

REALIZING THE BENEFITS FROM WATER CONSERVATION

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INTRODUCTION

Conservation planners generally believe that a long-term conservation program can reduce water consumption by 10 to 20 percent over a 10- to 20-year period. Water demand may continue to rise, but it should rise at a rate that is one to 1 1/2 percent per year slower than projected without a conservation program in place. Conservation in this range can usually be economically justified by the expected postponement or downsizing of capital facilities, such as water treatment plants and storage reservoirs. Conservation planners have been promising these benefits for over ten years now. The question is: "Are we realizing the expected benefits?" This paper will explore that issue and offer some methods to verify that conservation programs are living up to expectations.

Quantifiable benefits to water utilities that reduce water demand include:

- Reduction in operation and maintenance (O&M) expenses resulting from lower use of energy for pumping and less chemical use in water acquisition, treatment, and disposal.
- Reduced water purchases from wholesale water providers.
- Deferral or downsizing of capital facilities may be possible. Lowering the rate of increase in demands can postpone facility construction and, in cases

where growth is slowing, avoid the last water supply or treatment increment. The types of water utility capital facilities most likely affected include water storage reservoirs, raw-water transmission facilities, water treatment plants, finished water storage, and groundwater pumping stations. Fewer or smaller facilities also reduce staffing costs.

HOW WATER CONSERVATION CAN AFFECT WATER/WASTEWATER SYSTEMS

Existing water systems are affected by reduced consumption in a variety of ways. A recent report on the topic assessed the impact of water conservation on a number of U.S. utilities, based on the source of water, be it surface water, groundwater, both, or purchased water (Bishop and Weber, 1996). This report can serve as an example for categorizing the impacts, which are described in the following paragraphs.

Water System Operating Costs

Water conservation will lower pumping energy expended to acquire, treat, and distribute the water. The volumes of chemicals used in water treatment that are dosed on a flow basis, such as chlorine, are reduced. This directly reduces operation and maintenance expenses. Shown in Table 1 is the energy use and significance in total O & M costs.

TABLE 1

TYPICAL AMOUNT OF ENERGY USED TO DELIVER WATER

Type of Water	Energy Use (KW/1000 gal)	Electricity of Total O & M (Percent)	Electricity (Percent of Total Cost)
Groundwater	1.2	18	7
Surface Water	0.7	11	4
Purchased Water	0.6	4	3

Source: AWWA, 1991

Water System Design Criteria

New water facilities present an opportunity to downsize or postpone expansions. This can occur if the design of the facility is dependent on water flows. Table 2 shows typical design criteria for water facilities that may be affected by reduced consumption. Reduction in average day affects how much water must be developed, or

imported and stored, prior to treatment and use. Reduction in peak day demand affects the sizing and timing of water treatment plant expansions and treated water storage. Water pipelines and pumping stations are affected by peak hour pumping. Peak hour pumping is dependent on customer peak hour demands plus required fire flows. The latter is based on the type of land use to be protected.

**TABLE 2
HOW WATER SYSTEM ELEMENTS ARE AFFECTED BY USAGE VOLUME**

System Element	Design Criteria Based On			
	Average Day	Peak Day	Peak Hour	Fire Flow
Source Water Acquisition	√			
Raw Water Storage	√			
Water Pipelines			√	√
Water Treatment Plants		√		
Pumping Stations			√	√
Treated Water Storage		√		√

Wastewater System Operations

Wastewater systems see similar O&M benefits from conservation as water systems - lower energy and chemical use. Most wastewater collection systems are designed to flow by gravity. Nevertheless, energy is required in force mains, to lift the wastewater into treatment plants, and to process the waste. Only part of the energy use at treatment plants is dependent on flow, most of the energy use is for waste aeration or biological treatment. Disposal usually involves pumping of treated wastewater to receiving waters or to land disposal sites, and these costs may be dependent on flow volume. Each system is different and ascertaining the savings is done on a case by case basis.

