METHODOLOGY FOR ANALYSIS OF THE ENERGY INTENSITY OF CALIFORNIA'S WATER SYSTEMS,

AND

AN ASSSESSMENT OF MULTIPLE POTENTIAL BENEFITS THROUGH INTEGRATED WATER-ENERGY EFFICIENCY MEASURES

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Principle Investigator:

Robert Wilkinson, Ph.D.
Environmental Studies Program
University of California, Santa Barbara *

* Contact:
(wilkinson@es.ucsb.edu) phone: 805 569 2590
1428 West Valerio Street, Santa Barbara, CA 93101

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EXECUTIVE SUMMARY

Critical elements of California's water infrastructure are highly energy intensive. Moving large quantities of water long distances and over significant elevations in California, treating and distributing it within the state's communities and rural areas, using it for various purposes, and treating the resulting wastewater, accounts for one of the largest uses of electrical energy in the state. Improving the efficiency with which water is used provides an important opportunity to increase related energy efficiency. (*"Efficiency"* as used here describes the useful work or service provided by a given amount of water.) Significant potential economic as well as environmental benefits can be cost-effectively achieved in the energy sector through efficiency improvements in the state's water systems.

This exploratory study for the California Institute for Energy Efficiency examines the energy intensity of water used in specific geographic areas of the state, and it estimates the potential energy benefits of efficiency improvements of water use. (*Energy intensity* is the total amount of energy, on a whole-system basis, required for the use of a given amount of water in a specific location.) A methodology was developed to account for total energy requirements for water used within a specific service area. A user-friendly and adjustable spread-sheet tool was created to apply the methodology, and a geographic information system (GIS) application was developed to represent the data in a map-based system. Data was obtained for sample areas to demonstrate the application of the methodology and tools.

The study found that the energy intensity of water varies considerably by geographic location of both end-users and sources. Water use in certain parts of the state is highly energy-intensive due to the combined requirements of conveyance over long distances with significant elevation lifts, local treatment and distribution, and wastewater collection and treatment processes. The analysis also indicates that significant potential *energy* efficiency gains are possible through implementation of cost-effective *water* efficiency improvements.

The municipal and industrial (M&I) sector is considerably more energy intensive than agriculture for a variety of reasons. Significant water and energy efficiency improvements have been demonstrated in the M&I sector in many areas of the state. In the agricultural sector, there is wide variability in both water use efficiency and energy intensity of the water used depending on a number of factors including sources of water, irrigation practices, and price. This analysis focused on the M&I sector for two reasons: greater energy intensity, and availability of data.

An important element of this exploratory research project has been a review of previous work, both in practice and on paper, addressing energy elements of water and wastewater processes and systems. Background information is included on each element of the water system (supply through wastewater treatment), along with references and sources, in order to facilitate further research.

This exploratory study identifies significant potential cost-effective energy efficiency benefits from integrated energy, water, and wastewater efficiency programs. It also acknowledges important work already undertaken by various agencies, departments, associations, private sector users, and non-governmental organizations in the area of combined end-use efficiency strategies.

The report concludes with recommendations for further research priorities based on the exploratory work undertaken for this project.

OVERVIEW

Water Systems Account for Significant Energy Use in California

Water systems in California, including extraction of “raw water” supplies from natural sources, conveyance, treatment and distribution, end-use, and wastewater treatment, account for one of the largest energy uses in the state. The total energy embodied in a unit of delivered water (that is, the amount of energy required to transport, treat, and process a given amount of water) varies with location, source, and use within the state. In most areas, the energy intensity will increase in the future due to limits on water resources and regulatory requirements for water quality and other factors.[1]

Interbasin Transfers

California’s water systems are uniquely energy-intensive, relative to national averages, due to pumping requirements for major conveyance systems which move large volumes of water long distances and over thousands of feet in elevation lift. Some of the interbasin transfer systems (systems that move water from one watershed to another) are net energy producers, such as the San Francisco and Los Angeles aqueducts. Others, such as the State Water Project (SWP) and the Colorado River Aqueduct (CRA) require large amounts of electrical energy to convey water. On average, approximately 3,000 kWh is necessary to pump one acre-foot (AF) of SWP water to southern California,[2] and 2,000 kWh is required to pump one AF of water through the CRA to southern California.[3]

As outlined in this study, energy inputs for local treatment and distribution, on-site uses (facility-level pumping, processing, thermal requirements for end-uses), and wastewater collection and treatment, must be added to the energy required to provide “raw” water supplies (from imports and/or local supplies) in order to develop an estimate for total embodied energy or energy intensity.

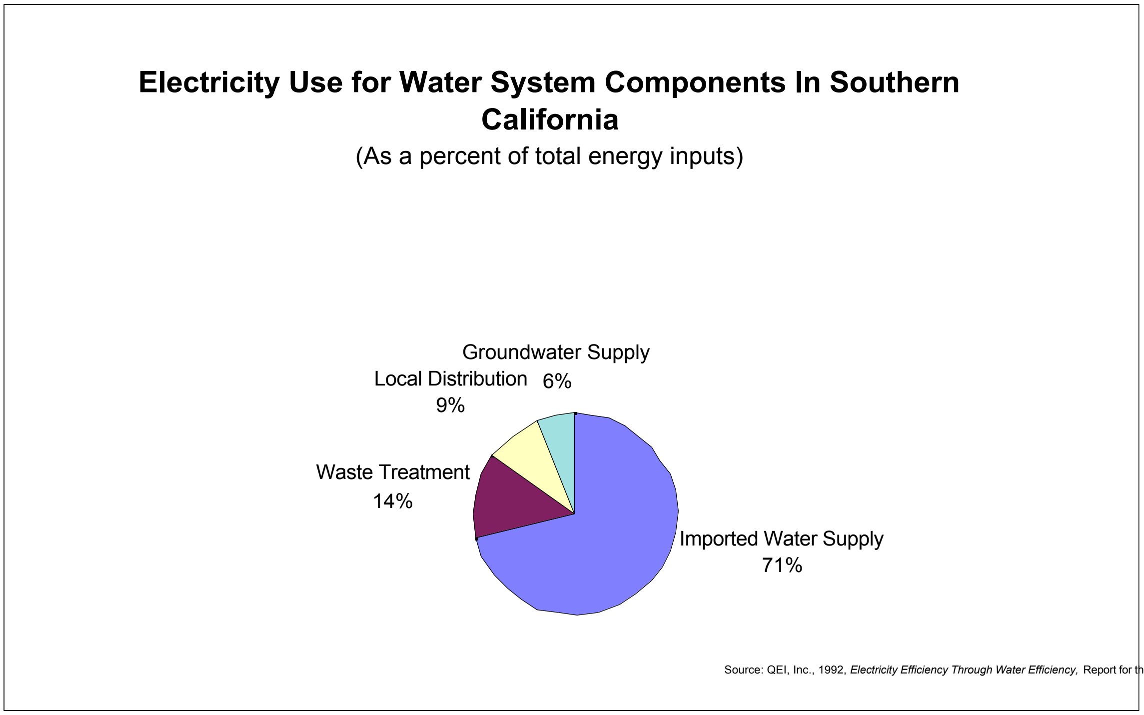
> ***Energy intensity***, or *embodied energy*, is the total amount of energy, calculated on a whole-system basis, required for the use of a given amount of water in a specific location.

Total energy requirements for use of marginal (e.g. imported) supplies of water in Southern California were estimated in 1992 in a study prepared for Southern California Edison at 3,519 kWh/acre-foot (0.01 kWh/gallon).[4] This is an *average* figure for marginal supplies for the region. In specific geographic areas, the figure is *higher* due to additional pumping requirements. The average energy requirement for blended water (local and imported supplies) was estimated at 2,439 kWh/AF due to less energy intensive local supplies.

Water system operations provide a number of challenges for energy systems due to factors such as large loads for specific facilities, time and season of use, and geographic distribution of loads. Key pumping plants are among the largest electrical loads in the state. For example, the SWP’s Edmonston Pumping Plant, situated at the foot of the Tehachapi mountains, raises water 1,926 feet (the highest single lift of any pumping plant in the world) and is one of the largest single users of electricity in the state.[5] In total, the SWP is the largest single user of electricity in the state.[6]

Water use in homes located in some areas of the state accounts for the equivalent of a major end-use electrical appliance. For example, a study conducted for Southern California Edison found that the energy required to provide water use in a typical southern California residence can rank third behind the air conditioner and refrigerator as the largest energy-user "in" the home.[7] (For homes with efficient refrigerators and without air conditioners, water use may be the *largest* energy user.) Approximately sixty percent of the state's population is located in Southern California.

The following graph indicates the average constituent energy inputs for water systems in southern California as a percent of total energy use for water systems.



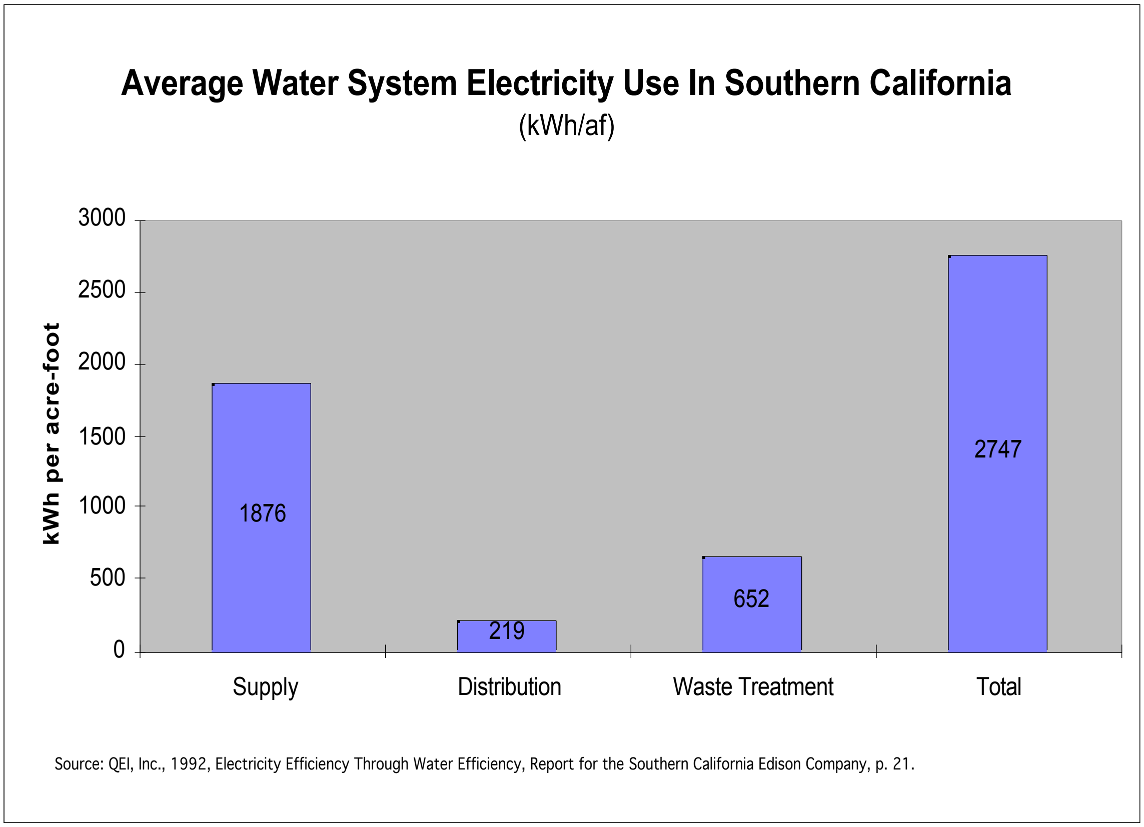
Electricity Use for Water System Components In Southern California

(As a percent of total energy inputs)

Source: QEI, Inc., 1992, *Electricity Efficiency Through Water Efficiency,* Report for the

Source: QEI, Inc., 1992, *Electricity Efficiency Through Water Efficiency*, Report for the Southern California Edison Company, p. 2.

The percentages in the pie graph above are represented in energy units (kWh/af) in the following graph. (The "supply" figure includes imported and groundwater.)



Source: QEI, Inc., 1992, Electricity Efficiency Through Water Efficiency, Report for the Southern California Edison Company, p. 21.

The analysis for this exploratory research seeks to account for all energy inputs to water systems based on a specific geographical area of use.

California Energy Use

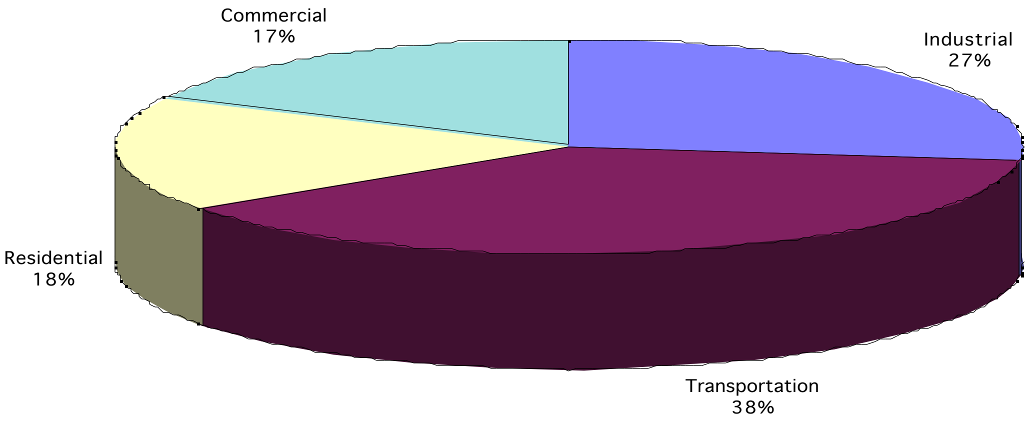
California uses more energy than most nations, with a total consumption of more than seven quads (quadrillion BTUs).[8] On a per capita consumption basis, however, California ranks 48th in the nation,[9] and on the basis of energy used per dollar of gross product, California ranks 46th.[10]

According to the California Energy Commission, California's electricity use has increased an average of 2.3 percent per year since 1977. The greatest share of electricity consumption is in the commercial sector, using 34 percent of the total and growing at an average annual rate of 3.3 percent. Residential electricity consumption has increased 2.3 percent per year on average, and industrial demand has grown at 1.4 percent per year.[11] By some projections, the state's population could increase 50 percent by 2020,[12] and energy requirements will continue to rise with it.

The Metropolitan Water District of Southern California (MWD) reached similar findings. MWD estimates that energy requirements to deliver water to residential customers equals as much as 33 percent of the total average household electric use.[13] A recent study for the Electric Power Research Institute (EPRI) by Franklin Burton indicates that at a national level, water systems account for an estimated 75 billion kWh (3% of total electricity demand).[14] Due to California's settlement patterns, topography, and climate patterns, energy use for water systems is greater than in other areas. Water systems in California are estimated to use about 6.9% of the state's electricity.

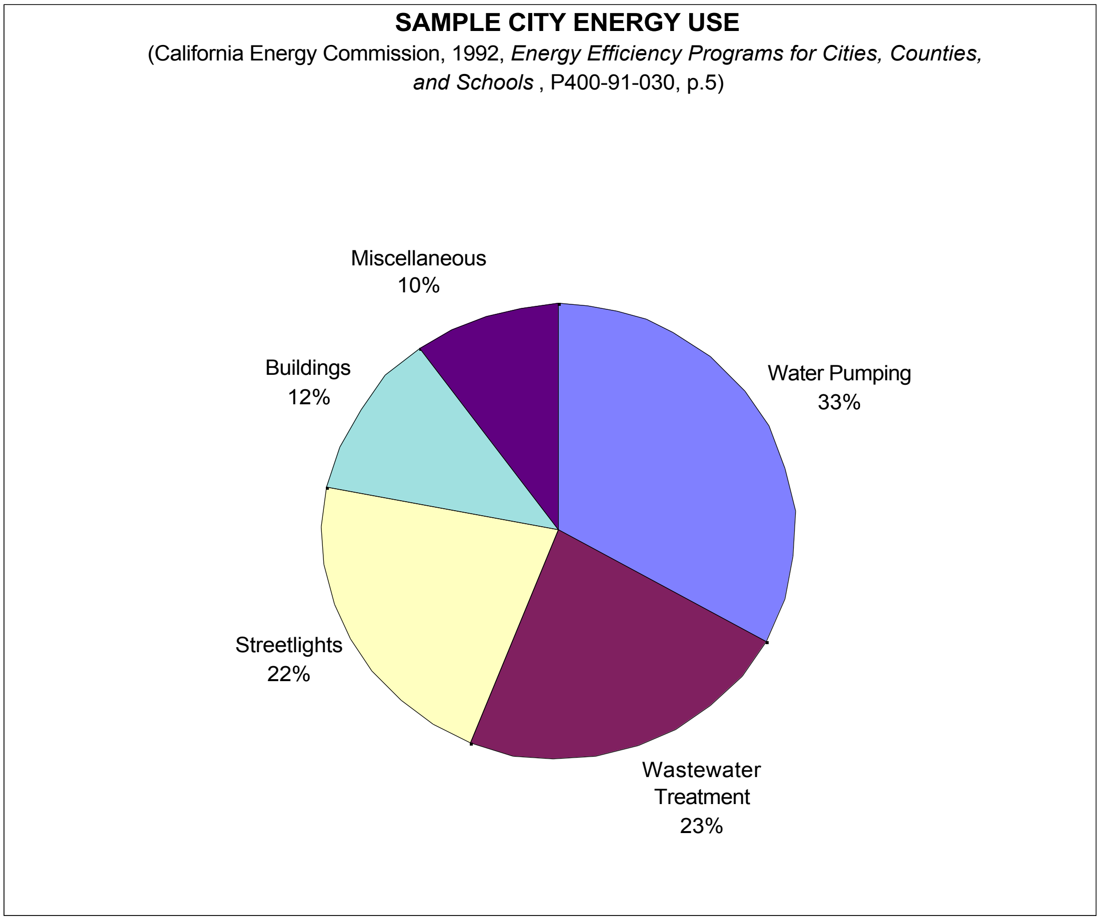
The following pie graph indicates the general categories of energy use in the state. Note that all three non-transportation sectors (residential, commercial, and industrial) account for nearly two-thirds of the state's energy use (62%). Energy use for water systems in each of these three is significant.

California Energy Consumption by Sector—1993



Source: California Energy Commission, www.energy.ca.gov

The distribution of energy used in urban settings is represented in the following graph. Note that more than half the energy use (56%) is for water and wastewater pumping. Additional water-related energy is included in the "buildings" category.



SAMPLE CITY ENERGY USE

(California Energy Commission, 1992, *Energy Efficiency Programs for Cities, Counties, and Schools* , P400-91-030, p.5)

Energy inputs to water systems is primarily in the form of electricity for pumping and processes. As Burton Franklin notes: electricity is used "to power equipment such as pumps, fans and blowers, mixers, centrifuges, ozone generators, and ultraviolet (UV) disinfection equipment," and electrical energy use is projected to increase by 20% over the next 15 years.[15]

Other important energy inputs include fuel for pumps (usually natural gas or diesel) and thermal energy for water heating and cooling.

Water Sources and Use in California

The distribution, in both time and space, of water sources in California impact the energy requirements of water systems. A brief review of the context for water systems is provided here.

Three principle sources provide the state with water: (1) **surface water**, which is often diverted or extracted and stored in reservoirs; (2) **groundwater**; and (3) **imported supplies**, principally from the Colorado River.[16] On average, about 200 million acre feet per year (mafy) falls as precipitation, two-thirds of which falls in the northern one-third of the state.[17] About 71 mafy is surface runoff, stored and redistributed for human use.[18] Water from the Colorado River Basin supplements in-state supplies and provides for about 14 percent of the state's total water; it provides more than 60 percent of the 8.4 million acre-feet used in southern California.[19] Groundwater supplies an average of about 7 mafy, but in drought years, this may increase drastically. Overdraft and contamination has reduced the availability of groundwater supplies throughout the state, and salt-water intrusion in coastal aquifers is already a problem in some coastal areas.

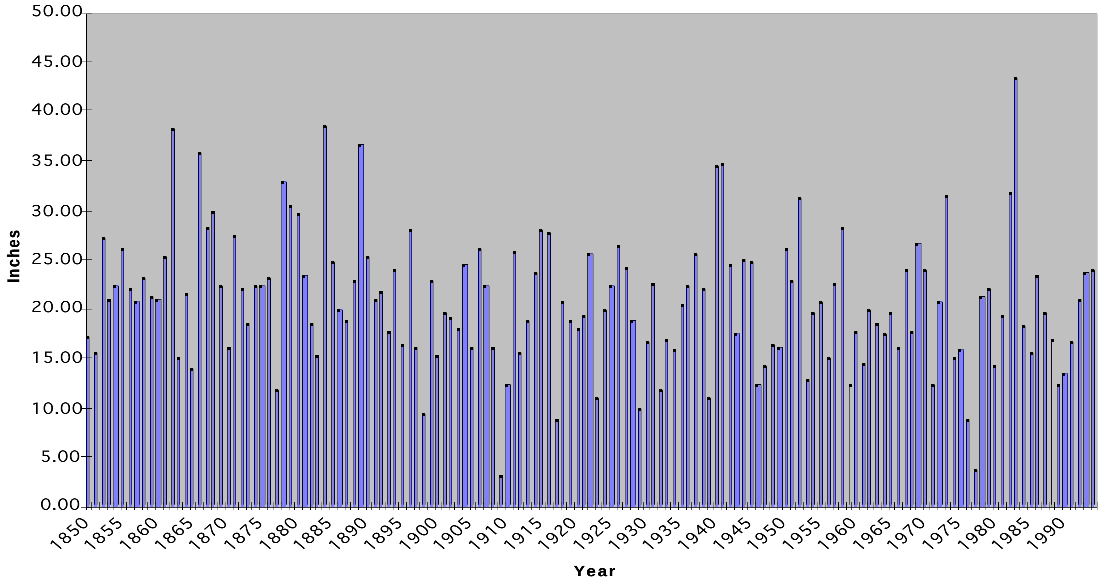
California Average Annual Water Supply and Extractions From All Sources

Water Source	Million Acre Feet per Year (mafy)
Precipitation	193.0
Natural recharge, percolation, and non-developed uses (a)	122.0
surface runoff (historical range: 15 mafy [1977] to 135 mafy [1983])	70.8
Average annual water supply (b)	85.0
Total groundwater resources	850.0
Economically recoverable groundwater resources	250.0
Extractions of surface water (c)	21.6
Extractions of groundwater	15.0
"Use" of groundwater (does *not* include overdraft)	7.1
Overdraft (d)	1.3
"Net" use of groundwater ("use" plus overdraft)	8.4
Surface storage capacity (reservoirs) (e)	42.8
Delta extractions (f)	10.3
Reclaimed water	0.2
Desalination	0.017
Imported Water	
Colorado River imports (g)	5.2
"Local imports"	1.0

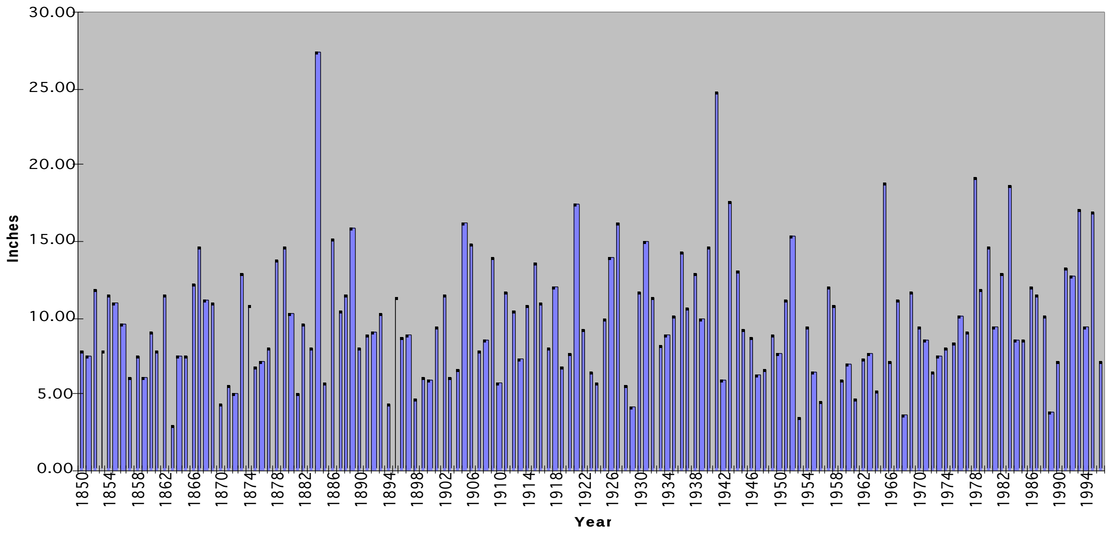
Sources: California Department of Water Resources. *California Water Plan Update*, Bulletin 160-93. 1994. California Legislative Analyst's Office. Colorado River Water: Challenges for California." October 16, 1997. (http://www.lao.ca.gov/101697_colorado_river.html)
(a): "Non-developed" uses are evaporation, evapotranspiration from native plants, and percolation/
(b): Appears to include groundwater extractions including overdraft of 15 mafy and surface at 70 mafy.
(c): Based on sum of local, SWP, CVP, and other federal projects.
(d): DWR projects no overdraft from 2000 forward (Vol. 1, p. 6, Table 1-2), although it states on the same page that "...the reductions in overdraft seen in the last decade in the San Joaquin Valley will *reverse as more ground water is pumped* to make up for reductions in surface supplies from the Delta." (emphasis added)
(e): California Department of Water Resources, Division of Dams. "Dams Statistical File," July 1997.
(f): Based on figures for SWP and CVP.
(g): California's entitlement is 4.4 mafy

Precipitation fluctuates greatly from place to place and year to year, however, and floods and droughts are legendary. The highest annual rainfall recorded was 161 inches in the Santa Lucia Mountains, but Bagdad in the Mojave Desert once had no measurable rain for 25 months, a U. S. record.[20] Actual rainfall deviates significantly from the average more often than not. In 1996, for example, San Francisco had a 50 percent increase over "normal", while in the same year, Imperial County had less than 30 percent of its usual rainfall of 2.75 inches.[21] Northern California experienced a "500-year flood" in January 1997 when warm rains followed record snowfalls. In 1997, Los Angeles experienced its longest dry spell in its history—219 days—followed by the wettest February (1998) in over 100 years—nearly 12 inches.

