receiving large subsidies, subjecting agricultural water to market forces could help the state achieve many of its other goals, including conservation, water security and even economic stimulus. Some balance should be struck between the needs of agriculture and other water users that allows farmers to remain profitable and prosperous but also shifts water policy in favor of reasonable market pressures that result in higher levels of conservation and free up water for alternate uses.

APPENDIX A


Cost-Effectiveness of Water Supply Improvement Alternatives
Water Use Efficiency Measures (Conservation)
DWR 2009 general estimate for agricultural water use efficiency
Agricultural Efficiency 2000 ROD-WPU 2005
CALFED 2006 comprehensive agricultural water use efficiency
Urban Efficiency LACEDC estimate
CALFED 2006 comprehensive urban water use efficiency
Pacific Institute 2002 urban water use efficiency
Goleta Water District (plumbing retrofit rebates) - short-term
Irvine Ranch Water District (plumbing retrofit rebates) - short-term
Metropolitan Water District (various incentives) - short-term
City of Santa Monica (plumbing retrofit rebates) - short-term
Seawater Desalination
DWR 2009 general estimate for ocean water desalination
Marin Municipal Water District 10 MGD facility EIR estimate
Marin Municipal Water District 5 MGD facility EIR estimate
Santa Barbara similar facility 6.7 MGD
Santa Barbara Charles Meyer 6.7 MGD (rehabilitated)
Poseidon Resources Carlsbad 2011 estimate
Carlsbad, Poseidon Resources 50 MGD (R4RD estimate)
Residents for Responsible Desalination (R4RD general estimate)
Pacific Institute 2005 general estimate
Energy Recovery, Inc. (estimate)
Singapore-Tuas/Black & Veatch
Ashkelon Plant, Israel
Surface Storage Projects
River Mile 274 Temperance Flat Reservoir
Shasta Reservoir Comprehensive Project 5 (dam raise)
North-of-Delta Sites Reservoir
Los Vaqueros Reservoir Expansion
0
1,000
2,000
3,000
4,000
$/af

RESOURCES

Affordable Desalination Collaboration. (2011). Seawater Desalination: Fresh Water from the Sea: About the ADC. Retrieved June 25, 2011, from http://www.affordabledesal.com/

Agricultural Water Management Council. (January 1, 1999). Memorandum of Understanding Regarding: Efficiency Water Management Practices by Agricultural Water Suppliers in California. Retrieved June 8, 2010, from http://www.agwatercouncil.org/images/stories/pdfs/awmcmou.pdf

Bach, Maryanne. (May 24, 2005). Statement of Maryanne Bach, Director, Research and Development, Bureau of Reclamation, U.S. Department of the Interior, Before the Committee on Resources Committee U.S. House of Representatives on Desalination. Retrieved June 25, 2011, from http://www.usbr.gov/newsroom/testimony/detail.cfm?RecordID=241

BizFed. (June 29, 2010). Water Bond May be Pulled from Ballot. In *Los Angeles County Business Federation*. Retrieved July 15, 2010, from http://www.bizfed.org/news/water-bond-may-be-pulled-ballot

Burt, C.M. (March 10, 1999). Irrigation Water Balance Fundamentals. *Conference on Benchmarking Irrigation System Performance Using Water Measurement and Water Balances*. Retrieved June 16, 2011, from http://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1066&context=bae_fac&sei-redir=1#search=%22canal%20seepage%20groundwater%20recharge%20california%22

CALFED. (August 2006). Water Use Efficiency Comprehensive Evaluation: Bay-Delta Program Water Use Efficiency Element. Retrieved June 11, 2010, from http://calwater.ca.gov/content/Documents/library/WUE/2006_WUE_Public_Final.pdf

CALFED Bay-Delta Program. (August 28, 2000). Programmatic Record of Decision. Retrieved June 15, 2011, from http://calwater.ca.gov/calfed/library/Archive_ROD.html

California Department of Water Resources. (October 2003). Water Desalination Findings and Recommendations. Retrieved June 25, 2011, from http://www.water.ca.gov/desalination/pud_pdf/Findings-Recommendations.pdf

California Department of Water Resources. (November 2009). 2009 Comprehensive Water Package: Special Session Policy Bills and Bond Summary. Retrieved December 1, 2009, from http://www.water.ca.gov/legislation/docs/01272010waterpackage.pdf

California Department of Water Resources. (December 2009). California Water Plan Update 2009: Integrated Water Management. Bulletin 160-09. Retrieved December 30, 2009, from http://www.waterplan.water.ca.gov/cwpu2009/index.cfm

California Department of Water Resources. (November 2010). CALFED Surface Storage Investigations Progress Report. Retrieved August 15, 2011, from http://www.water.ca.gov/storage/CALFED%20Progress%20Report%202010/index.cfm#progressreport

California Natural Resources Agency. (December 2, 2009). 2009 California Climate Adaptation Strategy. Retrieved November 25, 2011, from http://www.energy.ca.gov/2009publications/CNRA-1000-2009-027/CNRA-1000-2009-027-F.PDF