Wastewater is chlorinated at least once during the treatment process, and sometimes dechlorinated. Use of these chemicals is flow dependent.

Wastewater System Design Criteria

Shown in Table 3 are the impacts of conservation (wastewater flow reduction) on design of new facilities. Design criteria for land disposal systems are volume dependent. Most facilities are based on peak wet weather flow, which can benefit from infiltration/inflow (I/I) control programs, but are little affected by conservation programs which save much less water than I/I contributes.

**TABLE 3
HOW WASTEWATER SYSTEM ELEMENTS ARE AFFECTED BY CONSERVATION**

System Elements	Design Criteria Based On		
	Average Dry Weather Flow	Peak Wet Weather Flow	Solids Loading
Collection Systems		√	
Interceptors		√	
Treatment Plants		√	√
Disposal to Receiving Water		√	
Land Disposal	√	√	

Other Benefits

Other benefits that sometimes are significant and possibly can be quantified include:

- Lower withdrawals from supply sources
- Lower discharges of treated wastewater to receiving waters
- Lessened environmental impacts of construction
- Creation of water conservation jobs
- Customer savings in utility bills

EVALUATING THE BENEFITS FROM CONSERVATION

Many water utilities use benefit-cost analysis to evaluate, select, and/or justify conservation program tailored to local conditions. The more documentation we have on the actual benefits from conservation, the more believable are the results from a benefit-cost analysis of potential programs. The methodology for benefit-cost analysis is explained in various references (Macy and Maddaus, 1989).

Unfortunately there is not a lot of published data yet on the benefits that have been realized from water conservation programs. Consequently when evaluating possible new programs, it is necessary to estimate the benefits using published procedures. Benefits of water conservation can be estimated by following the procedure published by AWWA (1993). A synopsis follows. Benefits will change with time, as water savings change (increase), and capital facilities can be deferred. Normally the benefits are forecasted over at least twenty years, as this is the common time horizon for benefit cost analysis. Benefits are tabulated separately for each perspective to be used in a benefit-cost analysis. Perspectives can include that of water utility, program participants (and utility customers) and society as a whole.

Utility Benefits

Reduced Purchases of Raw or Finished Water

In the case of a water retailer buying less water from a water wholesaler, the benefits from reduced water purchases can be directly figured from their contract. If raw water is purchased it must be treated, so there are benefits from reduced water treatment and storage requirements (see below). Sometimes there are minimum purchase requirements or monthly fixed charges that must be considered.

Reduced Operation and Maintenance Costs

Energy cost savings can be determined from the utility's energy bill. The unit energy cost can be determined by subtracting the fixed charges and the non water production related energy costs from the total annual bill and dividing by the annual water produced. The unit savings, in \$/1000 gallons saved, can be multiplied by the water savings, in 1000 gallons, to yield total annual energy cost savings.

Chemical costs are normally flow-related and can be expressed on a \$/1000 gallons produced and used to value the water savings.

The study sponsored by AWWA contains estimates of these types of benefits for some utilities (Bishop and Weber, 1996). Generally these benefits are small compared to capital deferral benefits.

