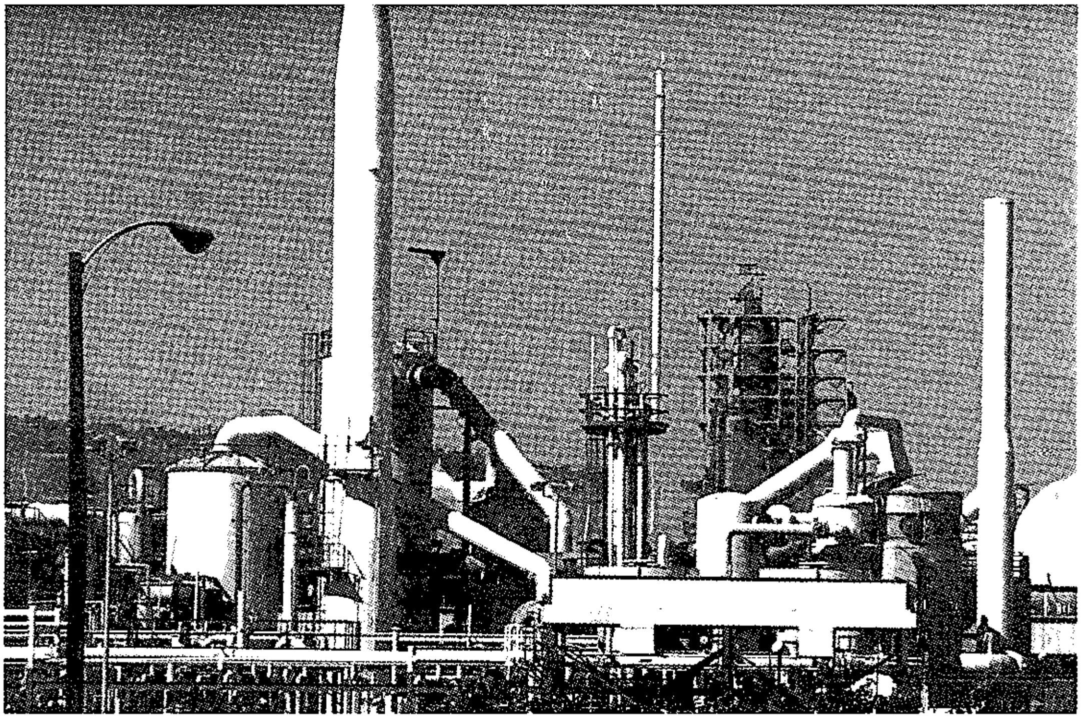
COST OF INDUSTRIAL WATER SHORTAGES



CALIFORNIA URBAN WATER AGENCIES

November 1991

Prepared by SPECTRUM ECONOMICS, INC.,
San Francisco, California

COST OF INDUSTRIAL WATER SHORTAGES

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FOREWORD

California Urban Water Agencies (CUWA) is an organization of the largest urban water providers in California, which serve water to metropolitan areas comprising about two-thirds of the state's 31 million people and a larger proportion of its manufacturing activity. CUWA is very concerned about the erosion of reliability of California's water supplies and the resulting impact on urban activities including industries.

Recognizing that little research had been done on the issue of economic impacts of water shortages on the industrial sector, CUWA retained Spectrum Economics, Inc., to prepare this report. This analysis is based on the most extensive set of data ever collected on industrial water use, water conservation, and shortage impacts on industry. Some of the assessments of industrial impacts are based on responses to hypothetical water shortage scenarios. The potential impacts of such shortages on jobs and the economy would be large even though the amount of water involved is relatively small. The economic well-being of California demands that urban water agencies understand and avoid such impacts.

It was necessary to put some practical bounds on the effort required to produce this analysis. This project includes the major manufacturing sectors. It excludes commercial activities, institutional sectors, and service industries, and it mainly covers industrial activity occurring within the areas served by CUWA member agencies. It also excludes the impact of water shortages on California's landscape industry which is reported to be suffering some 20 to 30 percent business reduction in this drought year.

It is clear from the findings of this project and related work in other urban sectors that: a) California's economy and business climate are being eroded as a result of unreliable water supplies; and b) the urban water supply industry and state policy makers need to know more about the impacts of water shortages, and should incorporate reliability considerations into water supply planning in a more adequate way. California Urban Water Agencies intends to proceed with additional work in these critical areas.

California Urban Water Agencies

COST OF INDUSTRIAL WATER SHORTAGES: EXECUTIVE SUMMARY

Water is now recognized by California industry as a scarce resource to be managed like other inputs to the production process. Industry has responded to the new water-scarce environment with 1) aggressive efforts to increase water use efficiency, 2) high cost conservation to protect plant production from water shortages, and 3) a re-evaluation of California's desirability as a location for new or expanded business operations.

California Urban Water Agencies (CUWA) authorized Spectrum Economics, Inc., to conduct a survey of industrial plants in California. Targeted industries were those most affected by water policy, whose activities have the greatest impact on the health of the California economy: high volume water using industries with a large employment base. The surveyed industries shipped products valued at $127 billion in 1990. The survey's purpose was to determine industrial water use patterns, the extent of adopted conservation and the potential for plant production losses and employment reductions associated with hypothetical 15% summer-seasonal and 30% year-long reductions in water supplies.

Survey data and analytic findings are presented at four levels. This Executive Summary describes broad-brush major policy implications that emerged from the study. Chapter 1 contains a more detailed discussion of major conclusions. The body of the report describes the role of water in California industry and presents study methodology and findings. Technical information is included in the Appendix.

WATER USE EFFICIENCY IMPROVEMENTS

Water conservation has been a growing business practice in California industry for two decades -- since the passage of the Clean Water Act in 1972. Conservation efforts accelerated in response to the current drought and deadlines imposed by the Water Quality Act of 1987.

Significant Water Conservation Savings and Potential Savings. Sampled industries saved more than 76,000 acre-feet in 1989 compared to 1985 annual usage -- a nearly 20 percent reduction in water use. The potential exists to save an additional 61,000 acre-feet per year, but only at a much higher cost per acre-foot saved. The type of forthcoming conservation projects shows that the low-cost, easy solutions generally have been adopted.

Two Major Water Conservation Incentives. Water conservation savings are driven by two major factors: (1) desire to reduce costs, and (2) desire to reduce the risks of plant production losses. Industries using the largest share of water directly in the manufacturing process are most sensitive to production losses due to water shortages, and most plants in those industry groups have conserved aggressively since 1985.

Reduced Conservation Opportunities. Plants have invested significant amounts of money in conservation. As plants become more efficient in water use, fewer options exist to absorb water supply shortages. Conservation coming on-line by 1992 evidences increasingly higher costs to reduce intake water further.

ECONOMIC CONCERNS ABOUT FURTHER CONSERVATION

Economic considerations associated with continued water shortages are significant and of increasing concern to manufacturers.

Conservation Raises The Threshold. Yesterday's conservation "hardens" today's plant water requirements. Growth in plant output during the drought years was supplied, in part, by plant water conservation. Further water supply shortages would cause economic hardship to high volume water using industries which have conserved water aggressively -- including California's Computer, Electronic Components, and Aircraft industry groups which are among the largest manufacturing industries.

Premium for Increased Reliability. Many of the surveyed plants have conserved water with unit costs considerably higher than purchased water. The difference between avoided utility costs for purchase, treatment, and disposal and observed high costs for plant-augmented water reflects, in part, the value of -- a "premium" for -- increased supply reliability.

Enhanced Economic Efficiency. Economic efficiency for the State would be enhanced if urban water utilities could assure reliable industrial water supplies at lower costs than plants are now having to pay for conservation. California's industries could then use scarce capital for investments to maintain and increase their competitive position instead of investing it in high cost conservation projects.

INDUSTRIAL BUSINESS CLIMATE

The current drought as the harbinger of declining water supply reliability has eroded business confidence.

Reassessment of California's Desirability for Business Operations. Plant managers believe that production would be at risk in the event of further water shortages. Consequently, some industries are reconsidering plant and equipment investment plans and, in some cases, are looking elsewhere for plant expansions.

Potential Production and Job Losses. Surveyed manufacturers believe that further water supply limitations on California's plants would result in plant output reductions which could amount to billions of dollars of lost production along with tens of thousands of lost jobs.

Need for Action. The margin of reliability needed to prevent lost production and lost jobs amounts to no more than 100,000 acre-feet per year of dependable supply. This is less than 2 percent of the total urban water use and 0.3 percent of the State's total developed water supplies. Further actions to save water in new ways, and new policies to assure adequate water supplies to industry must be expected. The prospect of large losses by California's key industries due to poor water supply reliability dictates the need for innovative solutions.

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Spectrum Economics, Inc.

1.0 REPORT CONCLUSIONS

1.1 Water Is A Critical Input To Industrial Manufacturing

The current drought has focused attention on the economic impacts of potentially recurrent water shortages. The last major California water supply project to be constructed was the State Water Project started in 1963. Since then, State population has grown from 17.5 million to 31 million and the Gross State Product has grown from $76 billion to $732 billion -- substantial growth compared to relatively static water supplies. Water shortages are predicted to be a recurrent feature in California's urban areas unless supply improvements are achieved. California's preeminent position as the nation's largest industrial State will be diminished if California's water supply reliability problems are not solved. This report addresses this problem and discusses how water supply reliability affects the State's economic vitality.

California manufacturing uses less than 2 percent of water consumed in the State -- much less than residential users and only a small fraction of use by the State's agricultural sector. Nevertheless, water is a critical input to the production process for a number of California manufacturing industries -- including the largest and most economically important industries in the State. **Manufacturing plants have taken extensive steps to conserve water during the current drought, in some cases spending many times the cost of utility-supplied water to improve efficiency of in-plant water use.**

The California economy has not remained static during the current drought, even though water supplies available to industry have been limited by drought management plans. This research shows that industrial plants made up the shortfall in needed water supplies by aggressive conservation. Conservation, the Governor's Water Bank and the fortuitous March 1991 rainfall so far have shielded manufacturing industries from severe economic losses due to drought-reduced water supplies. The number and type of existing and planned conservation projects found in this research suggests that savings from future conservation likely will be less than that achieved between 1985 and 1989 because industrial conservation has been widely adopted.

Reliable water supplies are important to California's manufacturing industries. Plants in industries critical to the California economy will face production constraints imposed by water supplies if water supplies continue to be limited. Supply disruptions contribute to higher unit costs of production and underutilized capital equipment. Uncertainty about reliable water supplies increases the risk of investment in new plant and equipment. Plants in process-water intensive industries will not ignore the risk of expanding plant capacity where water cannot be reliably assured. **Responses to survey questions reveal an erosion in business confidence that reliable water supplies will be available to support plant growth. Plant managers are reconsidering their expansion plans.** The evidence shows that industry managers are looking elsewhere for plant expansions.

Lack of water supply reliability is one more business problem -- joining air pollution, traffic congestion, and housing costs -- that discourages plant and equipment investment in California. California's economic health is vulnerable to plant and equipment investment decisions by its key industries. The consequences of a reduction in the reliability of water supplied to California industry must be carefully assessed by policymakers.

1.2 CUWA Sponsored Industrial Survey To Learn Implications Of Reduced Water Supply Reliability

Information on the current water needs of industrial water users is limited. Survey research was sponsored by California Urban Water Agencies (CUWA) to answer questions about industrial water use patterns, conservation practices and water requirements. The survey was directed to plants within industries which are the most affected by water policy and whose economic health most affects the rest of the State -- high volume water using industries which also have a large employment base. The data were gathered during the fourth quarter of 1990 and into early 1991 in a stratified sample of 640 plants of different sizes randomly selected within 22 high volume water using 3-digit Standard Industry Classification (SIC) industry groups in 12 counties of the San Francisco Bay Area and the Southern California region. The industry groups included in the survey account for 52 percent of manufacturing production, 45 percent of manufacturing employment and for 72 percent of industrial water use in these two regions.

This report:

1. Examines the need for reliable water supply to encourage investment in process-water intensive plant and equipment vital to the continued economic health of California (Section 2.0);

2. Explains how the survey was conducted (Section 3.0);

3. Describes water use levels, sources, trends and within-plant water applications for the surveyed industries (Section 4.0);

4. Explains the extent and cost of conservation found in industry with reference to expected microeconomic behavior, estimates the amount and cost of conservation, and estimates the potential for further water conservation in the surveyed large water using industry groups (Sections 5.0 and 6.0);

5. Examines industry group responses which indicate that production cutbacks result from worsening water supply conditions; estimates the economic costs of water shortages to those industry groups and within the 12 counties (Section 7.0).

1.3 Manufacturing Industries Committed To Conservation

Water conservation is an established business practice in California's industries. Over the last 20 years the three largest water using industry groups in the 12 counties -- Refining, Industrial Chemicals, and Fruit and Vegetable Processing -- reduced their annual potable water intake by nearly 66 percent, 170,000 acre-feet (AF). Substantial recirculation replaced once-through cooling and there was a shift from potable to nonpotable sources. These industry groups reduced their water intake in part as a strategy to reduce wastewater discharge to comply with the 1972 Clean Water Act (CWA). These actions intensified during the 1980s in response to the 1977 amendment to the CWA.

Even after 15 years of operating under the Clean Water Act and its 1977 amendment, the survey uncovered widespread actions between 1985 and 1989 to conserve water. Sixty-six percent of responding plants implemented conservation measures during the past five years -- 459 installed conservation projects were reported by 158 plants. Drought and the 1987 Water Quality Act compliance deadline for wastewater effluent controls (1989) have contributed to this recent big push in conservation in the industrial sector.

The plants which use a high percentage of water directly in the manufacturing process have the most to lose in a water shortage -- and are doing the most to conserve water. Survey respondents that have not pursued conservation are mostly plants with a low percentage of water used directly in the manufacturing process. Water use in these plants is mostly for employee sanitation needs and landscaping. The few plants which do use water in process applications and report no installed conservation projects also report that they have planned conservation projects in progress. Survey responses show that the number of installed water-saving projects will increase nearly 50 percent by the end of 1992 -- 212 more projects coming on-line among the surveyed plants. The 671 identified existing and planned conservation projects among the sampled plants can be extrapolated to indicate that nearly 3,600 conservation projects have been installed or initiated in the 12-county population of industry groups studied.

Through the current drought, water utility imposed rationing to industry has been made-up by in-plant conservation. Estimates show that the surveyed industry groups conserved more than 76,000 AF in 1989 compared to 1985 annual usage, a water use reduction of nearly 20 percent. During this five-year period, estimated utility supplied water to these industry groups declined only 23,000 AF, or 6.5 percent. Industrial growth offset two-thirds of the conserved water. Conservation reduced water use per unit of production and allowed continued plant expansion over the drought years. The demand for water has been "hardened" by plant production growth supported by conservation. Yesterday's conservation "hardens" today's plant water requirements. Plants in this circumstance have reduced ability to accommodate periodic shortages without some reduction in plant production.

Conservation has improved water-use efficiency since 1985. All but two industry groups have reduced water use in relation to output. Six industry groups have improved water use efficiency significantly more than the others. These are shown on Table 1-1.

TABLE 1-1
INDUSTRY GROUPS WITH HIGHEST UNIT WATER USE INDEX IMPROVEMENT: 1985 TO 1989

SIC CODE	Industry Groups	1989 Unit Water Use Index (1985=100)
285	Paint	46
357	Computers	50
371	Vehicles	54
367	Electronic Components	56
203	Fruit & Vegetables	61
372	Aircraft	63

Source: Table 6-7 Spectrum Economics, Inc.

The unit water use index shows, for example, that the Paint industry group produced its 1989 output with 46 percent of the water per unit of production required in 1985. Computers, Electronic Components and Aircraft industry groups are among the conservation leaders. These are three of the four largest employing manufacturing industry groups in California accounting for 395,000 jobs in 1989. The savings in water use implied by these unit water use index improvements represents significant investments (and success) in conservation. These industries, critical to California's economic health, have aggressively adopted conservation.

Plants that have already invested significant amounts of money in conservation programs and technology would require increasingly larger investments to reduce utility intake water further. **Where few ways remain to substitute other inputs for water in the production process, there is less ability to mitigate water supply cutbacks with additional conservation.** Inferences made from efficiency gains since 1985 on top of the extent of water conservation over the preceding 15 years suggest that the elasticity of substitution -- a measure of the ability to substitute other inputs for water -- has been reduced within many of the surveyed industry groups. A plant that has made substantial investment in conservation may have few remaining economic alternatives but to respond to water shortages by cutting production.

1.4 Key Shift in Conservation Patterns – Potential For Additional Conservation

Industries which use the largest percentage of plant water directly in the manufacturing process -- rinsing, washing, diluting, etc. -- are generally the most vulnerable to water supply shortages and are doing the most to conserve water. The largest concentration of conservation projects is found in the industry groups which also report major production and employment reductions if faced with further water supply cutbacks. These vulnerable industries include Computer and Electronic Components, Aircraft and Food industry groups.

Three important findings can be seen from the change in type of reported water conservation projects coming on-line between 1990 and 1992:

1. Process water recycling is replacing cooling water recycling as the focus of conservation projects.

2. The percentage of easy and low-cost projects among the planned projects is declining compared to the installed projects. **The easy opportunities for conservation have been largely exploited.**

3. Planned and potential conservation projects identified in this research include projects with sharply rising costs per acre-foot of conserved water.

The average capacity of process water recycling projects has declined from 163 acre-feet per year (AFY) over the period 1985 to 1989 to 33 AFY for forthcoming projects. The number of process water recycling projects is increasing and diffusing across industry. Cooling water and the largest process water recycling projects appear to be largely implemented. Smaller, more costly projects are being implemented. (An acre-foot is equivalent to 325,900 gallons of water -- enough water to support two average families for a year.)

Estimating future conservation potential must take account of the saturation of existing conservation, economic forces and available technology. This research incorporates these factors and provides an estimate of the likely potential for additional savings of utility supplied water. **Potential remaining conservation in California's large water using industry groups at the end of 1989 is estimated to be 61,000 AF of annual water intake, or 19 percent of the 1989 water intake of these industry groups.** Based on the evidence of 23,000 AF of planned conservation savings coming on-line by 1992 the additional increment will be costly. Plants in most of the surveyed industry groups are seen to be spending many times more than the unit cost of purchased water to protect themselves from drought rationing and uncertain utility water supplies. The values of sales revenues and market shares dependent on water lead to this strategy.

Table 1-2 shows the estimated 1989 water use for the largest water using industry groups along with their estimated conservation achieved during the five years ending 1989 and their estimated potential for additional conservation.

TABLE 1-2
CONSERVATION SINCE 1985 – POTENTIAL REMAINING YEAR-END 1989: LARGE WATER USING INDUSTRIES IN 12 COUNTIES

SIC CODE	Industry Groups	1989 Industry Water Use TAFY	Estimated Conservation 1985 - 1989 TAFY	Potential Additional Conservation TAFY
20	Food Groups	82.3	23.9	10.0
291	Refining	126.7	21.9	24.3
281	Chemicals	27.2	3.6	11.0
327	Concrete	19.1	3.8	1.8
372	Aircraft	13.6	4.9	2.1
265	Paper Boxes	12.4	2.5	3.6
357,367	Computers/Electronics	15.0	9.1	3.9
Subtotal		**296.3**	**69.7**	**56.7**
Others	Misc	25.3	6.7	4.3
Total		**321.6**	**76.4**	**61.0**

TAFY = Thousand Acre-Feet Per Year
Source: Tables 6-10, 6-11

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The table shows how much each of these industry groups contributed to the 76,000 AF of estimated conservation and an estimate of each industry group's remaining potential for conservation. Both the estimated conservation and the potential for more conservation are estimated keyed to water use efficiency improvements measured by the industry unit water use indices. The estimated potential additional conservation assumes adopted technologies and existing economic conditions. If industrial growth continues, the potential additional conservation will be offset by increased plant production in the same way that two-thirds of existing conservation was overtaken by increased production.

1.5 High Cost Conservation Explained By The Value of Reliable Supplies

Plant management considered water as a very low cost input until:

1. Treating and disposing of water became very costly;

2. Limited water supplies became a constraint on production during the current California drought.

These factors have changed management perspective -- not suddenly, but in an evolutionary way since passage of the Clean Water Act in 1972, its amendment in 1977, the drought of 1976-77, the Water Quality Act of 1987, and with "one last shove" during the current drought. **Industry now recognizes** water as a scarce resource to be managed like the other inputs to the production process.

Marginal cost curves for plant-augmented, or conserved water, are estimated for each industry and compared to the cost of buying, treating and disposing of water -- the costs avoided by conservation. Plants facing rising wastewater disposal costs during the 1980s adopted conservation to reduce the overall cost of acquiring and disposing of water. Much of the conserved water has been less costly than avoided utility water and wastewater disposal services.

Numerous conservation projects with **water costs many times higher than avoided costs** are found in most of the surveyed industry groups. These, too, represent rational economic decision-making. Plant managers are responding to a different motivation than cost reduction. Facing limited and unreliable water supplies, they have chosen strategies to lower their exposure to risk of production interruption. Plants replaced utility supplies water with conserved water to support production growth in response to supply limits on utility intake water. This explains the numerous conservation projects found among the surveyed industry groups with costs ranging up to several thousands of dollars per acre-foot more than avoided utility costs. The value of the additional plant production guaranteed by an augmented supply of in-plant water compared to the prospect of lost plant production due to uncertain utility supply is sufficient to justify very high cost water conservation projects.

Plausibly, water has become -- or management perceives it could become -- a limiting input. Management perception of adequacy of future water supplies plays a central role in deciding to provide plant-augmented water supplies more costly than utility supplied water. Plants have invested in projects to reduce reliance on utility supply sources even where the plant-augmented water has much higher costs than the avoided utility charges. **The difference between avoided utility costs for purchase, treatment and disposal, and observed high costs for plant-augmented water reflects, in part, a premium paid to reduce uncertainty.**

The value of supply reliability is difficult to measure from outside the plant. To plant managers with hundreds of thousands, or millions, of dollars of production at risk every day, protecting against disruption of a vital input is easily understood. Simple calculations which assume certainty about future supplies of water and a neutral attitude about taking on additional risk will underestimate the value of water supply reliability. **The high costs for plant-augmented water found in this report represents, in part, a premium to assure increased plant water supply reliability.**

Even though high costs for conserved water make economic sense to the individual plants, this does not imply economic efficiency for the State in terms of balancing scarce water and financial capital resources. If the urban water utilities could assure reliable water supplies at lower costs than observed in this research, California's industries could make better use of their scarce capital to maintain and increase their competitive positions in world markets.

1.6 Responses Show Industries At Risk To Reduced Water Reliability

The water quantity needs of California's industries are small relative to quantities used elsewhere in California, but important because of the value of the output of these industries. An acre-foot of water supports an average of $1.8 million of plant shipments in the High Technology/Defense industry groups -- the largest industry groups in the State. The same acre foot supports nearly $400,000 for plant shipments on average for all of the surveyed industry groups.

The extent to which a plant is negatively effected by water shortage relates, in part, to the extent of existing conservation and, in part, to the way water is used in the plant. Water is used in a plant for cooling, sanitation, irrigation, and as an input to the manufacturing process. Differences in the proportion of water used in each of these ways explains, in part, why shortages cause production problems. Water used as a direct input to the manufacturing process is the leading water use category for most of the surveyed industry groups, with Refining and Industrial Chemicals being the major exception. The research shows that plants with high process water requirements are likely to reduce production as one way to react to water supply shortages.

The survey asked two water shortage scenario questions to develop data about how plants would be effected by hypothetical 15% and 30% water supply shortages. The analysis of responses to hypothetical water supply shortages shows that production cutbacks is one feasible response to water supply shortages. As shown in this report, the survey responses translate to billions of dollars of economic losses to California industry associated with industrial water shortfalls which range between 50,000 and 100,000 annual acre-feet -- less than 2 percent of total urban water requirements. With billions of dollars at stake for a margin of reliability associated with no more than 100,000 acre-feet, further actions to save water in new ways, and new policies to assure reliable water supplies to industry must be anticipated. While the individual responding plants reported production cutbacks as a contemplated shortage response, when the individual plant responses are summed to industry totals, the losses become so large that this would be an untenable outcome for the State. Consequently, **the reported losses are less a prediction of the future than they are a measure of the importance of adequate and reliable water supplies to California industry.**

The largest reported output reductions would be concentrated within the largest industrial sectors of the State -- Computer and Electronic, Refining and Food industry groups -- the same industry groups that have aggressively adopted conservation. In most cases, plants that would reduce plant output report that they would reduce production line employment as well. The reduced output from the surveyed industry groups for a 30% one-year hypothetical water supply shortage, keyed to 1990 value of shipments, amounts to an estimated $11.8 billion. Seventy-one percent of the estimated direct production losses due to such a one-year water shortage are projected to occur in four industry groups as shown on Table 1-3.

TABLE 1-3
LARGEST INDUSTRY PRODUCTION LOSSES DUE TO HYPOTHETICAL WATER SUPPLY SHORTAGE

SIC CODE	Industry Groups	Direct Losses: 30% Supply Shortage Scenario
291	Refining	$ 3.2 Billion
357 & 367	Computer and Electronics	2.2 Billion
208	Beverages	1.6 Billion
201,3,5 & 9	Combined Food Industry Groups	1.3 Billion
Subtotal		**8.3 Billion**
Others	Misc Industry Groups	3.5 Billion
Total		**11.8 Billion**

Source: Table 7-3 Spectrum Economics, Inc.

Direct employment losses are estimated to be 46,000 lay-offs for the same hypothetical 30% water shortage. This is 5.4 percent of the 1989 labor force in the surveyed industry groups. **The largest direct employment losses would be concentrated in the Computer, Electronic, Aircraft and Food industry groups.** Employment in Northern California's Computer and Electronic Components industry groups would be hard-hit by a 30% water supply shortage. These two industry groups would sustain 66 percent of the reported job loss in the northern California industry groups. Computer Components and Computer Equipment are process water intensive. Microchips are manufactured in a wet environment with much necessary rinsing. Computer Equipment manufacturing uses a lot of water for rinsing. These industry groups are the largest manufacturing employers and would sustain the largest employment reductions -- 12,800, over 9 percent of northern California employment in these industry groups. Santa Clara County -- Silicon Valley -- would sustain the largest share of the computer industry losses.

2.0 THE ROLE OF WATER IN THE CALIFORNIA BUSINESS CLIMATE

California's industry uses less than 2 percent of developed water delivered in California compared to 15 percent in the residential sector, and about 80 percent in the agricultural sector. This section provides a frame of reference on California's industry and reports responses to survey questions about the importance of water supplies to investment plans for plant expansion and relocation. The survey responses lead to the conclusion that California's economic health is vulnerable to plant expansion and relocation decisions keyed to managements' assessments of water supply reliability. Water supply reliability is one more business problem -- joining air pollution, traffic congestion, and housing costs -- that will influence plant investment decisions.

2.1 California's Industry Top-Ranked In The Nation

California is a world-class economic power, ranked eighth largest in the world, slightly smaller than the United Kingdom. The cornerstone of California's economic success story is its manufacturing sector led by High Technology and Defense industry groups -- Aircraft, Aerospace, Computer and Computer Components. The state economy has experienced sustained growth at twice the U.S. average over the last decade in spite of increasing competition from foreign manufacturers. California's manufacturing sector is ranked number 1 in the U. S. -- 70 percent larger than New York, which is number 2, in value added, and 80 percent larger in employment.

TABLE 2-1
CALIFORNIA'S RANK IN U.S. MANUFACTURING

	Value Added ($ Billion, 1987)	Employment (Million, 1989)
UNITED STATES	1,167.0	19.61
CALIFORNIA	134.0	2.16
NEW YORK	79.3	1.19
OHIO	71.7	1.12

Source: California Statistical Abstract, 1990.

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9/9/91

The health of the state's High Technology and Defense industry groups is central to California's economic health. Figure 2-1 shows that High Technology and Defense industry groups (SIC: 357, 366, 367, 372, & 376) are the leading industrial employers in the state. These two industry groups provide 27 percent of manufacturing employment in Southern California and 42 percent in the San Francisco Bay Area. Each job in these industry groups indirectly supports 1.8 additional jobs in Trade, Services and diversified manufacturing in the state.

California's High Technology and Defense industry groups are the largest industrial sectors in the state as measured by Value of Shipments. Figure 2-2 shows the size of the surveyed industry groups. Industry groups categorized above as High Technology/Defense account for 37 percent of Northern California industrial shipments, and 24 percent of the industrial base in the more diversified Southern California economy, as shown on Table 2-2. The five industry groups included within High Technology/Defense shipped over $73 billion in products during 1990 -- four times the value of 1990 agricultural shipments. The health of these industries ripples backward to many input suppliers and forward to other manufacturing groups expanding total value to nearly $117 billion based on Department of Water Resources' estimate of output multipliers.

TABLE 2-2
HIGH TECHNOLOGY/DEFENSE SHARE OF MANUFACTURING
Value of Shipments (1990)
$ Billion

SIC CODE	Description of Plant	State	North	South
372,6	Aircraft & Aerospace	31.4	3.9	26.1
366,7	Communication & Electronic Components	21.0	11.2	8.5
357	Computer and Office Equip.	21.0	14.1	5.5
	Subtotal	73.4	29.2	40.1
	Total Manufacturing	287.0	79.0	166.5
	High Tech/Defense: percent of Total Manufacturing	26%	37%	24%

Source: Data from 1987 Census of Manufactures forecast to 1990 by CCSCE, April, 1991
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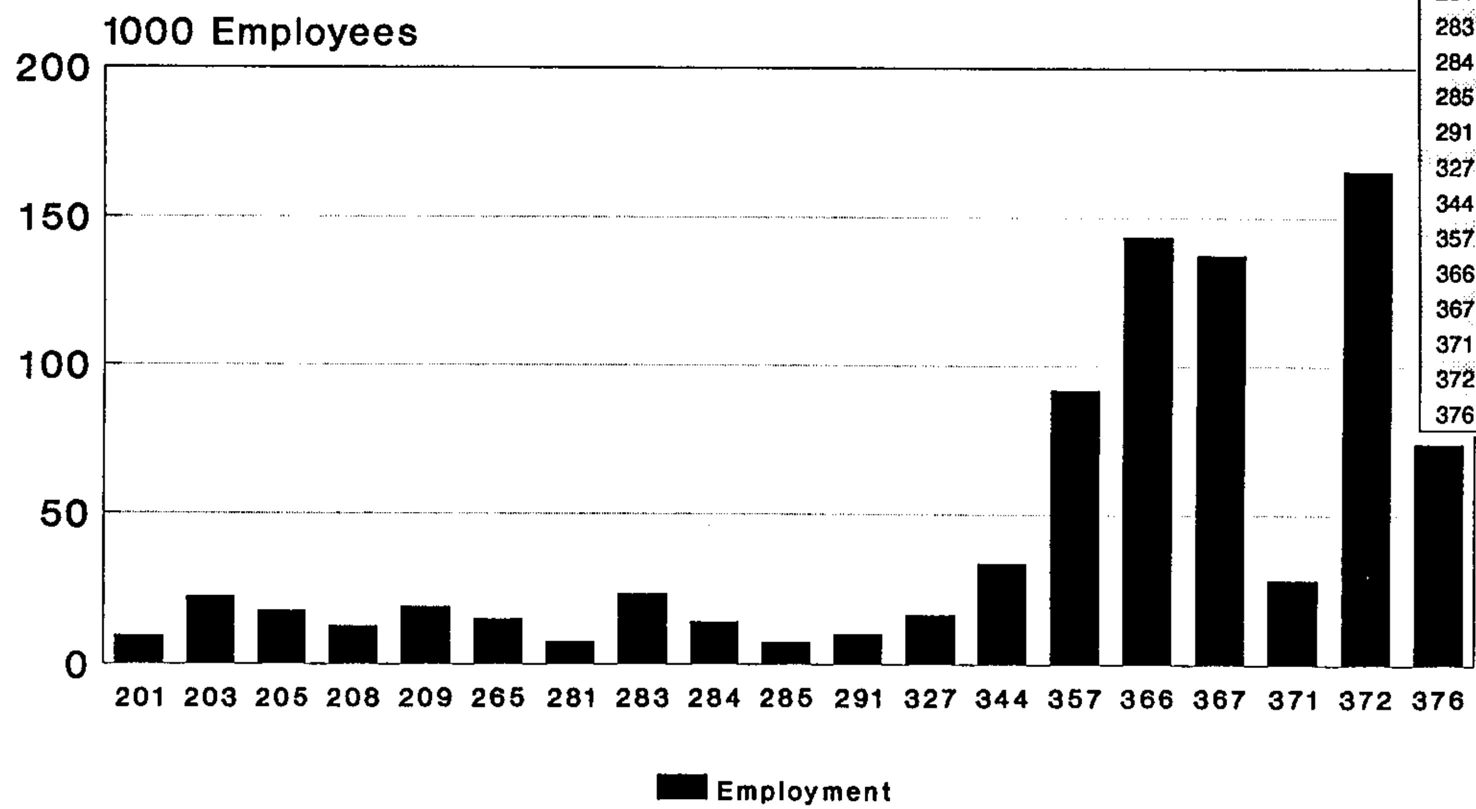
Figure 2-1
Employment by Industry
-- 1989 --

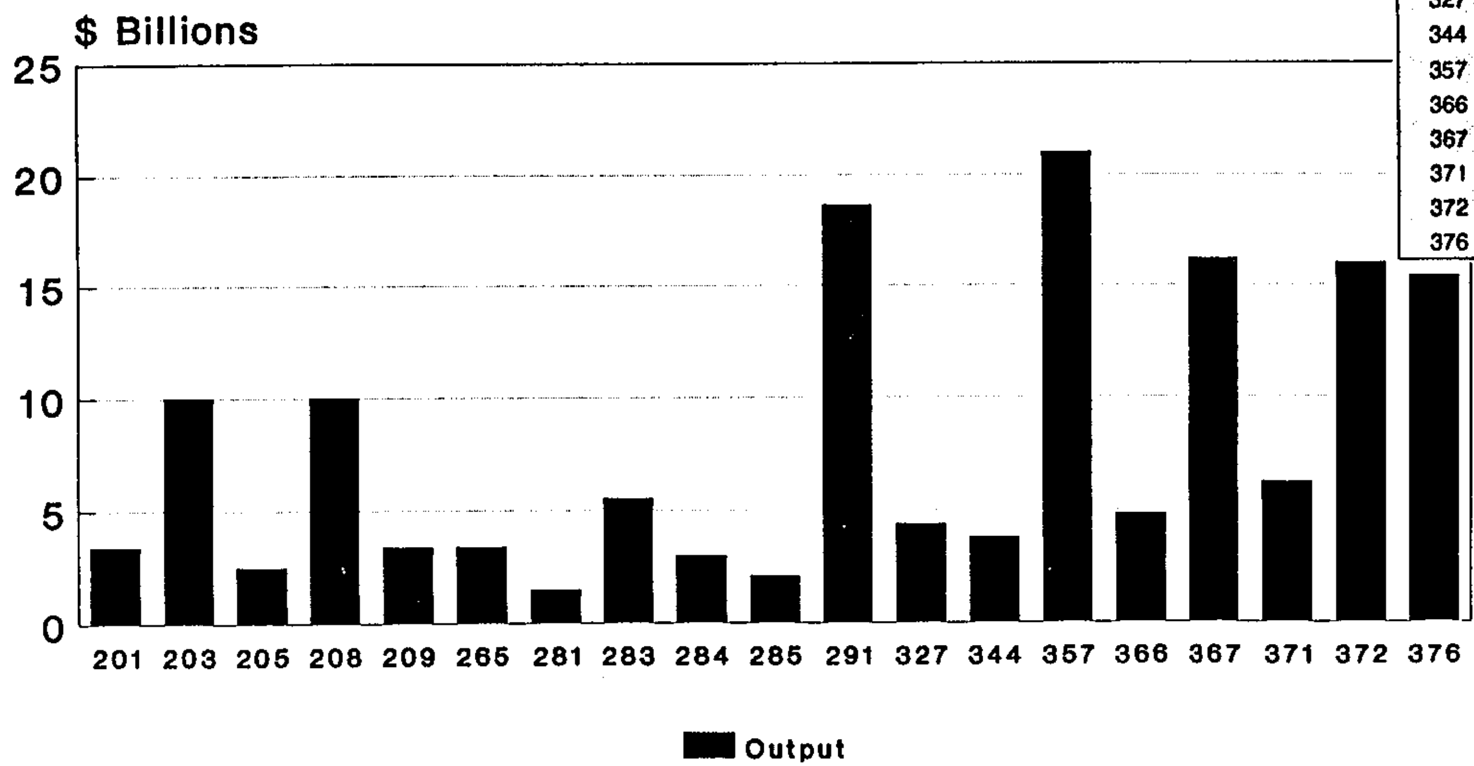


SIC Code	Industry
201	Meat
203	Fruits & Vegetables
205	Bakery
208	Beverages
209	Misc. Foods
265	Paperboard
281	Inorganic Chemicals
283	Drugs
284	Soap
285	Paints
291	Refining
327	Concrete
344	Fabricated Metals
357	Computer
366	Communications
367	Computer Components
371	Motor Vehicles
372	Aircraft
376	Aerospace

Source: E.D.D. 1989

Spectrum Economics, Inc. Sept. 1991

Figure 2-2
Value of Shipments by Industry
-- 1990 --



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284	Soap
285	Paints
291	Refining
327	Concrete
344	Fabricated Metals
357	Computer
366	Communications
367	Computer Components
371	Motor Vehicles
372	Aircraft
376	Aerospace

Source: Census of Manufactures 1987
forecast to 1990 by CCSCE, April 1991

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2.2 Industrial Water Use Supports High-Valued Production

California, more than the other major U.S. industrial centers of manufacturing, has an increasingly unreliable water supply system. Water supply unreliability is one more business problem -- joining air pollution, traffic congestion, and housing costs -- to discourage plant and equipment investment in California. Technology evolves quickly. Plant locations and new plant production facilities to produce the technologies of the 21st century are under evaluation. Location and expansion decisions depend on a host of criteria -- and water supply reliability has become one of them.

According to the Center for Continuing Study of the California Economy (CCSCE), two trends bear importantly on California's economic future over the next decade.[1]

1. Investment in plant and equipment will grow faster than the rest of the economy.

2. Demand for manufactured high technology products will nearly double as both the U.S. and world market expands.

Each of these trends implies upgrading plant and equipment. Major new plant investments in capital-intensive, high technology industries will be required to keep up with the growing demand for products that have been the cornerstone of the California economy. While the Defense industries are expected to shrink during the rest of this decade, increased output from California's high technology industries may largely offset the declining defense industries -- unless the high technology growth migrates outside of California.

The water quantity needs of the California High Technology/Defense industry groups are small compared to quantities used elsewhere in California but important relative to the value of their output. An acre-foot of water supports an average of $1.8 million of plant shipments and 16 jobs annually in the High Technology/Defense industry groups. The same acre-foot supports slightly less than $400,000 annual shipments on average and 2.6 jobs annually in the surveyed industry groups. Table 2-3 shows the annual number of jobs and value of shipments per acre-foot for each of the industry groups surveyed. For comparison, one acre-foot of water applied to irrigated agriculture supports 0.008 jobs on average statewide -- 8 jobs per 1000 AF. The average value of irrigated crop production per acre-foot of applied water in the Central Valley ranges between $150 in the Sacramento Valley and $315 in the San Joaquin Valley.[2]

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[1]California Center for Continuing Study of the California Economy, California Economic Growth - 1991.

[2]Census of Agriculture, 1987; DWR, "Crop Water Use in California," Bulletin 113-4, 1986.

TABLE 2-3
WATER USE RELATED TO SHIPMENTS AND EMPLOYMENT

SIC CODE	Description of Plant	Jobs Per Annual Acre foot	Value of Shipments 1990 Per Acre Foot $1000
201,5,9	Meat, Bakery, Misc. Food	2.1	319.0
203	Fruits & Vegetables	1.0	209.1
208	Beverages	0.3	153.2
265	Paper	1.2	253.3
283,285	Drugs, Paints	4.2	829.8
284	Soaps and Cleaners	4.2	812.9
291	Refining	0.2	129.9
344	Fabricated Metal Products	4.0	393.2
357	Office & Computer Equip.	14.6	3,121.8
366,381	Communications Equip.	23.3	751.6
367	Electronic Components	15.9	1,733.9
371	Motor Vehicles	9.9	1,735.8
372,6	Aerospace & Aircraft	13.8	1,731.7
AVERAGE: SURVEYED INDUSTRY GROUPS		2.6	387.4
AVERAGE: W/O REFINING		4.2	549.8
AVERAGE: HIGH TECH/DEFENSE		16.0	1,802.6

1. 1990 employment data from CCSCE, April, 1991.
2. Value of shipments 1990 from CCSCE, April, 1991.
3. Water use estimate from Table 4-2.

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2.3 Reduced Water Supply Reliability Has Eroded Business Confidence

Reliable water supplies are an important consideration to California's industries. Supply disruptions contribute to higher unit costs of production and underutilized capital equipment. Uncertainty about reliable water supplies increases the risk of investment in new plant and equipment. California's water shortage this year -- and increasingly unreliable urban water supplies through the 1990s -- adds "a specter of uncertainty that weighs heavily on high tech, capital intensive, water critical manufacturers."[3] A large number of firms report that they would expand plant and equipment investments, and locate new plant production facilities, outside of California if reliable water supplies cannot be assured to support future plant growth. The survey responses lead to the conclusion that California's economic health is vulnerable to plant expansion and relocation decisions keyed to managements' assessments of water supply reliability.

2.3.1 Expansion Plans At Risk To Water Shortages

The survey asked whether plants would change expansion plans in response to hypothetical water shortage scenarios. The responses revealed that industries are concerned about the availability of adequate water supplies to support growth and plant expansion plans. Of those that answered the question, (183 respondents) 37 percent of the plants in the survey indicated that a 30% water supply shortage would cause them to reconsider their expansion plans.[4] The responses, rank ordered on Table 2-4 by the "yes" to 30% water shortage scenario, show that the Aerospace, Food, and Chemical industry groups indicated a significantly higher than average propensity towards changing plant expansion plans than the other industries. Paper, Refining and Computer and Office Equipment industry groups also indicated higher than average propensity to change expansion plans. The weighted average of the responses shown on the bottom line is weighted by plant production employment.

2.3.2 Relocation Plans Under Consideration

The responses to the relocation question reflect the fixed nature of plants. Some open-ended responses to the survey question revealed that the positive answers on Table 2-5 imply locating new plant expansion facilities out of state or out of the country, more than relocating the existing facility. Other responses indicated that the respondents would close the plant and move under a 30% water shortage. Our interpretation of the responses on Table 2-5 is that most respondents answered the question with respect to locating new facilities elsewhere rather than closing existing facilities.

Of those that answered the question (183), 26 percent indicated that they would relocate either the existing facility or locate new facilities out of state under the 30% water shortage scenario. Refineries, which indicated a clear need to reconsider expansion plans on Table 2-4, show no ability to relocate on Table 2-5. Chemicals, Food, Computers, Aerospace and

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[3]Source: Aerospace respondent's comment.

[4]Hypothetical water shortage scenarios are described in detail on page 7-2

Paper all indicated above average inclination to relocate in response to water shortage. The weighted average of the responses shown on the bottom line is weighted by plant production employment.

TABLE 2-4
CHANGE EXPANSION PLANS DUE TO WATER SHORTAGES?

SIC CODE	Description of Plant	15% Shortage Scenario			30% Shortage Scenario		
		Yes	No	DK	Yes	No	DK
376	Aerospace	67 %	33 %	0	78 %	22 %	0
20	Food	42 %	58 %	0	53 %	45 %	2 %
28	Chemicals	30 %	60 %	10 %	50 %	50 %	0
265	Paper	22 %	78 %	0	44 %	56 %	0
291	Refining	33 %	67 %	0	44 %	56 %	0
357	Computer and Office Equip.	42 %	58 %	0	42 %	58 %	0
367	Electronic Components	30 %	68 %	2 %	30 %	68 %	2 %
372	Aircraft	18 %	82 %	0	27 %	73 %	0
344	Fabricated Metal	13 %	87 %	0	25 %	75 %	0
366	Communication Equip.	0	100 %	0	4 %	91 %	4 %
371	Motor Vehicles	0	100 %	0	0	100 %	0
	WEIGHTED AVERAGE	29 %	70 %	1 %	37 %	61 %	2 %

DK = Don't Know Source: Survey Question III.13

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TABLE 2-5
CHANGE RELOCATION PLANS DUE TO WATER SHORTAGES?

SIC CODE	Description of Plant	15% Shortage Scenario			30% Shortage Scenario		
		Yes	No	DK	Yes	No	DK
28	Chemicals	20 %	70 %	10 %	50 %	40 %	10 %
20	Food	32 %	58 %	11 %	40 %	53 %	7 %
357	Computer and Office Equip.	23 %	69 %	8 %	38 %	62 %	0
376	Aerospace	37 %	63 %	0 %	37 %	63 %	0
265	Paper	33 %	56 %	11 %	33 %	67 %	0
367	Electronic Components	18 %	76 %	6 %	24 %	68 %	8 %
372	Aircraft	14 %	86 %	0 %	29 %	71 %	0
344	Fabricated Metal	13 %	87 %	0 %	25 %	75 %	0
366	Communication Equip.	0	100 %	0 %	4 %	88 %	8 %
291	Refining	0	100 %	0 %	0	100 %	0
371	Motor Vehicles	0	100 %	0	0	100 %	0
	WEIGHTED AVERAGE	19 %	77 %	4 %	26 %	69 %	5 %

DK = Don't Know Source: Survey Question III.14

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3.0 INTRODUCTION AND OVERVIEW OF STUDY OBJECTIVES

Spectrum Economics, Inc., was retained by California Urban Water Agencies to complete survey research with these objective:

1. Determine how water is used in selected industrial sectors -- notably what share of the water is used directly in the manufacturing process in contrast to ancillary water uses in the plant;

2. Compile existing types of water conservation technologies used and estimate the amount and cost of water conserved in selected industrial sectors;

3. Estimate the potential for further water conservation in selected industrial sectors;

4. Estimate the economic costs of water shortages to different industries and the economic consequences of temporary, yet recurring, water shortages to California industry.

Information on the current water needs of industrial water users is limited.[1] Information about increases in water use efficiency in industry in recent years is also limited. This is confirmed by the following finding of Planning and Management Consultants, Ltd. in a 1990 report to Metropolitan Water District of Southern California:

> "Because of the site-specific and industry-specific factors influencing the adoption of water conservation, little information can be found in the literature concerning the potential for aggregate savings in the nonresidential sector."[2]

As a result, there is inadequate information about the economic impacts of water shortages to industry to guide water allocation decisions based on economic considerations. This research was undertaken to fill that gap.

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[1]Department of Water Resources, 1982, Water Use By Manufacturing Industries in California, 1979, Bulletin 124-3, is the latest published research on water use by California industry. The U.S. Department of Commerce discontinued collecting water use data as part of its Census of Manufactures after 1982.

[2]PMCL, Commercial and Industrial Water-Use in Southern California, 1990, p.11.

3.1 Industries Surveyed Are Important To The Economy And Dependent On Water Supply

The survey was directed to plants within industry groups which are large water using industries which also have a large employment base. These industries are the most affected by water policy; their economic health most affects the rest of the state. Geographically, the survey was restricted to plants in two major contiguous urban areas of the state: the San Francisco Bay area and the Southern California urban area which runs from Los Angeles to San Diego. Figure 3-1 shows the counties from which the sample was drawn. They are, in the north: Alameda, Contra Costa, San Francisco, San Mateo, Santa Clara and Solano counties; and in the south: Los Angeles, Orange, Riverside, San Bernardino, San Diego, and Ventura counties.[3] These counties account for the majority of industrial activity in the state. In 1987, the latest year for which data were available, these counties produced 85 percent of the state manufacturing output and employed 88 percent of the state manufacturing labor force.[4] In 1979, manufacturing sector water use in these counties accounted for 62 percent of statewide manufacturing water use.[5]

Plants were classified by industry type using 3-digit Standard Industrial Classification Codes. The particular 3-digit industry groups chosen were the largest water using, largest employing industry groups according to data on industry water use from 1979 (the latest available) and on industry employment from 1986 (also the latest available when selected).[6] Figures 3-2 and 3-3 show water use and employment, respectively, of the industry groups chosen.[7] Statewide, 22 industry groups are included in the survey. These industry groups accounted for 72 percent of the 1979 fresh water use in manufacturing in the 12-county survey area.[8] In the survey area, these industry groups cover 52 percent of 1990 manufacturing output and

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[3]Throughout the rest of this report, North will refer to the six county San Francisco Bay area, and South will refer to the six-county Southern California area.

[4]Figures for 1987 are from the Census of Manufactures. The comparable figures forecast to 1990, are 86 percent of output and 87 percent of employment.

[5]DWR, Bulletin 124-3, Water Use by Manufacturing Industries in California in 1979, 1982.

[6]DWR, Bulletin 124 and U.S. Bureau of the Census, 1988, County Business Patterns, 1986.

[7]The employment numbers reflect all employees during the week of March 12. Seasonal industries, such as the food industries, may show low numbers. However, this was taken into account in including these industries.

[8]Freshwater use underestimates total intake water by the usage of brackish water. This chiefly affects the petroleum refining and industrial chemicals sectors. Freshwater is that category of plant water which may be supplied by a water utility, and thus subject to the shortage scenarios discussed later in this report.

FIGURE 3-1
Counties in Study Area

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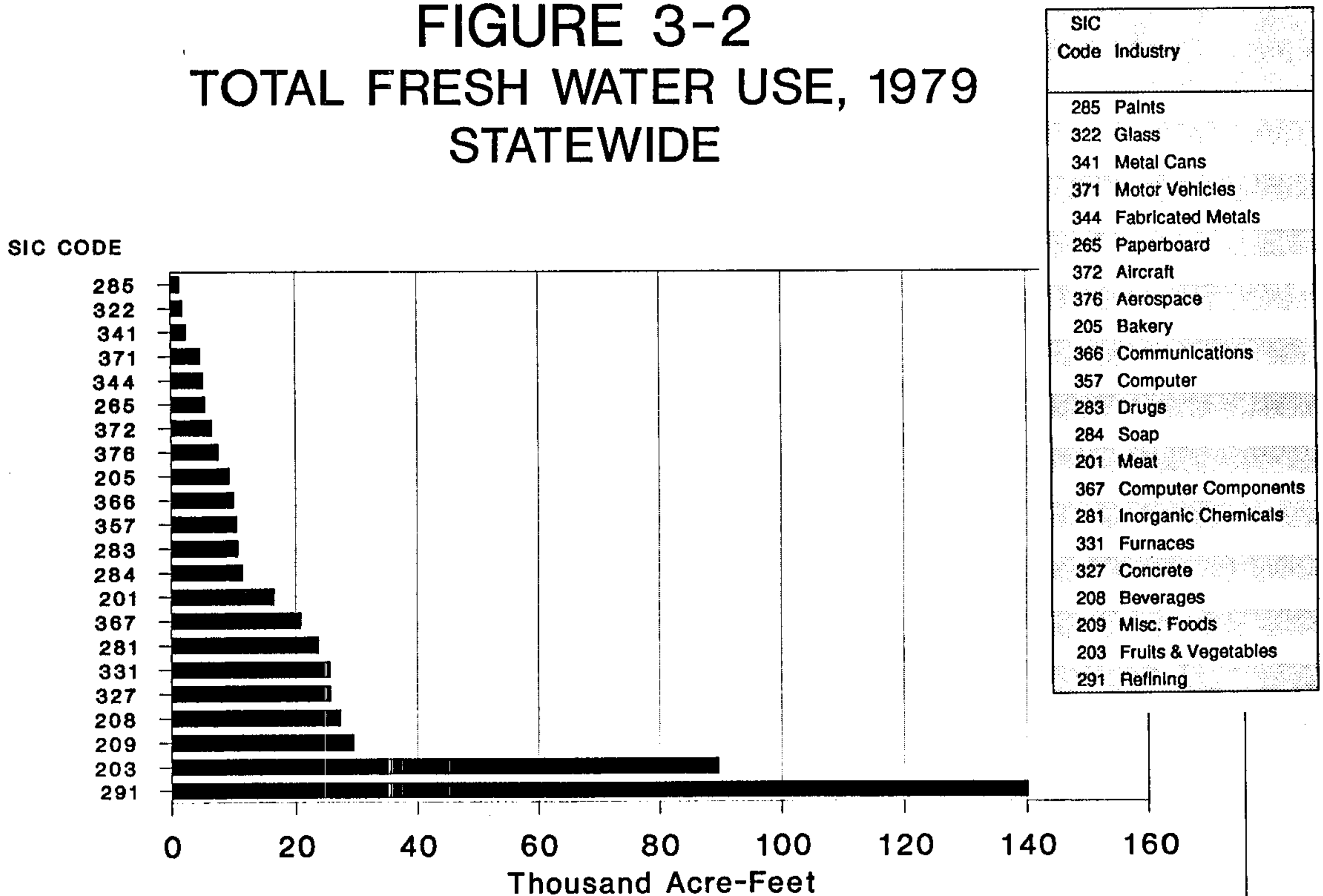
FIGURE 3-2
TOTAL FRESH WATER USE, 1979
STATEWIDE



Source: Cal. DWR, Bulletin 124-3, 1982

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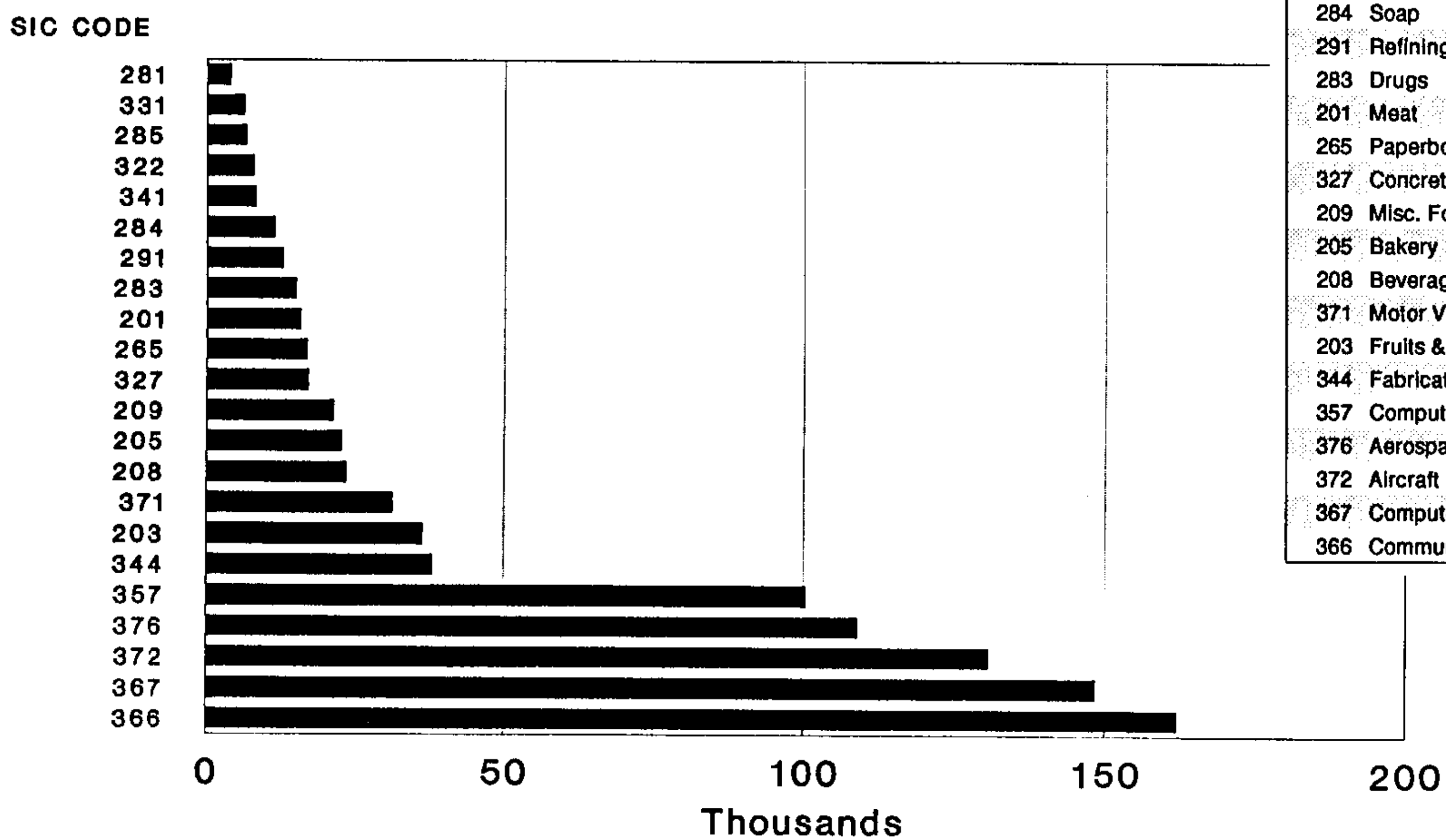
FIGURE 3-3
EMPLOYMENT 1986
STATEWIDE



SIC Code	Industry
281	Inorganic Chemicals
331	Furnaces
285	Paints
341	Metal Cans
284	Soap
291	Refining
283	Drugs
201	Meat
265	Paperboard
327	Concrete
209	Misc. Foods
205	Bakery
208	Beverages
371	Motor Vehicles
203	Fruits & Vegetables
344	Fabricated Metals
357	Computer
376	Aerospace
372	Aircraft
367	Computer Components
366	Communications

Source: County Business Patterns, 1986

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45 percent of 1989 manufacturing employment.[9] Comparing the figures shows that 11 of the top 15 water using industry groups are among the top 15 industry groups in numbers of employees.

