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MUNICIPAL WATER USE AND WATER RATES DRIVEN BY SEVERE DROUGHT: A CASE STUDY[1]

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ABSTRACT: This paper synthesizes and interprets data pertaining to the evolution of average water revenue, water use, and the average cost of water supply in the City of Santa Barbara, California, from 1986 to 1996, a period which included one of the most devastating droughts in California this century. The 1987-1992 drought hit the study area particularly hard. The City of Santa Barbara was dependent exclusively on local sources for its water supply. That made it vulnerable as the regional climate is prone to extreme variability and recurrent droughts. The 1986-1992 drought provided a rare opportunity to assess the sensitivity of municipal water use to pricing, conservation, and other water management measures under extreme drought conditions. Our analysis indicates that the average cost of water rose more than three-fold in real terms from 1986 to 1996, while the gap between the average cost of supply and the average revenue per unit of water (= 100 cubic feet) rose in real terms from $0.14 in 1986 to $ 0.75 in 1996. The rise of $3.08 in the average cost of supplying one unit of water between 1986 and 1996 measures the cost of hedging drought risk in the study area. Water use dropped 46 percent at the height of the drought relative to pre-drought water use, and remains at 61 percent of the pre-drought level. The data derived from the 1987-1992 California drought are unique and valuable insofar as shedding light on drought/water demand adaptive interactions. The experience garnered on dmught management during that unique period points to the possibilities available for future water management in the Arid West where dwindling water supplies and burgeoning populations are facts that we must deal with.

(KEY TERMS: water management; water conservation; water demand; economics; water policy; decision making; water law; water development.)

INTRODUCTION

During the water years 1986-1987 through 1991-1992 (with water years elapsing from October 1 of any calendar year through September 30 of the following calendar year), California endured one of the most severe droughts of the 20th century (Loaiciga *et al.*, 1993; Loaiciga and Leipnik, 1996). Of the ten hydrologic regions in which the State of California is divided (see page 50 of California Department of Water Resources, 1994), the Central Coast hydrologic region suffered particularly strong hydrologic, economic, and environmental impacts from the 1986-1992 drought. The Central Coast region roughly includes the counties of Monterey, San Benito, Santa Barbara, Santa Cruz, and San Luis Obispo. Within the Central Coast region of California, annual streamflow was below average for the duration of the 1986-1992 drought. For water years 1986-1987 to 1991-1992 annual streamflow in the Central Coast was equal to 19 percent, 20 percent, 19 percent, 9 percent, 43 percent, and 53 percent of the annual average, respectively (California Department of Water Resources, 1993). To compound matters, the Central Coast region received only a nominal annual delivery of 32,000 acre feet (32,000 AF = 39.456 x 10^6 m^3) from the California State Water Project, a vast system for inter-regional water transfers. None of this water, however, was allocated to Santa Barbara County, which includes the study area of this work. The County of Santa Barbara, thus, relied completely on local surface water and ground water supplies in a region subject to substantial climatic variability (Loaiciga et al., 1993; Turner, 1996).

This article analyzes the evolution of water use, average water revenue, and average water cost of water supply in the City of Santa Barbara, California, from 1986 to 1996; i.e., from pre-drought to post-drought conditions. The drought of 1986-1992 presented hydrologists and water planners with a truly

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exceptional opportunity to observe the evolution of municipal water use, average water revenue, and average water cost in a mid-sized community (approximately 94,000 inhabitants at present) solely dependent on local water sources (Lawrence et al., 1994). The remainder of this article presents an account and interpretation of related hydrologic/economic events associated with this remarkable natural event.

AN OVERVIEW OF CONDITIONS IN THE STUDY AREA

Climate, Surface Waters, *and* Ground Waters

The focus of this study is the water system of the City of Santa Barbara, California, throughout the 1986-1992 drought. The City of Santa Barbara is located within Santa Barbara County, at the southern end of the Central Coast hydrologic region of California (see Figure 1). It is a coastal community of some 90,000 plus residents which boasts a service-oriented economy whose pillars are tourism, higher education, high-technology industry, retail trade, finance, and real estate. In 1986, prior to the 1986-1992 drought, the City of Santa Barbara derived its municipal water supplies from its local aquifer and from the Santa Ynez river, whose yield it shares with several neighboring agencies of Santa Barbara County, and for which the focal point was, and is, the Cachuma reservoir. The Cachuma reservoir, with a current storage capacity of about 190,000 AF (234.27 x 106 m3) dams the Santa Ynez river, capturing median annual runoff of about 23,000 AF (28.359 x 10^6 m^3) generated over a drainage area of approximately 400 sq. mi. (1,035 km^2).

The climate of the Santa Barbara region shows high inter-annual variability (Loaiciga et *al.*, 1992; Turner, 1996). Its sources of precipitation are almost exclusively westerly cold fronts moving land wards from the Pacific Ocean and southwesterly, subtropical, flow originating also in the Pacific Ocean. Occasionally, polar fronts descending from arctic regions generate rainfall in the area as well. Figure 2 shows a time series of annual rainfall recorded in the City of Santa Barbara since 1868. Median annual rainfall is 15.77 in. (40.05 cm) and inter-annual variability in rainfall is high. For example, the historical record shows an all-time low rainfall of slightly below 5 in. (12.7 cm) in 1879, and a maximum of about 45 in. (114.3 cm) in 1940, for a range of nearly 40 in. (101.6 cm) in annual rainfall. Streamflow fluctuations in the Santa Ynez River are also extreme, with a runoff regime characterized by negligible flow during the summer months (July-September) and concentrated floods in winter and spring (typically from February to April) following heavy rainfall. Turner (1996) has documented the persistence of dry streamflow conditions in the Santa Ynez river, emphasizing the challenges of water supply under such variable, and drought prone, climatic conditions.

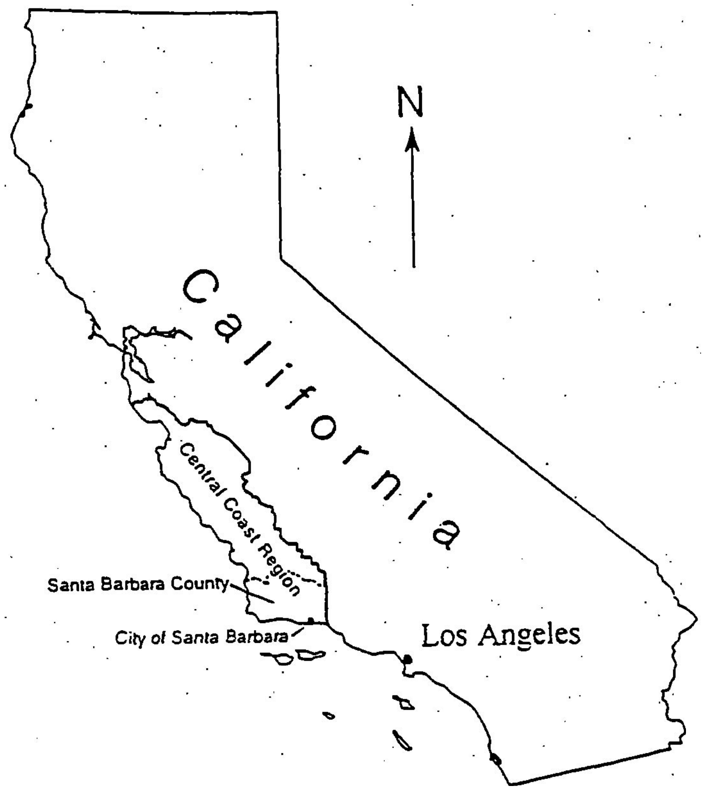


Figure 1. Generalized Location Map of the Study Area.

Ground water, the second source of water to the City of Santa Barbara, has been extensively studied by Martin (1984), Martin and Berenbrock (1986), and McFadden et al. (1991). The estimated total ground storage capacity of the City's aquifers is estimated at about 108,800 AF (134.2 x 10^6 m^3), of which only about 5,550 AF (6.843 x 10^6 m^3) is extractable in any one year (EIP Associates, 1994). The estimated perennial safe yield is on the order of 1,400 AFY (1.726 x 10^6 m^3/yr) according to the City's Long-Term Water Supply Program. Ground water recharge to the productive, confined, aquifer is highly dependent on percolating rainfall through heavily fractured bedrock aquifers (McFadden et al., 1991).

Prior to the drought, the City of Santa Barbara was diverting a total of about 14,000 AF/year (17.262 x 10^6 m^3 /year) from the Santa Ynez river. Between.

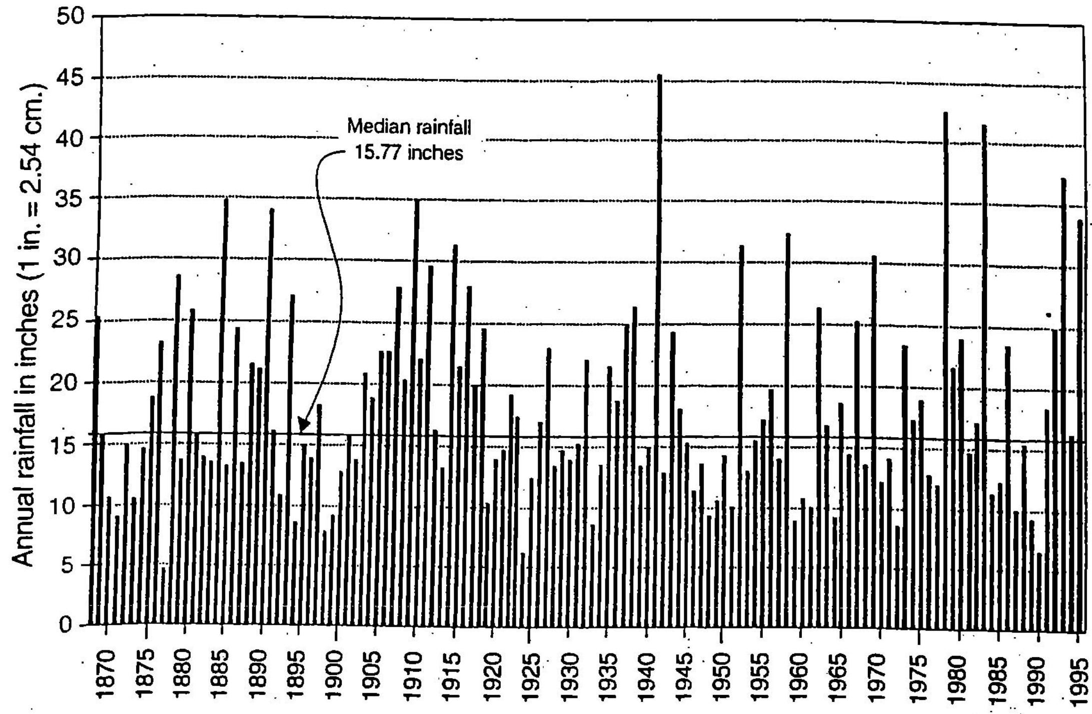


Figure 2. Annual Rainfall Totals for the City of Santa Barbara, Water Years 1868 to 1995. (Source: Public Work Department of the City of Santa Barbara) (1 in. = 2.54 cm)

1,000 and 2,000 AF (1.233 x 10^6 and 2.466 x 10^6 m3) of ground water was added annually to surface water supplies to meet pre-drought water use on the order of 15,000 to 16,000 AF/year (18.495 x 10^6 m3 to 19.728 x 10^6 m^3/year).

Water Use in the Pre-Drought Era

The City of Santa Barbara records annual water use in terms of total potable production and total metered sales. Total potable production refers to the total amount of water produced and sent into the distribution system for delivery to all customers. Total potable production includes water which cannot be accounted for due to leaks in the delivery system, water meter error, fire fighting, customer theft, etc. Total metered sales, on the other hand, refers to water that is actually delivered and recorded on the customer's water meter. The metered sales ratio is the total metered sales divided by the total potable production. From the pre-drought through the post-drought era in Santa Barbara, this ratio has ranged from 91 percent to 96 percent (Source: Public Works Department of the City of Santa Barbara).