Annual Rainfall in San Francisco Since 1

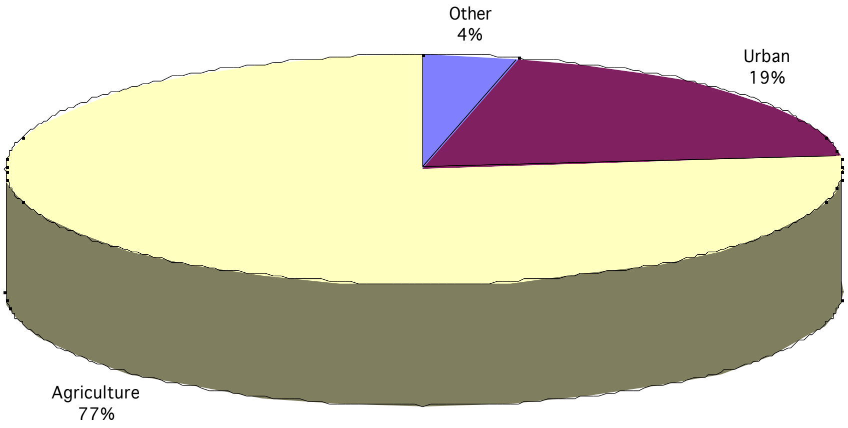


Annual Rainfall in San Diego Since 1

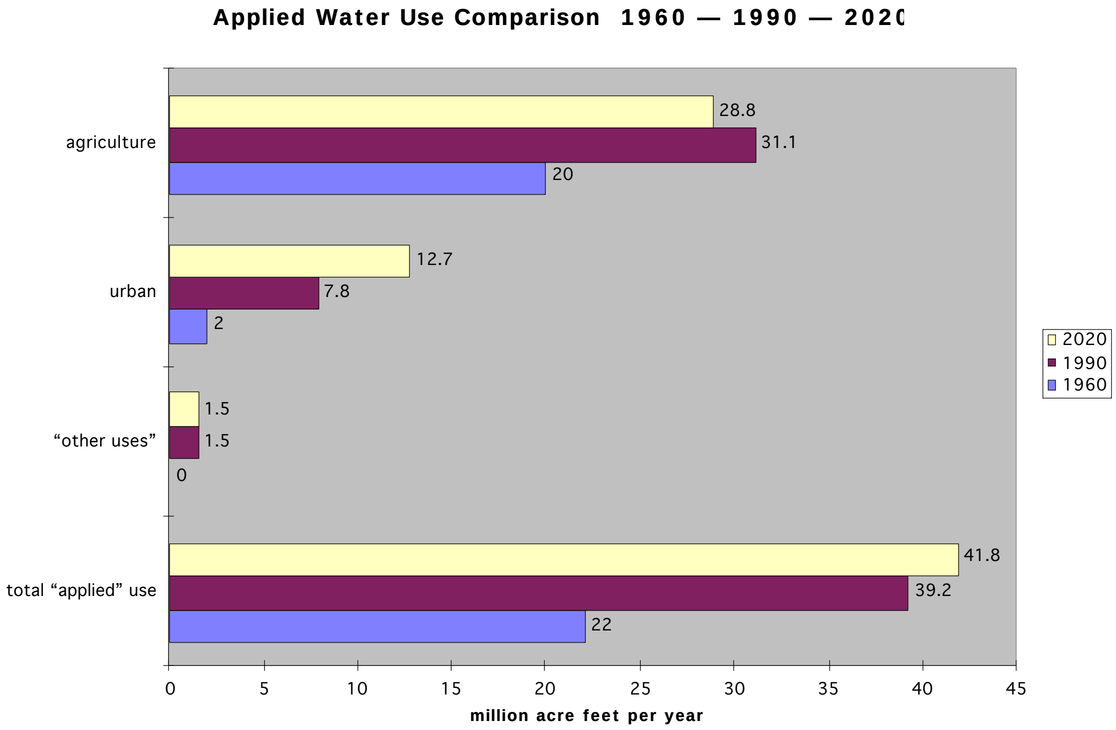


The water diversion, conveyance, and storage systems developed in California in this century, such as the Central Valley and State Water Projects, the Colorado and Los Angeles Aqueducts, are remarkable engineering accomplishments. These water works move millions of acre-feet of water around the state annually. The state's 1,200-plus reservoirs have a total storage capacity of 42 million acre feet (maf).[22]

Total Water Use—1990



Water in California is extracted from natural systems primarily for use in the urban and agricultural sectors. The urban water use sector includes residential, commercial, industrial, and institutional uses, as well as municipal uses such landscaping and fire-fighting. As the state's population continues to grow, urban uses of water are steadily increasing. Agricultural demand, however, peaked at the end of the 1980s and is declining.[23] In the early 1970s, agriculture used about 85 percent of the state's developed water supply.[24] By the end of the 1980s, the percentage of the state's water used by agriculture had fallen to 80 percent. Irrigated land area increased from about 4 million acres in 1930 to a high in 1981 of 9.7 million acres.[25] In place of the continuing increase in water used for irrigation projected in earlier forecasts, the state now projects a continued decline in water use for agriculture.[26] Land retirement, crop shifting, water transfers, and improved efficiencies in irrigation as well as conveyance and management will all contribute to a reduction in water used for irrigation.[27] Despite this decline, however, total extractions from the state's water systems has increased through the years, with flows for the environment decreasing as a result.



* Total of "other outflow" and "environmental", a category which is not disaggregated for 1960.
Assumes total water resources of 85 mafy for 2020, consistent with 1960 and 1990 data.

Source: California Department of Water Resources. *California Water Plan Update*, Bulletin 160-93. 1994.

With very real limits to the state's water system, and every major supply source being reduced, the state's water systems may be fairly said to be stressed. Every major water supply source in California is currently beyond the physical or legal capacity to be sustained. California's entitlement to Colorado River water is 4.4 mafy, but it has been taking 5.2 mafy.[28] An average of 1.3 mafy of groundwater extraction is overdraft [29] (extractions exceed recharge by more than 18 percent). In severe drought years, this overdraft may be as high as four to 10 mafy,[30] which drastically depletes economically recoverable groundwater resources.

The municipal and industrial (M&I) sector accounts for approximately 20% of the state's developed water use. The costs of water supply options have increased significantly, and water supplies to meet urban demand is the subject of environmental and other concerns. Water management agencies are therefore seeking to meet water service needs through an "integrated resource management" approach involving a number of management strategies.

Whole-Systems Approach to Water/Energy Analysis

This exploratory research project analyzes "whole-system" energy use in water systems for selected locations in California. Data for total energy use in each area includes the extraction and conveyance of water imported from outside of a local watershed, extraction of local supplies (e.g. surface and groundwater sources), treatment and distribution of potable supplies, and wastewater collection and treatment. The sum of these energy inputs equals the net or "embodied" energy for water used in a specific location and is referred to as the *energy intensity*.[31] Potential efficiency improvements in water use in the urban or "M&I" sector are examined to estimate potential energy efficiency improvements.

Whole-systems analysis is an ambitious analytical undertaking due to the links of water systems to other key resource, environmental, and economic systems. As used in the present analysis, the concept is inclusive of direct energy inputs to water systems. Secondary and tertiary impacts (positive and negative) are not within the scope of this exploratory effort. Important research questions relating to related environmental and economic implications and benefits are listed in the appendix.

It is important to note that this broader analytical approach is useful for water managers and decision-makers who are seeking to comply in cost-effective and economically efficient ways with regulatory requirements and policies to manage for multiple objectives. Water and wastewater service providers are facing significant management challenges due to increasing demands for services caused by rapid population growth, the promulgation of more stringent and comprehensive environmental and health standards and regulations, and increasing operating and capital costs.

Management and investment strategies based on whole-systems analysis provide potential opportunities for superior return on investment (public or private), because the solution to one problem (e.g. capacity of wastewater treatment facilities) may be found in efficiency strategies that also reduce requirements for extraction of water from natural systems, pumping requirements, treatment needs, and so on. Furthermore, the total multiple benefits accruing from efficiency improvements should be calculated based on whole-system impacts, not on sub-sets such as wastewater flow reduction alone. The whole-system methodology is an important tool for more accurate cost/benefit analysis.

Opportunities for Efficiency Improvements in Water Management

Water and wastewater managers have developed a number of effective technical and management approaches to increasing efficiencies of both water and energy systems. Important progress has been made in all sectors of water systems, and a combination of both technical and management opportunities exist for further improvement.[32] Burton found in his study for EPRI that further improvements are possible: "Improved efficiency can be brought about by better management of operations and the incorporation of technological changes." [33]

In certain important respects, water management trends are following the energy sector experience of the past several decades. For example, the Metropolitan Water District, the largest water utility in the state, noted in the introduction to its 1990 *Water Management Plan*:

> During the last decade, the arena of long-term water resources planning has been broadened to include conservation as a promising management alternative. Water supplies are currently undergoing the same change which took place in the energy industry during the 1970s. Metropolitan has made

> water conservation an integral part of water resources planning. This required consideration of the full implications of conservation in an engineering, economic, social, and environmental sense.[34]

MWD's management approach embraces water efficiency improvements as an extension of supply: "A gallon of water conserved is a gallon of water that can be directed to another use." [35] MWD reported in 1998 that, along with its member agencies, it had "replaced approximately 1 million water-wasting toilets with ultra-low flush models and distributed approximately 3 million low-flow showerheads." [36] According to MWD's estimates, these new fixtures save more than 44,000 acre-feet annually.

EPRI's *Water and Wastewater Industries: Characteristics and Energy Management Opportunities* report identifies key elements of water efficiency strategies. [37] In particular, the report identifies "new and emerging electrotechnologies" that are "environmentally superior to many conventional treatment techniques and offer substantial operating savings to the municipal utility industry. In many cases, these savings provide rapid payback for capital investments." It also notes that "energy management involves evaluation of plant equipment processes, installation of controls, and reduction of operating costs by implementing energy management systems."

Technological Changes That May Increase Energy Efficiency in Facilities

- High efficiency electric motors.
- Adjustable speed drives for driving process equipment.
- Improved process instrumentation and control that allows better management and control of equipment operations.
- Replacement of coarse bubble diffusers with fine pore air diffusers for improved and more efficient wastewater aeration.
- Increased use of cogeneration by utilizing methane gas generated by anaerobic digestion of organic solids in wastewater treatment plants.
- Use of storage for flow equalization to reduce peak demand.

Franklin L. Burton, 1996, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities.* (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.1-4.

Technical and management approaches to improved water and energy efficiency are linked to economic signals and policy frameworks. Significant potential exists in all sectors of California's economy for improvements in energy and water efficiency. Dramatic savings of water and energy have been demonstrated in the commercial and industrial sector, in institutions and public services, in the residential sector, and in agriculture.[38] Potential irrigation efficiency improvements for landscape and crop irrigation are significant. Permanent savings of 25 to 50% for large water users, combining indoor and outdoor water uses, have been demonstrated.[39] Water efficiency potential extends far beyond the basic showerhead and faucet retrofit programs many people think of when considering water efficiency programs. Pricing structures, public education, and other measures are being used by water managers to increase water use efficiency.

"Best Management Practices" (BMPs) have been developed and refined for California's urban water sector which incorporate both technical and management elements.[40] The BMPs are being implemented to varying degrees by urban water management agencies.[41] A similar process has also been developed for the agricultural sector, though it is less comprehensive and has yet to be widely employed.[42] A detailed discussion of each measure may be found on the CUWCC web site as noted. As noted in the section on recommended research, an comprehensive analysis of efficiency potential for the BMPs and other measures should be undertaken.

Data for Specific Geographic Locations

The energy intensity of water is usually determined by geographic factors including the location of the sources of water and the location of end-use. Water in California is often moved from one area to another via conveyance facilities. Total energy requirements for the conveyance of water in systems like the SWP and the CRA to particular destinations may be estimated with reasonable accuracy.[43] In a given geographic area, the water used may be a mix of imported and/or local supplies from surface or groundwater sources. [44] Each of these sources can be identified and an energy value per unit of water from each may be determined.

Water is typically treated and delivered by a local water management entity, and the wastewater generated by users is usually collected and treated in specific geographic areas.[45] Each responsible entity, from imported supply delivery agencies to local treatment and distribution, to wastewater authorities, operate within specific geographic areas. In many cases the boundaries for jurisdiction of these agencies overlap or are inconsistent. The analysis must therefor account for geographic boundaries and attribute the appropriate energy factor for each element of the system. The use of geographic information systems (GIS) to delineate the boundaries and record energy and other data is envisioned as a next step in the research initiated here. One significant benefit of the use of GIS is the ability to define areas of use based on location, and to attribute the energy per unit of water values accordingly.

Methodology for Analysis

One objective of this exploratory research project is the development of a methodology for the calculation of total embodied energy in water in a particular location or geographic area of use. To meet this objective, a spread-sheet tool has been developed with equations embedded to calculate total energy requirements for water use. Both the equations and the data input to the spread-sheet are fully transparent, so the user can alter elements as needed. The spread-sheet can be linked directly to GIS applications, such that data can be calculated and displayed for the user through the GIS tool.

For purposes of this exploratory project, all data listed in the spread-sheet is referenced to the text (located in the notes section of the appendix) which explains the source of the data and other information.

Energy and Water Units

The units for energy are kilowatt hours (kWh) and therms. Therms (based on the energy content of fuel) are 100,000 British thermal units (BTUs). For comparison of total energy, therms are converted to kWh equivalent.

The common unit for water supply is an "acre-foot" (AF). An acre-foot of water is the volume of water that would cover one acre with one foot. An acre-foot equals

325,851 gallons, or 43,560 cubic feet, or 1,233.65 cubic meters. (See conversion table in the Appendix.) Wastewater is typically measured in "million gallons per day" (MGD). Figures have been converted to AF to provide consistency. One MGD equals 1,120 AF per year, and one AFY equals 0.000893 MGD. One acre-foot equals 0.325851 MG.

Energy Inputs Included (and Excluded) in the Analysis

The methodology developed for this analysis seeks to account for all of the energy inputs embodied in water delivered to and used in specific locations. Energy inputs for extractions from natural systems through end-uses to ultimate disposal or re-use are included.

For purposes of this analysis, power generated by water systems separate from the delivery and conveyance systems is not included in the calculations. This is because power would be generated in any event, regardless of the ultimate use of the water, and whether power is generated or not does not influence the energy requirements for delivery and use. For example, hydro-power generation from water flowing from northern California to the Delta is not counted in this analysis because it would be generated whether the water flows out the Golden Gate or is pumped out of the delta to southern California in the SWP. The calculations for the SWP therefore start at the delta. (This methodology is not intended to diminish the role and importance of hydro-power production. The consideration is strictly the correct methodology for assessment of the total embodied energy in each unit of water used in a specific location.)

Power generated as part of the conveyance systems, however, is counted because it is directly related to the volumes of water pumped through the system. (For example, power recovered from the Warne and Castaic plants on the west branch of the SWP recover a portion of the energy inputs in the system from the Banks through Wind Gap pumping plants in the Central Valley and the Edmonston and Oso pumping plants that lift water over the Tehachapi Mountains. Total energy requirements are adjusted to credit back to the system the power generation against the pumping requirements to a given point in the system.

Policy Implications

This exploratory research project addresses the linkage between efficiency improvements in water and energy use in California and the potential multiple benefits to be derived from them. Efficient water and energy use, and the facilitation of cost-effective measures to improve efficiency for both, is an important policy challenge and opportunity. Multiple benefits from integrated strategies constitute potential opportunities for policy development.

With better information regarding the energy implications of water use, public policy and combined investment and management strategies between energy, water, and wastewater agencies and utilities can be improved. Potential benefits include improved allocation of capital, avoided capital and operating costs, reduced burdens on rate-payers, and environmental benefits. Other societal goals, including restoration and maintenance of environmental quality, can also be addressed more cost-effectively through policy coordination. Full benefits derived through water/energy efficiency strategies have not been adequately quantified or factored into policy, although the California Public Utilities Commission adopted principles supporting such approaches in 1989.[46] Recent drought cycles in California, coupled with economic considerations and an increasing concern for environmental impacts, have confirmed the importance of efficient resource use as a policy objective. Energy efficiency benefits accruing as a result of water efficiency programs hold significant potential.

ENERGY USE IN WATER SYSTEMS

Overview of Energy Inputs to Water Systems

There are four principle energy elements in water systems:

1. primary water extraction and supply delivery (imported and local)
2. treatment and distribution within service areas
3. on-site water pumping, treatment, and thermal inputs (heating and cooling)
4. wastewater collection and treatment

Pumping water in each of these four stages is energy-intensive and constitutes a major use of California's total energy. Other important components of energy embodied in water use include groundwater pumping, treatment and pressurization of the water supply systems, treatment and thermal energy (heating and cooling) applications at the point of end-use, and wastewater pumping and treatment.

> ***1. Primary water extraction and supply delivery***
> Moving water from near sea-level in the Sacramento-San Joaquin delta to the San Joaquin-Tulare Lake Basin, the Central Coast, and Southern California, and from the Colorado River to metropolitan Southern California, is highly energy intensive. As noted, approximately 3,000 kWh is necessary to pump one acre-foot (AF) of SWP water to southern California, and 2,000 kWh is required to pump one AF of water through the CRA to southern California.[47] Groundwater pumping also requires significant amounts of energy depending on the depth of the source. (Data on groundwater is incomplete and difficult to obtain because California does not manage groundwater resources, other than in adjudicated basins, and meters and data reporting are not required.)
>
> ***2. Treatment and distribution within service areas***
> Within local service areas, water is treated, pumped, and pressurized for distribution. Local conditions and sources determine both the treatment requirements and the energy required for pumping and pressurization.
>
> ***3. On-site water pumping, treatment, and thermal inputs***
> Individual water users use energy to further treat water supplies (e.g. softeners, filters, etc.), circulate and pressurize water supplies (e.g. building circulation pumps), and heat and cool water for various purposes.
>
> ***4. Wastewater collection and treatment***
> Finally, wastewater is collected and treated by a wastewater authority (unless a septic system or other alternative is being used). Wastewater is sometimes pumped to treatment facilities where gravity flow is not possible, and the standard treatment processes require energy for pumping, aeration, and other processes. (In cases where water is reclaimed and re-used, the calculation of total energy intensity is adjusted to account for wastewater as a *source* of water supply. The energy intensity generally includes the additional energy for treatment processes beyond the level required for wastewater discharge, plus distribution.)

Water pumping, and specifically the long-distance transport of water in conveyance systems, is a major element of California's total demand for electricity. Water use, based on embodied energy, is the second or third largest consumer of electricity in a typical Southern California home after refrigerators and air conditioners. Electricity required to support water service in the typical home in Southern California is estimated at between 14% to 19% of total residential energy demand. If air conditioning is not a factor the figure is even higher.[48] Nearly three quarters of this energy demand is for pumping imported water.

Both California State Water Project (SWP) and Colorado River supplies are energy-intensive due to pumping requirements. The SWP supplies average 2,956 kWh/acre foot for delivery pumping alone, with Colorado River supplies averaging 1,916 kWh/acre foot.[49] For the 1989-90 fiscal year, Colorado river pumping[50] (without accounting for station service and transmission losses) was 2,434,567,313 kWh.[51] The SWP required approximately 3,420,092,000 kWh in the same year.[52] The cost of this electricity is incorporated into water rates.

Primary Users: M&I and Agricultural

The two major water users in California are agriculture (at around 80% of the total extracted amounts) and urban or "M&I" (municipal and industrial) sector at around 20%. The present analysis is focused on the M&I sector for several reasons. First, important data for the agriculture sector analysis is unavailable or difficult to obtain due to prevailing groundwater law and other factors. Second, water use in the M&I sector is considerably more energy-intensive than in agriculture due in large part to major inter-basin conveyance systems.

Water managers typically identify urban water use in a broad category called *municipal and industrial* (M&I), which generally includes residential uses as well as commercial and institutional, industrial, and municipal uses. An important sub-set of M&I water use is the non-residential category of *commercial, industrial, and institutional* (CII) users.[53]

As noted above, this analysis focuses on the M&I sector due to its energy intensity and the availability of data.

Major Supply Systems: Interbasin Transfers

Major inter-basin water transfers in California began at the turn of the 20th century. Early transfers, such as the Colorado River diversions to the Imperial Valley, were gravity fed and therefore required no energy for pumping. The infamous Los Angeles aqueduct and San Francisco's water from Hetch Hetchy Valley (in Yosemite National Park) are *net energy producers* due to the hydro-power production of the systems. Systems built later in the century, however, required significant pumping plants ad energy inputs to run them to lift water over mountain ranges. The State Water Project and the Colorado River Aqueduct are the two most energy-intensive systems in the state, and are therefore the focus of this analysis.

The State Water Project

The State Water Project (SWP) is managed by the California Department of Water Resources (DWR) and provides water for agricultural and urban uses.[54] SWP facilities include

28 dams and reservoirs, 22 pumping and generating plants, and nearly 660 miles of aqueducts.[55]

The SWP stores water in the Feather River watershed in Northern California. Lake Oroville, the project's largest storage facility, has a capacity of about 3.5 million acre-feet. Three smaller upstream reservoirs provide additional storage.[56] (Oroville Dam is the tallest and one of the largest earth-fill dams in the United States.)[57] Power is generated at the Oroville Dam as water is released down the Feather River, which flows in natural water courses into the Sacramento River, through the Sacramento-San Joaquin Delta, and to the ocean through the San Francisco Bay.

Water is pumped out of the delta for the SWP at two locations. From the northern Delta, Barker Slough Pumping Plant diverts water for delivery to Napa and Solano counties through the North Bay Aqueduct.[58] Further south at the Clifton Court Forebay, water is pumped into Bethany Reservoir by the Banks Pumping Plant. From Bethany Reservoir, the majority of the water is conveyed south in the 444-mile-long Governor Edmund G. Brown California Aqueduct to agricultural users in the San Joaquin Valley and to urban users in Southern California. The South Bay Pumping Plant also lifts water from the Bethany Reservoir into the South Bay Aqueduct.[59]

State Water Project
Names and Locations of Primary Water Delivery Facilities


Edward Hyatt Powerplant
Thermalito Diversion Dam Powerplant
Thermalito Pumping-Generating Plant
Thermalito Afterbay
Lake Oroville
Antelope Lake
Lake Davis
Frenchman Lake
Barker Slough Pumping Plant
Cordelia Pumping Plant
Delta
Clifton Court Forebay
H. O. Banks Delta Pumping Plant
South Bay Pumping Plant
Bethany Reservoir
Del Valle Pumping Plant
North Bay Aqueduct
South Bay Aqueduct
Lake Del Valle
W. R. Gianelli Pumping-Generating Plant
O'Neill Forebay
San Luis Reservoir
Dos Amigos Pumping Plant
Governor Edmund G. Brown California Aqueduct
Las Perillas Pumping Plant
Badger Hill Pumping Plant
Devil's Den Pumping Plant (under construction)
Bluestone Pumping Plant (under construction)
Polonio Pass Pumping Plant (under construction)
Coastal Branch
Buena Vista Pumping Plant
J.R. Teerink Wheeler Ridge Pumping Plant
A. D. Edmonston Pumping Plant
Alamo Powerplant
Pearblossom Pumping Plant (three units under construction)
Mojave Siphon Powerplant (under construction)
Silverwood Lake
Devil Canyon Powerplant
Lake Perris
I. J. Chrisman Wind Gap Pumping Plant
Oso Pumping Plant
W. E. Warne Powerplant
Pyramid Lake
East Branch
Castaic Lake
West Branch

DWR provides the following description of water conveyance in the SWP:

California State Water Project

The California Aqueduct moves water south along the west side of the San Joaquin Valley. It transports water to the Gianelli Pumping-Generating Plant and the San Luis Reservoir[60] which has a storage capacity of more than 2 million acre-feet.[61] SWP water not stored in San Luis Reservoir, and water released from San Luis, continues to flow south through the San Luis Canal, a portion of the California Aqueduct jointly owned by the Department and the USBR. As the water flows through the San Joaquin Valley, it is raised over 1,000 feet by four pumping plants—Dos Amigos, Buena Vista, Teerink, and Chrisman — before reaching the foot of the Tehachapi Mountains. In the San Joaquin Valley near Kettleman City, the Coastal Branch Aqueduct extends west to serve municipal and industrial water users in San Luis Obispo and Santa Barbara counties.

The remaining water conveyed by the California Aqueduct is delivered to Southern California. Pumps at Edmonston Pumping Plant, situated at the foot of the mountains, raise the water 1,926 feet — the highest single lift of any pumping plant in the world. Then the water enters 8.5 miles of tunnels and siphons as it flows into the Antelope Valley, where the California Aqueduct divides into two branches, the East Branch and the West Branch. The East Branch carries water through the Antelope Valley into Silverwood Lake in the San Bernardino Mountains. From Silverwood Lake, the water flows through the San Bernardino Tunnel into the Devil Canyon Powerplant. The water continues down the East Branch to Lake Perris, the southernmost SWP reservoir. Water in the West Branch flows through the Warne Powerplant into Pyramid Lake in Los Angeles County. From there it flows through the Angeles Tunnel and Castaic Powerplant into Castaic Lake, terminus of the West Branch.

California Department of Water Resources, 1996, *Management of the California State Water Project*. Bulletin 132-96.