There is a difference between North and South in terms of the importance of the industry groups selected for survey: they represent 61 percent of manufacturing output in the North and 48 percent in the South. They differ likewise in employment coverage: they represent 55 percent of manufacturing in the North and 42 percent in the South. These industry groups are a larger portion of the manufacturing base of the North than of the South.

One final characteristic is used to define the set of plants covered by this survey: employment-size class. The manufacturing base of these two regions differs in one very important way. Though manufacturing in the South is more diverse than in the North, the large water using industry groups located in the South have a much larger percentage of employment in plants occurring of 100 or more employees. Plants of 50 or more employees in the North were surveyed to include a similar percentage of total manufacturing employment.[10,11]

3.2 Sample Design

To adequately describe water use in manufacturing according to the objectives laid out in Section 3.0, yet keep the survey manageable, it was determined to survey plants according to a stratified random sample. This sampling method involves identifying population subgroups which have distinct characteristics with respect to the data solicited in the survey. Thus we defined the strata as the 3-digit SIC groups in the North (plants over 50 employees) and South (plants over 100 employees) which were the largest water-using and employing industry groups.

Population refers to the set of all plants in a stratum; sample is that subset of plants to which surveys were sent. It was necessary to identify the population and then randomly

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[9]These numbers are shown in greater detail in Appendices C and D.

[10]No single source contains data crosstabulating water use by county, SIC and employment size class to give a complete indication of the potential coverage implied by surveying only the employment size classes in the particular industries in the twelve counties.

[11]Using data on water use per employee for industries in Southern California, we were able to estimate that firms employing over 100 employees in the 11 industries used 65 percent of all manufacturing water in Southern California. Similar data for Northern California were not available. See Planning and Management Consultants, Ltd., 1990, Commercial and Industrial Water Use in Southern California, a report to the Metropolitan Water District of Southern California.

select those that would be in the sample. The population by county of 3-digit SIC groups by employment size was obtained from Duns Marketing Services. This is shown with number of establishments cross-tabulated by county and SIC groups in Appendix B, in the columns labelled "Population".[12]

Determination of the sampling fraction (the fraction of plants in each stratum to be sent surveys) completes the sample design. Rather than being fixed, the sampling fraction varied across strata to improve the accuracy (reduce the sample variation) of population estimates (objective 1 in Section 3.0). That is, a higher fraction was sampled in strata with a higher variance of plant size, to obtain adequate population coverage. Though the fraction is the same for all counties in a stratum, the sampling fractions implicit in Appendix B will differ for counties within an SIC group and region because only integer numbers of plants can be sampled.[13] The sampling fraction used ranged from 25 percent to 100 percent. The average for the North was 48 percent, for the South 52 percent.

The plants actually sampled in a stratum were chosen at random; plants in an industry were not chosen simply because they were the largest water users or largest employers within the county. The objective of the sampling plan was to see how plants in these industry groups and counties use and conserve water -- not how the largest plants or largest water using plants operate. Random sampling of plants within the county industry groups assures fair representation so that the survey results can be generalized to industry patterns.

The 22 sampled industry groups, number of plants sampled and responses to the survey are shown on Table 3-1. Blank cells in the table signify that the stratum was not surveyed, not that no plants existed in the stratum. A total of 640 plants was surveyed. A total of 238 responses was received. The response rates (percent of responding sampled plants) fall between 14 and 67 percent statewide by industry group, and 37 percent overall. The response distribution reasonably matches the sample distribution.[14] Responses somewhat overstated the actual number of food plants and understate the actual number of computer and electronics plants (357 and 367). Over the 12 counties, at least, industry generalizations from these samples appear reasonable.

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[12]These data were cross-checked with data found in U.S. Bureau of the Census, 1988, County Business Patterns, 1986 detailing number of establishments by employment size class, county and 3-digit SIC group, and found to match reasonably well. Some differences in the two population sizes is explained by duplicate records of firms in the Duns listing.

[13]The fraction sampled can of course, differ across region for the same SIC group, since these are considered to be separate strata. An example is SIC 208, with 74 percent sampling in the north and 92 percent sampling in the South.

[14]This response rate does not describe employees or output covered by the sample, as will be discussed in Section 3.4.

TABLE 3-1
DISTRIBUTION OF MANUFACTURING PLANTS BY INDUSTRY TYPE

SIC CODE	Description of Plant	Industry Population (Number of firms)			Sampled Firms (Firms receiving survey)			Responses (Usable surveys)			Response Rates (Percent)			Distributions of Firms In Total:		
		North	South	TOTAL*	North	South	TOTAL	North	South	TOTAL	North	South	TOTAL	Population	Sample	Responses
201	Meat Products		15	15		15	15		3	3		20.0	20.0	1.2%	2.3%	1.3%
203	Preserved Fruits & Vegetables	24	33	57	19	32	51	6	11	17	31.6	34.4	33.3	4.4%	8.0%	7.1%
205	Bakery Products	27		27	22		22	12		12	54.5		54.5	2.1%	3.4%	5.0%
208	Beverages	23	24	47	17	22	39	5	5	10	29.4	22.7	25.6	3.7%	6.1%	4.2%
209	Misc. Foods & Kindred Prod.		46	46		32	32		13	13		40.6	40.6	3.6%	5.0%	5.5%
265	Paperboard Containers & Boxes	26		26	21		21	11		11	52.4		52.4	2.0%	3.3%	4.6%
281	Industrial Inorganic Chemicals	11		11	7		7	4		4	57.1		57.1	0.9%	1.1%	1.7%
283	Drugs	20		20	12		12	7		7	58.3		58.3	1.6%	1.9%	2.9%
284	Soap, Cleaners, & Toilet Goods		23	23		22	22		4	4		18.2	18.2	1.8%	3.4%	1.7%
285	Paints & Allied Prod.	5		5	4		4	2		2	50.0		50.0	0.4%	0.6%	0.8%
291	Petroleum Refining	6	20	26	6	17	23	4	8	12	66.7	47.1	52.2	2.0%	3.6%	5.0%
322	Glass, Glassware	5		5	4		4	1		1	25.0		25.0	0.4%	0.6%	0.4%
327	Concrete, Gypsum, Plaster Prod.	16		16	13		13	6		6	46.2		46.2	1.2%	2.0%	2.5%
331	Blast Furnace & Steel Prod.	7		7	6		6	1		1	16.7		16.7	0.5%	0.9%	0.4%
341	Metal Cans, Shipping Containers	9		9	7		7	1		1	14.3		14.3	0.7%	1.1%	0.4%
344	Fabricated Stuctural Metal Prod.	38		38	23		23	12		12	52.2		52.2	3.0%	3.6%	5.0%
357	Computer & Office Equip.	170	89	259	52	38	90	9	7	16	17.3	18.4	17.8	20.1%	14.1%	6.7%
366	Communication Equipment	33	83	116	29	41	70	13	12	25	44.8	29.3	35.7	9.0%	10.9%	10.5%
367	Electronic Comp. & Acc.	230	171	401	67	44	111	30	16	46	44.8	36.4	41.4	31.2%	17.3%	19.3%
371	Motor Vehicles & Equip.	10		10	8		8	5		5	62.5		62.5	0.8%	1.3%	2.1%
372	Aircraft & Parts		106	106		45	45		20	20		44.4	44.4	8.2%	7.0%	8.4%
376	Guided Missiles, Space Vehicles, Parts		17	17		15	15		10	10		66.7	66.7	1.3%	2.3%	4.2%
	Total or Average	660	627	1287	317	323	640	129	109	238	40.7	33.7	37.2	100%	100%	100%

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Source: U.S. Dept of Commerce, Bureau of the Census, 1988. "County Business Patterns, 1986: California" and Spectrum Economics, June 1991.
*TOTAL is total of North counties and South counties, not statewide total.

Single responses from industry groups 322, 331 and 341 caused them to be dropped from the analysis. Though surveyed, they will not appear through the remainder of this report.

3.3 Survey Design and Execution

The survey instrument which was sent to the sampled plants is shown in Appendix A. This instrument was developed with the use of several aids: a review of the literature for previous industrial water use surveys and studies, an advisory committee of water agency managers, site visits to plants in six different industries, and telephone contacts with plant engineers in others.

The resulting design produced a questionnaire with three sections, eliciting information regarding:

- **Plant Operations**, including production and employment from 1985 to 1989, capacity utilization and seasonality;

- **Plant Water Use**, including intake from 1985 to 1989, seasonality, categories of use in 1985 and 1989, recycling, wastewater, and conservation technologies implemented and planned; and,

- **Plant Response to Shortage Scenarios**, prompting for access to alternative supplies (including conservation-project-generated water) before asking about economic impacts.

The survey instrument devotes substantial space to eliciting data on installed and budgeted conservation projects. The shortage scenarios, at the back of the instrument, were carefully constructed to reflect feasible shortage levels that could be expected in California over the next decade. The questions were carefully designed to elicit additional conservation strategies to mitigate utility water shortfalls before prompting for plant production and employment relationships to water supply shortfalls.

Recognizing that the survey was 14 pages long and that some questions asked for five-year-old data, survey execution was deemed to be equally important as survey design. Thus careful attention was paid to the format of execution.

A pretest of the survey was conducted, designed to be as much like the full survey as possible. The size of the pretest was 35 plants, evenly divided between North and South, but not covering all the strata previously identified. The survey and cover letter were sent to the chief executive officer at the plant. This person was generally either the president of the company or the plant general manager.

The cover letter introducing the pretest survey (text included in Appendix A) was designed to cause the managers to treat the survey as an important item to complete and return. The body of the cover letter was the same for all recipients, but was on letterhead appropriate to the geographic location of the plant. The signatures on the letters were of locally-recognizable water officials, either politicians or utility leaders. The instruction page of the survey suggested that the survey might best be filled out with different plant personnel having responsibility for different sections, hoping to maximize the number of questions that would be answered.

Because the responsibility for filling out the pretest survey would rest with an individual who was unknown to the researchers, it was decided to follow up each survey with a phone call, with the purpose of finding out to whom the survey had been directed within the plant, whether a response was forthcoming, and if there were any clarification questions. A postcard was mailed approximately two weeks after the survey as a reminder, and in case phone contact had not been established. In several cases, the postcard arrived at the plant though the survey had not been received or had been misplaced. A new survey was mailed to these plants

Twenty pretest responses were received, implying a 57 percent response rate. However, some surveys were deemed unusable because of nonresponse to the critical question on output, leaving the effective response rate at roughly 30 percent.[15] The response rate observed in the pretest was assumed to reflect the response rate that would pertain to the full survey, and was incorporated into the sampling fractions reflected in Appendix B.[16]

Another lesson learned from the pretest was that the internal routing caused delays in return of the survey, and that telephone follow-up was essential. The wording of several questions changed slightly also as a result of the survey, though the data points sought remained roughly the same.[17] As plant production level was discovered to be confidential in many industries during the pretest, the production question was changed to allow an index of production (1985=100) to be reported.

The full survey mailout took place in late October and early November, 1990. Telephone follow-up began immediately. Staff of the Southern California Water Committee were retained to help with the telephone follow-up, in part to provide a local contact for the

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[15]However, all but one pretest response included answers to water intake volume.

[16]The expected response rate for the survey was 50 percent, implying that twice as many surveys should be mailed out as were responses desired based on the sampling method. Revising the expected response rate downward was a very important lesson of the pretest.

[17]Questions II.4, II.10 and II.11 were added to the pretest survey to create the final version. Questions II.10 and II.11 were added due to the difficulties encountered in gathering this data directly from sanitation agencies.

plants in the South. A reminder postcard was mailed to all plants three weeks after the survey. A large number of surveys were remailed -- 60 percent over the next several weeks -- as it was often easier to mail another survey than to track the path of the survey within a plant.

Because the plants who had not returned the survey by mid-December were not expected to do so during the holiday season, a second postcard mailout took place in early December to the plants not yet responding. The hope was that the plant would be prompted to reply before the end of the year. A thank-you postcard was mailed to responding plants. After the first of the year (1991) the telephone follow-up effort was broadened to include water supply utility staff as an attempt to raise the level of attention paid to the survey.

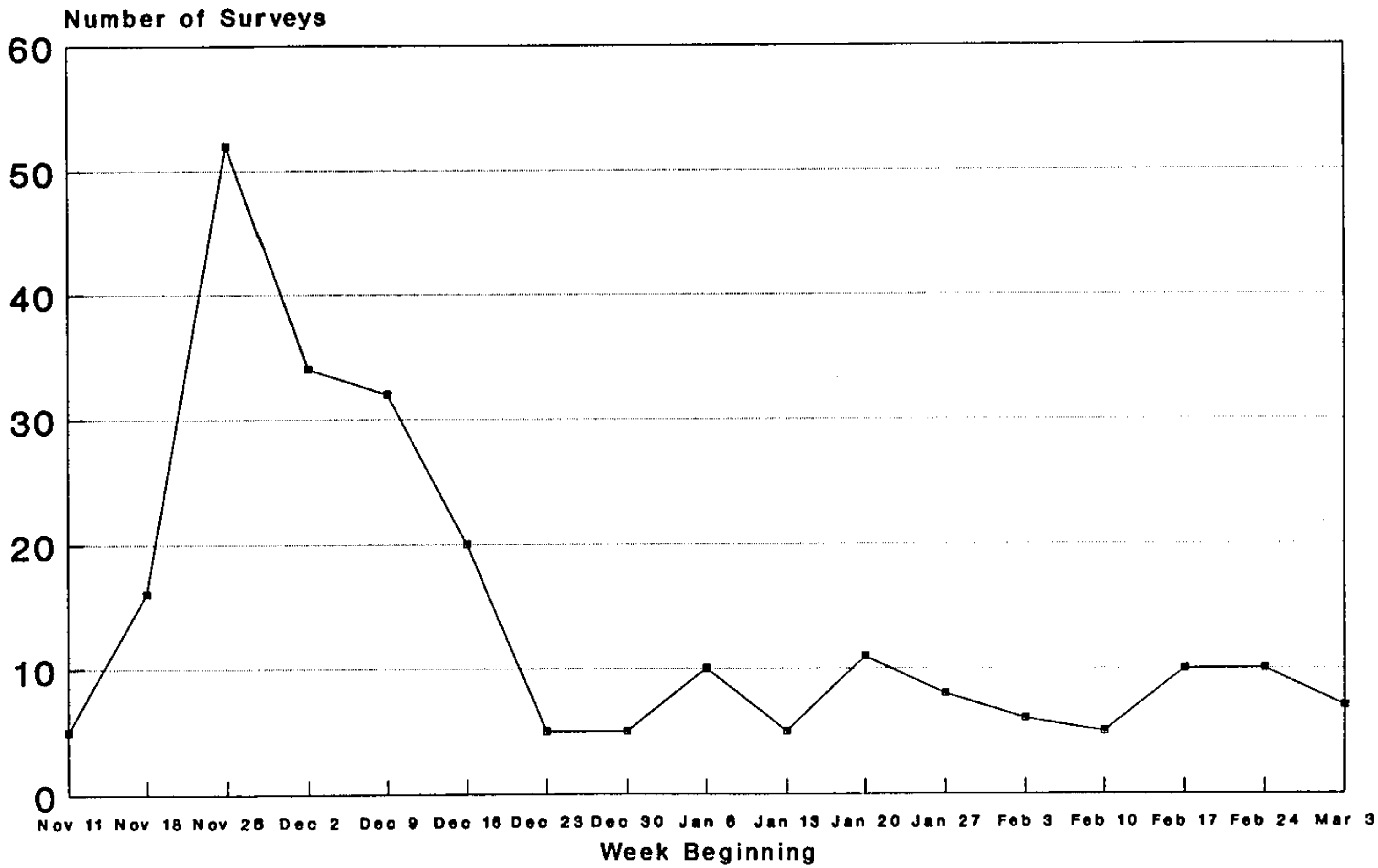
Figure 3-4 shows the time trend of responses. Not surprisingly, a large percentage of the final 238 were returned quickly, followed by a period with few returns centered around the holiday season. The small pick-up in returns in early 1991 are partially reflective of a greatly intensified follow-up effort. As the surveys came in, the telephone follow-up effort became more directed at plants in strata which were lacking responses. This effort was only partially successful, and some SIC groups had to be dropped.

Identifiable reasons for nonresponse to the survey included the following reasons:

- Not engaged in manufacturing,
- Will not participate in random survey,
- Plant closed,
- Located in a common-metered industrial or office park, and
- No water used in manufacturing process.

As the survey was intended to measure the impact of water shortages on manufacturing plants, any plant that either used no water or was not engaged in manufacturing (usually identified in the telephone follow-up) was not asked to fill out the survey. This did not bias the results, which are aggregate impacts, not plant average impacts. Plants which leased space from an office or industrial park were also not asked to fill out the survey if they did not pay their water bill directly because they would not know their water use or have as direct an incentive to conserve water.

FIGURE 3-4
SURVEYS RECEIVED BY WEEK



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3.4 Statistical Procedures

The response to the survey question about labor use was very important in terms of relating the sample responses to the full population values. The percent of sample coverage of the labor in each stratum is shown on Table 3-2. Several points should be made about the table. First, one would expect a higher response rate to go along with a higher percentage of coverage. The connection between the two percentages is the sampling fraction. A high response rate with a low sampling fraction means that a disproportionately small share of the industry is actually covered by the responding plants. Industry groups 265, 285, 327 and 344 fall into this category. The petroleum refining industry has both a high sampling fraction and a high response rate and is thus the industry with the best labor coverage.

The single response in industry groups 322, 331, and 341 makes statistical inference impossible. These industry groups are not reported. A decline in labor coverage going back in time means that there is an increase in sampling error in the early years. This applies mostly to Computers (357) and Communications Equipment (366). Estimated and reported water use numbers for 1985 to 1987 are more uncertain for these industries than are the values for 1988 and 1989.

Appendix E shows equations and describes how water use estimates were developed. The statistical properties of the included SIC industry groups are also described. Confidence intervals are calculated for each industry group's water use estimate for each of the five years.

TABLE 3-2
POPULATION LABOR COVERAGE IN SAMPLED INDUSTRIES

SIC CODE	Description of Plant	Number of Usable Surveys	Survey Response Rate (%)	Industry Labor Represented in Sample 1989 (%)	1988 (%)	1987 (%)	1986 (%)	1985 (%)
201	Meat Products	3	20.0	14.9	15.0	15.8	18.0	17.8
203	Preserved Fruits & Vegetables	17	33.3	10.6	9.1	8.4	8.8	8.0
205	Bakery Products	12	54.5	10.9	10.2	10.7	7.4	7.4
208	Beverages	10	25.6	18.7	18.5	16.9	17.0	15.6
209	Misc. Food & Kindred Prod.	13	40.6	16.9	15.3	13.1	9.5	9.3
265	Paperboard Containers & Boxes	11	52.4	8.9	8.5	7.8	8.0	8.4
281	Industrial Inorganic Chemicals	4	57.1	11.8	11.5	10.7	10.3	10.2
283	Drugs	7	58.3	12.1	11.8	14.2	15.9	15.9
284	Soap, Cleaners, & Toilet Goods	4	18.2	3.7	3.5	3.5	3.7	3.5
285	Paints & Allied Prod.	2	50.0	5.3	5.0	5.3	6.0	7.0
291	Petroleum Refining	12	52.2	58.7	49.9	52.8	54.8	52.6
322	Glass & Glassware	1	25.0	3.7	4.0	5.0	4.9	5.0
327	Concrete, Gypsum, Plaster Prod.	6	46.2	2.0	2.1	2.2	2.4	1.7
331	Blast Furnaces	1	16.7	0.0	0.0	0.0	0.0	0.0
341	Metal Cans & Containers	1	14.3	3.6	0.0	0.0	0.0	0.0
344	Fabricated Metal Prod.	12	52.2	2.0	1.9	1.7	1.5	1.3
357	Computer & Office Equip.	16	17.8	8.3	7.2	4.8	3.5	3.0
366	Communication Equipment	25	35.7	3.6	3.4	2.9	2.9	2.8
367	Electronic Comp. & Acc.	46	41.4	26.6	25.9	25.4	25.4	22.2
371	Motor Vehicles & Equip.	5	62.5	31.4	28.3	30.7	35.8	33.8
372	Aircraft & Parts	20	44.4	12.6	18.3	13.3	13.2	12.7
376	Guided Missles, Space Vehicles, Parts	10	66.7	37.4	40.2	41.8	38.3	47.6
	Total or Average	238	37.2	15.5	16.5	15.0	14.7	14.1

Source: Scenario Questions, E.D.D.

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4.0 PLANT PRODUCTION AND WATER USE

A primary objective of this study is to estimate total water use for the large water using industries in the 12 counties included within the survey. Much of the analyses that follow depend on an estimate of total water use in each of the 3-digit SIC groups included in the survey. It bears repeating that the primary motivating factor for engaging in this study is the dearth of data on industrial water use in California. This section provides data and information about:

1. Industry water use among the large water using industries for 1989 and the change in annual water use since 1985 -- highlighting changes made in water use patterns during the included drought years, 1987 - 1989;
2. Industry water sources -- potable, nonpotable, groundwater, surface/brackish;
3. Industry plant water use patterns -- process, boiling, cooling, sanitary, irrigation;
4. Seasonality of water use -- monthly distribution by each industry and the total;
5. Water use related to employment;
6. Historical water use: 1970 - 1979 - 1989: Comparison with DWR Bulletin 124.

4.1 Industry Water Use: 1989

4.1.1 Method To Estimate Industry Water Use Totals

Industry water use estimates are built from the responses to question II.1 in the survey instrument regarding annual water intake volume. As the survey is not a census, a method was developed to expand the survey responses to industry totals. Either plant production or employment, both of which are intimately related to industry activity, could be used to relate survey totals to industry totals. Both are collected by various government agencies and reported for the industries by county and 3-digit SIC code.

The water use reported by respondent plants could be expanded to the 12-county industry totals with reference to external Census of Manufacturing production data or State of California Employment Development Department (EDD) employment data. Either approach would yield an acceptable estimate of industry population water usage so long as the plants included in the sample are a representative cross-section of the whole industry, and external industry data reasonably match the sampled data.

Output is the ideal basis to expand survey water use responses to industry totals. It is better to link an input to its output rather than to another input. Table 4-1 shows, however, that a greater number of surveys which provided good water use data also reported employment. Moreover, Census of Manufacturing output data only exist for 1987 while EDD data are available annually. Survey responses include water use for five years, 1985 - 1989 and require an annual relationship to the expanding factor. Furthermore, output is reported in the survey in a mix of units: dollar value of shipments, physical output units, or an index. Thus, employment is used as the basis to expand survey responses to industry totals.

TABLE 4-1
NUMBER OF SURVEY RESPONSES TO PARTS OF QUESTION I.9

Variable\Year	1989	1988	1987	1986	1985
Plants Reporting Employment & Water Use	205	181	174	164	158
Plants Reporting Production & Water Use	161	147	138	126	118

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The definition of employment used in this study is full-time production employees. By restricting employment to production workers, we have a more proximate link between employment and output or industry activity. Past studies of water use in industry have linked industrial water use to employment, though it is not clear that they defined employment as production employment.[1]

All employment data were taken directly from EDD publications and printouts provided to us for the years 1985 through 1989 by 3-digit SIC code. EDD industry classifications changed slightly in 1988 due to a reclassification of 4-digit SIC codes because of redefinition of SIC groups by the Federal Office of Management and Budget. The 3-digit SIC codes in the survey affected by this reclassification were 357 and 366. In both of these industries, the EDD data showed a shift in employment between 4-digit SIC subgroups due to the reclassification.

[1]See 1990 PMCL report, Commercial and Industrial Water Use in Southern California, and 1982 DWR Bulletin 124-3, Water Use by Manufacturing Industries in California, 1979.

EDD numbers show employment dropping from 100,000 to 80,000 in industry 357 and from 172,000 to about 70,000 in industry 366. For our purposes, we needed a consistent reference benchmark. For 366, lost jobs were tracked to industry 381; jobs were returned to 366 to correct the data anomaly. In 357 tracking of reclassified jobs was not possible. 20,000 workers still remained unaccounted for. Thus the employment number for 1988 and 1989 for Industry 357 is the best estimate for this value.

An alternative description of the method for estimating population water intake is to say that the same water use per production employee reported in the sampled plants is attributed to all production employees in the industry for a given year. Annual samples were taken of water use and employment and expanded the water use per production employee to the industry as a whole. As water use per employee is revealed to change over time (see Section 4.3), the water use per sampled employee is calculated separately for each year, given both changing water use per employee and the changing number of plants reporting both water and production employment in each year.[2] Consequently, the sample size supporting industry water use totals changed annually decreasing from 205 in 1989 to 158 in 1985.

4.1.2 Estimated Industry Water Use: 1989

The 12-county industry water intake numbers for each 3-digit SIC group are shown on Figure 4-1. The data are shown on Table 4-2. The surveyed industries used 329,000 AF in 1989 -- 293.7 million gallons per day. Refining is the largest water using industry followed by the Beverage industry, Industrial Chemicals and Fruit and Vegetable processing and Concrete. These five industries use 71 percent of the water in the surveyed industries.

Except for Beverages, water use in the surveyed food industries has dropped dramatically since 1979. (This is discussed later in section 4.6) Water use in beverages has doubled from under 19,000 AF to 39,000 AF in the intervening ten years. As water is the essential ingredient, and population, per capita consumption and markets have both grown, water use in the Beverage industry has increased. The High Technology industries (357,366, and 367) use 6.4 percent of the water; the Defense industries (372, 376) use 5.2 percent of the water, with the Aircraft plants in SIC code 372 using the largest amount of this.

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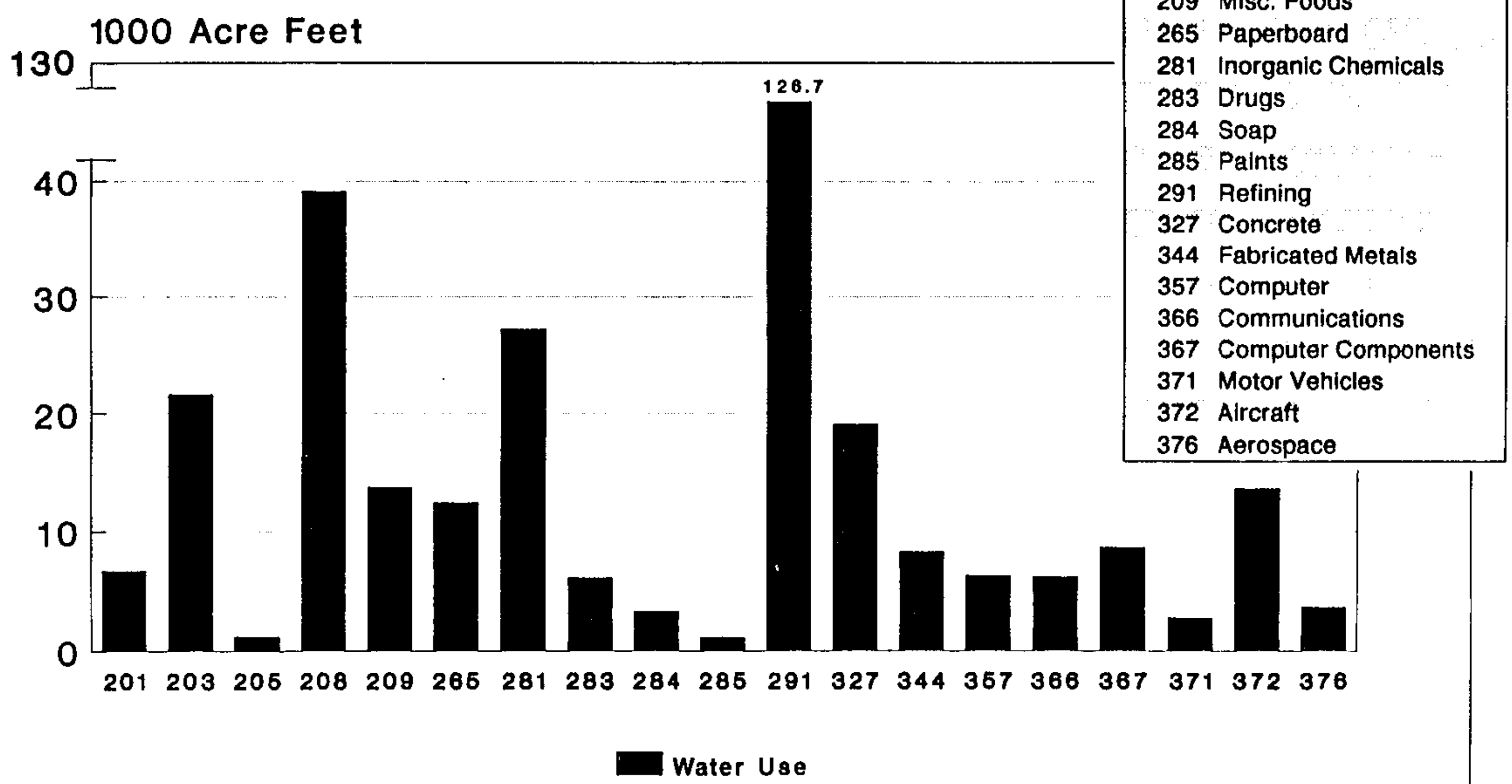
[2]Four plants which reported data for 1989 only were dropped from the 1989 water use estimate because their reported water use per employee numbers were radically different from the remaining industry average. With no time series information available for these plants, they greatly influenced the population estimates for 1989 only, causing the industry time series estimate to grow in a fashion not clearly supported by other data. Three plants in SIC 367 were dropped as outliers; one in SIC 366 was dropped.

FIGURE 4-1

Water Use by Industry
12 County Total - 1989



Source: Survey Question II.1

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TABLE 4-2
INDUSTRY WATER USE IN 1989
12 COUNTY TOTAL

SIC CODE	Description of Plant	1989 Water Use (TAF)	1989 % Of Total
291	Petroleum Refining	126.7	38.5
208	Beverages	39.1	11.9
281	Industrial Inorganic Chemicals	27.2	8.3
203	Preserved Fruits & Vegetables	21.6	6.6
327	Concrete, Gypsum, Plaster Prod.	19.1	5.8
209	Misc. Food & Kindred Prod.	13.7	4.2
372	Aircraft & Parts	13.6	4.1
265	Paperboard Containers & Boxes	12.4	3.8
367	Electronic Comp. & Acc.	8.7	2.6
344	Fabricated Metal Prod.	8.3	2.5
201	Meat Products	6.7	2.0
357	Computer & Office Equip.	6.3	1.9
366	Communication Equipment	6.2	1.9
283	Drugs	6.1	1.9
376	Guided Missles, Space Vehicles, Parts	3.7	1.1
284	Soap, Cleansers, & Toilet Goods	3.3	1.0
371	Motor Vehicles & Equip.	2.8	0.9
205	Bakery Products	1.2	0.4
285	Paints & Allied Prod.	1.1	0.3
322	Glass & Glassware Prod.	1.0	0.3
341	Metal Cans & Containers	0.3	0.1
	Total	329.0	100.0

Source: Survey Question II.1 Spectrum Economics
TAF – Thousand Acre Feet 9/9/91

4.1.3 Sources of Industry Water

Total industrial water use is larger than utility supplied water because some large water using plants use groundwater and nonpotable water including brackish water -- water from either the ocean or the estuary system of San Francisco. Table 4-3 shows the distribution of water use by source for the surveyed industries. Most industries rely exclusively on potable water. Table 4-3 shows that Industrial Chemicals (281), Refining (291) and Paper (265) rely heavily on other than utility supplied potable water. Refining still remains the largest user of potable water; but Chemicals drops to 2,700 AF/year of potable water -- much less than even the High Technology and Defense plants.

The High Technology and Defense industries, which require very high quality water, rely exclusively on utility supplied potable water. The Aircraft industry (372), part of the Defense group, is shown on Table 4-3 to be the fifth largest potable water using industry. As this industry is shown on Appendix C to be almost exclusively located in Southern California, its water requirements doubtless rank third to the local refineries and beverage plants. Packaged food products (209) require utility supplied potable water while some fruit and vegetable operations use substantial amounts of groundwater. As a result, the Packaged Misc Foods are nearly as reliant on utility water as the Preserved Fruits and Vegetables.

There has been the misperception that water intensive industries are primarily self-supplied from own wells or from diverted surface or ocean water.[3] While it is true that Industrial Chemicals, Paper, and Petroleum Refining do rely on substantial quantities of groundwater and diverted surface water, Table 4-3 shows that all but the Industrial Chemicals plants also consume large quantities utility supplied potable water. Four of the Industrial Chemical plants in our survey are sited on the Sacramento River and consume large quantities of diverted water as well as large quantities of utility supplied nonpotable water. But these are the exceptions. Two-thirds of the industrial water use -- 216.6 TAF in 1989 -- is utility supplied potable water. Excluding Refining, the largest non-potable water use, 80 percent of the surveyed industries water is utility supplied.

While the Concrete plants (327) sampled show no use of nonpotable water, references on the survey instruments reveal that concrete plants do use nonpotable water and surveyed plants report that they could use more nonpotable water if it were available.

Survey respondents were asked to report the mix of sources of water over the five year period. The data show that the percentages on Table 4-3 have changed only slightly since 1985. Figure 4-2 shows the Refining industry's reported change in source of water between 1985 and 1989. Potable water use is down from 50 percent in 1985 to 45 percent in 1989. Nonpotable and groundwater use have replaced this share of potable water use. Judging

[3]PMCL, "Commercial and Industrial Water Use in Southern California," March, 1990.

TABLE 4-3
SOURCE OF WATER SUPPLIES
1989

SIC CODE	Description of Plant	Total 1989 Water Intake	Utility Supplied				Own Supplied			
			Potable		Non-Potable		Groundwater		Other Surface	
			1000 AF	(%)	1000 AF	(%)	1000 AF	(%)	1000 AF	(%)
201	Meat Products	6.7	6.7	100	0.0	0	0.0	0	0.0	0
203	Preserved Fruits & Vegetables	21.6	13.6	62	0.0	0	8.0	38	0.0	0
205	Bakery Products	1.2	1.2	100	0.0	0	0.0	0	0.0	0
208	Beverages	39.0	39.0	100	0.0	0	0.0	0	0.0	0
209	Misc. Food & Kindred Prod.	13.7	12.5	91	0.0	0	1.2	9	0.0	0
265	Paperboard Containers & Boxes	12.4	5.4	43	0.0	0	0.0	0	7.0	57
281	Industrial Inorganic Chemicals	27.2	2.7	10	12.5	46	1.0	3	11.0	41
283	Drugs	6.1	6.1	100	0.0	0	0.0	0	0.0	0
284	Soap, Cleansers, & Toilet Goods	3.3	3.3	100	0.0	0	0.0	0	0.0	0
285	Paints & Allied Prod.	1.1	1.1	100	0.0	0	0.0	0	0.0	0
291	Petroleum Refining	126.7	57.0	45	41.8	33	24.0	19	3.8	3
327	Concrete, Gypsum, Plaster Prod.	19.1	19.1	100	0.0	0	0.0	0	0.0	0
344	Fabricated Metal Prod.	8.3	8.3	100	0.0	0	0.0	0	0.0	0
357	Computer & Office Equip.	6.3	6.3	100	0.0	0	0.0	0	0.0	0
366	Communication Equipment	6.2	6.1	99	0.1	1	0.0	0	0.0	0
367	Electronic Comp. & Acc.	8.7	8.6	99	0.1	1	0.0	0	0.0	0
371	Motor Vehicles & Equip.	2.8	2.8	100	0.0	0	0.0	0	0.0	0
372	Aircraft & Parts	13.6	13.1	96	0.0	0	0.5	4	0.0	0
376	Guided Missles, Space Vehicles, Parts	3.7	3.7	100	0.0	0	0.0	0	0.0	0
	Total	327.7	216.6	66	54.5	17	34.7	11	21.8	7

Source: Survey Question II.1

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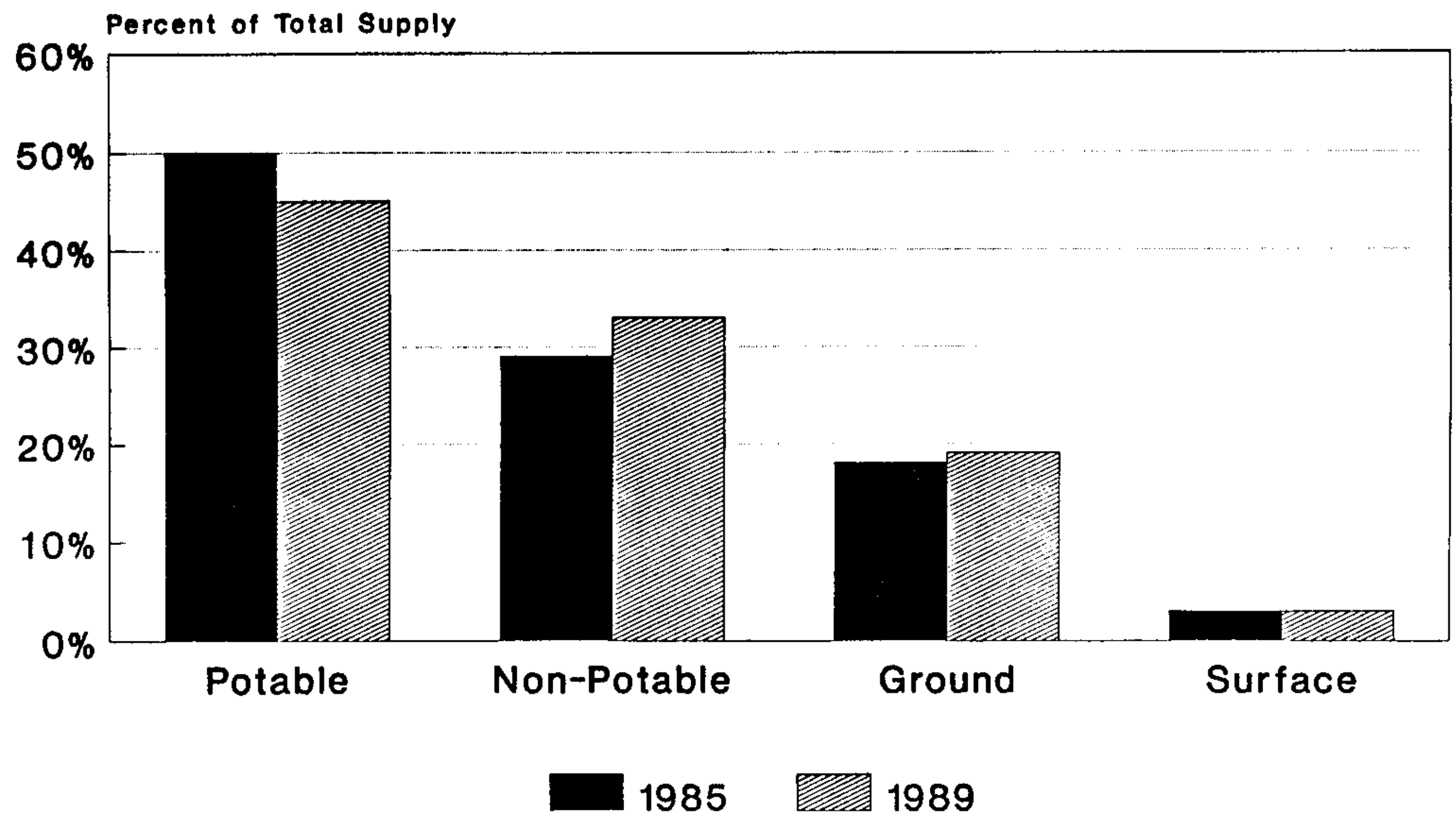
FIGURE 4-2

Change in Supply Sources for Refining Sector (1985 - 1989)



Source: Survey Question II.1

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by the Concrete plant responses and knowledge about the potential for increasing nonpotable water use in refining, more use could be made of nonpotable water for the concrete plants if it were available.

4.2 Industry Water Use Trends: 1985 - 1989

There is no current time series of industrial water use data in California. DWR last published Bulletin 124 water use estimates for the years 1972 and 1979. The Federal Census of Manufacturers last reported on industrial water use for the year 1982. PMCL did a large survey of nonresidential water use in Southern California in 1988 but reported no explicit industry totals and provided no time series. Water use estimates have been prepared covering the period 1985 through 1989. This period includes 1986, one of the wettest years in California history, followed by three years of drought.

4.2.1 Underlying Industry Production Trends

Industry production trends are reviewed succinctly to provide the background for water use trends.

Forecasts by the California Center for Study of the California Economy (CCSCE) show that production adjusted for inflation has increased in all but three of the surveyed industries over the five year period. Of these three, Communication Equipment (366) may reflect real price declines more than real production decreases; products in the High Technology industries (357, 366, & 367) came under substantial price competition during this period. The available data are not sufficiently accurate to conclude that output in the industry declined.[4] Table 4-4 shows Value of Shipments in 1987 constant dollars and employment in the surveyed industries for 1987 and 1990. 1985 data are not available. There was, however, growth in these industries between 1985 and 1987.

Output has grown, while employment has declined. Employment has dropped significantly in the High Technology/Defense and Vehicle industries and grown in the Food, Paper and Chemical industries. The divergence since 1987 between growth in Value of Shipments and decline in labor force in the High Technology, Defense and Vehicle industries means that water use trends must be understood in relation to production trends.

Dramatic improvements in labor productivity have occurred in these industries and will continue to occur throughout the 1990s. Labor productivity growth in the other sectors of

[4]CCSCE, Information provided to Spectrum, May, 1991.

TABLE 4–4
EMPLOYMENT & VALUE OF SHIPMENTS ($1987) IN THE SURVEYED INDUSTRIES

SIC CODE	Descriptions of Plant	1987 Employment (1000)	1987 Shipments ($ Billions)	1990 Employment (1000)	1990 Shipments ($ Billions)	% Change Employment (%)	% Change Shipments (%)
201,5,9	Misc. Foods	67.7	9.5	74.3	9.6	9.7	1.1
203	Preserved Fruits & Veg.	50.6	7.9	55.4	9.1	9.5	15.2
208	Beverages	26.8	7.7	27.8	9.4	3.7	22.1
265	Paperboard Containers & Boxes	18.0	3.0	18.3	3.2	1.7	6.7
283,5	Drugs & Paints	28.9	4.3	31.2	5.0	8.0	16.3
284	Soap, Cleansers, & Toilet Goods	14.4	2.6	14.8	2.9	2.8	11.5
291	Petroleum Refining	24.2	15.6	23.8	17.5	–1.7	12.2
327	Concrete, Gypsum, Plaster Prod.	19.4	3.1	21.6	3.4	11.3	9.7
344	Fabricated Metal Prod.	40.5	3.9	39.7	3.9	–2.0	0.0
357	Computer & Office Equip.	106.0	16.3	104.1	21	–1.8	28.8
366	Communication Equipment	170.4	15.1	132.6	14	–22.2	–7.3
367	Electronic Comp. & Acc.	150.4	13.6	142	16.2	–5.6	19.1
371	Motor Vehicles & Equip.	33.3	6.0	30.2	5.9	–9.3	–1.7
372,6	Aircraft & Aerospace & Parts	252.7	28.7	243.5	30.1	–3.6	4.9
	Total	1003.3	137.3	959.3	151.2	–4.4%	10.1%

Source: CCSCE, May 1991

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manufacturing can be expected over the rest of this decade as computer-augmented technology diffuses across industry, and plants mature in their use of computer controls and other labor saving technologies. Water use follows production trends, not labor force trends.

4.2.2 Estimated Industry Water Use: 1985 - 1989

Against the general backdrop of increasing output from California's large water using industrial base, Figure 4-3 shows the recent five year water use trends for each of the surveyed industries in the 12 counties. The data are provided on Table 4-6. Water use in 12 of the industries -- 60 percent of plants -- peaked in 1987 or before. The data show that water use declined among the surveyed industries over the post-1987 drought period. This also may have coincided with a final "push" to comply with the March 31, 1989 deadline for Best Practical Control Technology for industrial wastewater discharge under the 1987 Water Quality Act.

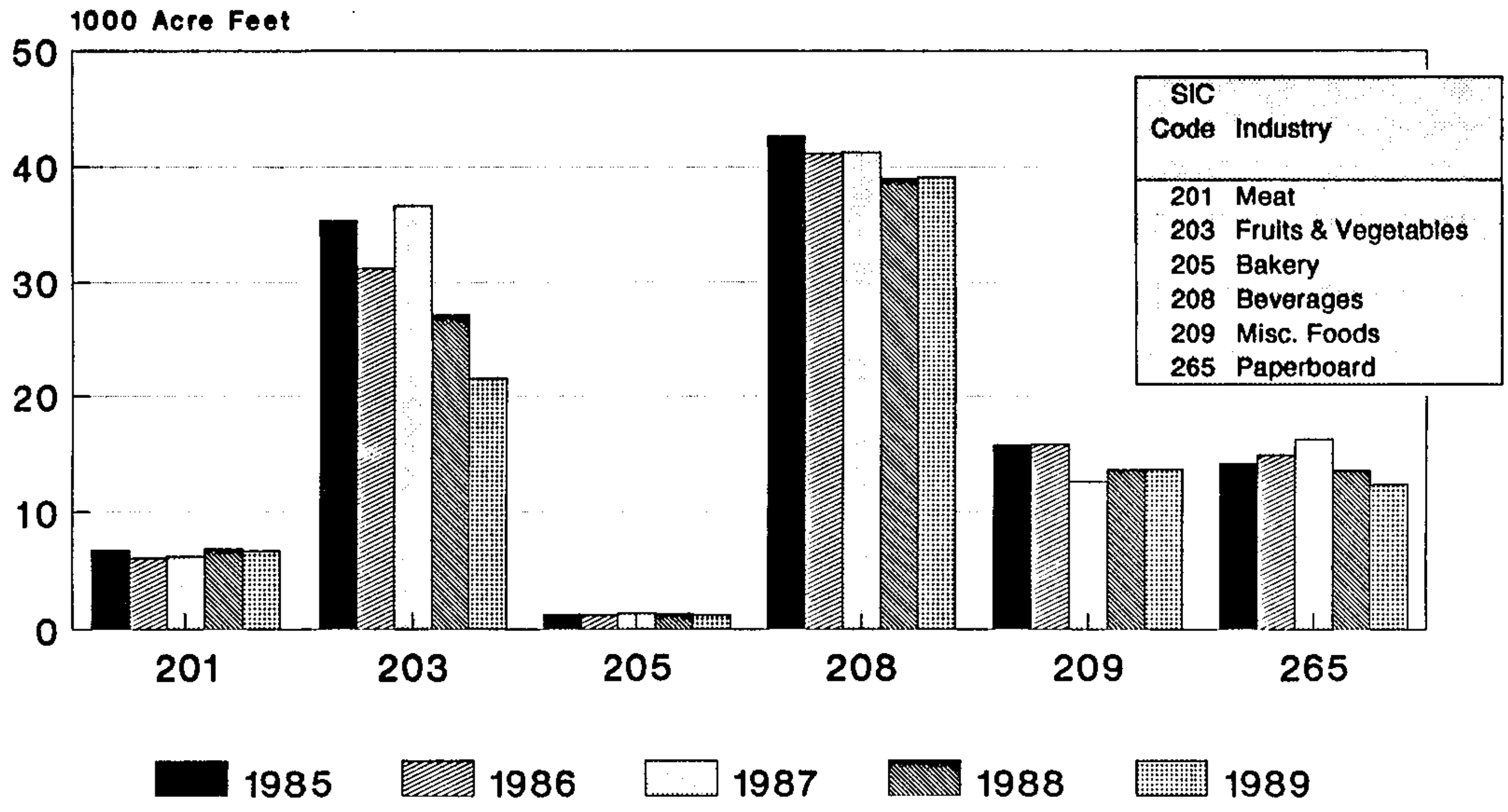
In all but six industries surveyed, water use in 1989 is lower than in prior years -- dramatically so in some industries. Led by Fruit and Vegetable packing, six industries have reduced water use more than 10 percent during the five year period as shown on Table 4-5.

TABLE 4-5
LARGEST WATER USE REDUCTIONS: 1985-1989

SIC CODE	Industry Group	% Reduction
203	Fruits and Vegetables	40
371	Motor Vehicles	33
344	Fabricated Metals	30
366	Communication Equipment	29
281	Industrial Chemicals	17
209	Miscellaneous Food	13

Source: Table 4-6 Spectrum Economics, Inc. 9/9/91

FIGURE 4-3a
Estimated Water Intake By Industry
12 County Total



Source: Survey Question II.1

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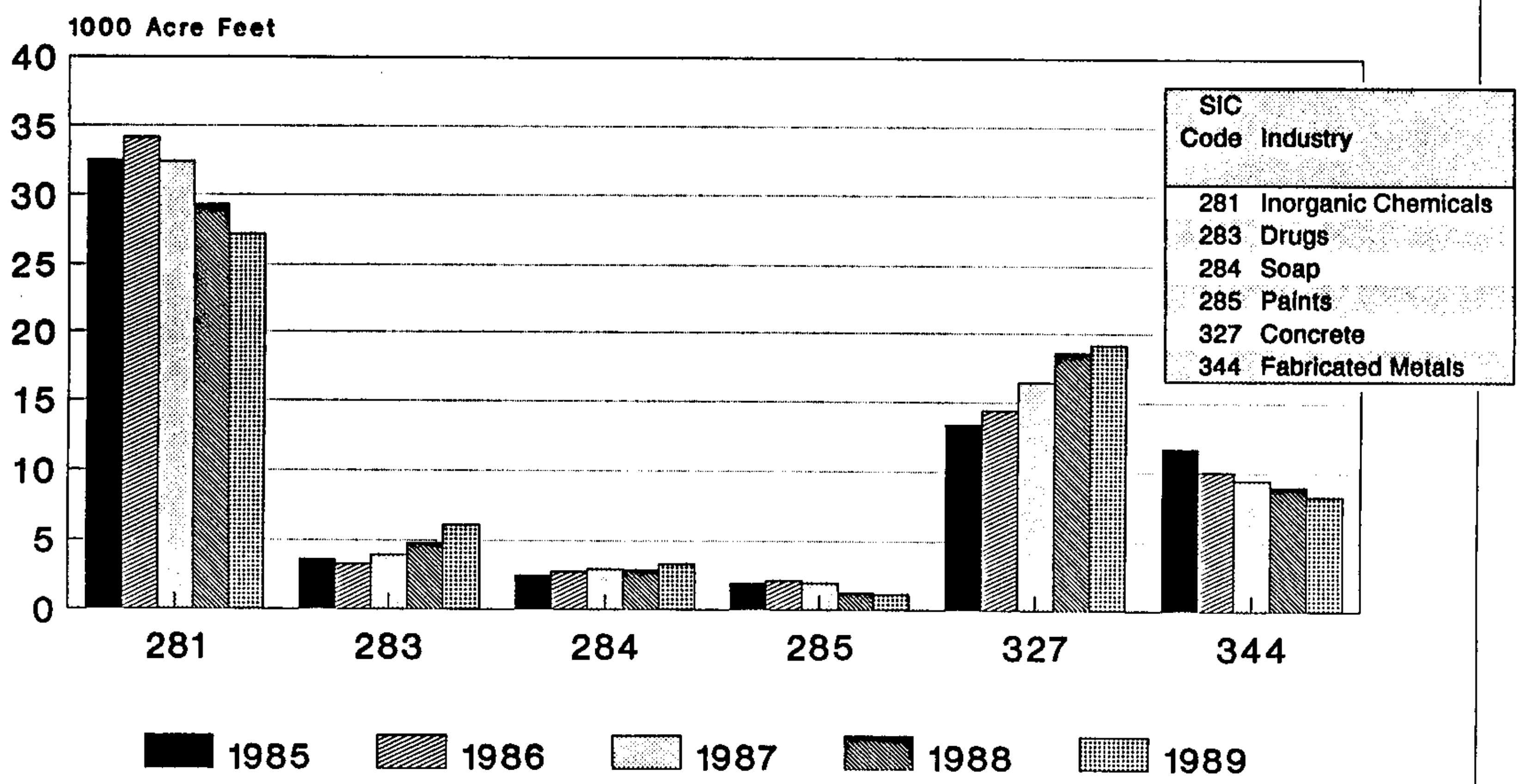
FIGURE 4-3b

Estimated Water Intake By Industry
12 County Total



Source: Survey Question II.1

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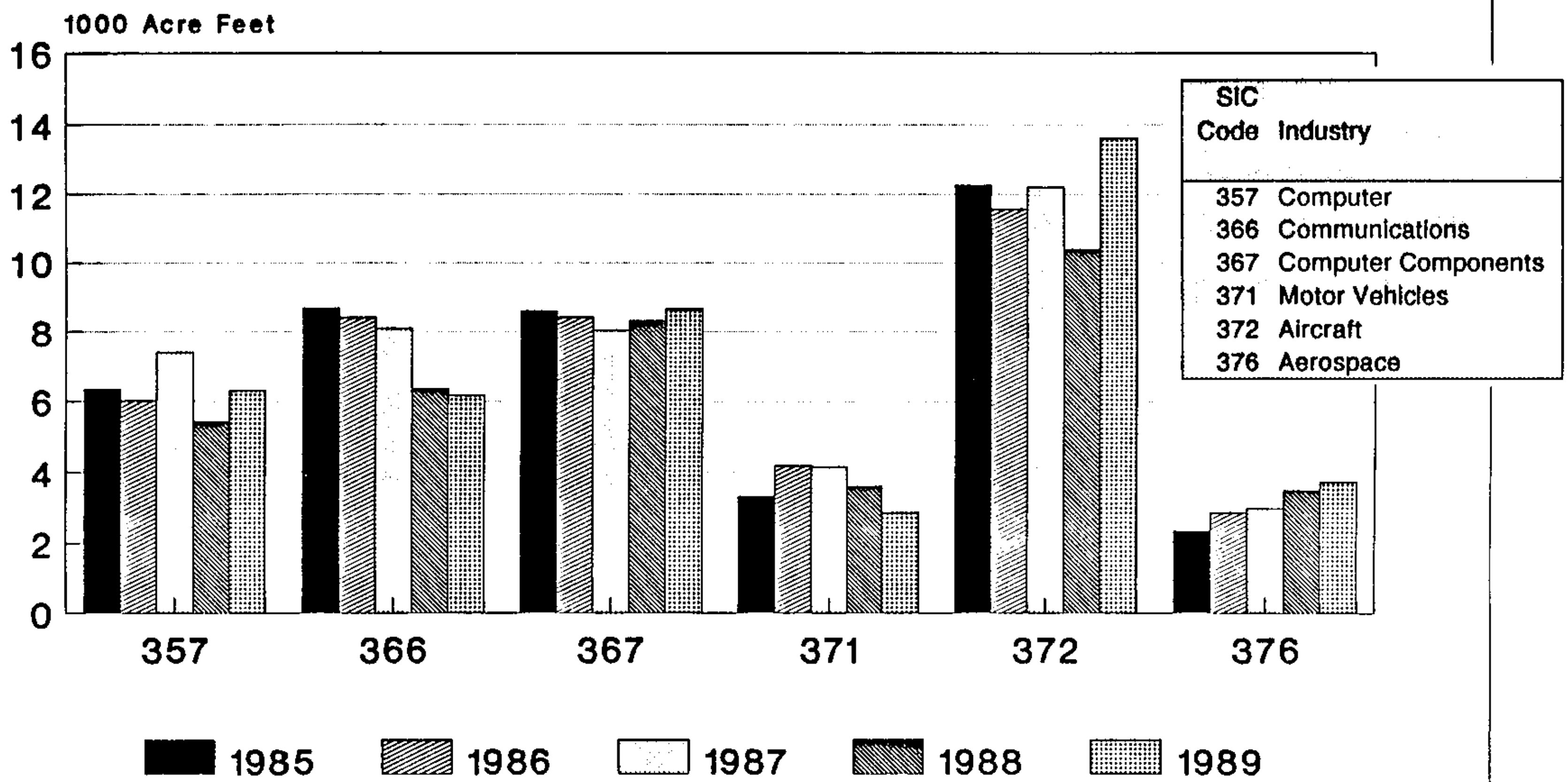
FIGURE 4-3c

Estimated Water Intake By Industry
12 County Total



Source: Survey Question II.1

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TABLE 4-6
ESTIMATED INDUSTRY WATER INTAKE 1989-1985
12 COUNTY TOTAL

SIC CODE	Description of Plant	1989 Water Use (TAF)	1988 Water Use (TAF)	1987 Water Use (TAF)	1986 Water Use (TAF)	1985 Water Use (TAF)
201	Meat Products	6.69	6.88	6.21	6.06	6.75
203	Preserved Fruits & Vegetables	21.57	27.12	36.62	31.21	35.30
205	Bakery Products	1.21	1.32	1.38	1.20	1.25
208	Beverages	39.10	38.91	41.24	41.15	42.63
209	Misc. Food & Kindred Prod.	13.67	13.60	12.56	15.79	15.77
265	Paperboard Containers & Boxes	12.36	13.54	16.29	14.93	14.17
281	Industrial Inorganic Chemicals	27.21	29.29	32.35	34.11	32.45
283	Drugs	6.09	4.76	3.94	3.25	3.62
284	Soap, Cleansers, & Toilet Goods	3.31	2.83	2.93	2.71	2.43
285	Paints & Allied Prod.	1.14	1.21	1.93	2.09	1.89
291	Petroleum Refining	126.72	136.65	125.09	120.29	128.28
327	Concrete, Gypsum, Plaster Prod.	19.14	18.53	16.41	14.42	13.38
344	Fabricated Metal Prod.	8.27	8.97	9.47	10.04	11.73
357	Computer & Office Equip.	6.29	5.42	7.41	6.02	6.33
366	Communication Equipment	6.16	6.34	8.08	8.40	8.67
367	Electronic Comp. & Acc.	8.66	8.30	8.03	8.42	8.59
371	Motor Vehicles & Equip.	2.85	3.58	4.16	4.19	3.30
372	Aircraft & Parts	13.61	10.39	12.21	11.58	12.26
376	Guided Missles, Space Vehicles, Parts	3.71	3.47	2.97	2.84	2.33
	Total	327.74	341.11	349.25	338.68	351.09

Source: Survey Question 11.1
TAF - Thousand Acre Feet

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TABLE 4-7
INDUSTRIES WITH INCREASED WATER USE: 1985-1989

SIC CODE	Description of Plant	% Increase
283	Drugs	68
284	Soaps and Cleansers	36
327	Concrete	43
367	Computer Component	1
372	Aircraft	11
376	Aerospace	59

Source: Table 4-6 Spectrum Economics, Inc. 9/9/91

Six industries are shown by survey data show to have increased water use over the five year period. They are listed on Table 4-7.