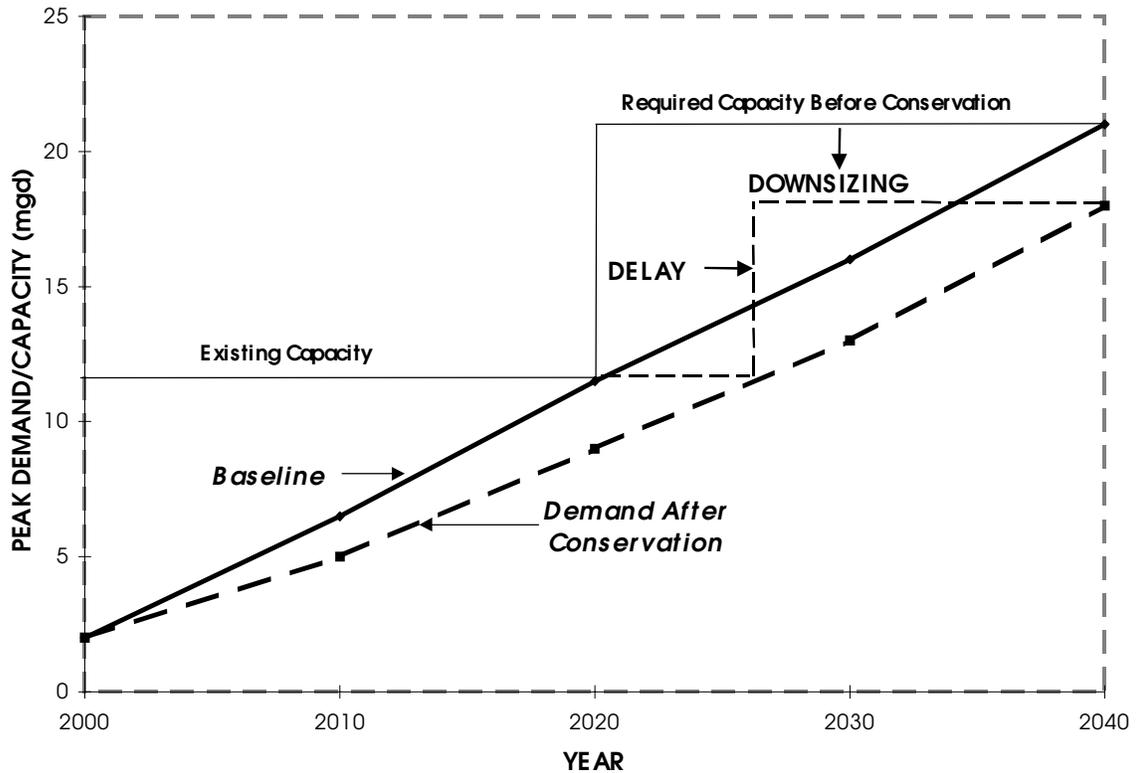
Deferred, Downsized, or Eliminated New Capital Facilities

Most capital facilities are designed to meet peak demands in some future year. Typical design horizons are 10 to 20 years. Although indoor conservation measures will reduce average day and peak day demands, savings in landscape, cooling water and other summer uses will have greater effects on reducing the peak. In cities with arid climates, peak to average day ratios of 2.0 to 3.0 are common. In humid or colder climates, peak day ratios of 1.2 to 1.7 are common. The peak day ratio can be determined by comparing utility water production records using the following formula:

Peak day ratio = highest day production/average day production

The timing of capital facilities depends on the rate of growth in peak demand and the capacity of existing facilities. If the planned facilities are dependent in the growth of water demand, then reduction in future water use can affect the timing of construction of these facilities. Figure 1 illustrates how water conservation could affect the timing of capital facilities (Maddaus, Gleason, and Darmody, 1996). In this case, a facility needed in 2020 could be delayed about 7 years. In the example shown, demand reduction would reduce peak-day demands by about 20 percent. The resultant dollar savings to the utility are the difference in the present value of the costs associated with building the facility in 2027 instead of 2020.

FIGURE 1 - EXAMPLE OF DELAYING AND/OR DOWNSIZING A CAPITAL FACILITY



If demand is leveling off as growth slows down, then reducing demand may reduce the need for the last expansion. In this case, the last expansion can be downsized. The capital cost savings associated with a smaller facility can be converted to present worth, and added to other conservation benefits.

Information on the timing and sizing of capital facilities can often be found in the utility's capital facility plan, water supply plan, and/or water master plan. Unfortunately, sometimes the capital facilities are only identified a few years in advance, and projections of needed facilities must be made by use of demand projections and the design criteria.