The SWP is the largest consumer of electrical energy in the state, requiring an average of 5,000 GWh per year.[62] The energy required to operate the SWP is provided by a combination of DWR's own hydroelectric and coal-fired generation plants and power purchased from other utilities. The project's eight hydroelectric power plants, including three pumping-generating plants, and a coal-fired plant produce enough electricity in a normal year to supply about two-thirds of the project's necessary power.

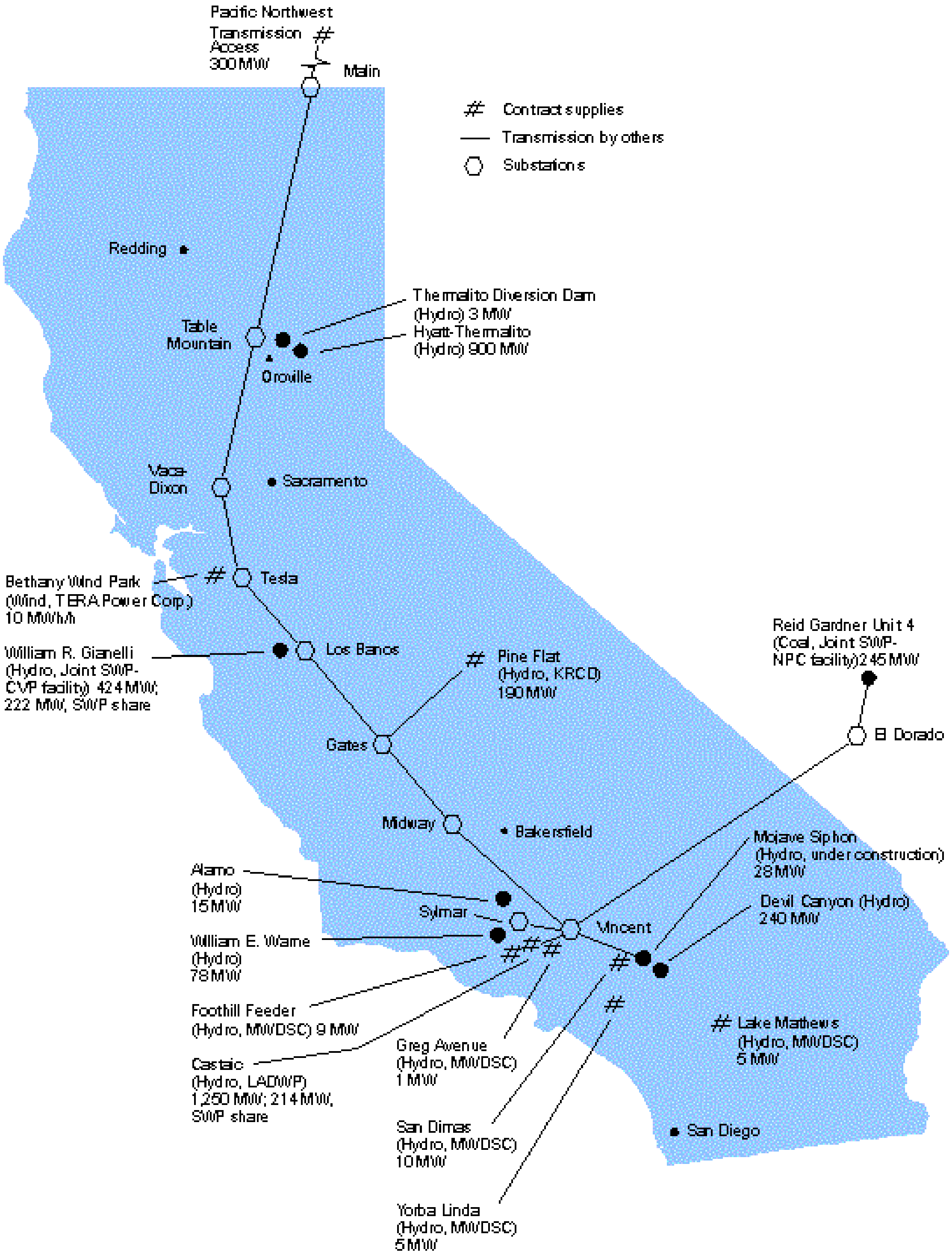
Energy requirements would be considerably higher if the SWP was delivering full entitlement volumes of water. The project has in fact been delivering approximately half its contracted volumes. As DRW comments:

> Facilities were designed and built to meet demands for water through 1990; these demands were projected to be about 4.0 million acre-feet. Actual demand, however, has not developed as projected, owing to circumstances such as slower population growth, changes in local use, local water conservation programs, and conjunctive use programs. The most SWP entitlement water delivered to date was about 2.8 million acre-feet in 1989.[63]

MWD provides the following information on SWP energy requirements:

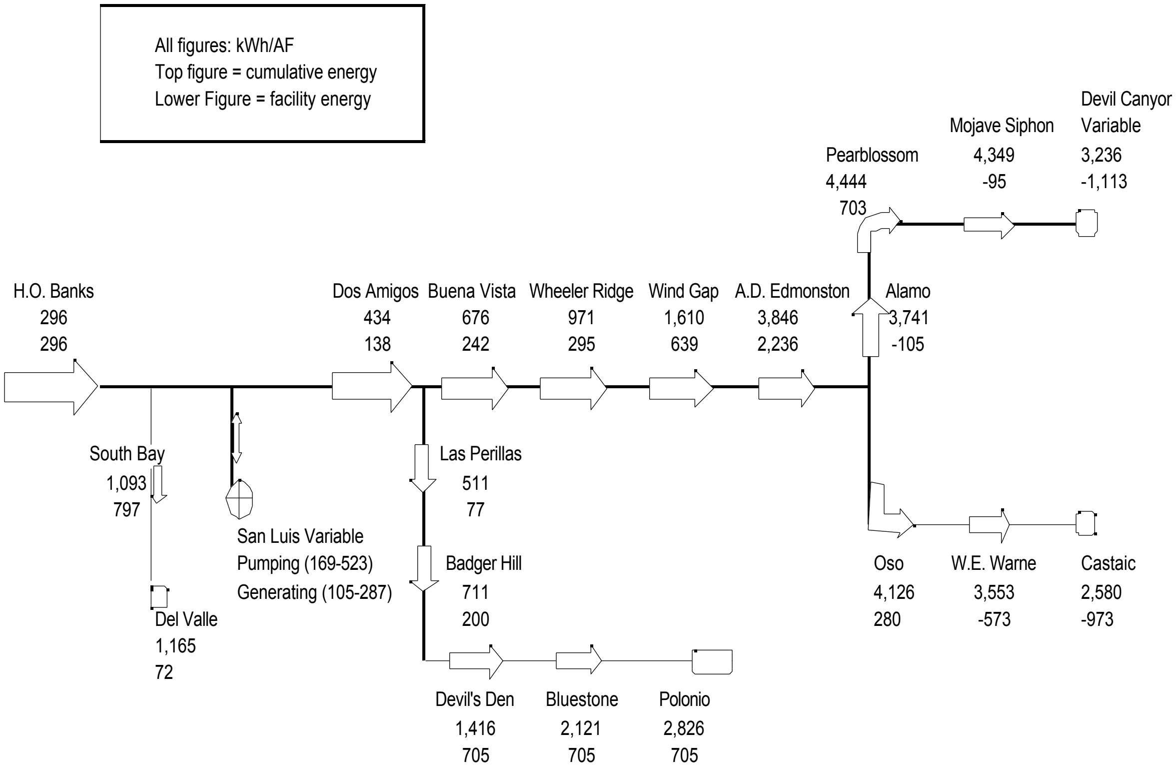
> The electric power required to pump SWP water is primarily off-peak energy with a substantial portion supplied by Edison under a 1979 Power Contract and 1981 Capacity Exchange Agreement. On-peak energy is provided by SWP power generation facilities located throughout the state. DWR has long-term transmission contracts with PG&E and Edison for delivery of power from SWP generation facilities to SWP pumping plants.
>
> Metropolitan pays approximately 60-80 percent of the total power costs incurred by DWR for the SWP depending upon delivery, since it is the largest and one of the last contractors on the aqueduct, and its water is pumped the furthest. Approximately 3,000 kWh (net) are required to pump one acre-foot of water to the Los Angeles basin from the Sacramento-San Joaquin Delta. Metropolitan's SWP deliveries require approximately 2,700 GWh of energy annually. [64]

State Water Project
Names, Locations and Generating Capacity of Primary Power Facilities



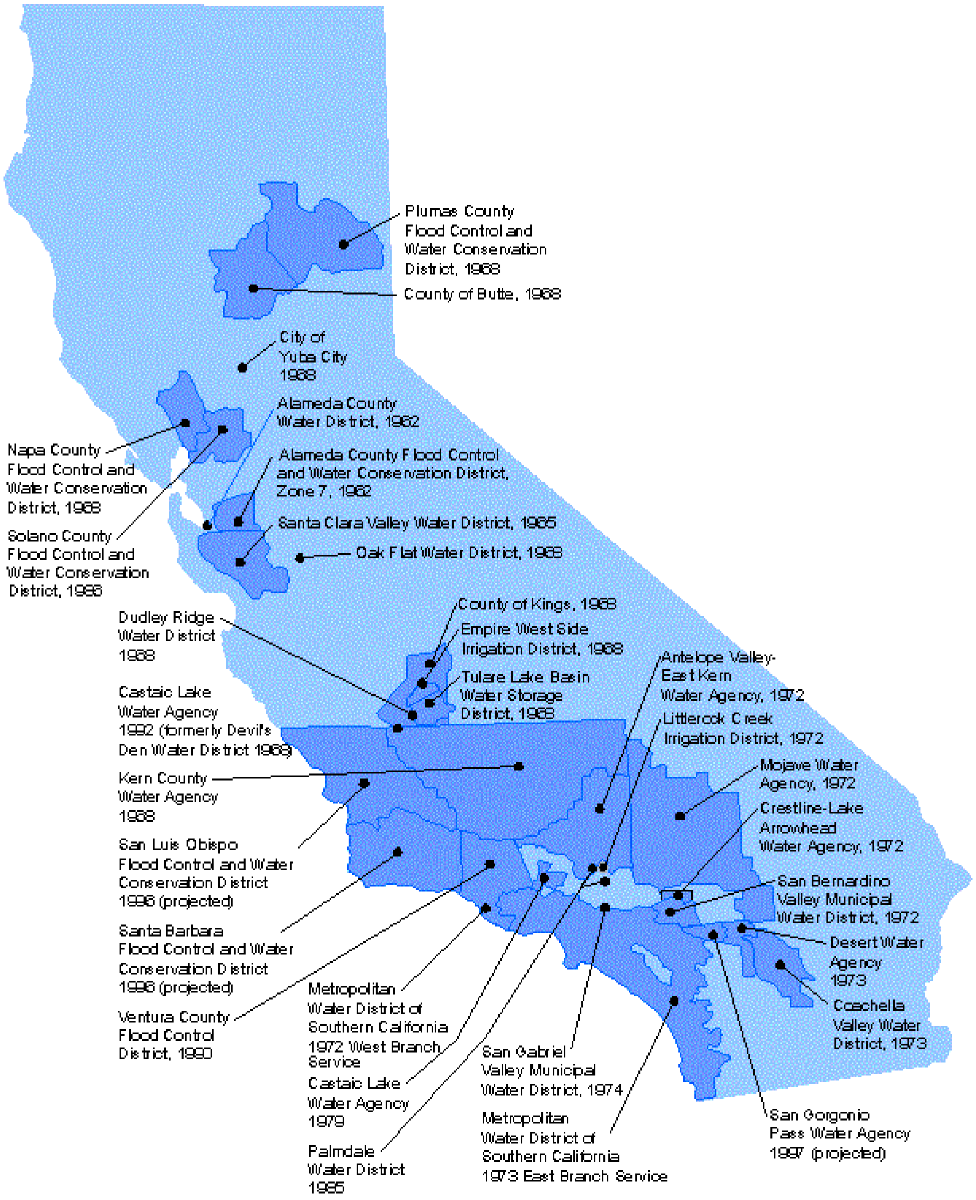
The following chart shows energy requirements to pump an acre-foot of water through each pumping station on the SWP. Also shown is the cumulative kilowatt-hours necessary to pump the water as it moves south down the state and the recovery energy from generators on the down-hill runs.

State Water Project
Kilowatt-Hours Per Acre Foot Pumped
(Includes Transmission Losses)



Source: Based on data from: California Department of Water Resources, State Water Project Analysis Office, Division of Operations and Maintenance, *Bulletin 132-97*, 4/25/97.

State Water Project
Water Delivered in Calendar Year 1995 and Delivery Locations



State Water Project
Water Deliveries by Section

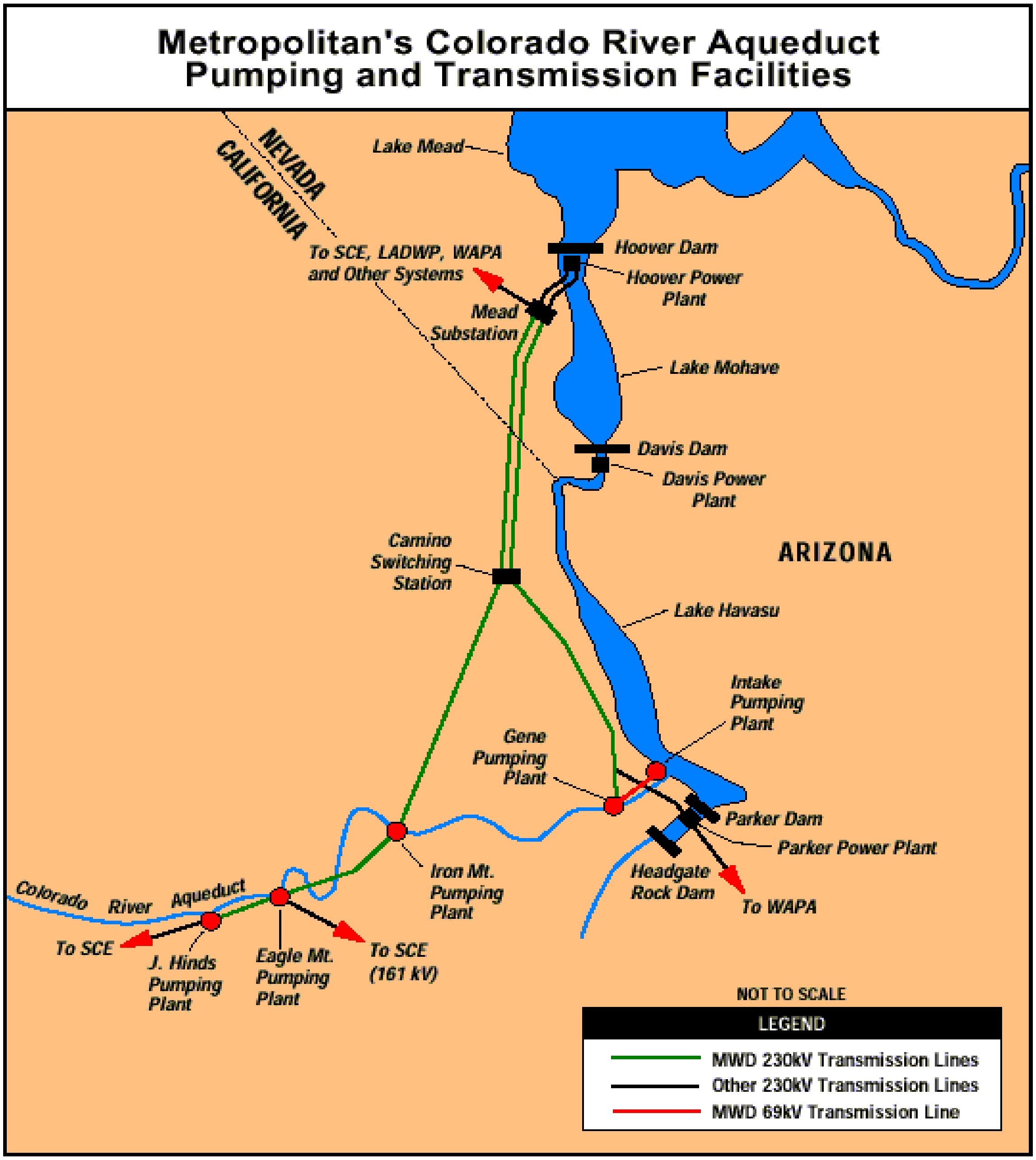
Colorado River Aqueduct

Significant volumes of water are imported to Southern California from the Colorado River via the Colorado River Aqueduct (CRA). Though MWD's entitlement to Colorado River water is 550,000 afy, it has extracted as much as 1.3 mafy through waste reduction arrangements with IID (adding about 106,000 afy) and by using "surplus" water.[65] The Colorado River water supplies require about 2,000 kWh/af for conveyance to Lake Mathews in the Los Angeles basin.

The Colorado River Aqueduct extends 242 miles from Lake Havasu on the Colorado River to its terminal reservoir, Lake Mathews, near Riverside. The Colorado River aqueduct was completed in 1941 and expanded in 1961 to a capacity of more than 1 MAF per year. Five pumping plants lift the water 1,616 feet, over several mountain ranges, to southern California. To pump an average of 1.2 million acre-feet of water per year into the Los Angeles basin requires approximately 2,400 GWh of energy for the CRA's five pumping plants.[66] On average, the energy required to import Colorado River water is therefore about 2,000 kWh/AF. The aqueduct was designed to carry a flow of 1,605 cfs (with the capacity for an additional 15%).

The sequence for pumping the water supplies is as follows: The Whitsett Pumping Plant elevates water from Lake Havasu 291 feet out of the Colorado River basin. At "mile 2," Gene pumping plant elevates water 303 feet to Iron Mountain pumping plant at mile 69, which then boosts the water another 144 feet. The last two pumping plants provide the highest lifts - Eagle Mountain, at mile 110, lifts the water 438 feet, and Hinds Pumping Plant, located at mile 126, lifts the water 441 feet. [67] The five pumping plants each have nine pumps. The plants are designed for a maximum flow of 225 cubic feet per second (cfs). The CRA is designed to operate at full capacity with eight pumps in operation at each plant (1800 cfs). The ninth pump operates as a spare to facilitating maintenance, emergency operations, and repairs.[68]

Colorado River Aqueduct
Pumping and Power Transmission Facilities



MWD has recently improved the system's energy efficiency. The average energy requirement for the CRA was reduced from approximately 2,100 kWh /af to about 2,000 kWh /af "through the increase in unit efficiencies provided through an energy efficiency program."[69] The energy required to pump each af of water through the CRA is essentially constant, regardless of the total annual volume of water pumped. This is due to the 8-pump design at each pumping plant. The average pumping energy efficiency does not vary with the number of pumps operated, and the same 2,000 kWh /af estimate is appropriate for both the "Maximum Delivery Case" and the "Minimum Delivery Case."[70]

Based on the relatively steep grade of the CRA, limited active water storage, and transit times between plants, the system does not generally lend itself to shifting pumping loads from on-peak to off-peak. Under the Minimum Delivery Case, the reduced annual water deliveries would not necessarily bring a reduction in annual peak load, since an 8-pump flow may still need to be maintained in certain months.[71]

Electricity to run the CRA pumps is provided by power from hydroelectric projects on the Colorado River as well as off-peak power purchased from a number of utilities. The Metropolitan Water District has contractual hydroelectric rights on the Colorado River to "more than 20 percent of the firm energy and contingent capacity of the Hoover power plant and 50 percent of the energy and capacity of the Parker power plant."[72] Energy purchased from utilities makes up approximately 25 percent of the remaining energy needed to power the Colorado River Aqueduct.[73]

Regional Distribution

The Metropolitan Water District

The Metropolitan Water District of Southern California (MWD) is a regional water wholesaler that imports water from the Colorado River and Northern California for resale to agencies in Southern California. Because MWD is the principal water supplier for southern California and an important link in the state's two most energy-intensive interbasin water transfers, the SWP and the CRA, it is described in some detail in this section.

The Colorado River is MWD's primary source of water supply, and MWD is the largest user of SWP supplies. MWD provides about 60 percent of the water used by the nearly 16 million people living in portions of Los Angeles, Ventura, Orange, Riverside, San Bernardino, and San Diego counties.[74] The area served covers about 5,200 square miles.

MWD owns and operates transmission infrastructure and has long-term entitlements to the Hoover power plant and perpetual rights to the Parker power plant which provide sufficient power for the CRA. Metropolitan pays "approximately 70 percent of the total SWP power and transmission costs" arising from DWR's long-term agreements, and it Metropolitan owns generates hydroelectric power along Metropolitan's water distribution system.[75]

Metropolitan generates hydroelectric energy within its system. MWD "sells energy from 15 small and conduit hydroelectric units in its Southern California water distribution system. The units have a combined peak capacity of approximately 101 MW, and the energy from the units is sold to DWR, Edison and PG&E under long-term contracts. A total of approximately 330 GWh per year is sold from these power plants." [76] "Metropolitan also owns and operates five water filtration plants, which currently require approximately 30 GWh of energy annually. This energy is provided by the local serving utility under retail tariffs.” [77]

Metropolitan's Integrated Resources Plan identified the following water supply sources as “developable” to meet southern California’s water uses: Colorado River Aqueduct, State Water Project, recycling wastewater, recovering groundwater, conservation, desalination, storage and water transfers and exchanges.[78]

Member Agencies of the MWD of Southern California

City of Anaheim
Foothill MWD
City of San Fernando
City of Beverly Hills
City of Fullerton
City of San Marino
City of Burbank
City of Glendale
City of Santa Ana
Calleguas MWD
Las Virgenes MWD
City of Santa Monica
Central Basin MWD
City of Long Beach
Three Valleys MWD
Inland Empire Utilities Agency
City of Los Angeles
City of Torrance
Coastal Municipal Water District
MWD of Orange County
Upper San Gabriel Valley MWD
City of Compton
City of Pasadena
West Basin MWD
Eastern Municipal Water District
San Diego County Water Authority
Western MWD of Riverside County