Campbell, Kate. (June 22, 2011). Regulations will set standards for measuring water. *AgAlert: The Weekly Newspaper for California Agriculture*. Retrieved June 30, 2011 from http://www.agalert.com/story/?id=2269

Carlton, Jim. (March 17, 2004). Is Water Too Cheap? As Contract Renewals Loom, Environmentalists, Tax Group Call for Farmers to Pay More. The Wall Street Journal. Retrieved November 25, 2011, from http://ebookbrowse.com/wsj-is-water-too-cheap-03-14-04-highlighted-doc-d13046352

City of Santa Barbara Water. (May 8, 2008). The Charles Meyer Desalination Facility. Retrieved June 25, 2011, from http://www.santabarbaraca.gov/Government/Departments/PW/DesalSum.htm

Cooley, H., Gleick, P. H., Christian-Smith, J. (September 2008). More with Less: Agricultural Water Conservation and Efficiency in California: A Special Focus on the Delta. Retrieved June 11, 2011, from http://www.pacinst.org/reports/more_with_less_delta/more_with_less.pdf

Cooley, H., Gleick, P. H., Wolff, G. (June 2006). Desalination, With a Grain of Salt: A California Perspective. Retrieved June 11, 2011, from http://www.pacinst.org/reports/desalination/desalination_report.pdf

Dibble, S., Gardner, M. (May 3, 2009). California's Water: A Vanishing Resource: Lined Canal Ends Seepage, Saving Water: County to gain; Mexican farmers, wetlands to lose. *San Diego Union-Tribune*. Retrieved June 16, 2011, from http://www.utgreen.uniontrib.com/news/eco-news_20090515d.html

Edwards, Chris. (June 13, 2007). Agricultural Subsidies. *The Cato Institute*. Retrieved November 25, 2011, from http://www.cato.org/research/downsizing/agriculture/agriculture_subsidies.html

Fryer, James. (March 18, 2010). An Investigation of the Marginal Cost of Seawater Desalination in California. *Residents for Responsible Desalination*. Retrieved June 11, 2011, from http://r4rd.org/wp-content/uploads/2009/07/Cost_of_Seawater_Desalination__Final_3-18-09.pdf

Fuguitt, D., Wilcox., S.J. (1999). *Cost-Benefit Analysis for Public Sector Decision Makers*. Westport: Quorum Books.

Gleick, P. H., Haasz, D., Henges-Jeck, C., Srinivasan, V., Wolff, G., Cushing, K. K., Mann, A. (November 2003). Waste Not, Want Not: The Potential for Urban Water Conservation in California. Retrieved June 11, 2011, from http://www.pacinst.org/reports/urban_usage/waste_not_want_not_full_report.pdf

Gleick, Peter H. (January 8, 2011). Viewpoints: State needs more water storage – underfoot. In *The Sacramento Bee*. Retrieved June 7, 2011, from http://www.sacbee.com/2011/01/08/3308379/state-needs-more-water-storage.html

Goleta Water District. (November 27, 2011). Facts and Figures. *Welcome to Goleta Water District*. Retrieved June 20, 2011, from http://www.goletawater.com/about-the-district/facts-and-figures/

Gorman, Steve. (December 1, 2009). California water allocation hits record-low level. In *Reuters*. Retrieved June 7, 2011, from http://www.reuters.com/article/2009/12/02/us-usa-california-drought-idUSTRE5B105D20091202

Hanak, Ellen. (2005). Water for Growth: California's New Frontier. *Public Policy Institute of California*. Retrieved November 25, 2011, from http://www.ppic.org/content/pubs/report/R_705EHR.pdf

Hinojosa-Huerta, O., Nagler, P.L., Carrillo-Guerrero, Y., Zamora-Hernandez, E., Garcia-Hernandez, J., Zamora-Arroyo, F., Gillon, K., Glenn, E.P. (Fall 2002). Andrade Mesa Wetlands of the All-American Canal. *Natural Resources Journal*, *42*, 899-914. Retrieved June 16, 2011, from http://lawlibrary.unm.edu/nrj/42/4/08_hinojasa_huerta_andrade.pdf

IA Drip-Micro Common Interest Group Market Development Subcommittee. (2008). Drip-Micro Irrigation Payback Wizard. Retrieved June 15, 2011, from www.dripmicrowizard.com

International Desalination Association. (2011). Desalination at a glance. Retrieved June 25, 2011, from http://www.idadesal.org/pdf/IDA%20guide_webonly.pdf

Keeley, Graham. (May 13, 2008). Barcelona force to import emergency water. In *The Guardian*. Retrieved June 19, 2009, from http://www.guardian.co.uk/world/2008/may/14/spain.water

Legislative Analyst's Office. (October 22, 2008). California's Water: An LAO Primer. Retrieved November 25, 2011, from http://www.lao.ca.gov/2008/rsrc/water_primer/water_primer_102208.aspx#chapter5

Levin, M., Henry, P. J. (2000). *Cost-Effectiveness Analysis 2nd Edition: Methods and Applications*. Thousand Oaks: Sage Publications.

Littleworth, A.L., Garner, E.L. (1995). *California Water*. Point Arena: Solano Press Books.