Keep in mind that the 1985 water use estimates rest on 158 observations while the 1989 water use estimates rest on 205 observations. Sampling error, therefore, increases for some industries going back in time. The confidence interval widens. The interested reader is directed to Appendix E for a discussion of the calculation of confidence intervals and to Table E-1 for the calculations. For instance, Table E-1 shows that the 1989 water use estimate for Electronic Components (367) for 1989 falls wholly within the confidence interval for 1985 water use. Hence, the increase shown for the industry is statistically non-significant. Although not shown on either of these tables, this also applies to the Computer industry group (357). Water use trends cannot be inferred statistically from the data for these two industry groups. Otherwise, the trends shown on Tables 4-5 and 4-7 are statistically significant.

4.2.3 Plant Expansion Plans

Plant utilization rates together with survey responses to resizing plant operations suggest that several of the large water using industries in the 12 county area can be expected to change the size of operations over the next few years. Table 4-8 shows the answers to survey questions about plant capacity utilization and plans to resize the operation. The table shows the percentage of plants that operated above 95 percent of capacity in 1989 and the percentage that operated below 70 percent of capacity. These capacity utilization points are assumed to be crossover points when industries might be expected to resize.

TABLE 4–8
PLANT EXPANSION PLANS

SIC CODE	Description of Plant	1989 Plant Capacity Utilization: Less Than 70% (%)	1989 Plant Capacity Utilization: Greater Than 95% (%)	Plan To Resize: Yes (%)	Plan To Resize: No (%)
201	Meat Products	0	0	0	100
203	Preserved Fruits & Vetables	50	50	33	67
205	Bakery Products	38	24	25	75
208	Beverages	12	24	13	87
209	Misc. Food & Kindred Prod.	27	27	36	64
265	Paperboard Containers & Boxes	30	30	20	80
281	Industrial Inorganic Chemicals	25	50	50	50
283	Drugs	16	50	57	43
284	Soap, Cleansers & Toilet Prod.	50	0	25	75
285	Paint & Allied Prod.	0	0	50	50
291	Petroleum Refining	0	42	33	67
327	Concrete, Gypsum, Plaster Prod.	25	25	17	83
344	Fabricated Metal Prod.	45	27	30	70
357	Computer & Office Equip.	40	10	27	73
366	Communication Equipment	26	37	14	86
367	Electronic Comp. & Acc.	36	20	34	66
371	Motor Vehicles & Equip.	50	0	40	60
372	Aircraft & Parts	26	26	18	82
376	Guided Missles, Space Vehicles, Parts	37	62	43	57

Source : Survey Questions I.11 & I.16

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With one notable exceptions -- Drugs (283) -- more than half of the plants in the industries reported no plans to resize the operation. The Drug industry has innovated several new biotechnology products in recent years and will expand production facilities, led by some of the Silicon Valley "break-outs." Fruit and Vegetable processors (203) are reducing plant operations in the coastal areas and moving the plants toward lower cost labor. In 1989, half of the packing plants in the 12 county area operated at less than 70 percent capacity and may be expected to contracted or shut-down. Water use was shown above to have decreased dramatically in the Fruit and Vegetable plants between 1987 and 1989. Some of the reduction may have been associated with plant closures. Fifty percent of Industrial Chemicals (281) plants operated above 95 percent utilization and half of the plants report plans to resize. This industry will expand. Two-thirds of Refineries (291) reported no current plans to resize operations. Refineries are waiting for final resolution of future fuel formulas keyed to the Administration's Clean Air Act before initiating any major plant expansions or modifications.

4.3 Water Use and Employment

Water use requirements vary greatly between industries depending mostly on differences in the cooling load, wastewater disposal limitations and process use differences -- as well as the extent of industry adopted conservation. Water use differences within plants of an industry defined by 3-digit SIC codes vary in relation to the exact product and its production process, the technology of the production process, and the extent of plant adopted conservation. While recognizing these difference, it is common to relate plant or industry water use to the number of employees. Mostly, the reason for this benchmark is that industry employment data can be developed from external sources. The annual estimates of water use within this report are tied to annually sampled production workers in relation to the industry total. While labor and water may be common across plants and industries, virtually everything else that dictates water use may differ. Consequently, great care must be taken in forming conclusions about water-use-per-employee trends.

Table 4-9 shows the five year water use per production employee from the sampled plants. There are two distinct trends in the five years of data:

1. The industries which have achieved dramatic growth in labor productivity in recent years show increasing water use per production worker;

2. The industries with stable or growing employment show declining water use per production worker.

No conclusions about conservation differences among industries can be inferred from examining water use in relation to employment -- at least over the most recent five years of

TABLE 4-9
WATER USE PER PRODUCTION EMPLOYEE
GALLONS / OPERATING DAY

SIC CODE	Description of Plant	By SIC Code 1989	1988	1987	1986	1985	Ranked By 1989 Data SIC CODE	1989	1988	1987	1986	1985
201	Meat Products	1081	1064	1063	1087	1179	291	18242	19703	19142	18376	18496
203	Preserved Fruits & Vegetables	1575	1981	2544	2252	2348	208	7249	7318	7920	8129	7697
205	Bakery Products	128	141	156	128	135	281	3365	3903	4485	4608	4255
208	Beverages	7249	7318	7920	8129	7697	327	2168	2206	2129	2054	1975
209	Misc. Food & Kindred Prod.	1103	1088	970	1261	1356	203	1575	1981	2544	2252	2348
265	Paperboard Containers & Boxes	1272	1377	1586	1486	1419	265	1272	1377	1586	1486	1419
281	Industrial Inorganic Chemicals	3365	3903	4485	4608	4255	209	1103	1088	970	1261	1356
283	Drugs	773	604	603	529	578	201	1081	1064	1063	1087	1179
284	Soap, Cleansers & Toilet Goods	516	429	492	494	460	283	773	604	603	529	578
285	Paints & Allied Prod.	427	405	692	762	678	284	516	429	492	494	460
291	Petroleum Refining	18242	19703	19142	18376	18496	344	432	498	495	492	528
327	Concrete, Gypsum, Plaster Prod.	2168	2206	2129	2054	1975	285	427	405	692	762	678
344	Fabricated Metal Prod.	432	498	495	492	528	357	249	229	272	217	224
357	Computer & Office Equip.	249	229	272	217	224	366	160	161	183	186	185
366	Communication Equipment	160	161	183	186	185	376	157	145	125	127	127
367	Electronic Comp. & Acc.	128	122	116	123	114	372	156	123	140	135	147
371	Motor Vehicles & Equip.	151	177	214	222	157	371	151	177	214	222	157
372	Aircraft & Parts	156	123	140	135	147	367	128	122	116	123	114
376	Guided Missles, Space Vehicles, Parts	157	145	125	127	127	205	128	141	156	128	135

Source: E.D.D. & Survey Question I.10 & II.1

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data.[5] Water use must be examined in relation to plant production to form useful conclusions about conservation. Moreover, forecasting future water use in relation to fixed water-use-per-employee ratios ignores both changing trends in labor productivity and the diffusion of conservation.

4.4 Water Use Differences Among Industries

Industry's problems caused by water shortages relate, in part, to the way water is used in the plant -- cooling, process, sanitation, irrigation. Understanding how water is used differently among the largest water using industries is necessary to understand how shortages would cause production problems.

Water is not ancillary to plant production for the surveyed industries. Figure 4-4 shows how water is used in the responding plants by industry group for 1989. Water used directly in the manufacturing process is shown to be the leading water use category in most of the industries. Refining and Industrial Chemicals are the major exceptions.

Process use includes:

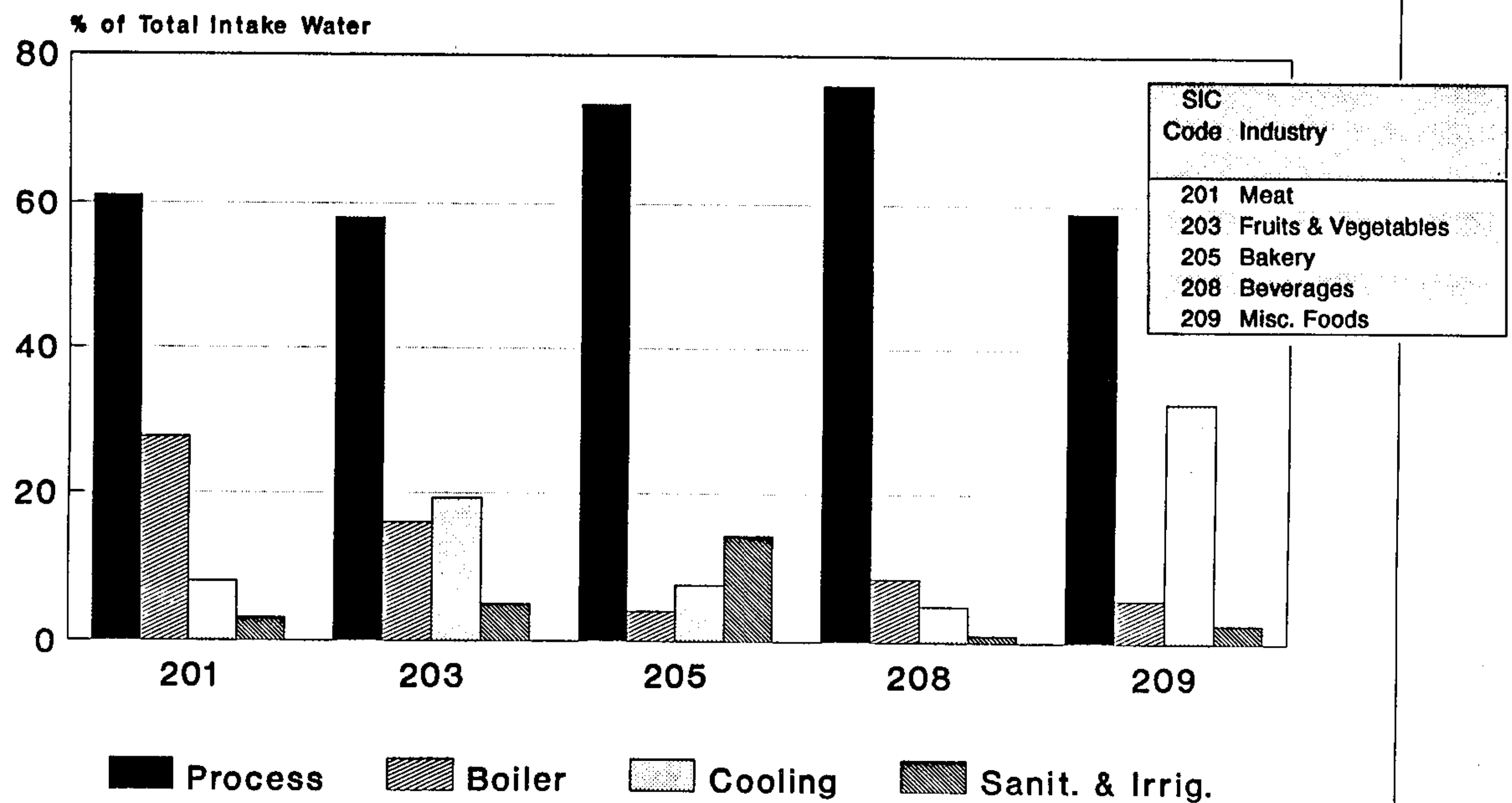
1. Embodied in product
2. Washing/rinsing/diluting
3. Other uses.

The Food industries show the highest percent of process water use -- between 60 and 80 percent directly in the process as can be seen on Figure 4-4a. For example, water <u>is</u> the major ingredient of the product for the Beverage industry (208). But water also is used importantly to wash bottles and clean equipment. Water is used to wash and can fruits and vegetables -- and goes into the cans with the product. Water is used as an ingredient of bakery products and for cleaning. Water also has important uses within the process for manufacture of the Drug, Cleansers and Paint industries (283,4,5). Water becomes part of the product of the Soaps and Cleansers industry (284) and part of the product of latex paints in the Paint industry (285). It is an essential ingredient of the product in the concrete (327) industry. The sampled paper industry is a water intensive process like virtually all paper manufacturing processes.

Among the High Technology industries, Computer Components (367) and Computer Equipment (357) are the most water intensive. Microchips (367) are manufactured in a wet

[5]Over the longer time horizon, for instance, comparing DWR Bulletin 124 for 1972 and 1979 with each other and with data from this survey, reveals that water use per employee has decreased. Wastewater discharge limitations post the implementation of the Clean Water Act of 1972 had the effect of increased recycling of water use to reduce discharge -- notably cooling water recycling.

FIGURE 4-4a
Typical Intake Use Profile



Source: Survey Question II.3

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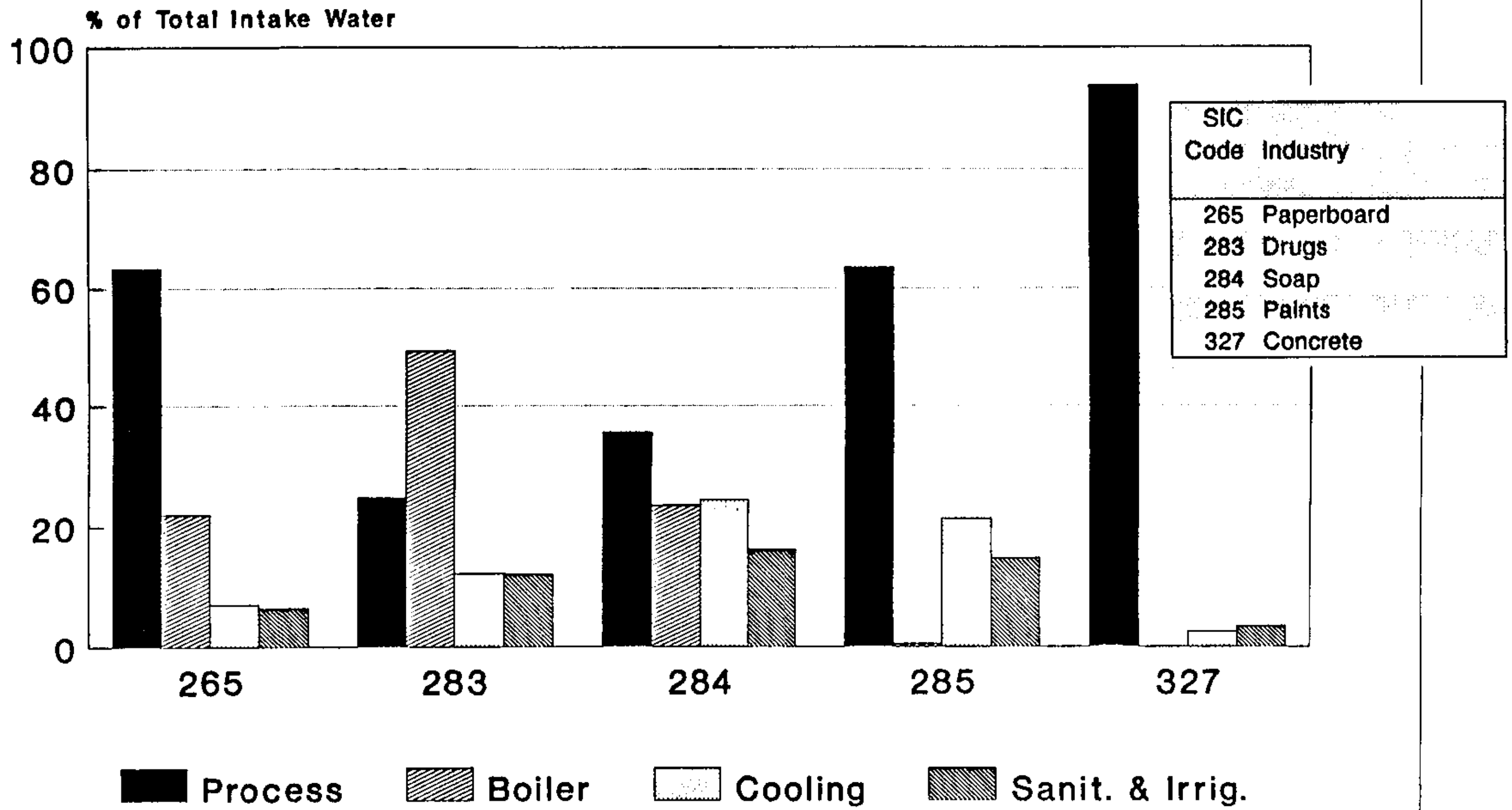
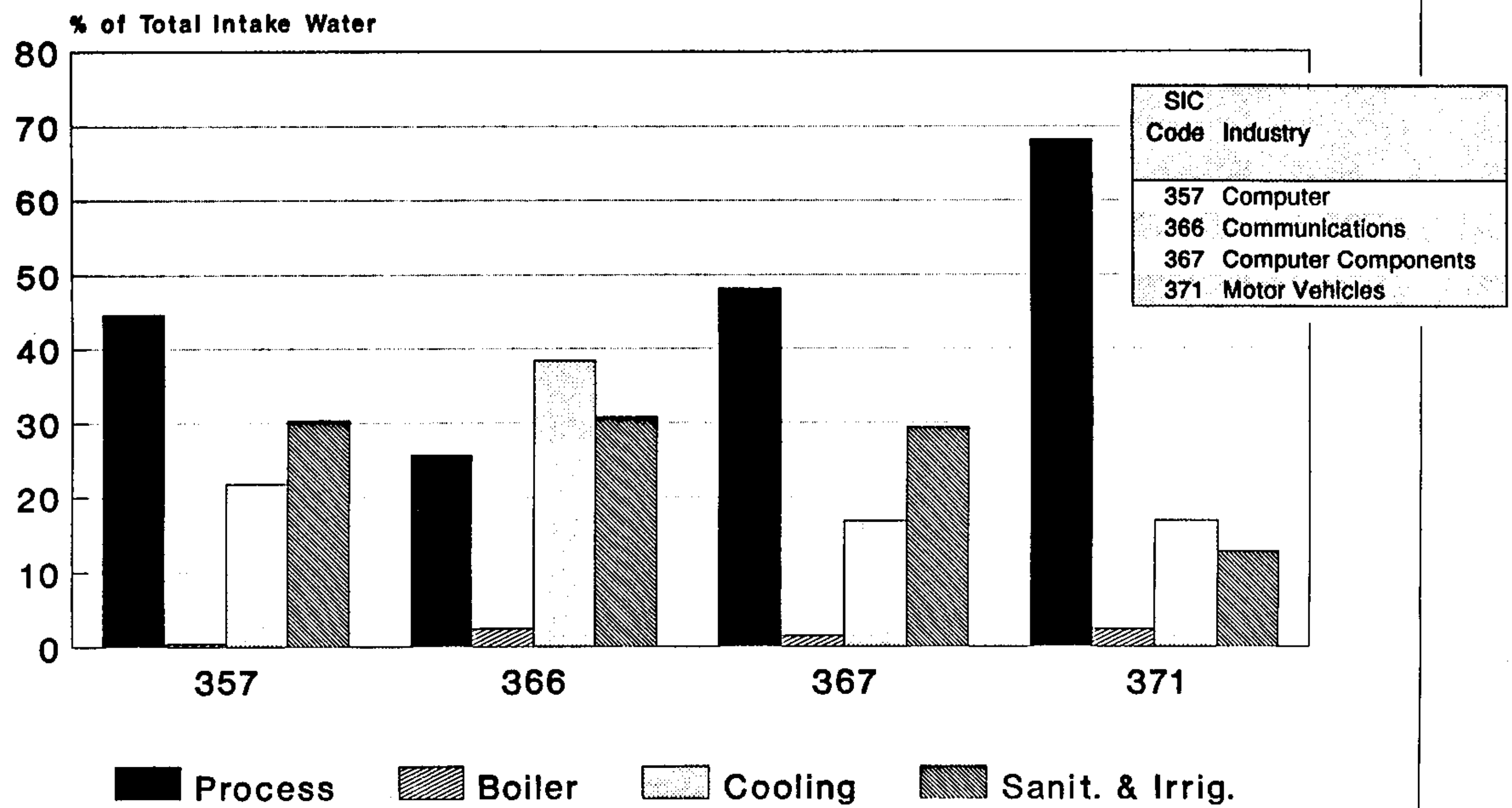
FIGURE 4-4b
Typical Intake Use Profile



Source: Survey Question II.3

Spectrum Economics, Sept. 1991

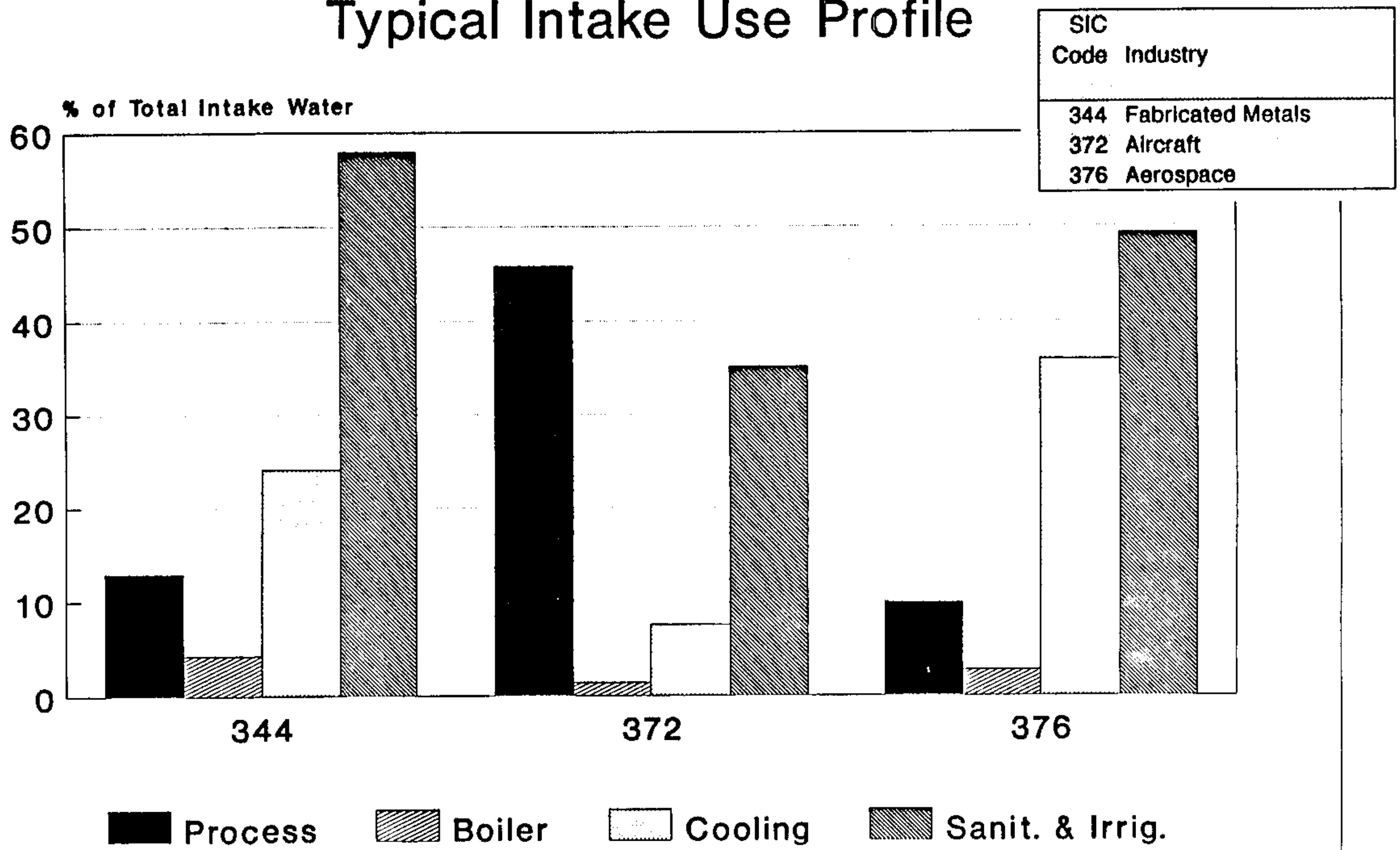
FIGURE 4-4c
Typical Intake Use Profile



Source: Survey Question II.3

Spectrum Economics, Inc. Sept. 1991

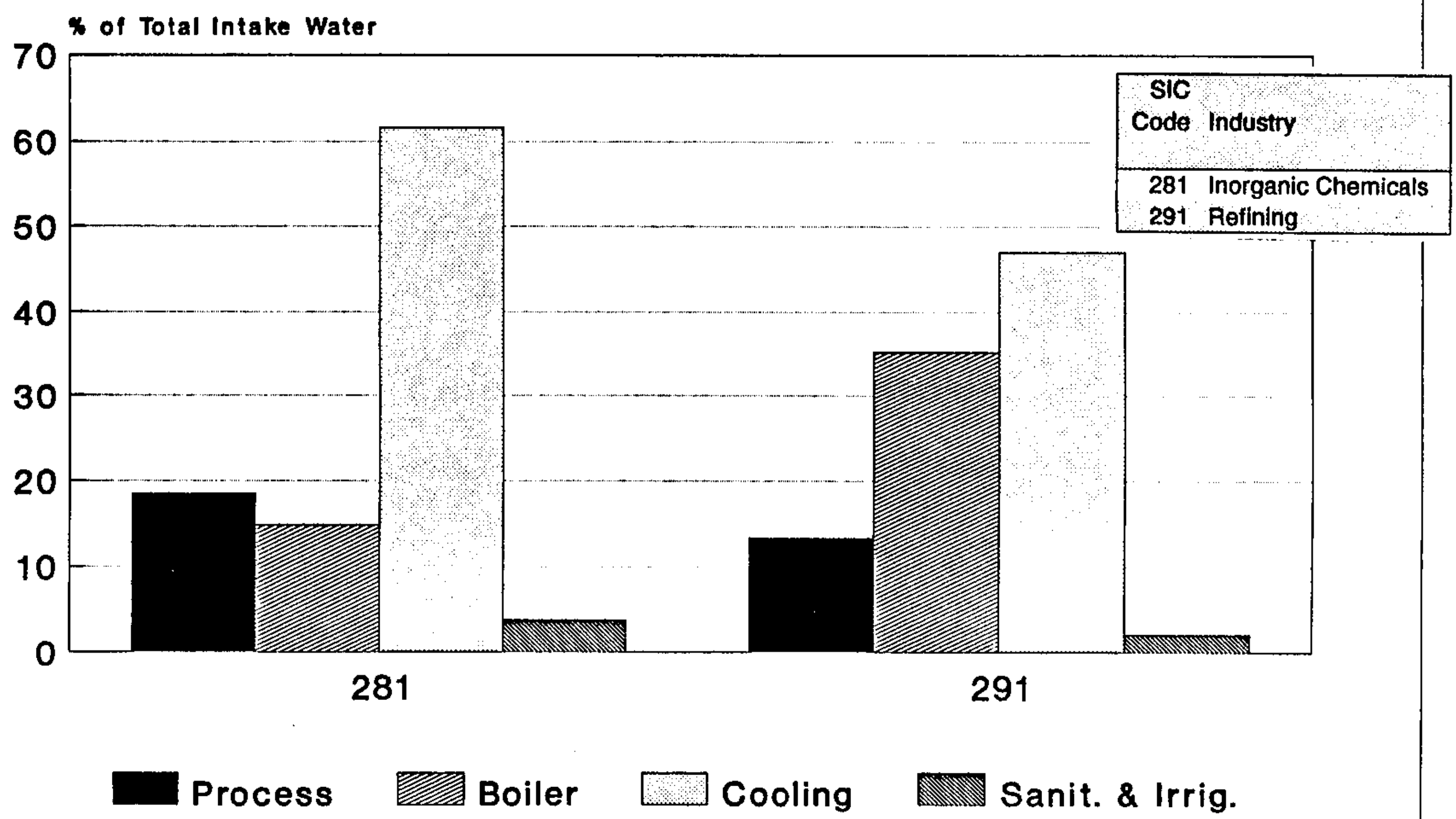
FIGURE 4-4d
Typical Intake Use Profile



Source: Survey Intake II.3

Spectrum Economics, Inc. Sept. 1991

FIGURE 4-4e
Typical Intake Use Profile



Source: Survey Question II.3

Spectrum Economics, Sept. 1991

environment with much necessary rinsing. Computer Equipment manufacturing (357) uses a great deal of water also for rinsing. In contrast to the computer and microchip industries, the Communication Equipment industry (366) is shown to be less process water intensive. Most of the water use is used for air cooling.

Motor Vehicle manufacturing (371) is also process water intensive. The water is used for rinsing and washing. A significant amount of metal plating (which is process water intensive) occurs in the Aircraft industries (372). This also occurs in the Fabricated Metals industry (344), but to a lesser extent. While the overall Aerospace industry (376) is not process water intensive, electronic applications within this very large Defense industry depend heavily on water as part of the process. Activities within the industry include the same types of operations found in the High Technology industries -- rinsing and washing electronic components.

Petroleum Refining and Industrial Chemicals are both large water using industries and both use water mostly for cooling. Section 4.1.3 previously showed that the Industrial Chemical water use was mostly nonpotable and surface water. This water is cooling load to a large extent. The refineries by contrast have both a large cooling load and a large steam requirement. Steam requires potable water while cooling can use nonpotable sources. While the Refining sector uses a large amount of water relative to all other industrial sectors -- three times as much as the next largest using sector Beverages (208) -- its potable water use for steam, process and sanitary is only 52 percent of its total requirement. Potable water used for cooling could be replaced by air cooling or by increased use of nonpotable water, including plant-produced water.

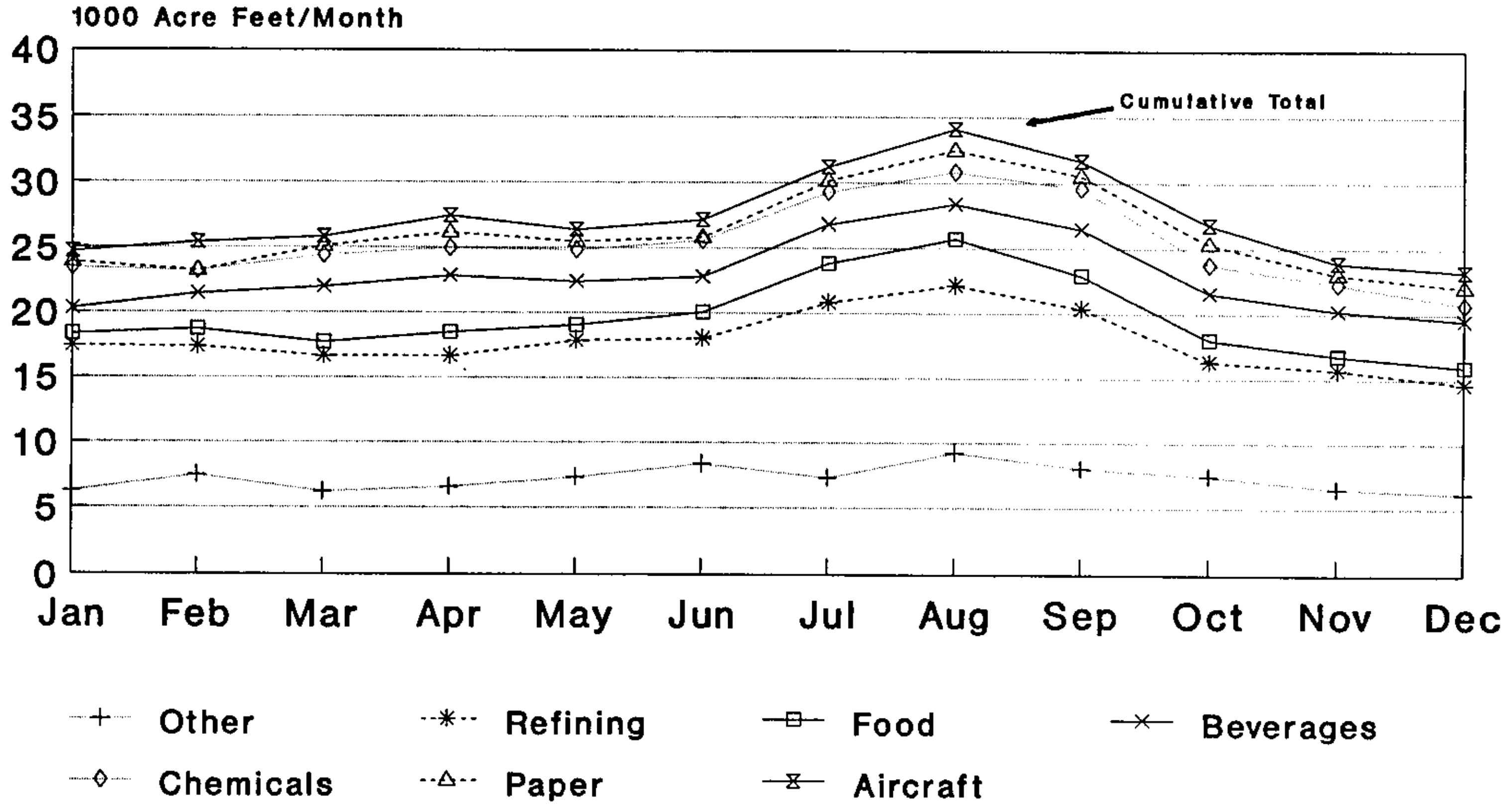
4.5 Seasonality of Water Use

Driven mostly by the seasonal needs of the food packing industry coincident with the summer air conditioning peak, water requirements peak in August. Forty percent of industrial water is consumed during the four months, June through September. A seasonal water shortage during this period would have a larger impact on industry than a shortage in other times.

Figure 4-5 shows the monthly use patterns for selected industries with the most pronounced seasonal use patterns and large water requirements. Shown also is the industry total. Water use peaks in August near 35,000 AF/month and drops to 25,000 AF during December, January and February. The seasonal summer peak is 27 percent higher than the annual average.

FIGURE 4-5

Seasonality of Water Use
Cumulative Water Use over Industry



Source: Survey Question II.2

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4.6 Historical Water Use: 1970, 1979, 1989

So many changes have occurred within the industries over the last twenty years that industry production in 1989 is hardly comparable to production in prior years. Nonetheless, the available data from DWR's prior Bulletin 124s for 1970 and 1979 are presented on Figure 4-6 to compare with the estimate of 1989 fresh water use. DWR data are adjusted to conform to the same 12 counties included within our survey.

Three patterns can be observed from the data:

1. Industries which were mature by 1970, and used very large amounts of water, reduced their fresh water intake dramatically over the last 20 years. These include:

    203 Fruit and Vegetables
    281 Industrial Chemicals
    291 Refining

    Over the last 20 years these three industry groups alone have reduced their fresh water intake by nearly 65 percent -- 170,000 AF annually. Substantial recirculation replaced once through cooling and there was a shift from potable to nonpotable sources. Particularly the Chemical and Petroleum industries, which had been discharging water directly into navigable waters prior to the Clean Water Act, were induced to make operational changes by the 1972 legislation. These largest water using industries appear to have reduced their freshwater intake as one strategy to reduce their wastewater discharge.

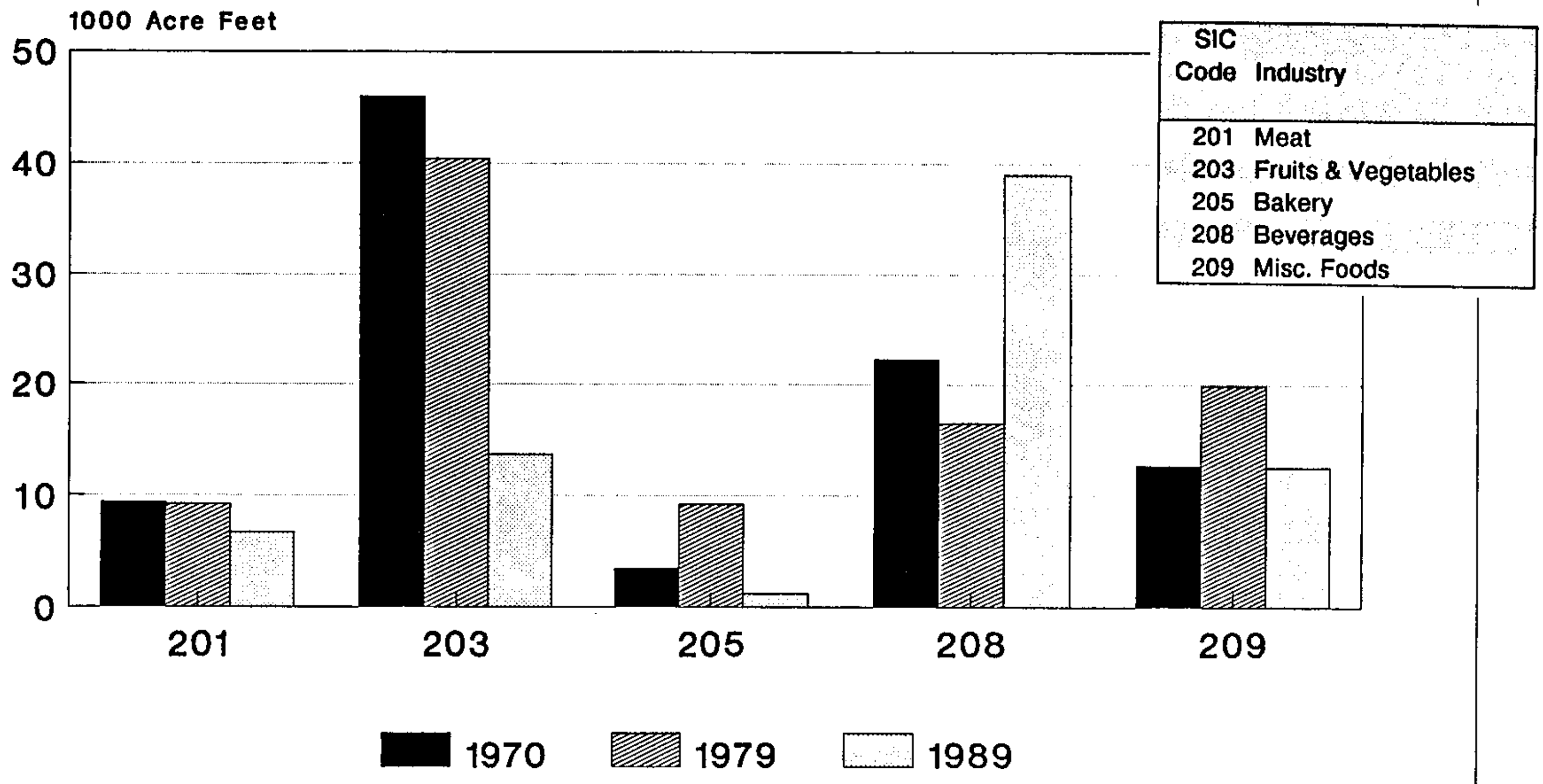
2. Industries which grew dramatically during the 1970s reduced water use after 1979. These are most of the industries on Figure 4-6.

    The 1977 amendment to the 1972 Clean Water Act required pretreatment of industrial discharge to wastewater utilities. (See 40 CFR 403 for the pretreatment regulations.) These broadsweeping regulations appear to have caused a second round of actions to reduce intake water as one strategy to reduce wastewater discharge. These regulations -- and possibly the drought of 1976-1977 -- appear to have modified the way water is used in plants in these groups.

3. Industries, tied to population and cyclical Defense industry growth, increased water use since 1979. Examples are:

    208 Beverages
    344 Fabricated Metals
    372 Aircraft

FIGURE 4-6a
Historical Fresh Water Use by Industry



Source: DWR Bulletins, 124-2, 124-3 &
Survey Question II.1
DWR Water Data For 12 Counties

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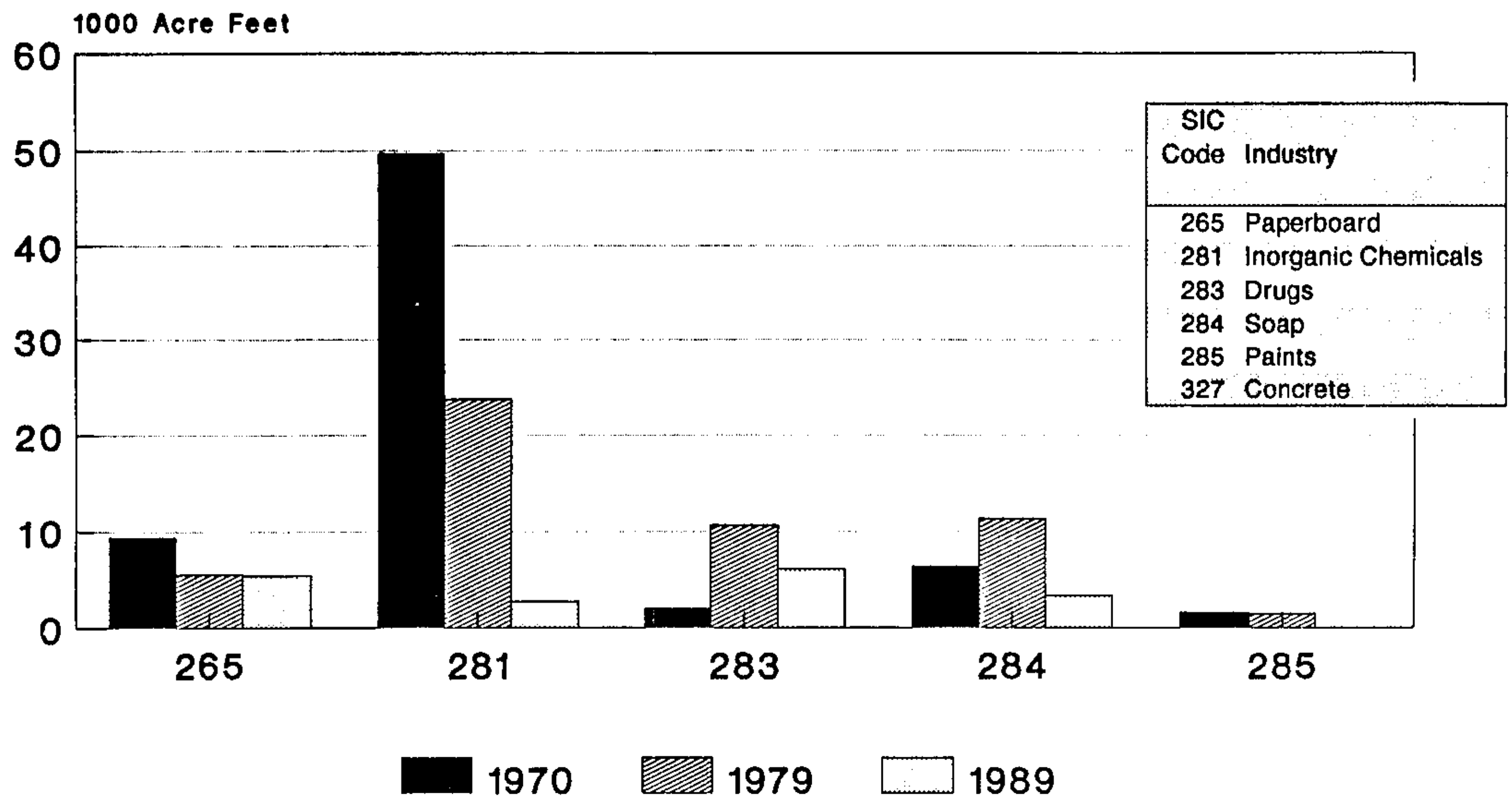
FIGURE 4-6b

Historical Fresh Water Use by Industry



Source: DWR Bulletins, 124-2, 124-3 &
Survey Question II.1
DWR Water Data For 12 Counties

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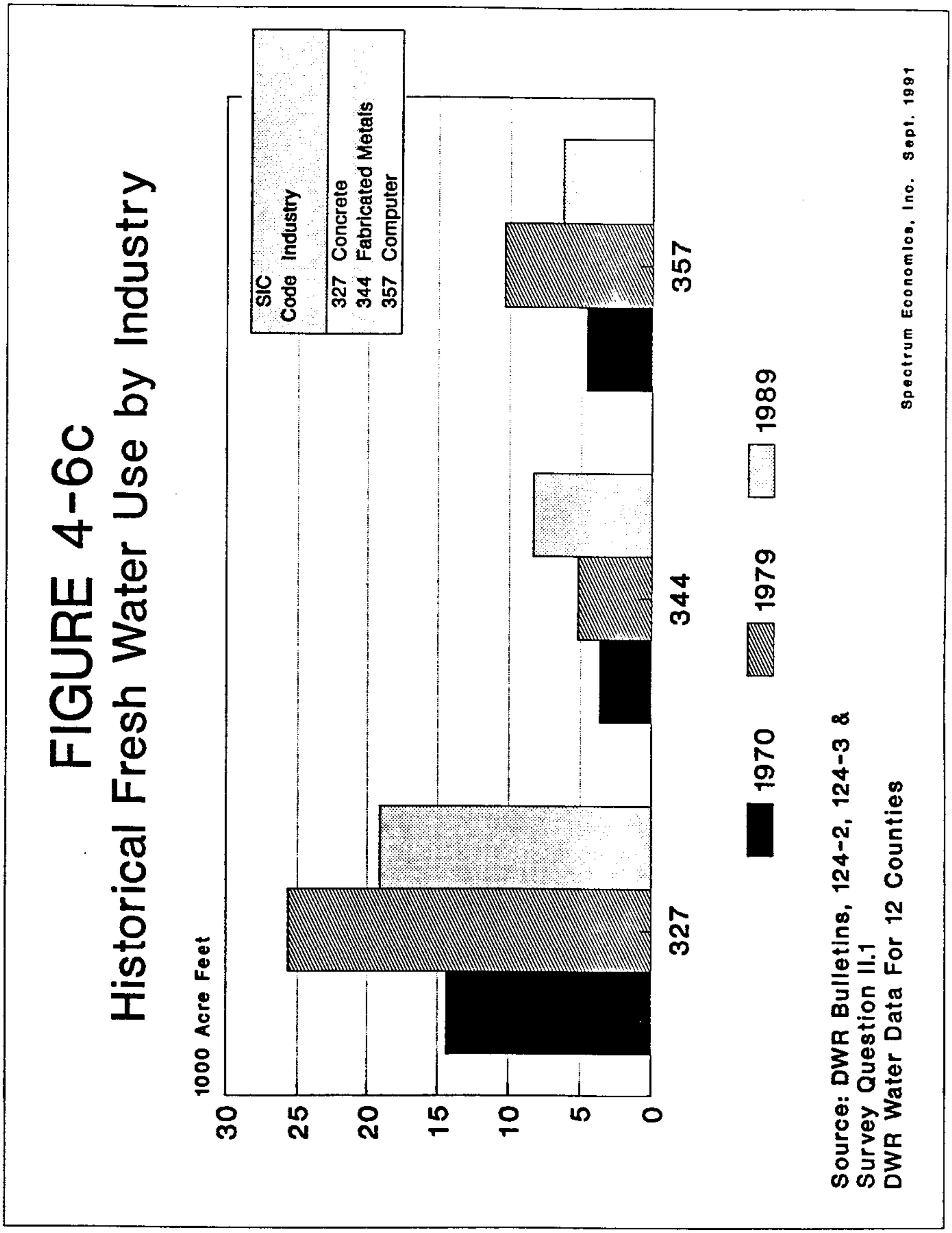
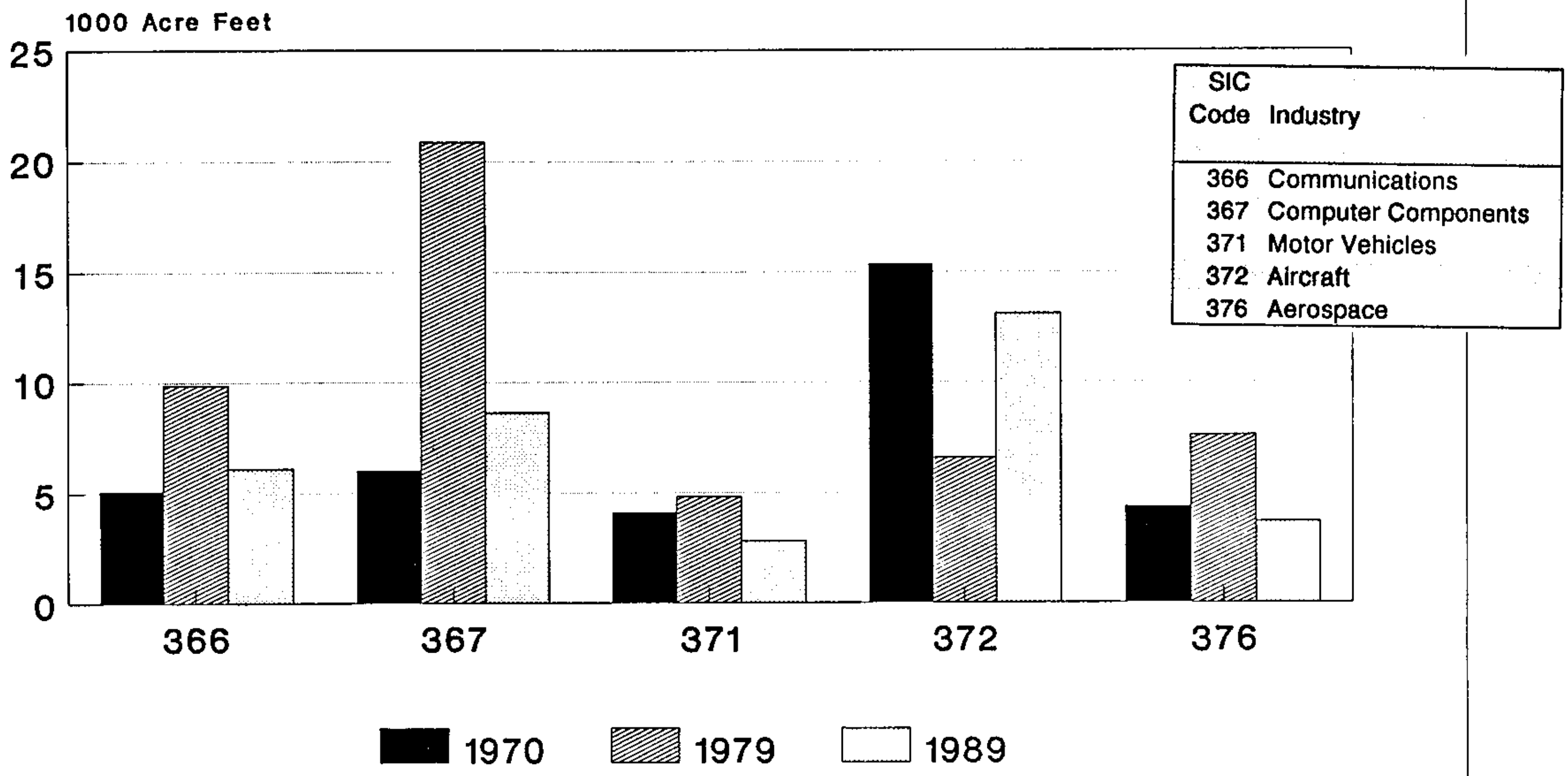


FIGURE 4-6c
Historical Fresh Water Use by Industry
1000 Acre Feet
30
25
20
15
10
5
0
327
344
357
SIC Code Industry
327 Concrete
344 Fabricated Metals
357 Computer
1970
1979
1989
Source: DWR Bulletins, 124-2, 124-3 &
Survey Question II.1
DWR Water Data For 12 Counties
Spectrum Economics, Inc. Sept. 1991

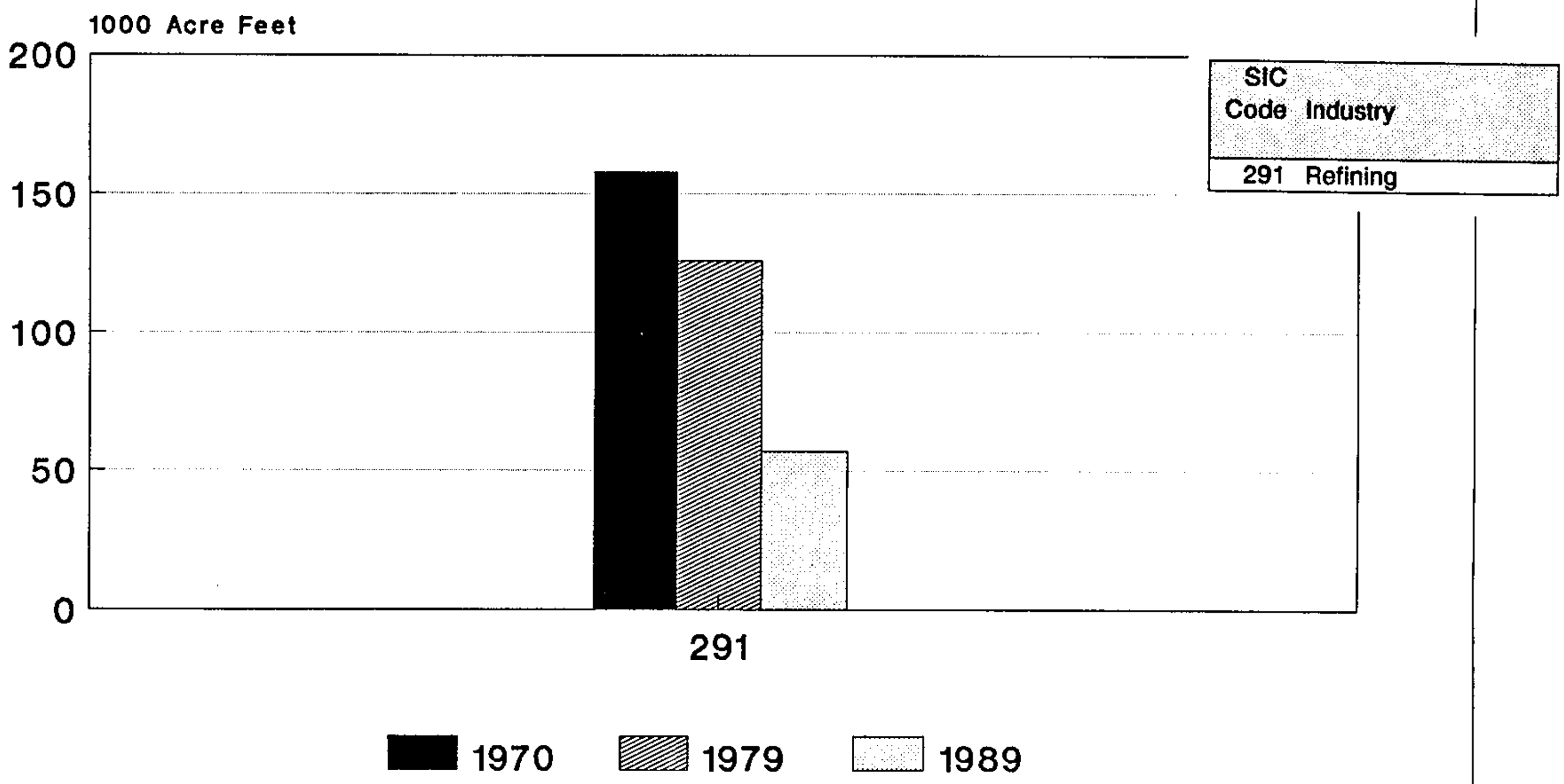
FIGURE 4-6d
Historical Fresh Water Use by Industry



Source: DWR Bulletins, 124-2, 124-3 &
Survey Question II.1
DWR Water Data For 12 Counties

Spectrum Economics, Inc. Sept. 1991

FIGURE 4-6e
Historical Fresh Water Use by Industry



Source: DWR Bulletins, 124-2, 124-3 &
Survey Question II.1
DWR Water Data For 12 Counties

Spectrum Economics, Inc. Sept. 1991

Water use in the Beverage group (208) reflects very rapid growth of the industry post 1979 as both new products have been introduced and accepted, and international trade has increased. The Fabricated Metals group (344) is directly linked to the expansion of the Aircraft sector.

While a substantial number of interesting research questions are posed by this time series, the essential theme to emphasize is the amount that fresh water use has been reduced. Refineries have reduced fresh water intake 100,000 AF/year in the last 20 years. Some of this reflects closures and consolidations within the refining sector; but much of it reflects substantially increased cooling tower recirculation and improved cooling tower technology to reduce required make-up water. Industrial Chemical plants freed up over 40,000 AF/year by switching to nonpotable sources.

During the 1980s, effluent controls replaced dilution as the industrial operating environment in California. The Water Quality Act of 1987 extended the compliance deadline of Best Practical Control Technology to limit effluent discharge under section 304 of the regulations to March 31, 1989. This has caused -- and continues to cause -- a reduction of fresh water inflow as one way to limit wastewater discharge.[6]

[6]Environmental Law Institute, Clean Water Deskbook, Washington, D.C., 1988. This reference provides a very cogent overview of the water quality laws.

5.0 INCENTIVES FOR CONSERVATION

This section of the report investigates the incentives for industrial water conservation. Incentives vary across industries in relation to the value of the water to the production process and the cost of water plus wastewater pretreatment and discharge. In certain industries, wastewater disposal and pretreatment costs add a substantial element of cost to using intake water. A simple microeconomic model is postulated that explains why plants have aggressively pursued conservation. The costs avoided by conservation are estimated for each industry. The marginal value of water to plants, expressed as lost plant operating profits due to shortage, is estimated from survey and industry data. Conservation is shown to be adopted both to reduce costs and/or to reduce the risk of plant production losses.