MWD Service Area and Member Agencies

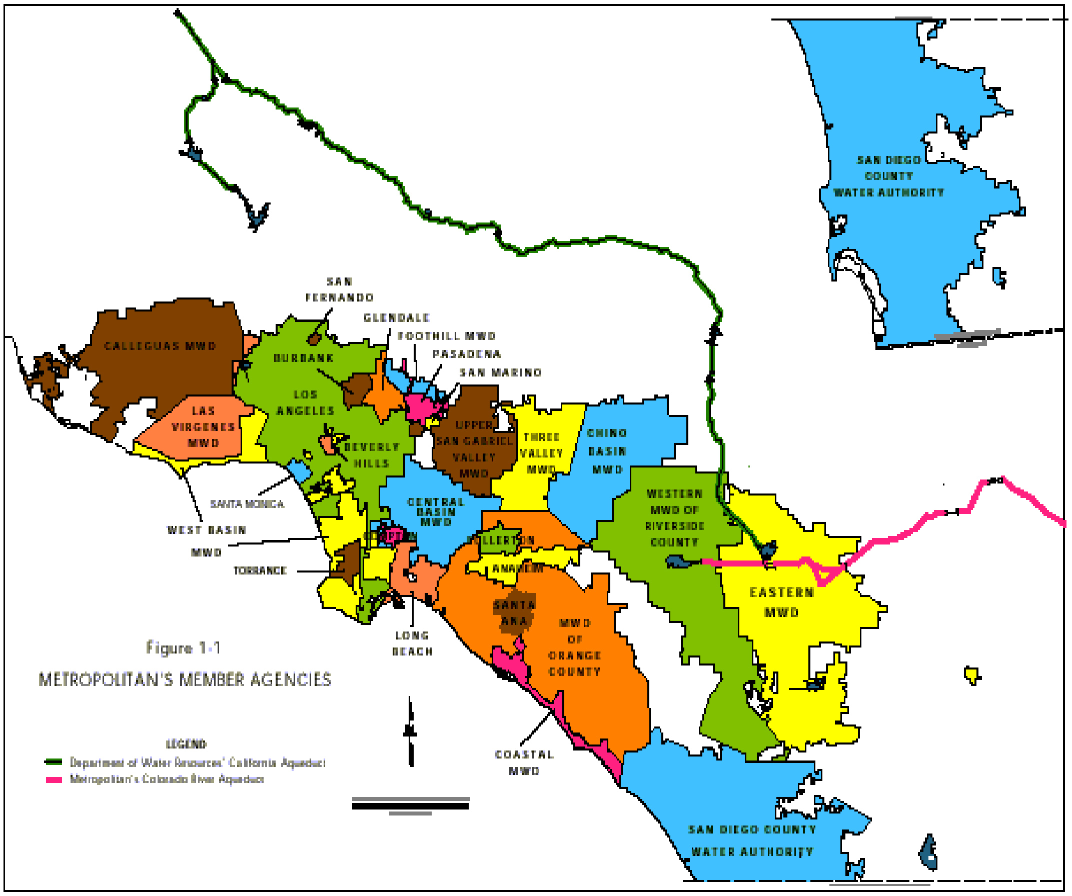
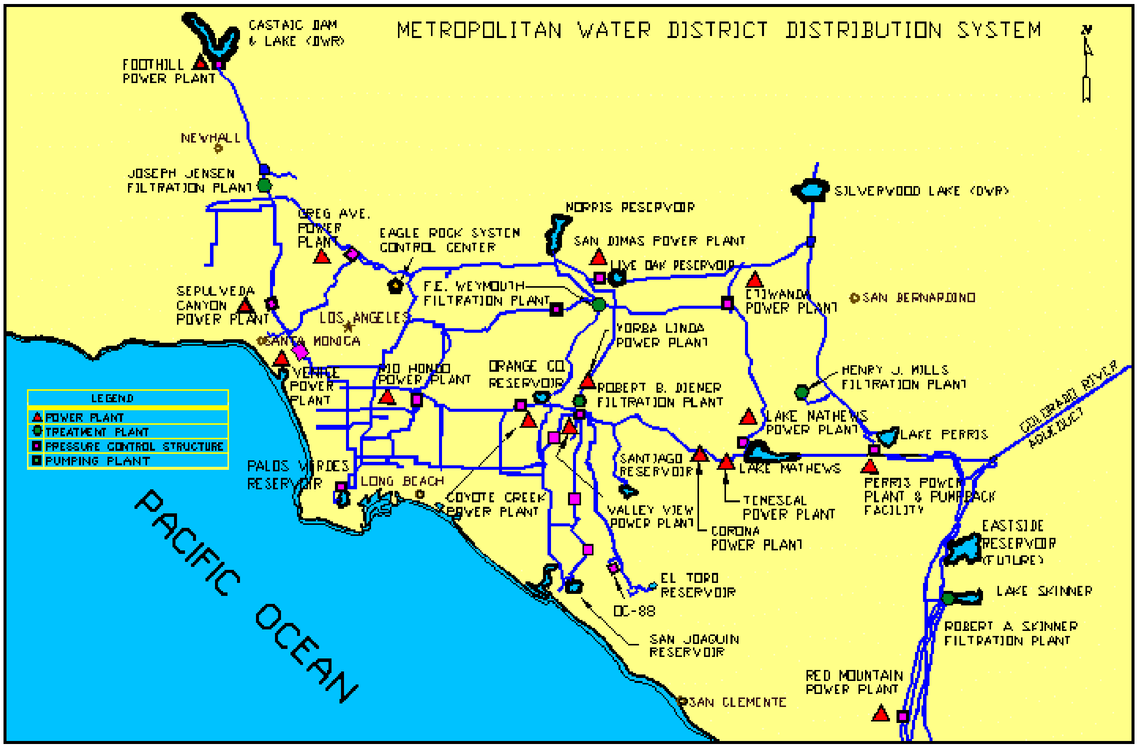
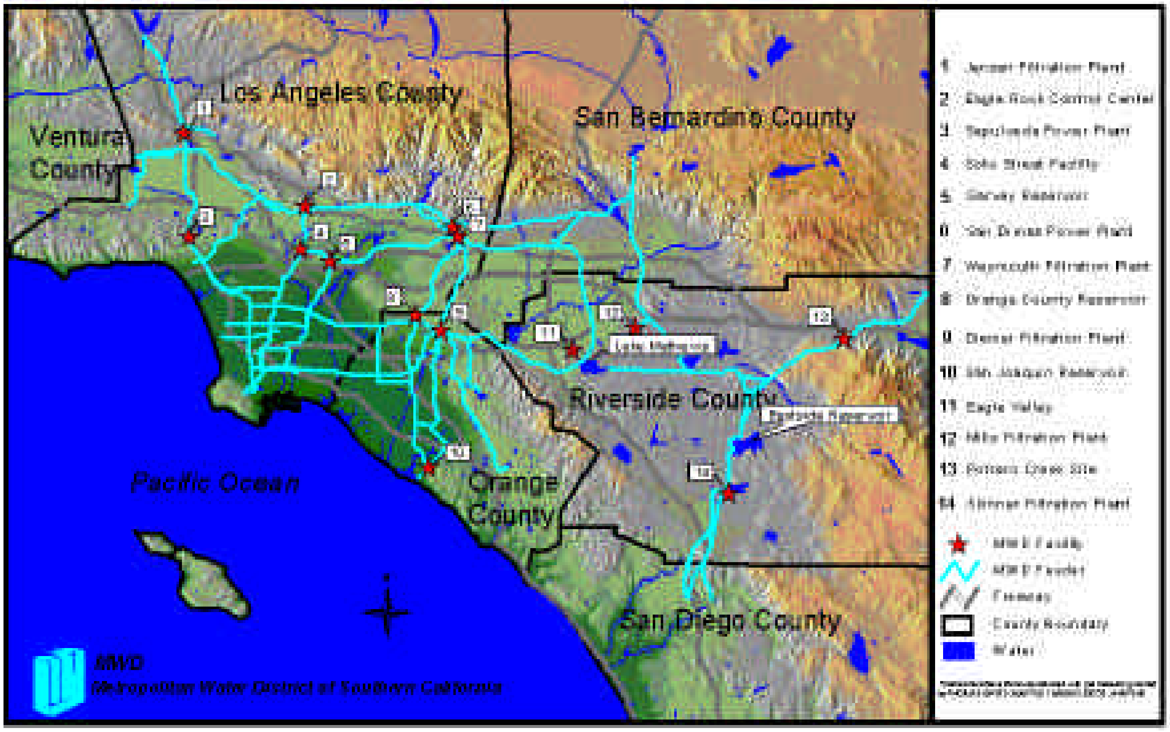


Figure 1-1
METROPOLITAN'S MEMBER AGENCIES

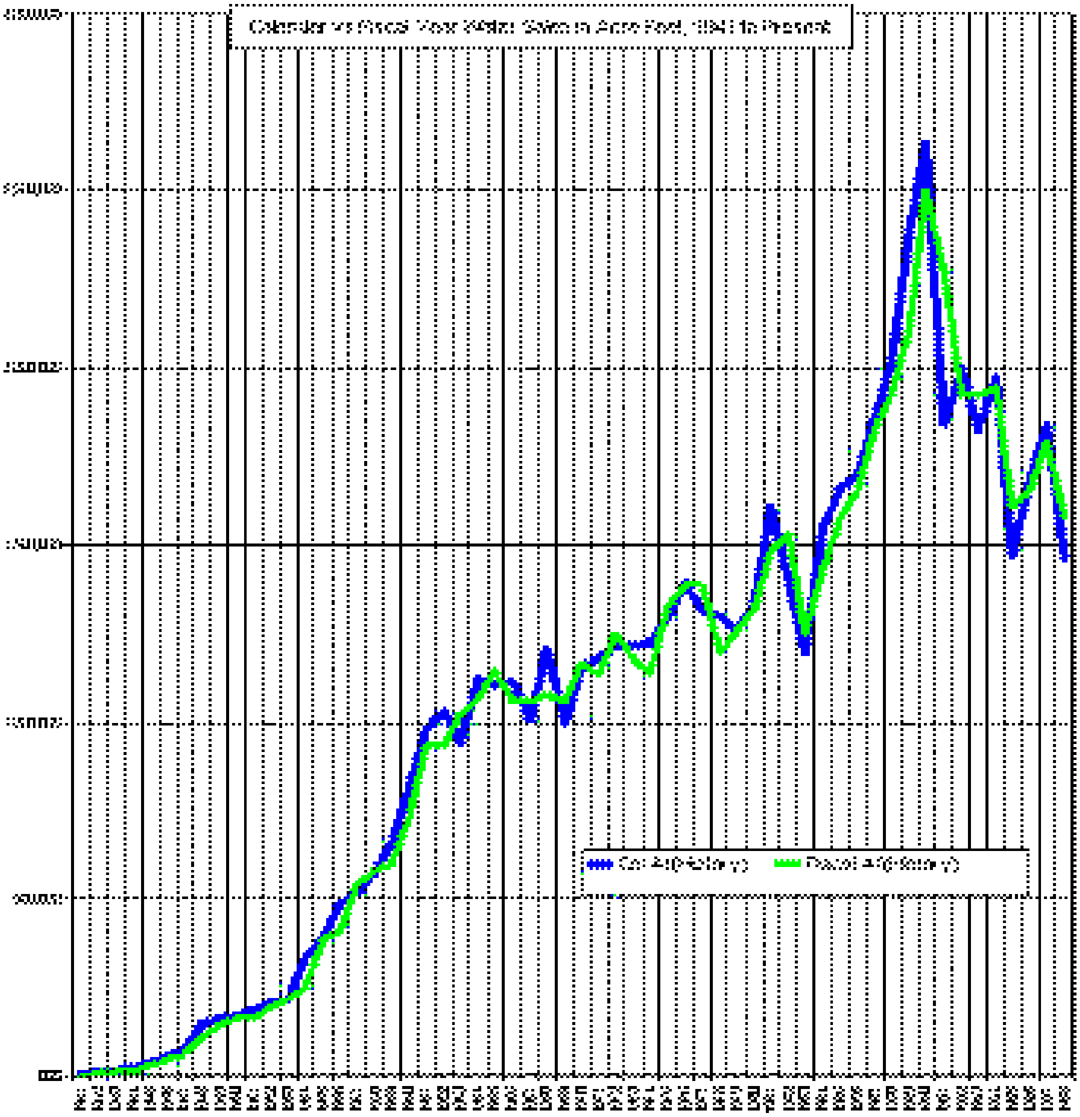
Metropolitan Water District of Southern California
Water Distribution System



MWD Facilities



MWD Annual Water Sales
1941-1998
(in acre-feet)



Local Sources (Surface and Groundwater)

Approximately one-third of the water used in southern California is provided by local surface and groundwater resources.[79] In some areas, all water is provided by local supplies. In others, imported water from the Colorado River and/or the SWP make up all of the supply. In most areas in southern California, water supplied to users is a variable mix of SWP, CRA, and local supplies depending on the time of year, the hydrologic conditions in the particular year (e.g. wet conditions in the northern part of the state vs. local conditions).

Local supplies are considerably less energy-intensive than CRA and SWP imported supplies due to the pumping requirements for importing both CRA and SWP water. Some ground water pumping is required.

The present analysis and methodology disaggregates imported and local supplies, and it provides for identification of energy requirements for each source on a per kWh basis. In cases where pumps are driven by fuel rather than electricity, the energy is recorded in thermal units (therms/Btus) and then converted to kWh for comparison and aggregation.

Treatment and Distribution

Once water is extracted from surface and/or groundwater sources and delivered to a geographic area where it is to be used, it is processed through treatment and/or filtration systems to meet health and other quality standards. It is then delivered to end-users through local distribution systems which typically require pumping for delivery and pressurization to required levels for fire protection. Pressure it typically regulated at the point of connection (POC) to an end-user.

The treatment processes and the system distribution and pressurization require varying amounts of energy depending on factors such as water quality, the topography of the area served, and system requirements. Treatment requirements, and therefor energy inputs, are increasing.[80] As Franklin Burton notes: "Recently promulgated regulations will have a significant impact on energy consumption in water treatment because many water utilities will install energy-consuming technologies such as ozone for disinfection and membrane filtration for the removal of particulate and organic matter. New filtration facilities will also be required to be added to existing surface supplies that currently are not treated (other than disinfection). Existing facilities will also be upgraded if they do not meet new requirements for disinfection."[81] Treatment is designed to deal with contaminants such as the following:

- trihalomethanes (TTHMs)
- haloacetic acids (HAAs)
- chlorinated organic compounds that are suspected carcinogens
- gastrointestinal illnesses
- Giardia lamblia
- Cryptosporidium

Conventional surface water treatment technologies commonly use physical methods such as sedimentation and filtration to remove suspended material from the water and chemical disinfection – mostly with chlorine – to control bacteria, viruses, and *Giardia lamblia*. Chemical processes may be added such as coagulation to enhance the effectiveness of sedimentation and chemical softening to remove the dissolved salts responsible for hardness. Water delivery systems at the local level require the following energy inputs.[82]

> After treatment, water is usually pumped at high pressure to the distribution and storage system. Distribution pumping serves several purposes including:
>
> - overcoming pipe friction within the distribution system
> - providing adequate pressure for the water users
> - providing adequate pressure for supplying hoses and/or pumper trucks for fire fighting
> - supplying water to elevated storage
>
> The term "adequate pressure" can vary widely from one system to the next, with a typical range of 40 to 100 pounds per square inch (psi) (276 to 689 kPa) measured in the distribution mains. For fire flow conditions, both adequate quantities and pressures are required. Often minimum requirements established for fire flows are 500 gallons per minute (gpm) (32 L/s) at 20 psi (138 kPa), but fire flows in densely populated areas can range from 1,500 to 3,000 gpm (96 to 192 L/s).

End-Use (Pumping, Treatment, Processes, and Thermal)

Once water is delivered to an end-user, additional energy inputs are required for some or all of the following functions:

- treatment (e.g. water softening and/or additional filtration)
- recirculation loops within buildings and facilities
- additional pressurization
- thermal requirements (heating and/or cooling)
- wastewater pumping

Efficiency improvements in the residential sector include appliances in the residential sector such as showers, faucet aerators, dishwashers, and washing machines. The present exploratory analysis has not focused on end-use energy inputs. Important efficiency opportunities clearly exist at this level, and it is recommended as an area for further research.

Wastewater Catchment and Treatment

Most M&I water users are connected to wastewater systems which collect and treat it to prescribed standards.[83] (Some areas utilize septic systems.) Increasingly, water is being re-used following treatment. (See following section.) Otherwise treated water is returned to natural water courses or to the sea. Wastewater systems require energy for pumping in the collection systems and for pumping, treatment operations and processes, and solids processing in the treatment facilities.[84] New treatment processes such as UV also use energy.[85] Franklin Burton describes the treatment processes in *Water and Wastewater Industries: Characteristics and Energy Management Opportunities* as follows:

> Wastewater treatment requires a combination of physical operations (such as pumping, screening, settling, and filtration) and chemical and biological processes for the removal of pollutants. In biological processes, cultures of microorganisms are used to clean the water by removing suspended and dissolved organic pollutants. The most common form of biological treatment used in wastewater treatment is activated sludge. Activated sludge requires

> aeration, either by mechanical aerators or blower-operated diffused air, to supply oxygen to the microorganisms. Wastewater aeration, pumping and solids processing account for most of the electric energy used in wastewater treatment. [86]

Wastewater catchment systems are generally designed to operate with gravity flow. In many instances, however, pumping is required to move wastewater to the treatment facility.[87] Wastewater pumps are less energy-efficient than water pumps because of the tolerances required.

> Pumping stations for untreated wastewater must be capable of handling a variety of solids, grease, grit, and stringy material. To pass these materials, the pumps must contain sufficient clear passages so the pumping units do not become clogged. Because of the type of pump construction required for reliable operation, efficiencies of wastewater pumps are generally low (60 to 75 percent) when compared to water pumps, which have efficiencies ranging from 75 to 85 percent.[88]

Pumping energy required to handle wastewater at all times of the day and night is also more difficult than in water supply systems because storage is usually not an option.

> In most cases, there is little storage capacity in community sewer systems to absorb the peak flow rates. Pumping stations, therefore, have to be designed to handle the peak flow rates to prevent system backup and overflows. Because system pumping stations need to be operational at all times, particularly during peak flow rate conditions, most of the stations are provided with a standby or redundant power source such as engine-generators. Regulatory agencies may also require the installation of standby units to maintain system reliability.[89]

Franklin Burton provides a useful summary of wastewater treatment systems: [90]

> Wastewater treatment plants vary widely in terms of the processes employed. The processes depend largely on the level of treatment required as prescribed by the discharge permit issued by the regulating agency. Levels of treatment required are defined customarily as “preliminary” (removal of coarse solids); “secondary” (substantial removal of organic material and suspended and dissolved solids); and “advanced” or “tertiary” (essentially complete removal of organic matter and suspended solids, typically accompanied by some reduction in nutrients such as nitrogen and phosphorus).

Burton notes that: “Historically, the term preliminary and/or primary treatment referred to physical unit operations; secondary treatment referred to chemical and biological unit processes; and advanced or tertiary treatment referred to combinations of all three. These terms are arbitrary, however and in most cases are of little value even though they continue to be used.” He argues sensibly for a more useful definition. “A more rational approach to wastewater treatment is first to establish the level of contaminant removal (treatment) required before the wastewater can be reused or discharged to the environment. The required unit operations and processes necessary to achieve that required level of treatment can then be grouped together on the basis of fundamental considerations. The unit operations or processes may be grouped and termed preliminary treatment, primary treatment, conventional secondary (biological) treatment, or advanced wastewater treatment. Disinfection of the final effluent is almost always required before discharge or reuse.”

Wastewater Treatment Processes

Preliminary Wastewater Treatment

Preliminary wastewater treatment is defined as the removal of wastewater constituents that may cause maintenance or operational problems with the treatment operations, processes, and ancillary systems.

Primary Wastewater Treatment

In primary treatment, a portion of the suspended solids and organic matter is removed from the wastewater. This removal is usually accomplished with physical operations such as screening and sedimentation. The effluent from primary treatment will ordinarily contain a considerable amount of organic matter.

Conventional Secondary Wastewater Treatment

Secondary treatment systems are intended to remove soluble and colloidal organic matter that remains after primary treatment. Secondary treatment is generally understood to imply a biological process. Biological treatment consists of applicati8on of a controlled natural process in which microorganisms remove soluble and colloidal organic matter from the wastewater and are, in turn removed themselves.

Advanced Wastewater Treatment

Advanced wastewater treatment has many definitions. Commonly, the term is defined as the level of treatment required beyond conventional secondary treatment to remove constituents of concern including nutrients, toxic compounds, and increased amounts of organic material and suspended solids.

Disinfection

Disinfection is practiced to protect water quality for subsequent use. A water body into which inadequately disinfected wastewater effluent is discharged may become contaminated by pathogenic (disease causing) organisms such as bacteria and viruses contained in the waste stream.

Solids Management

As wastewater treatment plants expand and are called upon to remove greater amounts of pollutants, large quantities of solids are produced that have to be processed. Most of these solids has a high organic fraction that will biodegrade (hence the term “biosolids”). Organic material will putrefy and cause odors unless properly processed and stabilized.

Effluent Disposal and Reuse

For reuse applications, additional treatment processes may be necessary, and effluent transport facilities (pumping stations and pipelines) may also be required.

Burton, Franklin L., 1996, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities.* (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.2-14.

Estimates of Electricity Use in Wastewater Treatment (National Average)

The unit electricity requirements expressed as kilowatt hours per million gallons (kWh/mg) for each generic system were computed by a weighted average over the range of capacities to determine a single value to be used in projecting the national use. The values used are:

955	kWh/mg for trickling filters
1,322	kWh/mg for activated sludge
1,541	kWh/mg for advanced wastewater treatment without nitrification
1,911	kWh/mg for advanced wastewater treatment with nitrification

The value used for a level of treatment less than secondary was taken as about 50 percent of the value for activated sludge treatment (661 kWh/mg).

For secondary treatment, a weighted unit value was used assuming that 70 percent of the capacity was activated sludge and 30 percent was trickling filters. The weighted value is 1,212 kWh/mg.

For advanced wastewater treatment, it was assumed that, for 1988, 10 percent of the capacity included nitrification; for the future (when needs met), it was assumed that 50 percent of the capacity included nitrification. The weighted values are 1,578 and 1,726 kWh/mg, respectively.

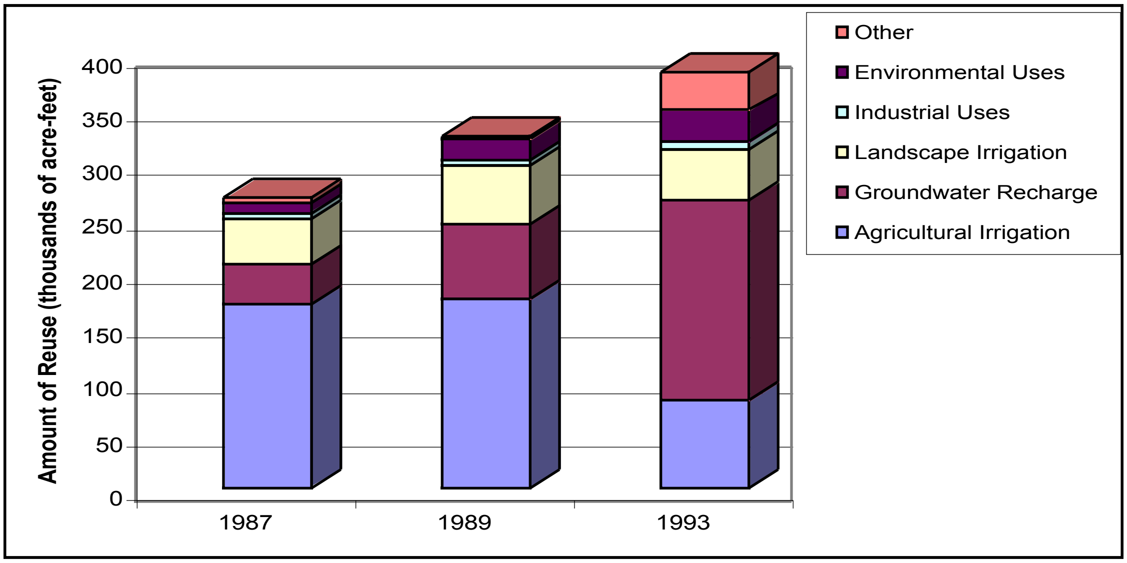
Burton, Franklin L., 1996, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities.* (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.2-45.

Wastewater Reuse

Water is increasingly being used more than once within systems at both the end-use level and at the municipal level. At the end-use, water is recycled within processes such as cooling towers and industrial processes prior to entering the wastewater system. Once-through systems are increasingly being replaced by re-use technologies. At the municipal level, water re-use has become a significant source of supplies for both landscape irrigation (e.g. for freeways and golf courses) and for commercial and industrial processes. MWD is supporting 33 recycling programs in which treated wastewater is used for non-potable purposes.[91]

In a case study for the Pacific Institute, Arlene Wong identified the following trends in reuse in California:

Comparison of Water Reuse Activities for 1987, 1989, 1993



Source: Arlene Wong, 1999, "Use of Reclaimed Water in Urban Settings: West Basin Recycling Project and South Bay Water Recycling Program", in Lisa Owens-Viani, Arlene Wong, and Peter Gleick, Eds., *Sustainable Use of Water: California Success Stories*, Pacific Institute, January 1999, based on data from : The 1987 and 1989 data are from *Water Recycling 2000*, 1991. The 1993 data is from *Survey of Future Water Reclamation Potential*, 1993. The two surveys used different methodology and received different response rates, and thus are not directly comparable. However, as three different snap shots in time, they do offer a general overview of water reuse amounts.

Desalination

Desalination of sea water is energy intensive. The City of Santa Barbara is the only water supplier in California, other than island-based operations, which has built a facility to provide municipal supplies of desalinated water. The facility is not being operated due to high operating costs linked to energy requirements. Actual energy use for trial operations in Santa Barbara were 6,842.87 kWh/AF. Projected long-term average energy use is 21 kWh /1000 gallons, or 6,759 kWh/AF.[92] This is total energy, including pumping sea water, pre-treatment, reverse osmosis filtration, and pressurization for delivery to the city.

MWD has ventured into the desalination business, and in 1999 it projected a more optimistic assessment of desalination technology. Its web site included the following statement:

> Desalting seawater has previously been too expensive for Southern California to use on a widespread basis. However, Metropolitan has successfully tested a refined distillation process that is expected to cut desalination costs by more than 50 percent.[93]

A new facility being built in Tampa, Florida may yield both new approaches to desalination and new data, although unique circumstances with the facility and the financing mechanisms supporting it may limit its applicability in other areas.

ENERGY ANALYSIS

Methodologies Developed

Energy Matrix

One element of the present exploratory project was to develop a method for analyzing the energy intensity of water used in a given location. The following section steps through a spreadsheet tool developed as part of this exploratory work. The spreadsheet is fully transparent in its assumptions. It is constructed such that changes in inputs (e.g. the amount of SWP water supplied to a given agency, or the amount of groundwater pumped with specific motors) and structure (e.g. new energy elements) can be easily adjusted or added.

One option for future development is to post a revised spreadsheet on the web with full access for use and alteration.

Geographical Information System Application

A geographical information system application is also being developed as a tool for water managers and decision-makers. The GIS application will link to the spreadsheet to provide users with the data directly from the spreadsheet analysis. Users will be able to click on a water use zone (e.g. a city) and a screen will pop up providing data for that geographic area.

A version of the GIS can be provided through the web at no cost to the user, and the program is user-friendly and accessible to all levels of computer literacy.

The GIS would not be user-adjustable, so data provided could be secure. The spreadsheet tool, on the other hand, could be downloaded such that users could consider an infinite number of water supply and use scenarios and estimate the energy intensity of each option.

Spreadsheet Matrix for Energy Intensity Analysis

The following series of boxes are derived from a series of linked sheets in an excel spreadsheet. Each box sets forth information on a specific element in the calculation. For example, the first box contains information on the amount of water imported to a sample(hypothetical) city in southern California. The city received equal amounts of water from the east branch of the SWP and the Colorado River Aqueduct. It receives no west branch SWP supplies, and it has no other imported source.

Water Supply Sources

(Imports)

Agency	Year	SWP-West	SWP-East	CR	Other	Total Imported Supplies
		af	af	af	af	af
Sample City / Authority	98	0	30,000	30,000	0	60,000

The sample city also has local surface and groundwater supplies, and it reclaims water for reuse in its service area. Groundwater volumes are identified by electric pumped and gas pumped sources.

Water Supply Sources

(Local Supplies)

Agency	Year	Surface	Groundwater (elec pump)	Groundwater (gas pump)	Reuse	Total Local Supplies
		af	af	af	af	af
Sample City / Authority	98	500	5,000	5,000	10,000	20,500

The next box sums the water supplies.

Water Supply Sources

(Imported and Local Supplies)

Agency	Year	Total Imported Supplies	Total Local Supplies	Total Supplies
		af	af	af
Sample City / Authority	98	60,000	20,500	80,500

Each source of water requires a different amount of energy inputs. The next series of boxes identifies the energy inputs for each different source.

Figures for the SWP (east and west branches) and CRA are derived from MWD and DWR documents as presented in the description of the projects in the text. (See also the diagram of the SWP pumping system.)

Energy Factors For Supply - Imported Supplies

(in energy units per unit of water)

		SWP-West	SWP-East	CR	Other
Agency	**Year**	kWh/af	kWh/af	kWh/af	kWh/af
Sample City / Authority	98	2,580	3,236	2,000	0

Groundwater, surface water, and reclaimed water data is provided by the agency in the form of total volume of water pumped and total amounts of energy (kWh of electricity and/or therms of gas) used. The spreadsheet calculates the kWh equivalent of therms and the kWh/af.