In the case of wastewater facilities, it is necessary to understand how reduced wastewater flow will affect the design of new facilities. Water conservation has a small effect on peak day flows (which are more affected by infiltration/inflow). Water conservation can have a large effect on treated effluent disposal facilities, especially, land disposal facilities. A similar analysis to the above

example can be used to figure present worth savings from wastewater facility deferral or downsizing.

In order to defer this expansion 3 years, the conservation program must save three years worth of growth in water demand by 2010. For example, if demand is growing at the rate of 3 percent per year then the needed reduction by 2010 is 9 percent. A lower reduction will defer the facility fewer years. This reduction must be expressed in the same terms as the design criteria, normally peak day demand reduction. Although average day reductions may be higher, on a percentage basis, only the reduction in the peak day use is relevant. Peak day reductions are mostly dependent on outdoor water conservation. Indoor conservation helps, but is not as significant.

Environmental Benefits

Reduced water use can benefit the environment in a number of ways:

- Water is left in rivers, reservoirs, groundwater basins where it can be used for enhancing environmental purposes
- Lower energy consumption can have secondary benefits by reducing energy production
- Reduced wastewater flows mean that less effluent must be disposed of, often with some environmental impacts

Quantifying the environmental benefits is not simple. Since the benefits usually do not accrue to the utility that is sponsoring the water conservation program, they are often not quantified. Various environmental impact assessment texts offer guidance on valuing these benefits.

Socio-Economic Benefits

Water conservation programs can involve considerable effort and materials to cause water demand patterns to shift. Some conservation programs are labor intensive. Utilities starting programs will add staff and may hire contractors. These jobs and the materials purchased can add to the local economy.

CASE STUDIES OF PEAK DAY DEMAND MANAGEMENT

Available case studies on peak day demand reduction are few and far between. The first case of a conservation program reducing the peak demand and the need to expand supply was the City of Tucson's *Beat the Peak* program in the 1970s. A major new supply was delayed by a conscious effort of residents to landscape with very limited use of turf grass, using instead native landscaping materials. Tucson still has a strong emphasis on desert landscaping but updated figures on peak day water savings are not available.

Most of the available data on conservation water savings is from programs that have been run one at a time. Savings data are from metered water records of customers impacted by the program, which are read every month or two. While these data are useful for evaluating new programs, the estimates are not directly transferable to peak day demand reductions. We do not have much experience trying to relate annual water savings from one customer class to overall system peak day savings. This limits our ability to accurately forecast benefits from programs that may reduce peak day demands.

In an effort to shed some light on peak day demand management, three case studies are presented herein. Austin, Seattle, and East Bay Municipal Utility District

were selected because they have historical peak day data, going back 20 to 30 years, and they have had active conservation programs in place for many years. Comparison of long-term trends in peak day demand among these three utilities can help us develop an understanding of how we are doing on managing peak day demands.

City of Austin, Texas

The City of Austin started a water conservation program in 1983. It prepared its first plan in 1986. By 1993 it had a population of 545,000 persons and the City received a state grant to prepare a new water conservation plan. Montgomery Watson was hired to prepare the plan. They found that a plan focusing on peak demand reduction would be cost-effective because expansions of two water treatment plants could be deferred. A ten percent demand reduction would defer the first plant expansion five years and the second by eight years. The marginal benefit of the saved water was \$2.18 per 1000 gallons saved, of which seventy-two percent was due to capital deferral and the remainder to operation and maintenance cost savings (Montgomery Watson, 1993).

After the City adopted the plan, staff implemented the following programs directed at reducing peak demands:

- Irrigation audits of residential customers
- Irrigation rebates to improve irrigation systems
- Public information campaign in the summer to create awareness of efficient watering practices
- Amended the commercial landscape code to require Xeriscape and efficient irrigation

The City has also reduced average day consumption through programs directed at indoor consumption, such as offering rebates for Ultra Low Flush toilets and commercial/industrial water audits. Of course the peak day programs also reduce the average day demands, as well as peak day demands.