5.1 Economic Model of Intake Water Supply and Wastewater Disposal

Water costs historically have been a small fraction of total plant operation costs for most industries. Water was an abundant resource to be applied to the production process in whatever manner was necessary to complement the installed capital equipment.[1] Plant profit maximizing decisions treated water as a very low cost input until recently when:

1. Treating and disposing of water became very costly;

2. Limited water supplies became a constraint on production during the current California drought.

These factors have changed management perspective -- not suddenly, but in an evolutionary way since passage of the Clean Water Act in 1972, its amendment in 1977, its revision with the Water Quality Act of 1987, and with "one last shove" during the current drought. Regardless of exactly when it occurred -- there is no 1973 OPEC crisis to exactly date when water, like energy, became another business problem to solve -- water is now recognized by industry as a valuable, scarce resource to be managed like the other inputs to the production process.

Effluent reduction may be a major driving force nationwide; but in California limited or unreliable water supplies have become an equally, if not more, significant force for water

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[1]There are few econometric estimates of the substitutability of capital equipment for intake water for industries. One citation: Babin, Willis, and Allen, "Estimation of Substitution Possibilities between Water and Other Production Inputs," American Journal of Agricultural Economics, p. 148-151, 1982.) Diana C. Gibbons, The Economic Value of Water, "Industry," (Washington: Resources For The Future, 1986.) surveyed the economic literature industrial water use for the 20 years prior to 1986 in only eleven pages.

conservation. As a result, reducing water inflow by increasing reuse and recirculation within the plant is now widespread within California's plants. There is no research in the literature that has analyzed water use decisions under this new regime of unreliable supplies and wastewater discharge restrictions.

Industrial water consumers will take measures to create more "supply" out of their existing usage both to lower their cost of operations and to avoid actual -- or the perceived risk of potential -- production losses from shortages of varying lengths. These two motivating forces are discussed in the next three sections.

5.1.1 Water Cost Has Four Components

From industry's perspective, the cost of water is not simply its purchase price. Rather, the direct cost of using water is the sum of four components:

1. Purchase price
2. Process water pretreatment cost
3. Wastewater pretreatment cost
4. Wastewater discharge fees.

These four components of the cost of water services differ across industries according to plant production process requirements, available water supply sources, discharge requirements, and serving utility circumstances which govern prices for intake and wastewater disposal.

To these four direct price signals, we must add less direct costs to understand the total cost of using and disposing of water in the 1990s industrial environment:

1. Potential penalty fees for over-use of water
2. Fines for wastewater discharge violations
3. Legal fees and litigation awards for actions related to toxic discharges.

These indirect costs add to the cost of using and disposing of water and must figure into the plant's cost minimization decisions. Plant management may be risk averse toward litigation problems and this would add an intangible, but real, inducement to reduce water intake as one way to reduce disposal and risk of litigation.

5.1.2 Cost Minimizing Drives The Mix of Unconstrained Water Sources

As seen in Section 4.1.3, plant water can be purchased from a utility, pumped from an aquifer, or diverted from surface or brackish water. Conservation is one other option: water can be "produced" within the plant to augment external supplies. Economic behavior implies that plants would invest in equipment to recycle and reuse water until the incremental cost of additional plant-augmented water was less than or equal to the cost of purchasing, treating and disposing of utility water.

For a given plant production level (assuming no limits on external water supplies), finding the optimal mix of external source and plant-augmented water supplies entails balancing water supply alternatives to achieve the minimum cost water supply mix. In the post-Clean Water Act industrial environment, reducing effluent discharge drives this solution toward a mix of plant-augmented water (reused and recycled) and purchased water.

The cost reduction achieved from conservation depends on where in the plant the water is saved. Water saved from a process stream which would require pretreatment avoids costs that water saved from nontreated streams, such as sanitation or landscape water use, do not incur. A project which recycles a small portion of total plant usage but targets process water may be more desirable because it generates substantial savings in intake pretreatment costs. For example, conservation projects which reduce intake water to be used for employee sanitation do not result in the same avoided cost as projects which conserve treated process water; e.g., deionized (DI) water in the computer industries. The sanitary flows have no associated pretreatment costs per unit of intake while DI water has high treatment costs. To model the plant's decision-making process requires separating the streams of water through the plant between uses which require some pretreatment and those that require none.

Drought penalty fees since 1987 have increased the cost of buying utility water. Moreover, drought management plans have restricted utility water use largely to a baseline keyed to 1986 or 1987 usage. Given the growth in industry output seen on Table 4-4, restricted utility supplies may have:

1. Limited the amount of purchased water to less than the minimum cost solution would dictate; or,

2. Added substantial penalty charges to the cost of using utility water in excess of the baseline set for the plant.

3. Increased management perception that shortages may become more frequent.

As a result of utility cost increases and drought limits, the cost of plant-augmented water became lower than utility supplies for incremental supplies available to certain California plants. Consequently, output growth and plant expansion in recent years have been supplied by plant-augmented water -- conservation -- to a larger extent than prior to 1987.

5.1.3 Profit Maximizing Under Constrained Water Availability Explains High Cost Conservation

A plant facing constraints on utility-supplied water must solve a different management problem if its production is growing. Management perception that water shortages will be a more likely future occurrence faces the same problem: take steps to assure adequate water supplies. Economic theory suggests that in this case the cost of plant-augmented water can exceed the sum of observed prices for purchased water and wastewater discharge. If the plant's utility supplied intake water is limited by drought management plans, then water conservation should proceed until the cost of incremental plant-augmented water is equated to the value of using the water in the production process -- the value of marginal product for the input water. This is a different solution than the cost minimization problem described above and can lead to high costs for plant-augmented water if:

1. Utility water supply constraints are substantially binding -- or management is uncertain about the adequacy of future supplies;

2. The plant is increasing output;

3. Recirculation and reuse has already been adopted to such a degree that further conservation is high cost;

4. The value of added plant production exceeds the cost of the increased recirculation.

Estimating the profit maximizing water supply mix for plants in California is complicated by two other considerations:

1. Plant managers, facing water supply unreliability, will choose strategies that lower their exposure to risk of production interruption. If utility water supply is viewed as uncertain, they will invest in conservation projects to reduce reliance on outside supply sources even if the plant-augmented water has higher cost than the utility prices. The willingness to pay more for plant-augmented water reflects the value of the additional plant production with a guaranteed supply of plant-augmented water compared to the prospect of an uncertain utility supply and lost plant production. This difference represents the value of increased reliability to reduce uncertainty.

2. Wastewater disposal capacity bottlenecks -- both the size of the outflow pipe connecting to the public sewer line and municipal treatment plant capacity

limitations -- cause a sharp increase in the wastewater disposal costs if the industrial plant is near its authorized limit. Wastewater agencies have varying degrees of unused capacity. Therefore, the incremental capacity rates passed back to plants vary in relation to different utility problems. This incremental capacity charge can be a large cost to avoid.[2]

Either of these considerations -- reducing uncertainty and avoiding large incremental capacity charges -- leads to the conclusion that the incremental value of conserved water to an individual plant may be higher than the costs for utility water intake plus wastewater disposal services.

5.2 The Direct Inducements of Industrial Water Conservation

The direct inducements of industrial water conservation projects begin with the savings gained by reducing intake water and wastewater discharge. The cost savings represent "avoided costs" and are a useful justification for pursuing conservation or alternative supply options. Avoided costs are dependent on the total volumes saved, intake and wastewater streams reduced, onsite treatment costs for intake supplies and wastewater discharge, and the particular utility water and wastewater rate structure. A wide range of costs for plant-augmented water (conservation) would be expected both among industries and among plants of any industry.

The implementation of the many conservation projects found in the survey data doubtless are motivated for other reasons as well. Reducing the risk of production disruption, and enhancing reliability of supply are also important, as is reducing the risk of litigation. Under drought conditions, good will to the community -- "We're doing our part" -- also is important.

5.2.1 Utility Water Supply Costs

Calculating avoided intake water supply cost is straightforward. The plants in our sample are metered water customers. Intake water is a variable operating cost. The more they use the more they pay. In some places in California and in other parts of the country, water usage fees are flat rates based on intake pipe size, number of employees, or some other fixed index of water use which does not change directly with the amount of water used. In these cases, the avoided cost of conservation may be zero because plants would not be

[2]This was discovered in follow-up interviews with otherwise assumed-to-be "outliers" to be a governing consideration for some high cost conservation projects.

rewarded for the water they save. All retailers serving the plants in our sample charge by metered use and therefore provide at least some incentive for conservation.

Water retailers were surveyed in order to obtain industrial rates for water. California industrial water rate levels are illustrated by a few utilities' rates shown on Table 5-1. Because the plants in our sample are large users relative to other types of municipal accounts the price tabulated is the last block price charge. Utility potable water varies between $215 and $650 per acre-foot in Southern California and between $413 and $749 per acre-foot in Northern California. An illustrative sample of retail water rates in the areas covered by the survey averages $496 per acre-foot. These rates are shown on Table 5-1.

TABLE 5-1
SAMPLE OF ILLUSTRATIVE INDUSTRIAL WATER RATES

Water Retailer	Rate ($/HCF)	Rate ($/AF)
Southern California		
City of Anaheim Utilities Dept.	0.49	215
Irvine Ranch Water District	0.53	231
City of Industry	0.51	222
L.A. Dept. of Water and Power	1.31	572
City of Ventura	1.26	550
Mesa Consolidated Water District	1.05	457
City of Inglewood	1.50	650
Northern California		
Alameda County Water District	0.95	413
East Bay Municipal Utility District	0.99	431
Contra Costa Water District	0.97	423
San Jose Water Company	1.11	481
City of Sunnyvale	1.72	750
Weighted Average of Illustrative Water Utilities	1.14	496

Source: Selected Utility Rate Schedules, 1991. Spectrum Economics, Inc.

Approximate weighted average by volume. 9/9/91
HCF = Hundred Cubic Feet, 748 gallons.

Drought penalty charges are not shown on the table. Drought penalty charges are fees charged for water use over the allocated baseline. EBMUD rates provide an example of how drought charges serve as an incentive to reduce water consumption. The volumetric rate, $431 per acre-foot, shown on Table 5-1 applies to consumption up to the level of 1986 usage. After that the rate goes up as follows:

To 110% of 1986	$654 per AF
To 120% of 1986	$871 per AF
Above 120%	$1,307 per AF

Drought penalties drive-up the marginal costs of water significantly as shown by the EBMUD example. Facing these increasing rates, the growing plant has had a strong inducement to reduce its external supply needs by way of plant conservation. Moreover, if plant management perceives that it may face "drought" rates more frequently in the future, conservation investments will be estimated to pay-back faster.

5.2.2 Pumped Groundwater and Nonpotable Water Costs

Some SIC groups such as refineries and chemical manufacturers use significant amounts of groundwater pumped from wells on-site. The unit cost of well water varies with electricity rates, pumping efficiency, water depth, as well as any treatment needed once above ground. Data on Table 5-2 show that the industry groups using substantial groundwater are paying between $72 and $189 dollars per acre-foot. Paper and Chemicals are shown on the table to indicate that they use groundwater; but no data are provided because survey responses were judged to contain data problems.[3]

[3] For instance, the Chemical plants show $1,683 as the cost of pumping; this may be an error or it may include some treatment costs.

TABLE 5-2
GROUNDWATER PUMPING COSTS

SIC CODE	Description of Plant	$/AF
203	Food	72
265	Paper	*
281	Chemicals	*
291	Refining	189
209	Misc. Food	155

* Data limitations preclude accurate determination of these industries' cost. Spectrum Economics, Inc. 9/9/91

The industry groups on Table 5-2 also use significant amount of nonpotable water. Plant-specific cost data for this source were not obtained.

5.2.3 Industrial Wastewater Disposal Costs

Varying percentages of water used in the plants must be discharged to a wastewater utility facility. Wastewater disposal costs are comprised of wastewater discharge fees and the plant's wastewater pretreatment costs. Two following sections describe and estimate these costs.

5.2.3.1 Sewer Service Charge Rate Components

How a sewer district structures wastewater rates determines the avoided costs. Wastewater costs to a plant are not reduced if the plant pays a flat fee for wastewater services. To determine if this was the case, the survey asks three questions about wastewater fee structures:

1. Do you pay a flat fee?
2. Do you pay a fee based on volume?
3. Do you pay a fee based on concentrations of pollutants?

The results of these questions are shown on Table 5-3. Some plants pay both a fixed charge and a volumetric component to the sewer service charge. A high percentage (81%) of the plants in the sample are charged for wastewater on a per unit basis. These are variable charges to be avoided by reducing effluent discharge.

TABLE 5-3
HOW IS YOUR COMPANY CHARGED FOR WASTEWATER DISPOSAL?

Does Rate Structure Contain:	Yes	No
Flat Fee?	33%	67%
Volume Rate per Unit of Discharge?	81%	19%
Strength Charges per Unit of Wastewater?	52%	48%
Note: More than one type of rate structure applies in some cases.		

Source: Survey Question II.11

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5.2.3.2 Plant Wastewater Variable Costs

Industrial wastewater disposal costs are determined by three main factors: flow, biochemical oxygen demand (BOD), and total suspended solids (TSS). Municipal wastewater disposal charges are based on the total amount, or loadings, of each of these factors and in some cases by peak flow rates of each factor. Loadings for BOD and TSS are typically calculated by multiplying the flow of effluent by the concentration of each factor. Because flow is a direct cost component by itself and an indirect component of the loading calculation, conservation projects which modify effluent flow can have a substantial impact on total wastewater charges. The extent of this impact is determined in part by how closely the specific plant is monitored by the local sanitation district.

Examining a typical sewer service charge equation will illustrate how reduction in intake and hence effluent flows effect wastewater disposal costs. The sewer charge equation is as follows:

Sewer Service Charge = FLOW CHARGE + BOD CHARGE + TSS CHARGE

where:

FLOW CHARGE = FLOW * Unit Cost of Flow

BOD CHARGE = (BOD per unit of FLOW)*FLOW * Unit Cost of BOD

TSS CHARGE = (TSS per unit of FLOW)*FLOW * Unit Cost of TSS.

Reducing effluent flows by conservation efforts does not lead to a straightforward calculation of reduced sewer service charges equal to the change in flow multiplied by the unit cost of flow. The total savings calculation is complicated by the fact that flows tend to be inversely related to BOD and TSS; i.e., loadings become more concentrated and do not decrease as the liquid decreases. Because sewer service charges are based on total loadings, conservation projects which reduce flow and not entrained waste material should have less effect on total cost. Effluent flow is reduced and concentrations increase, leaving the cost from flow charges reduced but total BOD and TSS load unchanged. The net result is unique to each plant.

Cost should not be reduced for BOD and TSS charges if the increase in concentrations is adjusted by the wastewater sanitation district. However, if the BOD and TSS concentrations are not adjusted then the savings from conservation realized by the plant are the savings resulting from changes of flow assuming away the effect of concentrations on BOD and TSS charges. Increased concentrations will only be factored into a plant's sewer rates if the plant reports increased concentrations or the sewer district inspects and detects increased concentrations.

The avoided cost associated with the reduction of a unit of sewer discharge used in this report is the total annual sewer charges divided by the total effluent flow. The data are taken from responses to survey questions II.10 and II.11. This assumes that a unit of reduced flow also reduces BOD and TSS. The costs reported below also include other charges levied by the sanitation district that might not be avoided by conserving water. These other charges may include fixed connection charges and inspection and monitoring fees. Although these inclusions represent a problem, the average sewer service charges for each industry calculated are used for two reasons.

1. Only total sewer service charges and total effluent flows were given on the survey instrument. Flow unit costs were asked for; but many plant managers did not know what the flow component of the sewer charge was and did not answer.

2. Because of the difficulty in determining the extent to which plants in our sample are monitored it was not possible to determine if only the flow costs were realized or if the cost reductions extended to the BOD and TSS charges as well.

The avoided wastewater costs estimated below are an upper bound because of the inclusion of BOD and TSS and possibly other nonvariable costs. The industry wastewater cost estimates may be considered screening level of accuracy.

5.2.3.3 Estimated Industry Specific Wastewater Discharge Costs

The estimates of average sewer service charges as well as wastewater flows and total expenditures for the industry groups in the sample are shown in Table 5-4. The first column is the total estimated intake taken from Table 4-2. Estimates of return flows, the percent of total intake which is returned to the sewer, were based on the responses from the survey by relating the responses to survey question II.1 to II.10 -- intake to discharge. The estimated discharges for the sampled industries are calculated by multiplying the percentage of return flows by the 1989 total intake.

Variations in return flows across industries can be explained in terms of the underlying manufactured product and manufacturing process. For example, processes which have lower return flows have relatively high water intake amounts embodied in product or large cooling loads where the loss is accounted for in evaporation. For example, in the Concrete industry groups (327), the percent of intake water embodied in product is upwards of 90 percent which explains the 5 percent return flow. The Paints industry groups (285) is another example where the low return flows is explained by the percent of intake water embodied in product -- 44 percent. One counter intuitive result was for the Beverages industry (208). It was expected that the beverage industry groups return flows would be much lower, closer to 20-30 percent than that measured from the plants in the sample (75 percent). Many soft drink producers do have lower return flows in the expected range, but beer manufacturers in the sample only use 18 percent of their intake water embodied in product. Because beer manufactures are very large water users, they have considerable impact on the estimated average return flow for the industry.[4]

High return flows are usually associated with production processes which use very small amounts in production, such as in the communications industry (366). In industries where there is significant intake water used in the process and high return flows, most of the water is being used for rinsing. This is the case for the high technology industry groups 357 and 367 -- Computers and Computer Components.

As described previously, the average annual sewer service charge for each industry was estimated by dividing the total annual sewer service costs by the total sewer discharge for each plant responding to the question. The industry average was then calculated by computing the mean over all plants within the industry weighted by the amount discharged. Variations in sewer service charge mostly reflect differences in the factor loadings of flow, BOD, and TSS across industries. With the exception of meats (201), the food industry groups, (203, 205, and 208) have high loadings and as a result have relatively high average

[4]Further work could usefully separate the beer plants from the soft drink plants because the Beverage industry is the second largest water using industry in the state. Anecdotal evidence suggests that there is a wide variation among beer producers in the percentage of water used directly in the product. This variation results from varying levels of in-plant conservation.

TABLE 5-4

ESTIMATED WASTEWATER FLOWS, SEWER SERVICE CHARGES, AND TOTAL EXPENDITURES

SIC CODE	Description of Plant	Total(1) Intake 1989 (TAF)	Estimated(2) Return Flows (%)	Estimated Wastewater Discharge (TAF)	Average Sewer Service Charge ($/AF) (4)
201	Meat Products	6.7	90	6.0	509
203	Preserved Fruits & Vegetables	21.6	76	16.4	1240
205	Bakery Products	1.2	81	1.0	1096
208	Beverages	39.1	75	29.3	1783
209	Misc. Food & Kindred Prod.	13.7	93	12.7	536
265	Paperboard Containers & Boxes	12.4	56	6.9	1087
281	Industrial Inorganic Chemicals	27.2	28	7.6	(3)
283	Drugs	6.1	84	5.1	846
284	Soaps, Cleansers, & Toilet Goods	3.3	95	3.1	1254
285	Paints & Allied Prod.	1.1	54	0.6	NA
291	Petroleum Refining	126.7	63	79.8	(3)
327	Concrete, Gypsum, Plaster Prod.	19.1	5	1.0	4530
344	Fabricated Metal Prod.	8.3	92	7.6	487
357	Computer & Office Equip.	6.3	94	5.9	443
366	Communication Equipment	6.2	70	4.3	498
367	Electronic Comp. & Acc.	8.7	75	6.5	405
371	Motor Vehicles & Equip.	2.8	61	1.7	1101
372	Aircraft & Parts	13.6	86	11.7	224
376	Guided Missles, Space Vehicles, Parts	3.7	55	2.0	313
	Average/Total	327.7	64	209.4	573

1) Source: Survey Question II.1, II.10
2) Source: Survey Questions II.10, II.11
3) The firms sampled from the Petroleum Refining and the Industrial Inorganic Chemicals Industries had their own NPDES permit and had minimal or no discharges to a public sewer
4) Source: Spectrum Question II.11
NA) Total annual water discharge costs were not given by the surveys in this industry
TAF - Thousand Acre Feet

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annual unit service charges. In contrast, the High Technology and Defense industry groups have relatively low service charges because they pretreat their wastewater stream to remove loads of BOD and TSS. Pretreatment reduces their municipal sewer costs.

5.2.4 Industrial Pretreatment Costs

The sewer service charges described above are not the only costs associated with wastewater disposal. Pretreatment costs apply for a certain percentage of total wastewater flow. Industries which pretreat much of their effluent flow have significantly higher disposal costs. **If only sewer service charges were used to estimate the costs of effluent discharge, the avoided costs of conservation projects which reduce effluent in these industries would be significantly underestimated.**

5.2.4.1 Distribution Of Industry Pretreatment

Industrial pretreatment refers to treating wastewater typically laden with metals, organic, and inorganic constituents before discharge into municipal sewer lines or other sewer outfalls. Pretreatment is usually motivated by contaminant limits placed by the local sanitation district or regulatory bodies such as the EPA or, in California, the Regional Water Quality Control Boards. Once limits are set, each plant attempts to minimize total discharge cost by choosing an optimal level of waste separation. Effluent flows are separated into pretreated flows and non-treated flows in such as way that pretreated costs are minimized while wastewater strength limits are not exceeded.

Pretreating effluent flows can be very expensive. Once a particular pretreatment technology is chosen, the pretreatment equipment costs are mainly driven by peak flows. Variable operating and maintenance costs are determined by flows. Plant managers attempt to minimize pretreatment flow by segregating effluent into different quality flows. Flows from the end of a process or rinse bath are typically high in toxic constituents and are likely candidates for pretreatment.

Survey questions II.8 and II.9 asked the following series of questions on pretreatment;

1. Do you pre-treat any wastewater?
2. What was the volume pretreated?
3. What was the annual cost and capital cost of your pretreatment equipment?

Of the 91 plants providing useful data, 54 percent indicated that they use some pretreatment. Table 5-5 shows how that percentage is distributed over the selected industry groups. Because of the small sample size in the industry groups, the costs estimated from these data may suffer from selection bias.

TABLE 5-5
PERCENTAGE OF PLANTS
PRETREATING WASTEWATER*

SIC CODE	Percent Yes	Number Responding
201	100	2
203	25	8
205	33	3
208	25	4
209	43	7
265	33	6
283	33	3
284	0	3
291	100	4
327	100	2
344	50	2
357	40	8
366	0	4
367	75	20
371	100	2
372	100	4
376	85.7	7
Total	54	91

Source: Survey Question II.8
* Note: Some industry groups not included because of insufficient data.

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For most of the food industry groups except meats (201) the percent of plants pretreating wastewater is relatively low compared to the Refining, Vehicles and Defense industry groups. The food industry groups have high amounts of organic material in their waste stream which are compatible with treatment at typical wastewater treatment plants. Waste dough, vegetable matter, sugars, all contribute to high loadings of BOD and TSS. These types of waste can be removed by the screening, filtering, and activated sludge treatment process used in most secondary municipal wastewater treatment facilities.

In contrast to the wastewater streams of the food industry groups, wastewater of the High Technology and Defense industry groups contain metals, extreme pH, and organics which are toxic to the bacteria used in the activated sludge treatment. Because excessive amounts of these toxic constituents could destroy the effectiveness of the treatment facilities, sanitation districts require plants with these types of waste to pretreat their effluent. The semiconductor industry (367) has a particularly high percentage of plants which pretreat. The Communication industry (366) reported no pretreatment costs.

5.2.4.2 Estimated Industry Specific Pretreatment Costs

The estimated flows being pretreated were calculated in the same manner as the estimates for wastewater flows and are shown in Table 5-6. Pretreatment flows were estimated as a percent of wastewater discharged for each responding plant in the survey. The wastewater stream was then multiplied by the percent pretreated to provide the industry total.

There is a difference between the percent pretreated shown on Tables 5-5 and 5-6. On Table 5-5, the percentage in column 2 is the number of plants which pretreat divided by the total number of plants in the industry. This is only a preliminary indicator of pretreatment activity for a given industry because it ignores both the percent pretreated within a plant and the relative size of wastewater flows between plants. A more accurate measure of pretreatment is shown on Table 5-6. This percentage reflects the total amount of wastewater being pretreated by the plants in the sample for each industry and can be used as an estimate for each industry.

The average unit pretreatment costs were calculated by dividing the total pretreatment operating and maintenance costs from survey question II.9 by the total flow treated for each plant. Industry average cost are shown on Table 5-6. **The pretreatment costs on Table 5-6 cannot be observed in any market as part of the cost of using water.** Nonetheless, they are a big determinant of the cost of using water -- or reducing the use of water. Water conservation projects save these costs. (Plant coverage shown on Table 5-5 implies, however, that there could be large sampling error embedded within the estimates reported on Table 5-6.)

TABLE 5-6
ESTIMATED PRETREATEMENT VOLUMES AND AVERAGE UNIT COSTS

SIC CODE	Description of Plant	Total(1) Wastewater Discharge (TAF)	Estimated(2) Pre-Treatment (%)	Estimated(3) Pretreated Wastewater Discharge (TAF)	Average(4) Unit Pretreatment Cost ($/AF)
201	Meat Products	6.0	100	6.0	166
203	Preserved Fruits & Vegetables	16.4	25	4.1	174
205	Bakery Products	1.0	26	0.3	341
208	Beverages	29.3	94	27.6	77
209	Misc. Food & Kindred Prod.	12.7	71	9.0	487
265	Paperboard Containers & Boxes	6.9	84	5.8	2779
281	Industrial Inorganic Chemicals	7.6	100	7.6	4242
283	Drugs	5.1	3	0.2	16251
284	Soaps, Cleansers, & Toilet Goods	3.1	0	0.0	0
285	Paints & Allied Prod.	0.6	17	0.1	0
291	Petroleum Refining	79.8	100	79.8	1095
327	Concrete, Gypsum, Plaster Prod.	1.0	0	0.0	0
344	Fabricated Metal Prod.	7.6	4	0.3	20242
357	Computer & Office Equipment	5.9	72	4.3	6493
366	Communication Equipment	4.3	0	0.0	0
367	Electronic Comp. & Acc.	6.5	44	2.9	2342
371	Motor Vehicles & Equip.	1.7	100	1.7	2271
372	Aircraft & Parts	11.7	11	1.3	44270
376	Guided Missles, Space Vehicles, Parts	2.0	30	0.6	1771
	Total	209.4	72.3	151.5	1,644

1) Source: Scenario Question II.10
2) Source: Scenario Question II.9
3) Calculated by multiplying Total Wastewater Discharge by Estimated Percent Pre-Treated
4) Source: Scenario Question II.9
TAF - Thousand Acre Feet

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The food industry groups have relatively high sewer service charges and relatively low pretreatment costs. On the other hand, the High Tech and Defense industry groups have unit pretreatment costs which are five to ten times higher. The extremely high unit pretreatment costs in the Drugs, Fabricated Metals and Aircraft industry groups are correlated with very low flows. Even though unit pretreatment costs are high, the flow pretreated in these cases is very low. Plants with higher treatment streams have lower unit costs. This suggests that there are economies of scale in pretreating flows.

5.3 Avoided Costs of Conservation

This section summarizes the elements of water cost to estimate the costs avoided by reducing water use. These avoided intake water costs and disposal costs can be compared to the costs of a conservation project designed to reduce the intake of municipal water.

Intake water may be either utility provided potable or nonpotable water; or it may be pumped groundwater, or surface water. Except for the Refining industry, the analysis that follows in Section 6.0 only considers the cost of utility provided potable water due to data limitations. This assumption will cause the estimated water costs for Paper (265), Industrial Chemicals (281) and Fruit and Vegetables (203) to have an upward bias in relation to the percentages of lower cost water from other sources shown on Table 4-3.

Intake water is treated prior to use for some of the industry groups. For instance, DI treatment costs in the computer industry groups (357 and 367) are very high. Data were not provided in the survey on the amount and cost of treated intake water. Because data were not provided, advanced treatment of intake water was excluded from the Total Unit Cost Calculations. This assumption will cause the estimated water costs for certain industry groups to have a low bias -- significantly low for industry groups which use DI water in the manufacturing process.

The cost of intake water, therefore, can be stated as the cost of water plus the cost of pretreatment for the percentage of water pretreated. This is shown in Equation (1).

(1) Water Intake Costs = $/AF + (% treated * treatment cost per AF)

Total Unit Avoided Cost (TUAC) per AF of intake water is calculated for two wastewater streams through the plant: pretreated wastewater and not pretreated as follows:

(2) $TUAC_{treated}$ = [Water Intake Costs + % Return Flow * ((Sanitation Unit Charge) + (Pretreatment Unit Cost))]

(3) $TUAC_{untreated}$ = [Water Intake Costs + % Return Flow * (Sanitation Unit Charge)]

(4) $TUAC_{total}$ = % Treated * $TUAC_{treated}$ + % Untreated * $TUAC_{untreated}$

As indicated in section 5.2.3.1, the avoided wastewater costs estimates have a high bias because of the assumption of constant BOD and TSS loadings and possible inclusion of other nonvariable costs in the data provided.

Example: Meat Products -- Data for the example are shown on the first row of Table 5-7.

Meat Products TUAC = [$496 + .9 *(($509) + (1 * $166))]

= $1,104 per AF of intake water saved.

This number, $1,104, is shown in the last column of Table 5-7. Table 5-7 brings together all of the components of avoided costs estimated above expressed in dollars per acre-feet of intake water. For the example, an approximate statewide average cost for intake water, excluding any drought surcharges, $496 per acre-foot, is plugged into column 1 of the table.

Avoided costs of reducing intake water are shown to range between $845 for Communication Equipment (366) to $5,307 for Computer Equipment (357). **Pretreatment cost is the largest part of the cost of water in the Computer industry.** Both the percentage of the wastewater stream treated and the treatment cost are high. Conservation in the Computer industry must be driven by the need to avoid these costs.[5]

Table 5-7 shows intake water rates fixed at $496 AF, the average for the illustrative utilities shown on Table 5-1. Examining the Total Unit Avoided Cost column, drought rates that would add about $600 per AF to the cost of intake water would increase the cost of water a substantial percentage for all but the Computer (357) and Aircraft (372) industry groups with their already high cost -- between nearly 90 percent for Concrete, Communication and Aerospace industry groups and about 45 percent for the average of Food industry groups and 40 percent for the rest. Drought penalties can be seen to be a strong inducement to augment incremental water supplies within the plant by conservation.

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[5] Avoiding the high cost of DI make-up water -- unknown -- is another important driving cause of conservation of process water.

TABLE 5-7
ESTIMATED AVOIDED COST OF WATER

SIC CODE	Description of Plant	Intake(1) Water Rates ($/AF)	Estimated(2) Return Flows (%)	Wastewater(2) Sewer Service Charge ($/AF)	Percent(3) of Wastewater Pre-Treated (%)	Pretreatment Unit Cost(3) ($/AF)	Untreated Avoided Cost Per AF of Intake ($/AF)	Pretreated Avoided Cost Per AF of Intake ($/AF)	Total Unit Avoided Cost Per AF of Intake ($/AF)
201	Meat Products	496	90	509	1.00	166	0	61246	61246
203	Preserved Fruits & Vegetables	496	76	1240	0.25	174	94736	107960	98042
205	Bakery Products	496	81	1096	0.26	341	89272	116893	96453
208	Beverages	496	75	1783	0.94	77	134221	139996	139650
209	Misc. Food & Kindred Prod.	496	93	536	0.71	487	50344	95635	82501
265	Paperboard Containers & Boxes	496	56	1087	0.84	2779	61368	216992	192092
281	Industrial Inorganic Chemicals	496	28	(4)	1.00	4242	0	119272	119272
283	Drugs	496	84	846	0.03	16251	71560	1436644	112513
284	Soaps, Cleansers, & Toilet Prod.	496	95	1254	0.00	0	119626	0	119626
291	Petroleum Refining (5)	353	53	(4)	1.00	1394	0	74235	74235
327	Concrete, Gypsum, Concrete Prod.	496	5	4530	0.00	0	23146	0	23146
344	Fabricated Metal Prod.	496	92	487	0.04	20242	45300	1907564	119791
357	Office & Computer Equip.	496	94	443	0.72	6493	42138	652480	481584
366	Communication Equipment	496	70	498	0.00	0	35356	0	35356
367	Electronic Comp. & Acc.	496	75	405	0.44	2342	30871	206521	108157
371	Motor Vehicles & Equip.	496	61	1101	1.00	2271	0	206188	206188
372	Aircraft & Parts	496	86	224	0.11	44270	19760	3826980	438554
376	Guided Missiles, Space Vehicles, Parts	496	55	313	0.30	1771	17711	115116	46933
						Average Industry Avoided Cost	44351	249701	114969

(1) Weighted average of illustrative retail agency rates for California. See Table 5-1
(2) Survey Question II.10
(3) Survey Question II.9
(4) Any incremental sewer service charges included in Pretreatment Costs.
(5) Specific water purchase rate data collected for SIC 291.

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A caveat is in order: the data on Table 5-7 are indicative only. The data reported within the survey allow for screening level of estimates. Both the cost estimates and the percentage distributions of streams are screening level estimates -- indicative, but not definitive.

5.4 Benefits of Increased Reliability

An appreciation of the value of the underlying production associated with water is central to understand part of the motives behind industrial conservation. In the words of one plant manager interviewed post-survey (whose sentiment was echoed by several others) "Production is King." Using water efficiently is an important element to any production process. However, the annual savings of water and wastewater costs from a typical conservation project is typically dwarfed by the revenue streams associated with the water. The daily plant production for the selected industries which is at risk due to water shortage is substantial. Several plant managers reported that they could be forced to reduce a three-shift operation to two shifts if water supply were reduced. A plant will not risk loss of part of a day's production due to a critical but small input, water, if it can be avoided. Plant responses to the water shortage scenario questions reveal the importance of water to the production process and confirm the impetus to avoid any loss of production.

5.4.1 Value Of Marginal Product For Water

Scenario questions III.5 and III.12 probed for income and cash flow reductions due to water supply shortages. Table 5-8 shows the responses to the questions for each scenario. Thirty percent of plants answering the question report reduced operating income for a 15% cutback of water supply; 39 percent Don't Know and 31 percent report No. For a 30% cutback of water supply, 40 percent of plants report reduced income; 41 percent report Don't Know and 20 percent report no reduction.

The overall average understates the impacts to those industry groups reporting losses. More than half of Food industry plants report income losses, with Beverage plants reporting the highest percentage of losses -- 80 percent of plants. Seventy-five percent of the Soaps and Cleansers report income losses. Water is an important ingredient of the product in both the Beverage and Soaps industries.

Table 5-9 shows the lost gross operating profit by industry for water supply shortages benchmarked to 1989 industry operating revenues. Gross operating profit equals value of shipments less purchased inputs less labor payroll. The remaining value, referred to as gross operating profit, is a before tax value which includes interest payments, depreciation on plant and equipment, proprietors' income, and profit. It can be considered the net cash flow from

TABLE 5–8
PERCENT OF FIRMS EXPECTING REDUCED INCOME WITH REDUCED WATER SUPPLY

		Scenario 1 15% Water Supply Shortage			Scenario 2 30% Water Supply Shortage		
SIC CODE	Description of Plant	Yes (%)	No (%)	Don't Know (%)	Yes (%)	No (%)	Don't Know (%)
201	Meat Products	67	33	0	67	0	33
203	Preserved Fruits & Vegetables	29	35	35	41	29	29
205	Bakery Products	50	10	40	50	10	40
208	Beverages	80	0	20	80	0	20
209	Misc. Food & Kindred Prod.	45	9	45	55	0	45
265	Paperboard Containers & Boxes	20	30	50	50	10	40
281	Industrial Inorganic Chemicals	50	50	0	50	50	0
283	Drugs	20	20	60	40	0	60
284	Soap, Cleansers & Toilet Goods	50	0	50	75	0	25
285	Paints & Allied Prod.	0	50	50	50	0	50
291	Petroleum Refining	60	10	30	60	0	40
327	Concrete, Gypsum, Plaster Prod.	40	0	60	40	0	60
344	Fabricated Metal Prod.	33	33	33	33	22	44
357	Computer & Office Equip.	21	43	36	36	21	43
366	Communication Equipment	8	72	20	12	52	36
367	Electronic Comp. & Acc.	25	34	41	39	20	41
371	Motor Vehicles & Equip.	20	40	40	40	20	40
372	Aircraft & Parts	21	21	57	21	29	50
376	Guided Missles, Space Vehicles, Parts	10	20	70	20	10	70
	Weighted Average(1)	30	31	39	40	20	41

1) Weighted by number of firms

Source: Scenario Questions III.5, III.12

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TABLE 5-9
MARGINAL OPERATING PROFIT PER ACRE FOOT

		Income Loss				Water Loss		Income Loss Per Acre-Foot	
		Scenario 1 15% Water Supply Shortage		Scenario 2 30% Water Supply Shortage				Marginal Income Loss Per Acre Foot	
SIC CODE	Gross Operating Profit 1989(1,2) ($mil)	Reduction(3) (%)	Direct Loss ($mil)	Reduction(3) (%)	Direct Loss ($mil)	Total 1987 Intake(4) (TAF)	15% Reduction (TAF)	0 – 15% ($/AF)	15 – 30% ($/AF) (5)
203	1754.4	5.0	88.2	9.1	160.4	36.0	5.40	16,325	13,375
205	989.3	11.0	108.8	23.4	231.9	1.4	0.21	517,887	586,250
208	2337.7	7.6	177.2	14.6	341.2	41.2	6.18	28,666	26,551
209	939.5	3.2	30.4	13.0	122.4	12.5	1.88	16,200	49,061
265	627.8	8.1	50.6	20.1	126.4	16.3	2.45	20,683	31,000
284	1315.4	10.2	134.4	31.5	414.2	2.9	0.44	308,968	643,172
285	597.4	0.0	0.0	7.7	46.2	1.9	0.29	0	162,013
291	2035.4	5.8	117.1	10.2	208.1	125.1	18.76	6,240	4,850
327	566.4	2.8	15.9	6.0	33.9	16.4	2.46	6,474	7,287
344	859.3	5.2	44.6	9.4	80.7	9.5	1.43	31,292	25,362
357	7393.2	4.7	345.2	10.8	800.1	7.4	1.11	310,959	409,820
366	1733.9	0.3	4.9	1.0	17.1	8.1	1.22	4,039	9,997
367	5676.8	3.1	173.3	5.7	325.5	8.0	1.20	144,451	126,813
371	1095.3	0.1	0.6	17.3	189.1	4.2	0.63	887	299,263
372	3150.8	2.0	61.9	4.4	137.4	12.2	1.83	33,816	41,259
376	6340.2	0.2	10.3	2.3	145.0	3.0	0.45	22,915	299,379
Total	37,412.7		1,363.2		3,379.4	306.1	45.9	Average 77,358	143,971

1) Gross Operating Profit = Value Added - Payroll for 1987; Escalated to 1989 By Growth Factors Estimated by CCSCE
2) Source: Census of Manufactures 1987
3) Survey Questions III.5 & III.12: Percent of Plants Responding 'Yes' Times Percent Loss Reported
4) Survey Question II.1
5) Direct Loss for 30% Cutback Less Direct Loss for 15% Cutback Divided by 15% Water Reduction.
TAF - Thousand Acre Feet

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operations after paying for all inputs. Data from the 1987 Census of Manufacturing forecast to 1989 were used to estimate gross operating profit.

Table 5-9 shows that the direct marginal losses total $1.4 billion for the 15% shortage and $3.38 billion for the 30% shortage. The largest cash flow losses for the 30% cutback are in the industry groups shown on Table 5-10. The Computer and Computer Component industry groups (357 and 367) are shown to have high gross operating income at risk to water shortages.

TABLE 5-10
LARGEST INDUSTRY INCOME LOSSES
30% WATER SUPPLY SHORTAGE

SIC		$ Million (1989)
357	Computer	800
284	Soups and Cleaners	414
208	Beverage	341
367	Electronic Components	326
Note: These represent responses to a hypothetical shortage. These industry groups have not faced a 30 percent shortage.		

Source: Scenario Question III.12 — Spectrum Economics, Inc. 9/9/91

5.4.2 Value Of Marginal Product For Water Per Acre-Foot

Incremental lost gross operating profit per acre-foot can be estimated from the lost gross operating profit. The acre-foot value can be considered a rough estimate of the marginal lost operating income to the plant due to water shortage.[6] This represents the opportunity cost of losing access to 15 - 30 percent of normal water use. This value is referred to as the value of the marginal operating profit for the input, water.

[6]The calculation represents an "average" marginal concept: between 0 and 15% and between 15% and 30%.

The values are shown for the 15% and 30% shortage scenarios on Table 5-9. The values are estimated as the marginal losses between 0 and 15% cutback and between 15% and 30% cutback. These range between $4,850 for the refining industry (291), the largest water using industry, to $643,172 for the Soaps and Cleansers industry (284). The Computer industry (357) has the third highest marginal value per acre-foot for the 30% water shortage scenario, $409,820. At the margin of a 30% water supply cutback, management expectations about plant cash flow values would be very sensitive to water supplies given these values.

These values do not imply that water is worth as much as $500,000 - $600,000 per acre-foot. The operating profits from marginal plant production using the unit of water, however, is worth $500,000 - $600,000 to plant management. Rather than forego this acre-foot and incur the lost opportunity to use the water in combination with other inputs to the production process, industries would invest substantial amounts of capital to avoid losses of this magnitude. Lost opportunity value is estimated plausibly at the values shown on Table 5-9 (given the reported survey responses) if, in fact, the elasticity of substitution is low. Elasticity of substitution is a measure of the ability to substitute one input for another maintaining the same level of output. As discussed in further detail in sections 6.3 and 7.3, elasticity of substitution appears to be declining for most of these industries; i.e., plants are becoming less able to substitute conservation technology for utility supplied water.

Table 5-9 shows that the water supplies implied by a 15% water shortage amounts to 45,900 acre-feet annually. This amount applies to the 12 counties and 17 large water using industry groups reported on Table 5-9. Relative to approximately 6.0 million acre-feet required by these urban areas, the amount of water needed to avoid problems reported by these industry groups is less than 1 percent. The high values shown on Table 5-9 suggest that the water supply situation would have to be extreme before water utilities would be justified in reducing supplies to these industry groups.

5.4.3 Community Relations

Assessing the potential for conservation or other alternative water provision options turns on more than just achieving certain avoided-cost goals or increasing the reliability of supplies. A plant manager must address other issues which may encourage or discourage conservation efforts.

One prime indirect benefit from implementing conservation projects derives intrinsically from better public relations. In post-survey interviews, plant manager after plant manager emphasized the value of improving relations with the surrounding community and the water company which served them. This was especially true in communities where water rationing had taken place. One example of this is demonstrated by the signs posted outside many of the brown-lawned electronic plants in Silicon Valley saying, "We're Doing Our Share to Conserve."

Relations with the local water retailer are also important. Many plants implement conservation projects to demonstrate to the water supplier that they are doing their part to use water efficiently. By demonstrating water use efficiency, plants believe that the local water utility will either reduce or eliminate their water supply cutbacks during general rationing. Whether this strategy has been successful is unclear from our survey; but it demonstrates the plants' concerns.

6.0 INDUSTRIAL CONSERVATION AND ESTIMATED COST OF WATER SAVED

Every plant is capable of recycling and reusing water and conservation is widespread among the sampled plants throughout the state. This section documents the diffusion of conservation and the amount and cost of water saved by conservation. Four objectives are achieved.

1. The diffusion of conservation across the surveyed industry groups is determined. Technologies adopted are shown.

2. An estimate of the amount of water saved by the conservation projects is made based on the reported conservation project data. A second estimate based on water use efficiency improvements in the industry groups is also provided. Water use efficiency is shown to have improved over most of the surveyed industry groups.

3. The cost per acre-foot of plant-augmented water is estimated for each industry and compared to each industry's avoided costs by conservation. Plants are shown to have lowered their costs of operation by some conservation projects and reduced their risk of supply disruption by increasing the amount of plant-augmented water in their mix of supplies. Plants are shown to be increasing the amount of plant-augmented supplies to meet their growing demands for water. Plants are shown to be choosing incremental projects to save water at costs well above the costs of utility supplies to protect valuable plant production.

4. A case study of the refining industry is presented because it is the largest water using industry. Expenditures for planned conservation investments in refineries are shown to be related to the potential for income losses due to water shortage more than to cost reductions. Uncertainty about supply affects the optimal choice of water; investments in incremental conservation measures are justified on risk reduction rather than reducing water costs.

The evidence from the examination of conservation projects in this section shows that avoided costs detailed in Section 5 explain much but not all of the existing and forthcoming amount of water conservation. The number of high cost conservation projects -- well above avoided costs -- found in many industry group requires additional explanation. Expenditures for high cost conservation are consistent with the economic behavior described in Section 5.1. Profit maximizing plant behavior predicts that plants will take steps to conserve water at very high cost rather than risk production losses. There is abundant evidence shown in Section 6.6 that this is taking place in most of the sampled industry groups.

6.1 Distribution of Conservation By Type of Project

Conservation projects fall into three categories:

Existing projects (survey question II.12);

Planned projects (survey question II.13);

Contingency projects (survey questions III.2 and III.9).

The intent of the question eliciting data about existing projects was to learn about steps taken since 1985 to reduce water use. Projects reported in some cases were installed before 1985. All of the projects reported are included in the data set. The planned projects are described explicitly in the survey as those for which budgeting has been approved. Contingency projects are those reported to us as plant actions to mitigate potential utility water supply shortages. The two shortage scenarios are not differentiated in reporting the contingency projects. However, the planned projects are considered to be coming on-line between 1990 and 1992, whereas the contingency projects are considered speculative.

6.1.1 Existing Conservation Projects

Table 6-1 shows the number of the existing and planned conservation projects by reported technology. Sixty-six percent of survey respondents have implemented some kind of conservation measures within the last five years -- 459 identified conservation projects on-line among 158 plants which reported installed projects. Eighty-two plants -- 34 percent -- reported no new conservation projects over the period 1985 - 1989.

The 82 plants that reported no existing conservation projects fall into three categories:

1. Survey responses contain generally poor data;

2. Plants responding generally use no water in the production process; most or all water is used for employees and landscape irrigation;

3. Plants report no existing projects, but use water in the process and report either, or both, planned projects and contingency projects.

The second group, plants that use little or no water in the production process, is the largest category of plants with no reported conservation. The third group, plants which use water in the production process and have implemented no conservation, is the smallest -- 20 plants. These plants are now considering conservation plans. Of the 82 plants reporting no existing

TABLE 6–1
TYPES OF EXISTING AND PLANNED CONSERVATION PROJECTS IN SAMPLED PLANTS

	Existing Projects		Planned Projects	
Name of Project Type	Number	Percent	Number	Percent
Recycle cooling water	57	12.4	23	10.8
Landscape/Irrigation practices	50	10.9	17	8.0
Recycle process water	46	10.0	37	17.5
Change water nozzles/reduce flow rate	40	8.7	12	5.7
Retrofit with low flow showers/toilets	33	7.2	9	4.2
Improve control systems	32	7.0	10	4.7
Education programs	27	5.9	16	7.5
Install automatic water shut off valves	21	4.6	10	4.7
Lower flow setting	21	4.6	5	2.4
Reuse sequentially in processes	18	3.9	6	2.8
Change clean–up procedures	16	3.5	9	4.2
Leak monitoring	15	3.3	7	3.3
Replace water cooling with air cooling	15	3.3	8	3.8
Switch to intermittent use	9	2.0	4	1.9
Reuse between process and cooling	9	2.0	5	2.4
Switch to dry processes	7	1.5	4	1.9
Increase use of well water	6	1.3	1	0.5
Change to/from continuous processing	6	1.3	1	0.5
Production shutdowns or relocations	5	1.1	4	1.9
Switch to smaller tanks/sinks	4	0.9	1	0.5
Other	22	4.8	23	10.8
Total	459	100.0	212	100

Source: Survey Questions II.12, II.13

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conservation projects, 49 are in the North and 33 are in the South. An additional observation is that plants which have been conserving water for years before 1985 still found conservation projects to list on the survey.

The industrial sector has responded to concerns about water shortages and wastewater problems with increased water saving investments and programs. The types of existing projects that have the widest acceptance by the responding plants involve recycling cooling water or process water. Reducing flow rates, adding control systems, and substituting intermittent flows for continuous flows appear prominently among the reported existing projects. Landscape projects are the second largest existing conservation strategy reported in the survey. Landscape projects do not imply simply allowing the lawn to go brown, although this may be the case at some plants. Sophisticated moisture monitoring systems connected to irrigation systems are reported within the data set as well as drought resistent revegetation.

6.1.2 Planned Conservation Projects

The surveyed plants also report 212 additional projects planned to come on-line between 1990 and 1992. The number of installed industrial water saving projects statewide is about to increase 46 percent. These new projects reside mostly within plants with installed water saving projects. Only 20 additional plants report planned projects which did not report past conservation activities.

Two important findings can be inferred from Table 6-1 by the change in the types of reported projects in the planning stage.

1. Process water recycling is replacing cooling water recycling as the largest percentage of conservation projects -- 17.5 percent, up from 10 percent.

2. The percentage of easy and low cost projects is declining among the planned projects compared to the installed projects:

Change continuous flow	down 62 %
Lower flow settings	down 48 %
Retrofit low flow	down 42 %
Change water nozzles	down 34 %
Improve control systems	down 33 %

The larger savings modifications, such as cooling tower projects, and the lower cost projects, such as nozzle change-outs, are giving way to more process water recycling involving production modifications. This represents a shift in emphasis in industrial water conservation to the higher cost projects focused on saving process water.

6.1.3 Contingency Conservation Projects

Contingency projects are those reported in response to water supply shortage scenarios to mitigate the effect of the shortage. There are 199 contingency projects reported in the survey returns. Unlike the existing and planned projects, contingency projects do not have capital budget approval by management. These projects can be regarded only as ideas from the survey respondent. It is important to keep in mind that a contingency project in one plant may be an installed or planned project in another. Even though the contingency projects are hypothetical, they provide a view of the types of conservation project types still under consideration.

Table 6-2 shows the different types of contingency projects reported. As with the existing and planned conservation projects, reusing and recycling cooling and process water are the most widely reported contingency conservation project type. Landscape/irrigation practices, retrofitting toilet/shower fixtures, and education programs also remain viable conservation project types.

6.1.4. High Cost Contingency Projects

The contingent conservation projects probably define the envelope of conservation possibilities for many responding plants. Table 6-3 lists the highest cost contingency projects for industry groups with at least eight listed contingency projects among the sampled plants. Only 48 out of the 199 reported projects provided water savings and cost information. As shown, these contingency projects range in costs from $3,000 to over $8,000 dollars per acre-foot. High cost projects also vary considerably with respect to water savings: from 1.3 annual acre-feet savings for a modified rinse operation in the Electronic Components (367) industry group to 60+ acre-feet savings by refitting a refining unit or an aerospace operation with air cooling instead of water cooling.

Recycling and reusing cooling and process water are frequently the most expensive projects across industry groups. These project types also make up a large portion of the relatively low cost projects that have already been implemented or planned. The fact that these conservation project types have been the mainstay of current conservation efforts and are some of the most expensive contingency projects points out that there is considerable range of engineering and cost variation among these conservation project types.

TABLE 6-2
TYPES OF CONTINGENCY CONSERVATION PROJECTS IN SAMPLED PLANTS

Type of Project	Number	Percent
Recycle cooling water	34	17
Recycle process water	22	11
Landscape/Irrigation practices	17	9
Retrofit with low flow showers/toilets	16	8
Education programs	14	7
Install automatic water shut off valves	11	6
Reuse sequentially in processes	10	5
Change clean-up procedures	9	5
Production shutdowns or relocations	9	5
Change water nozzles/reduce flow rate	8	4
Lower flow setting	7	4
Replace water cooling with air cooling	7	4
Leak monitoring	7	4
Improve control systems	7	4
Reuse between process and cooling	4	2
Change to/from continuous processing	4	2
Switch to intermittent use	2	1
Switch to dry processes	1	1
Other	10	5
Total	199	100

Source: Survey Questions III.2, III.9

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TABLE 6-3
HIGH COST CONTINGENCY CONSERVATION PROJECTS

SIC CODE	Description of Plant	Most Expensive Contingent Conservation Projects	Expected Annual Savings (Acre Feet)	Estimated Total Annual Cost per Acre Foot
203	Fruits and Vegetables	Reuse Between Process and Cooling	1.6	$4,300
209	Miscellaneous Food	Improve Control Systems	13.5	$4,708
265	Paper	Recycle Cooling Water	8.3	$5,691
291	Petroleum Refining	Replace Water Cooling with Air Cooling	62	$8,265
357	Computer Equipment	Recycle Cooling Water	12.2	$8,365
366	Communication Equipment	Change Water Nozzles/Reduce Flow Rates	1.6	$3,252
367	Electronic Components	Reuse Sequentially in Process	1.3	$8,192
372	Aircraft & Parts	Recycle Process Water	7.2	$3,330
376	Guided Missiles, Space Vehicles	Replace Water Cooling with Air Cooling	69	$3,355

Source: Survey Questions III.2 and III.9

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6.2 Water Savings By Conservation Technology

The number and types of projects among 158 plants reporting conservation provides one measure of the diffusion of conservation. The amount of water saved by industry groups and by technology type provide other dimensions. Table 6-4 shows the reported water savings by technology estimated from a smaller set of conservation projects which provided data of project type and water savings from the project. The data on this table are the raw data

TABLE 6-4
WATER SAVED BY ADOPTED TECHNOLOGIES IN SAMPLED PLANTS
1985 - 1989
(AF/YEAR)

Name of Project Type	Existing Projects		Planned Projects	
	Amount	Percent Saved	Amount	Percent Saved
Replace water cooling with air cooling	6,697	40.4	26	0.7
Recycle process water	4,900	29.5	736	18.7
Recycle cooling water	2,168	13.1	309	7.9
Reuse sequentially in processes	1,234	7.4	59	1.5
Reuse between process and cooling	237	1.4	282	7.2
Improve control systems	233	1.4	725	18.5
Education programs	180	1.1	38	1.0
Install automatic water shut off valves	180	1.1	20	0.5
Landscape/Irrigation practices	105	0.6	546	13.9
Lower flow setting	70	0.4	1	0.0
Change water nozzles/reduce flow rate	64	0.4	35	0.9
Change clean-up procedures	36	0.2	6	0.2
Switch to intermittent use	23	0.1	4	0.1
Switch to dry processes	21	0.1		
Production shutdowns or relocations	13	0.1	105	2.7
Leak monitoring	11	0.1	74	1.9
Retrofit with low flow showers/toilets	10	0.1	3	0.1
Change to/from continuous processing	9	0.1	2	0.1
Other	393	2.4	960	24.4
Total	16,584	100.0	3,931	100.0
Total Number of Projects Including Water Saving Estimates	317		178	

Source: Survey Questions II.12, II.13

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reported from those responding plants with water saving responses. The data are indicative of the relative savings possible with the listed technologies. Care should be taken in forming comparisons between data on Tables 6-1 and 6-4 because of differences in plant coverage. Table 6-4 includes 317 existing and 178 planned projects that included water savings estimates.

The existing projects from sampled plants that provided water savings have annual water savings of 16,584 acre-feet. For these projects, 53 percent of savings are associated with cooling water -- either improved recycling or switch to air cooling. The savings from planned projects suggest that savings in the future are associated more with changes in the production process than with cooling. More than 20 percent of the planned projects are related to process water use compared to only 9 percent for cooling. Improved control systems, related to process water, will account for a significantly increased share of the water saved. One of the main ways reported to improve control systems was to monitor more closely actual water use in the plant. Investment in flow metering at different points in the production process as well as committing manpower to monitor water use are included in this method to save water. Landscaping investments show up importantly in the planned projects compared to the existing projects. The planned projects include more use of reclaimed water, drought-tolerant revegetation, monitoring, and irrigation systems to water at night.

6.3 Distribution Of Conservation Projects Among Industry Groups

Table 6-5 shows an estimate of the annual water savings by industry group for 1989 determined from the reported existing projects, and an estimate of expected annual water savings determined from reported planned projects. The estimated water savings by industry group is an expansion from the 317 reported conservation projects among the sampled plants on Table 6-4 grouped by industry totals. The industry expansion is keyed to the survey responses which reported water saved along with the type of conservation projects. In 142 reported existing projects, there were no data provided of the amount of water saved. The projects not matched with water savings were dropped for the industry group expansion on Table 6-5. For this reason, the estimates only can be considered a low approximation of conservation savings. (A more defensible estimate of water saved from existing conservation is shown as 76,400 AF later on Table 6-10.)