Long Beach Water Department. (2011). Water Use Prohibitions. *Long Beach Water Department: The Standard in Water Conservation and Environmental Stewardship*. Retrieved June 20, 2011, from http://www.lbwater.org/water-use-prohibitions

Marlow, Jeffrey. (September 21, 2009). The Pursuit of Cost-Effective Desalination. *The New York Times*. Retrieved June 25, 2011, from http://green.blogs.nytimes.com/2009/09/21/on-the-pursuit-of-cost-effective-desalination/

Metropolitan Water District of Southern California. (September 2011). Metropolitan Water District of Southern California At a Glance. Retrieved June 20, 2011, from http://www.mwdh2o.com/mwdh2o/pages/news/at_a_glance/mwd.pdf

Mitra, Sramana. (May 9, 2008). Hydro-Alchemy. *Forbes*. Retrieved June 25, 2011, from http://www.forbes.com/2008/05/08/mitra-energy-recovery-tech-science-cx_sm_0509mitra.html

Net Resources International. (2011). Ashkelon, Israel. *Water-Technology.net: News, views and contacts from the global Water industry*. Retrieved June 25, 2011, from http://www.water-technology.net/projects/israel/

Officer, L., Williamson, S. H. (2011). GDP Deflator. *Measuringworth.com*. Retrieved June 8, 2010, from http://www.measuringworth.com/glossary/gdpdeflator.html

Pacific Institute. (2011). Publications. Retrieved September 15, 2011, from http://www.pacinst.org/publications/

Poseidon Resources. (2011). Frequently Asked Questions: The Desalination Project. Retrieved June 25, 2011, from http://www.carlsbad-desal.com/faq.aspx?id=1

Risbud, Aditi. (June 12, 2006). Cheap Drinking Water from the Ocean: Carbon nanotube-based membranes will dramatically cut the cost of desalination. *Technology Review Published by MIT*. Retrieved June 25, 2011, from http://www.technologyreview.com/energy/16977/page1/

SBMission.org. (2011). Santa Barbara Mission History: The Story of Mission Santa Barbara. Retrieved August 15, 2011, from http://www.sbmission.org/history.html

Schwarzenegger, Arnold. (June 19, 2009). Executive Order S-11-09. Retrieved June, 7, 2011, from http://gov.ca.gov/news.php?id=12561

Schwarzenegger, Arnold. (November 14, 2008). Executive Order S-13-08. Retrieved November 26, 2011, from http://www.gov38.ca.gov/executive-order/11036/

Stahl, Lesley. (December 27, 2009). Why California is Running Dry. In *60 Minutes*. Retrieved December 28, 2009, from http://www.cbsnews.com/stories/2009/12/23/60minutes/main6014897.shtml

The Economist. (October 22, 2009). California's water wars: Of farms, folks and fish: A truce in California's long and bitter fight over water at last appears possible. In *The Economist*. Retrieved December 28, 2009, from http://www.economist.com/node/14699639

The Field Poll. (July 9, 2010). Field Research Corporation. Retrieved June 11, 2011, from http://www.field.com/fieldpollonline/subscribers/Rls2342.pdf

US Bureau of Reclamation. (June 2004). Shasta Lake Water Resources Investigation, Initial Alternatives Information Report. Retrieved August 15, 2011, from http://www.usbr.gov/mp/slwri/docs/initial_alter_info_rpt/full_report.pdf

US Bureau of Reclamation. (July 2006). Los Vaqueros Expansion Investigation, California, Initial Economic Evaluation for Plan Formulation. Retrieved August 15, 2011, from http://www.usbr.gov/mp/vaqueros/docs/init_econ_eval/index.html

US Bureau of Reclamation. (December 2007). Shasta Lake Water Resources Investigation, Plan Formulation Report. Retrieved August 15, 2011, from http://www.usbr.gov/mp/slwri/docs/plan_form_rpt_12-2007.pdf

US Bureau of Reclamation. (September 2008). North-of-the-Delta Offstream Storage Investigation. Retrieved August 15, 2011, from http://www.usbr.gov/mp/nodos/docs/NODOS_PFR_rev_090808.pdf

US Bureau of Reclamation. (October 2008). Upper San Joaquin River Basin Storage Investigation, Plan Formulation Report. Retrieved August 15, 2011, from http://www.usbr.gov/mp/sccao/storage/docs/usjrbsi_pfr/full_report.pdf

US Bureau of Reclamation. (February 23, 2010). Change in Discount Rate for Water Resources Planning. *Federal Register*. Retrieved June 8, 2010, from http://edocket.access.gpo.gov/2010/2010-3137.htm

US Environmental Protection Agency. (July 2002). Cases in Water: How Efficiency Programs Help Water Utilities Save Water and Avoid Costs. Retrieved June 20, 2011, from http://www.epa.gov/WaterSense/docs/utilityconservation_508.pdf

US General Accounting Office. (April 1994). Water Subsidies: Impact of Higher Irrigation Rates on Central Valley Farmers. Retrieved November 24, 2011, from http://archive.gao.gov/t2pbat3/151713.pdf