Energy Use For Supply - Local Supplies

(in energy units per unit of water)

		Ground (elec pump)	Ground (gas pump)	(Therms to kWh equiv)	Surface
Agency	**Year**	kWh	therms	kWh	kWh
Sample City / Authority	98	4,000,000	100,000	2,930,000	0

The imported supply energy is calculated based on a stated kWh/af factor (from DWR and/or MWD or other sources of imported water) and the total amount imported from each source.

Energy Use For Supply - Imported (Colorado River and Other)

		CR	CR	Total CR	Other	Other	Total other
Agency	**Year**	af	kWh/af	kWh	af	kWh/af	kWh
Sample City / Authority	98	30,000	2,000	60,000,000	0	0	0

Energy Factors For Supply - Imported Supplies

(in energy units per unit of water)

		SWP-West	SWP-East	CR	Other
Agency	**Year**	kWh/af	kWh/af	kWh/af	kWh/af

Each source of water supply may be identified and calculated separately. The spreadsheet can be expanded to accommodate as many individual sources as required. this example includes both electric and gas-pumped groundwater supplies, in addition to surface (requiring essentially no energy) and reuse.

NOTE: Where water supplies are net energy providers, such as with the LA Aqueduct, the calculations will record an energy contribution rather than requirement.

Energy Use Factors For Supply - Local Supplies (Surface)

(in energy units per unit of water)

Agency	Year	Surface af	Energy Surface kWh	Total E. Surface kWh/af
Sample City / Authority	98	500	1	0.002

Energy Use Factors For Supply - Local Supplies (Groundwater)

(in energy units per unit of water)

Agency	Year	GW (elec) af	GW (elec) kWh	Total E. GW (elec) kWh/af	GW (gas) af	GW (gas) kWh (equiv)	Total E. GW (gas) kWh/af
Sample City / Authority	98	5,000	4,000,000	800	5,000	2,930,000	586

A more refined methodology for calculating the marginal difference between wastewater treatment required under applicable standards and the level of treatment required for reuse is not included here. The reduced energy requirements for delivery to the area of use (e.g. it has already been imported to the location of use or pumped from groundwater sources) should be calculated as part of the analysis. This is an appropriate follow-on research question.

Energy Use Factors For Supply - Local Supplies (Reuse)

(in energy units per unit of water)

Agency	Year	Reuse af	Total Reuse kWh	Reuse kWh/af
Sample City / Authority	10	10,000	22,000,000	2,200

Energy inputs for regional distribution, for example by a wholesale entity such as MWD, are included in the matrix. Data has been difficult to secure, however. In some places, MWD reports that energy production from hydro facilities within its distribution system make it an energy producer. The head for the hydro production from the SWP and CRA would of course be energy inputs in the SWP and CRA expended to elevate the water in the previous stage.

Further research is needed to quantify the appropriate energy figures. (Included in the report is a map of MWD pumping facilities and other information. MWD also provides real-time data on its pumping facilities throughout its service area. The data, therefore, must be readily available.

A related question and important factor for analysis is the actual sources of water delivered to each member agency. This example uses a simple 50/50 mix of SWP and CRA imports. Each recipient of MWD water receives a portion of either SWP east or west branch supplies and/or CRA, plus various local supplies. The matrix developed will accommodate, and in fact is designed for, accounting for multiple sources of supplies with differing energy intensities. Again, this data would assist the analysis.

Regional Distribution

Agency	Year	Amount Delivered af	Total Energy kWh	Energy per Acre-Foot kWh/af
Sample City / Authority	98	varies	N/A	N/A

Energy inputs for potable treatment (treatment, filtration, and/or required processes to meet applicable standards) and the energy required to pressurize and deliver supplies to customers is recorded next.

Potable Treatment

Agency	Year	Amount Treated af	Total Energy kWh	Energy per Acre-Foot kWh/af
Sample City / Authority	98	80,500	500,000	6

Potable Distribution

Agency	Year	Amount Distributed af	Total Energy kWh	Energy per Acre-Foot kWh/af
Sample City / Authority	98	80,500	2,500,000	31

End-use energy factors for heating and cooling water, pumping water through circulation loops, providing additional treatment and pressure for various processes, etc. is an important element of total energy intensity of use. Specific items are identified, and can be expanded, in the matrix. This exploratory research effort did not attempt to place values on these energy uses at this time. The methodology allows for inputs as applicable.

On-Site End-Use Energy Use - Thermal

		thermal (heating)	**thermal** (heating)	**thermal** (heating)	**thermal** (cooling)	**thermal** (cooling)	**thermal** (cooling)	**Total Energy**
Agency	**Year**	kWh	therms	(kWh equiv)	kWh	therms	(kWh equiv)	kWh
Sample City / Authority	98							

On-Site End-Use Energy Use - Pumping and Processes

		Volume Pumped	**Pumping Energy**	**Energy per AF Pumped**	**Volume Processed**	**Processing Energy**	**Energy per AF Processed**
Agency	**Year**	af	kWh	kWh/af	af	kWh	kWh/af
Sample City / Authority	98						

As discussed in detail in the text, wastewater collection and treatment require energy inputs. Not all water that enters a facility, however, exits as wastewater. Water evaporated in cooling systems and processes, used for irrigation of landscape, included in products, etc. must be deducted from the wastewater figure. The matrix applies a percentage factor to total water inputs that can be adjusted and customized based on a specific facility. Alternatively, it can be set at an average for a service area based on measured data or other assumptions.

Wastewater Collection

		Amount Collected	**Energy**	**Energy per Acre-Foot**
Agency	**Year**	af	kWh	kWh/af
Sample City / Authority	98	56,350	250,000	4

Wastewater Treatment

Agency	Year	Amount Treated af	Energy kWh	Energy per Acre-Foot kWh/af
Sample City / Authority	98	56,350	1,000,000	18

The matrix provides a mechanism for analyzing energy at each stage of the process. For example, the following two boxes contain analysis of imported and local supplies. All variables are linked to the inputs in previous sheets, so changes for example in the mix of imported to local supplies will appear automatically in the calculations below.

Energy Analysis

Imported Supplies

Source	**SWP-West**	**SWP-East**	**CR**	**Other**	**Total**
	af	af	af	af	af
	0	30,000	30,000	0	60,000
Percent of Total Supplies	% of total	% of total	% of total	% of total	% of total
	0	37	37	0	75
Percent of Imported Supplies	% of Imported	% of Imported	% of Imported	% of Imported	% of Imported
	0	50	50	0	100
Energy per Acre-Foot	kWh/af	kWh/af	kWh/af	kWh/af	
	2,580	3,236	2,000	0	N/A
Energy Input	kWh	kWh	kWh	kWh	kWh
	0	97,080,000	60,000,000	0	157,080,000

Energy Analysis

Local Supplies

Source	Surface	Groundwater (elec pump)	Groundwater (gas pump)	Reuse	Total
	af 500	af 5,000	af 5,000	af 10,000	af 20,500
Percent of Total Supplies	% of total 1	% of total 6	% of total 6	% of total 12	% of total 25
Percent of Local Supplies	% of local 2	% of local 24	% of local 24	% of local 49	% of local 100
Energy per Acre-Foot	kWh/af 0	kWh/af 800	kWh/af 586	kWh/af 2,200	N/A
Energy Input	kWh 1	kWh 4,000,000	kWh 2,930,000	kWh 22,000,000	kWh 28,930,001

Other energy inputs, such as those for wastewater collection and treatment, are represented below.

Weighted Average Energy Analysis

Wastewater Collection and Treatment

Amount Collected and Treated	**Collected** af 56,350	**Treated** af 56,350
Percent of Total Supplies	% of total 70	% of total 70
Energy per Acre-Foot	kWh/af 4	kWh/af 18
Weighted Average	kWh 175,000	kWh 700,000

Summary Table

The following summary table contains a synthesis of data from the forgoing sheets and provides a calculation of both total energy at each stage of the process and an aggregate figure for energy use per unit of water (kWh/af).

Total Energy Use per Acre-Foot Used in a Specific Location

(figures in average kWh for each element)

Imported Supplies	Local Supplies	Regional Distrib	Potable Treat	Potable Distrib	On-Site Therm	On-Site Pmp/Prc	Waste W Collec	Waste W Treat	TOTAL ENERGY	ENERGY INTENSITY
kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh	kWh/af
157,080,000	28,930,001	N/A	500,000	2,500,000	N/A	N/A	250,000	1,000,000	190,260,001	2,363
% of total	% of total	% of total	% of total	% of total	% of total	% of total	% of total	% of total	% of total	
82.6	15.2	N/A	0.3	1.3	N/A	N/A	0.1	0.5	100.0	

POTENTIAL EFFICIENCY IMPROVEMENTS

Water Systems and Potential Efficiency Improvements

The present analysis focuses on efficiency improvements in the M&I sector, even though it constitutes only 20% of California's extracted water use.

The majority of developed water used in California (on the order of 80%) is applied as irrigation. Both groundwater and surface water sources are tapped for this purpose, and the energy intensity of supplies varies considerably with source and place of use, as well as with technologies used for conveyance and irrigation. This analysis has not examined the agricultural sector due to problems with data acquisition and because the average energy intensity is lower than that in the M&I sector. The principle reason for this lower energy intensity is that most of the supplies used for irrigation are not transported over significant elevation gains. There are important exceptions to this general statement, and there is certainly efficiency improvement potential in the agricultural sector. Research on the energy benefits of water system efficiency improvements in the agricultural sector is recommended.

The present analysis focuses on the M&I sector due to its higher average energy intensity and because of the availability of metered water and energy data. A considerable amount of work has been done on water use in the residential sector, and the efficiency improvements available through interior appliance changes and exterior landscape design and irrigation changes is reasonably well understood. The other major M&I use areas classified as CII (commercial, industrial, and institutional), and the energy used in wastewater treatment processes, merit greater research attention. Accordingly, this preliminary study has focused proportionately more attention on the CII sector.

Water-Efficiency Potential in the Residential Water Use Sector

Water efficiency potential in the residential sector is generally categorized into indoor use and outdoor use. Efficiency improvements in interior use may achieved with plumbing fixture changes (shower heads, faucet aerators, toilets, washing machines, dish washers, and other appliances) and by repairing leaks. Exterior use changes generally are achieved through a combination of irrigation systems changes and landscape changes.

Temporary, low-cost approaches such as home surveys and the installation of toilet dams have been found to be far less reliable and effective as permanent efficiency improvements achieved through the replacement or initial installation of water-efficient devices. Citing a study by A&N Technical, the CUWCC notes that the "average level of savings from home water surveys decreased over time, reaching about 50% of initial yield by the fourth year following the survey."[94]

Water managers and policy-makers share a concern that water efficiency improvements need to be reliable over time. Water management authorities have therefore focused on the installation of quality plumbing fixtures that will reliably reduce water use while providing equal or even superior water-use services to the consumer.

For purposes of this analysis, water efficiency improvements achieved within residences typically translate into wastewater savings. On the other hand, exterior savings due to improved landscape irrigation and landscape design do not.

The present analysis has not focused on the residential sector in detail because reasonable estimations of efficiency potential are available. A number of studies have been conducted on water use and efficiency potential. While further work on the quantification of residential sector water savings is needed to refine the numbers, it was not within the scope of this exploratory analysis to undertake that work. In addition to the work of the CUWCC, research by Amy Vickers, A&N Technical, M Cubed, the Rocky Mountain Institute, Bill Maddaus, and studies like the Pacific Institute's *California Water 2020: A Sustainability Vision*, have outlined residential water efficiency opportunities.[95] For a recent report surveying a number of success stories in water efficiency improvements see *Sustainable Use of Water: California Success Stories*.[96]

Water-Efficiency Potential in the Commercial, Industrial, and Institutional (CII) Sector [97]

Water managers typically identify urban water use in a broad category called *municipal and industrial* (M&I), which generally includes residential uses as well as commercial, institutional, industrial, and municipal uses. An important sub-set of M&I water use is the non-residential category of *commercial, industrial, and institutional* (CII) users.

While the potential to increase water-use efficiency in the residential sector has received considerable attention, the potential in other urban sectors is less well understood, possibly due in part to the large variety of water uses, technologies, and processes in those sectors. However, recent surveys and actual experiences at specific sites suggest that significant opportunities exist in each of these sectors for efficiency improvements and cost savings.

Various definitions of water uses and differing methodologies have been used by analysts to classify water uses in the CII sector.[98] For the purposes of the present analysis, the following CII uses are defined as follows, as adapted from Charlie Pike: [99]

Commercial and Industrial Water Uses

Commercial water use includes water for motels, hotels, restaurants, office buildings, and other commercial facilities.

Industrial water use includes water for industrial processes such as fabrication, processing, washing, and cooling.

Institutional water use includes indoor and outdoor uses at schools, colleges, universities, churches, hospitals, and government facilities.

Municipal water use includes water system management and uses such as fire suppression and landscape irrigation in public parks.

Water savings potential in the CII sector is significant. Two recent studies have attempted to estimate the potential CII sector savings. The first is an audit program sponsored by MWD[100] for its service area in which the district audited over 900 commercial, industrial, and institutional water users in its service area.[101] The second is a study sponsored by the US EPA and conducted by the California Department of Water Resources in which data was studied from three audit programs (a total of 744 audits) in 12 utility service areas nationwide (seven in California). [102] In MWD's service area, CII accounts for about 25% of water use,[103] and efficiency potential is conservatively estimated at 23% based on a recent analysis by MWD.[104] The 23 percent overall savings should be considered conservative, however, because the study was careful to employ conservative assumptions regarding both potential conservation measures and economic factors. Only measures within a specified payback period (usually no more than 5 years) were included as opposed to investments that still exceed normal rates of return. Recommendations did not include all available conservation measures, instead favoring very basic responses. For example, landscape water efficiency improvements represented 9 percent of identified savings based on adjusting irrigation control programming alone. Landscape savings, even with this modest approach, was "a large portion of the potential savings at many sites" in the MWD study. A more comprehensive approach such as converting CII landscapes and irrigation systems to more water-efficient (and maintenance-efficient) designs was not included. Using a *technical efficiency potential at current cost-effectiveness* test, a significantly higher water efficiency potential would be feasible.

The California Department of Water Resources (DWR) estimated in 1990 that the CII sector accounted for an average of 32 percent of urban water use, totaling over 2.4 million acre-feet, with 18 percent attributed to commercial and 9 percent to industrial uses.[105] The following chart indicates the savings by types of uses.

Average Potential Savings for Commercial and Institutional Categories

Type of Business	**Number of Site Audits**	**Average Savings (%)**	**Standard Deviation**
Car wash	12	27	24
Church–nonprofit	19	31	17
Communications & research	10	18	22
Corrections	2	20	6
Eating and drinking places	102	27	14
Education	168	20	16
Healthcare	90	22	14
Hospitality*	222	22	13
Hotel & accommodations	120	17	11
Landscape irrigation	6	26	19
Laundries	22	15	17
Meeting/recreation	20	27	21
Military	1	9	–
Offices	19	28	17
Sales	56	27	15
Transportation & fuels	24	31	20
Vehicle dealers & services	12	17	10
Total Sites	741		

*Hospitality includes "eating & drinking" and "hotels & accommodations"

Source: Pike, Charles W., 1997, "Study of Potential Water Efficiency Improvements in Commercial Businesses", Final Report, U.S. Environmental Protection Agency / California Department of Water Resources, April.

Water efficiency potential is higher for certain key industries according to the ERI study:

Water Savings Potential for Selected Industries

Customer Group	**Number of Surveys**	**Potential Water Savings (%)**
Waste Treatment	2	81
Petroleum Refineries	2	65
Primary Metal Industry	5	52
Paper Mills/Paper	9	39

(Potential savings assumes all recommendations are implemented.)

Source: ERI Services, Inc. 1997, "Commercial, Industrial and Institutional Water conservation Program, 1991-1996." Prepared for Metropolitan Water District of Southern California. Irvine, CA.

The MWD findings (23% savings)[106] are consistent with a recent Department of Water Resources (DWR) analysis in which investigators concluded that: "Commercial water-use volume may be cost-effectively reduced by approximately 22 percent." [107] Potential water savings, defined to include most institutional uses, ranges to about 50%, with results ranging from 20-25% in the analysis. According to the DWR analysis, the potential for water savings are greatest in the following categories: offices, health care, sales, eating and drinking, hotels and accommodation, education, landscape irrigation, laundries, meeting and recreation. (The figures vary by region in this study.)

Average Projected Savings for Each Category

category of use		*percent savings*
institutional:	hospitals	22
	schools	21
	hotels	20
commercial:	office buildings	40
	laundry	29
industrial:	beverage processors	16
	metal finishers/PC board manufacturers	15
	food processors	19

Source: Ploeser, Jane H., Charles W. Pike, and J. Douglas Kobrick, 1992, "Nonresidential Water Conservation: A Good Investment", *Journal American Water Works Association*, Vol. 84, No. 10, October.

Several studies have been conducted examining efficiency potential in these categories. One interesting finding is that within the overall CII sector in Southern California, 80% of the water is used by 20% of the customers.[108] From the standpoint of water managers seeking to facilitate and support efficiency improvements, this focus greatly increases the prospects for targeted strategies to assist large users with efficiency programs. Implementation at the large-user level also provides important models for the other 80-90% of CII users (on the order 300,000 accounts in southern California), which undoubtedly possess profitable efficiency improvement opportunities.

In assessing the potential for future efficiency improvements in the CII sector, it is important to recognize that by the late 1980s many firms and institutions had already demonstrated dramatic savings. Some have used these past improvements to suggest that the opportunities for additional reductions are limited. Recent analyses, however, indicates that many opportunities still exist for highly cost-effective efficiency improvements. Several lessons are evident. One is that new ideas and technologies continue to improve the cost-effectiveness of efficiency measures. Second, many CII users have never implemented even the most basic efficiency improvements. Third, many improvements are the result of careful analysis and overcoming the "human," not technological or economic, factors (*i.e.* changing behavior) in many public and private institutions.

It is also worth noting that water-efficiency potentials estimated in the DWR and MWD studies indicating (22% and 23% savings) are conservative, since the economic criteria reflect very short payback periods and the conservation recommendations primarily involve simple technological improvements. Examples of water-efficiency achievements for specific sites show that modest estimates are routinely surpassed.

Total costs to customers for implementation at all sites in the MWD study were estimated at $12,500,000, with the potential dollar value of water savings at $7,500,000 per year, which represents a simple payback of 1.7 years. Some measures requiring operational changes were assumed to have no investment (such as adjusting the blowdown for cooling towers or rescheduling irrigation times). An examination of the sites involved in the follow-up survey shows that the simple payback for all measures was 1.6 years, and the average payback for those measures reported implemented was 0.8 year. It is not surprising that customers would chose to implement those measures with shorter payback periods. [109]

A few examples of past CII savings are worth noting:

Examples of CII Efficiency Improvements [110]

A **Dow Chemical plant** in Pittsburgh, California reduced water use by 95% between 1972 and the mid-1980s.[111]

A 1979 **"Review of Water Conservation in the City of Los Angeles"** conducted by Brown and Caldwell (prepared for LADWP) found that "45 businesses reduced water use an average of 45% during California's 1976-1977 drought." Savings of over 50% were reported as follows: [112]

- Standard Nickel-Chromium Plating Company	79%
- Anheuser-Busch	63%
- National Standard Company	63%
- Tyre Brothers Glass Company	56%
- Airesearch Manufacturing Company	50%

EBMUD conducted a survey of its industrial customers after they had achieved higher-than-expected water savings. In 1988, EBMUD requested its industrial customers to reduce water use 9% from 1986 levels. Industry cut back three times that much (28%). A year later the district again requested that industrial users cut back 5% from the same 1986 base. The result was a savings of five times the requested amount (26%).[113]

A study of **15 companies in California** conducted by Brown and Caldwell and the California Department of Water Resources found that "Conservation measures effectively reduced water use at the (15) case study companies," with "typical reductions" of 30% to 40% of pre-conservation use.[114] The San Jose work was not an audit program. It examined the results of efficiency measures with a payback of one year, average, and as such, provides an indication of what an audit program could accomplish. The study found that the payback period for capital investment was usually less than one year, with average savings of $50,000 per year and over $100,000 per year for some companies. Finally, the report concluded that "The cost-effective water conservation measures successfully used at the case study facilities can readily be adopted by other facilities and other industries."

In response to drought conditions, the **City of San Luis Obispo** achieved savings of 40% in its government facilities through a combination of leak repair, irrigation improvements, and other measures. The average savings for governmental uses in San Luis Obispo was 57% for the six-months period from May through October 1990.[115] Specific savings for governmental uses in San Luis Obispo are as follows:

- buildings	42%
- trees	31%
- library	54%
- parks	57%
- golf course	55%
- swimming pool	52%
- police building	73%
- fire buildings	87%
- bus yard	88%
total savings	**57%**

The **University of California, Santa Barbara**, reduced overall water use by nearly 50% through a variety of cost-effective efficiency measures that saved money as well as water, wastewater, and energy.[116]

Water and Wastewater Treatment

Historically, water and wastewater facilities have been designed with the emphasis on process reliability; efficient utilization of electricity has not received equal consideration.[117] Opportunities exist for electric utilities to develop and implement programs aimed at energy management that will provide substantial benefits both to the electric utilities themselves and to their water and wastewater customers.[118]

At water treatment plants, most of the electricity used is for pumping. Fraklin Burton found that: In water systems, energy management opportunities mainly relate to pumping equipment and operational control systems. The greatest opportunities include using premium efficiency motors and adjustable speed drives, selecting efficient pumps, utilizing effective instrumentation and control, managing pumping operations by the efficient use of available storage and high-efficiency pumping units, and operating emergency generators for peak clipping. Significant reductions in energy use and cost are reported at existing facilities through energy management. In many applications, measures such as the installation of high efficiency motors, adjustable speed drives, and fine pore diffusers can be accomplished with payback periods of three years or less.[119]

Energy Efficiency Measures For Water and Wastewater Systems

Energy efficiency measures, as defined here, are measures that have the primary impact of reducing energy consumption. As a secondary impact, peak demand may be reduced. Some of the more common energy efficiency measures are discussed below.

High Efficiency Motors. The replacement of motors in existing plants with high-efficiency motors has significant potential for strategic conservation, as well as some load management potential, because most of all the electric energy used in wastewater plants is due to motors.

Adjustable Speed Drives (ASDs). ASDs have become more attractive to customers in recent years because developments in electronics have increased efficiencies and reduced costs. ASDs are a means of controlling flow rates through reducing the speed of the motor, rather than throttling fluids.

Fine Pore Diffused Air Systems. Diffused air systems use a combination of low pressure blowers (usually 7 to 10 psi), an air piping system, and submerged air diffusers in the aeration tanks. Fine pore diffusers produce fine air bubbles that provide better oxygen transfer efficiency in wastewater than other types that produce coarse (large) bubbles.

Increased Instrumentation and Control. Treatment plants can benefit from instrumentation and controls (I&C) to monitor dissolved oxygen (DO) in the aeration basins, control the aeration equipment to maintain set DO levels, and optimize the overall performance (including electricity consumption) of the aeration system.

Burton, Franklin L., 1996, Water and Wastewater Industries: Characteristics and Energy Management Opportunities. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, pp.2-46-48.

Load Management Measures

Energy Management Systems (EMS). EMS can serve several purposes in a wastewater treatment plant; their greatest benefits can be peak shaving. EMS can be used to stagger start and duty cycle wastewater transfer pumps, start backup generators when peak demand approaches, and monitor and control DO levels.

Cogeneration Using Digester Biogas. If anaerobic digesters are used for biosolids stabilization, the biogas produced by the fermentation of organic matter can be used to power engine-driven equipment or to generate electricity.

Operation of Backup Generators During Peak Periods. Almost every wastewater treatment plant has emergency generators to provide power to operate essential systems. During other times, these generators are seldom used and can be operated for peak shaving at some plants.

Burton, Franklin L., 1996, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities*. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.2-49.

POLICY IMPLICATIONS AND OPPORTUNITIES BASED ON FINDINGS

The multiple and combined benefits of water, wastewater, and energy efficiency have been recognized in policy and practice in California and at the national level. The present analysis builds on important work undertaken by California government agencies and energy and water utilities, and the logic of multiple benefits is embedded in state and federal policy, including the *Energy Policy Act* of 1992, which includes efficiency standards for plumbing devices and a requirement for implementation of cost-effective energy and water efficiency measures within 10 years in federal facilities.[120]

One reason for undertaking this exploratory analysis was to determine if energy benefits based on technical efficiency potential in the area of water use could be supported by policy measures. This section explores several policy processes related to water-use efficiency and considers possibilities for multiple benefits from combined water, wastewater, and energy efficiency strategies.

Several important policy initiatives are discussed here as they relate directly to the exploratory analysis. The first is the "Best Management Practices" process developed in the California urban water sector (and more recently in the agricultural sector as discussed briefly). The second is a partnership between water, wastewater, and energy utilities in southern California which produced important conceptual approaches, though it was terminated prematurely. Policies supporting efficiency potential in the CII sector is also discussed.

This section focuses particular attention on the California BMP process because of its direct relation to the analysis of the energy efficiency potential derived from water efficiency improvements. Also, the BMP process anticipates and supports the multiple-benefits analysis and related policy approaches which are the subject of this exploratory project.

The "Best Management Practices" Framework for Water Use Efficiency Improvements

Policies and programs facilitating and supporting energy and water efficiency have made significant contributions toward cost-effective improvements in the use of resources in California. While energy efficiency programs, particularly in the electric utility sector, have undergone major changes in the 1990s (in part due to changes in the regulatory framework for the industry), the water sector has moved forward with an important and constructive program known as "Best Management Practices" (BMPs). This section describes the BMP process, its background, and its success over the past decade. The process is ongoing, and it appears that the successful efforts of the various stakeholders involved over the past 10 years will be recognized with the creation of a formal role for the Conservation Council in certification of BMP performance.