Table 6-5 shows that 66,100 AF were saved in 1989 from installed conservation; 26,100 AF of savings are forthcoming from planned projects. 178 of 212 planned projects provided an estimate of expected water savings from the project. The largest water savings are associated with three of the largest water using industry groups:

291 Refining
265 Paper

TABLE 6-5
WATER SAVINGS FROM CONSERVATION - EXISTING AND PLANNED

SIC CODE	Description of Plant	Total(1) Intake 1989 (TAF)	Water Saved from Existing Conservation Projects(2) (%)	Annual Water Saved From Existing Conservation(3) (TAF)	Potential Water Savings from Planned Conservation Projects(4) (%)	Annual Potential Water Savings From Planned Conservation(5) (TAF)
201	Meat Products	6.7	2%	0.13	5%	0.33
203	Preserved Fruits & Vegetables	21.6	28%	8.41	11%	2.37
205	Bakery Products	1.2	7%	0.10	2%	0.02
208	Beverages	39.1	2%	0.78	10%	3.91
209	Misc. Food & Kindred Prod.	13.7	24%	4.24	2%	0.27
265	Paperboard Containers & Boxes	12.4	39%	7.91	6%	0.74
281	Industrial Inorganic Chemicals	27.2	9%	2.72	0%	0.00
283	Drugs	6.1	3%	0.18	3%	0.18
284	Soaps, Cleansers, & Toilet Goods	3.3	5%	0.17	5%	0.17
285	Paints & Allied Prod.	1.1	19%	0.26	1%	0.01
291	Petroleum Refining	126.7	21%	32.95	10%	12.67
327	Concrete, Gypsum, Plaster Prod.	19.1	2%	0.38	9%	1.72
344	Fabricated Metal Prod.	8.3	NA	0.00	NA	0.00
357	Computer & Office Equip.	6.3	18%	1.38	9%	0.57
366	Communication Equipment	6.2	9%	0.62	12%	0.74
367	Electronic Comp. & Acc.	8.7	16%	1.64	9%	0.78
371	Motor Vehicles & Equip.	2.8	5%	0.14	8%	0.23
372	Aircraft & Parts	13.6	21%	3.67	9%	1.22
376	Guided Missles, Space Vehicles, Parts	3.7	10%	0.41	5%	0.19
	Total	327.7	20%	66.10	8%	26.1

1) Source: Survey Question II.1.

2) Percent saved is an average over SIC group calculated by dividing water saved by total intake plus water saved.
Source: Survey Question II.12.

3) Total amount saved estimated by dividing one minus the average percent saved from current conservation projects into the total 1989 intake and then multiplying by the average percent saved.

4) Source: Survey Questions II.13.

5) Total amount saved estimated by multiplying average percent saved from planned conservation projects by the total 1989 intake.

TAF = Thousand Acre Feet

na- Not enough information from returned surveys to generalize to industry.

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203 Fruits and Vegetables.

Large percentage water savings from existing projects are also associated with:

209 Miscellaneous Foods
284 Paints
357 Computer Equipment
367 Electronic Components
372 Aircraft

Figure 6-1 shows the distribution of percentage water savings by industry based on reported survey information. Paper (265) has saved the largest percentage from the reported existing projects. The industry groups listed above are shown on the figure to be the largest percentage water savers.[1]

The planned water savings estimated from reported projects are also shown on Table 6-5. The largest planned savings shown in the data set are located in the following industry groups, ranked ordered by savings:

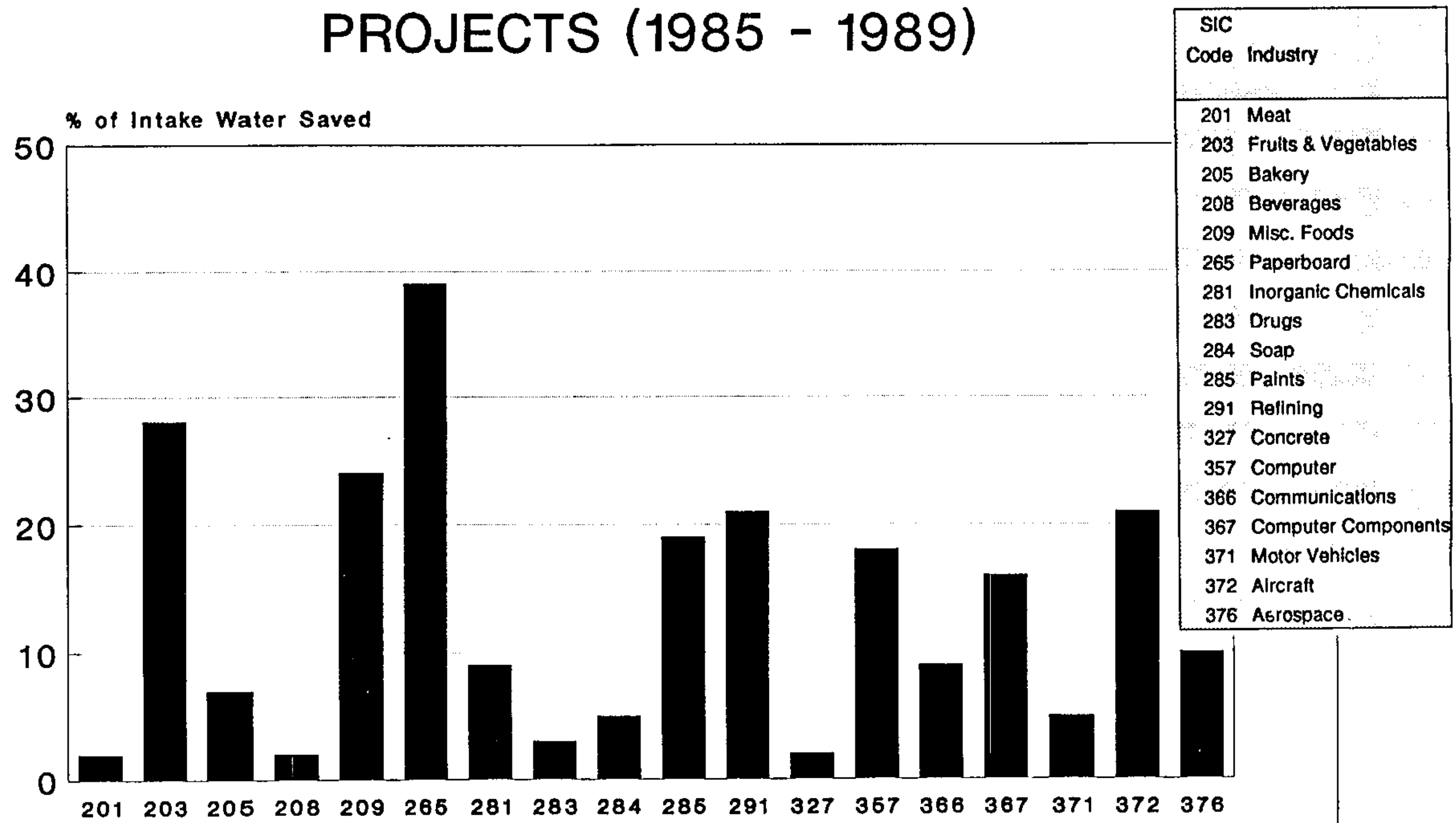
291 Refining
208 Beverages
203 Fruits and Vegetables
372 Aircraft
327 Concrete

Eighty-four percent of planned conservation projects reported expected water savings compared to 69 percent for the existing projects. The estimates of water savings in the last column on Table 6-5 represent better data coverage.

Figure 6-2 provides an indication of the diffusion of conservation among surveyed industry groups in terms of the number of reported projects by plant. To normalize for different sample sizes, reported projects were divided by responding plants to yield the average number of reported projects per plant -- total projects over total plants in the industry sample. After 20 years of operating under the Clean Water Act's inducements to reduce intake water, Refining remains the industry with the largest number of reported projects per

[1]Some of the industries shown with low percentage of water savings reflect spotty reported data rather than actual low water savings efforts. This applies to Vehicles (371). Spotty reported water savings coverage over the water savings data set renders conclusions from Figure 6-1 indicative but not conclusive for each industry group.

FIGURE 6-1
WATER SAVED FROM EXISTING CONSERVATION PROJECTS (1985 - 1989)



Source: Survey Question II.12

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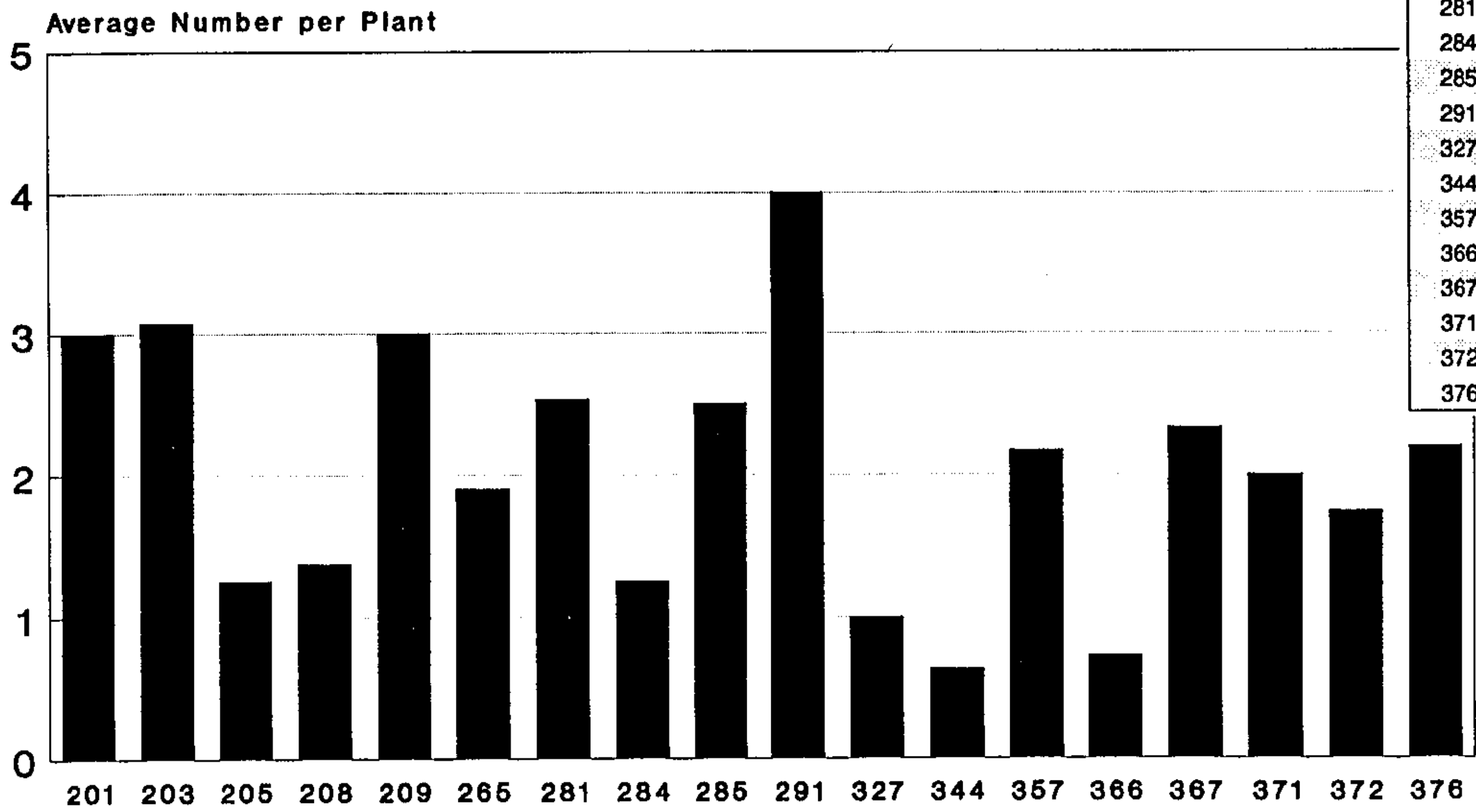
FIGURE 6-2
AVERAGE NUMBER OF REPORTED CONSERVATION PROJECTS PER PLANT



SIC Code	Industry
201	Meat
203	Fruits & Vegetables
205	Bakery
208	Beverages
209	Misc. Foods
265	Paperboard
281	Inorganic Chemicals
284	Soap
285	Paints
291	Refining
327	Concrete
344	Fabricated Metals
357	Computer
366	Communications
367	Computer Components
371	Motor Vehicles
372	Aircraft
376	Aerospace

The average number of projects per plant is underestimated for SIC group 291 due to aggregation.

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plant.[2] The key observation from Figure 6-2 is that industry groups reporting the largest percentage of water used directly in the manufacturing process also show substantial activity to reduce intake water -- Food industry groups, except of Bakeries and Beverages, Computers and Electronic Components, Vehicles and Aircraft/Aerospace. Conversely, Communication Equipment (366) has a low percentage of water used directly in the production process and fewer than one conservation project reported per responding plant.

Table 6-6 shows the largest water saving technologies in the largest water saving industry groups: existing and planned. Shown are practices/technologies accounting for most of the water savings within the selected industry groups. This table provides a "shopping list" of water saving technologies that have been and are being installed in these industry groups that could be transferred to other plants.[3]

This table reinforces the conclusion from Table 6-1 -- process water recycling and improved control systems are becoming more important to future water savings while cooling water recycling is becoming less important.

6.4 Industrial Water Use Efficiency Improvements

One objective of the study is to understand how industry has improved efficiency in the use of water since 1985. The change in the relationship between plant production and water intake since 1985 shows whether plants in the survey are using more or less water to manufacture products. For each industry, the plant specific and the industry average efficiency gain since 1985 has been calculated. Survey responses show that water use efficiency has improved significantly since 1985.

[2]The number of projects for each refinery are understated on Figure 6-2 because a number of projects were aggregated in the data set.

[3]Table 6-6 reports projects which also provided water savings. For instance, four refinery cooling projects were reported with no associated water savings. Therefore, there is a zero for refinery cooling water recycling.

TABLE 6-6
WATER SAVINGS BY INDUSTRY AND THE TECHNOLOGY USED (1)
EXISTING AND PLANNED

SIC CODE	Description of Plant	Total(2) Water Saved (TAFY)	Distribution of Savings Over Conservation Technologies(3): Recycle Cooling Water (TAFY)	%	Recycle Process Water (TAFY)	%	Reuse (TAFY)	%	Improve Control Systems (TAFY)	%	Other(4) (TAFY)	%
Savings From Existing Projects												
203	Preserved Fruits & Vegetables	8.41	5.64	67.0	0.12	1.4	0.49	5.8	0.04	0.5	2.13	25.3
209	Misc. Food & Kindred Prod.	4.24	3.43	81.0	0.02	0.5	0.38	9.0	0.23	5.5	0.17	4.0
265	Paperboard Containers & Boxes	7.91	1.82	23.0	4.51	57.0	0.02	0.2	0.13	1.7	1.43	18.1
291	Petroleum Refining	32.95	0.00	0.0	11.20	34.0	3.29	10.0	0.03	0.1	18.42	55.9
357	Computer & Office Equip.	1.38	0.46	33.0	0.04	3.0	0.06	4.0	0.28	20.5	0.55	39.5
367	Electronic Comp. & Acc.	1.64	0.33	20.0	0.07	4.0	0.41	25.0	0.13	8.0	0.71	43.0
372	Aircraft & Parts	3.67	2.98	81.0	0.18	5.0	0.00	0.0	0.04	1.0	0.48	13.0
	Total Saved	60.21	14.65		16.14		4.65		0.89		23.88	
		Percent By Technology	24%		27%		8%		1%		40%	
Savings From Planned Projects												
203	Preserved Fruits & Vegetables	2.37	1.10	46.5	0.08	3.5	0.00	0.0	0.02	1.0	1.16	49.0
209	Misc. Food & Kindred Prod.	0.27	0.02	7.7	0.22	81.0	0.00	0.0	0.03	11.0	0.00	0.3
265	Paperboard Containers & Boxes	0.74	0.00	0.0	0.35	47.4	0.08	10.5	0.00	0.0	0.31	42.1
291	Petroleum Refining	12.67	0.96	7.6	1.31	10.4	0.96	7.6	1.01	8.0	8.43	66.5
357	Computer & Office Equip.	0.57	0.00	0.0	0.57	100.0	0.00	0.0	0.00	0.0	0.00	0.0
367	Electronic Comp. & Acc.	0.78	0.11	13.9	0.47	59.7	0.00	0.3	0.00	0.0	0.20	26.1
372	Aircraft & Parts	1.22	0.02	2.0	1.04	85.5	0.00	0.0	0.04	2.9	0.12	9.5
	Total Saved	18.62	2.22		4.04		1.04		1.10		10.22	
		Percent By Technology	12%		22%		6%		6%		55%	

1) Only those Idustries with the most conservation are presented here.
2) Source: Table 6-3
3) Source: Survey Question II.12, II.13
4) Other includes additional conservation technologies listed on Table 6-1.
TAFY = Thousand Acre Feet per Year

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6.4.1 Measuring Plant And Industry Water Use Efficiency Gains

The ratio of water use to units of production characterizes the plant production technology in terms of the amount of water necessary to produce a unit of output.[4] Comparing across an industry, plants can be expected to differ in their level of water use per unit of production depending on their exact production process, their wastewater management problems and their progress toward conservation, to name three important differences. With data on physical output and water input, water use ratios can be calculated and plants rank-ordered by their efficiency in the use of water. As noted in Section 4.1, few plants provided output data, and those that did provided diverse units that prevent straightforward aggregation to an industry output value. Many more plants responded to the questions with an index of production, 1985 = 100.[5]

Except for refineries where water use per barrel of throughput could be estimated, (See Section 6.7.) output coverage for plants can only be indexed to their 1985 production levels. The production index method is quite a good measure to compare across plants within an industry or between industries because it allows us to compare output changes to water use changes since 1985 without regard to units of production. The water use efficiency calculation allows us to rank order the plants in an industry by improved water use efficiency and examine the distribution of efficiency improvements among plants.

A time series of the unit water use index shows how plants have changed water use relative to output. The changes in the unit water use, or efficiency index, indicate that plants have or have not substituted other inputs for water during the last five years. The data do not allow conclusions about which plants were absolutely more efficient in 1985 -- only how their efficiency has changed since 1985. For instance, one refinery, brought on-line in 1979, is air cooled and uses about one-third of the industry average water. But its water use efficiency index has not changed as much as other refineries over the last five years.

The unit water use index for each plant is constructed from the ratio of two indices: the index of production and the index of water use.

$$\textbf{Unit Water Use Index} = \frac{\textbf{Index of Water Use}}{\textbf{Index of Production}}$$

[4]This value does not give an indication of how much output would be lost if the firm were to face a water cutback because it is an average measure of water use, not a marginal measure. The output elasticity of water is such a marginal measure, describing the percentage of output lost (gained) due to a one percent decrease (increase) in water use. This elasticity is estimated from survey responses in section 7.3.

[5]The pretest revealed that many plants treat their plant production as proprietary. They were, however, willing to provide the index values.

The value for the 1985 index is set at 100. A level of less than 100 for 1989 shows that production occurred in 1989 with less water per unit of production and indicates an improvement in efficiency.

To show how industry water use efficiency has changed over the last five years, the plant indices of water use and output are averaged across each industry group, weighing each plant by its relative size in terms of water use and employment. Production employment is chosen as a proxy for the size of plant output in physical units because of the problems of mixed and unknown units. This proxy is reasonable within an industry where the production process is similar in terms of capital intensity and labor inputs, and necessary due to data limitations.

To take maximum advantage of the data provided, not only plants which reported five continuous years of data, but all plants with at least two years of data are included. The reasons why plants provided less than five years of data are numerous, but include not having five years of data within reasonable access, moving a plant's location and starting a new plant. To use this shorter-termed data, the plant was spliced in at the industry average index level for the first year in which the plant was able to provide data. The implicit assumption in this method is that the plant is no different in the missing years than the industry average. This is more likely to be true for plants that were in existence but unable to provide the full history, than for plants that started operations in the period 1985 to 1989. Plants that started up in this period often showed tremendous efficiency gains that were due more to moving up the learning curve of production than because of investments in water conservation. For this reason, several plants which could clearly be identified as start-up plants were excluded from the industry average calculation.

6.4.2 Estimated Industry Efficiency Gains

The industry trends in unit water use are shown on Table 6-7, with some SIC groups excluded due to insufficient numbers of observations. Figure 6-3 plots the 1989 unit water use index value compared to the 1985 benchmark for all industry groups. The 1989 unit water use index value is lower in all but two of the 18 industry groups covered -- production uses less water per unit of output than it did in 1985. The exceptions to the efficiency trend are Soaps and Cleansers (284) and Aerospace (376). The Soaps and Cleansers industry group shows no efficiency improvement -- water use and output both increased 44 percent -- while Aerospace (376) shows a significant efficiency loss. Water is a significant part of the product in the Soaps industry. Output has consistently declined since 1986 in the Aerospace industry while water use has declined only slightly.

Six industry groups have improved their water use efficiency significantly more than the others. These are shown on Table 6-8. The Computers, Electronic and Aircraft industry groups are among the leaders. The simple average 1989 unit water use index value for these

TABLE 6-7
INDUSTRY AVERAGE INDICES OF WATER USE, PRODUCTION & UNIT WATER USE INDEX

SIC CODE	Index	1985	1986	1987	1988	1989
201	Water Use	100	90.4	81.6	85.5	82.8
	Production	100	98.5	93.1	94.4	87.6
	Unit Water Use	100	91.8	87.6	90.6	94.5
203	Water Use	100	97.7	109.8	88.1	79.5
	Production	100	113.1	118.6	127.7	131.3
	Unit Water Use	100	86.4	92.6	69.0	60.6
205	Water Use	100	95.2	94.1	86.2	84.7
	Production	100	94.1	100.6	107.9	113.0
	Unit Water Use	100	101.3	93.5	79.9	75.0
208	Water Use	100	104.9	103.6	101.5	102.8
	Production	100	101.9	106.1	105.4	108.8
	Unit Water Use	100	102.9	97.7	96.3	94.6
209	Water Use	100	103.0	100.4	126.5	125.3
	Production	100	109.4	120.4	141.1	159.4
	Unit Water Use	100	94.1	83.4	89.7	78.6
265	Water Use	100	100.4	107.4	97.3	92.5
	Production	100	98.5	98.5	107.3	110.4
	Unit Water Use	100	101.9	109.0	90.7	83.8
281	Water Use	100	105.5	104.0	101.3	96.5
	Production	100	106.3	107.0	108.3	106.0
	Unit Water Use	100	99.2	97.2	93.6	91.0
284	Water Use	100	116.5	120.7	116.4	144.4
	Production	100	105.9	116.3	128.1	143.8
	Unit Water Use	100	110.0	103.7	90.8	100.4
285	Water Use	100	95.2	78.0	45.8	45.7
	Production	100	106.6	100.2	98.9	99.4
	Unit Water Use	100	89.3	77.8	46.4	46.0
291	Water Use	100	97.3	97.9	101.0	99.3
	Production	100	107.8	109.3	111.9	116.3
	Unit Water Use	100	90.3	89.6	90.2	85.4
327	Water Use	100	98.0	102.4	105.7	105.2
	Production	100	113.4	119.6	128.3	140.3
	Unit Water Use	100	86.4	85.6	82.3	75.0
344	Water Use	100	103.2	108.6	112.1	109.7
	Production	100	105.5	117.2	159.9	157.4
	Unit Water Use	100	97.9	92.7	70.1	69.7
357	Water Use	100	87.9	94.0	90.9	78.5
	Production	100	115.9	129.1	141.1	155.8
	Unit Water Use	100	75.8	72.8	64.4	50.4
366	Water Use	100	100.2	94.9	89.0	87.8
	Production	100	100.8	100.5	106.9	99.3
	Unit Water Use	100	99.4	94.4	83.2	88.4
367	Water Use	100	107.4	100.9	104.3	100.4
	Production	100	134.5	167.3	166.6	178.5
	Unit Water Use	100	79.8	60.3	62.6	56.3
371	Water Use	100	134.3	114.5	90.6	80.0
	Production	100	147.8	137.3	107.9	146.8
	Unit Water Use	100	90.9	83.4	84.0	54.4
372	Water Use	100	98.2	103.6	120.9	109.1
	Production	100	117.6	135.6	170.7	173.7
	Unit Water Use	100	83.5	76.4	70.8	62.8
376	Water Use	100	96.2	101.0	102.2	96.7
	Production	100	104.3	97.4	88.7	81.9
	Unit Water Use	100	92.3	103.7	115.3	118.0

Source: Survey Questions I.9 & II.1

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six large industry groups shows that they have improved their water use practices so that 1989 production could be manufactured with only 53 percent of the water used to manufacture a unit of production in 1985.

TABLE 6-8
TOP SIX INDUSTRY GROUPS UNIT WATER USE INDEX IMPROVEMENTS

SIC CODE	Description of Plant	1989 Unit Water Use Index (1985=100)
285	Paints	46.0
357	Office & Computer Equipment	50.4
371	Motor Vehicles & Equipment	54.4
367	Electronic Components	56.3
203	Fruit & Vegetables	60.6
372	Aircraft & Parts	62.8
	Simple Average	53.4

Source: Table 6-7

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The 16 industry groups shown on Figure 6-3 with an improvement in water use efficiency divide into three major categories:

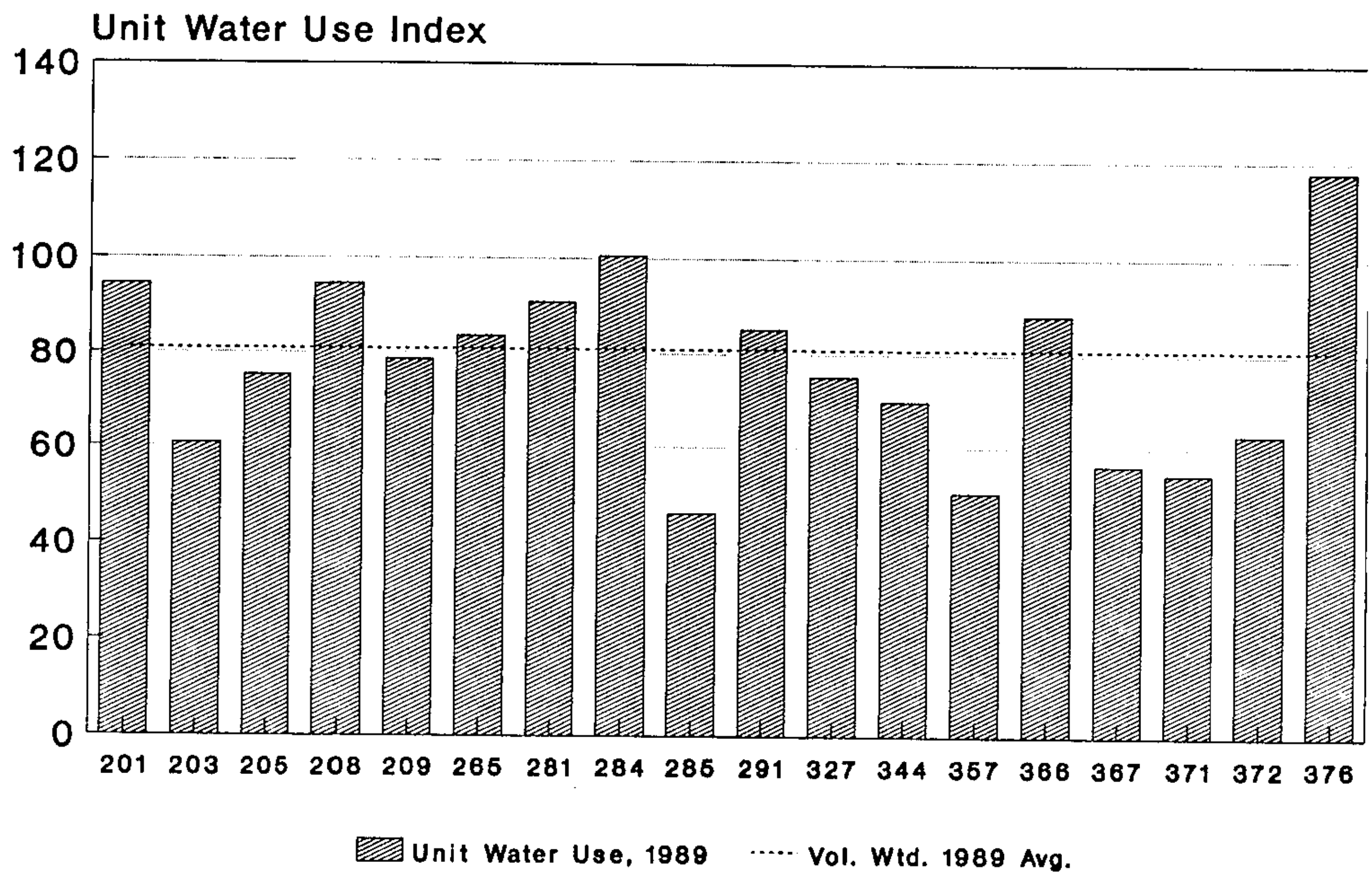
1. Growing industry groups which show production up, with water down;

2. Static industry groups which show production stable, with water down; and

3. Growing industry groups which show production up, with water stable.

One industry declined in production (201), with water decreasing even faster, while another shows growth both in production and water, with production growing faster (209). Focusing just on the water use index, 11 of the 18 groups show water use down, while seven show water use up over the period 1985 to 1989. Industries are grouped on Table 6-9.

FIGURE 6-3
INDUSTRY UNIT WATER USE INDEX



SIC Code	Industry
201	Meat
203	Fruits & Vegetables
205	Bakery
208	Beverages
209	Misc. Foods
265	Paperboard
281	Inorganic Chemicals
284	Soap
285	Paints
291	Refining
327	Concrete
344	Fabricated Metals
357	Computer
366	Communications
367	Computer Components
371	Motor Vehicles
372	Aircraft
376	Aerospace

Source: Survey Questions I.9 & II.1

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TABLE 6-9
INDUSTRIES GROUPED BY WATER AND PRODUCTION INDICES

Production Up, Water Down:

203	Preserved Fruits & Vegetables
205	Bakery Products
265	Paperboard Containers and Boxes
281	Industrial Inorganic Chemicals
357	Office and Computer Equipment
371	Motor Vehicles and Equipment

Production Stable, Water Down:

285	Paints and Allied Products
366	Communications Equipment

Production Up, Water Stable:

208	Beverages
291	Petroleum Refining
327	Concrete, Gypsum, Plaster Products
344	Fabricated Structural Metal Products
367	Computer and Electronic Components
372	Aircraft and Parts

Production Down, Water Down More:

201	Meat Products

Production Up More Than Water:

209	Miscellaneous Food and Kindred Products

Production Down More Than Water:

376	Guided Missiles, Space Vehicles, Parts

Production Up Less Than Water:

284	Soaps, Cleaners and Toilet Goods

6.5 Estimated Industry Conservation

Water conservation has improved significantly during the five years from 1985 to 1989. Sections 6.1 and 6.3 described what technologies and methods were employed to achieve conservation in which industry groups. Table 6-5 previously provided one estimate of existing and planned annual water savings from conservation. In this section, water savings from conservation since 1985 is estimated with a second method and the potential for additional conservation is estimated.

6.5.1 Increase in Annual Conservation From 1985 To 1989

Water conserved by industry groups in 1989 was previously estimated in Section 6.3 linked to reported existing conservation projects. A second estimate for 1989 has been made based on the water use efficiency indices. Without relying on the detailed information in Sections 6.1, 6.2 and 6.3 of exactly what changes have been made to the production process to use less water, the plants in most industry groups are shown to be using less water per unit of output in Section 6.4. An industry-wide average unit water use, or water use efficiency, index value for 1989 of 81 implies that the average industry used 81 percent of the water used in 1985 to produce equivalent 1985 output, using the more efficient 1989 water use technology. Multiplying the industry-wide water usage for 1985 by the industry average efficiency for 1989 yields the water necessary in 1989 to produce 1985 output. The difference between actual 1985 water use and the water use necessary to produce the 1989 level of output with improved efficiency provides an estimate of water conservation between 1985 and 1989. This estimate appears as the final column on Table 6-10.

For the 18 industry groups on Table 6-10 with adequate statistical coverage, the total estimated annual conservation achieved in 1989 was 76,400 AF. This estimate agrees reasonably well with the 66,100 AF estimated annual water savings on Table 6-5. Of the two estimates, the 76,400 AF is considered a better estimate because the reported project data underlying Table 6-5 are incomplete. The two largest water saving industry groups were Preserved Fruits and Vegetables (203) and Petroleum Refining (291). These accounted for very nearly half the total over the period. The largest percentage changes occurred in the Paint (285), High Technology industry groups (357 and 367), Vehicles (371) and Aircraft (372) industry groups. The Vehicle conservation estimate on this table differs greatly from that based on reported projects for Table 6-5. Data limitations on Table 6-5 are the explanation.

One caution should be noted: many of these plants faced water utility-imposed drought cutback programs. Some of the reduced water use programs such as reduced landscaping are transitory in nature. Future efficiency levels will be influenced by continued technology and process improvements but offset by relaxed efforts to restrict nonessential water use for

TABLE 6–10
WATER CONSERVATION IN 1989

SIC CODE	Description of Plant	Industry Water Usage 1985 (1000AF)	Avg 1989 Unit Water Use 1985=100	Estimated Growth Factors 1985–1989	Estimated Annual Conservation 1989 (1000AF)
201	Meat Products	6.7	94.5	1.014	0.4
203	Preserved Fruits & Vegetables	35.3	60.6	1.207	16.8
205	Bakery Products	1.3	75.0	1.014	0.3
208	Beverages	42.6	94.6	1.305	3.0
209	Misc. Food & Kindred Prod	15.8	78.6	1.014	3.4
265	Paperboard Containers & Boxes	14.2	83.8	1.090	2.5
281	Industrial Inorganic Chemicals	32.5	91.0	1.223	3.6
284	Soaps, Cleansers, & Toilet Goods	2.4	100.4	1.104	0.0
285	Paints & Allied Prod.	1.9	46.0	1.223	1.2
291	Petroleum Refining	128.3	85.4	1.166	21.9
327	Concrete, Gypsum, Plaster Prod.	13.4	75.0	1.131	3.8
344	Fabricated Metal Prod.	11.7	69.7	1.000	3.6
357	Office & Computer Equip.	6.3	50.4	1.402	4.4
366	Communication Equipment	8.7	88.4	0.904	0.9
367	Electronic Comp. & Acc.	8.6	56.3	1.263	4.7
371	Motor Vehicles	3.3	54.4	0.978	1.5
372	Aircraft & Parts	12.3	62.8	1.066	4.9
376	Guided Missiles, Space Vehicles, & Parts	2.3	118.0	1.066	-0.4
	Total or Average	347.5	81.1		76.4

Source: Spectrum Estimate

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landscaping and employees. Relaxing the restrictions can be expected to slow continued efficiency growth when normal rainfall patterns are resumed.[6]

6.5.2 Potential Additional Conservation

Sections 6.1 and 6.3 described conservation in terms of those identified projects in place by 1989, those planned and budgeted, and those which would be considered to mitigate the hypothetical water shortages scenarios presented in part III of the survey. Section 6.4.1 described conservation improvements using water use efficiency gains as the basis. This section synthesizes the two previous approaches with the goal of estimating the potential for future conservation.

6.5.2.1 Complexity of Estimating Potential Additional Conservation

Estimating potential additional conservation entails an understanding of:

1. Water use efficiency improvements to-date;

2. The diffusion of practices/technologies to conserve water;

3. Engineering-economic forces that will enhance or impede further adoption of conservation practices.

Having discussed the first point in the previous section, each plant is now compared to the industry average with an eye towards the second and third points. To do so, the plants are rank ordered in terms of their 1989 unit water use index values. Some plants improved efficiency more than the average, others less. The question to be answered is what about their particular production technology changes makes the above and below average plants different? Why did some plants make tremendous efficiency gains in the last five years while others did not? What kinds of efficiency gains could be attained by the plants which are below the average efficiency gain?

One method of imputing potential additional conservation in an industry would be to conduct full water audits of a sample of plants, noting the technical improvements possible and the water each project would conserve. Relating the savings in the audited plants to the saturation of these types of technologies across the industry and the likely speed of further

[6] This is the usual demand forecasting problem of trying to estimate embedded conservation and transitory conservation.

diffusion would provide a fairly reliable estimate of the potential for additional conservation -- assuming a reliable estimate of saturation and speed of technology diffusion. Estimating saturation and diffusion rates is (1) a different exercise from the engineering audit (2) difficult and (3) depends on economic forces.

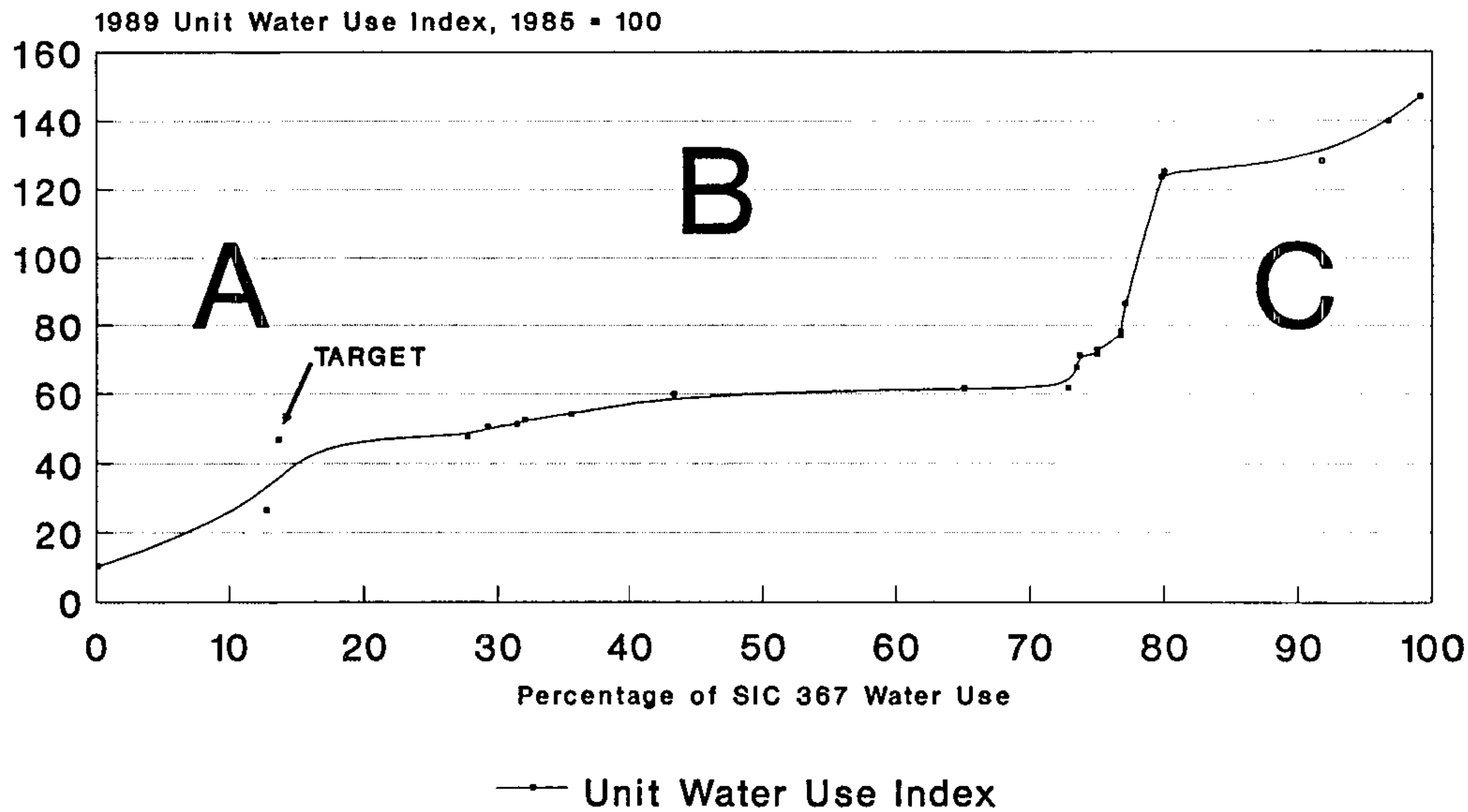
An engineering audit estimate of conservation, while revealing the mix of technically feasible options, does not take into account the business environment in which these plants operate; that is, the market conditions and competitiveness of each industry. The only way in which the potential industry conservation determined from a plant audit could actually be achieved is if it were mandated by regulation. The actual potential for conservation to be realized in an industry is greatly influenced by market factors specific to each industry. This suggests the need for an estimating approach which takes these factors into account.

The efficiency profile of each industry provides a way to estimate potential additional industry conservation. The industry profile is a graph, such as Figure 6-4 for the Computer and Electronic Components industry. The plants in the industry group are rank-ordered in terms of their 1989 efficiency index level (the vertical axis) and plotted relative to their 1989 water usage (cumulatively, along the horizontal axis). When such a profile contains distinct parts, such as the those labelled A, B, and C in Figure 6-4, plants in the industry may be grouped with respect to their efficiency gains as the below average plants in C, the close-to-the-industry-average plants in B, and the industry leaders in A. If the plants in C had achieved the efficiency gains exhibited by the average plants in B -- thus flattening the curve -- a certain amount of water conservation is implied. If the average plants in B had achieved a little more efficiency growth -- thus lowering the curve -- a certain amount more of water conservation would be implied. In short, flattening and lowering the industry profile implies the potential for more conservation.

Potential additional conservation can be estimated with reference to a set target improvement level along the industry profile for each industry group. The challenge is to set the target so that the estimated additional conservation is plausible and conservative. The gains implied by the plants in A have been achieved by plants facing similar market conditions for their products and their inputs as the other plants in the B and C groups. This level of improved water use efficiency is feasible both technically and economically. The remainder of the plants in the "B" and "C" groups can be assumed to improve unit water use in reference to some higher target value without assuming that they all become A plants in their water use efficiency. By shifting the entire industry average with reference to a target value instead of assuming that B and C plants become A plants makes the estimated potential for conservation conservative.

A caveat mentioned before needs to be repeated. The efficiency index as calculated in the previous section shows changes over the last five years for plants, not the absolute level of plant efficiency. That is, all plants start at an efficiency index equal to 100 in 1985 and thus differences in the level of absolute efficiency across plants cannot be ascertained (with the exception of the refineries (291). See Section 6.7.) Hence plants which engaged in a lot of

FIGURE 6-4
PLANT UNIT WATER USE INDEX BY INDUSTRY: ELECTRONIC COMPONENTS



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conservation prior to 1985 and continued to operate at a steady high level of efficiency from 1985 to 1989 will show little change in the efficiency index over time, while a plant which was inefficient relative to other plants in 1985, but put much conservation in place during the period 1985 to 1989 will show a marked change in the efficiency index. As such, it would be misleading to assert that all plants should be able to attain the gains of the most-improved plant.

A concrete example illustrates this point in the refinery sector, where absolute efficiency comparisons are possible. A relatively new, air-cooled refinery made a 9.1 percentage point improvement in efficiency, while an old water-cooled refinery made a 22.6 percentage point improvement. The absolute water use efficiency measure of barrels of water used per barrel of refinery crude oil input is 0.34 for the newer refinery while the older (but more improved) refinery used 1.8 barrels of water per barrel of output in 1989. Without a complete switch to air-cooling, the older refinery cannot achieve the absolute efficiency of the newer refinery. Neither can the air cooled refinery make the percentage gains that the water cooled refineries can. Nonetheless, as the industry average is about 1.1 barrel of water per barrel of oil, and some water-cooled refineries reduced their water use to 0.8 - 0.9 barrels per barrel of crude oil in recent years, a conservative target improvement that reasonably estimates potential additional conservation can be set for the entire Refining industry that allows for the very efficient air-cooled refinery's restricted ability to make further gains. The target can be established to recognize that some refineries may make little contribution to achieving the industry goal and others may be expected to make most of the contribution.

6.5.2.2 Estimated Potential Additional Conservation

The estimate of potential additional conservation for each industry is shown in Table 6-11. Sixty-one thousand annual acre-feet (61,000 AF/year) of water could be conserved from these industry groups if the average and below average plants made efficiency gains sufficient to move the entire industry average up to the target observed in the industries by the slightly above average plants. Not all plants in the industry are expected to move to the target; rather, the existing industry average is expected to move to the target. This is conservative.

The estimated 61,000 acre-feet of potential additional conservation is 19 percent of the 1989 intake water of these industry groups -- probably a costly increment, given the reduction in water use that has occurred since the 1972 Clean Water Act, and the evidence from the plant-augmented costs estimated to be discussed in Section 6.6.2. The largest potential savings occur in the Refining and Industrial Chemical industry groups. While these large water using industries have made significant reductions in water use, there still remain opportunities in those two industry groups to reduce water use.

TABLE 6-11
POTENTIAL ADDITIONAL INDUSTRIAL WATER CONSERVATION IN 12 COUNTY STUDY AREA

SIC CODE	Description of Plant	WTD 1989 Unit Water Use Index	Unit Water Use Index Target	Avg. Percent Improvement	Industry Water Usage – 1989 (TAFY)	Potential Additional Conservation(1) (TAFY)
201	Meat Products	94.5	86.7	8.2	6.7	0.5
203	Preserved Fruits & Vegetables	60.6	54.0	10.9	21.6	2.3
205	Bakery Products	75.0	62.2	17.1	1.2	0.2
208	Beverages	94.6	85.3	9.8	39.1	3.8
209	Misc. Food & Kindred Prod	78.6	60.3	23.3	13.7	3.2
265	Paperboard Containers & Boxes	83.8	59.1	29.5	12.4	3.6
281	Industrial Inorganic Chemicals	91.0	54.2	40.4	27.2	11.0
284	Soaps & Cleansers	100.4	67.8	32.5	3.3	1.1
285	Paints & Allied Prod.	46.0	40.8	11.3	1.1	0.1
291	Petroleum Refining	85.4	69.0	19.2	126.7	24.3
327	Concrete, Gypsum, Plaster Prod.	75.0	70.1	6.5	19.1	1.3
344	Fabricated Metal Prod.	69.7	48.1	31.0	8.3	2.6
357	Office & Computer Equip.	50.4	42.3	16.1	6.3	1.0
366	Communication Equipment	88.4	76.7	13.3	6.2	0.8
367	Electronic Comp. & Acc.	56.3	47.7	15.2	8.7	1.3
371	Motor Vehicles	54.4	40.7	25.2	2.8	0.7
372	Aircraft & Parts	62.8	53.2	15.3	13.6	2.1
376	Guided Missles, Space Vehicles, & Parts	118.0	85.3	27.7	3.7	1.0
	Total or Average	81.1		19.0	321.6	61.0

TAFY = Thousand Acre-Feet Year

1) Substituting reclaimed water for potable water is not considered part of these estimates.

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This estimate of potential additional conservation is based on technologies that were adopted under the economic conditions of recent years. Changing economic conditions and new technologies would increase the opportunity to conserve water in the future. The intent of the Water Quality Act of 1987 specifically has been to induce new technology to achieve wastewater discharge reductions. Hence, the conservation projects in the data set reasonably include most of the technology that is likely to be relied on throughout this decade. The potential additional conservation shown on Table 6-11 is a great deal larger than the estimate of savings from planned conservation shown on Table 6-5. The potential for additional conservation is larger than savings from projects underway.

For perspective, the potential additional industrial water savings from these industry groups in the 12 county area is about one-half of one percent (0.5%) of the total non-industrial urban water use in California. The additional savings for industry equals about 1 gallon for every 700 gallons of water used in California irrigated agriculture.

The estimates need some explanation. Table 6-11 shows the average water use index for each industry, the target unit water use index and the average percent improvement to target. The average percent improvement in unit water use multiplied by the 1989 industry-wide water usage yields an estimate of the industry potential additional conservation in the last column. **This gives a reasonable and conservative estimate of the likely potential additional savings factoring in both existing economic forces and available technology.** This is a more realistic and more conservative estimate of potential conservation than would be derived by assuming the entire industry switches to the practices of the most efficient plant.

The adopted industry efficiency improvement targets are selected along the industry efficiency profile as a plant near the 33rd percentile. This target which does not expect all plants to move up to the highest state of art and allows for the fact that some plants in the industry may be at or near the state of art and cannot achieve much added conservation.

In several industry groups it was necessary (due to a small number of plants with calculable efficiency indices) to choose a plant from a higher percentile efficiency gain as the potential conservation improvement target. This is only unsettling when the improvement potential percentile level represents plants covering a small percentage of water use or employment in the industry. The groups are Meats (201) with only 18 percent of employment represented by plants in the sample defining the target improvement; Beverages (208) and Fabricated Metals (344), both at the 22nd percentile; Aircraft (372) also at the 18th percentile, and Aerospace (376) at the 2nd percentile. The 376 percentile is so low for two reasons: one is that there are some very large plants in 376, the second is that these same plants do not show efficiency improvements. This may be due to the fact that virtually the entire Aerospace industry made all of its water use efficiency gains before 1985 and the selected target plant is the last plant; or it may be true that technology in the industry does not lend itself to water use efficiency improvements; it may also be true (as will be assumed) that the plants could improve to the selected target level. In the other industry groups with this problem -- notably 208 -- there is the possibility that the plants showing up as having little efficiency gain in recent years achieved their improvements earlier.

6.6 Unit Costs of Conserved Water

Potential costs per AF can be determined for existing, planned and contingency conservation projects identified in the survey to evaluate conservation costs under different conditions. These conservation costs can be compared to the alternative costs that can be avoided to determine whether costs are lowered by conservation, and if so, how much. A large number of conservation projects having little identified costs can be found among both the existing and planned projects -- landscape projects, education, etc. At the other end of the spectrum, a significant number of installed and planned projects have estimates of high costs per AF of water. So, too, the contingency projects included some with high costs.

The costs per AF for installed, planned and contingency projects are plotted as a series of marginal cost curves for plant-augmented water for each industry based on data provided from survey questions II.2, II.13, III.2 and III.9. These are compared to the estimated avoided cost of buying and disposing of utility water supplies, which is the horizontal line on the figures. Average avoided costs by industry are estimated by Spectrum and shown on Table 5-7.

6.6.1 Calculation of Annual Investment and O&M Costs

A key aspect of this analysis is to compare the costs of water-saving measures between plants and industry groups to the avoided costs of buying, treating and disposing of water. The majority of these costs are in capital investment. To make valid year-to-year comparisons, capital recovery charges or annual "rental" rates for these facilities were calculated.

In several post-survey interviews, plant managers indicated that they chose projects which gave a three-year payback; i.e., project approval decisions expected the savings to recover the initial costs within three years. The implied internal rate of return was computed assuming that these projects generally had a 20-year lifetime (or a 5 percent depreciation rate) and the expected inflation rate (for O & M) was 5 percent. From these assumptions, the implied pre-tax discount rate on corporate investments is 23 percent. This rate was rounded down to 20 percent based on previous surveys of corporate discount rates done by Spectrum Economics for other agencies and clients. This is roughly equivalent to an after-tax corporate discount rate of 12 percent or a shareholder after-tax rate of 8 percent.

The water conservation practices/technologies from questions II.12 to II.13 were split into two groups. For **technologies which recycle/reuse water** and for **process modifications to reduce water use**, a 20-year lifetime was used to calculate annualized costs. This decision was based on the tax treatment of such investments. The same method was used by Brown and Caldwell in their study of conservation practices.[7] For **sanitation and housekeeping practices** a 10-year lifetime was used because many of these projects are treated separately for tax purposes and have a range of depreciation schedules.

For **wastewater treatment** capital costs, a 20-year lifetime was used. Past investments were inflated by the Producer Price Index for General Machinery to 1988 levels for this category.

The levelized annual payments were added to operating and maintenance (O&M) costs for conservation projects to give total costs.[8] The cost per acre-foot was calculated by dividing total costs by expected annual water savings in the case of conservation and by the amount of water treated and discharged water for wastewater. Costs for treated and discharged water were then converted to intake water equivalents based on the survey-reported return and treatment rates on responses to questions II.8 through II.11.

6.6.2 Industry Plant-Augmented Water Supply Costs

In response to rising costs for wastewater disposal and drought-limited supplies of utility intake water, plants have turned to conservation. Sections 6.1 and 6.3 have discussed the measures taken by industry to reduce water use. During the past several years existing plants, particularly in Northern California, have been virtually unable to use more than their 1986 or 1987 base-year consumption. Consequently, added water requirements of the plant to support growth of production have been largely supplied by plant-augmented water.

The costs per acre-foot for the existing and planned conservation projects within each industry are plotted on the following figures together with the contingency projects reported within the scenario questions III.2 and III.9. The scenario responses are considered

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[7]Brown and Caldwell, "Case Studies of Industrial Water Conservation in the San Jose Area," February, 1990.

[8] Levelized annual payments do not give the true annual "rental" payments that these plants would face in a market-price structure because levelized payments decline in real terms from year to year. However, most plant engineers and accountants are more familiar with this method than the more accurate asset-rental or trended-capital base method that would be the preferred alternative.

contingency conservation projects to respond to the hypothetical 15% and 30% water supply shortages.[9]

In a perfect market the installed projects would be expected to have lower costs per acre-foot than planned projects. The contingency projects would be expected to have even higher costs per acre-foot. Plant-augmented cost curves are unique to each plant and have no necessary relationship to other plants because there is no way to trade water among plants of an industry or between industry groups. Each plant and each industry has unique characteristics which determine the choice of conservation project mix. Hence, one plant's installed projects' costs could be higher than another plant's planned costs. Consequently, existing, planned and contingency projects can overlap each other in costs within an industry because of unique plant differences.

Individual plants may not implement first all of the low cost measures for a number of reasons. Most plants have a number of separate production units, and many water-saving changes are made when these units are shutdown for maintenance -- particularly the easier, low-cost change-outs. Some of the conservation technologies entail risks to production quality and costs. Different unit supervisors will balance their choices of conservation investments in any given year between conservation risk/return considerations and comparable risk/return considerations from other modifications to the production process. Many projects are implemented as a package. Either the physical installation process requires that several projects all be done at once (e.g., installing a new production unit with its support equipment) or the synergy between the projects is such that several are undertaken to enhance overall conservation savings. The result of these factors is a spread of observed conservation costs and savings between plants but with a generally increasing cost trend over time. The average costs of projects chosen in a time period can be rank-ordered to show the marginal costs of water conservation.

The projects ordered by cost per acre-foot of water saved and by category -- existing, planned, and contingency -- can be plotted on the following figures. These plants represent industry supply curves which relate to quantity saved or conserved. For the industry groups which provide sufficient data, the following figures and discussions detail some of the factors and observations that apparently motivate conservation investments. Also plotted on the figures are the avoided cost estimates from Table 5-7. (Avoided costs plotted are defined as the sum of intake water plus wastewater pretreatment costs plus wastewater discharge

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[9]Projects occur in the data set in nearly all industries with very high costs per acre feet that are excluded on the following tables. In a few cases, we determined by telephone follow-up that these projects actually saved water only as a side purpose of the project. In most cases, we have not yet followed-up to find out exactly what is motivating these extremely high cost reported conservation projects. For the sake of exposition, we have simply not reported them. [They remain a part of the data set, but are not plotted.] These outliers deserve further investigation. Their cost would not be inconsistent with profit maximizing behavior explained in Section 5.1. Their cost may also reflect in some cases the excluded costs of process water pretreatment discussed in Section 5.3.

fees.) The plotted avoided costs assume the illustrative average cost for purchased intake water determined on Table 5-1. Drought surcharges are not included.[10] **Drought surcharges could add between $300 to $1,200 per acre-foot to the avoided cost lines plotted.**

6.6.2.1 Fruits and Vegetables (203)

Figure 6-5 shows the cost curves for the Fruit and Vegetable packing industry. For this industry group the cost curve for existing projects is lower than the curve for planned projects except there are a few outliers from each category costing between $3,000 and $4,500 per AF. Contingency project are shown ranging in cost from below the cost of installed projects to nearly $4,500 per AF of saved water. Planned and contingency projects, as expected, do cap the high-cost projects. (Remember, one plant's planned project may be another plant's contingency.)

Given the avoided cost per acre-foot of $1,400 shown on the figure (or closer to $2,000 with drought surcharge for water used above 1986 or 1987 levels), why do we see projects with a cost greater than the avoided cost? The answer is found in basic microeconomics as explained in Section 5.1.

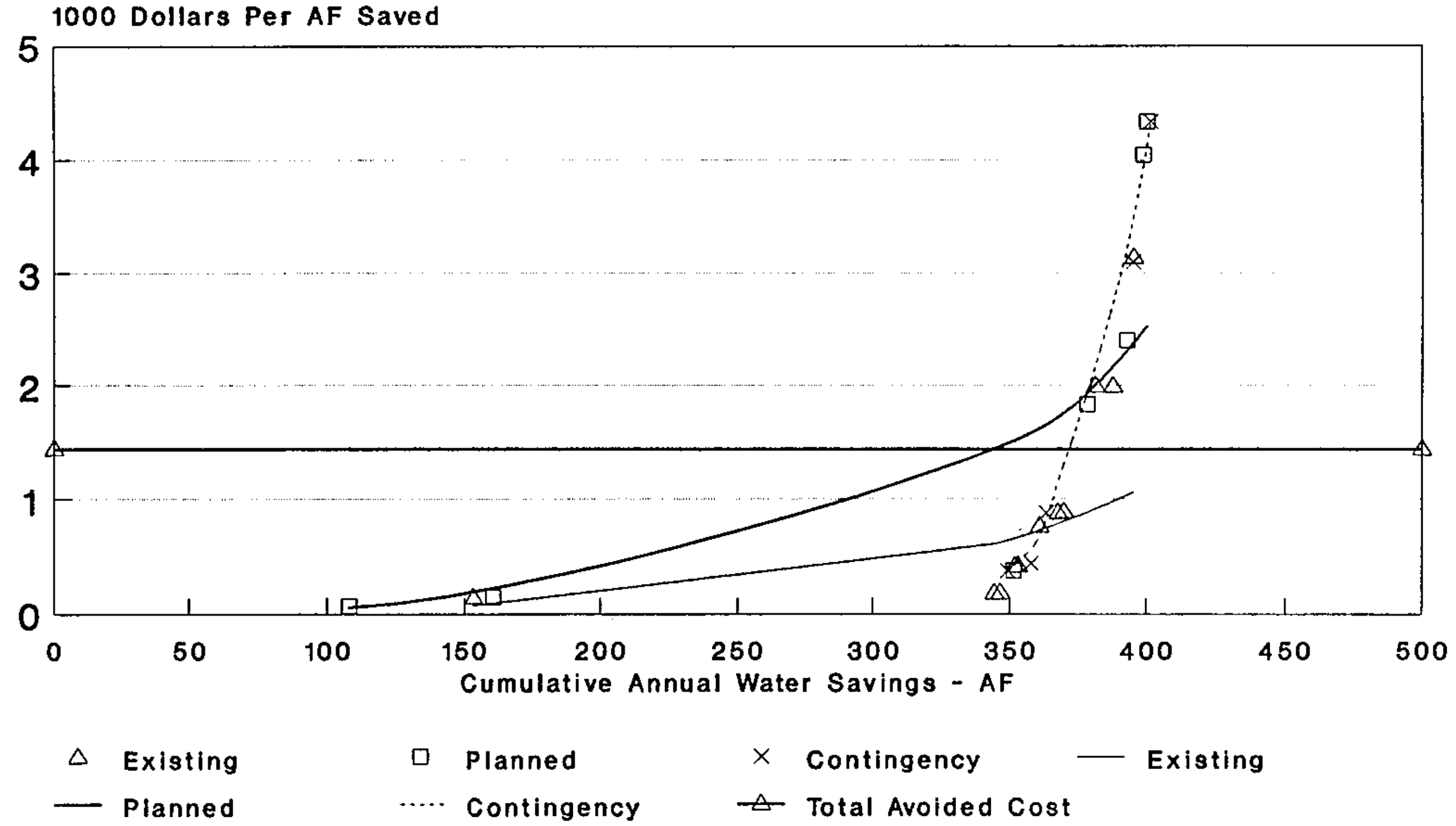
> If the plants are limited by utility drought management plans, then further requirements for water will come from plant-augmented supplies -- by conservation. Plants will increase their use of individual plant-augmented water supplies until the marginal cost of producing the water is equated with the marginal value of using the water.