Figure 2 shows trends in the peak day ratio and the peak day consumption, expressed on a gallons per person per day basis, over the last 30 plus years. During this period the population of Austin has more than doubled. The peak day ratio declined until the early 1980s and has been fairly steady since then. The peak day consumption has also declined over this period, and actually continued to decline until about 1990 and then leveled off. The City's conservation program started in the mid-1980s and has certainly contributed to this decline. There were obviously other factors at work causing the decline between 1965 and 1985. These could have included a decline in the average irrigated

area per new account, a higher density of new development, more environmental consciousness of excessive water use, etc. The net result of this decline in peak day use is to defer expansion of water treatment

plant capacity in the City. On the other hand, compliance with the Safe Drinking Water Act may accelerate construction of some water quality enhancement projects (Lutes, 1999).

FIGURE 2 – CITY OF AUSTIN PEAK HISTORICAL CONSUMPTION AND PEAK DAY RATIO



City of Seattle

In the 1980s the City of Seattle had a peak day demand consistently over 300 mgd. Then in 1992 a water shortage occurred and it was necessary for the City to ban outside watering all summer. After the shortage was over the peak demands rebounded, but have never recovered to the pre-shortage level. In 1994-1997, after the shortage, the peak day has been between 260 and 270 mgd, and may in fact still be declining slightly. The reduction in peak day demand since 1982 has been over thirty percent, in spite of serving twenty percent more

people (Dietemann, 1998). Figure 3 shows the decline in peak day ratio and peak day consumption, on a per capita basis. The City has had a conservation program in place throughout this period, with activities increasing over time. The actions the City has taken to maintain peak day water savings include:

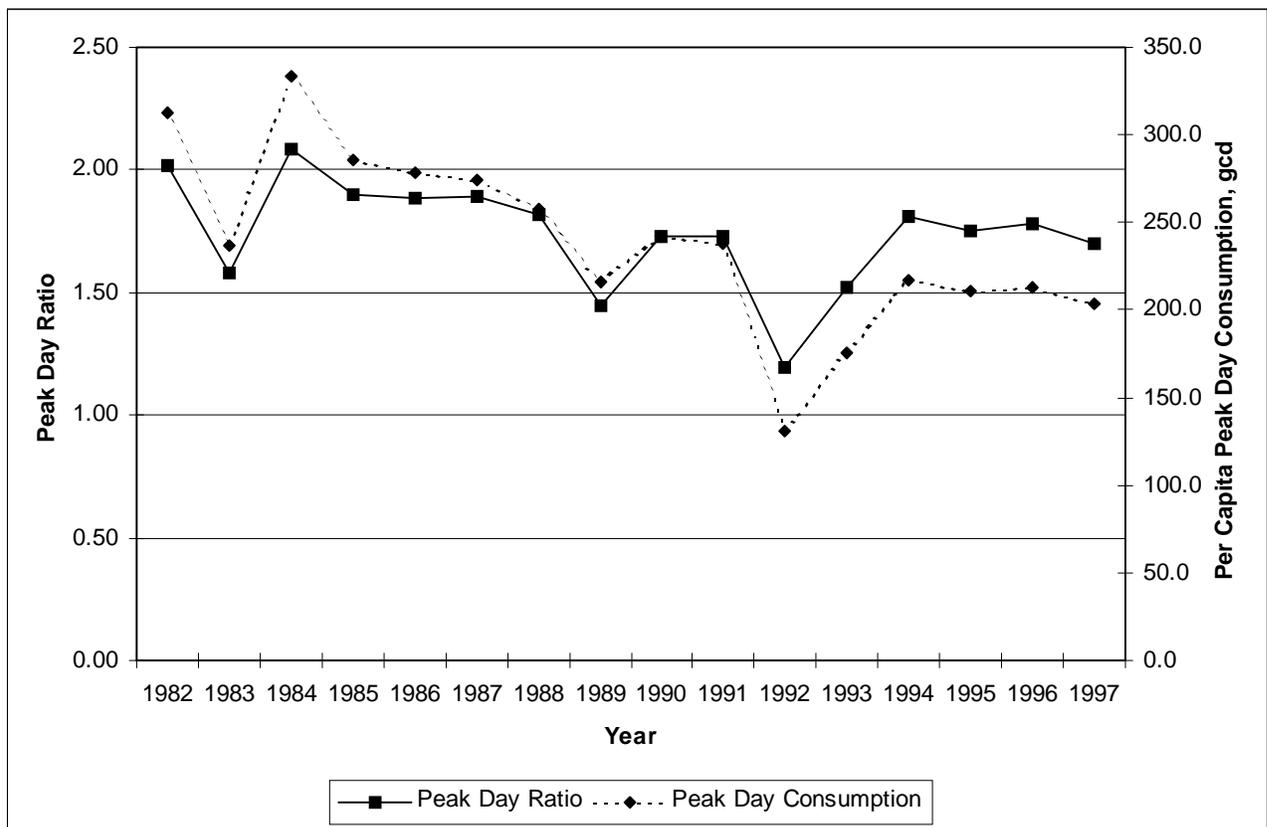
- Peak season water rates that make water 1.5 to 2.6 times more expensive in the four summer months (depending upon customer class)