The BMP concept and approach to achieving increased water-use efficiency throughout the M&I sector is important to the present analysis of energy efficiency for several reasons. First, the process involves a coordinated effort to better understand the uses of water in the M&I sector, the possibilities for increased efficiencies, and the cost-effectiveness of alternative approaches. Second, the BMP process explicitly includes consideration of water, wastewater, and energy consideration, and as such, is seeking to develop a comprehensive approach to resource management. Finally, the California Urban Water Conservation Council (CUWCC -- the entity comprised of the signatories to the process as described below) has developed considerable competence in both technical assessments and policy development. With an increasing role in water management efforts in the state, the CUWCC is well-positioned to utilize the energy-intensity analysis analyzed in the present exploratory project.

Research Report Note:

This exploratory research project originally envisioned utilizing an assessment currently being undertaken of the overall water savings attributable to the California BMPs as a basis for calculations of energy efficiency potential. Unfortunately, the release of the study examining water savings has been delayed indefinitely.

Certain BMPs have been analyzed and a water efficiency factor or range is stated.[121] These factors can be used to estimate a portion of the savings attributable to the BMPs, but it is only a sub-set of the BMPs' total impact.

The BMP process has been driven from its inception by considerations of a major water rights hearing (as described further below). The implications of this legal and political context is than estimates of water efficiency potential have been conservative (e.g. efficiency potential is understated, and greater efficiencies than those formally stated are routinely achieved by end-users and water agency programs throughout the state). Therefore, the BMP process may be viewed as a credible, if conservative, basis for assessing the potential for increasing water use efficiency.

This point is made directly in the MOU: "It is probable that average savings achieved by water suppliers will exceed the estimates of reliable savings."[122]

The BMP Concept and Process

The "Best Management Practices" process is a promising approach to water management, and it has demonstrated important and impressive results in certain areas. The basic idea behind BMPs is that technically feasible, cost-effective, and socially acceptable water-efficiency improvements can and should be made through a variety of measures ranging from technology retrofit programs to pricing approaches and public education. If fully and properly implemented, BMPs should yield significant economic, social, and environmental benefits in a "win-win" for all parties.

The concept behind "Best Management Practices" (BMPs) as a guiding framework for water policy is the creation of an "industry standard" for the management and reasonable and beneficial use of the water resources.[123] Through the BMP process, technical aspects of water distribution and use are joined by economic factors and management issues within a legal and political framework. The BMP concept has the potential to provide positive benefits to California's economy and environment and to become a model policy for broader application in resource management. Some of that potential has been realized. The BMP list is a specific set of policy measures intended to be implemented as a package as part of an agreement between water suppliers and environmental and public interest organizations.

"Best Management Practices" are defined as "a policy, program, practice, rule, regulation or ordinance or the use of devices, equipment or facilities which meets either of the following criteria:

(a) An established and generally accepted practice among water suppliers that results in more efficient use or conservation of water, or,

(b) A practice for which sufficient data are available from existing water conservation projects to indicate that significant conservation or conservation related benefits can be achieved; that the practice is technically and economically reasonable and not environmentally or socially unacceptable; and that the practice is not otherwise unreasonable for most water suppliers to carry out.”[124]

The BMP list has been substantially revised from earlier versions, and there are currently 14 BMPs:[125]

Summary of “Best Management Practices” For California’s Urban Sector

BMP 1	Water Survey Programs For Single-Family Residential and Multi-Family Residential Customers
BMP 2	Residential Plumbing Retrofit
BMP 3	System Water Audits, Leak Detection And Repair
BMP 4	Metering With Commodity Rates For All New and Retrofit of Existing Connections
BMP 5	Large Landscape Conservation Programs And Incentives
BMP 6	High-Efficiency Washing Machine Rebate Programs
BMP 7	Public Information Programs
BMP 8	School Education Programs
BMP 9	Conservation Programs For Commercial, Industrial, and Institutional Accounts
BMP 10	Wholesale Agency Assistance Programs
BMP 11	Conservation Pricing
BMP 12	Conservation Coordinator
BMP 13	Water Waste Prohibition
BMP 14	Residential ULFTs Replacement Programs

Source: Memorandum of Understanding Regarding Urban Water Conservation in California, April 8, 1998. California Urban Water Conservation Council, 455 Capitol Mall, Suite 705, Sacramento, CA 95814-4406. www.cuwcc.org Additional explanatory text is included in the MOU for each BMP.

The California Urban Water Conservation Council (CUWCC) was created through the MOU in 1991 to manage the process of implementing and updating the BMPs.[126] The CUWCC is comprised of the signatories to the MOU. As or December 1999 there were 236 signatories to the MOU in the following categories:[127]

Signatory Parties to the MOU

Group 1:	Retail and Wholesale Water Suppliers	154
Group 2:	Public Advocacy Organizations	18
Group 3:	Other Interested Groups	64

The general goal of the BMP process is to implement a set of policies and technologies that will cost-effectively improve water-use efficiency in California's urban sector. The primary reason for engagement and the specific goal of water agencies is to secure continuing supplies of water from sources such as the delta based on a demonstration of reasonable and beneficial use.

Background on the California "Best Management Practices" Process

The BMP process was developed in reaction to a State Water Resources Control Board (SWRCB) concern regarding reasonable and beneficial use of water in the context of extractions from the Sacramento-San Joaquin Delta. The California Constitution requires that water be used reasonably and beneficially in California. Recent court cases, such as the *Audubon* case (Mono Lake), the Imperial Irrigation District case (regarding water wasted in unlined canals), and the "Raconelli" decision (eight cases regarding Delta water rights and management), had raised serious questions regarding water rights and "reasonable" water uses.[128] These cases and rulings brought into question the practices and levels of efficiency of use of water in the state. "Reasonable and beneficial use" has been interpreted as both avoidance of waste and efficient use as well as beneficial use of water resources.

The SWRCB convened hearings, commonly referred to as the "Bay-Delta" hearings, to determine future allocation of key water supplies in California. Recipients of water in California must demonstrate that it is being used reasonably and beneficially. SWRCB made initial estimates of water efficiency potential in the urban sector.[129] Some water purveyors challenged the estimated efficiency improvement potential contained in the report and commissioned their own studies.[130] The BMP process was developed to meet the requirements of reasonable and beneficial use. BMPs are envisioned as a means of establishing an evolving "industry standard" for reasonable and beneficial use. The urban BMPs form the basis for an agreement, through a memorandum of understanding (MOU), upon which purveyors, environmental organizations, and public-interest groups agree on reasonable and beneficial use. Estimates of reasonable and reliable savings through efficiency improvements in turn are being used as part of a process to determine water rights and allocation in the state.

The MOU addresses the water rights hearing as follows:

> The BMPs, the estimates of reliable savings and the processes established by this MOU are agreed to by the signatories for purposes of the present proceedings on the San Francisco Bay/Sacramento-San Joaquin Delta Estuary ("Bay/Delta") and in order to move the water conservation process forward. "Present Bay/Delta proceedings" is intended to mean those Bay/Delta proceedings presently underway and those conducted until a final water rights decision is reached by the State Water Resources Control Board ("State Board").[131]

DWR observed in 1989, as the BMP process was being established, that "A major consideration in these hearings (the SWRCB Bay-Delta hearings) is how urban water districts are currently conserving and how they will implement additional Best Management Practices."[132] From the purveyor's perspective, BMPs were developed in part to demonstrate reasonable use in order that they may continue to receive water allocations. A manager for the Metropolitan Water District summed up the agency's perspective in 1989: "Best Management Practices will show the State Board that water districts are serious about conservation. At the same time, we will get enough water for our reasonable needs."[133]

In 1990, DWR noted that the agreement on BMPs "will allow water districts to satisfy conservation requirements of the State Water Resource Control Board." Assuming that an agreement would be reached, "The signed MOU will be given to the SWRCB this spring (1991) to satisfy conservation requirements for the Bay-Delta water rights proceedings."[134] MWD also commented that the BMP process and the agreement were intended to resolve the issue of urban water conservation as it relates to the Bay-Delta hearings: "This agreement will demonstrate our commitment to improving the efficiency of water use. At the same time the MOU will remove urban water conservation as a controversy in the Bay-Delta proceedings."[135] The MOU was signed in 1991. Sixteen initial BMPs were agreed to (revised to 14 as of 1999), and specific definitions and parameters, implementation schedules, and coverage requirements are set forth in the MOU.[136] (Evolving into the CalFed process, the Bay-Delta proceedings continued through the 1990s.)

The MOU contains a provision under which signatories agree to send a letter to the state board as follows:[137]

> The signatories will make the following recommendations to the State Board in conjunction with the present Bay/Delta proceedings and to the EPA to the extent the EPA concerns itself with the proceedings:
>
> (a) That for purposes of the present Bay/Delta proceedings, implementation of the BMP process set forth in this MOU represents a sufficient long-term water conservation program by the signatory water suppliers, recognizing that additional programs may be required during occasional water supply shortages;
>
> (b) That for purposes of the present Bay/Delta proceedings only, the State Board and EPA should base their estimates of future urban water conservation savings on the implementation of all of the BMPs included in Section A of Exhibit 1 to this MOU for the entire service area of the signatory water suppliers and only on those BMPs, except for (I) the conservation potential for water supplied by urban agencies for agricultural purposes, or (ii) in cases where higher levels of conservation have been mandated;.
>
> (c) That for the purposes of the present Bay/Delta proceedings, the State Board and EPA should make their estimates of future urban water conservation savings by employing the reliable savings assumptions associated with those BMPs set forth in Section C of Exhibit 1 to this MOU;
>
> (d) That the State Board should include a policy statement in the water rights phase of the Bay/Delta proceedings supporting the BMP process described in this MOU and that the BMP process should be considered in any documents prepared by the State Board pursuant to the California Environmental Quality Act as part of the present Bay/Delta proceedings.

The BMP process initially identified specific practices *already in place* in various water management agencies in California. Participants analyzed "proven" measures that deliver water efficiency improvements and reduce waste.[138] In the bargaining that took place, water agencies agreed to list these measures as "best" practices and to implement them, while environmental and other public interest organizations agreed to support conservative estimates of the amounts of water which the measures would save.

The parties agreed that:

> California's economy, quality of life and environment depend in large part upon the water resources of the State. The signatories also recognize the need to provide reliable urban water supplies and to protect the environment. Increasing demands for urban, agricultural and environmental water uses call for conservation and the elimination of waste as important elements in the overall management of water resources.[139]

Implementation of the BMPs

Important work has been done to implement the BMP process by the California Urban Water Conservation Council (CUWCC), an institution created as part of the BMP process, and by the DWR and numerous water agency, industry, and environmental and public interest organization participants. Some agencies have demonstrated leadership and become examples of high-quality management. Others have been slow to follow. As a recent review of performance notes: "The level of implementation has varied considerably across water suppliers."[140]

As stipulated in the MOU, the water management agencies agree to work proactively with other legal authorities, such as wastewater and energy utilities, to accomplish the goal of efficiency improvement. Both the concept of multiple benefits and the logic of shared responsibility is clear in the agreement. Even where agencies are constrained, the agreement calls for signatories to work with other entities to develop programs that achieve multiple benefits. As such, the BMP program is considerably ahead of other resource policy efforts.

The term "implementation" is explicitly defined for purposes of the MOU as follows:

> "Implementation" means achieving and maintaining the staffing, funding, and in general, the priority levels necessary to achieve the level of activity called for in the descriptions of the various BMPs and to satisfy the commitment by the signatories to use good faith efforts to optimize savings from implementing BMPs.[141]

The MOU contains important and well-crafted language regarding the signatories' "good faith" responsibilities:[142]

> While specific BMPs and results may differ because of varying local conditions among the areas served by the signatory water suppliers, a good faith effort to implement BMPs will be required of all signatory water suppliers. The following are included within the meaning of "good faith effort to implement BMPs":
>
> (a) The proactive use by a signatory water supplier of legal authorities and administrative prerogatives available to the water supplier as necessary and reasonable for the implementation of BMPs.
>
> (b) Where implementation of a particular BMP is not within the legal authority of a signatory water supplier, encouraging timely implementation of the BMP by other entities that have the legal authority to carry out the BMP within

that water supplier's service area pursuant to existing legal authority. This encouragement may include, but is not limited to, financial incentives as appropriate.

(c) Cooperating with and encouraging cooperation between other water suppliers and other relevant entities whenever possible and within existing legal authority to promote the implementation of BMPs.

(d) Optimizing savings from implementing BMPs.

(b) For each signatory water supplier and all signatory public advocacy organizations, encouraging the removal of institutional barriers to the implementation of BMPs within that water supplier's service area. Examples of good faith efforts to remove institutional barriers include formal presentations and/or written requests to entities requesting approval of, or amendment to, local ordinances, administrative policies or legislation which will promote BMP implementation.

In addition to the "good faith" obligation, signatories seeking an exemption from the provisions of the agreement are required to follow a rigorous procedure as follows:[143]

> A signatory water supplier will be exempt from the implementation of specific BMPs for as long as the supplier substantiates each reporting period that based upon then prevailing local conditions, one or more of the following findings applies:
>
> (a) A full cost-benefit analysis, performed in accordance with the principles set forth in Exhibit 3, demonstrates that either the program (i) would not be cost-effective overall when total program benefits and costs are considered; OR (ii) would not be cost-effective to the individual water supplier even after the water supplier has made a good faith effort to share costs with other program beneficiaries.
>
> (b) Adequate funds are not and cannot reasonably be made available from sources accessible to the water supplier including funds from other entities. However, this exemption cannot be used if a new, less cost-effective water management option would be implemented instead of the BMP for which the water supplier is seeking this exemption.
>
> (c) Implementation of the BMP is (i) not within the legal authority of the water supplier; and (ii) the water supplier has made a good faith effort to work with other entities that have the legal authority to carry out the BMP; and (iii) the water supplier has made a good faith effort to work with other relevant entities to encourage the removal of institutional barriers to the implementation of BMPs within its service area.
>
> Signatory water suppliers shall submit exemptions to the Council within two months following the start of the reporting period for which the exemptions are being claimed.

Performance Challenges

Water-use efficiency is a major factor in policy discussions, and the Bay-Delta water rights issue remains contentious. The SWRCB process has now evolved into the "CalFed" process.[144] It is clear that any long-term water management system arising from these processes will include a water-use efficiency provision. The urban BMP program is being considered as part of the criteria for water-use efficiency, and the CUWCC is being considered as the certification agency to verify compliance with BMPs.

The creation of the *voluntary* BMP process and the initial efforts of the CUWCC have produced important but limited results. The parties agree that significant net water supplies can be made available through efficiency improvements, but implementation of BMPs and the consequent realization of water efficiency potential in many water service areas has been disappointing. As of 1997 (based on the 1995-1996 biennial report), less than half the state's population was covered by the program. Fewer than half of the retail water agencies that had signed the MOU had submitted reports, and of those, less than half were implementing key BMPs such as BMP 1, Residential Water Surveys (Audits), BMP 2, Plumbing Retrofits, BMP 5, Large Landscape Water Audits and Incentives, BMP 9, Commercial, Industrial, Institutional Water Conservation, and BMP 16 (now BMP 14), Ultra-low-flush Toilet Replacements.[145] Not a single agency had submitted a cost-effectiveness analysis supporting claims for exemptions from the program, though many have exempted themselves on key measures (e.g. 22 suppliers for BMP 2, 23 for BMP 5, 28 for BMP 9, and 24 for BMP 16).[146]

On the positive side, 75% of the wholesale water suppliers and 88% of the combined retail/wholesale suppliers had submitted reports on their activities by 1997. The total investment in efficiency by retail, wholesale, and combined agencies for 1995-96 was $48,922,965, split nearly evenly between wholesale ($23.4 million) and retail ($25.5 million).[147]

It has become clear that voluntary action, while sufficient for some key players, is not enough to bring about sufficient levels of implementation of the BMP program. Waste, inefficient use, and poor management practices persist. State authorities cannot conclude at this point that water is being put to "reasonable and beneficial use" in all areas when some agencies are ignoring the BMP measures. For this reason, there is consideration at the state level of making the BMPs mandatory. The CUWCC is considering the eventuality of a certification and compliance role under a "beyond voluntary" BMP process.

Future BMP Progress

The BMP process is an important new model of cooperative information-sharing and decision-making between diverse stakeholders. While implementation has lagged in some quarters, there is strong commitment among many of the leading water managers and public interest advocates in the state. The work commissioned by the CUWCC has greatly improved our understanding of the technical dimensions of water use and efficiency potential. The methodologies developed have also contributed to more effective implementation by those who have chosen to adopt them. If policy measures in California provide stronger mandates for implementation, considerable improvements in water use efficiency can be expected.

To enhance the process, clear and more detailed criteria and methodologies for determining total benefits and costs would be beneficial. With a more comprehensive matrix, including energy data, the question of how much efficiency is possible, appropriate, and cost-effective can be more accurately answered. The important question is "how much efficiency potential exists at a certain cost/price level?" This factor is key both to purveyors who wish to optimize allocation of their resources and to consumers who seek optimal allocation of their resources.

The energy efficiency benefits derived from the BMP policy has not been quantified, in part because the total water savings have not been estimated. Studies have examined parts of the energy/water equation, and “embodied” energy has been calculated for certain areas.[148] The application of energy-intensity data to the water efficiency information would provide important information for policy.

Agricultural Sector “Efficient Water Management Practices” Program

As noted above, this exploratory project does not include analysis of the energy intensity or efficiency potential of water used in the agricultural sector. It is important to note, however, that efficiency opportunities exist in this sector, and a corollary to the urban sector BMP program has been developed in the agricultural sector. Stimulated by state legislation passed in 1990 (*Agricultural Water Suppliers Efficient Water Management Practices Act of 1990* (AB 3616)), agricultural water users have been discussing approaches to increased water use efficiency.

In 1999, a “Memorandum of Understanding” (MOU) was drafted in response to the legislation.[149] Pump efficiencies and energy savings potential is included in the “Generally Applicable Efficient Water Management Practices” which are required of signatories (with conditions and exceptions).[150] Item number 6 in List A of the MOU is: “Evaluate and improve efficiencies of water suppliers’ pumps,” and it states in part: “A program to evaluate and improve the efficiencies of such pumps may result in energy savings or peak load reductions, or reveal capacity limitations due to inefficient facilities. Over the long term, the water supplier may be able to reduce operational costs and improve operational efficiency.”[151]

The MOU also addresses, with significant reservations, the issues of metering, measuring and monitoring water use, water pricing options, and various approaches to increasing water use efficiency. Future research on the energy intensity of water should seek to incorporate agricultural uses.

The Southern California Energy and Water Partnership

In 1990, Southern California Edison, the Metropolitan Water District of Southern California, the Los Angeles Department of Water and Power, and the Southern California Gas Company, formed the *Southern California Energy and Water Partnership*. As the director of MWD commented at the time of its formation, “The Partnership is founded on the principle that pooling resources and cooperatively developing conservation programs is mutually beneficial and cost-effective.”[152] The partnership was joined by the sanitation district of Orange County, the cities of Anaheim, Burbank, Glendale, Pasadena, and Santa Monica, the Central Basin Municipal Water District, the Municipal Water District of Orange County, and the West Basin Municipal Water District.

The collaborative effort worked for several years to develop joint energy/water efficiency programs. Some excellent work was undertaken involving co-funding of efficiency measures based on combined energy, water, and wastewater efficiency improvements.[153] SCE coordinated efforts for water/energy efficiency programs at federal facilities in the region under an agreement with the General Services Administration (GSA). Much of the focus of this partnership was on technologies such as ULF toilets, showerheads, and horizontal axis washing machines. Efforts undertaken included a study by Barakat and Chamberlin on combined water/energy/wastewater benefits attributable primarily to ULF toilet replacement programs. The study concluded that water pumping required $110/acre foot (1992 dollars) of electricity cost in the Southern California area.[154] Unfortunately, for a variety of reasons the Partnership is no longer active.

The *Southern California Energy and Water Partnership* developed a cost-sharing approach for efficiency measures. A specific focus of the program was the replacement of older toilets with ultra-low-flow (ULF) retrofits, as well as high efficiency washing machine rebates, and public information efforts. The agencies agreed on a cost-sharing formula in which MWD picked up 60% of the program costs, with the wastewater and energy partners each picking up 20%.[155] An example of a co-funding breakdown for a $580,000 retrofit program to replace 5,000 toilets with ULF technology is:

Southern California Energy and Water Partnership

(cost-sharing percentages)

MWD	60%
Wastewater agencies	20%
SC Edison	20%

Source: Barakat & Chamberlin, Inc., 1992, A Framework for Sharing the Costs of an Ultra-Low-Flush Toilet Retrofit Program, Final Report to Metropolitan Water District of Southern California, October 5, 1992, p. 3.

The partnership effort was initiated by Edison and catalyzed by the severe drought in California in the late 1980s. The effort was facilitated in part by DSM policies for energy utilities in the state. With the end of the drought and the deregulation of the electricity industry, the partnership evaporated. Recently the energy and water utilities have reestablished a joint program to incentivize the use of horizontal axis washing machines.

Policy Implications of Findings for the CII Sector

Various policy measures are available which can encourage, facilitate, and incentivize increased water-use efficiency in the CII sector. A number of models exist.

The urban "Best Management Practices" include two measures directed specifically at the CII sector. The first stipulates that agencies, at a minimum, support CII water conservation by offering audits and incentives that target the top 10 percent of industrial and commercial customers, providing follow up audits at least once very five years if necessary. A second measure establishes a CII review program which ensures that agencies review any proposed water uses for new commercial and industrial water service and make recommendations for improved water-use efficiency before completion of the building process.

Some agencies have developed water conservation programs for the CII sector utilizing a combination of audits, financial incentives, water rate structures, and educational programs. The following examples, while not exhaustive, illustrate the range of programs in place and the positive water efficiency improvements achieved.

MWD followed its audit program with a menu of rebates available to CII customers who undertake water-efficiency improvements. MWD offers customers fixed-rate rebates for retrofitting or replacing toilets or urinals, flush valves, pre-rinse spray heads, conductivity meters for cooling towers, or horizontal-axis washers.[156] Initial estimates of savings potential in this sector were 15 percent for commercial and institutional and 20 percent for the industrial sector. The findings of the program exceeded these estimates by a considerable margin, with an overall potential for 29 percent water savings. This was adjusted to 23 percent when two remarkably heavy water-using wastewater facilities were excluded. Examining the audit results by sector shows the industrial sector with 26 percent identified savings, the commercial sector with 20 percent identified savings, and the institutional sector with 19 percent identified savings.

The **East Bay Municipal Utility District (EBMUD)** offers both audit and rebate programs to CII customers. Rebates are provided for conservation measures recommended in the course of an audit and are designed to offset part of the initial cost of hardware upgrades or retrofits that are expected to result in significant savings. Rebates are based on estimated water savings at a rate of $0.73 per billing unit (748 gallons)—$318 per acre-foot—of water saved and may cover up to half of the installation cost of an eligible conservation measure.

The **City of San Jose's** Environmental Services Department implemented a Financial Incentive Program for commercial and industrial users. The primary motivating factor behind the program was reducing wastewater. To qualify, proposed projects must reduce wastewater by at least 1,496 gallons per year, and equipment must be purchased or leased within six months of the project being approved by the city. Equipment must have a life expectancy of no less than five years, and leases must be for a minimum period of three years.[157] The amount of the awards was initially based on the city's avoided cost of treating the water the new equipment would conserve, as well as its avoided cost of expanding the wastewater treatment plant. The city determined its (avoided cost) savings to be $1,000 per acre-foot, and initially offered customers $435 per acre-foot saved. However, in October 1991, they doubled the incentive, to $870 per acre-foot, to encourage more companies to apply. In 1998, the incentive was again doubled, to $1,740 per acre foot, the percent of a project's capital costs paid increased from 30 to 50 percent, and the $20,000 maximum award increased to $50,000 per project. These incentive amounts are cost-effective when compared to the city's reclaimed and other water conservation programs, such as ULFTs.[158]

In 1988, the **City of Palo Alto** was ordered by the San Francisco Water Department (its chief water supplier) to reduce its annual water use by 25 percent. In response, the city initiated a pilot Water Efficiency Program in September 1991 that included a water audit program for industrial facilities, which accounted for approximately 19 percent of the city's total water consumption. The city decided to focus on internal plant operations, examining domestic uses (toilets and faucets), heating, venting, and air conditioning (HVAC) systems, and processing applications (materials transportation, rinse baths, lubrication systems, and chemicals). Three companies were chosen from the responses to a mailing describing the audit program. The companies—an ice cream plant, a pharmaceutical company, and an electronic components manufacturer—each implemented some of the changes recommended during the audits. Palo Alto's conservation programs (CII and residential) were so successful that the city reduced overall water consumption by 35 percent.[159] One of the most successful consequences of the information discovered during the pilot study was the passage of a city ordinance that prohibits the installation of once-through cooling systems.[160]

Since 1992, the **Contra Costa Water District (CCWD)**[161] has offered free audits to all of its CII customers, and it performs an average of 200 audits per year. CCWD also offers financial incentives to commercial customers for upgrading selected plumbing fixtures, machines, and HVAC equipment. The incentives include $75 for each low-flow toilet, horizontal-axis washing machine, or commercial dishwasher using no more than 1.6 gallons per rack installed; $200 for each conductivity meter installed (conductivity meters automate cooling tower bleed water); and half of the cost, up to $500, of each pressure washer or recirculating pump installed. Funds are available on a first-come/first-serve basis. After the customer receives an audit and the project is approved, the customer has one year in which to upgrade its equipment. According to Water Conservation Specialist Ray Cardwell, when Safeway installed conductivity meters at its seven stores in the CCWD service area that use cooling towers, average water use by those stores dropped from 3,000 gpd to 300 gpd, resulting in a payback period of less than one month. The Safeway program was a joint effort between PG&E and the CCWD.[162]

The Green Business Program is a coalition of 12 government agencies that works with Bay Area businesses to upgrade equipment like irrigation timers, washing machines, conductivity meters, etc. The program pays up to 50 percent of the material cost of water-conserving equipment.[163] To allay these fears, the agencies offer an "amnesty" program—if violations are found when the customer has come forward to participate, the customer is not fined but given a courtesy "ticket" and the opportunity to fix any violation.