Prior to the 1986-1992 drought, water use had been relatively stable for several years. Table 1 shows the annual total potable production by water year going back to 1969. From water year 1968-1969 to water year. 1982-1983, total production, varied between 12,636 AFY (15.580 x 10^6 m^3/year) in water year 1977-1978 and 15,141 AFY (18.669 x 10^6 m^3/year) in water year 1971-972, with a median total production of 13,874 AFY (17.106 x 10^6 m^3/year). By the pre-drought water year 1985-1986, total potable production had been close to or above 16,000 AFY (19.728 x 10^6 m^3/year) for three consecutive years. Water year 1986-1987 was the first one in the recent drought and people's attitude towards water consumption had not yet been influenced by protracted dry weather.. With a population of 80,695 people and a total potable production of 16,641 AF (20.518 x 10^6 m^3), per capita water consumption in Santa Barbara in year. 1986-1987 reached a level of 184 gallons per day (697 liter per day). The 1986-1987 per capita daily consumption in Santa Barbara was slightly above the national average of 158 gallons per day (600liters per day) (Tchobanoglous and Schroeder, 1987).

Water Supply Implications of the 1986-1992 Drought

In order to better understand the implications of the 1986-1992 drought from the perspective of water supply in Santa Barbara, one must consider primarily the amount of streamflow generated in the Santa

Ynez River and the evolution of water storage in Cachuma reservoir during that period. Figure 3 shows unimpaired streamflow (i.e., measured streamflow augmented to account for upstream diversions) of the Santa Ynez River at Cachuma reservoir for water years 1918 through 1992. Runs of below-median annual streamflow are frequent in the Santa Ynez River (Figure 3). Drought conditions, as defined by persistent below-median annual streamflow (see Loaiciga and Leipnik, 1996), interspersed by an occasional above-median streamflow year, existed between 1919 and 1925, 1928 and 1934, 1947 and 1951, and from water year 1986-87 to water year 1991-92. The Bradbury Dam at Cachuma reservoir was completed in 1959 with a total storage capacity of 200,000 AF (246.6 x 10^6 m^3), and developed an annual target draft of about 45,000 AF (55.485 x 10^6 m^3) (Turner, 1996). The purpose of developing Cachuma reservoir was to smooth the extreme streamflow variability and associated uncertainties in water supply in the service region of the Santa Ynez river. Thus the 1986-1992 drought was the first to be experienced in Santa Barbara during full utilization of Cachuma reservoir yield.

Figure 4 shows the time series of monthly unimpaired flows at Cachuma reservoir from October of 1984 through September of 1992. The winter of 1986

TABLE 1. Total Potable Water Production for the City of Santa Barbara, Water Years 1968-69 lo 1994-95 (Source: Public Works Department of the City of Santa Barbara).

Water Year	Total Potable Water Production (AF*)	Water Year	Total Potable Water Production (AF)
1968-69	12,683	1982-83	14,216
1969-70	14,565	1983-84	16,621
1970-71	14,232	1984-85	16,169
1971-72	15,141	1985-86	15,958
1972-73	13,577	1986-87	16,641
1973-74	13,796	1987-88	16.228
1974-75	14,189	1988-89	15.287
1975-76	14,916	1989-90	10.5 18
1976-77	12,791	1990-91	9,149
1977-78	12,636	1991-92	10,184
1978-79	13,525	1992-93	10,587
1979-80	13,952	1993-94	11,337
1980-81	14,663	1994-95	11,724
1981-82	13,529		

*1 AF = 1,233 m^3.

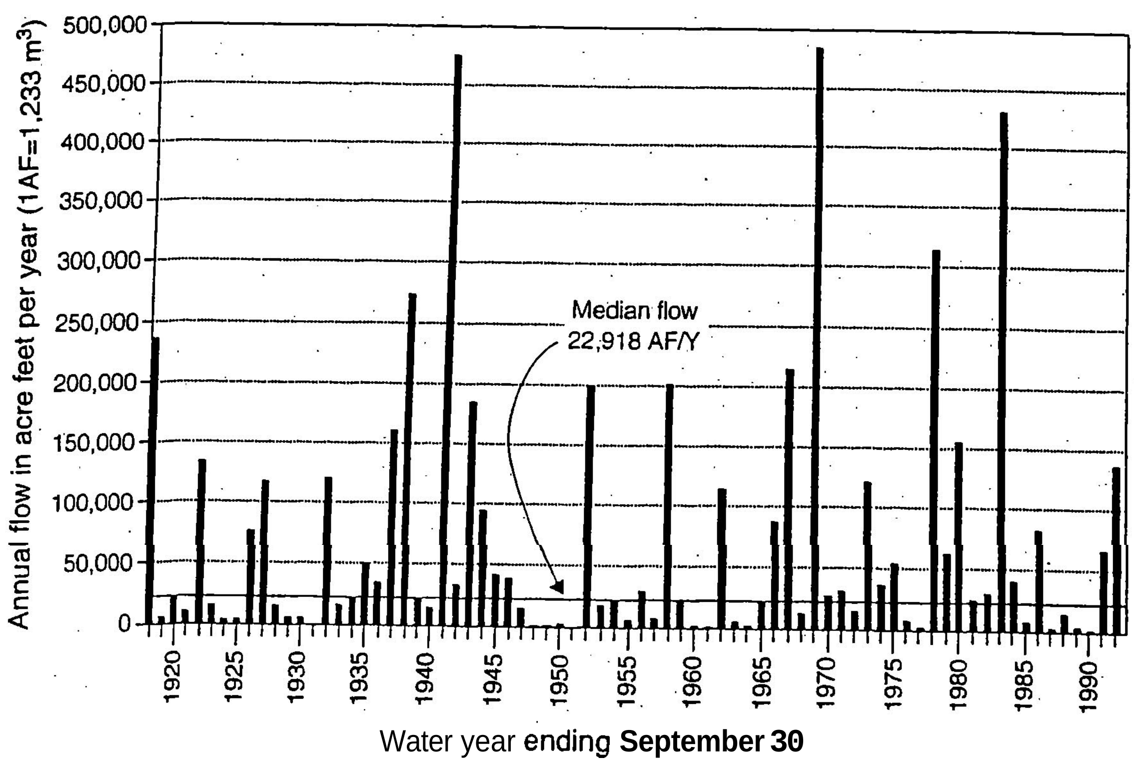


Figure 3. Unimpaired Flows of the Santa Ynez River at Cachuma Reservoir, Water Years 1918-1992. (Source: Santa Barbara County Flood Control and Water Conservation District) (1 AF = 1,233 m^3)

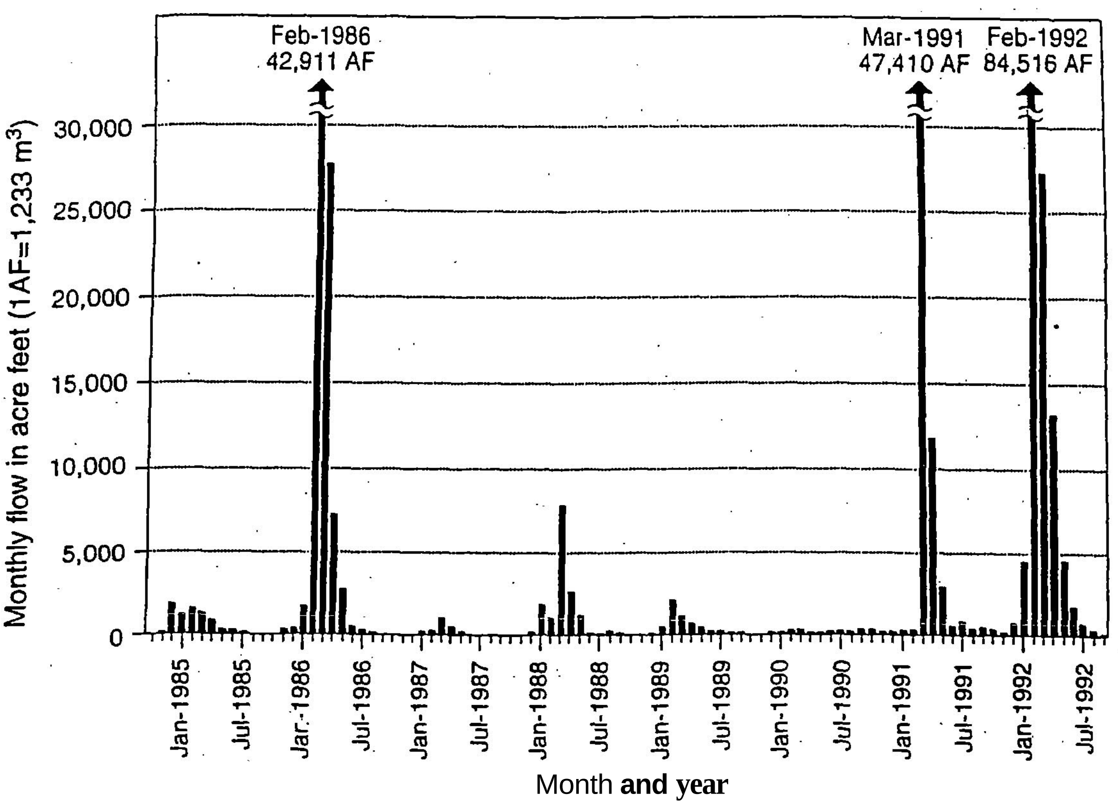


Figure 4. Unimpaired Flows of the Santa Ynez River at Cachuma Reservoir. Water Years 1985-1992. (Source: Santa Barbara County Flood and Water Conservation District) (1 AF = 1,233 m^3)

was indeed a very wet one (Figure 4). Thereafter, and except for a wet period in February/March of 1991, significant streamflow did not occur until the winter of 1992. The water supply impact of the observed streamflow regime shown in Figure 4 is put in clear perspective by analyzing Cachuma reservoir storage in the period 1986-1992 (Figure 5). The wet winter of 1986 filled the reservoir to capacity; Beginning in March of 1986, Cachuma storage started to decline until March of 1991, when the trend was temporarily reversed by heavy storms. By March of 1991, Cachuma reservoir storage had declined to about 25,000 AF (30.825 x 10^6 m^3). This storage was sufficient'to meet water demand for a few more months only in the service area of the Cachuma Project member units.

With reservoir storage dangerously low and local aquifers nearly depleted, the end to water supplies in Santa Barbara became a real possibility in the very short term. The communal anxiety and hardship inflicted by dwindling water supplies were well publicized by the media locally and nationally. Unorthodox schemes to pre-empt total depletion of available, water supplies were put forward in 1990 and early 1991, including a proposal to tanker water from the Canadian west coast in large ships. From this social upheaval and brainstorming emerged funding for the construction of an ocean desalination plant, in 1991, with a capital cost of $35 million and a prpduction capacity of 7,500 AF/year (9.248 x 10^6 m^3/year). In addition, Santa Barbara residents voted to approve' the permanent importation of State Water Project water at a price tag of close to $500 million, to be shared with several neighboring water agencies in Santa Barbara County and'San Luis Obispo County as well. Up to 1986, Santa Barbara County residents had declined to import northern California water. This reflected the hegemony of antigrowth political forces which equated water' importation with runaway population growth. By 1992, the drought had turned the tables around and water importation had become a reality.