- System development fees partially based on irrigated lot size
- Summer media campaign
- Financial incentives to commercial and industrial customers for reducing peak season uses such as cooling towers, food processing, ice production, commercial irrigation
- Reduction in non-revenue water by timing flushing, reservoir cleaning, etc. to avoid peak periods

The City has also undertaken programs to reduce indoor water use such as promoting the use of more efficient toilets and showerheads. Clearly, the water shortage of

1992 has played a major role in reducing peak demands, but since the rebound in use after the shortage, peak-day demands have not returned to prior levels. There are probably other factors at work in Seattle, but the City's conservation program was strong enough to sustain part of the reduction in peak day use that occurred after 1992. Furthermore, as Figure 3 shows, the peak day may still be declining. As a result of the decline in peak-day use, new supply facility expansions have been postponed, saving millions of dollars in debt service and helping to reduce short-term rate increases (Dietemann, 1998).

FIGURE 3 – CITY OF SEATTLE HISTORICAL PEAK CONSUMPTION AND PEAK DAY RATIO



East Bay Municipal Utility District

East Bay Municipal Utility District has probably had a water conservation program as long as any water agency in the US, starting in the mid-1970s. They have also

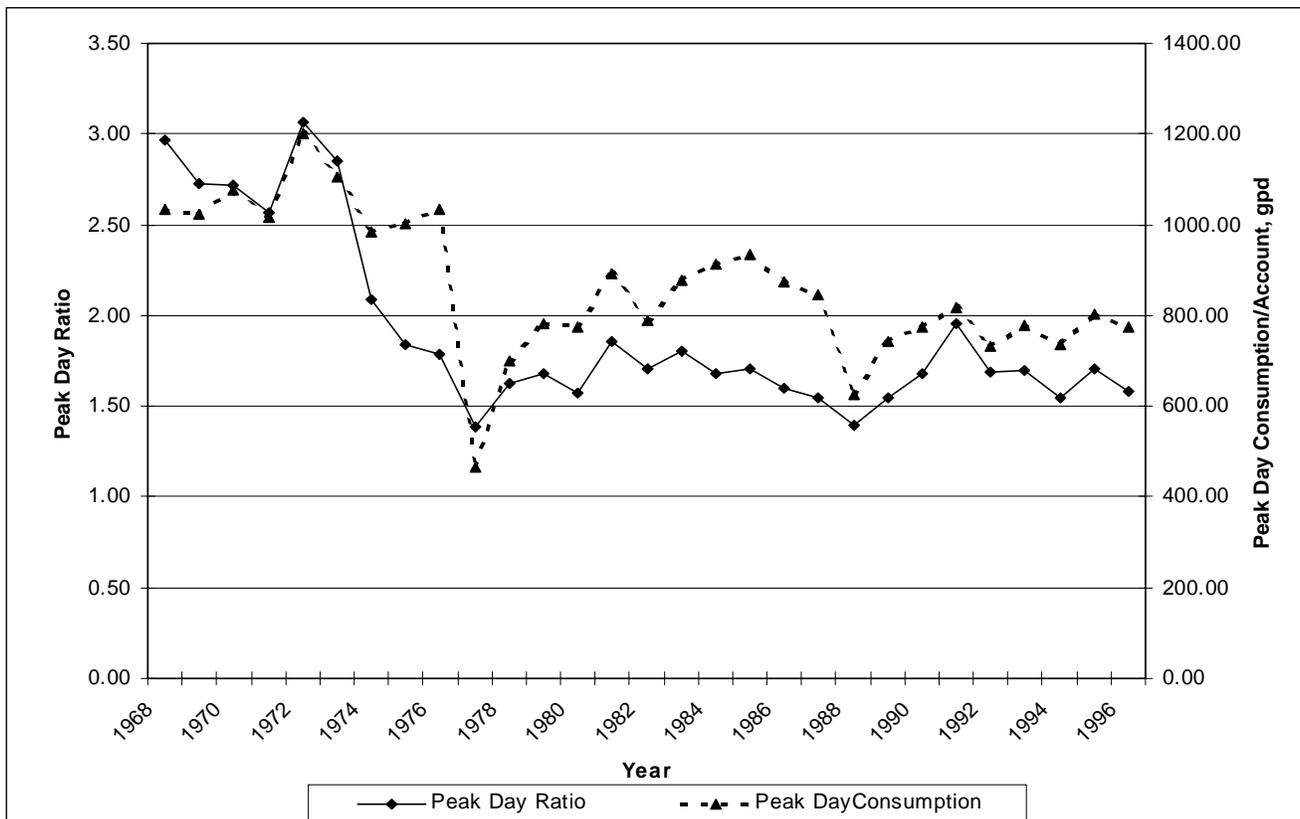
been through two droughts, which have caused water shortages, one in 1976-1977, and the other 1987-1992. Figure 4 shows peak day ratio and peak day