Summary of Policy Implications and Opportunities

Significant water efficiency improvement potential has been identified through various programs in California. Even when technically sound, cost-effective, and socially, desirable, many of the available opportunities have yet to be realized. In order to facilitate and encourage greater implementation of cost-effective technology and management measures, policy approaches need to be developed based on analysis of the multiple benefits of efficiency strategies.

The BMP process offers a unique and important opportunity to pursue policies to achieve multiple benefits through increased water, wastewater, and energy efficiencies.

RECOMMENDATIONS FOR FURTHER RESEARCH

The exploratory effort indicates that significant cost-effective energy efficiency potential exists in California through water efficiency improvements. Efficiency measures in the water sector have a number of important benefits in addition to energy savings, including environmental and economic benefits. Based on the promising results from this initial research effort, the following recommendations are set forth:

1. Apply the methodology and tools developed to specific areas of the state in which the energy intensity of water is highest. (This would include the most urbanized areas south of the Tehachapi Mountains to the Mexican border), central coast areas, the San Francisco Bay area, and other areas to be determined.

2. Further develop the methodology to include and quantify multiple benefits of efficiency improvements including air quality benefits (reduced energy use translating into reduced emissions based on actual power generation sources and time and season of use), capital and operating cost savings for both water and energy systems, and other economic and environmental benefits.

3. Investigate the pumping energy used within facilities and potential savings due to improved system efficiency.

4. Refine the already fairly well-developed methodology for estimating thermal energy savings within facilities resulting from water efficiency programs. (Previous work on showerhead and aerator replacement programs, horizontal axis washing machines, and other devices provides a strong basis for estimating thermal energy savings potential.)

5. Examine the energy implications of incorporating distributed water storage and treatment and technologies. These technologies range from cooling tower re-use treatment options grey water applications to rain water catchment for irrigation. In many cases, on-site storage and/or treatment may provide important energy efficiencies due to reduced pumping and treatment off-site.

Additional research efforts should focus on the following topics:

- quantifying energy efficiency potential by sector through water efficiency
- multiple benefits accounting for water efficiency and derived energy benefits
- peak load analysis and water systems
- implications for electricity transmission system of increased water pumping demand
- analysis of BMPs and energy benefits potential
- air quality implications of the water/energy efficiency link
- implications of decentralized electricity generation technologies on water use (location and amount)

APPENDIX

List of Acronyms
Conversion Factors
Member Agencies of MWD
Regulations Affecting the Water and Wastewater Industry

LIST OF ACRONYMS

AF	acre foot or acre feet
AFY	acre feet per year
ANSI	American National Standards Institute
AWRA	American Water Resources Association
AWWA	American Water Works Association
BMP	best management practices
CRA	Colorado River Aqueduct
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DAF	dissolved air filtration
DWR	California Department of Water Resources
EBMUD	East Bay Municipal Utility District
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FCD	flushes per capita per day
GCD	gallons per capita per day
GPD	gallons per day
GPF	gallons per flush
GPH	gallons per hour
GPM	gallons per minute
HCF	hundred cubic feet
IAPMO	International Association of Plumbing and Mechanical Officials
IID	Imperial Irrigation District
IWR-MAIN	Institute for Water Resources Municipal and Industrial Needs
LADWP	Los Angeles Department of Water and Power
M&I	municipal and industrial
MAF (or maf)	million acre feet
MAFY	million acre feet per year
MGD	million gallons per day
MOU	memorandum of understanding
MWD	Metropolitan Water District of Southern California
MWD-MAIN	Metropolitan Water District Municipal and Industrial Needs
MWRA	Massachusetts Water Resources Authority
PSI	pounds per square inch
RO	reverse osmosis
ROI	return on investment
SWP	State Water Project
SWRCB	California State Water Resources Control Board
TAF (or taf)	thousand acre feet
TDS	total dissolved solids
UAW	unaccounted-for-water
UCSB	University of California, Santa Barbara
UFF	unaccounted-for-flows (= UAW)
ULF	ultra-low-flow (1.6 GPF and less)
ULV	ultra-low-volume
UPC	Uniform Plumbing Code

Conversion Factors

distance
1 kilometer = 0.6214 miles
1 mile = 1.6093 kilometers
1 meter = 3.281 feet = 39.37 inches = 1.094 yards
1 foot = 0.3048 meter
1 yard = 0.9144 meter
1 inch = 2.54 centimeters
queen's chain = 22 yards (66 feet)

area
1 acre = 0.4047 hectares = 43,560 square ft
1 square mile = 640 acres = 2.590 square km = 259.00 hectares
1 square meter = 10.76 square ft = 1.196 square yards
1 square km = 100 hectares = 247.1 acres = 0.3861 square mile
1 hectare = 10,000 M2 = 2.47 acres
1 square foot = 929.03 square cm
1 square yard = 0.8361 square meter

volume and liquid measure
1 cubic meter = 264.2 gallons = 6.290 barrels
1 gallon = 0.0037829 cubic meter
1 cubic meter = 35.31 cubic feet
1 liter = 0.26425 gallons = 1.057 quarts = 33.81 fluid oz
1 gallon = 3.7854 liters
1 cubic foot = 0.0283 cubic meter = 7.481 gallons
1 cubic yard = 0.7646 cubic meter
1 cubic ft/second = 448.9 gal/min = 1.699 cubic meters/min
1 million gallons = 3.069 acre feet
1 mgd = 1,120 afy
1 afy = 0.000893 mgd
1 af = 325,851 gallons = 0.325851 mg = 43,560 cubic feet
1 af = 1,233.65 cubic meters

weight
1 pound = 453.59 grams
1 kg = 2.205 pounds
1 gallon water = 8.33 pounds
1 ton (metric) = 1,000 kg = 1.102 short tons = 0.9842 long tons
1 ton = 2,000 pounds = 907.18 kg

velocity
1 meter/second = 2.24 miles per hour
1 mile per hour = 0.447 meters per second

fuel consumption
1 km / liter = 2.3516 miles per gallon
1 mile / gallon = 0.425 kilometers per liter

energy
1 barrel oil = 6,000,000 Btu (av.) ((1 barrel = 42 gallons))
1 joule = 1 watt-second = 0.2390 calories
1 kilojoule = 0.9484 Btu
1 kilowatt-hour = 3413 Btu = 0.03413 therms
1 therm = 100,000 Btus = 29.3 kilowatt-hours
1 kilowatt = 1.341 horsepower

Member Agencies of MWD

City of Anaheim
201 S. Anaheim Boulevard
City Hall West, 11th Floor
Anaheim, CA 92805
(714) 765-4268

City of Beverly Hills
Public Works Department
9298 W. Third Street
Beverly Hills, CA 90210
(310) 285-2462

City of Burbank
Public Service Department
164 W. Magnolia Blvd.
Burbank, CA 91502
(818) 238-3550

Calleguas Municipal Water District
2100 Olsen Road
Thousand Oaks, CA 91362
(805) 526-9323

Central Basin Municipal Water District
17140 S. Avalon Blvd., #210
Carson, CA 90746-1218
(310) 217-2222

Coastal Municipal Water District
3 Monarch Bay Plaza, #205
Dana Point, CA 92629
(714) 493-3411

City of Compton
Water Department
City Hall
205 S. Willowbrook Ave.
Compton, CA 90220
(310) 605-5595

Eastern Municipal Water District
2270 Trumble Road
Perris, CA 92570
(909) 928-3777

Foothill Municipal Water District
4536 Hampton Road
La Canada Flintridge, CA 91011
(818) 790-4036

City of Fullerton
Water Engineering Division
303 W. Commonwealth Ave.
Fullerton, CA 92632
(714) 738-6886

City of Glendale
Public Service Department
141 N. Glendale Ave., 4th Level
Glendale, CA 91206-4496
(818) 548-2107

Inland Empire Utilities Agency
9400 Cherry Avenue
Building A
Fontana, CA 92335
(909) 357-0241

Las Virgenes Municipal Water District
4232 Las Virgenes Road
Calabasas, CA 91302
(818) 880-4110

City of Long Beach
Water Department
1800 E. Wardlow Rd.
Long Beach, CA 90807
(562) 570-2300

City of Los Angeles
Department of Water & Power
P.O. Box 111
Los Angeles, CA 90051
(213) 367-1338

Municipal Water District of Orange County
10500 Ellis Avenue
Fountain Valley, CA 92708
(714) 963-3058

City of Pasadena
Water & Power Department
150 S. Los Robles Ave., #200
Pasadena, CA 91101
(818) 405-4409

San Diego County Water Authority
3211 Fifth Ave.
San Diego, CA 92103
(619) 682-4100

City of San Fernando
City Hall
117 Macneil Street
San Fernando, CA 91340
(818) 898-1200

City of San Marino
California-American Water Co.
2020 Huntington Drive
San Marino, CA 91108-2022
(818) 289-7821

City of Santa Ana
Public Works Agency
217 N. Main St., 3rd Fl., M-22
Santa Ana, CA 92701
(714) 647-3345

City of Santa Monica
Utilities Division
1212 5th Street, 3rd Floor
Santa Monica, CA 90401
(310) 458-8230

Three Valleys Municipal Water District
1021 Miramar Avenue
Claremont, CA 91711
(909) 621-5568

City of Torrance
Water Division
3031 Torrance Blvd.
Torrance, CA 90509-2970
(310) 618-6216

Upper San Gabriel Valley Municipal Water District
11310 East Valley Blvd.
El Monte, CA 91731
(818) 443-2297

West Basin Municipal Water District
17140 S. Avalon Blvd., #210
Carson, CA 90746-1218
(310) 217-2411

Western Municipal Water District of Riverside County
450 Alessandro Blvd.
Riverside, CA 92517-5286
(909) 780-4170

Regulations Affecting the Water and Wastewater Industry

The following is from Franklin Burton, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities.* [164]

> Over the last 40 years, the number of treatment plants serving population centers in the United States has nearly tripled. Implementation of the federal Clean Water Act (CWA) brought about substantial changes in water pollution control to achieve "fishable and swimmable" waters.
>
> A significant event in the field of wastewater management in the United States was the passage of the Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) often referred to as the CWA. Before that date, there were no specific national water pollution control goals or objectives.
>
> A National Pollution Discharge Elimination System (NPDES) program was established based on uniform technological minimums with which each point source discharge had to comply. To date, over 60,000 permits have been issued under the SPDES program. EPA is the responsible governmental agency in administering the clean water program.
>
> In 1987, Congress enacted the Water Quality Act of 1987 (WQA), the first major revision of the CWA. Important provisions of the WQA are: (1) the strengthening of federal water quality regulations by providing changes in permitting and adding substantial penalties for permit violations, (2) significantly amending the CWA's formal sludge (biosolids) control program by emphasizing the identification and regulation of toxic pollutants in sewage sludge, (3) providing funding for state and EPA studies for defining non-point and toxic sources of pollution, (4) setting new deadlines for compliance including priorities and permit requirements for stormwater, and (5) establishing a phase-out of the construction grants program as a method of financing publicly owned treatment works (POTW). Subsequently, construction grants have been replaced largely by state revolving loan programs.
>
> The Ocean Dumping Ban Act of 1988 prohibited any dumping of wastewater solids into ocean waters after December 31, 1991. In 1993, EPA issued new regulations (40 CFR Part 503) for the use and disposal of biosolids from wastewater treatment plants. The regulations cover three general categories of beneficial use and disposal practices: application of land, surface disposal, and incineration. Limitations were established for items such as contaminants (mainly metals), pathogen content, and vector attraction reduction (vectors include birds, insects, and rodents). The general thrust of the Part 503 regulations is to support beneficial use.

SOURCES

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[1] Franklin Burton, in a recent study for the Electric Power Research Institute (EPRI), includes the following elements in water systems: “Water systems involve the transportation of water from its source(s) of treatment plants, storage facilities, and the customer. Currently, most of the electricity used is for pumping; comparatively little is used in treatment. For most surface sources, treatment is required consisting usually of chemical addition, coagulation and settling, followed by filtration and disinfection. In the case of groundwater (well) systems, the treatment may consist only of disinfection with chlorine. In the future, however, implementation of new drinking water regulations will increase the use of higher energy consuming processes, such as ozone and membrane filtration.” Burton, Franklin L., 1996, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities*. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.3-1.

[2] An acre-foot of water is the volume of water that would cover one acre to a depth of one foot. An acre-foot equals 325,851 gallons, or 43,560 cubic feet, or 1233.65 cubic meters. (See conversion table in the Appendix.)

[3] Metropolitan Water District of Southern California, *Integrated Resource Plan for Metropolitan’s Colorado River Aqueduct Power Operations*, 1996, p.5.

[4] QEI, Inc., 1992, *Electricity Efficiency Through Water Efficiency*, Report for the Southern California Edison Company, p. 2.

[5] California Department of Water Resources, 1996, *Management of the California State Water Project*. Bulletin 132-96.

[6] Carrie Anderson, 1999, “Energy Use in the Supply, Use and Disposal of Water in California”, Process Energy Group, Energy Efficiency Division, California Energy Commission, p.1.

[7] Third largest user of power in southern California residences based on a study for Southern California Edison by QEI, Inc., 1992, *Electricity Efficiency Through Water Efficiency*, Report for the Southern California Edison Company, pp. 23-24.

[8] California Energy Commission, http://www.energy.ca.gov/reports/stats/table58.html (March 4, 1998)

[9] California Department of Finance. California Statistical Abstract. Table P-2 “Resident Population July 1, 1996,” and Table P-23 “Per Capita Energy Consumption, 1994.” December 17, 1997. (http://www.dof.ca.gov/html/fs_data/stat-abs/toc.htm)

[10] California Energy Commission, http://www.energy.ca.gov/reports/stats/table58.html (March 4, 1998).

[11] California Energy Commission, http://www.energy.ca.gov/reports/stats/table41.html (March 4, 1998).

[12] Willis, Doug. “‘Serious’ water need predicted by 2020.” Associated Press. *Santa Barbara News-Press*. January 31, 1998.

[13] Metropolitan Water District of Southern California, 1999, Fact Sheet on Electric Industry Restructuring, 2/99 p. 2.

[14] Burton, Franklin L., 1996, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities*. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.ES-1.

[15] Burton found that: “More than 60,000 water systems and 15,000 wastewater systems are now operating in the United States. These facilities are among the country’s largest energy consumers, requiring an estimated 75 billion kWh nationally, about 3% of annual U.S. electricity use. Their electricity requirements will increase by 20% during the next 15 years as plants expand treatment capacity to meet population growth and as additional treatments are applied to meet the rigorous mandates of the Safe Drinking Water Act and the Clean Water Act. Emerging non-regulatory issues, such as improvement in drinking water taste and color, are expected to create additional energy needs.” Burton, Franklin L., 1996*, Water and Wastewater Industries: Characteristics and Energy Management Opportunities*. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, introduction.

[16] Conjunctive use of surface and groundwater, re-use of agricultural and urban water, inflow from Oregon, and other factors make precise accounting for water supplies a complicated task.

[17] Kahrl, William L., et al. *The California Water Atlas*. California Department of Water Resources, 1979. p. 3.

[18] California Department of Water Resources, 1994, *California Water Plan Update,* Bulletin 160-93.

[19] California Legislative Analyst’s Office. “Colorado River Water: Challenges for California.” December 16, 1997.

(http://www.lao.ca.gov/101697_colorado_river.html)

[20] Schoenherr, Allan A. *A Natural History of California*. University of California Press, 1992. p. ix.

[21] California Department of Finance. "California Statistical Abstract." November 1997. Table A-4. (www.dof.ca.gov)

[22] California Department of Finance. California Statistical Abstract. Table G-3 "Major Dams and Reservoirs of California." December 17, 1997. (http://www.dof.ca.gov/html/fs_data/stat-abs/toc.htm)

[23] California Department of Water Resources, November 1987, *California Water: Looking to the Future*, Bulletin 160-87 p.9; California Department of Water Resources, 1994, *California Water Plan Update,* Bulletin 160-93.

[24] California Department of Water Resources, Bulletin 160-74, 1974, p.2.

[25] California Department of Water Resources, November 1987, *California Water: Looking to the Future*, Bulletin 160-87 p.9.

[26] California Department of Water Resources, 1994, *California Water Plan Update,* Bulletin 160-93, Vol. 1, pp. 159-184. Projection for 2020 on p.181, Table 7-13. (See Figure 7-1 on page 159 for a comparison of Bulletin 160 projections.)

[27] DWR includes extensive discussion of the changes in the agricultural sector and in its water use in Bulletin 160-93.

[28] California Legislative Analyst's Office. "Colorado River Water: Challenges for California." December 16, 1997. (http://www.lao.ca.gov/101697_colorado_river.html)

[29] California Department of Water Resources, 1994, *California Water Plan Update,* Bulletin 160-93.

[30] Kahrl, William L., et al. *The California Water Atlas*. California Department of Water Resources, 1979. p. 3.

[31] Additional on-site energy for thermal requirements (heating and/or cooling) and for circulation and lift within individual facilities should also be included for a true "whole-system" analysis. This exploratory effort did not include those factors. Further analysis of the implications of water efficiency for these on-site energy uses is recommended.

[32] See for example: California Energy Commission, 1993, *California Energy Demand: 1993-2013: Prepared for Consideration in the 1994 Electricity Report Proceedings.* Volume X: The DWR Planning Area Forms, June; Miller, Peter, 1993, *State of California Energy Resources Conservation and Development Commission: Testimony of the Natural Resources Defense Council on Demand Forecast Issues.* San Francisco, CA: Natural Resources Defense Council; California Energy Commission, 1992, *Energy Efficiency Programs for Cities, Counties and Schools: Biennial Report to the Legislature on Senate Bill 880;* Chestnut, Thomas W., Anil Bamezai, and Casey McSpadden, 1992, *The Conserving Effect of Ultra Low Flush Toilet Rebate Programs.*, A&N Technical Services, Los Angeles: MWD.

[33] Burton, Franklin L., 1996, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities*. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.ES-1.

[34] Metropolitan Water District of Southern California (MWD), November 1990, *Water Management Pla*n, p.99. MWD's 1995 Water Management Plan follows the same policy approach. (Metropolitan Water District of Southern California (MWD), October 1995, *The Regional Water Management Plan for the Metropolitan Water District of Southern California*.)

[35] Metropolitan Water District of Southern California, 1998, "MWD Fact Sheet", 1/98. (See also MWD's web site at: http://www.mwd.dst.ca.us.

[36] Metropolitan Water District of Southern California, 1998, "MWD Fact Sheet", 1/98. (See also MWD's web site at: http://www.mwd.dst.ca.us.)

[37] Burton, Franklin L., 1996, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities*. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, Introduction (no page number).

[38] Dyballa, Cynthia and Christopher Connelly, 1992, *Electric and Water Utilities: Building Cooperation and Savings*, ACEEE Summer Study Program Paper.

[39] See CII section below.

[40] The BMPs are presented in a later section of this report. For a full listing and additional information, see the California Urban Water Conservation Council web site for a detailed list of efficiency measures and other related information: www.cuwcc.org

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[41] See discussion in the section on "Policy Implications" of this report below.

[42] See the California Department of Water Resources, "Efficient Water Management Practices by Agricultural Water Suppliers in California" Memorandum of Understanding, January 1, 1999.

[43] See pumping diagram of the SWP pumping system with cumulative pumping energy expressed in kWh/AF by location on the system and related maps.

[44] For example, a specific basin in an urban area may use 65% imported state water, 25% Colorado River water, and 10% ground water. Sewage is treated for the basin at a specific treatment plant. The energy embodied in interior and exterior (no sewage) water use, plus thermal energy for water heating and cooling, may be estimated. Impacts of efficiency improvements may then be determined based on marginal benefits including energy impacts. (See Figure 1 attached.)

[45] In some cases wastewater is directed to septic systems.

[46] CPUC Decision No. 89-12-057, December 20, 1989.

[47] Metropolitan Water District of Southern California, *Integrated Resource Plan for Metropolitan's Colorado River Aqueduct Power Operations*, 1996, p.5.

[48] QEI, Inc., 1992, *Electricity Efficiency Through Water Efficiency*, Report for the Southern California Edison Company, p. 24.

[49] Figures cited are *net* energy requirements (gross energy for pumping minus energy recovered through generation).

[50] The Colorado River water is lifted over 1,617 feet to move it over several mountain ranges.

[51] QEI, Inc., 1992, *Electricity Efficiency Through Water Efficiency*, Report for the Southern California Edison Company, p. 7.

[52] The SWP is pumped from near sea-level in the delta to Southern California over the Tehachapi Mountains. Further pumping is required to bring the water to the furthest reaches of the system.

[53] Wilkinson, Robert C., Arlene Wong, and Lisa Owens-Viani, 1999, "An Overview of Water-Efficiency Potential in the CII Sector"; *Sustainable Use of Water: California Success Stories*, Lisa Owens-Viani, Arlene Wong, and Peter Gleick, Eds., Pacific Institute, January 1999.

[54] "The SWP, managed by the Department of Water Resources, is the largest state-built, multi-purpose water project in the country. Approximately 19 million of California's 32 million residents receive at least part of their water from the SWP. SWP water irrigates approximately 600,000 acres of farmland. The SWP was designed and built to deliver water, control floods, generate power, provide recreational opportunities, and enhance habitats for fish and wildlife." California Department of Water Resources, *Management of the California State Water Project*. Bulletin 132-96. p.xix.

[55] California Department of Water Resources, 1996, *Management of the California State Water Project*. Bulletin 132-96.p.xix.

[56] Three small reservoirs upstream of Lake Oroville — Lake Davis, Frenchman Lake, and Antelope Lake — are also SWP facilities. California Department of Water Resources, 1996, *Management of the California State Water Project*. Bulletin 132-96.

[57] California Department of Water Resources, 1996, *Management of the California State Water Project*. Bulletin 132-96.

[58] The North Bay Aqueduct was completed in 1988. (California Department of Water Resources, 1996, *Management of the California State Water Project*. Bulletin 132-96.)

[59] The South Bay Aqueduct provided initial deliveries for Alameda and Santa Clara counties in 1962 and has been fully operational since 1965. (California Department of Water Resources, 1996, *Management of the California State Water Project*. Bulletin 132-96.)

[60] The San Luis Reservoir is jointly owned by the Department and the U.S. Bureau of Reclamation, which operates the Central Valley Project.

[61] The SWP's share of gross storage in the reservoir is about 1,062,000 acre-feet.

[62] Carrie Anderson, 1999, "Energy Use in the Supply, Use and Disposal of Water in California", Process Energy Group, Energy Efficiency Division, California Energy Commission, p.1.

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[63] California Department of Water Resources, 1996, *Management of the California State Water Project*. Bulletin 132-96.p.xix.

[64] Metropolitan Water District of Southern California, 1999, "Fact Sheet" at: http://www.mwd.dst.ca.us/docs/fctsheet.htm. Summary of Metropolitan's Power Operation. February, 1999.

[65] According to MWD, "Metropolitan's annual dependable supply from the Colorado River is approximately 656,000 acre-feet -- about 550,000 acre-feet of entitlement and at least 106,000 acre-feet obtained through a conservation program Metropolitan funds in the Imperial Irrigation District in the southeast corner of the state. However, Metropolitan has been allowed to take up to 1.3 million acre-feet of river water a year by diverting either surplus water or the unused portions of other agencies' apportionments." Metropolitan Water District of Southern California, 1999, "Fact Sheet" at: http://www.mwd.dst.ca.us/docs/fctsheet.htm.

[66] Metropolitan Water District of Southern California, 1999, http://www.mwd.dst.ca.us/pr/powres/summ.htm.

[67] Metropolitan Water District of Southern California, 1999, Colorado River Aqueduct: http://aqueduct.mwd.dst.ca.us/areas/desert.htm, 08/01/99.

[68] Among Metropolitan's power supply arrangements to be discussed is a provision for limited load shedding by Southern California Edison under which the Intake and Gene Pumping Plants can be shut down for certain limited periods of time during periods of peak electrical demands. Subsequent to such load shedding, Metropolitan occasionally operates all nine pumps at each of the Intake and Gene pumping plants (Total peak load of 311 MW) to refill the Copper Basin Reservoir.

[69] Metropolitan Water District of Southern California, 1996, "Integrated Resource Plan for Metropolitan's Colorado River Aqueduct Power Operations", 1996, p.5.

[70] Metropolitan Water District of Southern California, 1996, "Integrated Resource Plan for Metropolitan's Colorado River Aqueduct Power Operations", 1996, p.5.

[71] Metropolitan Water District of Southern California, 1996, "Integrated Resource Plan for Metropolitan's Colorado River Aqueduct Power Operations", 1996, p.5.

[72] Metropolitan Water District of Southern California, 1999, "Summary of Metropolitan's Power Operation". February, 1999, p.1, http://aqueduct.mwd.dst.ca.us/areas/desert.htm.

[73] Metropolitan Water District of Southern California, 1999, http://www.mwd.dst.ca.us/pr/powres/summ.htm. MWD provides further important system information as follows: Metropolitan owns and operates 305 miles of 230 kV transmission lines from the Mead Substation in southern Nevada. The transmission system is used to deliver power from Hoover and Parker to the CRA pumps. Additionally, Mead is the primary interconnection point for Metropolitan's economy energy purchases. Metropolitan's transmission system is interconnected with several utilities at multiple interconnection points. Metropolitan's CRA lies within Edison's control area. Resources for the load are contractually integrated with Edison's system pursuant to a Service and Interchange Agreement (Agreement), which terminates in 2017. Hoover and Parker resources provide spinning reserves and ramping capability, as well as peaking capacity and energy to Edison, thereby displacing higher cost alternative resources. Edison, in turn, provides Metropolitan with exchange energy, replacement capacity, supplemental power, dynamic control and use of Edison's transmission system.