As events unfolded, the Santa Ynez River received some large flows from heavy. rain in March of 1991. Cachuma storage rebounded.to about 65,000 AF (80.145 x 10^6 m^3) in April of 1991 (Figure 5). The rains of March 1991 provided a much needed, though partial, drought relief, and they were considered by many Santa Barbarans as a benevolent act of God – a miracle, in the words of many locals. In spite of the temporary respitebrought about by the March 1991 rains, Figure 5 shows that the Cachuma storage began to decline again until March of 1992, when

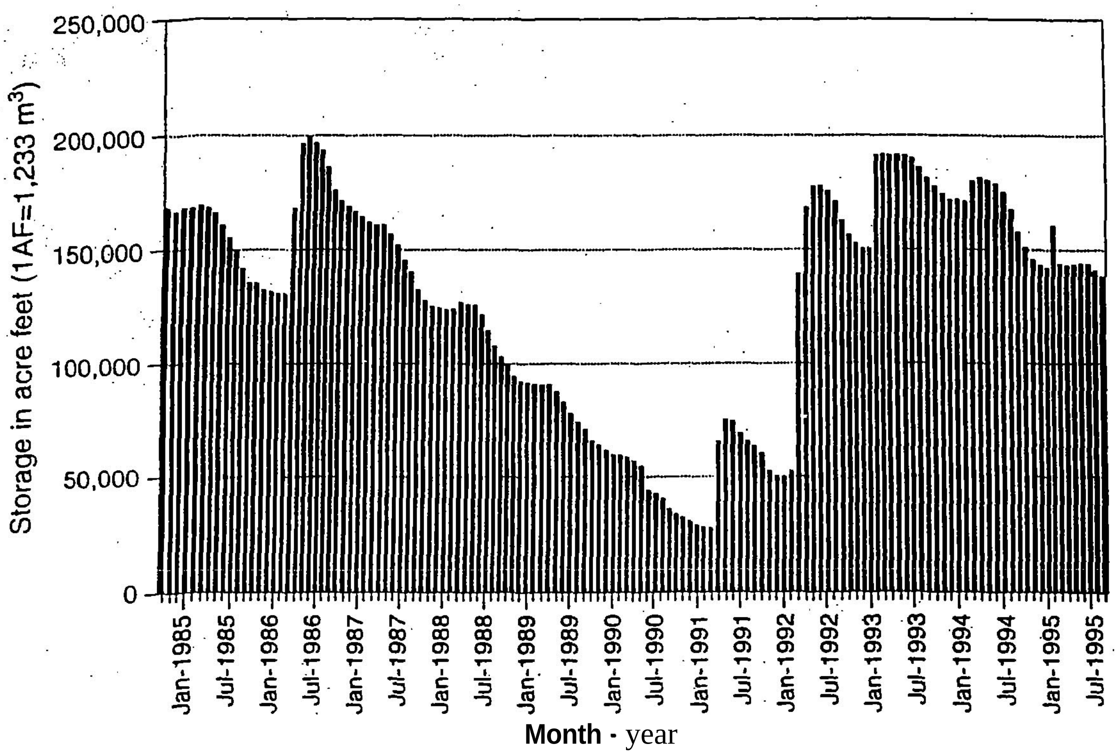


Figure 5. Monthly Distribution of Storage Capacity for Cachuma Reservoir, Water Years 1984-1995. (Source: Cachuma Operations and Maintenance Board) (1 AF = 1,233 m^3)

eavy springtime rains that year filled the reservoir ɔ near capacity. The reservoir spilled for the first .me since 1986 in February; 1993, now at a reduced apacity of 190,000 AF (234.27×10^6 m^3), some 10,000 .F (12.33×10^6 m^3) below the original 200,000 AF apacity. (The 10,000 AF loss in reservoir storage was aused by large sediment fluxes since the inception of he project.)

EVOLUTION OF WATER USE, REVENUE, AND COST

Vater Pricing by Water Purveyors

The Water Code of the State of California precribes .that municipalities, such as Santa Barbara, nay price water so as to cover all operating costs fixed and variable) associated with supplying water o customers (State of California Legislature, 1977). 'his is what we refer to herein as "average-cost" pricng; i.e., when the average cost per unit of water quals the unit average revenue. In actuality, it is ommon for cities and public water purveyors in Caliornia to price water at less than its average cost. The hortfall in revenue from water sales needed to cover all water-supply related operating costs is made up through a variety of financial instruments available to public water purveyors. These include, among others, allocation of interest generated from water-related investment accounts to the water budget, revenue raised from "utility" taxes, or the allocation of moneys directly from the "general" fund (which accrues mainly from property and other city taxes, plus returns on investment portfolios) to pay for the cost of water supply.

Water-rate structures vary widely among municipalities in California. In some cases, water supply and garbage collection charges are lumped into a single, and fixed, monthly or bimonthly bill to households. In most cases, such as in the City of Santa Barbara, water customers pay, on a monthly or bimonthly basis, a fixed "service" or "meter" charge plus a variable charge which depends on the amount of metered water use during the billing period. The schemes used to assess the variable charge varies widely across California, but they generally fall in three categories.' The first is the so-called uniform rate, whereby the price per unit of water is constant regardless of the amount of water used during the billing period. [The most common water unit used to measure deliveries to municipal water customers in California is the HCF or 100 cubic feet (= 2.83 m^3).] The second category takes the form of an increasing block-rate structure, in which the unit price of water is assigned increasingly larger values as water use rises. This is the rate structure which is currently in place in the City of Santa Barbara, and will be discussed in greater detail below. The third category consists of a declining block-rate structure, whereby the unit price of water is assigned increasingly smaller values as water use rises. To complicate matters, it is common to have different water-rate structures within the same municipality for different customers categories. Thus, for example, the City of Santa Barbara has different water-rate structures for residential, commercial, agricultural, and governmental (e.g., schools, public parks, etc.) customers. The differences in water rates among customer categories are explained by differentials in the cost of service to each customer category (Kennedy/Jenks Consultants, Inc., 1995), but they are also a reflection of the internal political process.

It is worth pointing out that about 20 percent of residential metered water connections in California are now operated by private water purveyors (Floyd Wicks, CEO, Southern California Water Company, Personal Communication, 1996), a growing industry. The Public Utilities Commission (PUC), a State regulating agency, oversees and authorizes' water rates implemented by private purveyors. Their water rates are set so as to cover all operating cost and yield a reasonable rate of return on investment. As many local governments streamline and downsize their operations, the private watersupply market has gained ground in California. In this respect, the total privatization of urban water supply in England is exemplary. Completed in the early 1990s, the transition to private hands has been accomplished remarkably well there. Under privatization, households in England may choose to pay water bills determined from either the assessed market value of the property or the metered volume of water consumption. Customers are allowed to pay the water bills in a lump sum or in installments, but due within each fiscal year (Philip J. Aldous, Thames Water Utilities, U.K., Personal Communication, 1996).

Causes of Water Use Decline During the Drought

The first three years of drought (water years, 1986-1987, 1987-1988, and 1988-1989) engendered uneasiness in the study area but, at the same'time, were generally perceived by Santa Barbara residents as yet another temporary oddity of the climate, soon to be reversed. The high water production for water years 1986-1987, 1987-1988, and 1988-1989 (see Table 1) lend support to this assertion. Water prices rose moderately (see Figure 7 for data on water rates during the drought) and water use was likewise moderately depressed. During the 1986-1988 period, it seems reasonable to hypothesize that water use changes were mainly driven by water price increases. The decline in water use during water year 1988-1989 may be partly attributed to a water conservation program instituted by the City of Santa Barbara in 1988. Unfortunately, there are no empirical data to allow us ascertain the relative contributions of water price changes and conservation to water use decline during the drought.

As the drought entered its fourth year (1989-1990) customers began to modify their water consumption behavior noticeably, most likely the result of a well-publicized "drought watch" campaign to promote water conservation. Customers cut down on their personal, recreational, and landscaping water use. In addition, they improved their water systems by repairing leaks and by retrofitting irrigation and household water delivery systems with water efficient devices. Some 22,000 low-flow toilets have been installed by Santa Barbara households since 1988 as part of the City's water conservation program. The City issues customers an $80 rebate for each standard toilet which is replaced by a low-flow toilet. This rebate program has lowered residential water use by about 314 AFY (387,100 m^3/yr).

By March of 1990, water scarcity became critically acute. Customers, in particular residential'customers, were using water sparingly. Water prices had become punitive, specially for water used over and above that needed to satisfy basic needs (see discussion about' Figure 7 below). A drought emergency was declared by the City of Santa Barbara in February of 1990, under which government agencies were directed to cut their anticipated water use by 20 percent. In addition, landscape irrigation, car washing, and filling of pools were prohibited within City limits. More "drought officers" were hired to patrol the City and enforce the drought emergency measures. They were authorized to issue $250 citations to violators for each offense. Water flow restrictors were installed in the water connections of two-time offenders. It is reasonable to hypothesize that by the end of 1990 water demand had become more sensitive to additional price increases relative to the pattern of 1986-1987 to 1988-1989. As drought conditions subsided in 1991 and vanished in 1992, customers began modifying their water use behavior again but this time in an opposite direction. Water prices remained relatively high and constant compared to pre-drough't years, but water use increased as customers moved to regain some of the amenities brought about by a freer use of water.

The variations in water use observed during water years 1986-1987 to 1991-1992 in Santa Barbara were aused by a complex and dynamic interaction among ater rates, changing patterns of customer behavior owards water use induced by the conservation campaign, and water supply system management during he study period. The data to be presented next quanify the magnitudes of water use changes caused by he drought.

he Single-Family Residential Sector

Prior to considering average water revenue and otal water use variations in the study area, it is nstructive to consider the evolution of water rates in he single-family residential sector of customers. The ingle-family sector represents the largest block of ustomers both in terms of its share of total water use about 44 percent of total metered water sales) and of evenues accruing from metered water sales. Table 2 hows total and single-family metered water sales lata for the .City of Santa Barbara by water year which during the drought went from May 1 of any given year to April 30 of the following year). Water consumption figures are expressed in units of hundred cubic feet (HCF = 2.83 m^3). It is seen in Table 2 that water consumption dropped from 6,676,890 HCF (18,895,598 m^3) in water year 19864987 to 3,602,345 HCF (10,194,636 m^3) in water year 1990-1991, an astonishing decline of 46 percent in total metered water consumption. By the end of water year 1994-1995, three years after the end of the drought, total water metered sales were only 68 percent of the 1986-1987 level. Similar 'percentage drops in single-family residential water consumption can be derived from Table 2. Table 2 also indicates that single-family residential water consumption, expressed as a percentage of total metered.water sales, has remained fairly stable from pre-drought to post-drought years, hovering at about 45 percent.

Figure 6 shows monthly water consumption distribution curves for the single-family residential sector in the.City of Santa Barbara calculated for five selected time. intervals. The greatest discrepancy between water consumption distribution curves corresponds to those,calculated in 1986 and 1991. In pre-drought 1986, 50 percent of the single-family residential customers used no more than 9 HCF/ month (25.5 m^3/month). In contrast, in 1991, 50 percent of the single-family residential customers used no more than 6.3 HCF/month (17.8 m^3/month). Monthly water consumption in 1991 was spread out over a much narrower range (1 HCF to 30 HCF, 2.83 m^3 to 85 m3) than that of 1986 (1 HCF to 250 HCF, 2.83 m^3 to 708 m3) in the single-family residential sector (Figure 6). Compared to the 1986 consumption. distribution curve, the distribution curves calculated during the 'drought period became steeper and shifted to the left of the 1986 curve. This implied a reduction. of water use at the high end (say, over 10 HCF = 28.3 m^3) and concentrated water use in the 1 HCF to 10 HCF (2.83 m^3 to 28.3 m^3) range during the drought years.

The complex evolution of water rates in Santa Barbara between 1986 and 1995 is best illustrated by Figure 7. There we show, for the single-family residential sector, (1) the monthly service (or meter) charge (which does not depend on the level of a customer's monthly water use), (2) the unit price for water as a function of a customer's level of monthly use, and (3) the month and year in which a given rate was instituted and the month and year of its

TABLE 2. Total Metered and Single-Family Residential Water Consumption, Data for the City of Santa Barbara. Water Years 1986-1987 to 1994-1995. Water consumption is reported in hundred cubic feet (HCF) units, where 1 HCF = 2.83 m^3. (Source: Adapted from data by the Public Works Department of the City of Santa Barbara)

Water Year	Total Metered. Water Sales (HCF)	Population	Single Family Metered Sales (HCF)	Single Family as Percentage of Total Metered Sales
1986-87	6,676,890	80,695	2,804,293	42.0
1987-88	6,526,009	81,995	2,936,704	45.0
1988-89	6,056,649	83,295	2,950,972	48.7
1989-90	4,239,116	84,672	1,734,392	40.9
1990-91	3,602,345	87,014	1,511,630	42.0
1991-92	4,145,724	90,006	1,768,448	42.7
1992-93	4,350,638	91,711	1,899,778	43.7
1993-93	4,625,222	92,756	2,073,034	44.8
1994-95	4,559,419	93,957	2,014,420	44.2