A number of projects are shown on Figure 6-5 above the industry avoided costs. The highest cost projects shown on the figure range up to $4,500. Minimizing cost is not the guiding principle for the incremental projects for plants within this industry. Rather, profit maximizing under both constrained access to utility water and uncertainty about the future availability of water governs the decisions evident in these high cost projects. Management perception and expectation of future water supply must play a central role in planning to provide plant-augmented water supplies so much more costly than utility supplied water.

[10]The figures are illustrative of statewide industry water prices, not plant-specific water costs. Further econometric work would include the plant-specific intake water costs including groundwater and non-potable water as discussed in Section 5.2.

FIGURE 6-5

MARGINAL COST OF CONSERVED WATER PRESERVED FRUITS & VEGETABLES



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Responses to survey questions revealed that the opportunity value of production linked to access to water for this industry is in the range of $15,000. Conserved water costing $4,500 makes sense if (1) the plant's access to lower cost utility water were constrained and/or (2) uncertainty governed expectations about access to adequate future supplies.

6.6.2.2 Miscellaneous Food Products (209)

The cost curves for this industry, shown on Figure 6-6, are dominated by a 463 annual acre-foot savings from an existing cooling recirculation project with a cost of $110 per AF. Building upon that project, existing, planned and future projects rise to nearly $5,000 per AF with contingency projects capping the high cost projects. The avoided costs for treated and untreated streams through the plants are sufficiently different that they are both plotted on the figure. A number of projects are seen to cost less than or near the avoided costs. The few existing and planned projects with costs greater than avoided costs can be explained with reference to the value of reliable water supplies to support expanded plant production.

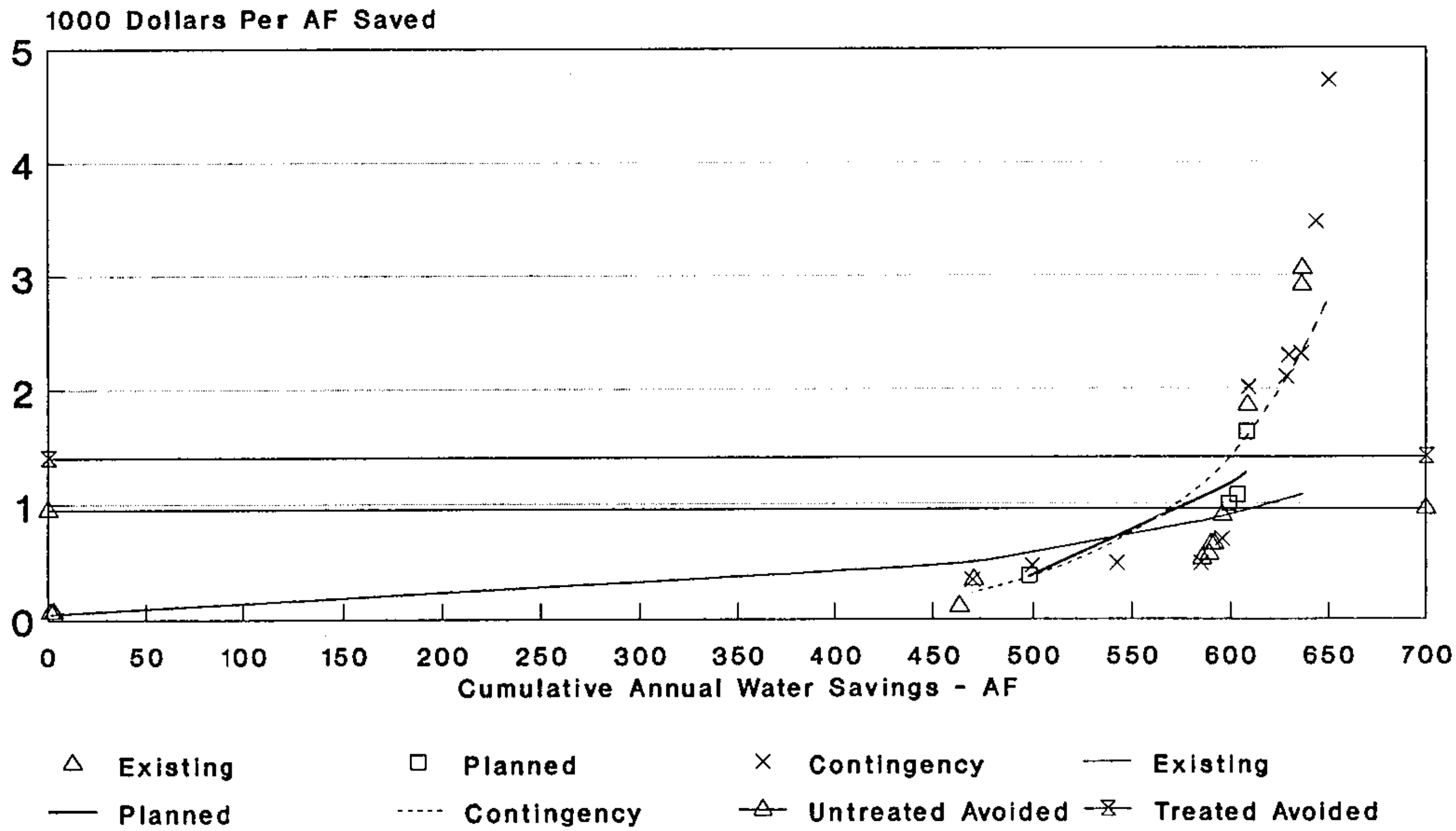
Fifty-five percent of plants in this industry reported that a 30% water supply cutbacks would result in lowered production. The marginal operating profit loss shown on Table 5-9 for the 30% cutback is $49,061 for this industry. (209 is a miscellaneous grouping including seafoods, roast coffee, potato chips, manufactured ice, etc. The very high marginal operating profit losses reflect substantially more value-added by process than observed for vegetable packing (203).) Plants would be expected to invest in high cost conservation project to avoid losses of this magnitude.

A number of contingency projects are seen to have substantially higher costs than the avoided costs -- as well as a number below the avoided costs. The list of contingency projects (not shown) includes a number of low cost contingency projects that are shown on the figure having lower cost than existing water supply options. These would suggest that some plants can lower their costs by adding more conservation. Again, one plant's contingencies may be another plant's planned projects.

6.6.2.3 Meat Packing and Commercial Baking (201 and 205)

For these two different industry groups three projects with sufficient data are shown for Meat Packing and eight are shown for Baking. Neither is plotted. Costs for plant-augmented water over the three categories ranged between $525 and $2,200 per AF for Baking and averaged $4,400 per AF for Meat Packing. Avoided costs for Meat Packing is $1,065 and averages $1,417 for Baking. The conservation projects for Meat Packing appear to be related to plant expansion requirements while the Bakery projects appear to be close in cost to avoided costs.

FIGURE 6-6
MARGINAL COST OF CONSERVED WATER
MISC. FOODS & KINDRED PROD.



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6.6.2.4 Paper (265)

Most existing, planned and contingency projects shown on Figure 6-7 for the Paper industry are below the avoided costs. The three high cost projects shown entail recycling of cooling and process water. Many of the low cost contingency projects entail reuse and improved controls. Plants reporting these projects can lower their costs by adding more conservation.

6.6.2.5 Drugs (283)

Curves are shown as Figure 6-8. Projects shown are mostly all process water avoiding and therefore correctly compared to the costs of avoided pretreated costs, shown to be $14,000. Planned projects are higher costs than existing projects. These projects are consistent with decisions to reduce costs.

6.6.2.6 Petroleum Refining (291)

Section 6.7 presents a detailed case study of refining. Only the highlights are discussed here. The most interesting observation about Figure 6-9 is that most of the existing and planned projects are very close to the avoided costs. Eight of 14 contingency projects have sharply rising costs. Refineries have shifted from utility water supplies to plant-augmented supplies (conservation) to lower their costs of operation. Table 5-9 showed previously that the marginal operating profit loss for Refining averages $5,550. Consequently, the last two contingency projects, one of which is a switch to air cooling at $8,250 per AF, may not be economically feasible.

6.6.2.7 Computer and Electronic Equipment (357)

The computer industry reported no planned projects. Figure 6-10 shows that existing projects can be found below both the cost of untreated avoided costs and below the avoided cost streams. The existing higher cost projects are process water reuse and recycling; hence, they do avoid pretreatment and are correctly compared to the high avoided treatment costs. The high cost contingency projects include cooling and process recycling. Their marginal costs are lower than the marginal operating profits shown on Table 5-9 to be as high as $409,000 for a 30% water supply shortage. Consequently, these projects can be anticipated to reduce the risk of interrupting production.

FIGURE 6-7
MARGINAL COST OF CONSERVED WATER
PAPERBOARD CONTAINERS & BOXES

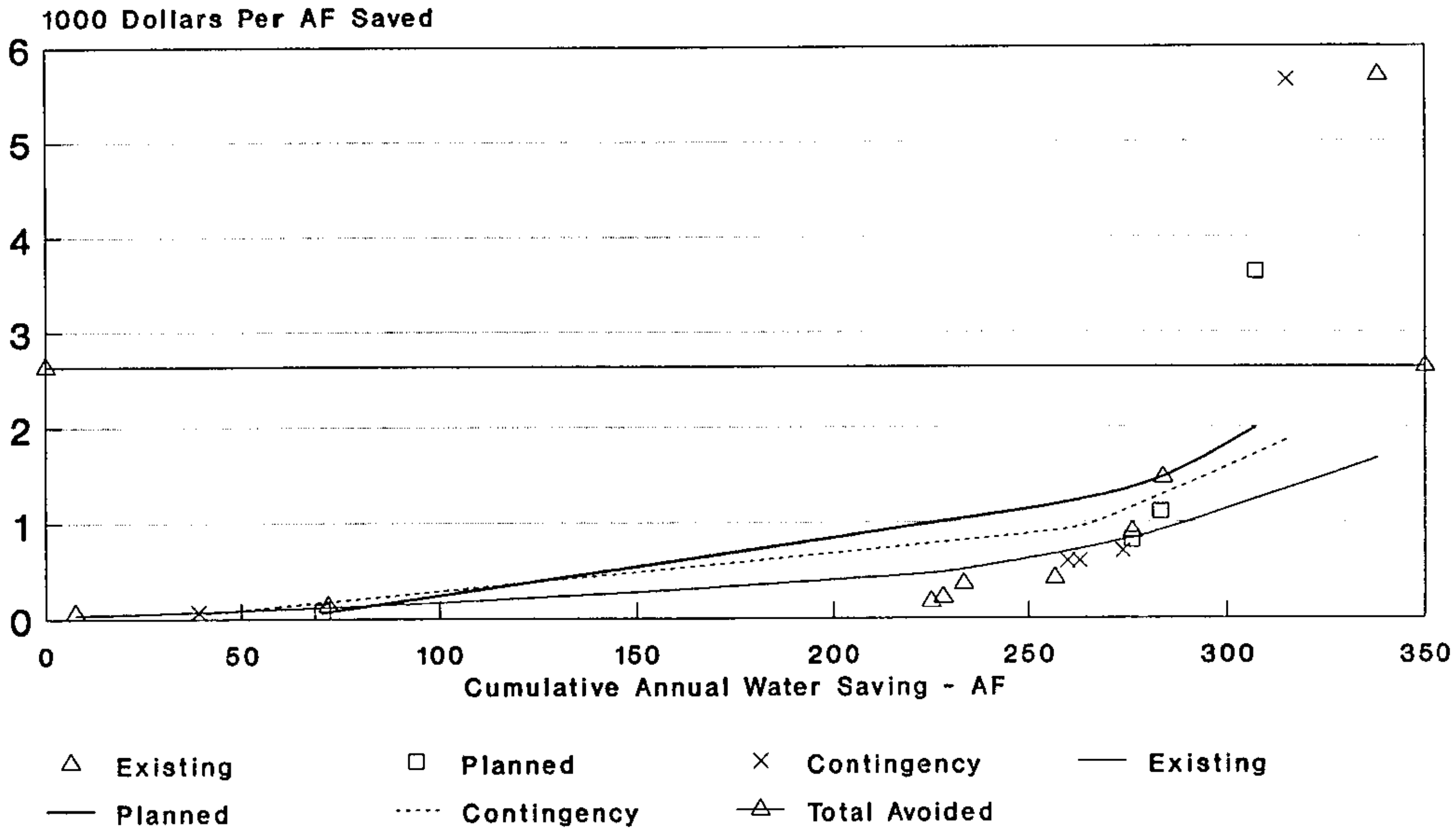

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FIGURE 6-8
MARGINAL COST OF CONSERVED WATER DRUGS

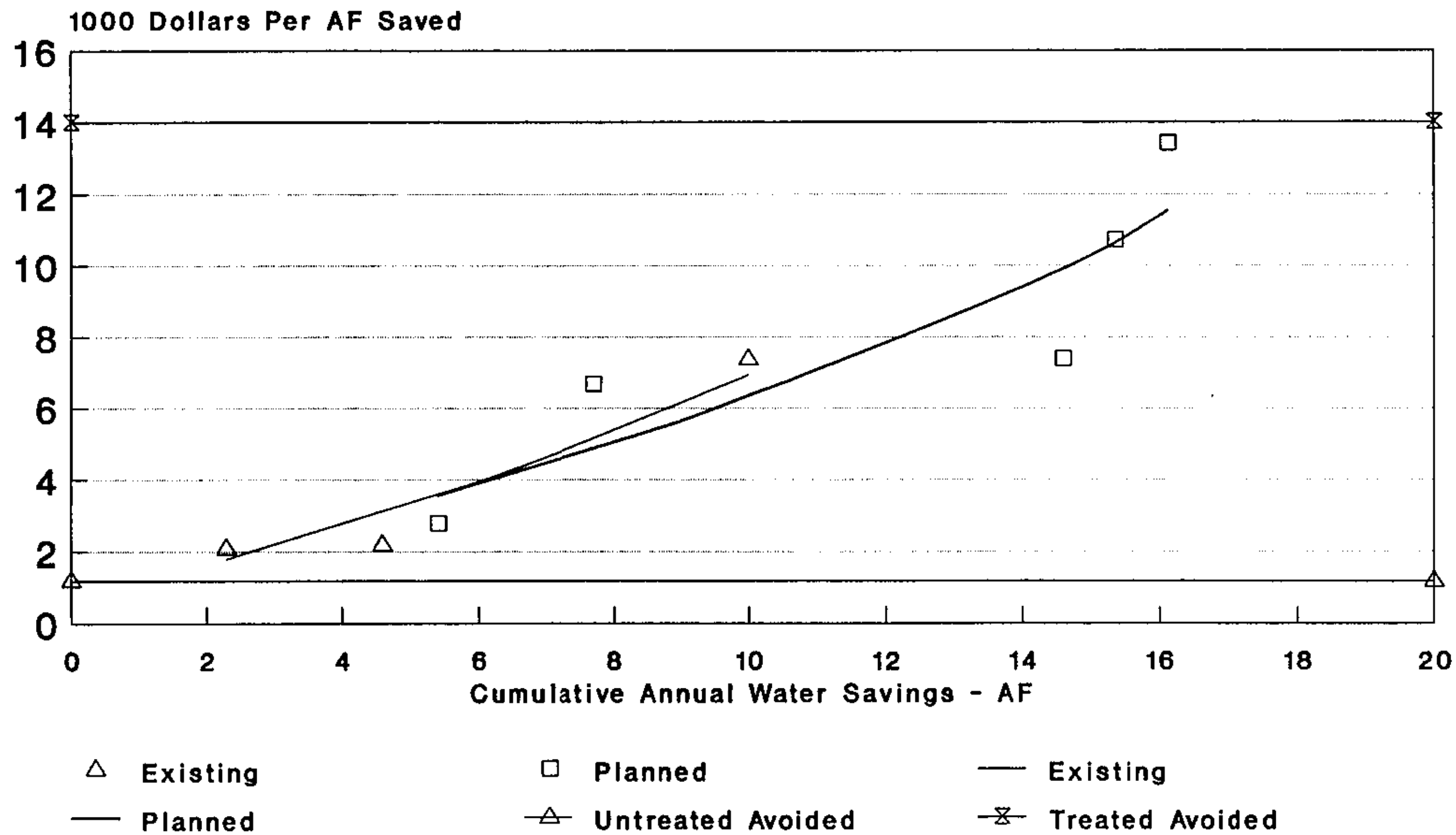

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FIGURE 6-9
MARGINAL COST OF CONSERVED WATER
PETROLEUM REFINING

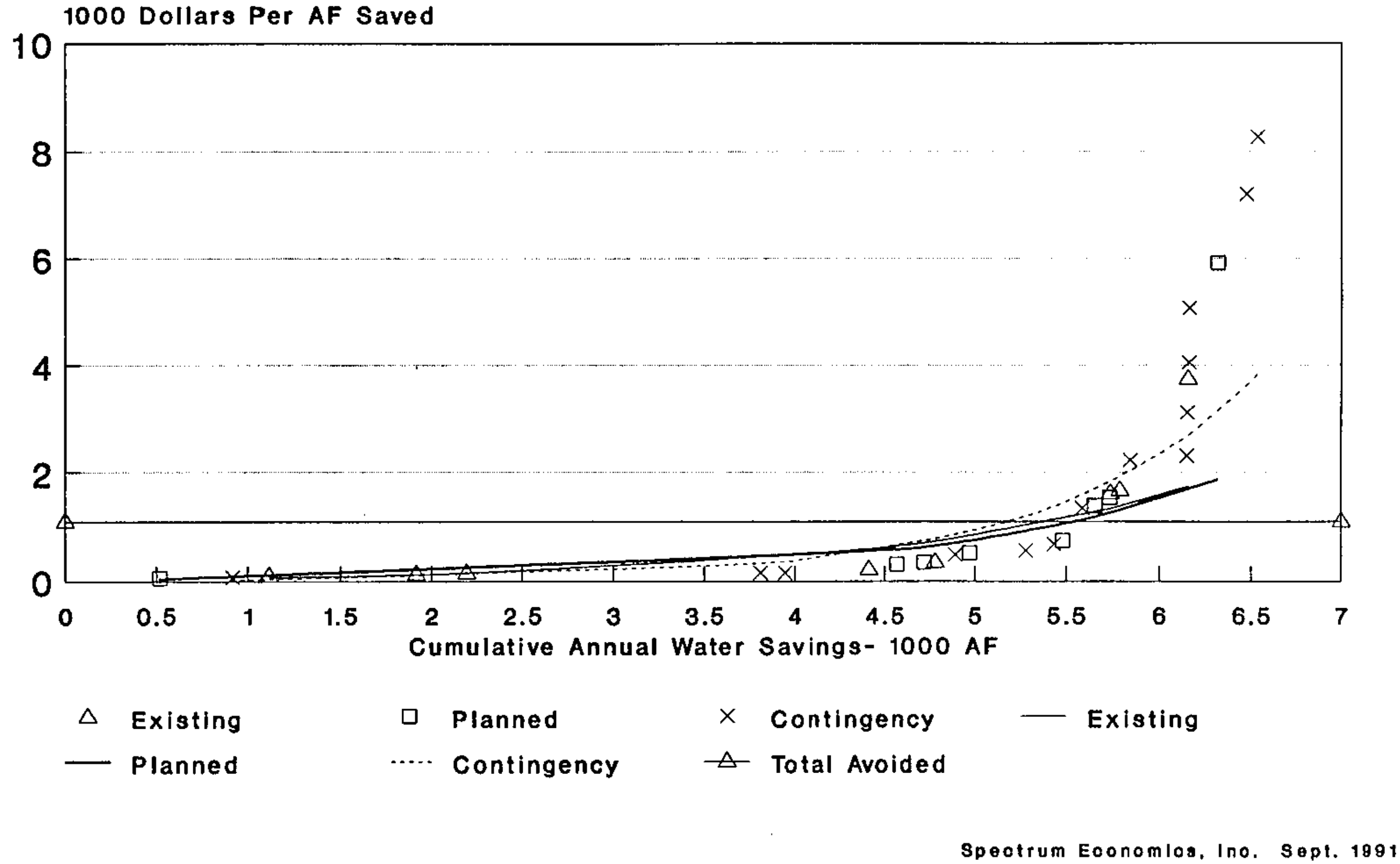
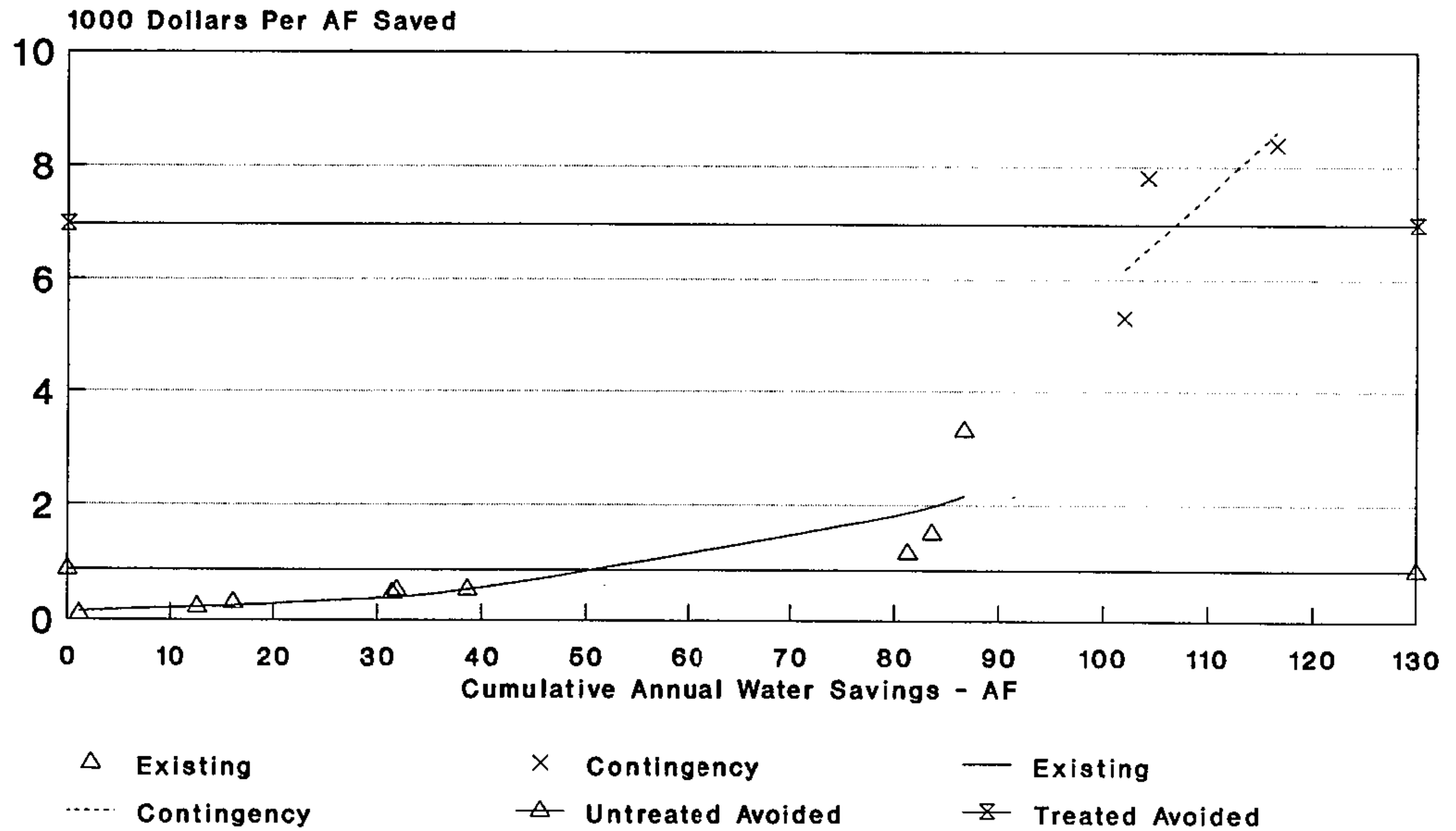


FIGURE 6-10
MARGINAL COST OF CONSERVED WATER
COMPUTER & OFFICE EQUIPMENT



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6.6.2.8 Communication Equipment (366)

Existing, planned and contingency projects for this industry are shown on Figure 6-11 to be small, costly and steeply rising in cost. This industry is less process water intensive than the other high technology industry groups. Little conservation is evidenced from the survey data in Sections 6.1 - 6.3 above. Most of the projects shown on Figure 6-11 have costs that do not relate to the low avoided costs for the industry. Economic theory would suggest that the cost of projects reported only can relate to the need for increased plant-augmented water to support increased plant production and/or supply reliability. The value of the marginal operating profit from water is shown to range from $4,000 to $10,000 on Table 5-9. There is a cluster of planned and contingency projects shown costing between $2,000 - $5,000 on Figure 6-11.

6.6.2.9 Electronic Components (367)

The largest usable data set of projects with reported costs and water savings is in this industry. Figure 6-12 shows that many projects fall below the avoided cost of untreated water and many more fall below the avoided cost of treated water. Many projects, therefore, can be said to have been undertaken to reduce costs. The projects trace a tight curve with contingency projects appearing over the range of costs but capping the high cost projects. The marginal operating profit of water in this industry is well above $100,000; hence, the high cost contingency projects, which include air cooling and process recycling, may be expected if the prospect of shortages becomes a sufficient inducement to management to make the investment.

6.6.2.10 Motor Vehicles (371)

Project costs for seven projects with sufficient data -- current, planned and contingency -- range from $353 per AF for automatic shut-off valves to $7,403 for a small installed air cooling project. These are not plotted because there are too few of any one category to plot. The avoided cost for Vehicles is $2,514 and five of the seven projects cost more than the avoided cost, ranging from $3,484 to the air cooling project. The marginal operating profit of water is shown to be $299,000 per acre-foot; clearly, this industry cannot risk losing production.

FIGURE 6-11
MARGINAL COST OF CONSERVED WATER COMMUNICATION EQUIPMENT

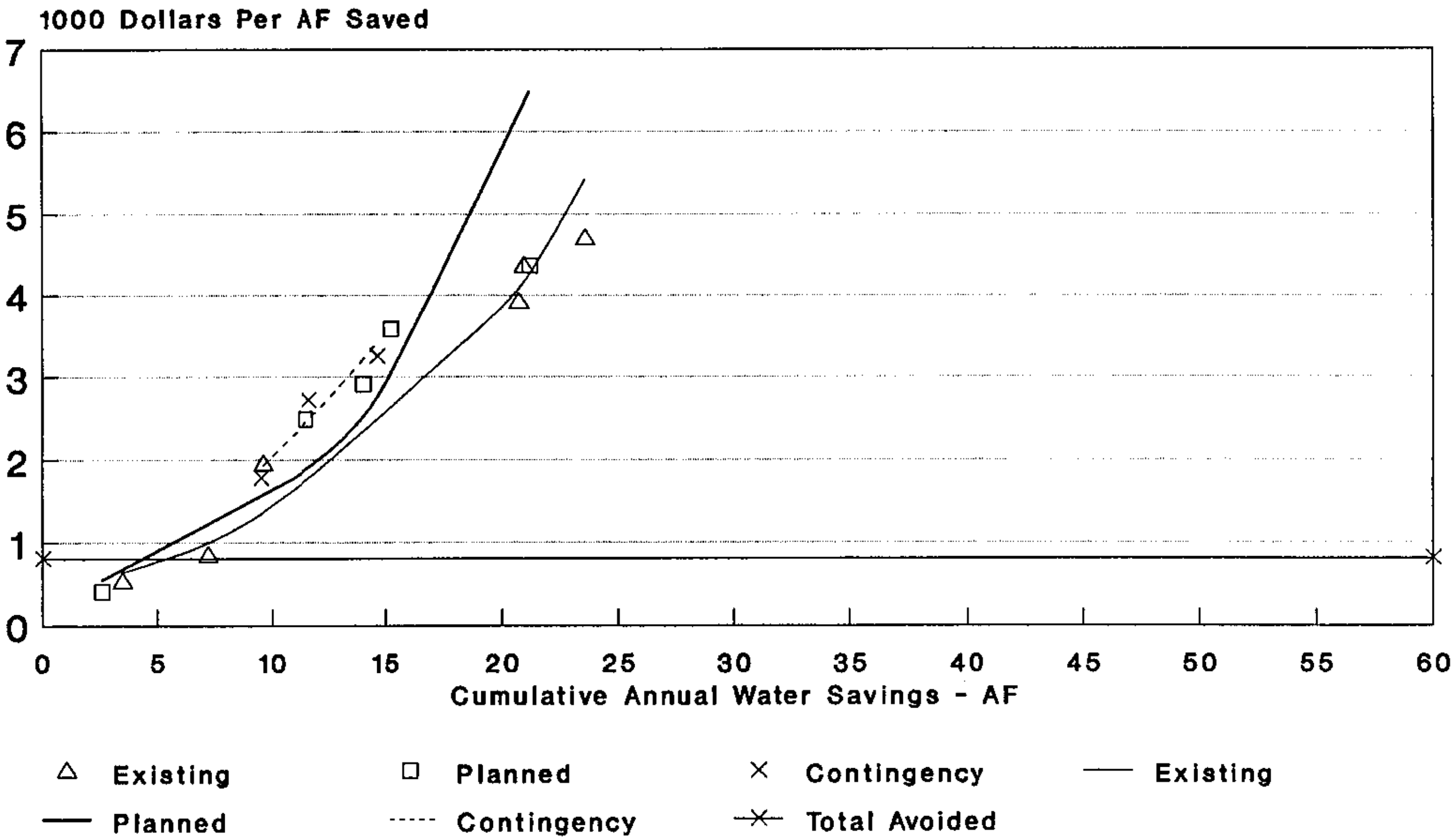

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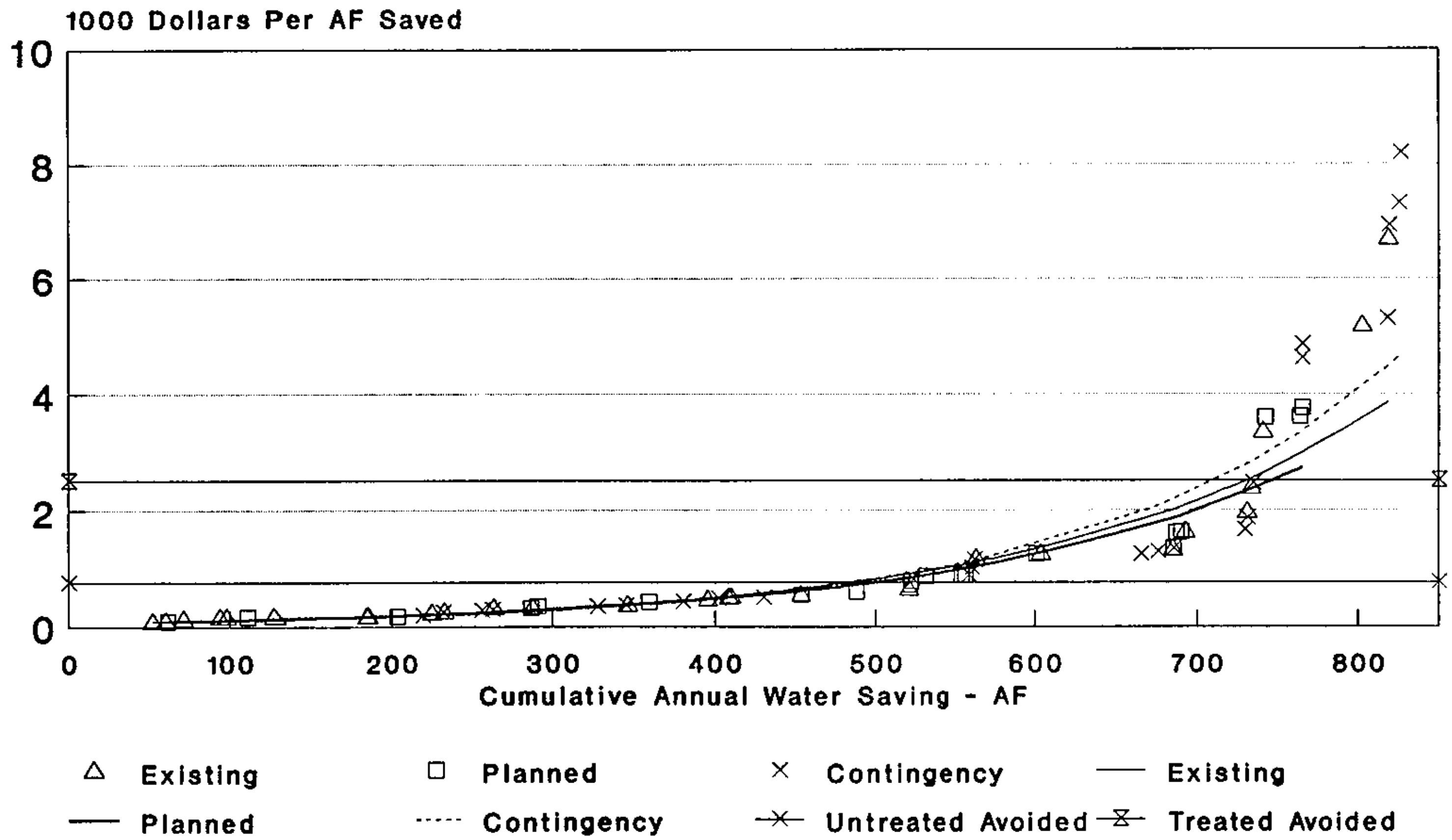
FIGURE 6-12
MARGINAL COST OF CONSERVED WATER
ELECTRONIC COMPONENTS



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6.6.2.11 Aircraft (372)

The Aircraft plants provided numerous projects which can be seen on Figure 6-13. The existing low-cost projects below the untreated avoided cost curve were large cooling projects. The higher cost smaller projects are mostly process recycling, improved controls, and retrofits. Virtually, all of the projects are below the avoided cost of treated water. Conservation in the Aircraft industry has lowered costs of operations.

6.6.2.12 Aerospace (376)

The Aerospace industry was the only industry which reported a decrease in water use efficiency in the last five years. Figure 6-14 shows that the industry also reports virtually no conservation projects during the last five years with data sufficient for inclusion. Reported planned projects are all below avoided costs. The industry can reduce costs by conserving more water. The industry probably can be expected to conserve more water as one means of cost control.

6.7 A Case Study: Water Use And Conservation At Petroleum Refineries[11]

The petroleum refining sector has made large improvements in water-use efficiency over the last five years and has planned conservation projects that will continue this trend. This section is a case study to pull-together several aspects of the study for the largest water using industry to examine the inducements to conservation. The analysis shows that planned conservation expenditures correlate less consistently with avoided costs than with expected losses from supply disruption. The strongest relationship in the survey data suggests that plant managers are planning to make conservation investments based on reducing perceived risks of water supply shortages. The data show that conservation expenditures increase as expected income losses from supply disruption increase.

6.7.1 Water Use by Petroleum Refineries

Petroleum refining (291) is the single largest industrial user of water in California. Refineries consumed 126,720 AF of water in 1989 according to Table 4-2. Because refineries are among the most intensive consumers and producers of toxic chemicals, these

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[11]Richard McCann provided this case study analysis.

FIGURE 6-13
MARGINAL COST OF CONSERVED WATER
AIRCRAFT & PARTS

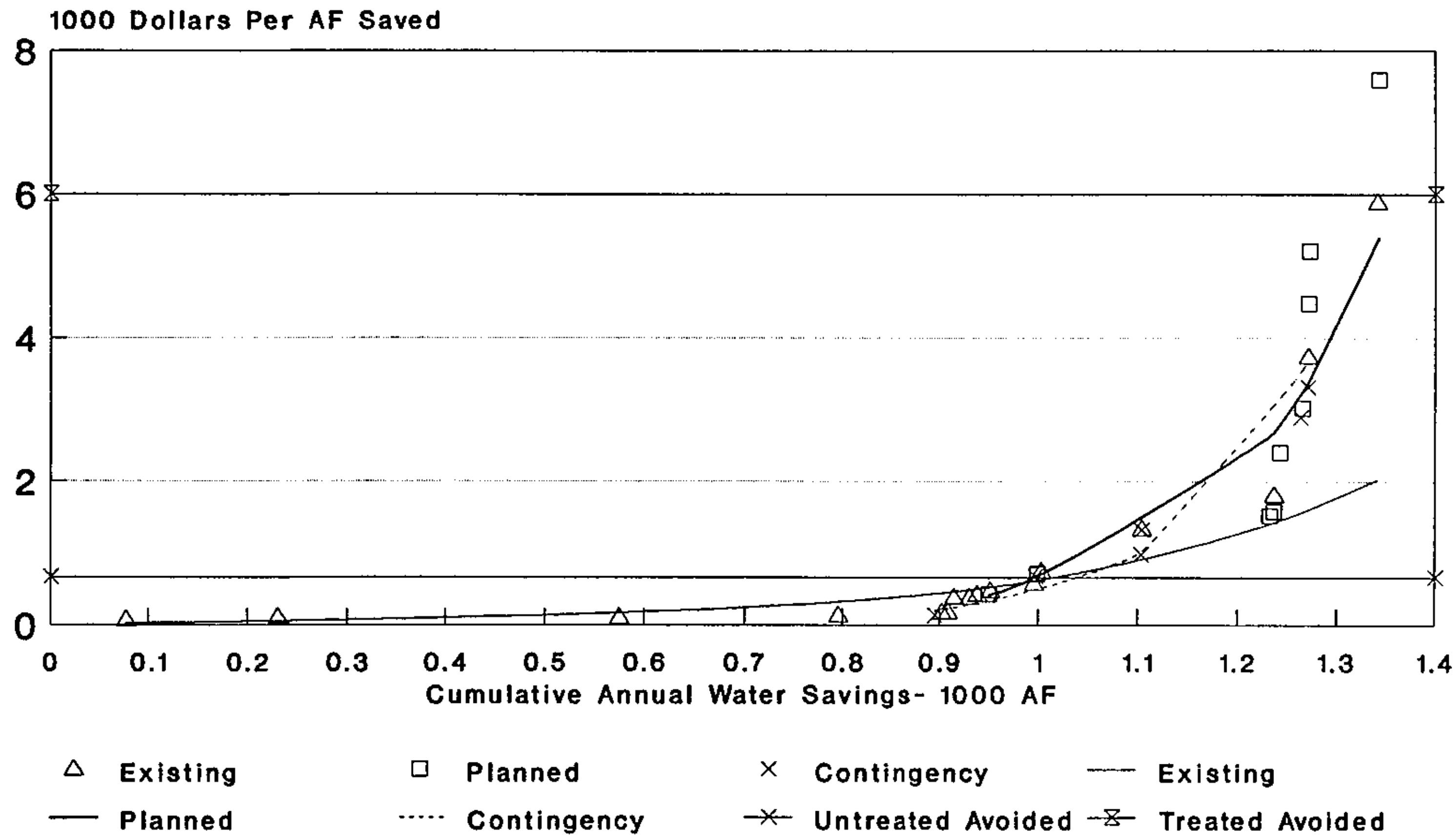

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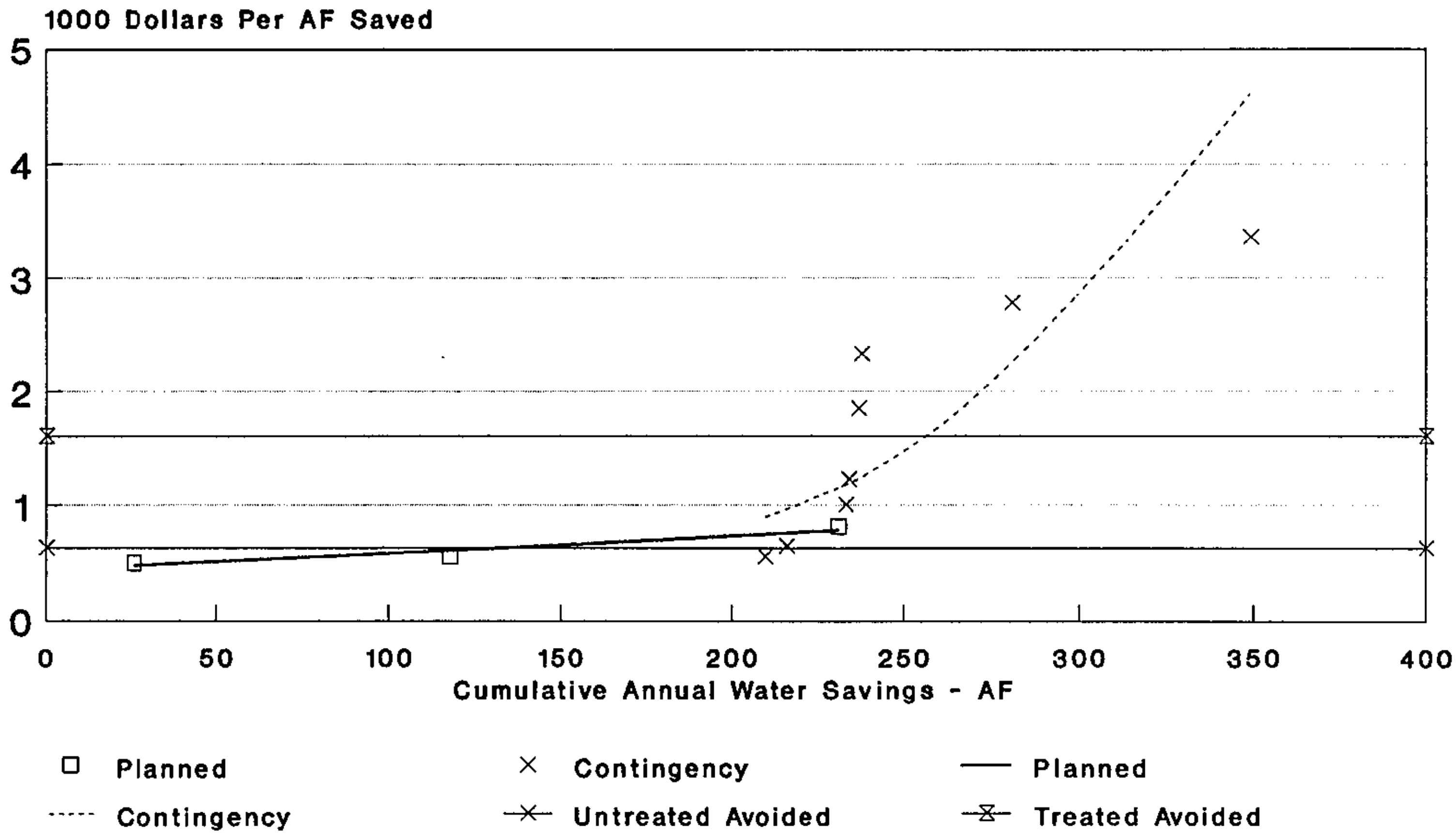
FIGURE 6-14
MARGINAL COST OF CONSERVED WATER
GUIDED MISSILES, SPACE VEHICLES, PARTS



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plants have been and remain targets for cleaning up their effluent streams. One effective way to decrease treatment costs is to reduce the volume of water treated. Reducing water use at refineries has been a significant goal for nearly two decades.

Eleven refineries provided responses to the survey, with seven located in Southern California and four in the Bay Area. The surveyed plants represent over 68 percent of California's 1989 refining capacity.[12] Nine provided sufficiently complete responses to be included in this analysis. The nine refineries processed between 10.2 and 95.5 million barrels of oil products in 1989 each with an average of 49 million barrels per year or about 135 thousand barrels per day (MBD). Average intake of water from all sources was 7,068 acre-feet in 1989. The product-to-water-intake ratio was 0.93; i.e, 0.93 gallons of oil were processed for each gallon of water consumed, with a range from 0.5 to 3.0. Six plants gave a five-year history of production and water consumption. Their average production increased 17.1 percent from 1985 to 1989 while average water use fell 1 percent. This translates to a water-use efficiency improvement of 18 percent over the five-year period -- an improvement in the product-to-water ratio from 0.79 to 0.93. Expressed another way, the barrels of water to barrels of crude input decreased from 1.3 to 1.1.

Refineries typically reuse water internally. The average recycling rate for water was 14.2 times before it was discharged or dissipated through evaporation. But there are actually two groups of refineries, two modes. Either:

1. Little is done and the recirculation rate is less than one;[13]

2. Recirculation is extensive and the rate ranges between 14 and 30 times.

Plant managers indicated that investment in recycling technology had been going on for a long time -- at least since 1956 in one case; the current and budgeted projects show that this process is continuing.

Recycling rates were expected to be correlated with the unit water use ratio. The analysis shows that little correlation exists between the unit water use ratio and the recycling rate, as shown on Figure 6-15. It appears that the output per unit of water <u>tends to decrease</u> as the recycling rate increases.

Two factors may explain this anomaly. The first is that production processes, which differ among refineries, require differing amounts of water, depending, in part, on the degree of thermal operations and coke production. The second is that the refineries which had the highest recycling rates are in Northern California where the crude slate is more likely to include heavy Alaska or San Joaquin Valley crude rather than the lighter, sweeter coastal

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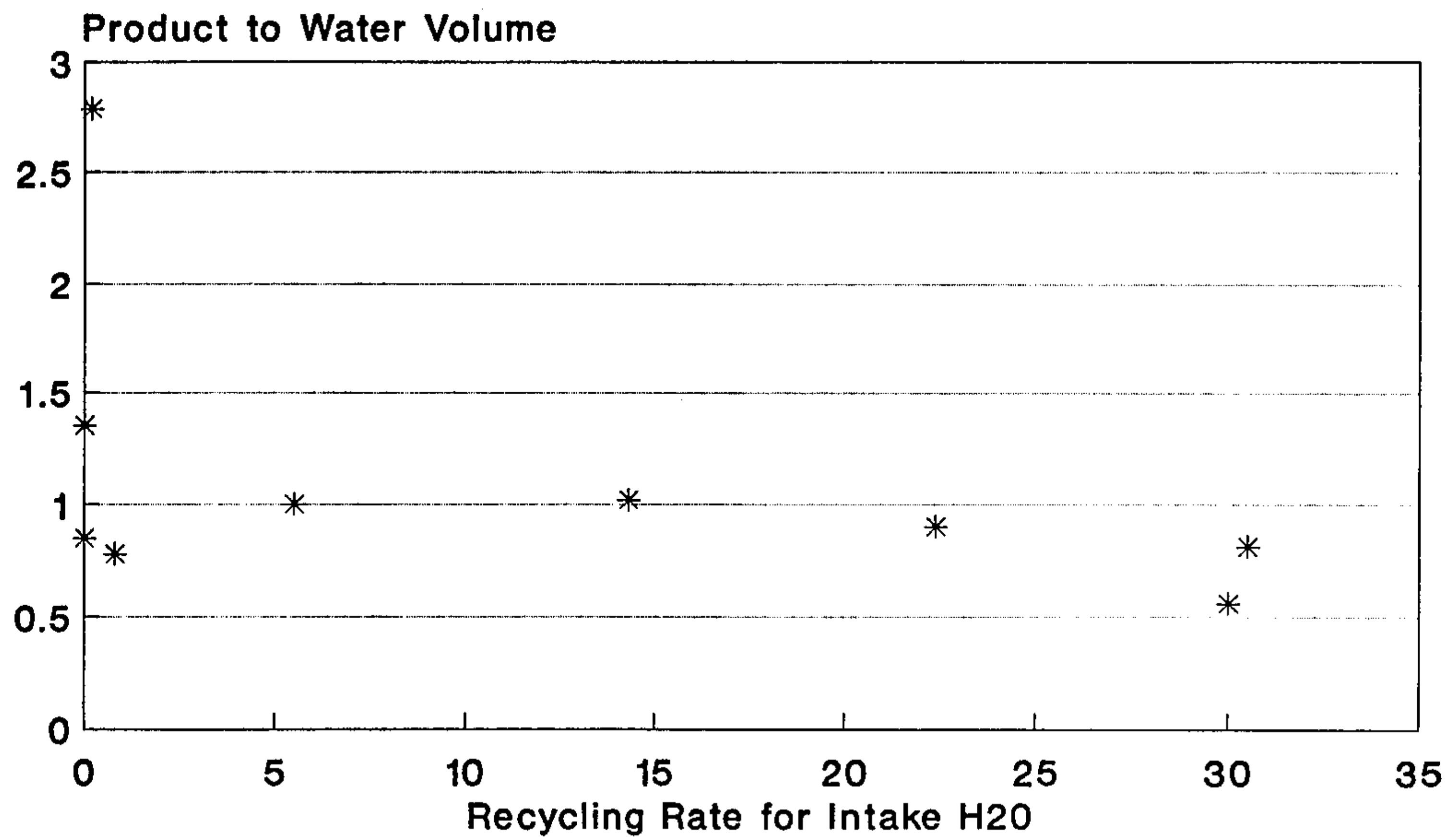
[12] Oil and Gas Journal, March 26, 1990.

[13] Two of these are air cooled refineries; the others are once-through water users.

FIGURE 6-15
WATER CONSUMPTION VS. RECYCLING REFINERIES (SIC 291) - 9 PLANTS



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crudes run in some Southern California refineries -- heavier crudes require more steam. These factors need further exploration before any useful conclusions can be drawn about refineries' ability to conserve more water.

6.7.2 Water Purchase Costs

The refining industry relies on a number of sources for its water supplies. Table 4-3 specifies the breakdown between potable water from municipal sources and the remainder from municipal nonpotable sources and groundwater.[14] The average municipal rate is $371 per acre-foot for the districts supplying the nine refineries.[15] The average for nonpotable sources is $319 per acre-foot, with groundwater typically costing less than $100 per acre-foot.[16] The average cost over all water sources is $353 per acre-foot with a range from $54 to $436. Most of the water costs fall into a narrow band reflecting the range of municipal rates statewide.

6.7.3 Wastewater Treatment Cost

Plants discharge between 35 and 60 percent of intake water, with the rest being lost to evaporative processes. All of the refineries surveyed pretreated 100 percent of their effluent before discharging it either directly to a body of water or to a sanitation district. Most frequently they discharge their effluent directly to nearby bodies of water, which requires an NPDES permit. To receive this permit, the plants had to build and operate large wastewater treatment plants.

Seven plants provided enough information to calculate the annual total and per acre-foot costs for pretreating wastewater. The average annual operating and maintenance (O&M) cost is $1,394 per acre-foot of treated water, with a range from $822 for an older plant to $1,971. The average annualized installed capital cost is $598 per acre-foot (in 1988 dollars) for the five plants that reported these costs. The O&M or "variable" cost component is the measure of avoidable wastewater treatment costs, although most of the treatment plants were installed in the 1985 to 1988 period to comply with the 1987 Water Quality Act. Plant

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[14] The calculation of water intake costs is based on 65 percent from potable sources based on responses from nine refineries versus the sample of 11 used to project population usage.

[15] Refineries are matched to retail water suppliers, allowing calculation of plant-specific water rates. Water purchase prices for other industries are based on regional average rates.

[16] For reclamation and nonpotable sources for which we did not have cost information, we assumed this was priced at 80 percent of the comparable municipal water rate.

managers may have viewed these capital costs as avoidable when making past conservation investment decisions; i. e., conservation over the last five years might have been directed at reducing the needed treatment plant capacity. The most cost-effective way to reduce treatment costs is to reduce the volume of wastewater, which implies reducing water intake and using water more efficiently.

The cost per acre-foot of discharge was converted to an acre-foot of intake for comparing the avoided costs of wastewater discharges with water conservation projects. The cost of treating each acre-foot of intake averages $743, which is the average return of intake, 53.3 percent, multiplied by the variable cost per acre-foot of treated water, $1,394.

The average avoided costs of intake and discharge of an acre-foot for the seven plants that provided data is $1,095 per acre-foot of intake water, with a range from $708 to $1649. This is based on acquisition and wastewater treatment costs.

6.7.4 Motivations for Conservation Measures

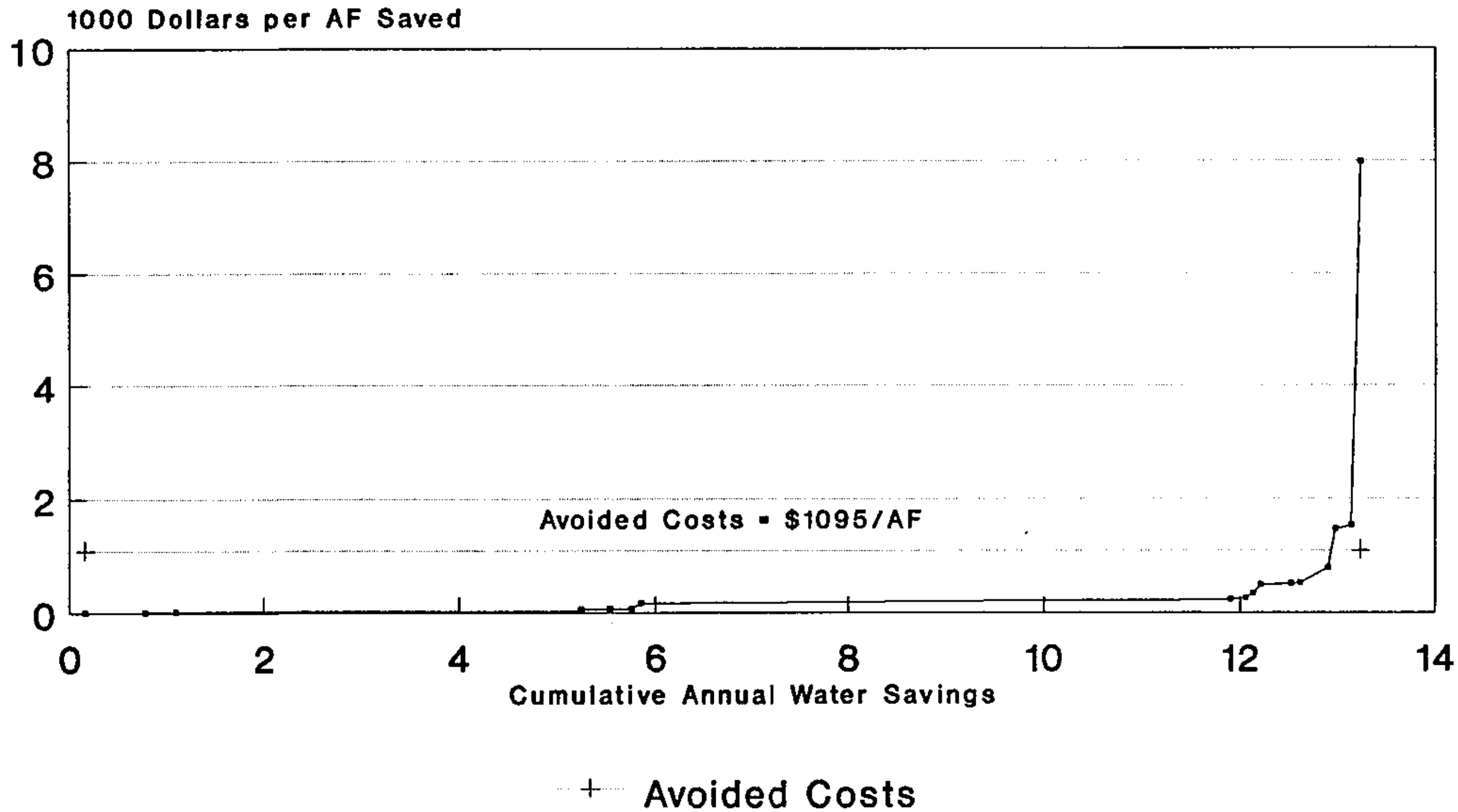
In response to the increasing costs of water purchase and disposal, these refineries have planned a range of conservation and demand reduction measures that include (in order of magnitude of savings):

- Reclaiming municipal wastewater,
- More recycling of process and boiler water,
- Enhanced cooling water recycling,
- Air cooling,
- Developing more groundwater sources, and
- Various education and monitoring programs.

Seven refineries provided sufficient information to calculate the costs of water saved through planned conservation measures. The data analyzed are a subset of data shown on Figure 6-9 with some added planned projects. The costs calculated can be interpreted as the marginal costs of water for each plant. Because these plants cannot exchange water savings between themselves through a water market, there is no necessary relationship of the costs among refineries. Each refinery has its own plant-augmented cost curve. Nonetheless, Figure 6-16 shows the relative rankings of the costs for planned conservation projects budgeted for construction over the 1989 to 1992 at seven refineries. This figure shows the cumulative distribution of conservation project costs and water savings among refineries and can be interpreted as an indicator of an industry-wide supply curve for plant-augmented water.