consumption, on a per account basis, going back to 1968. There was an expansion in their service area around 1974-75 that caused the peak day consumption to decline. The peak day ratio started to decline in the early 1970s and continued through the first drought. The decline during the drought occurred probably because the District rationed water during the summer of 1977. During this period industrial water use in the District was also dropping. The peak day ratio never recovered after the first drought to prior levels and has stayed relatively steady for the last twenty years. The peak day consumption, per account, did rebound after the first drought, dropping again during the second

drought, and rebounding again, but to a lower level than it had been before the second drought.

East Bay Municipal Utility District's has a long history of conservation and instituted very aggressive conservation programs since the mid-1980s, coincident with the second drought. Customers have been offered both indoor and outdoor programs that include water audits and financial incentives (Bennett, 1999). The fact that this rebound in peak day use after the second drought has not reached the pre-drought levels is probably due mostly to the District's conservation program that has kept water use efficiency in the forefront of customer's minds.

FIGURE 4 – EAST BAY MUNICIPAL UTILITY DISTRICT HISTORICAL PEAK CONSUMPTION AND PEAK DAY RATIO



Comparison of Case Studies

Comparison of the long-term trends in peak day ratio and peak day consumption for the three utilities lends support to several general observations. However, one should be cautious in drawing conclusions about the effectiveness of the conservation programs in these cities because there are many factors at work and the research we have done to-date does not allow us to isolate one effect from another. Nevertheless there are some obvious conclusions that can be drawn.