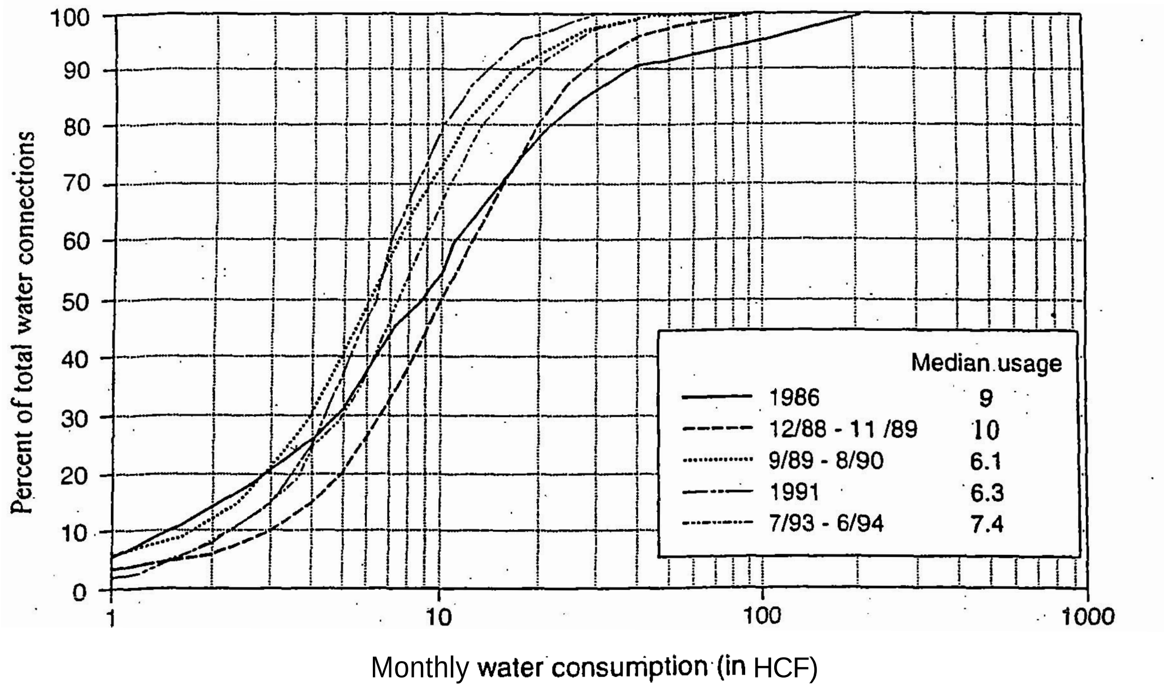
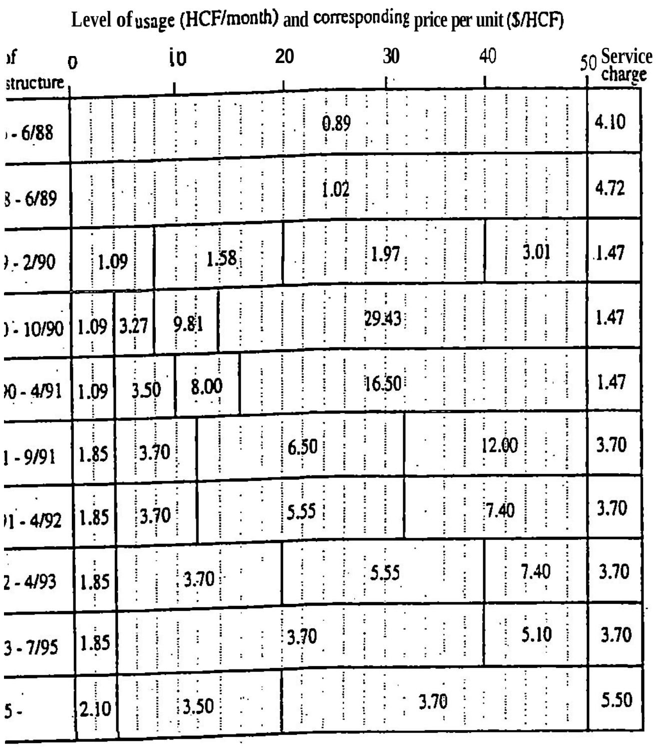


Figure 6. Single-Family Residential Consumption Distribution Curves for the City of Santa Barbara, 1986-1994. (Source: Public Works Department of the City of Santa Barbara, and Kennedy/Jenks Consultants, 1995) (1 HCF = 100 cubic feet = 2.83 m^3)

abolition. In the period June 1986 to June 1988, Santa Barbara had a uniform rate structure. Single-family residential customers paid a unit price of $0.89/HCF regardless of the level of monthly water use, plus a monthly service charge of $4.10. Thus, someone using, say, 20 HCF/month (56.6 m^3/month) received a monthly water bill of 20 x 0.89 + 4.10 = $21.9. Beginning in July 1989, Santa Barbara' switched to an increasing block rate structure, whereby the first 8 HCF (22.6 m^3, i.e., the first %lock") of water in any month were priced at $1.09/HCF; between 8 and 20 HCF (22.6 and 56.6 m^3, the second block) water was priced at $1.58/HCF; in the third block, between 20 and 40 HCF (56.6 and 113.2 m^3), the price of water was $1.97/HCF; the last block, over 40 HCF (113.2 m^3), was priced at $3.01/HCF. The monthly service charge was set at $1.47 in July 1989 (Figure 7). In March 1990, the block rate structure became much steeper.' According to Figure 7, in the period March 1990 to October 1990 a single-family residential customer using 20 HCF/month (56.6 m^3/month) was paying 1.09 x 4 + 3.27 x 4 + 9.81 x 6 + 29-43 x 6 + 1.47 = $253.35/month. The later is almost 12 times the monthly bill that would have applied in 1986 for the same amount of water used by a single-family residential customer. As of this writing, the monthly bill to a single-family residential customer using 20 HCF/month (56.6 m^3/month) is readily calculated from the water rate established in August 1995, which is written in the last row of Figure 7, as being equal to $69.90.

Variations in Total Metered Water Sales and Average Water Revenue

Table 3 presents water use and revenue date for fiscal years 1986-1987 to 1995-1996 in Santa Barbara (the fiscal year begins July 1 of any calendar year and ends on June 30 of the following calendar year). Columns 2 and 3 present the actual total revenue from water sales and metered water sales, respectively. Column 4 shows the average water revenue calculated 'by dividing the total revenue from water sales by the metered water sales. Column 5 shows the adjusted total revenue, which is the actual revenue of Column 2 expressed in 1994-1995 dollars after the effect of inflation (at 2.5 percent during the study period) is removed. Column 6 contains the adjusted metered sales, which are equal to the metered water sales of Column 3 normalized to a common 1994-1995 population consumption level,(the 1994-1995 population was 93,957). The adjusted metered sales compare water use over time once the effect of population growth has been removed. Column 7 in Table 3 lists the adjusted average water revenue, which is obtained by dividing the total 'revenue in Column 5 by metered sales in column 6. The adjusted average ter revenue provides a yardstick for comparison ndardized to 1994-1995 conditions. The adjusted rage water revenue went from $1.18/HCF in 1986-37 to $3.65/HCF in 1995-1996, a threefold increase m the pre-drought era to the post-drought era ble 3).



igure 7. Water Rate Structures for Single-Family Residential Units Which Were in Effect Before, During, and After the Drought in the City of Santa Barbara. (Source: Public Works Department of the City of Santa Barbara) (1 HCF = 100 cubic feet = 2.83 m^3)

Figure 8 is a plot of the adjusted average water venues and their corresponding adjusted total tered sales during the period 1986-1996. It was pothesized in a previous section that in the period 36-1987 to 1987-1988 changes in water use were gely driven by changes in water prices. Thus, the tion of the curve in Figure 8 comprised between rs 1986-1987 and 1987-1988 may be viewed as an proximate demand curve for water. On the other nd, the points in Figure 8 corresponding to years 38-1989, 1989-1990, and 1990-1991 imply large nges in water use caused by the combined effect of reased water rates and water conservation mea-es. Thus, the 1988-1989/1990-1991 data points re arrived at from the 1987-1988 point in the graph igure 8 by large shifts of the demand curve, rather than by water use-average revenue displacements along a demand curve.

The mathematical equation of the straight line between 1986-1987 and 1987-1988 in Figure 8 was determined to be:

$$P = 3.56 - 0.000000306Q \quad (1986\text{-}1987/1987\text{-}1988) \quad (1)$$

in which the (adjusted average) revenue P is given in $/HCF and the (adjusted total metered) water demand (or sales) Q is given in HCF. Under the assumption that Equation (1) is an approximation to the pre-drought demand curve for water, the pre-drought sensitivity, S_D, of water demand to average revenue changes can be approximated from it. S_D is defined as minus the percentage change in water demand divided by the percentage change in the average revenue of water. Notice that we are not equating sensitivity, as defined herein, with the classical definition of price elasticity under monopolistic water supply (i.e., there is a single water supplier in the water industry for the area under study). Price elasticity presupposes demand variations driven by price changes alone, while all other demand-influencing factors are held constant. With these important caveats in mind, and based on Equation (1), the pre-drought water sensitivity to average revenue fluctuations is given by:

$$S_D = 3{,}265{,}035\frac{P}{Q} \quad (1986\text{-}1987/1987\text{-}1988) \quad (2)$$

in which the average revenue P is in $/HCF, and the total water demand (or sales) Q is in HCF. Using the adjusted average revenue and adjusted total metered sales figures in Table 3, the reader can readily verify that the sensitivity of water demand fluctuated between 0.50 (in 1986-87, for P = $ 1.18/HCF and Q = 7,770,298 HCF) and 0.52 (in 1987-88, with P = $1.22/HCF and Q = 7,629,609 HCF).

The section of the curve in Figure 8 comprised between 1987-1988 and 1989-1990 represents a transitional stage, wherein water use changes are not due to changes in water price alone. Instead, those changes in water use arose from the confluence of price changes, changes in consumers' behavior towards water use, water system modifications, and tighter management of the water system. Between water years 1989-1990 and 1990-1991 there was another sharp shift in water use spearheaded by higher water rates and heightened water conservation measures that culminated with the state of emergency declared in February of 1990. Notice that the curve in Figure 8 became steeper in the period 1989-1990 to 1990-1991. Once customers had adopted most available water saving measures prior to 1989-1990,

TABLE 3. Water Sales and Average Revenue Data for the City of Santa Barbara, Fiscal Years 1986-1987 to 1996-1996. (Source: Public Works Department of the City of Santa Barbara) (1 HCF = 100 ft^3 = 2.83 m3)

Fiscal Yea. (1)	Total Revenue ($) (2)	Total Metered Sales (HCF) (3)	Average Price[a] ($/HCF) (4)	Adjusted Total Revenue[b] ($) (5)	Adjusted Total Metered Sales[c] (HCF) (6)	Adjusted Average Priced ($/HCF) (7)
1986-87	7,514,899	6,646,257	1.13	9,156,175	7,770,298	1.18
1987-88	7,849,727	6,631,474	1.18	9,330,859	7,629,609	1.22
1988-89	8,516,467	6,284,645	1.36	9,876,490	7,117,291	1.38
1989-90	9,854,983	4,943,011	1.99	11,150,009	5,540,215	2.01
1990-91	12,328,522	3,566,380	3.46	13,608,382	3,896,726	3.49
1991-92	13,883,662	3,806,591	3.65	14,951,185	4,009,619	3.73
1992-93	15,701,997	4,376,425	3.59	16,496,911	4,505,255	3.66
1993-94	15,771,912	4,470,600	3.53	16,166,210	4,516,454	3.58
1994-95	17,200,000	4,600,635	3.74	17,200,000	4,600,635	3.74
1995-96	17,800,00	▪ 5,227,200	3.41	17,365,854	4,761,393	3.65

[a]Obtained by dividing total revenues in Column 2 by total metered sales in Column 3.
[b]Obtained by adjusting total revenue in Column 2 to 1994-1995 dollars using a 2.5 percent annual inflation rate.
[c]Obtained by adjusting total metered sales in Column 3 to a common 1994-1995 population consumption level.
[d]Obtained by dividing the adjusted total revenue in Column 5 by the adjusted total metered sales in Column 6.

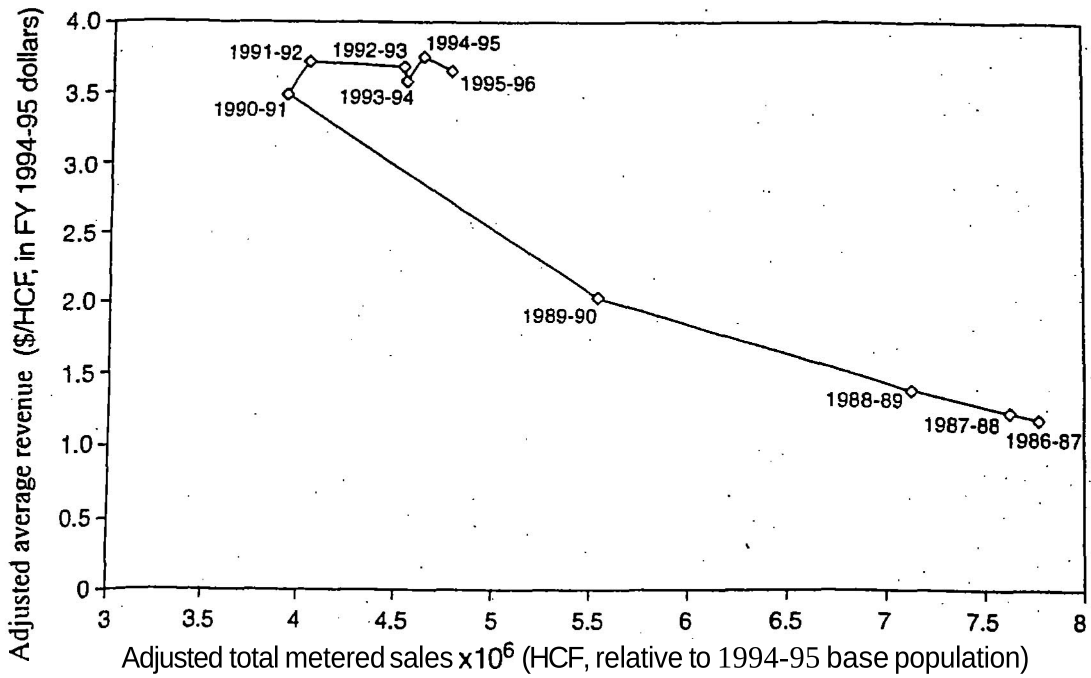


Figure 8. Average Revenue and Total Metered Sales for Water in the City of Santa Barbara, Fiscal Years 1986-1987 to 1995-1996. (Source: Public Works Department of the City of Santa Barbara) (1 HCF = 100 cubic feet = 2.83 m^3)

it became more difficult to achieve incremental water savings. Thus, larger price increases were required between 1989-1991 to achieve the same level of marginal water savings that were observed prior to 1989.