[74] The service area's population of nearly 16 million is expected to grow by about 225,000 people a year. By the year 2010, Metropolitan's consumer population is projected to be about 19.1 million and water demands are expected to increase from the present 3.4 million acre-feet per year to about 4.3 million during normal weather conditions. (Metropolitan Water District of Southern California, 1999, "Fact Sheet" at: http://www.mwd.dst.ca.us/docs/fctsheet.htm.)

[75] Metropolitan Water District of Southern California, 1999, "Fact Sheet" at: http://www.mwd.dst.ca.us/docs/fctsheet.htm. Summary of Metropolitan's Power Operation. February, 1999.

[76] Metropolitan Water District of Southern California, 1999, "Fact Sheet" at: http://www.mwd.dst.ca.us/docs/fctsheet.htm. Summary of Metropolitan's Power Operation. February, 1999.

[77] Metropolitan Water District of Southern California, 1999, "Fact Sheet" at: http://www.mwd.dst.ca.us/docs/fctsheet.htm. Summary of Metropolitan's Power Operation. February, 1999.

[78] Metropolitan Water District of Southern California, 1999, "Fact Sheet" at: http://www.mwd.dst.ca.us/docs/fctsheet.htm.

[79] "About 1.36 million acre-feet per year (34 percent) of the region's average supply is developed locally

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using groundwater basins and surface reservoirs and diversions to capture natural runoff." Metropolitan Water District of Southern California, 1996, "Integrated Resource Plan for Metropolitan's Colorado River Aqueduct Power Operations", 1996, Vol.1, p.1-2.

[80] See discussion of applicable regulations in the appendix.

[81] Burton, Franklin L., 1996, Water and Wastewater Industries: Characteristics and Energy Management Opportunities. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.ES-4.

[82] Burton, Franklin L., 1996, Water and Wastewater Industries: Characteristics and Energy Management Opportunities. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.3-5.

[83] Approximately 71 percent of the U.S. population (or 176 million people) is served currently by publicly owned treatment works (POTWs). The municipal wastewater treatment industry is composed of over 15,000 plants that handle a total flow of about 28,000 million gallons per day (mgd), according to the 1988 Needs Assessment Survey conducted by EPA. In the next 20 to 30 years, the U.S. Environmental Protection Agency (EPA) has estimated that nearly 87 percent of the U.S. population, or 247 million people, will be served by POTWs. Burton, Franklin L., 1996, Water and Wastewater Industries: Characteristics and Energy Management Opportunities. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.ES-2.

[84] Wastewater systems generally consist of three principal components: collection system (sewers and pumping stations), treatment facilities (including sludge – now termed "biosolids" – processing), and effluent disposal or reuse. Burton, Franklin L., 1996, Water and Wastewater Industries: Characteristics and Energy Management Opportunities. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report.

[85] "In the last five years, the use of UV light as a means of disinfecting wastewater treatment plant effluent has increased significantly. Its use has increases because of (1) the increased awareness o f the impact of chlorine and chlorinated compounds on the environment, (2) improvements in UV hardware, (3) regulations requiring reductions in chlorine residual in plant effluent, (4) regulations governing the storage and handling of chlorine, especially in its gaseous form, and (5) safety and operating concerns in the use and handling of chlorine and dechlorinating agents." Burton, Franklin L., 1996, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities*. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.2-32.

[86] Burton, Franklin L., 1996, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities*. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.ES-2.

[87] "Most of the pipelines in a collection system handling sanitary wastewater are gravity sewers. At certain locations, typically when the sewers reach depths of 20 to 30 ft below ground, it generally becomes cost-effective to lift (pump) the wastewater to a higher elevation."
Burton, Franklin L., 1996, Water and Wastewater Industries: Characteristics and Energy Management Opportunities. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.2-5.

[88] Burton, Franklin L., 1996, Water and Wastewater Industries: Characteristics and Energy Management Opportunities. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.2-5.

[89] Burton, Franklin L., 1996, Water and Wastewater Industries: Characteristics and Energy Management Opportunities. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, pp.2-5-2-6.

[90] Burton, Franklin L., 1996, *Water and Wastewater Industries: Characteristics and Energy Management Opportunities*. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.2-6.

[91] MWD estimates that reclaimed water will ultimately produce 190,000 acre-feet of water annually. Metropolitan Water District of Southern California, 1999, "Fact Sheet" at: http://www.mwd.dst.ca.us/docs/fctsheet.htm.

[92] Curt Gollrad, Ionics Corporation, (Contact: 617-926-2510 x556)

[93] Metropolitan Water District of Southern California, 1999, "Fact Sheet" at: http://www.mwd.dst.ca.us/docs/fctsheet.htm.

[94] A & N Technical Services, 1995, "What is the Reliable Yield from Residential Home Water Survey Programs: The Experience of LADWP" (AWWA Conference Proceedings, 1995), A & N Technical Services, Inc.(Cited as a reference in: Memorandum of Understanding Regarding Urban Water Conservation in California, (as amended September, 1991; February, 1993; March 9, 1994; September 30, 1997; and April 8, 1998), Exhibit 1, p.15. California Urban Water Conservation Council, 455 Capitol Mall, Suite 705, Sacramento, CA 95814-4406. The full MOU and related documents are available at: www.cuwcc.org.

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[95] See for example: Amy Vickers, 1991, "The Emerging Demand-Side Era in Water Management," Journal of the American Water Works Association, vol. 83, no. 10; Amy Vickers, 1993, "The National Energy Policy Act: Assessing Its Impacts on Utilities," Journal of the American Water Works Association, vol. 85, no. 8; Maddaus, William O., 1987, *Water Conservatio*n, American Water Works Association; Chestnut, Thomas W., Anil Bamezai, and Casey McSpadden, 1992, *The Conserving Effect of Ultra Low Flush Toilet Rebate Programs.*, A&N Technical Services, Los Angeles: MWD; Wilkinson, Robert C., 1991, *California BMP Assessment: Analysis of Methodology and Assumptions for Assessing Water Savings Potential Resulting from Specific "Best Management Practices",* Rocky Mountain Institute; Chapin, S.W., 1994, "Water-Efficient Landscaping: A Guide for Utilities and Community Planners," Water Efficiency Implementation Report #6, Rocky Mountain Institute; and many other excellent references.

[96] See: Lisa Owens-Viani, Arlene Wong, and Peter Gleick, Eds., *Sustainable Use of Water: California Success Stories*, Pacific Institute, January 1999.

[97] This section draws from several studies by Wilkinson and co-authors as follows: Wilkinson, Robert C., Arlene Wong, and Lisa Owens-Viani, 1999, "An Overview of Water-Efficiency Potential in the CII Sector"; Wilkinson, Robert C. and Arlene Wong, 1999, "Assessing Commercial, Industrial, and Institutional Water Efficiency Potential: The MWD Audit Program"; Wilkinson, Robert C., 1999, "Increasing Institutional Water-Use Efficiencies: University of California, Santa Barbara Program", Lisa Owens-Viani, Arlene Wong, and Peter Gleick, Eds., *Sustainable Use of Water: California Success Stories*, Pacific Institute, January 1999.

[97.] There are various definitions of commercial and other categories of M&I water use. One of the most comprehensive lists and perhaps the best basis available for categorization of commercial uses is found in Pike, C.W., 1997, "Study of Potential Water Efficiency Improvements in Commercial Businesses", Final Report, U.S. Environmental Protection Agency / California Department of Water Resources, April, Table 1, pp.2-5. The USGS lists water uses according to a categorization scheme. A study by MWD and ERI Services disaggregates the CII categories slightly differently for an extensive analysis of the sectors in Southern California. See Sweeten, Jon, and Ben Chaput, "Identifying the Conservation Opportunities in the Commercial, Industrial, and Institutional Sector", paper delivered to AWWA, June 1997.

[99] Pike, Charles W., 1994. "Water Efficiency Guide for Business Managers and Facility Engineers," California Department of Water Resources, October; Pike, Charles W., 1997, "Study of Potential Water Efficiency Improvements in Commercial Businesses", Final Report, U.S. Environmental Protection Agency / California Department of Water Resources, April.

[100] The goal of the program was to identify the water efficiency potential that can be achieved in the CII sector within MWD's service area using cost-effective measures and to provide users with the practical information necessary to take advantage of identified opportunities.

[101] See: Wilkinson, Robert C. and Arlene Wong, "Assessing Commercial, Industrial, and Institutional Water Efficiency Potential: The MWD Audit Program"; *Sustainable Use of Water: California Success Stories*, Lisa Owens-Viani, Arlene Wong, and Peter Gleick, Eds., Pacific Institute, January 1999.

[102] Audits were conducted by Metropolitan Water District (which provided a majority of the data), City of Tucson, Arizona, and the Massachusetts Water Resources Authority. See: Pike, Charles W., 1997, "Study of Potential Water Efficiency Improvements in Commercial Businesses", Final Report, U.S. Environmental Protection Agency / California Department of Water Resources, April.

[103] The CII sector in MWD's service area includes approximately 35,000 industrial customers and 350,000 commercial customers.

[104] Sweeten, Jon, and Ben Chaput, "Identifying the Conservation Opportunities in the Commercial, Industrial, and Institutional Sector", paper delivered to AWWA, 1997, p.8.

[105] Pike, Charles W. 1994. "Water Efficiency Guide for Business Managers and Facility Engineers," California Department of Water Resources, October.

[106] The survey work identified cost-effective water savings potential of 29 percent for all facilities studied, 23 percent when two wastewater treatment plants were excluded as outliers. Potential savings were higher than expected. The large sample size has also allowed for valuable analysis of water-savings potential by industry or commercial sector and by conservation measure. A follow-up survey of 605 customers (representing 69 percent of total surveyed water use) found that water savings from efficiency improvements implemented after the audits are 3,080 mgal over the lifetime of the measures installed, which is 26 percent of the potential lifetime water savings identified. See: Hagler Bailly Services, Inc. 1997. "Evaluation of the MWD CII Survey Database." Prepared for Metropolitan Water district of Southern California. San Francisco, CA.

[107] Pike, Charles W., 1997, "Study of Potential Water Efficiency Improvements in Commercial Businesses", Final Report, U.S. Environmental Protection Agency / California Department of Water Resources, April, statement of conclusion and range of 0-50% from p. 28, range of 20-25.6% from p.11.

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[108] The 20% figure is from Sweeten, Jon, and Ben Chaput, "Identifying the Conservation Opportunities in the Commercial, Industrial, and Institutional Sector", paper delivered to AWWA, 1997, p.1.

[109] ERI Services, Inc. 1997. "Commercial, Industrial and Institutional Water conservation Program, 1991-1996." Prepared for Metropolitan Water District of Southern California. Irvine, CA.

[110] For a variety of case studies see: Wilkinson, Robert C. and Arlene Wong, "Assessing Commercial, Industrial, and Institutional Water Efficiency Potential: The MWD Audit Program"; Wilkinson, Robert C., Arlene Wong, and Lisa Owens-Viani, 1999, "An Overview of Water-Efficiency Potential in the CII Sector"; and: Wilkinson, Robert C. and Arlene Wong, 1999, "Assessing Commercial, Industrial, and Institutional Water Efficiency Potential" in: *Sustainable Use of Water: California Success Stories*, Lisa Owens-Viani, Arlene Wong, and Peter Gleick, Eds., Pacific Institute, January 1999.

[111] Maddaus, William O., 1987, *Water Conservation*, American Water Works Association, p.59.

[112] Maddaus, William O., 1987, *Water Conservation*, American Water Works Association, p.59, citing DWR, *A Pilot Conservation Bill,* Bulletin #191, and Brown and Caldwell, June 1979, *Review of Water Conservation in the City of Los Angeles*.

[113] EBMUD, October 1990, "Industrial Water Conservation," p.1.

[114] Brown and Caldwell, 1990, *Case Studies of Industrial Water Conservation in the San Jose Area*, p.38.

[115] Ron Munds, Water Conservation Coordinator, City of San Luis Obispo, personal communication 1/3/91.

[116] Wilkinson, Robert C., 1999, "Increasing Institutional Water-Use Efficiencies: University of California, Santa Barbara Program", *Sustainable Use of Water: California Success Stories*, Lisa Owens-Viani, Arlene Wong, and Peter Gleick, Eds., Pacific Institute, January 1999.

[117] Burton, Franklin L., 1996, Water and Wastewater Industries: Characteristics and Energy Management Opportunities. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.ES-8.

[118] Burton, Franklin L., 1996, Water and Wastewater Industries: Characteristics and Energy Management Opportunities. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.1-1.

[119] Burton, Franklin L., 1996, Water and Wastewater Industries: Characteristics and Energy Management Opportunities. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.ES-6.

[120] *Energy Policy Act* of 1992. The Energy Policy Act sets minimum performance standards for plumbing fixtures as established by the American Society of Mechanical Engineers (ASME), the American National Standards Institute (ANSI). Applicable standards include A116.19.2 and A116.19.6.

[121] Where available, the water savings level is identified in Section F of each of the 14 BMPs. See: Memorandum of Understanding Regarding Urban Water Conservation in California, as amended September, 1991; February, 1993; March 9, 1994; September 30, 1997; and April 8, 1998; California Urban Water Conservation Council, 455 Capitol Mall, Suite 705, Sacramento, CA 95814-4406. The full MOU and related documents are available at: www.cuwcc.org.

[122] Memorandum of Understanding Regarding Urban Water Conservation in California, (as amended September, 1991; February, 1993; March 9, 1994; September 30, 1997; and April 8, 1998), Section 2.1 (2), p.6. California Urban Water Conservation Council, 455 Capitol Mall, Suite 705, Sacramento, CA 95814-4406. The full MOU and related documents are available at: www.cuwcc.org.

[123] A similar process was envisioned for the agricultural sector in California, but the process was much slower and resulted in an "Agricultural Water Management Council" which did not even meet until July 16 of 1997. (DWR, *Water Conservation News*, July 1997, p.3. At that time there were 60 signatories to the Agricultural MOU, with only three from the environmental community. Some agricultural interests have long denied the possibility of *any* improvement in water use efficiency in the agricultural sector, making reasonable discussions of improvement difficult. The effort has not been notably successful in furthering what many believe to be vast potential for cost-effective efficiency improvements in the sector.

[124] Memorandum of Understanding Regarding Urban Water Conservation in California, (as amended September, 1991; February, 1993; March 9, 1994; September 30, 1997; and April 8, 1998), p.5. California Urban Water Conservation Council, 455 Capitol Mall, Suite 705, Sacramento, CA 95814-4406. The full MOU and related documents are available at: www.cuwcc.org.

[125] As noted on page 7 of the MOU, "In 1997, the Council substantially revised the BMP list, definitions, and schedules contained in Exhibit 1. These revisions were adopted by the Council September 30, 1997." Memorandum of Understanding Regarding Urban Water Conservation in California, (as amended September, 1991; February, 1993; March 9, 1994; September 30, 1997; and April 8,

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1998), p.5. California Urban Water Conservation Council, 455 Capitol Mall, Suite 705, Sacramento, CA 95814-4406. The full MOU and related documents are available at: www.cuwcc.org.

[126] The CUWCC is a non-profit organization with 501(c)(3) tax status.

[127] CUWCC, personal communication 12/3/99.

[128] For the state constitutional requirement and related case law see California Constitution, Article X, Section 2,; the "Audubon" case (*National Audubon Society v. Superior Court of Alpine County*, 1983); (*Imperial Irrigation District v. State Water Resources Control Board,* 1986); and "Raconelli", consolidation of eight cases, (*United States v. State Water Resources Control Board*, 1986).

[129] State Water Resources Control Board (SWRCB), October 1988, *Water Quality Control Plan For Salinity - San Francisco Bay/Sacramento-San Joaquin Delta Sanctuar*y (draft).

[130] See for example: Brown and Caldwell, "Assessment of Water Conservation Potential in Metropolitan's Service Area: Preliminary Report" which was undertaken in direct response (pp.1-1, 1-2) to estimates made by SWRCB's staff of water efficiency potential in California.

[131] Memorandum of Understanding Regarding Urban Water Conservation in California, (as amended September, 1991; February, 1993; March 9, 1994; September 30, 1997; and April 8, 1998), Section 5.1, p.9. California Urban Water Conservation Council, 455 Capitol Mall, Suite 705, Sacramento, CA 95814-4406. The full MOU and related documents are available at: www.cuwcc.org.

[132] California Department of Water Resources, *Water Conservation New*s, October 1989, p.3.

[133] Ed Thornhill, Conservation Manager, MWD, quoted in the same issue of DWR, *Water Conservation New*s, October 1989, p.3.

[134] DWR and MWD quoted in, *Water Conservation New*s, December 1990, pp.1-2.

[135] DWR and MWD quoted in, *Water Conservation New*s, December 1990, pp.1-2.

[136] The initial time frame stipulated in the MOU runs from 1991 to 2001.

[137] Memorandum of Understanding Regarding Urban Water Conservation in California, (as amended September, 1991; February, 1993; March 9, 1994; September 30, 1997; and April 8, 1998), Section 5.2, p.9. California Urban Water Conservation Council, 455 Capitol Mall, Suite 705, Sacramento, CA 95814-4406. The full MOU and related documents are available at: www.cuwcc.org.

[138] A comprehensive assessment of the technical aspects and efficiency potential of the BMPs was undertaken by Wilkinson as a neutral third party under contract to the Metropolitan Water District in 1989 and 1990 as the MOU was being negotiated. The analysis focused in detail on the water-saving potential for the proposed BMP measures, and it included a review of practices and current information in each technical area. In general, it found that the BMPs were conservative relative to more effective programs already in place and running at various locations around the state. It also found that the assumptions regarding the levels of water efficiency improvements were significantly understated. See: Wilkinson, Robert C., 1991, *California BMP Assessment: Analysis of Methodology and Assumptions for Assessing Water Savings Potential Resulting from Specific "Best Management Practices",* Rocky Mountain Institute, Snowmass, CO 81654-9199.

[139] Memorandum of Understanding Regarding Urban Water Conservation in California, (as amended September, 1991; February, 1993; March 9, 1994; September 30, 1997; and April 8, 1998), "Recitals, A", p.4. California Urban Water Conservation Council, 455 Capitol Mall, Suite 705, Sacramento, CA 95814-4406. The full MOU and related documents are available at: www.cuwcc.org.

[140] Mitchell, David L. and Wendy Illingworth, *California Urban Water Agencies BMP Performance Evaluation,* Final Report, M. Cubed, July 1997, p.1.

[141] Memorandum of Understanding Regarding Urban Water Conservation in California, (as amended September, 1991; February, 1993; March 9, 1994; September 30, 1997; and April 8, 1998), p.5. California Urban Water Conservation Council, 455 Capitol Mall, Suite 705, Sacramento, CA 95814-4406. The full MOU and related documents are available at: www.cuwcc.org.

[142] Memorandum of Understanding Regarding Urban Water Conservation in California, (as amended September, 1991; February, 1993; March 9, 1994; September 30, 1997; and April 8, 1998), Section 4.4, p.8. California Urban Water Conservation Council, 455 Capitol Mall, Suite 705, Sacramento, CA 95814-4406. The full MOU and related documents are available at: www.cuwcc.org.

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[143] Memorandum of Understanding Regarding Urban Water Conservation in California, (as amended September, 1991; February, 1993; March 9, 1994; September 30, 1997; and April 8, 1998), Section 4.5, p.8. California Urban Water Conservation Council, 455 Capitol Mall, Suite 705, Sacramento, CA 95814-4406. The full MOU and related documents are available at: www.cuwcc.org.

[144] The "CalFed" Bay-Delta Program was established in May of 1995 as part of a "Framework Agreement" signed in June 1994 by Governor Wilson and Secretary of the Interior Babbitt.

[145] *California Urban Water Conservation Council, Best Management Practices Summary Report, 1995-1996,* for fiscal 1995-96, October 8, 1997, pp.3-4.

[146] *California Urban Water Conservation Council, Best Management Practices Summary Report, 1995-1996,* for fiscal 1995-96, October 8, 1997, pp.5-20.

[147] *California Urban Water Conservation Council, Best Management Practices Summary Report, 1995-1996,* for fiscal 1995-96, October 8, 1997, p.3.

[148] See for example: QEI, Inc., 1992, *Electricity Efficiency Through Water Efficiency*, Report prepared for the Southern California Edison Company; Barakat & Chamberlin, Inc., 1992, A Framework for Sharing the Costs of an Ultra-Low-Flush Toilet Retrofit Program, Final Report to Metropolitan Water District of Southern California, October 5, 1992.

[149] Memorandum of Understanding Regarding Efficient Water Management Practices by Agricultural Water Suppliers in California, January 1, 1999, (pursuant to the) *Agricultural Water Suppliers Efficient Water Management Practices Act of 1990* (AB 3616).

[150] Memorandum of Understanding Regarding Efficient Water Management Practices by Agricultural Water Suppliers in California, January 1, 1999, (pursuant to the) *Agricultural Water Suppliers Efficient Water Management Practices Act of 1990* (AB 3616), Exhibit A, List A, item 6, p.A-2.

[151] Memorandum of Understanding Regarding Efficient Water Management Practices by Agricultural Water Suppliers in California, January 1, 1999, (pursuant to the) *Agricultural Water Suppliers Efficient Water Management Practices Act of 1990* (AB 3616), Exhibit A, List A, item 6, p.A-2.

[152] Wodraska, John R., 1994, Memorandum to the Board of Directors from the General Manager, April 20, 1994, regarding "Update on the Southern California Water and Energy Partnership".

[153] Wodraska, John R., 1994, Update Memo to the MWD Board of Directors on the Southern California Water and Energy Partnership, April 20, 1994. The partnership included the Metropolitan Water District of Southern California, the Los Angeles Department of Water and Power, the Southern California Gas Company, Southern California Edison, the sanitation districts of Orange County, the cities of Anaheim, Burbank, Glendale, Pasadena, Santa Monica, and the Central Basin Municipal Water District, the Municipal Water District of Orange County, and West Basin Municipal Water District.

[154] Barakat & Chamberlin, Inc., 1992, A Framework for Sharing the Costs of an Ultra-Low-Flush Toilet Retrofit Program, Final Report to Metropolitan Water District of Southern California, October 5, 1992, p. 3.

[155] Southern California Water and Energy Partnership minutes, Executive board meeting, March 6, 1993.

[156] The audit program went through several changes in its five-year life as adjustments were made to streamline procedures and better respond to agency and customer needs. In the 18-month pilot phase, fifteen sites received full water-efficiency studies conducted by a senior engineer. These initial studies targeted high-volume water users, with lower-volume users filtered out to ensure cost-efficiency, and the average survey cost was $6,500. Reports to the customer reviewed the primary water uses at the site and recommend specific measures that would reduce water use. Only those measures that had a short simple payback period within the customer's stated tolerance would be recommended (usually 5 years or less). To provide a complete picture of expected savings, water, sewer, and the water-related energy and chemical costs savings were factored into the payback analysis.

[157] Wilson, E. 1998. City of San Jose. Personal communications. (See Wilkinson, Robert C., Arlene Wong, and Lisa Owens-Viani, 1999, "An Overview of Water-Efficiency Potential in the CII Sector" in: *Sustainable Use of Water: California Success Stories*, Lisa Owens-Viani, Arlene Wong, and Peter Gleick, Eds., Pacific Institute, January 1999.)

[158] Tovar, M. 1998. City of San Jose. Personal communications. (See Wilkinson, Robert C., Arlene Wong, and Lisa Owens-Viani, 1999, "An Overview of Water-Efficiency Potential in the CII Sector" in: *Sustainable Use of Water: California Success Stories*, Lisa Owens-Viani, Arlene Wong, and Peter Gleick, Eds., Pacific Institute, January 1999.)

[159] Zamost, B. 1993. "Offer Water Audits for Business and Industry," *Building Sustainable Communities Water Efficiency Series*, The Global Cities Project, San Francisco, CA.

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[160] Waik, V. 1998. City of Palo Alto. Personal communications, in: Wilkinson, Robert C., Arlene Wong, and Lisa Owens-Viani, 1999, "An Overview of Water-Efficiency Potential in the CII Sector", *Sustainable Use of Water: California Success Stories*, Lisa Owens-Viani, Arlene Wong, and Peter Gleick, Eds., Pacific Institute, January 1999.

[161] The Contra Costa Water District (CCWD) is both a water wholesaler and retailer to over 400,000 users.

[162] Ray Cardwell comments that one of the biggest challenges in implementing these programs is convincing corporate decision-makers of their value, since the cost of water is not usually a huge motivating factor. (Cardwell, Ray. 1998. Contra Costa Water District, Martinez, CA. Personal communications: Personal communications, in: Wilkinson, Robert C., Arlene Wong, and Lisa Owens-Viani, 1999, "An Overview of Water-Efficiency Potential in the CII Sector", *Sustainable Use of Water: California Success Stories*, Lisa Owens-Viani, Arlene Wong, and Peter Gleick, Eds., Pacific Institute, January 1999.)

[163] Cardwell, Ray. 1998. Contra Costa Water District, Martinez, CA. Personal communications: Personal communications, in: Wilkinson, Robert C., Arlene Wong, and Lisa Owens-Viani, 1999, "An Overview of Water-Efficiency Potential in the CII Sector", *Sustainable Use of Water: California Success Stories*, Lisa Owens-Viani, Arlene Wong, and Peter Gleick, Eds., Pacific Institute, January 1999.

[164] Burton, Franklin L., 1996, Water and Wastewater Industries: Characteristics and Energy Management Opportunities. (Burton Engineering) Los Altos, CA, Report CR-106941, Electric Power Research Institute Report, p.2-13-18.