Total annual planned savings at the seven refineries are 13,224 acre-feet at an average cost of $333 per acre-foot. This represents a reduction of 18.5 percent from 1989 (pre-

FIGURE 6-16
CONSERVED WATER SAVINGS AND COSTS
REFINERIES (SIC 291) - 1989-92



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conservation) usage levels. The annual cost of the last 700 acre-feet of planned conservation savings range from $785 to $8,000.

Figure 6-17 compares plant-specific estimates of avoided costs to plant specific costs of planned conservation projects. The avoided costs plotted previously in Section 6.6.2 are average industry marginal cost curves for the industry. Within-plant specifics cause each plant's avoided costs to differ, in fact, as shown on Figure 6-17.

Figure 6-17 shows the relationship between plant unit water use per barrel of refined product and

1. Avoidable water-use costs (e.g., water and sewage rates, treatment and disposal costs, etc.);

2. Unit costs of planned conservation spending for the 1989 to 1992 period.

The linkage between avoidable water-use costs and conservation spending per acre-foot to augment supplies also is shown on the figure by comparing the side-by-side bar charts. The bars for conserved water costs represent the average cost of all planned conservation projects within each of the included six refineries. The refineries' costs of conservation only loosely follows the avoided costs; the statistical relationship between the costs of conservation and avoided-costs is not strong. The most costly conservation project is shown to have much higher conserved water costs than avoided costs. It appears that not all of the conservation projects were motivated to reduce operating costs.

The lack of strong linkage between avoided costs and conservation spending led us to examine the relationship of expected output losses to conservation spending. Seven plants provided sufficient information. Figures 6-18 and 6-19 report the plant responses to scenario questions III.5 and III.12 -- what would 15% and 30% water shortages do to plant income? Plant reported income loss percentages are reported on the horizontal axis; the average cost of all planned conservation projects within each of the included seven refineries is plotted on the vertical axis.

Figures 6-18 and 6-19 show that spending on water conservation projects increases as managers' expectations of production losses increase due to possible water supply cutbacks. There is a clear positive trend relating potential for income losses to expenditures for conservation. This is a stronger relationship than the correlation between avoided costs and conserved water costs. It seems to indicate that plant managers are prompted more to lessen their exposure to supply risk than to reduce direct operating costs. Such a relation follows economic theory which says uncertainty is a cost which can change decisions from

FIGURE 6-17

COMPARISON OF WATER INTAKE & COSTS REFINERIES (SIC 291) - 6 PLANTS

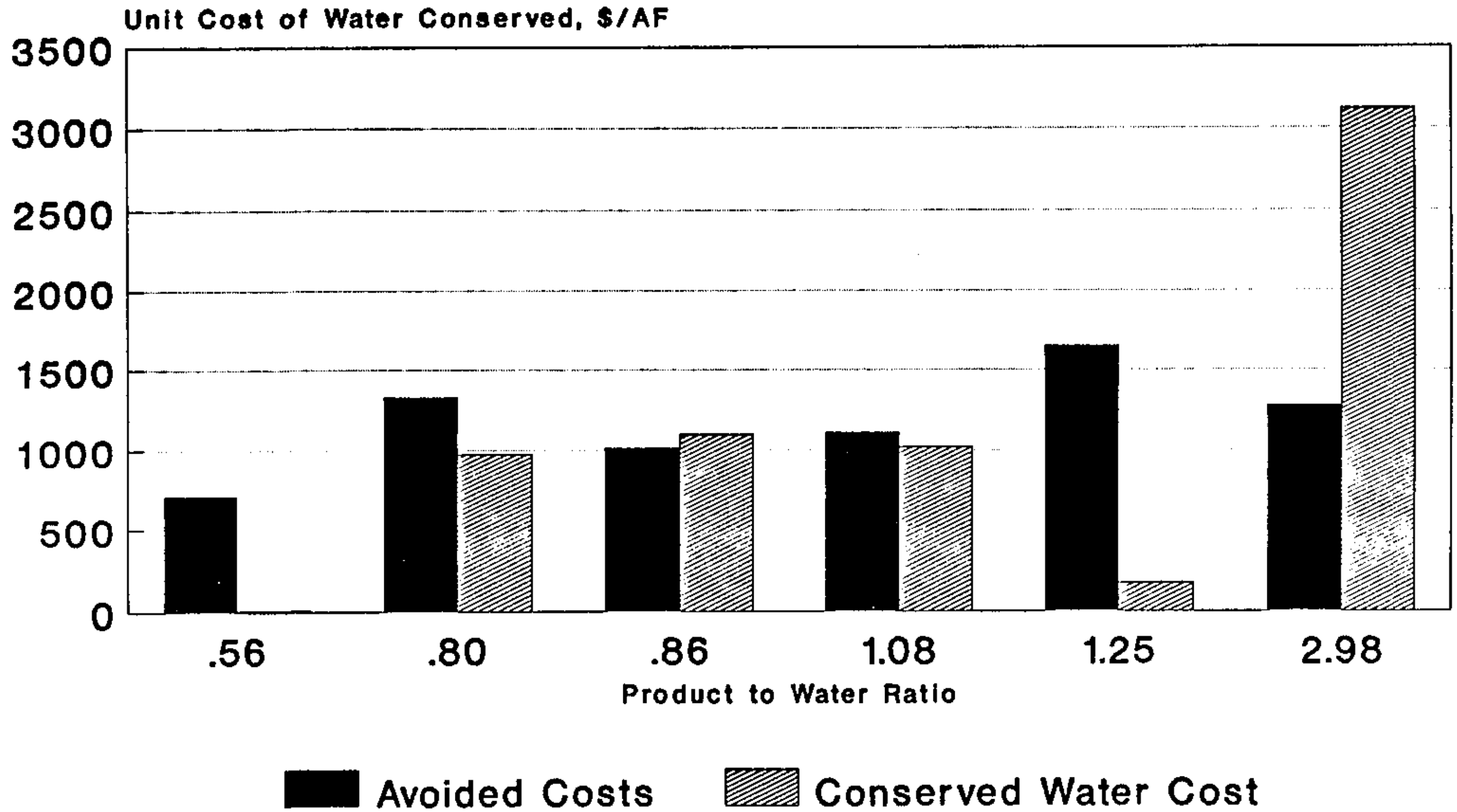

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FIGURE 6-18
SAVINGS SPENDING VS. EXPECTED LOSSES
REFINING (SIC 291) - 7 PLANTS

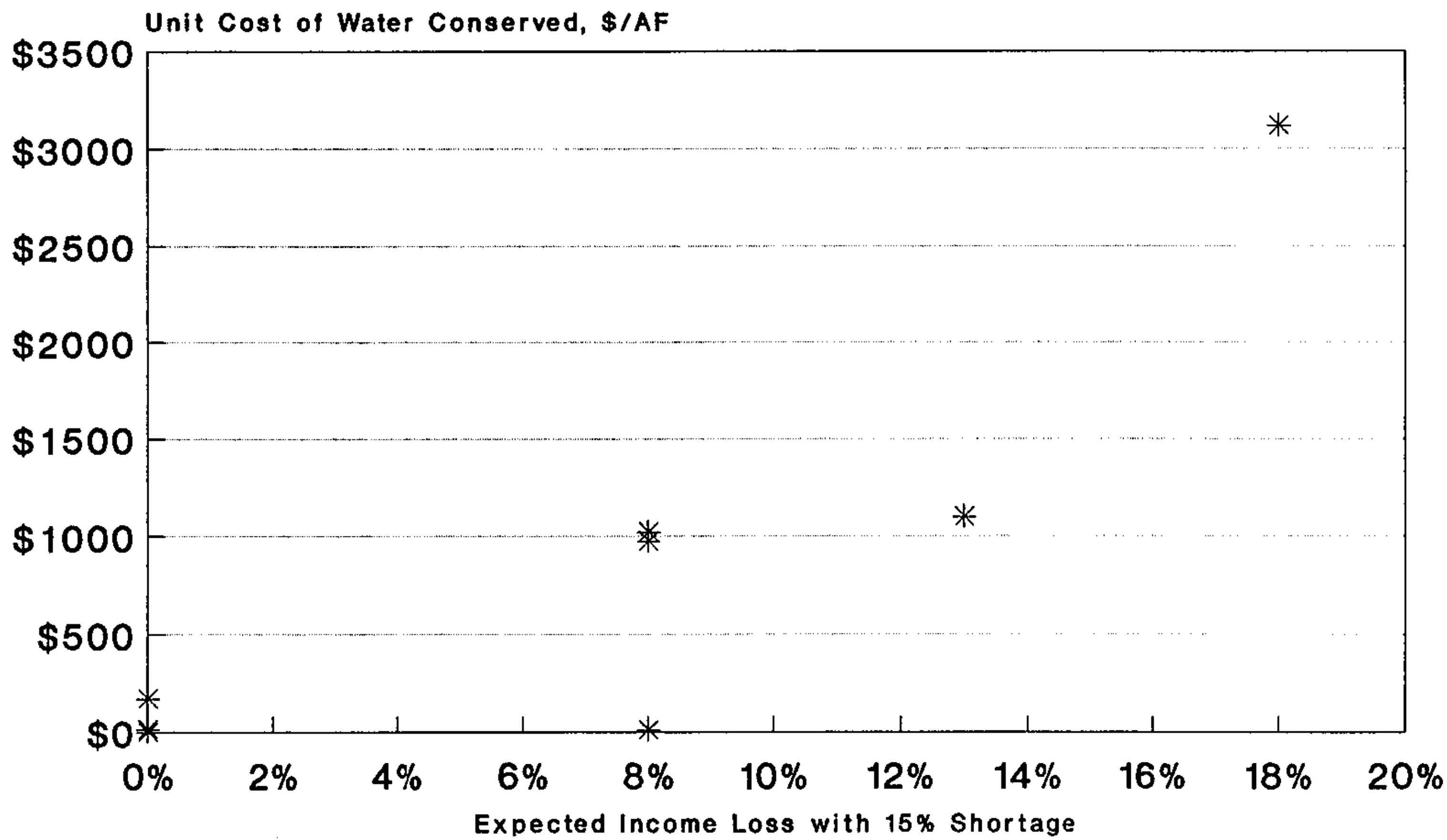

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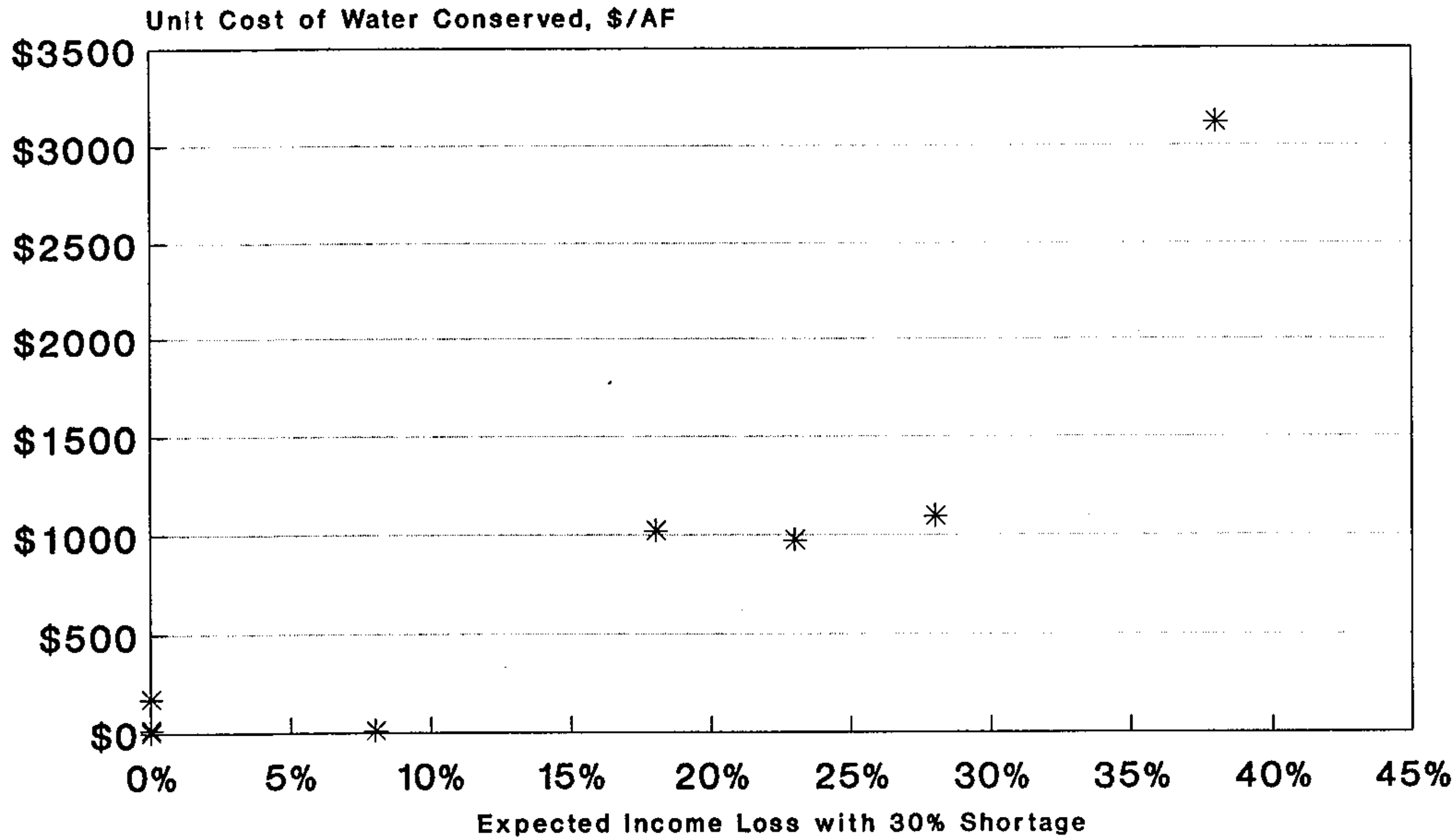
FIGURE 6-19
SAVINGS SPENDING VS. EXPECTED LOSSES REFINING (SIC 291) - 7 PLANTS



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the lowest-cost engineering outcome; or, stated differently, the figures show that industry will pay a premium for reliable water supplies.[17]

[17]The reported highest cost conservation projects are found in an air cooled refinery. This same refinery reports little tolerance with water supply variation.

7.0 INDUSTRY RESPONSE TO POSSIBLE FUTURE WATER SHORTAGES

The surveyed industries have very high production values attached to reliable water as shown previously in Section 5.4. These high values, in part, explain the intensive and costly conservation efforts described throughout Section 6.0. Through the current drought, water utility imposed rationing to industry has been made-up by in-plant conservation. Plants in most of the surveyed industries are seen to be spending many times more than the cost of purchased water to protect themselves from drought rationing and uncertain utility water supplies. The values of sales revenues and market shares dependent on water lead to this strategy. Eventually, as plants become more efficient in water use, fewer options exist to absorb water supply shortages and plants become vulnerable to shortage. Yesterday's conservation "hardens" today's plant water requirements. Further water supply shortages may cause economic losses.

If water supply reliability deteriorates through the 1990s, what would be the economic consequences? As conservation becomes more costly, would industry respond to future shortages with output and employment reductions?

A major objective of the survey was to find out if industry is vulnerable to water shortages and, if so, to estimate the potential economic costs of water shortages to California's industries. The survey was designed to ascertain if varying levels of utility supply shortages would cause plants to reduce output, income and employment. This section reports plant production and employment impacts associated with hypothetical 15% summer seasonal and 30% year-long water supply shortages to industry. The reported values represent incremental plant responses averaged over industry groups. This section also reports the calculated output elasticities of water and discusses the elasticity of substitution of conservation for intake water.

7.1 Declining Reliability Prompts Concern About Economic Health

The current drought has focused attention on the economic impacts of water shortages. The last major water delivery project was the State Water Project brought on-line in California started in 1963. Since then, population has grown from 17.5 million to 30.5 million and the Gross State Product has grown from $76 billion to $732 billion -- substantial growth compared to a relatively static water supply delivery infrastructure. Studies show that water shortage has become a recurrent feature of California's urban areas and will worsen unless major changes to water distribution occur.[1]

---

[1]Spectrum Economics, Inc., "Reliability Planning For Water and Other Public Utilities," Draft Report to Metropolitan Water District, April 3, 1991.

By 1995, the Southern California region faces a 50 percent chance of seasonal water shortage. In half of the years, unconstrained urban water demand will exceed available supplies. One year in ten the shortfall could be at least as much as 30 percent of normal demand. By 2000, without additional supplies, prospects of a water deficit will be near three years in four with the odds increased to one year in seven that the shortage could be at least as large as 30 percent of demand. While these statistics are specific to Southern California, the situation is not markedly different in parts of Northern California. This level of service dependability stands in sharp contrast to the expectations of a modern developed economy.

7.2 Shortage Scenarios Described

Two scenarios were formulated for this study to define shortages in terms of extent, frequency, duration and lead time. The scenario section of the survey appears at the end of the instrument <u>after</u> all factual questions about water use and conservation within the plant. The exact language of the scenario can be reviewed in Appendix A. In essence, the scenarios asked:

> We want to understand the costs that you will face if you must change your normal practices to adjust to reduced water supply reliability. . . . We ask some questions about how further shortages might affect your plant. These questions ask you to think about how you can further conserve, what alternative water supplies you might be able to develop, and, if your operations might still be affected.
>
> **If you are currently under emergency procedures to deal with the drought, do not consider the drought measures you have undertaken as part of normal operations.**
>
> Scenario 1: Your water utility will experience recurrent shortages between April and November which would require you to cutback to using 15% less utility water than normal for the eight month period. There will be some advance notice within the first quarter of a supply curtailment.
>
> Scenario 2: Your water utility will experience shortages which would require you to cutback to using 30% less utility water than normal. A cutback of this magnitude would last a year. You would have approximately three months warning.

Notice that the discussion before describing the shortage scenarios asked the respondents to think about further conservation and changing water supplies. The contingency projects reported in Section 6.0 came from the responses to question 2 shown below.

Each scenario then asked for several responses to a number of questions:

1. Can you increase the use of alternative water supplies?

2. What technology/practice might you adopt to reduce water use (in addition to already installed and planned conservation practices)?

3. Will you decrease plant output?

4. Will you lower employment?

5. Will you suffer income and cash flow reductions?

6. Will you change expansion plans?

7. Will you make relocation plans?

The scenario question format elicits a conservation response to mitigate water supply shortages before asking about production, employment and income effects of water shortages. The purpose of this order of questions was to prompt the respondents first to consider additional conservation to see if management might be able to cope with supply cutbacks by changing the way the plant uses water. Almost all of the survey instruments were returned between November, 1990, and March 1, 1991. **California's impending fifth year of drought was very much in respondents' minds during this period. The "March Miracle" rainfall had not occurred.**

7.3 Elasticity of Substitution And Plant Production Losses

Why would plants report output reductions associated with 15% water supply shortages when in some cases plants have conserved more than that in recent years and have lived with 15% shortages during much of the current drought? Two reasons can be provided.

1. Production has grown during the drought while utility water use has declined. Section 6.4 showed that plants are using less water to produce more products. In all of the sampled industries but two, Soaps and Cleansers (284) and Aerospace (376), water use efficiency has increased. In some of the dynamic High Technology industries, new plants have come on line but the industry is not using markedly more water than it used in 1985. These are two offsetting trends:

    1. Increased water use efficiency has reduced water requirements;

    2. Increased industry production from both new plants and higher plant utilization rates has raised water requirements.

On balance, the responses to the water shortage scenario questions indicate that increased production has overtaken increased efficiency. The water conserved in recent years has reduced the ability to accommodate further shortages without some reduction in plant production. As stated above, yesterday's conservation "hardens" today's plant water requirements.

2. The 15% scenario question describes a loss during the summer when water use is at its peak -- 35,000 AF per summer month compared to 25,000 AF per month in the winter. August peak water requirements are 30 percent higher than the annual average. The Food and Refining industries both have a summer peak and they have a high percentage of production loss responses to the 15% scenario. Particularly during the summer months when water needs are highest, there is less flexibility within those plants. A small water supply shortage could be expected to reduce plant production in some plants in these industries.

In short, industries have been conserving water to accommodate growth in output during the recent drought years and they have moved reasonably far along their plant-augmented supply curves. That is the evidence throughout Section 6.0. The responses to the shortage scenario questions below suggest that reducing plant production would be one economically feasible response to a 15% to 30% water supply shortages.

7.3.1 Elasticity of Substitution

The elasticity of substitution is one way to measure the ability to substitute other inputs for water. The elasticity is low if there is little opportunity to substitute. In cases where there still exist inexpensive ways to substitute other inputs for water in the production process, the ability to mitigate water supply shortages with conservation would be high. The data from the survey suggest that the elasticity of substitution of conservation technology for utility water has shrunk; plant managers have fewer options available to them to replace intake water. In view of the continued growth in output over recent years while utility supplied water has declined in most industries, the responses within the survey indicate a reduced ability to augment water within the plant by additional recycling. The efficiency gain indices shown in Section 6.4 are consistent with the conclusion that the elasticity of substitution has declined significantly for many of the industries over the last five years.

For plants that have invested significant amounts of money in conservation programs and technology, the elasticity of substitution would be small. To the extent that the elasticity of substitution has been reduced, many more combinations of other inputs would be required to replace each incremental reduction of water supply. In this case, the plant might have to reduce output because of technical limitations and/or the expense of additional combinations of other inputs would be even more costly than reducing output.

7.3.2 Output Elasticity Of Production For Water

The output elasticity of water measures the percentage change in output for a percentage change in the input, water. This elasticity can be estimated from the survey data. The estimates are shown on Table 7-1. The estimated elasticities are the marginal elasticities between 0 to 15% and 15% to 30% water supply shortages. Comparing the relative size of the elasticity measures among plants and/or industries gives an approximation of:

1. The relative importance of water to the production process, and

2. The elasticity of substitution.

Table 7-1 reveals that three industries show no, or virtually no, relationship between water shortages and production: Meat Packing (201), Communication Equipment (366) and Motor Vehicles (371). The Aerospace industry group (376) shows a very low relationship between water and production. The products which include water as essential ingredients -- Beverages (208), Soaps (284), and Paints (285) -- all show the highest elasticities at the 30% shortage. Bakery products show a high elasticity implying bakery water use is small, but critical ingredient.

All of the other industries show an increasing sensitivity of production to reduced water supplies between scenario shortages. In several industries, the elasticity increases significantly. The Electronic Components industry (367) shows little sensitivity to a 15% shortage, but a significantly higher sensitivity to a 30% shortage; so, too, for Drugs (283). The increase in the output elasticity measure is consistent with a reduction in the elasticity of substitution. Opportunities to replace intake water with plant-augmented water are declining where the output elasticity is increasing.

The output elasticity of water calculations on Table 7-1 are not wholly consistent with operating profit per acre-foot calculations for some industry groups on Table 5-9. For instance, Vehicles (371) and Aerospace (376) industry groups show zero and low output elasticities for a 30% water supply shortage, but high marginal operating profit losses on Table 5-9. The calculations are made over responses to different questions (III.10 and III.12), one related to physical output changes and one related to financial results. Further plant-level analysis is required to reconcile the disparity.

7.4 Production And Employment Losses Due To Water Shortages

Both the survey responses in Section 6.0 and post-survey interviews confirm that plants have taken aggressive steps to reduce water use during the current drought. The responses from the scenario questions and post-survey interviews indicate that many plant managers believe

TABLE 7-1
OUTPUT ELASTICITY OF WATER

SIC CODE	Description of Plant	Elasticity 0–15%	15–30%
201	Meat Packing	0.00	0.00
203	Preserved Fruits & Vegetables	0.27	0.35
205	Bakery Products	0.70	0.90
208	Beverages	0.69	1.14
209	Misc. Food & Kindred Prod.	0.24	0.49
265	Paperboard Containers & Boxes	0.40	0.70
281	Industrial Inorganic Chemicals	0.12	0.20
283	Drugs	0.01	0.31
284	Soap, Cleansers & Toilet Goods	0.38	1.39
285	Paints & Allied Prod.	0.76	0.97
291	Petroleum Refining	0.44	0.85
327	Concrete, Gypsum, Plaster Prod.	0.17	0.19
344	Fabricated Metal Prod.	0.15	0.41
357	Computer & Office Equip.	0.18	0.27
366	Communication Equipment	0.00	0.01
367	Electronic Comp. & Acc.	0.07	0.33
371	Motor Vehicles	0.00	0.00
372	Aircraft & Parts	0.07	0.30
376	Guided Missles, Space Vehicles, Parts	0.00	0.14

Source: Survey Question III.3 & III.10

Note: Elasticity is estimated over the range 0-15% and 15-30%.

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that production is vulnerable to water shortage. As will be seen below, the survey responses translate to billions of dollars of economic losses to California industry associated with water shortfalls which range between 50,000 and 100,000 annual acre-feet -- less than 2 percent of total urban water requirements. Estimated losses looming as large as these would induce much new technology to save water in new ways and new policies to assure reliable water supplies to industry. Consequently, from the perspective of the individual responding plants, the reported production losses appear real; from the analyst's perspective, however, when the individual plant responses are summed to industry totals, the result is an untenable outcome.

7.4.1 Anecdotal Evidence From Scenarios

A source of evidence of the sensitivity of industry to water supply shortages are the open-ended responses provided within the survey. These open-ended responses followed the elicited numerical answers. The following block repeats a selection of responses from a number of the scenario questions. These are all direct quotations, but lightly edited for conciseness. They are presented before the results to give the reader a glimpse into the mind of the survey respondents.

ANECDOTAL EVIDENCE FROM SCENARIOS

SIC	SID	COMMENT
203	178	[Citrus Concentrates] We feel that we are at our lowest possible water consumption rate and no further reductions are feasible. Reduced water volumes could force the plant to shut down and go out of business.
203	212	[Canned and Specialty Foods] Our water consumption has dropped drastically over the year. We are constantly working on water conservation.
205	24	[Commercial bakery - bread] We use limited amount of water; most water is used to mix our product. We would reduce production accordingly with shortage. Reduction of cleanup for batter mix may not be possible to maintain proper sanitation. Possibly would move to location where water is available.
205	95	[Cookies, crackers] Would have a definite negative impact on revenues and manufacturing costs. Plant could be closed and production moved to other plants.

205 198 [Commercial bakery - bread] Water cutbacks will have a direct effect on production.

208 41 [Soft drinks] Production requires a fixed formulation of water content. If other process modifications cannot accommodate a 15% curtailment, production may have to be reduced. . . . Curtailing production would require products to be shipped into L.A. from other areas adding transport costs.

208 99 [Soft drinks] Water is the base of our product. We would suffer in proportion to the cutback. Our company would have to find a location suitable for production.

208 102 [Soft drink] 68 percent of water use goes directly into product; the remainder is necessary to maintain sanitation and manufacturing practices.

208 141 [Beer] Products must be transshipped to market due to water nonavailability. Would not consider expansion of the plant due to water availability.

208 175 [Soft drink] We would be forced to cease operations during the peak season.

209 131 [Frozen specialties for airlines] Plant sanitation requirements would be a problem with USDA. Revenues could be decreased substantially depending on plant output.

209 155 [Food processing] Reduced production will cause severe income and cash flow reductions. . . . We would not expand at this facility; we would look to relocate in another state to make-up for reduced production.

209 306 [Misc food products] Over the last several years this facility has greatly reduced water consumption relative to invested capital. There is very little left than can be done to reduce water. Cutbacks will reduce output proportionately. No further major capital expenditures will be made.

291 73 [Refining] Increased costs would absorb all profit. We would design and build process water treatment plants that cannot otherwise be justified.

291 184 [Refining] Infeasible to accomplish 30% reduction without significant reduction in water cooling, which is main cooling mode in refineries.

291 223 [Refining] May cancel refinery expansion if cost of water alternatives are too high.

327 118 [Concrete] Concrete can use nonpotable water. This is common practice throughout the industry. There is no source at this location.

327	125	[Concrete] Water is one of four ingredients of concrete; reduced water reduces production, will reduce revenues, while fixed overhead remains the same. 30% reduction would force us to close the doors and go out of business.
357	15	[Rigid discs] Would not expand; start doing some re-processing in alternative locations.
357	132	[Electronic data terminals] Some production would be relocated out of state, or out of the country.
357	68	[Memory discs] Lower production, reduced revenues and higher costs. Expansion would be out of the water shortage area; i.e., other states or Japan.
367	5	[PCBs] Done everything but RO which appears to be uneconomic; further study in progress. Will reduce employment. 30% implies stop production 30% of the time; shut down second shift. Will not buy new equipment for expansion.
367	117	[PCBs] Our industry could not build a product with a lesser quantity of water than we use. [In response to 15% question.]
367	123	[Microwave tubes] Uncertainty of water supply in the face of having conserved water over a 5 year period leads us to very limited opportunities for further conservation. Would plan to move production to other plants with adequate water and with sufficient demonstrated ability to plan for and provide water needs for industry.
367	202	[Memory drives] Our business is very capital intensive which means we need high volume to spread the costs. Expansion would be out of the water shortage area; ie., other states or offshore; might transfer production to our plants in Japan.
367	307	[PCBs] Shift production outside of California.
367	219	[Electronics] Most new projects are not being implemented in Southern California. Will shift production to facilities where water is available.
376	120	[Missile systems] Would relocate wet processes work out of state if water restrictions cause economics of relocation to be favorable. . . . would necessitate laying off work force.

SID = Survey ID number.

7.4.2 Plants Reporting Reduced Operations

Table 7-2 shows the percentage of plants by industry reporting reduced production due to the 15% and 30% water supply shortage scenarios. Survey responses show that 23 percent of responding plants would reduce plant output if water supplies were temporarily reduced by 15% during the summer months. Twenty-four percent report "Don't Know;" 53 percent report they would suffer no reduction in output. For the 30% shortage scenario, these percentages change to 36 percent, Yes; 30 percent, Don't Know; and 34 percent, No.

The overall average understates the percent of plants in industries reporting production losses by averaging in the industries which report no production losses. Reviewing Table 7-2, there are a number of industries where 35 to 70 percent of plants report output reductions under even a 15% water shortage scenario. The percentage of plants in these industries reporting output reductions increases in all but two industries for the 30% shortage scenario. A very large number of plants within certain Food industry groups, Soaps, Paints and Refining report production cutbacks.

7.4.3 Industry And County Production Losses

The production losses reported are shown for both shortage scenarios on Table 7-3. The table shows the estimated losses to industry production based on reported reductions in plant production associated with the two hypothetical water supply reduction scenarios. Shown on the table are the direct impacts to these same industries within the 12 surveyed urban counties along with the total loss including indirect and induced losses. These additional losses are determined with output multipliers provided by DWR as preliminary multiplier estimates from their forthcoming revision to Bulletin 210, "Measuring Economic Impacts."

The industries included in the study account for 52 percent of manufacturing in the twelve counties.[2] Because of the sampling plan, they account for more than 72 percent of total industrial water use in these counties. These industries are the largest water using industries.

The direct loss of output from these industries, keyed to 1990 value of shipments, amounts to an estimated $3.8 billion for the 15% water shortage scenario. This loss increases to $11.8 billion under the 30% water shortage scenario. Indirect and induced losses increase the direct losses to more than $6.4 billion for 15% scenario and almost $20 billion for the 30%

[2]Three industries were dropped from the analysis due to insufficient survey responses: SIC 322, Glassware; 331, Blast Furnaces, Steel Products; 341, Metal Cans and Containers.

TABLE 7-2
PRODUCTION LOSSES DUE TO HYPOTHETICAL WATER SHORTAGES

SIC CODE	Description of Plant	Scenario 1 Output Reduction to 15% Water Shortage			Scenario 2 Output Reduction to 30% Water Shortage		
		Yes (%)	No (%)	Don't Know (%)	Yes (%)	No (%)	Don't Know (%)
201	Meat Products	0	67	33	0	33	67
203	Preserved Fruits & Vegetables	35	47	18	50	23	29
205	Bakery Products	70	20	10	70	10	20
208	Beverages	60	10	30	80	0	20
209	Misc. Food & Kindred Prod.	27	46	27	45	0	55
265	Paperboard Containers & Boxes	20	40	40	30	30	40
281	Industrial Inorganic Chemicals	50	50	0	50	50	0
283	Drugs	20	60	20	40	20	40
284	Soaps, Cleansers, & Toilet Goods	50	0	50	75	0	25
285	Paints & Allied Prod.	50	50	0	100	0	0
291	Petroleum Refining	50	50	0	70	30	0
327	Concrete, Gypsum, Plaster Prod.	20	40	40	20	40	40
344	Fabricated Metal Prod.	22	33	44	33	33	33
357	Computer & Office Equip.	14	57	29	29	57	14
366	Communication Equipment	0	79	21	4	54	42
367	Electronic Comp. & Acc.	14	64	23	32	39	30
371	Motor Vehicles & Equip.	0	79	0	0	100	0
372	Aircraft & Parts	13	60	27	27	40	33
376	Guided Missles, Space Vehicles, Parts	0	70	30	10	40	50
	Weighted Average(1)	23	53	24	36	34	30

1) Weighted by the number of firms.

Source: Spectrum Survey Scenario Questions III.3 & III.10

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TABLE 7–3
PRODUCTION LOSSES DUE TO HYPOTHETICAL WATER SHORTAGES

SIC CODE	Description of Plant	Output by Industry ($1990 Billions) State Total(1)	12 County Total(1)	Output Multiplier(2)	Scenario 1 15% Supply Shortage %Loss(3)	Direct Loss(4)	Total Loss(5)	Scenario 2 30% Supply Shortage %Loss(3)	Direct Loss(4)	Total Loss(5)
201	Meat Products	3.4	1.9	2.26	0.0	0.00	0.00	0.0	0.00	0.00
203	Preserved Fruits & Vegetables	10.0	4.5	1.90	4.1	0.18	0.35	9.3	0.42	0.80
205	Bakery Products	2.4	2.4	1.64	10.5	0.25	0.41	24.0	0.57	0.94
208	Beverages	10.0	6.0	1.81	10.3	0.62	1.12	27.4	1.64	2.97
209	Misc. Food & Kindred Prod.	3.8	2.6	1.60	3.6	0.09	0.15	10.9	0.28	0.45
265	Paperboard Containers & Boxes	3.3	3.1	1.65	6.0	0.19	0.31	16.5	0.52	0.85
281	Industrial Inorganic Chemicals	1.5	1.5	1.59	1.8	0.03	0.04	4.8	0.07	0.11
283	Drugs	5.5	4.4	1.61	0.2	0.01	0.01	4.8	0.21	0.34
284	Soaps, Cleansers, & Toilet Goods	2.9	2.7	1.79	5.7	0.15	0.27	26.5	0.71	1.28
285	Paints & Allied Prod.	2.1	1.6	1.66	11.4	0.18	0.30	26.0	0.41	0.69
291	Petroleum Refining	18.6	16.5	1.75	6.6	1.09	1.91	19.3	3.18	5.55
327	Concrete, Gypsum, Plaster Prod.	4.4	2.4	1.74	2.6	0.06	0.11	5.5	0.13	0.23
344	Fabricated Metal Products	3.8	3.2	1.55	2.3	0.07	0.12	8.4	0.27	0.42
357	Computer & Office Equip.	21.0	19.6	1.56	2.7	0.53	0.83	6.8	1.33	2.08
366	Communication Equipment	4.8	4.6	1.66	0.0	0.00	0.00	0.1	0.00	0.00
367	Electronic Comp. & Acc.	16.2	15.0	1.55	1.1	0.17	0.26	6.1	0.91	1.41
371	Motor Vehicles & Equip.	6.2	4.9	1.48	0.0	0.00	0.00	0.0	0.00	0.00
372	Aircraft & Parts	16.0	16.0	1.56	1.0	0.16	0.25	5.5	0.88	1.37
376	Guided Misssles, Space Vehicles, Parts	15.4	14.0	1.55	0.0	0.00	0.00	2.1	0.29	0.46
Total Surveyed Industries		151.2	127.0		Loss Totals	3.79	6.43		11.84	19.95
Total State Manufacturing (EST)		287.0	245.5		% Loss of Surveyed Industries	3.0	NA		9.3	NA
Percent of State Manufacturing		53.0	52.0							

1) Source: Census of Manufactures 1987 Forecast to 1990 By CCSCE

2) Source: Department of Water Resources. This output multiplier is defined as the overall output impact for a dollar change in the corresponding sector.

3) Source: Scenario Questions III.3, III.10. Percent loss is the average percent change per firm weighted by output.

4) Calculated by multiplying the industrial percent loss by the 12 county output in each industrial sector, billions of 1990 dollars.

5) Calculated as the direct loss multiplied by output multiplier, billions of 1990 dollars.

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scenario. The total losses include the ripple effects to the Service, Trade and Government sectors.

Seventy-one percent of the estimated direct production losses due to water shortage are projected to occur in the industry groups listed on Table 7-4. Except for refining, these industries use a significant share of water used in the plant is used directly within the production process. Statistical evidence shows that the percentage of water used directly in the production process is a significant explanatory variable for plants reporting economic losses to shortages. Water is a critical input to these industries. Refining, Beverages and Food are the largest water using industries. Section 4.6 previously reported that Refining and Food industries have significantly lowered the use of intake water supplies over the last two decades. Section 6.3 showed that all of these industries but Beverages have dramatically improved their water use efficiency since 1985. Conservation was shown throughout Section 6.0 to be widespread within these industries.

TABLE 7-4
LARGEST INDUSTRY PRODUCTION LOSSES TO HYPOTHETICAL SUPPLY SHORTAGE

SIC CODE	Description of Plant	Direct Losses: 30% Supply Shortage
291	Refining	$ 3.2 Billion
357 & 367	Computer and Electronics	2.24 Billion
208	Beverages	1.64 Billion
201,3,5 & 9	Combined Food Industry Groups	1.27 Billion
Subtotal		8.35 Billion
Percent of Total Direct Losses		71%

Source: Table 7-3

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Table 7-5 divides the production losses for the 30% scenario between the Bay Area six counties and the South Coast six counties. Both regions sustain comparable percentage losses. The largest dollar losses ($7.4 billion) are in the larger Southern California economy. Certain industry production losses follow regional patterns. Eighty-three percent of production losses in High Technology industries are concentrated in Northern California. Ninety percent of production losses in the Defense industries occur in Southern California. Southern California also has significant losses in Beverages and Soaps and Cleansers.

TABLE 7-5
DIRECT PRODUCTION LOSSES
DUE TO 30% HYPOTHETICAL WATER SHORTAGE
BY REGION

		Total Value of Shipments 1990 ($ Billions) (1)				Production Reduction (Percentage) (2)			Production Reduction ($ Billions)		
SIC CODE	Description of Plant	State Total	12 County Total	North Total	South Total	North % Loss	South % Loss	Weighted Average	North Total(3)	South Total(3)	12 County Total
201	Meat Products	3.4	1.9	0.5	1.4	0.0	0.0	0.0	0.00	0.00	0.00
203	Preserved Fruits & Vegetables	10.0	4.5	1.6	2.9	5.2	11.6	9.3	0.08	0.34	0.42
205	Bakery Products	2.4	2.4	1.0	1.4	24.0	24.0	24.0	0.23	0.34	0.57
208	Beverages	10.0	6.0	1.6	4.4	34.0	25.0	27.4	0.54	1.10	1.64
209	Misc. Food & Kindred Prod.	3.8	2.6	0.9	1.7	10.9	10.9	10.9	0.10	0.18	0.28
265	Paperboard Containers & Boxes	3.3	3.1	0.7	2.4	16.5	16.5	16.5	0.12	0.40	0.52
281	Industrial Inorganic Chemicals	1.5	1.5	0.5	1.0	4.8	4.8	4.8	0.02	0.05	0.07
283	Drugs	5.5	4.4	2.2	2.3	4.8	4.8	4.8	0.10	0.11	0.21
284	Soaps, Cleansers, & Toilet Goods	2.9	2.7	0.3	2.4	26.5	26.5	26.5	0.08	0.64	0.71
285	Paints & Allied Prod.	2.1	1.6	0.5	1.1	26.0	26.0	26.0	0.12	0.29	0.41
291	Petroleum Refining	18.6	16.5	6.3	10.1	15.0	22.0	19.3	0.95	2.23	3.18
327	Concrete, Gypsum, Plaster Prod.	4.4	2.4	0.3	2.1	5.5	5.5	5.5	0.02	0.11	0.13
344	Fabricated Metal Products	3.8	3.2	0.9	2.4	8.4	8.4	8.4	0.07	0.20	0.27
357	Computer & Office Equip.	21.0	19.6	14.1	5.5	8.5	2.4	6.8	1.20	0.13	1.33
366	Communication Equipment	4.8	4.6	2.1	2.6	0.0	0.1	0.1	0.00	0.00	0.00
367	Electronic Comp. & Acc.	16.2	15.0	9.1	5.9	7.5	3.9	6.1	0.68	0.23	0.91
371	Motor Vehicles & Equip.	6.2	4.9	1.5	3.4	0.0	0.0	0.0	0.00	0.00	0.00
372	Aircraft & Parts	16.0	16.0	0.3	15.7	5.5	5.5	5.5	0.01	0.86	0.88
376	Guided Missles, Space Vehicles, Parts	15.4	14.0	3.6	10.4	2.1	2.1	2.1	0.08	0.22	0.29
Total Surveyed Industries		151.2	127.0	47.9	79.1	Industry Losses			4.41	7.44	11.84
Total State Manufacturing (EST)		287.0	245.5	79.0	166.5	%Loss of Industries			9.2	9.4	9.3
Percent of State Manufacturing		52.7	51.7	60.6	47.5						

1) Source: Census of Manufactures 1987 Forecast to 1990 By CCSCE
2) Scenario Question III.10
3) Output Reduction = % Output Reduction multiplied by Value of Shipments

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The industries included in the survey amount to 61 percent of Northern California (Bay Area) industrial production and 48 percent of Southern California production.

Figure 7-1 reports the lost direct production by county associated with a 30 percent reduction in water supplied to the industrial plants. The largest economic impacts occur in the five counties shown on Table 7-6. Contra Costa's refining sector would be hard hit by a 30 percent reduction in water supply; the reduced output would be nearly 10 percent of the county industrial output. Losses by industry group for 12 counties are shown on Table 7-7. The small production losses shown for several counties on Figure 7-1 and Table 7-7 reflect a combination of two effects:

1. Smaller industrial base relative to other counties;
2. Less water critical industry.

TABLE 7-6
LARGEST COUNTY PRODUCTION LOSSES:
30% WATER SUPPLY SHORTAGE

County	$ Billion	% of County Manufacturing Value
Los Angeles	5.5	5.3
Santa Clara	1.9	5.9
Contra Costa	1.0	9.9
Alameda	0.9	5.8
Orange	0.7	2.6

Source: Figure 7-1; Appendix C

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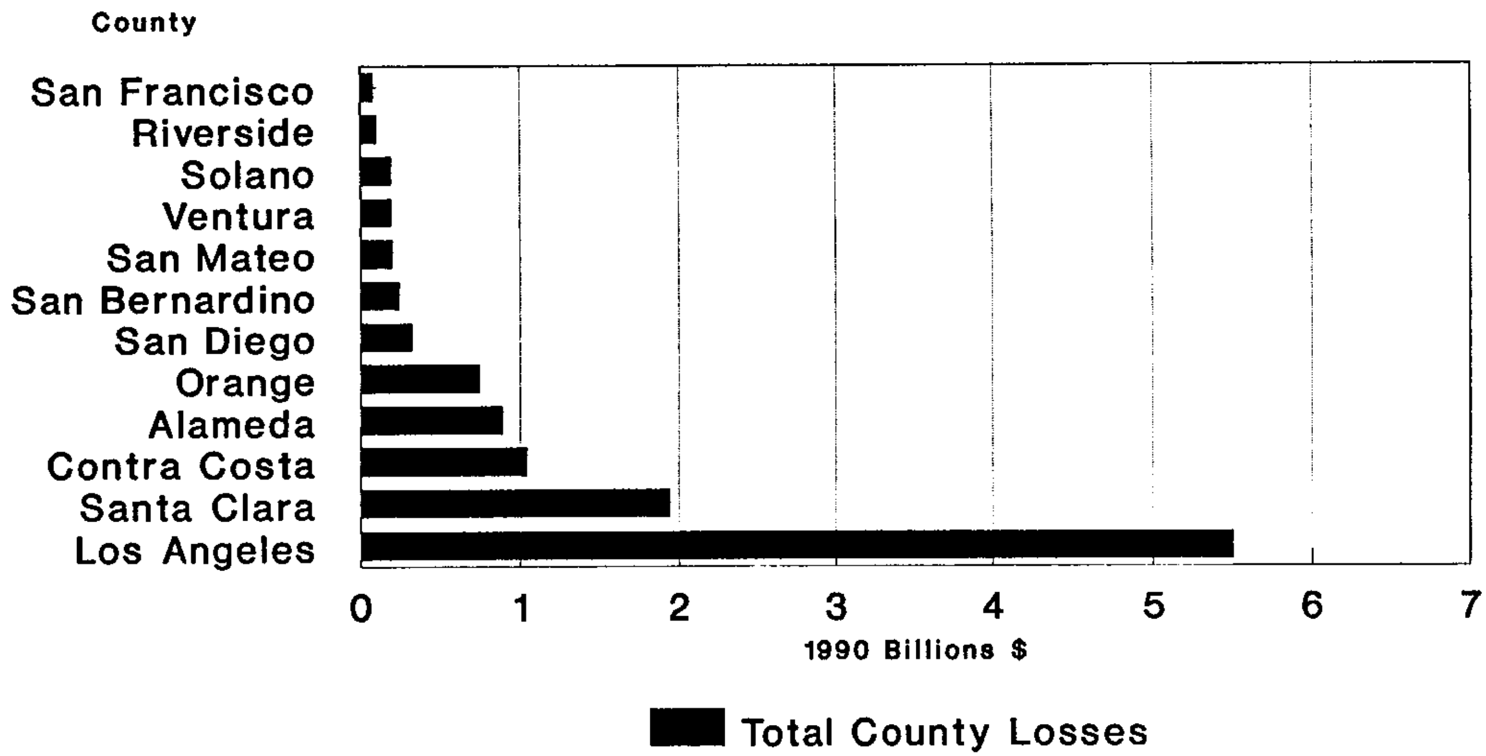
7.4.4 Plants Reporting Employment Reductions

Survey responses show that plants in these industries would reduce employment to mitigate income losses associated with water supply shortages. Table 7-8 shows the industry groups reporting lay-offs in these shortage situations. Twenty percent of reporting plants show that they would reduce employment in response to a 15% shortage; 27 percent Don't Know; and 53 percent report No. Thirty-two percent would reduce employment with a 30% shortage and 33 percent Don't Know. The No response dropped to 35 percent. The largest percentage of lay-offs would occur in those industries where water is the major component of the product -- Beverages (208), Soaps and Cleansers (284), and Paints (285).

Figure 7-1
Direct Production Losses by County
30% Water Supply Shortage



Source: Survey Questions &
Census of Manufactures, 1987
Forecast to 1990 by CCSCE

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TABLE 7-7
DIRECT PRODUCTION LOSSES – 30% WATER SUPPLY SHORTAGE
BY COUNTY
1990 ($) Billions

		North Counties(2)								South Counties(2)							
SIC CODE	Descriptions of Plant	North(1) % Loss	Alameda	Contra Costa	Santa Clara	San Francisco	San Mateo	Solano	North Loss(2)	South(1) % Loss	Los Angeles	Orange	Riverside	San Bernardino	San Diego	Ventura	South Loss(2)
	Industry Total		15.3	10.5	36.6	9.7	4.4	2.5	79.0		106.2	29.8	3.9	8.1	14.0	4.5	166.5
201	Meat Products	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
203	Preserved Fruits & Vegetables	5.2	0.01	0.00	0.03	0.02	0.01	0.01	0.08	11.6	0.15	0.08	0.02	0.03	0.00	0.05	0.34
205	Bakery Products	24.0	0.12	0.01	0.04	0.02	0.04	0.00	0.23	24.0	0.24	0.06	0.00	0.01	0.02	0.01	0.34
208	Beverages	34.0	0.13	0.01	0.18	0.02	0.02	0.18	0.54	25.0	0.87	0.12	0.00	0.03	0.09	0.00	1.10
209	Misc. Food & Kindred Prod.	10.9	0.06	0.01	0.01	0.01	0.01	0.00	0.10	10.9	0.12	0.04	0.00	0.01	0.00	0.00	0.18
265	Paperboard Containers & Boxes	16.5	0.05	0.02	0.03	0.00	0.01	0.00	0.12	16.5	0.23	0.10	0.01	0.03	0.01	0.02	0.40
281	Industrial Inorganic Chemicals	4.8	0.00	0.02	0.00	0.00	0.00	0.00	0.02	4.8	0.02	0.02	0.00	0.01	0.01	0.00	0.05
283	Drugs	4.8	0.02	0.01	0.07	0.00	0.01	0.00	0.10	4.8	0.05	0.05	0.00	0.00	0.01	0.00	0.11
284	Soap, Cleansers, & Toilet Goods	26.5	0.08	0.00	0.00	0.00	0.00	0.00	0.08	26.5	0.47	0.03	0.02	0.01	0.04	0.07	0.64
285	Paints & Allied Prod.	26.0	0.05	0.00	0.00	0.00	0.07	0.00	0.12	26.0	0.23	0.05	0.00	0.01	0.00	0.00	0.29
291	Petroleum Refining	15.0	0.00	0.95	0.00	0.00	0.00	0.00	0.95	22.0	2.23	0.00	0.00	0.00	0.00	0.00	2.23
327	Concrete, Gypsum, Plaster Prod.	5.5	0.01	0.00	0.00	0.00	0.00	0.00	0.02	5.5	0.05	0.02	0.01	0.02	0.02	0.00	0.11
344	Fabricated Metal Prd	8.4	0.02	0.01	0.02	0.01	0.02	0.01	0.07	8.4	0.12	0.03	0.01	0.02	0.01	0.00	0.20
357	Computer & Office Equip.	8.5	0.31	0.01	0.88	0.00	0.01	0.00	1.20	2.4	0.05	0.05	0.00	0.00	0.02	0.01	0.13
366	Communication Equipment	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00
367	Electronic Comp. & Acc.	7.5	0.05	0.00	0.61	0.00	0.02	0.00	0.68	3.9	0.09	0.07	0.01	0.04	0.01	0.01	0.23
371	Motor Vehicles & Equip.	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
372	Aircraft & Parts	5.5	0.01	0.00	0.01	0.00	0.00	0.00	0.01	5.5	0.71	0.01	0.02	0.03	0.07	0.02	0.86
376	Guided Missles, Space Vehicles, Parts	2.1	0.00	0.00	0.07	0.00	0.00	0.00	0.08	2.1	0.15	0.04	0.00	0.01	0.03	0.00	0.22
	Total County Loss		0.93	1.04	1.95	0.09	0.20	0.19	4.41		5.76	0.77	0.11	0.26	0.34	0.19	7.43
	% of Industry Total		6.1	9.9	5.3	0.9	4.6	7.6	5.6		5.4	2.6	2.8	3.2	2.4	4.2	4.5

1) Regional Percent Loss Estimated from Scenario III.10

2) Losses Calculated by Applying Regional Percent Losses to Value of Shipments in Each County

Source: Survey Questions & Census of Manufacturers, 1987

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TABLE 7-8
INDUSTRY EMPLOYMENT REDUCTIONS DUE TO HYPOTHETICAL WATER SHORTAGES

SIC CODE	Description of Plant	Scenario 1 Employment Reductions Due to 15% Water Shortage			Scenario 2 Employment Reductions Due to 30% Water Shortage		
		Yes (%)	No (%)	Don't Know (%)	Yes (%)	No (%)	Don't Know (%)
201	Meat Products	33	33	33	33	33	33
203	Preserved Fruits & Vegetables	29	47	23	41	35	23
205	Bakery Products	60	30	10	60	20	20
208	Beverages	60	10	30	80	0	20
209	Misc. Food & Kindred Prod.	27	27	45	55	0	45
265	Paperboard Containers & Boxes	30	40	30	40	30	30
281	Industrial Inorganic Chemicals	25	50	25	25	50	25
283	Drugs	0	100	0	40	20	40
284	Soap, Cleansers & Toilet Goods	25	0	75	75	0	25
285	Paints & Allied Prod.	50	50	0	100	0	0
291	Petroleum Refining	9	64	27	9	36	54
327	Concrete, Gypsum, Plaster Prod.	17	50	33	17	33	50
344	Fabricated Metal Prod.	22	56	22	33	44	22
357	Computer & Office Equip.	13	57	28	21	50	28
366	Communication Equipment	0	88	12	4	56	40
367	Electronic Comp. & Acc.	16	61	22	32	39	29
371	Motor Vehicles & Equip.	0	80	20	0	100	0
372	Aircraft & Parts	20	40	40	27	40	33
376	Guided Missles, Space Vehicles, Parts	10	40	50	20	20	60
	Weighted Average(1)	20	53	27	32	35	33

1) Weighted by number of firms

Source: Scenario Questions III.3 & III.10

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7.4.5 Industry and County Employment Losses

Direct employment reduction reported for the two water shortage scenarios is shown on Table 7-9. The industries included within the survey account for 45 percent of Manufacturing employment within the surveyed twelve counties. These same industries account for more than 72 percent of industrial water use.

Direct employment losses are estimated to be 18,000 for a 15% shortage and 46,000 for a 30% shortage. This is 5.4 percent of the 1989 labor force in these industries. (Current Manufacturing employment in California (1991) is approximately the same as shown on Table 7-9, although the distribution between industries may have changed. Labor productivity has risen significantly in the High Technology industries.) Linkages to other sectors would increase the direct losses three and one-half times as the effects ripple across the State. A 30% year long industrial water shortage would reduce employment nearly 160,000. A loss this large would change the state unemployment rate by 1.1 percentage points -- a significant increase in the widely watched economic indicator.

The largest direct employment losses would be concentrated in the High Technology, Aircraft and Food industry groups. These industry groups would incur 75 percent of the job loss as shown on Table 7-10.

TABLE 7-10
LARGEST INDUSTRIAL EMPLOYMENT REDUCTIONS IN 12 COUNTIES: 30% WATER SUPPLY SHORTAGE

SIC CODE	Description of Plant	Direct Employment Losses: 30% Supply Shortage
357	Office & Computer Equipment	8,380
367	Computer Components	7,350
201,3,5 & 9	Combined Food Industry Groups	10, 760
372	Aircraft and Aerospace	5790
Subtotal		32,280
Percent of Total Employment Losses		71%

Source: Table 7-9

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TABLE 7-9
EMPLOYMENT REDUCTIONS DUE TO HYPOTHETICAL WATER SHORTAGES

SIC CODE	Description of Plant	Employment by Industry (In Thousands) State Total(1)	12 County Total(1)	Type II Multiplier(2)	Scenario 1 15% Supply Shortage %Loss(3)	Direct Loss(4)	Total Loss(5)	Scenario 2 30% Supply Shortage %Loss(3)	Direct Loss(4)	Total Loss(5)
201	Meat Products	20.4	9.2	4.78	6.4	0.58	2.79	6.4	0.59	2.81
203	Preserved Fruits & Vegetables	54.3	22.0	3.93	2.4	0.52	2.05	7.3	1.61	6.31
205	Bakery Products	20.5	17.5	2.83	9.1	1.60	4.53	17.0	2.98	8.44
208	Beverages	28.0	12.4	5.93	9.9	1.23	7.29	27.9	3.47	20.59
209	Misc. Food & Kindred Prod.	22.8	18.6	5.04	3.6	0.67	3.38	11.3	2.11	10.62
265	Paperboard Containers & Boxes	17.6	14.7	3.59	6.6	0.98	3.52	16.9	2.49	8.95
281	Industrial Inorganic Chemicals	8.0	7.2	2.98	0.3	0.02	0.07	1.4	0.10	0.30
283	Drugs	24.0	23.2	2.87	0.0	0.00	0.00	4.5	1.04	3.00
284	Soap, Cleansers & Toilet Goods	15.3	13.9	5.48	5.5	0.76	4.17	27.0	3.76	20.61
285	Paints & Allied Prod.	7.3	7.0	4.33	3.2	0.23	0.99	16.0	1.12	4.86
291	Petroleum Refining	11.6	9.9	7.13	0.1	0.01	0.06	0.1	0.01	0.04
327	Concrete, Gypsum, Plaster Prod.	21.5	16.1	3.49	1.4	0.22	0.78	3.3	0.53	1.86
344	Fabricated Metal Prod.	41.3	33.4	2.78	2.3	0.77	2.13	6.6	2.20	6.11
357	Computer & Office Equip.	99.3	91.7	3.12	4.6	4.21	13.14	9.1	8.38	26.13
366	Communication Equipment	150.2	143.5	3.23	0.0	0.00	0.00	0.1	0.12	0.37
367	Electronic Comp. & Acc.	148.1	137.3	2.54	2.0	2.75	6.99	5.4	7.35	18.69
371	Motor Vehicles & Equip.	33.1	28.2	2.62	0.0	0.00	0.00	0.0	0.00	0.00
372	Aircraft & Parts	169.9	165.5	2.55	2.0	3.25	8.28	3.5	5.79	14.75
376	Guided Missles, Space Vehicles, Parts	80.5	74.0	2.31	0.5	0.36	0.83	2.6	1.92	4.45
Total Respondent Industries		973.5	845.5		Loss Totals	18.17	60.98		45.6	158.9
Total State Manufacturing (EST)		2162.2	1874.1		% Loss of Surveyed Industries	2.1	NA		5.4	NA
Percent of State Manufacturing		45.0	45.1							

1) Source: EDD 1989
2) Source: Department of Water Resources. This employment multiplier is defined as the overall employment impact for any one-job change in the corresponding sector.
3) Source: Scenario Questions III.4, III.11. Percent loss is the average percent change per firm weighted by employees.
4) Calculated by multiplying the industrial percent loss by the employment in each industrial sector for the 12 county study area.
5) Calculated as the direct loss multiplied by the employment multiplier.