Figure 8 shows an interesting evolution of the water use-average revenue relationship in the post 1990-1991 era. Water rates have remained relatively stable till present, while the metered water sales have steadily, albeit slowly, increased. As of this writing, djusted metered sales in 1995-1996 (4,761,393 HCF = 13.475 x 10^6 m3) are 61 percent of what they used to be in 1986-1987 (7,770,298 HCF = 21.990 x 10^6 m^3).

Variations in the Cost of Water Supply

Table 4 presents data on the cost of water supply from fiscal year 1986-1987 to fiscal year 1995-1996 in Santa Barbara. Columns 2 and 3 of Table 4 contain the total operating cost (fixed plus variable costs) and the total metered water sales respectively for years 1986-1987 to 1995-1996. Column 4 shows the average cost of water supply, obtained by dividing the total operating cost of each fiscal year by its total metered sales. Column 5 shows the total operating cost expressed for each year in terms of 1994-1995 dollars. Column 6 contains the total metered water sales normalized to the 1994-1995 population consumption level. Lastly, Column 7 shows the adjusted average cost of supplying water, which is calculated by dividing the adjusted total operating cost by the adjusted total metered water sales..

The average cost of water supply went from $1.32/HCF in 1986-1987 to $4.40/HCF in 1995-1996, implying more than a three-fold increase in the cost of water supply from pre-drought years to post-drought years (Table 4). The rise in the average cost of supply from 1986-1987 to 1995-1996 may be attributed largely to investments made during that period to mitigate future drought impacts. Those investments consisted of an ocean desalination plant and the importation of State Water Project water (see above for their total costs). The difference in average cost of water supply between 1995-1996 and 1986-1987 is $4.40 - 1.32 = $3.08/HCF. This difference can be considered as a premium paid for hedging drought risk by water supply augmentation, which involves long-term capital investments (desalination plant and State Water transfers to Santa Barbara), as well as capital replacement investments (reduction of water system leakage by pipe replacement). The Santa Barbara data have provided a rare opportunity to estimate of the average cost of hedging drought risk.

Figure 9 contains plots of the average revenue and average cost of water as a function of time for the period 1986-1987 to 1995-1996. It is seen how in 1986-1987 the average cost of water supply was almost matched by the average price of water, 'except for a small deficit of $1.32 - $1.18 = $0.14/HCF (from data in Tables 3 and 4). The pricing scheme in 1986-1987 was, therefore, very close to average-cost pricing. The gap between the average cost of water supply and the average price of water widened through the drought years, reaching a peak of $1.03/HCF in 1993, and at present, in 1996, is equal to (from data in Tables 3 and 4) a deficit of $4.40 - $3.65 = $0.75/HCF. The City of Santa Barbara supplements metered water sales with revenues that accrue from a utility user's tax and from income generated from interest earned on an investment "water" account. Even.

TABLE 4. Total Operating Cost and Average Cost Data for the City of Santa Barbara, Fiscal Years 1986-1987 to 1995-1996. (Source: Public Works Department of the City of Santa Barbara) (1HCF = 100 ft^3 = 2.83 m^3)

Fiscal Year (1)	Total Operating Cost ($) (2)	Total Metered Sales (HCF) (3)	Average Cost[a] ($/HCF) (4)	Adjusted Total Operating Cost[b] ($) (5)	Adjusted Total Metered Sales[c] (HCF) (6)	Adjusted Average Cost[d] ($/HCF) (7)
1986-87	8,400,000	6,646,257	1.26	10,234,584	7,770,298	1.32
1987-88	8,600,000	6,631,474	1.30	10,222,697	7,629,609	1.34
1988-89	13,719,748	6,284,645	2.18	15,910,701	7,117,291	2.24
1989-90	13,279,446	4,943,011	2.69	15,024,474	5,540,215	2.71
1990-91	13,361,575	3,566,380	3.75	14,748,679	3,896,726	3.78
1991-92	16,385,575	3,806,591	4.30	17,645,409	4,009,619	4.40
1992-93	20,106,575	4,376,425	4.59	21,124,470	4,505,255	4.69
1993-94	19,767,753	4,470,600	4.42	20,261,361	4,516,454	4.49
1994-95	19,212,361	4,600,635	4.18	19,212,361	4,600,635	4.18
1995-96	21,488,889	5,227,000	4.11	20,964,770	4,761,393	4.40

[a]Obtained by dividing total operating cost in Column 2 by total metered sales in Column 3.
[b]Obtained by adjusting total operating cost in Column 2 to 1994-1995 dollars using an annual inflation rate of 2.5 percent.
[c]Obtained by adjusting total metered sales in Column 3 to the 1994-1995 population consumption level.
[d]Obtained by dividing the adjusted total operating cost in Column 5 by the adjusted total metered sales in Column 6.

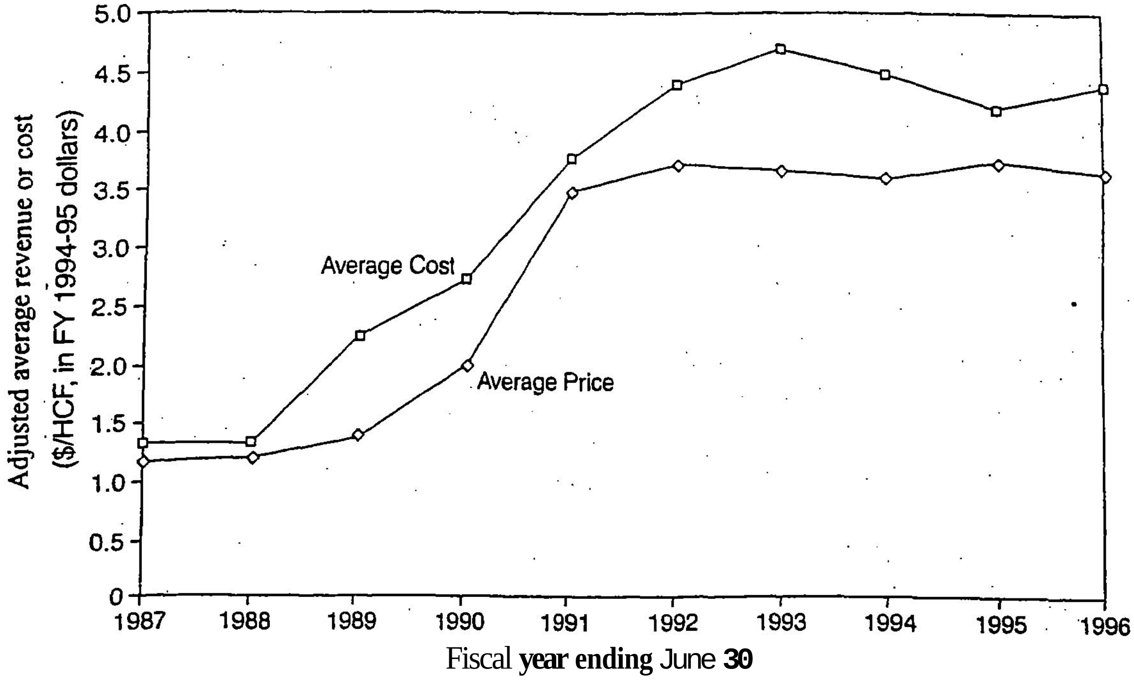


Figure 9. Average Revenue and Average Cost for Water in the City of Santa Barbara, Fiscal Years 1986-1987 to 1995-1996. (Source: Public Works Department of the City of Santa Barbara) (1 HCF = 100 cubic feet ≈ 2.83 m^3)

though these two additional sources of revenue offset any shortfalls in total revenue neededto cover total costs, one must realize that the greater the gap between metered sales and operating costs, the greater the percentage of water-investment revenues that needs to be dedicated to cover operating costs. This has potential detrimental, effects, such as reducing the ability to develop a healthy investment fund to help cover catastrophic losses in the water system that may arise from wild-fires or earthquakes, both common in.the study area.

CONCLUSIONS

This paper has presented a synthesis and interpretation of data pertinent to the evolution of water use, water rates, average water revenue, and average cost of water supply from 1986 to 1996, a period which included one of the most devastating droughts in California. The 1986-1992 drought hit the City of Santa Barbara, California, the case study area, particularly hard. The City of Santa Barbara was dependent exclusively on local sources for its water supply. That made it quite vulnerable as the regional climate is prone to extreme variability and recurrent droughts. The 1986-1992 drought provided a rare and valuable opportunity to observe the sensitivity of water demand to pricing, water conservation measures, and a public education campaign. In the early phase of the drought, water demand was depressed slightly by relatively mild water price increases. Subsequently, water price increases, water conservation, and public education commingled to reduce water use to about 50 percent of the pre-drought level. In the post-drought era, water rates have remained stable and high compared to pre-drought levels, while water use remains at about 61 percent of the pre-drought consumption.

The Santa Barbara data yielded estimates of the variation in the cost of water supply triggered by severe drought. That cost rose more than three-fold in real terms from 1986 to 1996. The rise in the average cost of water supply is attributable to large capital investments aimed at supply augmentation and conservation to mitigate future drought. In this sense, the rise of $3.08 in the cost of supplying one unit of water between 1986 and 1996 can be equated with the cost of hedging drought risk in the study area.

The gap between the average cost of supply and the average revenue generated per unit of water rose in real terms from $0.14 in 1986 to $0.75 in 1996, in spite of the fact that the average price of water more than tripled from 1986 to 1996. The widened gap between water sales and operating costs in the post-drought era hints to a greater reliance of investment-fund generated income. This may hinder the ability to develop a healthy future water fund which could serve as valuable insurance against other likely natural hazards.

The main conclusion learned from this study is that it is possible to depress water use significantly through a combination of water-rate manipulation, consumer behavior adaptation to drought, and water conservation measures supported by strict enforcement. Although it was not possible to separate how much of the water use decline is attributable to either water conservation or water pricing, it was learned how useful these tools are in diminishing water use while new water supplies are developed to weather out protracted drought. The data derived from the 1987-1992 California drought are unique and valuable insofar as shedding light on drought/water demand adaptive interactions. The experience garnered on drought management during that unique period points to the possibilities available for future water management in the Arid West, where dwindling water supplies and burgeoning populations are facts that we must deal with.

ACKNOWLEDGMENTS

The data gathered to conduct this study were largely and kindly provided by the Staff of the Public Works Department of the City of Santa Barbara to the authors during the period 1992-1996, during which the senior author served as a member of the Board of Water Commissioners of the City of Santa Barbara. Mr. Bill Ferguson, a water supply analyst with the Public Works Department of the City of Santa Barbara, deserves special recognition for his contribution to the database developed in this study. Several agencies partially assisted in funding this research, including the National Science Foundation and the Kearney Foundation of Soil Science. Several anonymous reviewers contributed to the betterment of this work by providing helpful comments.

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EMERGENCY RATE SURCHARGES IN RESPONSE TO DROUGHT CONDITIONS

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Introduction

Unanticipated drought conditions can impact the financial viability of retail water providers in two significant ways: first, for water purveyors, droughts may increase the variable cost of purchased water; second, usage restrictions and/or increased conservation due to other incentives may decrease revenues and, to a lesser extent, related variable costs. The effect of either or both of these impacts is likely to be an increase in the provider's immediate revenue needs.

There are several potential short-term rate responses to these unanticipated revenue needs, including the following four types of emergency measures.