1. The peak day ratio has declined over time, but much of this occurred before the onset of major long-term water conservation programs.
2. One reason the peak day ratio has been relatively stable over the last 10 to 20 years is that these utilities have had conservation programs directed at both indoor and outdoor demands. Although the emphasis may have been on peak day demand reduction, both types of programs affect average day demands. Hence both the numerator and denominator in the peak day ratio equation have been impacted.
3. The peak day consumption has also declined over time, and appears to have been more influenced by water shortages more than the peak day ratio.
4. The rebound in peak day consumption after water shortages has not been complete, there have been permanent reductions relative to pre-shortage levels.
5. At least part of the long-term decline in peak day consumption, and the incomplete rebound after water shortages, can be attributed to aggressive water conservation programs.
6. Peak day consumption, normalized to be on a per person or per account basis, is probably a better measure for tracking the effects of peak-reduction water conservation program effectiveness, than the peak day ratio.
7. A better understanding of the impacts of conservation programs on peak day consumption is needed, so that trends such as found in these three case studies can be fully understood and explained.

RECOMMENDATIONS

With few exceptions, planners are not publishing results of research and documentation on the benefits of conservation programs. We need more concrete examples of actual benefits to cite in our conservation plans. Until this is available, we must continue to use estimates of benefits in the benefit-cost analysis used to

evaluate potential programs. Estimating the benefits attributed to water use reduction requires technical expertise and an understanding of the conservation impacts on local water and wastewater systems.

One way we can develop more data on actual capital deferrals is to perform the estimation of the benefits “in reverse”. When a capital project is built, planners should analyze the timing and ask: “When would this project have been built in the absence of a conservation program?” Projects built today might have been needed five years ago had not a conservation program been in place. Projects are often in the planning stage for many years and old supply master plans are a good source of original thinking on facility timing. We need this type of information to help validate our promise of expected conservation benefits.

The following specific recommendations are made to utility planners:

1. O&M cost savings alone will not justify much of a conservation program, cost savings from capital deferrals are needed as well. To maximize capital deferrals, water conservation planners should focus on conservation measures that reduce peak day demand.
2. Capital facilities planned 10 to 20 years from now are good targets for benefits from capital deferrals; shorter time horizons leave little time to develop water savings; longer time horizons have less impact in terms of the present worth of the deferrals.
3. Planners should document and publish statistics on actual deferrals. Capital facilities built today or recently, in cities that have had a conservation program, offer a good source of data on the impacts of conservation programs on facility timing.
4. Wastewater treatment plant deferrals due to water conservation are rarely possible. Conservation planners should focus on deferring wastewater disposal projects, and especially land disposal or other disposal schemes with costs that depend on the volume of treated wastewater being disposed.
5. When water supply is obtained from, or treated wastewater disposed to, environmentally sensitive areas, efforts on quantifying environmental benefits are especially warranted.

When capital facilities can be deferred, true integration of water supply and water conservation occurs. In other words, water conservation is treated as a source of new water supply. This is an important goal in effective water resource planning.

REFERENCES

- American Water Works Association (AWWA). Water Industry Data Base. Denver, Colorado. 1991.
- Bennett, Richard. EBMUD, personal Communication, March 15, 1999.
- Bishop, D, and J. Weber. "Impact of Demand Reduction on Water Utilities", American Water Works Association Research Foundation, Denver, CO, 1996.
- Dietemann, A., "A Peek at the Peak", Paper presented at AWWA Water Conservation Division Mid-Winter Meeting, Austin, Texas, February 9, 1998.
- Lutes, Teresa. City of Austin, personal communication, March 11, 1999.
- Macy, P., and W. Maddaus. "Cost-Benefit Analysis of Conservation Programs", Jour. AWWA, 81:3:43 (Mar. 1989).
- Maddaus, W., G. Gleason, and J. Darmody. "Integrating Conservation into Water Supply Planning," Jour. AWWA, 88:11:57 (Nov 1996).
- Planning and Management Consultants, Ltd., AWWA, "Evaluating Urban Water Conservation Programs: A Procedures Manual," 1993.
- Watson, Montgomery. "City of Austin Water Conservation Plan," 1993.
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