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Table 7-11 shows that the industries included in the survey amount to 55 percent of Northern California industrial employment and 42 percent of Southern California employment. For the 30% water shortage scenario, total direct job loss in Northern California amounts to nearly 8 percent of the labor force in the surveyed industries. Employment in Northern California's Computer and Computer Components (357 & 367) industries would be particularly hard-hit by a 30% water supply shortage. These industries are shown on Table 7-11 to be the largest employers and to sustain the largest employment reductions -- 13,040, over 9 percent of northern California employment in these industries. These two industries would sustain 66 percent of the reported job loss in the northern California industries. Santa Clara County -- Silicon Valley -- would sustain the largest share of the computer employment losses.

Figure 7-2 shows the reduced employment by county associated with the 30% water shortage scenario. Largest employment impacts occur in the five counties shown on Table 7-12. The concentration of High Technology plants in Santa Clara County, and their dependence on water as a critical input in the production process, makes the county's labor force vulnerable to a 30% shortage in deliveries to these plants. Los Angeles would sustain comparable job losses, mostly in the Aircraft industry (372), but the County's economy is so diversified and so large that the reduction would be relatively less severe to the economic base. County employment reductions by industry group are shown as Table 7-13.

TABLE 7-12
LARGEST COUNTY EMPLOYMENT REDUCTIONS
30% WATER SUPPLY SHORTAGE

County	Lost Jobs (1000)	% of County Manufacturing Employment
Santa Clara	14.1	5.2
Los Angeles	17.5	2.0
Orange	3.9	1.5
Alameda	3.1	3.7
San Diego	2.3	1.7

Source: Figure 7-2; Appendix C

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TABLE 7-11
DIRECT EMPLOYMENT REDUCTIONS DUE TO A 30% HYPOTHETICAL WATER SHORTAGE BY REGION OF IMPACT

SIC CODE	Description of Plant	Total Employment 1989 (Thousands) (1)				Employment Reduction (Percentage) (2)			Employment Reduction (Thousands)		
		State Total	12 County Total	North Total	South Total	North % Loss	South % Loss	Weighted Average	North Total(3)	South Total(3)	12 County Total
201	Meat Products	20.4	9.2	2.3	6.9	6.4	6.4	6.4	0.15	0.44	0.59
203	Preserved Fruits & Vegetables	54.3	22.0	8.9	13.1	5.5	8.5	7.3	0.49	1.12	1.61
205	Bakery Products	20.5	17.5	5.5	12.0	17.0	17.0	17.0	0.94	2.04	2.98
208	Beverages	28.0	12.4	3.4	9.1	33.0	26.0	27.9	1.12	2.35	3.47
209	Misc. Food & Kindred Prod.	22.8	18.6	4.3	14.3	11.3	11.3	11.3	0.49	1.62	2.11
265	Paperboard Containers & Boxes	17.6	14.7	3.7	11.0	16.9	16.9	16.9	0.63	1.87	2.49
281	Industrial Inorganic Chemicals	8.0	7.2	2.6	4.6	1.4	1.4	1.4	0.04	0.06	0.10
283	Drugs	24.0	23.2	9.6	13.6	4.5	4.5	4.5	0.43	0.61	1.04
284	Soap, Cleansers & Toilet Goods	15.3	13.9	2.6	11.3	27.0	27.0	27.0	0.71	3.06	3.76
285	Paints & Allied Prod.	7.3	7.0	1.7	5.3	16.0	16.0	16.0	0.28	0.84	1.12
291	Petroleum Refining	11.6	9.9	4.6	5.3	0.0	0.1	0.1	0.00	0.01	0.01
327	Concrete, Gypsum, Plaster Prod.	21.5	16.1	3.4	12.7	3.3	3.3	3.3	0.11	0.42	0.53
344	Fabricated Metal Prod.	41.3	33.4	6.7	26.7	6.6	6.6	6.6	0.44	1.76	2.20
357	Computer & Office Equip.	99.3	91.7	60.6	31.1	12.6	2.4	9.1	7.63	0.75	8.38
366	Communication Equipment	150.2	143.5	27.5	116.0	0.0	0.1	0.1	0.00	0.12	0.12
367	Electronic Comp. & Acc.	148.1	137.3	78.4	58.9	6.9	3.3	5.4	5.41	1.94	7.35
371	Motor Vehicles & Equip.	33.1	28.2	4.9	23.3	0.0	0.0	0.0	0.00	0.00	0.00
372	Aircraft & Parts	169.9	165.5	1.8	163.8	3.5	3.5	3.5	0.06	5.73	5.79
376	Guided Missles, Space Vehicles, Parts	80.5	74.0	26.7	47.4	2.6	2.6	2.6	0.69	1.23	1.92
Total Respondent Industries		973.5	845.5	259.0	586.5	Industry Losses			19.60	25.98	45.58
Total State Manufacturing (EST)		2162.4	1874.1	468.8	1405.3	% Loss of Industries			7.6	4.4	5.4
Percent of State Manufacturing		45.0	45.1	55.3	41.7						

1) Source: EDD 1989
2) Spectrum Survey, Scenario III.11
3) Employment Reduction = % Employment Reduction multiplied by Employment

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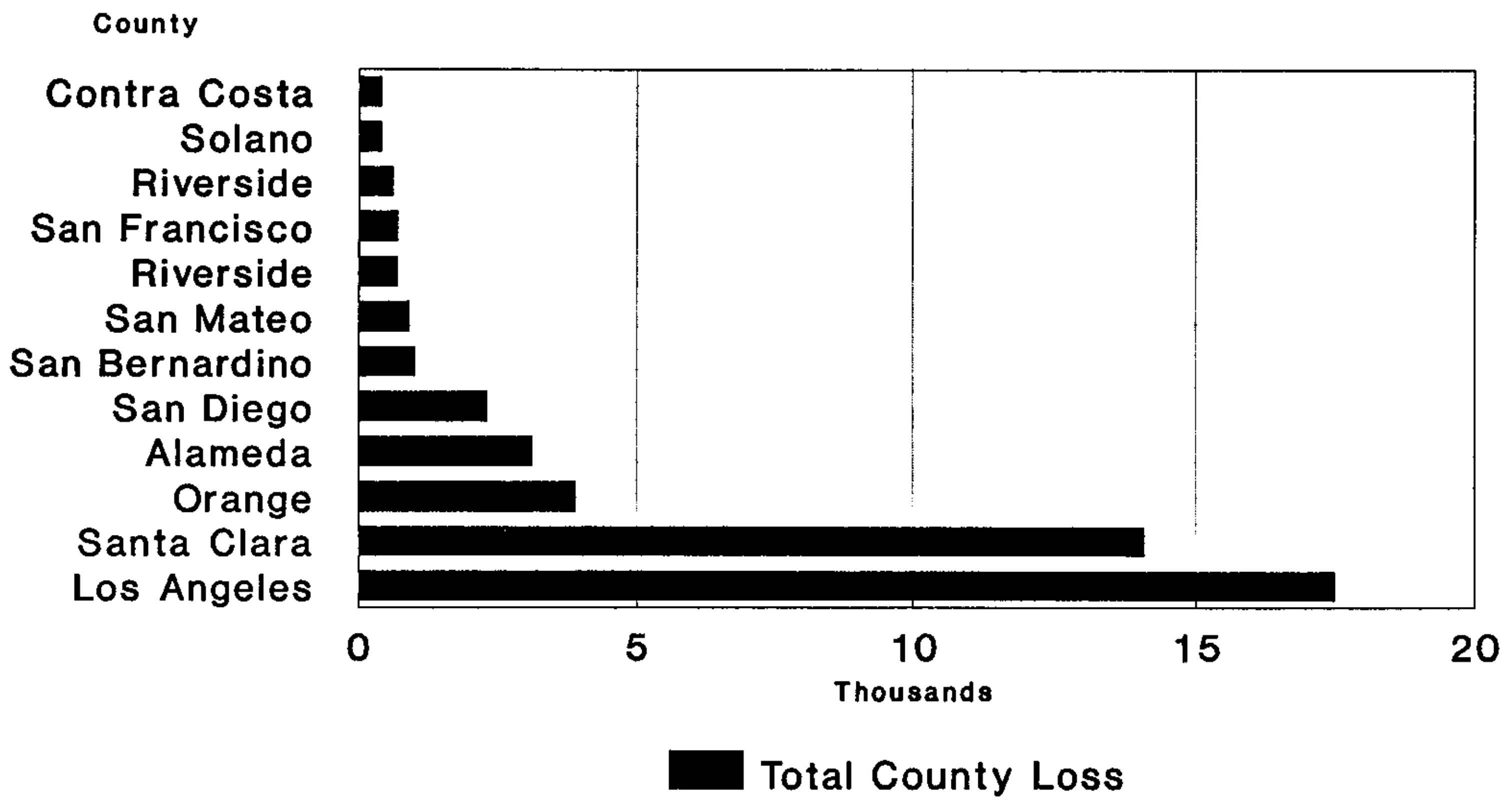
Figure 7-2
Direct Employment Reductions by County - 30% Supply Shortage



Source: Survey Question III.11 &
E.D.D. 1989

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TABLE 7-13
DIRECT EMPLOYMENT REDUCTIONS – 30% WATER SUPPLY SHORTAGE
BY COUNTY
(Thousands)

SIC CODE	Description of Plant	North(1) % Loss	North Counties(2) Alameda	Contra Costa	Santa Clara	San Francisco	San Mateo	Solano	North Loss(2)	South(1) % Loss	South Counties(2) Los Angeles	Orange	Riverside	San Bernardino	San Diego	Ventura	South Loss(2)
	Industry Total		83.2	31.5	269.8	41.8	35.1	7.4	468.8		891.7	259.1	31.1	57.3	135	31.1	1405.3
201	Meat Products	6.4	0.06	0.00	0.02	0.04	0.01	0.01	0.15	6.4	0.38	0.02	0.00	0.02	0.01	0.00	0.44
203	Preserved Fruits & Vegetables	5.5	0.04	0.01	0.27	0.09	0.02	0.06	0.49	8.5	0.43	0.39	0.09	0.09	0.03	0.10	1.12
205	Bakery Products	17.0	0.47	0.02	0.13	0.19	0.13	0.00	0.94	17.0	1.52	0.25	0.01	0.04	0.21	0.01	2.04
208	Beverages	33.0	0.40	0.12	0.24	0.06	0.08	0.22	1.12	26.0	1.59	0.33	0.03	0.12	0.23	0.05	2.35
209	Misc. Food & Kindred Prod.	11.3	0.21	0.03	0.08	0.12	0.04	0.00	0.49	11.3	1.31	0.17	0.01	0.03	0.06	0.04	1.62
265	Paperboard Containers & Boxes	16.9	0.33	0.04	0.18	0.01	0.07	0.00	0.63	16.9	1.19	0.39	0.08	0.12	0.05	0.04	1.87
281	Industrial Inorganic Chemicals	1.4	0.01	0.02	0.01	0.00	0.00	0.00	0.04	1.4	0.03	0.01	0.00	0.02	0.00	0.00	0.06
283	Drugs	4.5	0.07	0.02	0.25	0.01	0.09	0.00	0.43	4.5	0.32	0.24	0.00	0.00	0.05	0.00	0.61
284	Soap, Cleansers & Toilet Goods	27.0	0.42	0.02	0.16	0.03	0.05	0.03	0.71	27.0	2.66	0.13	0.06	0.06	0.06	0.09	3.06
285	Paints & Allied Prod.	16.0	0.10	0.00	0.01	0.04	0.11	0.00	0.28	16.0	0.65	0.12	0.01	0.05	0.01	0.00	0.84
291	Petroleum Refining	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1	0.00	0.00	0.00	0.00	0.00	0.00	0.01
327	Concrete, Gypsum, Plaster Prod.	3.3	0.05	0.01	0.03	0.00	0.01	0.01	0.11	3.3	0.16	0.05	0.04	0.09	0.06	0.02	0.42
344	Fabricated Metal Prod.	6.6	0.17	0.03	0.13	0.04	0.04	0.03	0.44	6.6	1.03	0.24	0.08	0.13	0.25	0.03	1.76
357	Computer & Office Equip.	12.6	0.35	0.03	7.14	0.03	0.08	0.00	7.63	2.4	0.30	0.30	0.00	0.00	0.12	0.03	0.75
366	Communication Equipment	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.1	0.07	0.03	0.00	0.00	0.01	0.00	0.12
367	Electronic Comp. & Acc.	6.9	0.40	0.04	4.72	0.03	0.21	0.00	5.41	3.3	0.87	0.64	0.03	0.02	0.31	0.08	1.94
371	Motor Vehicles & Equip.	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
372	Aircraft & Parts	3.5	0.05	0.00	0.00	0.00	0.01	0.00	0.06	3.5	4.53	0.22	0.12	0.14	0.54	0.18	5.73
376	Guided Missles, Space Vehicles, Parts	2.6	0.00	0.00	0.69	0.00	0.00	0.00	0.69	2.6	0.43	0.39	0.01	0.09	0.32	0.00	1.23
	Total County Loss		3.1	0.4	14.1	0.7	0.9	0.4	19.6		17.5	3.9	0.6	1.0	2.3	0.7	26.0
	% of Industry Total		3.8	1.3	5.2	1.7	2.7	4.9	4.2		2.0	1.5	1.8	1.8	1.7	2.1	1.8

1) Regional Percent Loss Estimated from Scenario Question III.11
2) Losses Calulated by Applying Regional Percent Losses to Employment in Each County
Source: Census of Manufactures 1987, Spectrum Economics, June 1991

Spectrum Economics
9/9/91

APPENDIX A

SURVEY INSTRUMENT

MWD
METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

Office of the General Manager

Dear

Study of Cost Impacts of Industrial Water Shortages

The State Water Resources Control Board (SWRCB) is presently engaged in an extensive water rights hearing process, entitled the Bay-Delta Hearings, that could have profound effects on water supply availability to industry and commerce in California.

California Urban Water Agencies (CUWA), an association of the eleven largest urban water agencies in California, has commissioned a study on the importance of water supply reliability to industrial water users in California. The main objectives of this study are to determine:

1. the economic cost of water shortages to industrial firms in California;
2. the role that reliable water supply plays in various industrial processes; and
3. the potential for further water conservation in the industrial sector.

Enclosed with this letter is a survey form designed to obtain information that will help the water industry provide the SWRCB with information on the need for water supply reliability in the industrial/commercial sector. Spectrum Economics, Inc. of San Francisco has been retained to conduct the study. Spectrum will maintain strict confidentiality with the information you submit. Your firm will not be referenced individually; the data you provide will be aggregated with others and shown by regional industrial groups only. The survey form asks for your water utility account numbers in case Spectrum needs to ask your local water agency for some additional data. We will provide the respondents with a summary of the final report.

Your prompt response to this survey is essential to successful completion of this important study. Please return the completed survey to Spectrum Economics, Inc. by November 21, 1990. Someone will be contacting your office soon to ask who is working on the survey response and to offer support. Thank you in advance for your cooperation.

Very truly yours,

Carl Boronkay
Carl Boronkay
General Manager

1111 Sunset Boulevard, Los Angeles, California • Mailing address: Box 54153, Los Angeles, California 90054 • Telephone (213) 250-6000

INDUSTRIAL WATER USE SURVEY

FOR

CALIFORNIA URBAN WATER AGENCIES (CUWA)

by

Spectrum Economics Inc.
120 Montgomery Street, # 1776
San Francisco, CA 94104
415-391-3558
Contact: Bill Wade

WHY SHOULD YOUR FIRM TAKE THE TROUBLE TO FILL OUT THIS FORM?

Water is a scarce resource in California. The Water Agencies need data about how you use water now, and how your future plans will affect water use. We have been asked to collect the data.

CUWA is a consortium of major California water providers who serve about 70% of the state's population, and have common concerns about drinking water quality, urban supply reliability, and water use efficiency.

CONFIDENTIALITY: Confidentiality is assured. Information on individual companies and plants will be aggregated with groups of plants, and no individual plant-specific information will be released either within the report, or to any water utility. Data entered into the data base will not be identifiable with a firm. Only the survey number will be tagged in the data base. The survey asks for account numbers to be used only in case we need to ask your water agency for additional data.

WHO SHOULD FILL OUT THIS SURVEY:

Section I	Plant Operations	Comptroller/Staff
Section II	Water Use and Conservation	Plant Engineer/Staff
Section III	Future Conditions	Comptroller and Plant Engineer

Survey Number [ ]

INDUSTRIAL WATER USE SURVEY

for

CALIFORNIA URBAN WATER AGENCIES (CUWA)

by

SPECTRUM ECONOMICS, INC.
120 Montgomery St., Suite 1776
San Francisco, CA 94104
(415) 391-3558

Contact: Bill Wade

This survey has three sections:

* Section I seeks information about plant production and operations
* Section II seeks information about water use and recent conservation efforts
* Section III asks about the impacts of possible recurrent water shortages in the future on plant operations.

Please note any corrections to the firm name and address, the names of the individuals who will be responding to the sections, and other information on this page.
Instructions for each section follow, below.

Company Name: [ ]

Company Address: Street [ ]

City [ ] California

Zipcode [ ]

Please enter the Name/Position/Phone of persons with responsibility for answering each section:

Section I [ ] Phone #

Section II [ ] Phone #

Section III [ ] Phone #

Is there more than one water meter or meter bank on the water supply (intake) to this plant YES [ ] NO [ ]

Please provide account numbers for water supply (except fire hydrant) and sanitation discharges for this plant

Water service account numbers:	Sanitation service account numbers:

Survey Number | |

SECTION I: PLANT OPERATIONS QUESTIONS

Instructions: Many of the questions which follow deal with annual data. We would like the answers to apply to calendar year 1989. Please note whenever the answers you give refer to a fiscal year, and what that fiscal year covers.

I.1 What do you produce or process at this plant? Please describe.

I.2 Please list the SIC Code classifications of this plant: Primary ______ Secondary ______

EMPLOYEES: Include only employees at this plant. Do not include employees at outside sales offices, warehouses, etc.

FULL-TIME EMPLOYEES:

I.3 In 1989, the average number of full-time employees was: ______

I.4 In 1989, the number employed directly in production was: ______

I.5 In 1989, the total full-time payroll (including FICA) was: $ ______

PART-TIME EMPLOYEES:

I.6 In 1989, average number of part-time employees was: ______

I.7 In 1989, average number employed in production was: ______

I.8 In 1989, total wages paid for part-time employees was: $ ______

PRODUCTION HISTORY

I.9 Please show how your production and production employment have changed in the last five years. In lieu of filling in these boxes, you may attach copies of the U.S Bureau of the Census, Annual Survey of Manufacture, Form No. MA 1000, for 1985 to 1989. If production numbers are confidential, please use an index, 1985 = 100. Please check the box if forms are attached. ☐

Year	Production Employment (Average number in the year)		Total Plant Production	
	Full-Time	Part-Time	Quantity	Units
1989				
1988				
1987				
1986				
1985				

Survey Number [ ]

PLANT OPERATION AND CAPACITY

I.10 In 1989, how many days did this plant operate? [ ] days

I.11 Thinking of plant capacity with reference to the number of days and shifts of operation in a normal year, what percent of plant capacity was utilized in 1989? [ ] %

If the 1989 capacity utilization rate was outside the range you consider normal for your plant, please describe briefly what caused the rate to be different and how much below or above normal.

SEASONALITY OF OPERATIONS

I.12 Did the plant work more than one shift per day in 1989? YES [ ] NO [ ]

I.13 In general, does the number of shifts per day vary according to season? YES [ ] NO [ ]

I.14 In 1989, how many shifts per day did the plant operate? Please circle 0, 1, 2 or 3 shifts per day, by month.

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3

I.15 For each month, please indicate the percentage of 1989 production produced in that month. Percentages in boxes should add to 100%

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC

I.16 Are you planning a significant expansion or reduction at this plant? YES [ ] NO [ ]

If yes, please describe when and how large:

Survey Number

SECTION II: WATER USE QUESTIONS

There are many units of measure which express water volume. When you answer water volume questions, please use the abbreviations below, and add any other measures and abbreviations you use here.

Acre feet	AF
Thousand gallons	1000G
Million gallons	MG
Hundred cubic feet	CCF
Other (please specify):	

II.1 Using units noted above, please tell us the source of your water for the last 5 years.

	Annual Volume				
Sources	1989	1988	1987	1986	1985
Local Water Utility:					
Potable (drinking) water					
Nonpotable water					
Own System:					
Ground water					
Surface water					
Other Sources (Specify):					
Total Intake					
Please enter units of measure					

Please check the measurement method used for intake data: Meter records ☐ Estimates ☐

II.2 Does your water use vary by month? YES ☐ NO ☐

If Yes,-continue
If NO, go to II.3

Please show the percentage of your annual water use by month. If you do not have monthly data, you can either estimate the percentage for each month, or report actual data in the ending month of a bimonthly or quarterly period.

For the year 1989:

JAN	FEB	MAR	APR	MAY	JUN
JUL	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**

Percentages in boxes should add to 100%

II.3 How do you use water in your plant? How has this changed? Please fill in the percent of annual water use for 1985 and 1989 for each purpose listed below.

	1989	1985
Process:		
Embodied in product		
Washing/Rinsing		
Other		
Boiler Feed		
Cooling/Condensing		
Employee Sanitary		
Irrigation, Landscape		
Other (specify):		
Unaccounted		
Total	100%	100%

II.4 Do you have a leak detection or leak monitoring program? YES ☐ NO ☐

If yes, between 1985 and 1989, how much has annual usage been reduced by the program?

Volume ☐
Units ☐

II.5 Do you have a water use balance diagram for this plant? YES ☐ NO ☐

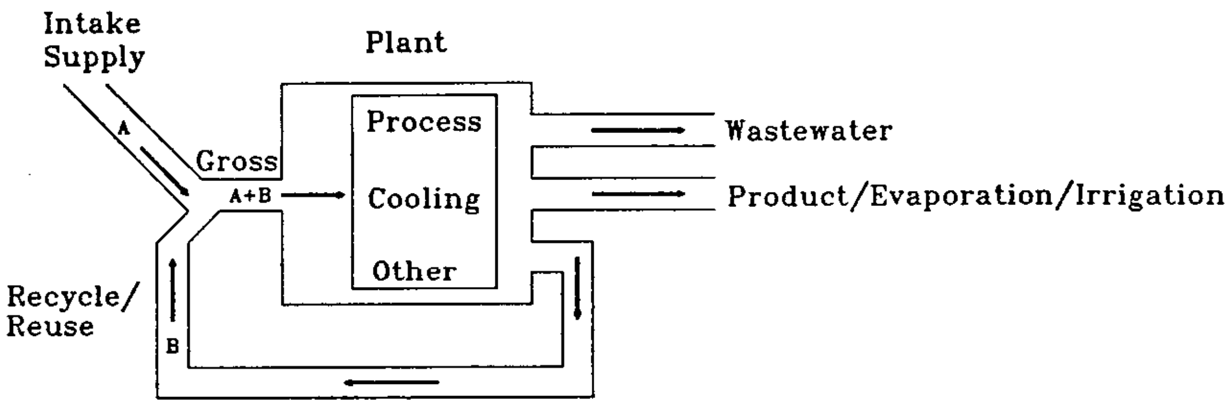
If YES, please attach a copy to this survey.

Survey Number [ ]

II.6 Do you recycle/reuse water at your plant? YES [ ] NO [ ]

If YES, continue
If NO, go to II.7

Please refer to the schematic diagram, below, showing intake and recycled water when providing the data on recycled water use, for 1989, in the table. Please show cooling and process recycling separately.



	1989 Water Volume			
	Intake (A)	Recycled (B)	Gross (A+B)	Units
Process				
Cooling, Condensing				
Others (specify:				
Total				

II.7 What is the cost of company-produced water from owned wells or surface water withdrawals, if any? Please provide annual O&M costs (e.g., pumping, treatment and maintenance) for 1989.

Total Annual O&M Costs $

Survey Number [ ]

II.8 Do you treat any wastewater before discharging it to a sewer? YES [ ] NO [ ]

If YES, go to II.9

If NO, go to II.10

II.9 What volume of total wastewater did you treat in 1989?

Volume Treated [ ] Units [ ]

What was the total annual O&M cost (e.g., energy, chemical and labor) of wastewater treatment in 1989?

Total Annual O&M Costs $ [ ]

What was the capital expenditure on the treatment equipment, and what year was the expenditure made?

Year [ ] Capital Expenditure $ [ ]

II.10 What was the amount and cost of wastewater discharged to a sanitation agency or municipality in 1989, excluding the cost of any treatment before discharge?

Total Annual Wastewater Discharge [ ] Units [ ]

Total Annual Wastewater Discharge Costs $ [ ]

II.11 How is your company charged for wastewater disposal? Please mark all of the following charges that your company pays.

Flat Fee per Billing Period (service charge)	YES	[ ]	NO	[ ]
Volume Rate per Unit Discharged	YES	[ ]	NO	[ ]
Strength Charges per Unit of Wastewater Component	YES	[ ]	NO	[ ]

(e.g., TSS/TDS (total suspended/dissolved solids), BOD/COD (biological/chemical oxygen demand), etc.)

If the Volume Rate applies, how is it determined?

If the Strength Charge applies, please provide detail (e.g., cents/lb TSS), for 1989, OR please please provide a copy of a recent sanitation agency bill with component charges detailed.

Survey Number

CURRENT IMPLEMENTATION OF WATER CONSERVATION PRACTICES AND TECHNOLOGIES

II.12 Water conservation practices/technologies can involve actions such as those listed below. Please note the practices/technologies implemented in your plant, the date put in place, the capital expenditure, the annual operating & maintenance costs including energy, and the annual water savings and other savings/costs.

On the left are a group of 20 technologies and practices regarding water conservation. On the right are several spaces. Starting with the most recent, please describe what steps you have taken to conserve water. Identify which techs/practices you have used, and describe briefly their use in your plant. It will be helpful if you can identify by number, and if you have used a technology not listed here, please use no. 21. Please tell us: Date, Capital Expenditure, Annual O&M, Water and Other Savings or Costs. Please report other savings or costs, such as labor, chemicals or energy, and units (not dollar value). An example is provided below.

Technologies which recycle/reuse water:
1 Recycle cooling water
2 Recycle process water
3 Reuse sequentially in processes
4 Reuse between process and cooling

Process Modifications to reduce water use:
5 Improve control systems
6 Switch to intermittent use
7 Switch to dry processes
8 Change clean-up procedures
9 Change to/from continuous processing
10 Change water nozzles/reduce flow rate
11 Install automatic water shut off valves
12 Switch to smaller tanks/sinks
13 Replace water cooling with air cooling

Sanitation and Housekeeping Practices:
14 Lower flow settings
15 Retrofit with low flow showers/toilets
16 Education programs
17 Leak monitoring
18 Landscape/irrigation practices
19 Production shutdowns or relocations
20 Increase use of well water

Other (specify)
21
22

No.	Description	Date Put in Place (mo/yr)	Capital Expenditure ($)	Annual O & M Cost ($/yr)	Water Savings (amount & units)	Other Savings/Costs (amount & units)
18	Automated irrigation system tied to weather station	4/88	$20,000	$2000/yr	10,000 ccf/yr	Incur 2000 kWh Save 200 labor hours
5	Solenoid valve on rinsewater supply	1989	$100 per tank (6 tanks)	Nil	315 ccf/yr	Neglible

Survey Number

PLANNED IMPLEMENTATION OF WATER CONSERVATION PRACTICES/TECHNOLOGIES

In question II.12, we looked at the past. Here, we want to look at concrete plans for the future.

II.13 As in the previous question, please note the practices/technologies for which you HAVE OR EXPECT BUDGETARY APPROVAL, along with estimated costs and savings.

On the left is the same group of 20 technologies and practices regarding water conservation. On the right are several spaces. Starting with the first planned, please describe what steps are planned to conserve water. Identify which techs/practices you will use, and describe briefly their use in your plant. It will be helpful if you can identify by number, and if you will use a technology not listed here, please use no. 21. Please tell us: Date, Capital Expenditure, Annual O&M, Water and Other Savings/Costs.

Technologies which recycle/reuse water:
1 Recycle cooling water
2 Recycle process water
3 Reuse sequentially in processes
4 Reuse between process and cooling

Process Modifications to reduce water use:
5 Improve control systems
6 Switch to intermittent use
7 Switch to dry processes
8 Change clean-up procedures
9 Change to/from continuous processing
10 Change water nozzles/reduce flow rate
11 Install automatic water shut off valves
12 Switch to smaller tanks/sinks
13 Replace water cooling with air cooling

Sanitation and Housekeeping Practices:
14 Lower flow settings
15 Retrofit with low flow showers/toilets
16 Education programs
17 Leak monitoring
18 Landscape/irrigation practices
19 Production shutdowns or relocations
20 Increase use of well water

Other (specify)
21
22

No.	Description	Starting Date (mo/yr)	Capital Expenditure ($)	Annual O & M Cost ($/yr)	Water Savings (amount & units)	Other Savings/Costs (amount & units)
18	Automated irrigation system tied to weather station	4/88	$20,000	$2000/yr	10,000 ccf/yr	Incur 2000 kWh Save 200 labor hours
5	Solenoid valve on rinse wate supply	1989	$100 per tank (6 tanks)	Nil	315 ccf/yr	Neglible

Survey Number

SECTION III. INDUSTRY RESPONSE TO POSSIBLE PERIODIC FUTURE WATER SHORTAGES.

In 6 of the past 15 years, California has experienced water supply shortages. These have ranged between 10% and 40%. We have all come to realize that water is a scarce resource in California, and we must use it efficiently.

We want to understand the costs that you will face, if you must change your normal practices to adjust to reduced water supply reliability. In Section II you have described actions for more efficient water use that you HAVE TAKEN, and programs for which you have received BUDGETARY APPROVAL. In this section we ask some questions about how further shortages might affect your plant. These questions ask you to think about how you can further conserve, what alternative water supplies you might be able to develop, and, if your operations might still be affected.

If you are currently under emergency procedures to deal with the drought, do NOT consider the drought measures you have undertaken as part of normal operations.

Survey Number [ ]

CASE I.

Your water utility will experience recurrent shortages between April and November which would require you to cutback to using 15% less agency water than normal for the eight month period. There will be some advance notice within the first quarter of a supply curtailment.

III.1 CAN YOU increase the use of alternative supplies, such as:

Surface water	NO	[ ]	YES BY	[ ]	Units	[ ]
Ground water	NO	[ ]	YES BY	[ ]	Units	[ ]
Utility nonpotable/reclaimed water	NO	[ ]	YES BY	[ ]	Units	[ ]
Other: [ ]	NO	[ ]	YES BY	[ ]	Units	[ ]

If yes for any of the above, have you investigated the impacts associated with the use of lower quality water?

YES [ ] NO [ ]

If yes, what sort of impacts would you expect to encounter and how might you solve them? What is the cost of the maximum investment you would consider implementing? Please describe:

III.2 What TECHNOLOGY/PRACTICE might you adopt to increase water saved (refer to list in last question in Section II)? Please provide an estimate of the cost and amount of water saving that may be possible. Please rank your choices--BEST at the top.

Water Conservation Technology/Practice No. *	Description	Estimated Capital Expenditure ($)	Estimated Annual O&M Cost/Yr ($)	Estimated Total Additional Water That Can Be Saved Each Year	Units

* Use number from list on page 9.

Survey Number [ ]

CASE I: (cont'd) Your water utility will experience recurrent shortages between April and November which would require you to cutback to using 15% less agency water than normal for the eight month period. There will be some advance notice within the first quarter of a supply curtailment.

III.3 WILL YOU:

					1-5%	6-10	11-15	16-20	21-25
Decrease plant output?	NO [ ]	DON'T KNOW [ ]	YES BY		[ ]	[ ]	[ ]	[ ]	[ ]
					26-30	31-35	36-40	41-45	46-50
					[ ]	[ ]	[ ]	[ ]	[ ]

Make other changes in production? Describe:

III.4 WILL YOU:

					1-5%	6-10	11-15	16-20	21-25
Lower employment?	NO [ ]	DON'T KNOW [ ]	YES BY		[ ]	[ ]	[ ]	[ ]	[ ]
					26-30	31-35	36-40	41-45	46-50
					[ ]	[ ]	[ ]	[ ]	[ ]

Make other changes in employment? Describe:

III.5 WILL YOU:

					1-5%	6-10	11-15	16-20	21-25
Suffer income and cash flow reductions?	NO [ ]	DON'T KNOW [ ]	YES BY		[ ]	[ ]	[ ]	[ ]	[ ]
					26-30	31-35	36-40	41-45	46-50
					[ ]	[ ]	[ ]	[ ]	[ ]

How? Reduced revenues? Increased costs?

III.6 WILL YOU:

Change expansion plans? NO [ ] YES [ ]

How?

III.7 WILL YOU:

Make relocation plans? NO [ ] YES [ ]

How?

Survey Number [ ]

CASE I ended on page 12; CASE II starts here.

CASE II.

Your water utility will experience shortages which would require you to cutback to using 30% less agency water than normal. A cutback of this magnitude would last a year. You would have approximately three months warning.

III.8 CAN YOU increase the use of alternative supplies, such as:

Surface water	NO [ ]	YES BY [ ]	Units [ ]
Ground water	NO [ ]	YES BY [ ]	Units [ ]
Utility nonpotable/reclaimed water	NO [ ]	YES BY [ ]	Units [ ]
Other: [ ]	NO [ ]	YES BY [ ]	Units [ ]

If yes for any of the above, have you investigated the impacts associated with the use of lower quality water?

YES [ ] NO [ ]

If yes, what sort of impacts would you expect to encounter and how might you solve them? What is the cost of the maximum investment you would consider implementing? Please describe:

III.9 What TECHNOLOGY/PRACTICE might you adopt to increase water saved (refer to list in last question in Section II)? Please provide an estimate of the cost and amount of water saving that may be possible. Please rank your choices--BEST at the top.

Water Conservation Technology/Practice No. *	Description	Estimated Capital Expenditure ($)	Estimated Annual O&M Cost/Yr ($)	Estimated Total Additional Water That Can Be Saved Each Year	Units

* Use number from list on page 9.

Survey Number [ ]

CASE II: (cont'd) Your water utility will experience shortages which would require you to cutback to using 30% less than normal. A cutback of this magnitude would last a year. You would have approximately three months warning.

III.10 WILL YOU:

Decrease plant output? NO [ ] DON'T KNOW [ ] YES BY

1-5%	6-10	11-15	16-20	21-25
26-30	31-35	36-40	41-45	46-50

Make other changes in production? Describe:

III.11 WILL YOU:

Lower employment? NO [ ] DON'T KNOW [ ] YES BY

1-5%	6-10	11-15	16-20	21-25
26-30	31-35	36-40	41-45	46-50

Make other changes in employment? Describe:

III.12 WILL YOU:

Suffer income and cash flow reductions? NO [ ] DON'T KNOW [ ] YES BY

1-5%	6-10	11-15	16-20	21-25
26-30	31-35	36-40	41-45	46-50

How? Reduced revenues? Increased costs?

III.13 WILL YOU:

Change expansion plans? NO [ ] YES [ ]

How?

III.14 WILL YOU:

Make relocation plans? NO [ ] YES [ ]

How?

END OF SURVEY. THANK YOU.

APPENDIX B

POPULATION OF INDUSTRIAL PLANTS AND SAMPLE SIZE

APPENDIX B–1

Northern California:
Population of Industrial Plants & Sample Size by County & Industry Group, >50 Employees

		Santa Clara		Alameda		San Francisco		San Mateo		Contra Costa		Solano			
SIC Code	Description of Plant	Population	Sample Size	Population	Sample Size	Population	Sample Size	Population	Sample Size	Population	Sample Size	Population	Sample Size	Total Population	Total Sample Size
203	Preserved Fruits & Vegetables	13	8	5	5	2	2	4	4	0	0	0	0	24	19
205	Bakery Products	5	5	11	7	6	6	4	3	0	0	1	1	27	22
208	Beverages	5	5	10	4	4	4	1	1	0	0	3	3	23	17
265	Paperboard Containers and Boxes	8	6	13	11	0	0	1	1	3	2	1	1	26	21
281	Industrial Inorganic Chemicals	1	1	2	2	0	0	1	1	7	3	0	0	11	7
283	Drugs	8	7	8	2	1	1	3	2	0	0	0	0	20	12
285	Paints and Allied Products	0	0	4	3	0	0	1	1	0	0	0	0	5	4
291	Petroleum Refining	1	1	0	0	0	0	0	0	4	4	1	1	6	6
322	Glass and glassware, pressed or blown	0	0	4	3	0	0	0	0	1	1	0	0	5	4
327	Concrete, gypsum, plaster products	2	1	7	5	0	0	3	3	3	3	1	1	16	13
331	Blast furnace and basic steel products	0	0	5	4	0	0	0	0	2	2	0	0	7	6
341	Metal cans and shipping containers	0	0	6	4	0	0	0	0	2	2	1	1	9	7
344	Fabricated structural metal products	12	8	16	8	2	1	2	2	4	2	2	2	38	23
357	Office and Computing Machines	125	34	33	13	3	1	4	2	5	2	0	0	170	52
366	Communication Equipment	20	17	7	6	1	1	4	4	1	1	0	0	33	29
367	Electronic components & accessories	194	54	24	9	1	0	10	4	1	0	0	0	230	67
371	Motor Vehicles and Equipment	3	3	5	3	0	0	0	0	1	1	1	1	10	8
	Total	397	150	160	89	20	16	38	28	34	23	11	11	660	317

Source of Information: U.S. Bureau of the Census, County Business Patterns, 1986
And California Department of Water Resources, "Water Use by Manufacturing Industries"
In California, 1979, Bulletin 124–3, May 1982
And Dun's Marketing Service

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APPENDIX B-2

Southern California:
Population of Industrial Plants & Sample Size by County & Industry Group, >100 Employees

SIC code	Description	Los Angeles		Orange		Riverside		San Bernardino		San Diego		Ventura		Total Population	Total Sample
		Population	Sample Size	Population	Sample Size	Population	Sample Size	Population	Sample Size	Population	Sample Size	Population	Sample Size		
201	Meat Products	13	13	1	1	0	0	0	0	1	1	0	0	15	15
203	Preserved Fruits and Vegetables	15	15	10	10	1	1	0	0	2	2	5	4	33	32
208	Beverages	11	11	4	3	1	1	3	3	3	3	2	1	24	22
209	Misc. Food and Kindred Products	33	24	8	6	0	0	3	1	2	1	0	0	46	32
284	Soap, Cleaners and Toilet goods	19	18	0	0	1	1	2	2	0	0	1	1	23	22
291	Petroleum Refining	20	17	0	0	0	0	0	0	0	0	0	0	20	17
357	Office and Computing machines	36	15	31	14	0	0	0	0	15	6	7	3	89	38
366	Communication equipment	36	19	16	7	3	1	2	1	16	8	10	5	83	41
367	Electronic components & Accessori	72	18	41	10	7	2	1	0	35	10	15	4	171	44
372	Aircraft and Parts	59	24	24	12	3	1	3	1	10	4	7	3	106	45
376	Guided missles, Space vehicles, pa	8	8	2	2	0	0	1	1	6	4	0	0	17	15
	Total	322	182	137	65	16	7	15	9	90	39	47	21	627	323

Source of Information: U.S. Bureau of the Census, County Business Patterns, 1986
And California Department of Water Resources, "Water Use Manufacturing Industries"
In California, 1979, Bulletin 124-3, May 1982
And Dun's Marketing Service

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APPENDIX C

VALUE OF SHIPMENTS

APPENDIX C
VALUE OF SHIPMENTS 1990
(Billion $)

SIC CODE	Description of Plant	State	12 County Total	North Total	South Total	North Counties: Alameda	Contra Costa	Santa Clara	San Francisco	San Mateo	Solano	South Counties: Los Angeles	Orange	Riverside	San Bernardino	San Diego	Ventura
	Industry Total	287.0	245.5	79.0	166.5	15.3	10.5	36.6	9.7	4.4	2.5	106.2	29.8	3.9	8.1	14.0	4.5
201	Meat Products	3.4	1.93	0.52	1.41	0.20	0.00	0.10	0.07	0.05	0.10	1.22	0.09	0.00	0.07	0.03	0.00
203	Preserved Fruits & Vegetables	10.0	4.51	1.59	2.92	0.25	0.04	0.65	0.39	0.13	0.13	1.27	0.73	0.20	0.29	0.04	0.39
205	Bakery Products	2.4	2.39	0.97	1.42	0.50	0.05	0.15	0.10	0.17	0.00	1.00	0.25	0.00	0.03	0.10	0.04
208	Beverages	10.0	5.99	1.59	4.40	0.39	0.04	0.52	0.05	0.07	0.52	3.46	0.47	0.01	0.10	0.36	0.00
209	Misc. Food & Kindred Prod.	3.8	2.56	0.91	1.65	0.52	0.07	0.13	0.11	0.08	0.00	1.12	0.36	0.01	0.12	0.04	0.00
265	Paperboard Containers & Boxes	3.3	3.13	0.72	2.41	0.33	0.11	0.21	0.00	0.07	0.00	1.37	0.60	0.07	0.20	0.06	0.11
281	Industrial Inorganic Chemicals	1.5	1.47	0.48	0.99	0.08	0.37	0.03	0.00	0.00	0.00	0.39	0.32	0.00	0.17	0.11	0.00
283	Drugs	5.5	4.41	2.16	2.25	0.38	0.13	1.43	0.00	0.22	0.00	0.94	1.06	0.04	0.00	0.21	0.00
284	Soap, Cleaners & Toilet Goods	2.9	2.69	0.29	2.40	0.29	0.00	0.00	0.00	0.00	0.00	1.77	0.12	0.06	0.02	0.15	0.28
285	Paints & Allied Prod.	2.1	1.59	0.46	1.13	0.21	0.00	0.00	0.00	0.25	0.00	0.87	0.21	0.01	0.04	0.00	0.00
291	Petroleum Refining	18.6	16.46	6.32	10.14	0.00	6.32	0.00	0.00	0.00	0.00	10.14	0.00	0.00	0.00	0.00	0.00
327	Concret, Gypsum, Plaster Prod.	4.4	2.40	0.33	2.07	0.19	0.09	0.05	0.00	0.00	0.00	0.88	0.28	0.18	0.37	0.28	0.08
344	Fabricated Metal Prod.	3.8	3.25	0.86	2.39	0.22	0.07	0.20	0.10	0.18	0.09	1.45	0.40	0.12	0.23	0.17	0.02
357	Computer & Office Equip.	21.0	19.63	14.10	5.53	3.62	0.06	10.32	0.04	0.06	0.00	2.17	2.06	0.00	0.04	0.92	0.34
366	Communication Equipment	4.8	4.63	2.07	2.56	0.10	0.05	1.76	0.01	0.15	0.00	1.05	0.48	0.04	0.04	0.85	0.10
367	Electronic Comp. & Acc.	16.2	15.01	9.12	5.89	0.69	0.04	8.16	0.02	0.21	0.00	2.31	1.85	0.21	1.14	0.14	0.24
371	Motor Vehicles & Equip.	6.2	4.94	1.53	3.41	1.47	0.01	0.00	0.05	0.00	0.00	2.58	0.14	0.25	0.37	0.05	0.02
372	Aircraft & Parts	16.0	15.98	0.27	15.71	0.11	0.00	0.11	0.05	0.00	0.00	12.99	0.27	0.39	0.50	1.19	0.37
376	Guided Missles, Space Vehicles, Parts	15.4	14.01	3.60	10.41	0.12	0.00	3.48	0.00	0.00	0.00	6.96	1.70	0.00	0.34	1.41	0.00
	County Total	151.2	127.0	47.9	79.1	9.7	7.5	27.3	1.0	1.6	0.8	53.9	11.4	1.6	4.1	6.1	2.0
	% of Industry Total	52.7	51.7	60.6	47.5	63.4	71.0	74.6	10.2	37.3	33.6	50.8	38.2	40.9	50.2	43.6	44.2

Source: Census of Manufacturers 1987 forecast to 1990 by CCSCE, April 1991

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APPENDIX D

EMPLOYMENT 1989

APPENDIX D
Employment 1989
(Thousands)

SIC CODE	Description of Plant	State	12 County Total	North Total	South Total	North Counties: Alameda	Contra Costa	Santa Clara	San Francisco	San Mateo	Solano	South Counties: Los Angeles	Orange	Riverside	San Bernardino	San Diego	Ventura
	Industry Total	2162.4	1874.1	468.8	1405.3	83.2	31.5	269.8	41.8	35.1	7.4	891.7	259.1	31.1	57.3	135.0	31.1
201	Meat Products	20.4	9.2	2.3	6.9	1.0	0.0	0.3	0.6	0.2	0.2	6.0	0.3	0.0	0.3	0.2	0.0
203	Preserved Fruits & Vegetables	54.3	22.0	8.9	13.1	0.6	0.3	4.9	1.6	0.4	1.1	5.0	4.5	1.1	1.1	0.3	1.1
205	Bakery Products	20.5	17.5	5.5	12.0	2.7	0.1	0.8	1.1	0.8	0.0	8.9	1.5	0.1	0.2	1.2	0.1
208	Beverages	28.0	12.4	3.4	9.1	1.2	0.4	0.7	0.2	0.2	0.7	6.1	1.3	0.1	0.5	0.9	0.2
209	Misc. Food & Kindred Prod.	22.8	18.6	4.3	14.3	1.9	0.3	0.7	1.0	0.3	0.0	11.6	1.5	0.1	0.2	0.6	0.4
265	Paperboard Containers & Boxes	17.6	14.7	3.7	11.0	1.9	0.2	1.1	0.0	0.4	0.0	7.1	2.3	0.4	0.7	0.3	0.2
281	Industrial Inorganic Chemicals	8.0	7.2	2.6	4.6	0.4	1.3	0.4	0.3	0.2	0.0	2.2	0.8	0.0	1.3	0.3	0.0
283	Drugs	24.0	23.2	9.6	13.6	1.5	0.4	5.5	0.3	1.9	0.0	7.2	5.3	0.0	0.0	1.2	0.0
284	Soap, Cleansers & Toilet Goods	15.3	13.9	2.6	11.3	1.6	0.1	0.6	0.1	0.2	0.1	9.8	0.5	0.2	0.2	0.2	0.3
285	Paints & Allied Prod.	7.3	7.0	1.7	5.3	0.7	0.0	0.1	0.3	0.7	0.0	4.0	0.8	0.1	0.3	0.1	0.0
291	Petroleum Refining	12.4	9.9	4.6	5.3	0.1	4.2	0.0	0.0	0.0	0.2	4.5	0.8	0.0	0.0	0.0	0.0
327	Concrete, Gypsum, Plaster Prod.	21.5	16.1	3.4	12.7	1.4	0.4	1.0	0.1	0.3	0.2	5.0	1.5	1.3	2.7	1.8	0.5
344	Fabricated Metal Prod.	41.3	33.4	6.7	26.7	2.6	0.4	2.0	0.6	0.6	0.4	15.7	3.7	1.1	2.0	3.8	0.4
357	Computer & Office Equip.	99.3	91.7	60.6	31.1	2.8	0.3	56.7	0.2	0.7	0.0	12.4	12.5	0.0	0.1	5.0	1.1
366	Communication Equipment	150.2	143.5	27.5	116.0	0.8	0.3	25.1	0.0	1.3	0.0	72.6	28.5	0.2	0.4	11.3	3.0
367	Electronic Comp. & Acc.	148.1	137.3	78.4	58.9	5.8	0.6	68.4	0.4	3.1	0.0	26.3	19.3	0.8	0.6	9.4	2.5
371	Motor Vehicles & Equip.	33.1	28.2	4.9	23.3	3.8	0.5	0.2	0.0	0.1	0.3	17.3	2.5	1.4	1.9	0.1	0.2
372	Aircraft & Parts	169.9	165.5	1.8	163.8	1.5	0.0	0.1	0.0	0.2	0.0	129.4	6.4	3.4	3.9	15.5	5.2
376	Guided Missles, Space Vehicles, Parts	80.5	74.0	26.7	47.4	0.0	0.0	26.5	0.0	0.1	0.0	16.4	14.9	0.2	3.4	12.5	0.0
	County Total	974.3	845.5	259.1	586.5	32.3	9.8	195.2	7.0	11.5	3.3	367.5	108.9	10.6	19.7	64.5	15.3
	% of Industry Total	45.1	45.1	55.3	41.7	38.9	31.0	72.3	16.8	32.8	44.1	41.2	42.0	34.1	34.4	47.8	49.1

Source: Employment Development Division 1989

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APPENDIX E

CONFIDENCE INTERVAL CONSTRUCTION FOR INDUSTRIAL WATER USE ESTIMATES

APPENDIX E

Confidence Interval Construction for Industrial Water Use Estimates

This appendix shows how the industrial water use estimates discussed in chapter 4.0 were calculated. The confidence intervals which provide a likely bound on the "true" water use values are also constructed within this appendix.

The industrial water use estimates calculated in this report are based on a weighted average of water use per production employee per operating day, or gallons per employee day (GED). These GED estimates were weighted by the number of production employees as a proxy for plant size. As shown by equation (1), the sample weighted mean GED is equal to the sum of water use divided by the sum of production employee days for all the plants sampled from a given SIC group. In equation (1) below, w is the water use, e represents production employees, d represents days of operation for sampled plant j in SIC group i.

$$GED_i = \frac{\sum_{j=1}^{n} w_{ij}}{\sum_{j=1}^{n} e_{ij} * d_{ij}} \qquad (1)$$

The calculation of the GED sample variance for each industry (i) is specified by equation (2)[1]. In words, the sample variance of the weighted mean is a function of the sample variance of the unweighted mean (far right hand side of equation 2) and a correction factor for the weights.

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[1] Yates, Frank (1981). Sampling Methods for Censuses & Surveys, 1981. London, England: Charles Griffen & Company Ltd.

$$VAR(GED_i) = \frac{(\sum_{j=1}^{n} e_{ij})^2}{\sum_{j=1}^{n} (e_{ij})^2} * VAR(\frac{w_{ij}}{e_{ij} * d_{ij}}) \qquad (2)$$

To estimate the total water use for a particular industry, the sample mean GED is multiplied by the total number of employees. This relationship is shown by Equation (3), where Wi is the total water use and Ei is the total number of production employees for SIC group i.

$$W_i = E_i * GED_i \qquad (3)$$

The number of production employees for a given industry are provided annually by the Employment Development Division. These are considered to be fixed population values. This means that the employment number is not a statistical variable, but a constant which scales the estimated GED to the industry total.

To calculate the confidence intervals for the water use estimates obtained using equation (3) an estimate of the sample variance is necessary. The weighted sample variance for GED's, VAR(GEDi), was calculated using the Univariate procedure of Statistical Analysis System (SAS) computer software package. These were then used to calculate the sample variance of the total water use estimates as specified by the equation(4):

$$Var(W_i) = (E_i)^2 * Var(GED_i) \qquad (4)$$

Assuming that the underlying GED's are normally distributed for each SIC group, confidence intervals can be constructed which represent the likely range in which the "true" unknown total water use values will fall. The confidence intervals are constructed around the water use estimates (Wi) from equation (3) by using the sample variance of the GED's and the t-statistic which accounts for the desired confidence level. For the purpose of this report a

90% confidence level was chosen to calculate the two-tailed t-statistic. The exact specification of the confidence interval calculation is shown by equation (5).

$$W_i + t_{.05} * \frac{1}{\sqrt{\sum_{j=1}^{n} e_{ij}}} * \sqrt{VAR(W_i)} \geq \overline{W_i} \geq W_i - t_{.05} * \frac{1}{\sqrt{\sum_{j=1}^{n} e_{ij}}} * \sqrt{VAR(W_i)} \qquad (5)$$

Where $\overline{W_i}$ is the unknown true population water use value.

Using equation 5, and converting from daily to annual flows, the resultant water use estimates, standard errors and upper and lower bounds, at the 90% confidence levels, are shown on Table E-1. The standard errors generally increase going back from 1989 to 1985 because the sample labor data declines going back in time. This reduction in labor coverage reduces the certainty of the GED's, and, subsequently, the certainty of the industrial water use estimates.

TABLE E–1
Statistical Properties of the Estimates of Industry Water Usage

SIC CODE	Description of Plant	1989				1988				1987			
		Mean	Std Err	95% Confidence Interval Bounds lower	upper	Mean	Std Err	95% Confidence Interval Bounds lower	upper	Mean	Std Err	95% Confidence Interval Bounds lower	upper
201	Meat Products	6.69	1.97	6.57	6.80	6.88	2.39	6.74	7.02	6.21	1.99	6.09	6.33
203	Preserved Fruits & Vegetables	21.57	8.63	21.19	21.95	27.12	10.53	26.62	27.62	36.62	15.37	35.88	37.35
205	Bakery Products	1.21	0.41	1.19	1.24	1.32	0.34	1.29	1.34	1.38	0.38	1.35	1.40
208	Beverages	39.10	9.97	38.53	39.66	38.91	9.74	38.35	39.47	41.24	10.96	40.57	41.90
209	Misc. Food & Kindred Prod.	13.67	22.93	12.75	14.59	13.60	8.16	13.26	13.95	12.56	9.04	12.16	12.96
265	Paperboard Containers & Boxes	12.36	8.00	11.86	12.86	13.54	8.70	13.00	14.09	16.29	10.33	15.62	16.95
281	Industrial Inorganic Chemicals	27.21	12.61	26.36	28.06	29.29	17.80	28.03	30.55	32.35	14.70	31.25	33.45
283	Drugs	6.09	29.94	4.30	7.88	4.76	29.77	2.95	6.56	3.94	28.22	2.23	5.65
284	Soap, Cleansers, & Toilet Goods	3.31	2.89	2.98	3.63	2.83	2.21	2.58	3.09	2.93	2.03	2.68	3.17
285	Paints & Allied Prod.	1.14	0.14	1.12	1.16	1.21	0.00	1.21	1.21	1.93	0.58	1.85	2.01
291	Petroleum Refining	126.72	30.94	125.72	127.72	136.65	33.96	135.45	137.84	125.09	32.50	123.94	126.23
327	Concrete, Gypsum, Plaster Prod.	19.14	15.60	17.13	21.14	18.53	10.15	17.21	19.84	16.41	12.18	14.83	17.98
344	Fabricated Metal Prod.	8.27	7.46	7.60	8.93	8.97	7.98	8.22	9.73	9.47	8.13	8.68	10.25
357	Computer & Office Equip.	6.29	2.01	6.21	6.37	5.42	1.90	5.34	5.51	7.41	2.67	7.28	7.55
366	Communication Equipment	6.16	1.17	6.10	6.22	6.34	1.15	6.29	6.40	8.08	1.87	7.99	8.17
367	Electronic Comp. & Acc.	8.66	14.77	8.46	8.86	8.30	17.39	8.06	8.54	8.03	16.60	7.80	8.26
371	Motor Vehicles & Equip.	2.85	1.52	2.81	2.88	3.58	2.26	3.53	3.63	4.16	3.23	4.08	4.23
372	Aircraft & Parts	13.61	9.61	13.43	13.78	10.39	4.61	10.32	10.46	12.21	5.94	12.11	12.32
376	Guided Missles, Space Vehicles, Parts	3.71	1.64	3.69	3.74	3.47	1.55	3.45	3.49	2.97	1.72	2.94	2.99

TABLE E–1
Statistical Properties of the Estimates of Industry Water Usage

SIC CODE	Description of Plant	1986 Mean	1986 Std Err	1986 95% Confidence Interval Bounds lower	1986 95% Confidence Interval Bounds upper	1985 Mean	1985 Std Err	1985 95% Confidence Interval Bounds lower	1985 95% Confidence Interval Bounds upper
201	Meat Products	6.06	1.47	5.97	6.14	6.75	1.65	6.65	6.84
203	Preserved Fruits & Vegetables	31.21	14.26	30.52	31.89	35.30	18.60	34.40	36.20
205	Bakery Products	1.20	0.45	1.17	1.23	1.25	0.53	1.22	1.29
208	Beverages	41.15	12.08	40.40	41.89	42.63	12.08	41.88	43.37
209	Misc. Food & Kindred Prod.	15.79	11.01	15.20	16.37	15.77	10.46	15.18	16.35
265	Paperboard Containers & Boxes	14.93	8.40	14.38	15.47	14.17	8.50	13.63	14.70
281	Industrial Inorganic Chemicals	34.11	15.81	32.92	35.30	32.45	13.68	31.44	33.47
283	Drugs	3.25	27.15	1.64	4.85	3.62	29.52	1.89	5.34
284	Soap, Cleansers, & Toilet Goods	2.71	1.81	2.49	2.94	2.43	1.67	2.21	2.64
285	Paints & Allied Prod.	2.09	0.36	2.04	2.14	1.89	0.61	1.81	1.96
291	Petroleum Refining	120.29	29.96	119.25	121.32	128.28	32.85	127.15	129.40
327	Concrete, Gypsum, Plaster Prod.	14.42	6.76	13.54	15.30	13.38	24.45	9.49	17.26
344	Fabricated Metal Prod.	10.04	8.72	9.18	10.90	11.73	9.65	10.73	12.73
357	Computer & Office Equip.	6.02	2.95	5.84	6.19	6.33	3.26	6.12	6.53
366	Communication Equipment	8.40	2.06	8.30	8.50	8.67	1.91	8.57	8.76
367	Electronic Comp. & Acc.	8.42	25.90	8.06	8.78	8.59	28.76	8.19	9.00
371	Motor Vehicles & Equip.	4.19	3.20	4.12	4.26	3.30	7.55	3.14	3.47
372	Aircraft & Parts	11.58	6.93	11.45	11.70	12.26	9.53	12.08	12.43
376	Guided Missles, Space Vehicles, Parts	2.84	1.65	2.82	2.86	2.33	1.34	2.31	2.34

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