- *Enforcing Percentage Reductions in Usage* - This method imposes the highest surcharges on those customers who do not meet reduced usage targets based upon their own historical volumes. This method may effectively penalize those customers who have historically conserved water.,

- *Fixed Rate Surcharge* - This method imposes a surcharge on the fixed rate. Based on the philosophy that all customers should share equally the cost of drought conditions, this method provides the most financial security to the water provider because fixed charge revenues are not generally affected by conservation.

- *Volume-Based Surcharge* - This method imposes a surcharge on the volume rate. While enhancing conservation incentives, this method may increase revenue volatility.

- *Inverted Block Surcharge* - This method imposes increasing surcharges on higher block levels of usage. While dramatically increasing conservation incentives, this method may also increase revenue volatility.

Unfortunately, it is not possible to predict with certainty the effect of these surcharges on revenue stability. Therefore, it is also wise to consider adjusting the level of operating reserves to mitigate the impact of a potentially volatile revenue stream. In general, reserve levels should allow for the fluctuation of revenues without additional rate impacts.

Assumptions

For this analysis, it is assumed that the utility in question faces drought conditions, and a commensurate decrease in anticipated revenues due to emergency usage restrictions and/or public education. In addition, the variable cost of purchased water has increased due to surcharges by the wholesale provider. It is assumed that the revenue loss and the increase in purchased water cost significantly outweigh the reduction in other variable expenses. Thus, the utility must consider a short-term; emergency, rate response.

Criteria

What form shall this rate response take? As noted above, there are several alternative surcharge designs which may be considered. Which one is chosen will depend largely upon the concerns of the utility's decision making body. These concerns may include some or all of the following issues.

- o Equity. Is the charge equitable? Does it adequately recover costs from those users who "should" pay? Is there a linkage between the ultimate charge and the cost to provide water to that customer?

- o *Political Acceptability.* Is the structure of the charge a politically acceptable response to drought conditions?

- o *Revenue Stability.* *Is* the anticipated **revenue** dependable or **will** surcharge revenues be volatile and potentially unpredictable?

- o Incentive *Power.* Does the rate improve or create a conservation incentive?

- o *Ease of* Implementation / *Administration.* Is the charge difficult to implement and administer?

- o *Simplicity.* Is the charge, and the philosophy behind it, understandable?

- o *Applicability.* Does *the* short-term charge fit the current rate structure?

These potential concerns are the criteria by which each optional short-term rate response is evaluated.

Analysis

In the following subsections, each of four types of short-term rate responses to drought conditions are defined and evaluated, under the assumed conditions and criteria described previously. It is important to note that, in many cases, a combination of these approaches may be the preferred strategy.

Enforcing Percentage Reductions in Usage. Under this method, varying surcharges are imposed upon utility customers according to their performance against conservation targets. The *customers' previous usage patterns provide a baseline for evaluating their performance against the target(s).* Those customers who do not meet reduced usage targets, based upon their own historical volumes, receive the highest surcharges.,

Conservation targets typically take the form of percentage decreases. A given utility may require a 15% decrease in consumption across the board, establishing staggered surcharges which escalate for those customers who do

not meet the target--as applied to their average usage for the same month over the last three years.

Comments. The policy and charge are relatively simple to implement, administer and understand. This type of surcharge can be made to fit almost any existing rate structure, as long as historical usage data is available. If the surcharge is tied to the volume charge, revenues may show some volatility due to the unpredictable behavior of the customer base in response to conservation measures. If the surcharge is tied, in full or in part, to the fixed charge, revenue stability may be enhanced. This policy may be perceived to be inequitable by those customers who have historically practiced water conservation. In such an instance, a customer who had not historically practiced conservation would receive a benefit, relative to the conserver, from this structure. As such, the charge may not be politically acceptable.

Fixed Rate Surcharge. Under this method, a surcharge is imposed on utility customers through the fixed rate portion of the water charge. The surcharge may be applied as a uniform charge per customer, or may vary by meter size. The uniform charge is based on the philosophy that all customers should share equally the cost of drought conditions; the varying charge is based on the philosophy that customers should pay for drought conditions according to their system capacity.

Comments. This charge is relatively simple to implement, administer, and understand. It is compatible with almost any existing rate structure. Revenue stability is excellent. This method provides the most financial security to the water provider because fired charge revenues are not generally affected by conservation. It does not, however, provide a conservation incentive. This approach may be politically acceptable because all customers share the 'cost" of drought conditions proportionately. However, it, in itself, is not the most equitable charge because it does not relate the ultimate customer charge to that customer's usage. A customer practicing conservation would not benefit from any additional incentives due to the surcharge.

volume-Based Surcharge. Under this method, a flat surcharge is imposed on the volume, or usage, rate. The volume-based surcharge is based on the philosophy that customers should pay a share of drought related "costs" based on their actual usage.

Comments. This charge is relatively easy to implement, administer, and understand. It is compatible with almost any existing rate structure. The volume-based surcharge enhances or provides a moderate conservation incentive, simply by charging more for more water used. This method may increase revenue volatility for the same reason, however; it is difficult to predict the customer response to increased usage charges. The response will. depend on seveml factors including, but not limited to, the level of existing rates, service area income levels, and publicity. This approach may be politically acceptable because customers share the burden of short-term revenue requirements based on their actual usage.

Inverted Block Surcharge. Under this method, increasing surcharges are imposed on higher block levels of usage. This structure is designed to enhance or provide a strong conservation incentive.

Comments. This charge may be difficult to implement, administer, and understand depending upon the sophistication of the existing billing system, and the type of existing rate structure. It is most compatible with an existing *inverted block structure, because it can be more easily understood, billed, and administered. The inverted block surcharge provides a strong conservation incentive. However, this approach may increase revenue volatility; it is difficult to forecast customer response to such a strong incentive. If one accepts the premise that the highest peaking customers should bear the burden of high usage during drought conditions, then this is an equitable charge. Due to the conservation incentive, this charge may be politically acceptable.*

Operating Reserves

Short–term surcharges should be supplemented by ,an increase in the minimum operating reserve balance, particularly in the case of any volume-based surcharges. These additional funds will provide a cushion against revenue volatility and; if adequate, will preclude the need for additional short–term rate increases.

Conclusion

There are several potential'short–term rate responses to unanticipated revenue needs brought about by drought conditions. These responses may include one or more of the following approaches:

- *Enforcing Percentage Reductions in Usage* - This method imposes the highest surcharges on those customers who do not meet reduced usage targets based upon their own historical volumes. This method may effectively penalize those, customers who have historically conserved water.

- *Fixed Rate Surcharge* - This method imposes a surcharge on. the fixed rate. It provides the most financial security to the water provider because fixed charge revenues are not generally affected by conservation.

- ***Volume-Based Surcharge*** - This method imposes a surcharge on the volume rate. While enhancing conservation incentives, this method may increase volatility in the revenue **stream.**

- *Inverted Block Surcharge* - This method imposes increasing., surcharges on higher block levels of usage. While dramatically increasing or providing conservation incentives, this method may also increase volatility in the revenue stream.

Since it is not possible to predict with certainty the effect of these surcharges on revenue **stability,** it is also wise to consider adjusting the level of operating reserves to mitigate the impact of a potentially volatile **revenue** stream.

WATER RATES AND REVENUE IMPACTS OF SEVERE DROUGHT RESPONSE, CITY OF SANTA BARBARA, 1990-1993

By

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Introduction

The City of Santa Barbara obtained some notoriety recently as a locality much impacted by the drought affecting all of California. Much attention was given to its water supply shortages and corresponding programs, to deal with these shortages. The City received wide publicity for its empty reservoir, banning of lawn watering, and construction of a desalination facility to add water supplies to the City. The City promoted a comprehensive water conservation program encouraging retrofit of existing homes and facilities and reduction of outside water .uses which received wide attention. As the drought emergency subsided, the City received many requests for information on its programs for supply augmentation - principally the construction of the desalination facility - and for demand reduction.

Less attentionhas been given to the revenue and budgeting side of drought response. The media asked few questions about the revenue aspects of dealing with the drought, other than in covering rate changes as they were requested by the City. Few of the inquiries from other water agencies requested information on how the revenue and budgeting operations of the water utility were affected by the drought emergency.

However, the fiscal aspects of dealing with drought may be the most interesting of the lessons to be learned from the Santa Barbara drought experience. Looking back at the Santa Barbara experience from a revenue and rate setting perspective can identify lessons to be learned or insights gained. In doing so, we will not be giving a detailed chronology of the drought; that can be gained elsewhere.[1,2] Instead, this paper will focus on certain phenomena of the fiscal impacts of the drought. It is hoped the City's experiences will be useful to others should they have a similar experience.

This paper was written by staff members who personally experienced the agency perspective of the drought emergency. Others may look at the same data and come to much different conclusions.

Water Supply History

At the start of the recent drought, the City of Santa Barbara water demand of 16,300 AFY was mostly dependent on local surface water supplies. Approximately 90% of water supplies came from reservoirs on the Santa Ynez River -- 55% from participation in a local Bureau of Reclamation Project at Lake Cachuma and 35% from wholly owned Gibraltar Reservoir. Ten percent of supplies came from local groundwater. In the mid 1980's it was recognized that these supplies were vulnerable to severe drought which could cause shortages of up to 50%. The City undertook a water planning effort which encouraged conservation and recommended new supplies. The planning efforts recommended enlargement of existing reservoirs to provide the needed water supplies. Desalination was identified as a possible alternative for the future, though was determined to be significantly more expensive than the other options. The City also initiated a reclaimed water project that replaced approximately 900 AFY in potable water demand in the late 1980's.

While this planning for additional water supplies was continuing through the 1980's, local rainfall was decreasing. By 1989 it was clear that Santa Barbara County was in a drought. When it didn't rain during the 1989-90 winter, the drought became very serious for the City of Santa Barbara and a local emergency was declared.

Water Rate and Revenue History

The Santa Barbara water utility is owned by the City of Santa Barbara and is operated as an enterprise fund. The water utility is self supporting: revenues from water sales support only water utility activities. No funding in support of the water utility comes from any other sources, including the general fund of the City. There is no property tax support for the City water utility. The major source of funding for the water utility is retail sales of water to its customers. The water rates for the City's customers are set by the City Council after review by the City's Board of Water Commissioners and the City Council Finance Committee. Other sources of revenue include hydroelectric sales, connection fees, interest income, and reimbursement from other water utilities.

City water utility customers have been metered since the 1940's. The City used a uniform metered rate until July 1989 when it changed to an inclining block rate, For single-family residential customers, the July 1989 rate change lowered the service charge and put into effect 4 blocks with gradual increases in unit prices ranging from $1.09 per unit for the first 8 units (each unit equals 100 cubic feet) to $3.01 per unit for monthly usage over 40 units. Commercial customers were given a two block system with a low rate for historical off-peak use and a higher rate for any overages. The change to the inclining block rate approach had been under consideration.

for some time and was instituted for long-term water conservation purposes. The change was unrelated to the then moderate drought situation.

In the late 1980's the annual budget for the water utility was approximately $10 million. Three major projects -- water main replacement, strengthening Gibraltar Dam, and reclaimed water – plus general salary increases started an escalation in the budget that would have happened regardless of the drought and later water supply projects.

Events of Winter 1989-90

By 1989 it was clear that the City was in a drought situation. In May 1989 shortages were declared from the Cachuma Reservoir and by November 1989 Gibraltar Reservoir, the City's other surface water supply, was empty. When no rain fell during the following rainy season, the City was facing a serious water supply situation: no supplies from Gibraltar Reservoir, 45% cutback from Cachuma Reservoir, and increased groundwater pumping from a groundwater supply already stressed and subject to seawater intrusion. Supplies for the coming year were estimated at 55% of normal demand, becoming worse if the drought continued.

The City's response was a declaration of drought emergency. The City initiated a number of demand reduction programs and policies including changing the water rates. For residential customers the incline of the block rate structure was severely steepened. Rates increased by a multiple of 3 from one block to the next. Thus, while Block 1 remained at $1.09, the Block 2 rate became $3.27, Block 3 was $9.81, and Block 4 was $29.43. Also, the blocks were shortened such that Block 1 had only 4 units and Block 4 started at 17 units. Customers that had low water use before the drought (less than five units per month) saw no change to their bills, while those with higher usage had to drastically change their water use habits or see much higher water bills. This was often difficult for customers with larger lots and substantial investment in landscaping.

An important pan of the demand reduction policies and programs was the public information effort needed to inform the City's customers about the drought emergency. The public information effort included paid advertising, direct mailing, numerous brochures and pamphlets, and extra staff to get the message out. The City budgeted an extra $150,000 to fund the public relations effort.

The City also made extensive efforts to augment supplies. The City cooperated in a regional emergency State Water Project that brought water supplies in through a temporary pipeline from Ventura County to the south of Santa Barbara County. This effort cost approximately $2 million. The City accelerated the reclaimed water project to attempt to complete Phase II of the project ahead of the planned implementation schedule. This did not necessarily add total dollars to the project, but did expend the dollars sooner than contemplated in the original project planning. The City also rehabilitated a number of older City wells that had been out of production and entered into contracts for delivery of water from wells drilled on a speculative venture.

The most newsworthy aspect of the City's emergency supply augmentation effort was the construction of the Temporary Emergency Desalination Project. After an intense selection process, this project was started in August 1990 and was delivering water to the City by March'1992. This project was constructed on a design-build-own concept by Ionics Inc. and capitalized on a five year payout, immediately adding $4 million annually to the Water Fund budget upon the initial delivery of water in March 1992.

Also occumng during the drought were continuing efforts to add long term supplies to the City's water supply mix. In June 1991 a regional vote approved a permanent connection to the State Water Project. While this vote did not have much of an immediate financial impact on the Water Fund budget, by 1996 it will add $4.5 million annually. This obligation limited the City's financing options for the other expenses being incurred.

The result of the City's demand reduction and supply augmentation efforts was a demand that went from a pre-drought average production of 16,300 AFY to 9,000 AF in water year 1990-91 and a water fund annual budget that increased from $11.1 million in FY 1989 to $15.1 million in FY 1991 with greater increases' to follow. The steeply inclining block rate kept water costs for low water, users at pre-drought levels while expensive.short and long-term supplies were added to ensure that the drought emergency would not return. It is important to recognize that the changes to the water rates during the drought brought fundamental changes to the way people looked at their water bill. For those using larger amounts of water, say 20 or more units per month, the increases in the cost of water was'not just a few dollars per month, but was a doubling or more of their water bill. For those using less than five units per month, the change in cost was minimal.

Coming Out of the Drought

In March 1991, after a dry December through February that made it appear that drought would last forever, Santa Barbara County experienced one of the wettest months of March on record. The rainfall coming after such a prolonged dry spell did not end the drought for the City and other local water purveyors but certainly took away some of its seriousness.. The. ensuing runoff filled Gibraltar Reservoir and added substantial supplies to Cachuma Reservoir (but did not end entitlement shortages from that.. source). The following winter of 1991-92 saw even more rainfall and resulting runoff into surface water reservoirs. Combined with the completion of the desalination facility, this enabled the City to declare the end of the drought condition in April 1.992 and with that, the end of all demand related restrictions.

During this period the City was continually adjusting its water rates to account for the newly increased expenses and the changing supply situation. The City changed its water rates six times between October 1990 and July 1993. The October 1990 rate change indexed the inclining block rate structure to actual expenses by setting the Block 2 rate at the average cost of water. The Block 1 rate became half the cost of water and the Block 3 and 4 penalty rates became multiples of Block 2. This resulted in a wst increase for lower users of water and a cost decrease for those in the higher usage blocks. While the drop in cost for higher users still left them with very high water bills -- much higher than pre-drought levels – and the increase for users in the Block 1 was not large, many customers had the perception that large users got a break at the expense of those conserving water during a drought.

Later rate changes either increased the size of blocks or decreased Block 3 and 4 penalty rates. It was clear during this period that the penalty rates were depressing demand at a time when abundant water supplies were available. However, it was difficult to reduce penalty rates much in advance of the recovery of demand because the Water Fund depended on the revenue. If water use did not return to near projected levels, revenue shortfalls would occur.

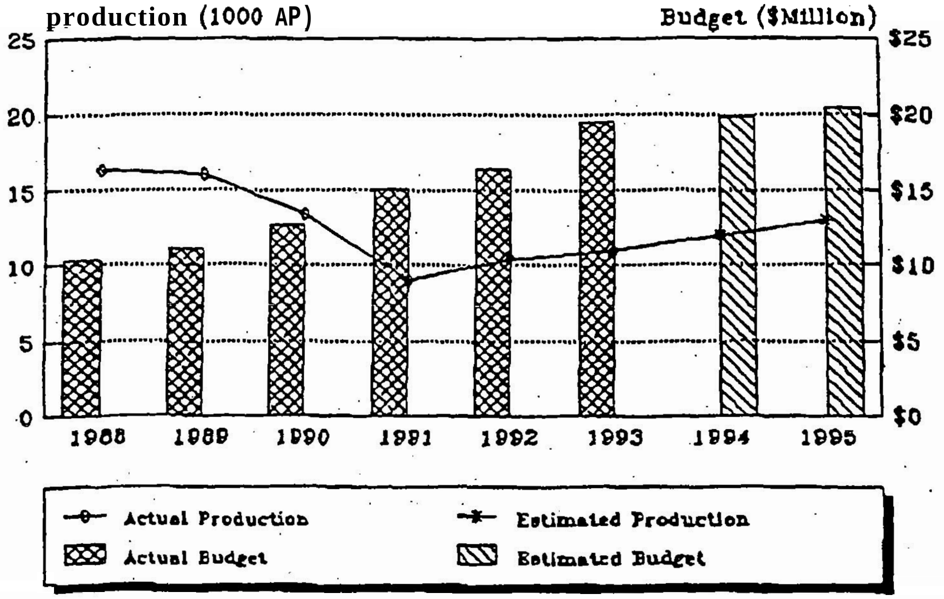
The slow ratcheting down of rates and increase of blocks has continued. The rates as of July 1, 1993 for single-family residential customers are $1.85 for the first 4 units, $3.70 for the next 36 units and $5.10 for use over that amount, plus a monthly service charge of $3.70. The incline of these rates is similar to the City's initial block rate structure, but the price of water has significantly increased.

As the drought situation became less intense and finally ended, the pressure to reduce demand eased, and then disappeared. City customers, without expressed encouragement from the City, kept demand below official targets which rose as City water supplies improved. The combination of water usage practices learned during the drought emergency and the higher price of water has kept demand well below pre-drought levels.

The end of the drought brought a challenge in forecasting what future demand would be. City customers had been through an emergency with severe restrictions placed on their use of water; they were given a wealth of information on how to reduce water use; they were encouraged through rebates and giveaways to retrofit existing facilities; and they faced much higher water prices. In other droughts, for example the 1977-78 drought, the rebound to prior use levels was fairly quick. However, those rebounds were usually helped by residential and commercial growth and were not accompanied by a significant change in the price of water. This time it is suspected the return will be fairly slow and the City has projected demand increases of 1,000 AF per year, with demand leveling off at 15,000 AFY in 1996. Figure 1. "Water Production and Budget" shows the City of Santa Barbara annual production for water years 1987-88 through 1992-93 and estimates for the following two years.

So far these projections have held, but it is unclear to what level demand will return. We do not expect demand to return soon to the pre-drought level of 16,300 AFY but it is unknown where demand will level off. While the future demand is unknown, future budgets are fairly well known. Figure 1 also shows actual budgets and budget projections for fiscal years

Figure 1. Water Production and Budget
City of Santa Barbara, 1988-95



1988 through 1995 increasing to $20.4 million by 1995. The steady increase is happening because of current expenses from drought related projects, particularly the desalination facility, and from anticipated expenses for construction of the connection to the State Water Project. These expenses ensure continued high water rates into the future and, if demand does not increase along with the budget, perhaps additional late increases. It is expected that if demand does nor return to needed levels, any rate increase recommendation would focus on increasing the service charge.

Water Rate Lessons from the Drought

The above chronology has related the major financial activities of the drought. It is appropriate now to review what we think are some of the water rate-related lessons we learned from the drought emergency:

1. Water rates can be effective in reducing demand. The use of the steeply inclining block rate gave a clear signal that the drought emergency was serious. The water rates were a key component of the demand reduction measures used by the City of Santa Barbara.

2. It is more difficult to use rates to encourage demand by reducing penalty rates once the drought is over. There may be revenue impacts if demand targets are not met. A reserve fund created going into the drought can give a utility more flexibility in this regard. A separate problem is the public's perception that the water utility is giving high water users a break at the expense of those who conserved during the drought. The City experienced difficulty getting the correct message across.

3. A big change in water rates is as easy as a small adjustment if the customers understand that it is necessary. The large increases in water rates for the City of Santa Barbara were relatively easy because the customers of the water utility understood the reasons behind the changes. The severity of the drought was well publicized and the addition of new supplies had wide public support.

4. Forecasting demand coming out of a drought can be very difficult. Changes in water use habits or changes in the cost of water can both greatly affect customer demand after the drought is over. The return to prior use levels may take much longer than anticipated. This must be recognized when making post-drought decisions on water rates, and should be a consideration going into the drought as well.

5. Using rates to both collect revenue and influence demand sets up inherent conflicts that may be difficult to resolve internally and may be difficult to explain to customers. From a revenue perspective, the main impact is that the revenue forecast becomes more uncertain. Any rate setting that is done this way must allow for a reserve to deal with possible revenue shortfalls.

6. The strategy of rewarding low water users with no increase in their water bill may have made rationing by rates more palatable, but also may have been shortsighted in the face of increased revenue requirements for costly new supplies that were broadly supported by the whole community.

The drought is over and the City of Santa Barbara water supply is in good shape both physically and fiscally. The major uncertainty now is how soon demand will return to more normal levels. Regardless of how demand responds, the Water Fund will remain in good financial condition. City staff have learned much during this period of decreasing and then replenished water supplies. The authors hope this review of the experiences will be helpful to others and would be pleased to respond to inquiries. The authors can be reached at the City of Santa Barbara, Public Works Department, P.O. Box 1990, Santa Barbara, CA, 93102, or by calling (805) 564-5460.

Notes

[1] Ferguson, Bill and Alison Whitney, "Demand Reduction in Response to Drought: the City of Santa Barbara Experience", Conserv93 Proceedings, 1993.

[2] Whitney, Alison, "Evolution of Public Information During the Drought and Beyond," Conserv93 Proceedings, 1993.

[SMPAPER.DOC]

MEASURING OVERALL CONSERVATION PERFORMANCE

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INTRODUCTION

Many water utilities invest hundreds of thousands of dollars, millions of dollars in some cases, to implement conservation or demand management measures. The conservation measures might include a public education and awareness program, conservation rates, provision of free low flow showerheads and toilet dams, fixture rebates, indoor and outdoor audit programs, and a number of other programs aimed at specific indoor or outdoor conservation targets. In this paper the notion of conservation is expanded to also include drought measures that might be required in short-term periods of water shortage. Given the extensive cost and effort required for a concerted demand management effort, performance measurement should be an integral part of most demand management programs, and most utilities do engage in some kind of performance measurement whenever possible. This paper will describe several methods for measuring conservation performance and develop a method for measuring overall conservation performance with an actual application of the method to Single Family Residential water sales at the Contra Costa Water District in Concord, California.

CONTRA COSTA WATER DISTRICT - A CASE STUDY

Contra Costa Water District (District) is a rapidly growing water utility in the East Bay area of San Francisco, California serving treated water directly to approximately 200,000 people (57,000 connections) and raw water to another 200,000 people through five municipal customers. The District provides an excellent example of the application of the method of overall conservation performance because of the variety of prohibition, restriction, price, and conservation efforts that were implemented during the acute drought shortage of 1991.

In January of 1991 the District's water allocation from The Bureau of Reclamation's Central Valley Project was reduced such that retail water sales had to be cut back from 126,000 acre feet to a net 91,400 acre feet, a reduction of 27.5 percent. The District reacted with a mandatory rationing program beginning April 1, 1991 designed to achieve an overall reduction of 26 percent for treated water customers by means of water allocations by customer groups. Single Family Residential customers were allocated 280 gpd for a family of four, with allowances for larger family sizes. The average water use at that time was 388 gpd. An excess usage charge of 2 to 10 times the existing water volume rate of $1.45 per hundred cubic feet was imposed for each 10 percent of water use in excess of the base allocation. The existing water volume rate (the cost of incremental water use) had just been increased the month before from $1.00 to $1.45 (44.6 percent) in keeping with budget requirements and expected water sales. However, fixed charges in the rate structure were not increased; so the total water bill increased only 24 percent. (Another volume rate increase of 16 percent was implemented in March of 1992 to adjust for new budget and volume amounts.)

Concurrent with the allocation program. the District implemented prohibitions that included the use of water for fountains, washing sidewalks. outdoor watering that results in runoff. and landscaping for new connections. Additionally, guidelines and restrictions were widely distributed on using a shutoff nozzle on hoses, serving water in restaurants only upon request, avoiding filling swimming pools, and so forth. Over 20,000 conservation kits were made available free to customers.

This intense program was lifted after one complete billing cycle for all customers and replaced with a 15 percent voluntary rationing program. Emphasis continued on indoor and outdoor voluntary conservation programs.

METHODS OF MEASURING CONSERVATION PERFORMANCE

There are at least three types of performance measurement approaches that can be used.

The first type of performance measurement applies engineering estimates to project water saving. For example, a free showerhead program might be expected to reduce flow by **4.3** gallons per capita per day (gpcd) and save 21.5 gallons per day for a household of five people.[1] Similarly, a residential lawn audit program might be expected to reduce irrigation water use by ten percent or 25 gallons per day for an average CCWD residence. This method of quantification of potential water savings is quite accurate if the initial conditions and the number of participants are known through the period of evaluation. If no other influences on water sales were present, water consumption during the period of analysis would be expected to decrease by the savings per dwelling unit times the number of participants months in the period. This method of analysis is quite acceptable for specific programs, but cannot be projected to bottom line water saving in any given period without an analysis of weather impacts and the impact of other programs that usually accompany any protracted effort to conserve water. This type of analysis is required, in any case, to develop benefit-cost justifications for programs.

- A second method of measuring conservation performance is to apply statistical analysis to specific measures. The essence of this approach is to compare a survey subset with a comparable control group and measure the differences. This may be done for a single conservation measure such as commercial lawn imgation, or for numerous indoor and outdoor measures such as would be identified and implemented in a residential audit. In the commercial lawn imgation example the program might involve an audit of current practices for 100 large account who agree to change practices and another 100 who will continue with existing practices. The test is to compare actual consumption for an extended period such as one summer for the change group with the control group. In this case the effects of weather and other common influences are neutralized. The statistical measure is simply to express the change group as a ratio to the control group where both groups have been put on a common basis such as gallons per day per acre of imgable land.

The residential audit program is more complex since different conditions will exist in each household both in the change group and the control group. The preferred method of analysis is an adaptation of regression analysis that derives a coefficient for each conservation measure (variable) based on total water use of each household with the specific measures that are employed. The coefficients derived in this method provide specific rates of savings for each measure without the need for applying engineering estimates to each measure.

- The third method, which will be developed in detail, is to analyze water consumption by customer group for a period before engaging in new conservation or drought measures and then project that pre-conservation pattern through the conservation period to be compared with actual consumption. This method of analysis can be undertaken for any level of disaggregation from individual accounts to the entire service area of a utility. Typically, the analysis is performed for as many customer classes (or class-area combinations) as are known to have different consumption patterns or are being singled out for specific conservation measures. The analytical methods used can be kept quite simple, using only a seasonal index and a weighted moving average of consumption. Refinements can be added by using regression analysis to identify the seasonal pattern, normalize consumption for weather, and measure the impact of water prices, household income, lot size, family size, and other variables that either describe or explain water consumption patterns. The analysis is usually done in gallons per day per account, household, employee, unit of output, or any other unit variable that will neutralize growth over time. When the per-unit performance analysis is completed, the results must, of course, be applied to the projected base units to derive total water savings. This method does not attempt to attribute water conservation performance to specific conservation measures. Moreover, it assumes stability in customer mix within each customer class/area which is reasonable for single family residential accounts but is often not appropriate for large commercial, industrial, institutional and municipal account classes. In these latter cases, it is important to disaggregate each class into homogeneous subsets.

MEASURING OVERALL CONSERVATION PERFORMANCE

There are four steps in the process of measuring overall conservation performance. The statistical methods that are recommended are described briefly in the following the steps.

- The first step is to remove the effects of abnormal weather from historical consumption (weather normalize consumption).[2] This is done by adjusting actual consumption with the opposite sign of the weather coefficients derived from regression analysis. If weather departures from normal affect consumption less than 2 or 3 percent in the peak months of any year, this step can be omitted since the next step will even out small variations. For CCWD the impact of abnormally hot weather in 1987 and 1989 increased consumption 34.3 gpd (6.4%) and 25.7 gpd (5.4 %), respectively. which had a significant effect in calculating the pre-drought rate-of-travel.

- Develop a weighted moving average and a seasonal index of the weather normalized consumption from the previous step. The author recommends using a 13 month moving average of consumption, weighted 1, 2. 2, 2, 2, 2, 2, 2, 2, 2. 2, 2, 1, that is centered on the middle or seventh month.[2, 3] Since the 13 months exceed the period of a year. the seasonal or monthly pattern is removed in the moving average, and the trend or cyclical patterns of the time series are provided both numerically and visually for evaluating the direction of the consumption time series.

  The seasonal index is developed by expressing each month's consumption as a ratio to the WMA, and the ratios for all the Januarys, and all the Februarys . . . . are averaged to derive a typical index (or ratio to average) for each month. The sum of all the monthly ratios must be apportioned to equal 12.0.

- The third step is to project the pre-conservation rate-of-travel through the conservation period. Some judgment has to be used in some cases; for the CCWD example, the WMA at the beginning of 1990 was used (375 gpd) as the pre-conservation rate-of-travel because this 13 month average period typified stable consumption prior to the downturn. The monthly forecasts of normalized consumption are derived by multiplying the pre-drought WMA by the seasonal index for each month.

- The last step is to take the difference, in gpd and percentage, between the projected normalized consumption and actual consumption. In the absence of any other major influence, this difference is presumed to be the overall effect of the conservation measures put in place. These results that are derived on a gpd per account basis can then be multiplied by the number of accounts to get total savings in millions of gallons per day or acre feet.

SUMMARY OF DROUGHT PROGRAM PERFORMANCE AT CCWD

The result of the drought program effort at CCWD was a 32.1 percent reduction in actual water consumption in 1991 compared to projected consumption for 1991 at the pre-1991 rate-of-travel. (TABLE 1) Consumption was down 42.1 percent during the summer months (May through October), and outdoor consumption, measured as the difference between total summer consumption and winter or indoor consumption) was down 73.3

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percent. The crisis was declared over in 1992 and the reduction in water use dwindled to a 16.5 percent in 1993 and to 13.7 percent in 1994. The impact of the varied conservation measures is also reflected in Figure 1. The weighted moving average of consumption drifted down from 402.1 gpd in 1987 to 374.9 gpd in 1988 and to 369.2 in 1989. The pre-crisis level of consumption (375.0 gpd) at the end of 1989 was projected into the future as the basis for measuring the impact of the combined drought measures implemented in 1991 and after.

The response pattern is a classic case. The crisis period of 1991 and 1992 reflects the combined effect of the prohibition, restriction, price and conservation efforts that were implemented during that period. After the crisis, water use drifted back up although prices were not reduced because the price increases were geared to budget requirements and water sales volumes. During 1993 and 1994, the WMA line stabilized at about 15 percent below the pre-crisis level of consumption, but for five months in 1995 consumption is below 1994 by 'almost 5 percentage points. It is interesting that winter consumption remains about 20 percent below winter normal consumption (reflecting permanent indoor conservation measures), but summer outdoor consumption (summer minus winter), which fell 73.3 percent in 1991 was only 9.1 and 8.1 percent below the summer outdoor norm in 1993 and 1994 respectively.

TABLE 1
SUMMARY OF CONSERVATION RESULTS 1990-1995

Year	Actual Consp	Normalized Actual	WMA	Forecast of Normal	Actual-Normal = Conservation	. % Conservation
1989	385.1	368.8	369.2	369.7	-0.8	-0.2%
1990	387.6	388.7	369.0	375.0	13.7	3.7
1991	254.5	354.5~	283.2	375.0	-120.5	-32.1
1992	300.0	300.0~	290.8	375.0	-75.0	-20.0
1993	320.2	315.8	311.7	375.0	-59.2	-15.8
1994	323.7	321.7	318.9	375.0	-53.3	-14.2
1994*	219.4	219.4#	325.4	291.2	-71.8	-24.7
1995*	205.0	205.0#	307.0	291.2	-86.2	-29.6

*** 5 Months**
~ Weather normalization coefficients not considered applicable during crisis period
 # Weather data not available for normalizing

Acknowledgments:

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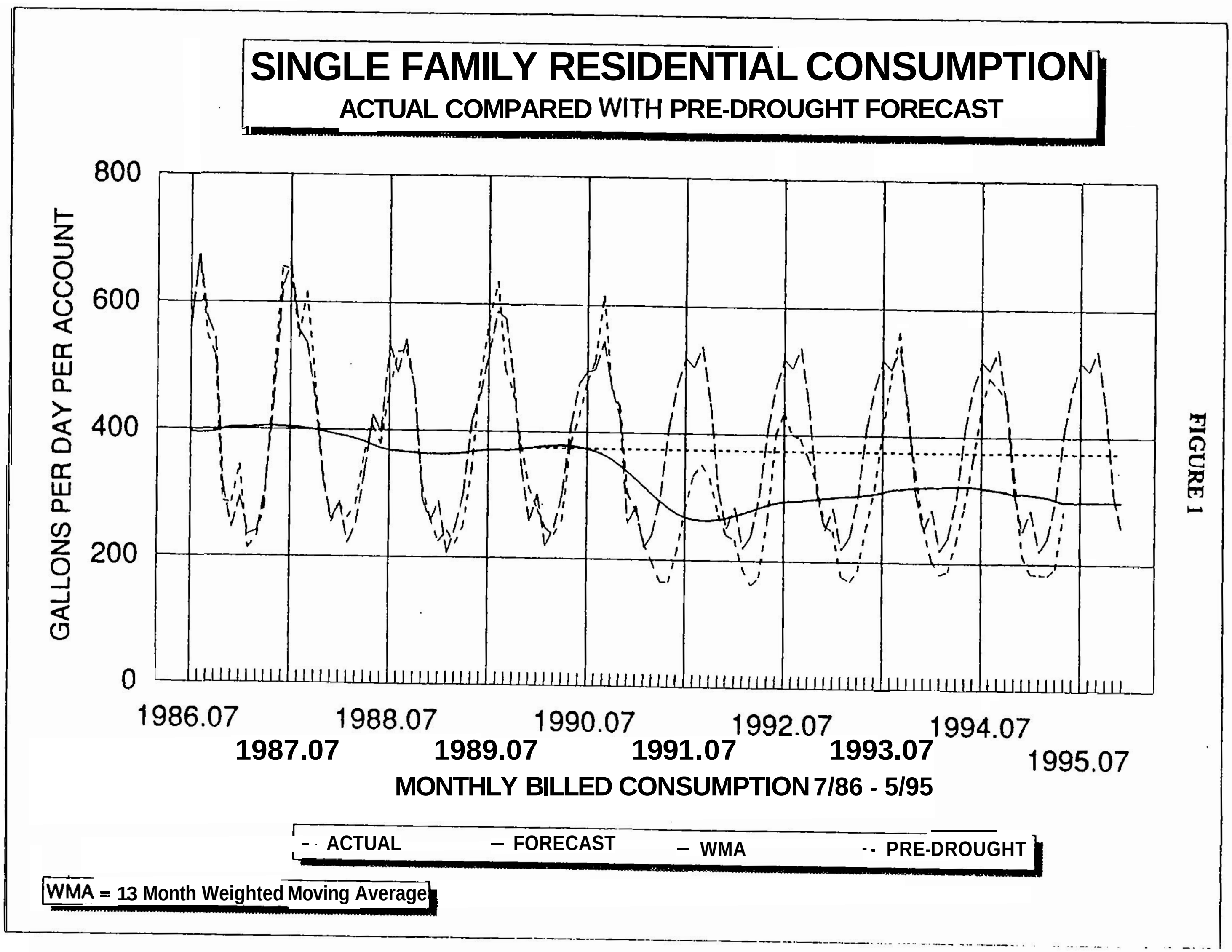
SINGLE FAMILY RESIDENTIAL CONSUMPTION
ACTUAL COMPARED WITH PRE-DROUGHT FORECAST


SINGLE FAMILY RESIDENTIAL CONSUMPTION
ACTUAL COMPARED WITH PRE-DROUGHT FORECAST
GALLONS PER DAY PER ACCOUNT
800
600
400
200
0
1986.07
1987.07
1988.07
1989.07
1990.07
1991.07
1992.07
1993.07
1994.07
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MONTHLY BILLED CONSUMPTION 7/86 - 5/95
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FORECAST
WMA
PRE-DROUGHT
WMA = 13 Month Weighted Moving Average

FIGURE 1