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Colloquium 1 of a Series

Water Science and Technology Board
Commission on Engineering and Technical Systems
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PREFACE

The Water Science and Technology Board Colloquia focus attention and debate on emerging issues in water science, technology, and policy. These colloquia provide forums to encourage discussion and debate of certain issues which the board believes should be addressed by the scientific and engineering communities. Clearly, by initiating this discussion, the board seeks to provoke individuals to consider such issues and to stimulate research on these topics.

The first colloquium addressed drought management and its impact on public water systems. The inquiry began with attempts to define drought, and ranged from the need to know more of cause and effect and improved forecasting, to the legal procedures required to implement various management alternatives. Individuals noted for their expertise in areas of drought management were invited by the board to present their views and insights on this subject at a meeting of 50 participants in Boulder, Colorado, on September 5, 1985.

It is apparent that drought preparedness has suffered from neglect. Historically, research efforts have focused on problems associated with water excess rather than water deficiency. Droughts may be infrequent, or of short duration, but they can have serious and long-lasting effects on a community. In the absence of adequate preparation, a drought may cause serious disruption for water users. Analyses of records of previous droughts implies that this information is not effectively communicated or understood by successive generations of water professionals or the public. The recent drought conditions in the northeastern United

States have focused attention on the need for water conservation and planning for future water needs. There also is a great need to educate the public about the advantages and disadvantages of proposed alternative courses of action.

The colloquium keynote address delivered by Gilbert White, and presentations made by Edward Clyde, attorney; John Dracup, University of California, Los Angeles; Ben Dziegielewski, Southern Illinois University at Carbondale; and Duane Georgeson, Los Angeles Department of Water and Power provide much of the substance of this report.

It was a pleasure to have had the opportunity to chair this colloquium and to synthesize the discussion contained in the report. The Water Science and Technology Board acknowledges the contributions of the participants in the colloquium and is especially grateful to those who made formal presentations. Finally, special recognition is due to Walter R. Lynn, the board's first chairman, whose idea it was to initiate this series of colloquia in the interest of water science, technology, and policy.

Robert L. Smith, Chairman
Colloquium on Drought Management and its Impact on Public Water Systems
April 1986

OVERVIEW AND CONCLUSIONS

Humankind is in a continuous struggle with a vast range of natural hazards. Many of these hazards (e.g., floods, earthquakes, tornadoes, and hurricanes) are encountered as short-duration, high-intensity, and relatively localized events. In this country, most research and formal emergency planning procedures are directed toward damage mitigation and rehabilitation needs associated with such events. Drought is different in that it seldom has a spectacular or sudden onslaught. Damage inflicted by drought usually occurs rather subtly over a span of months to years instead of minutes to days. Truly serious drought is usually a regionalized--as contrasted to localized--trauma, with the attendant need to broaden preplanning and mitigation efforts.

A precise definition of drought is difficult, because the meaningful threshold of significant moisture deficiency is a function of the water use being impacted. For the purpose of the colloquium, drought was considered to represent a period of time when streamflows, reservoir storage, and shallow ground-water levels are abnormally low as a result of climatically-induced moisture deficiency. Drought severity as it relates to public water systems is necessarily a function of human actions and/or inactions as well as the magnitude and duration of the individual hydrologic event.

There is need to direct both research and pragmatic mitigation efforts toward the neglected problems of water management during drought episodes. This colloquium was limited to the subject of drought as it affects the management of public water systems. The observations and recommendations summarized herein reflect that constraint. No attempt has been made to capture individual views. Instead, emphasis has been placed on those points for which a general consensus was identified in the floor discussion.

Research Concerns

There are numerous areas of inquiry where research can be expected to be productive. Categories of primary interest include cause and effect aspects of the drought mechanism, the probability distribution of drought events, measurement of the consequences of system failure, and the legal aspects of drought management.

Our lack of ability to provide a firm rationale and explanation of the drought mechanism impedes efforts to develop reliable alert systems. The development of such systems would represent a crucial step toward implementation of effective and efficient drought contingency plans. Our present capability to predict drought appears to be confined to empirical equations relating such factors as sunspot numbers to streamflow and various physical anomalies, such as sea surface temperature and the positioning of land-based high-pressure centers, and to projected precipitation patterns. Though such correlations have been well documented, why or when these relations trigger the occurrence of significant drought is not understood.

Analysis of drought frequency relationships has lagged appreciably behind the companion efforts related to flood discharge. There are several reasons for this, not the least of which relates to difficulties associated with the definition of drought. Annual peak discharges are a meaningful measure of flood size and are easily identified for purposes of flood frequency analysis. Neither minimum instantaneous flows nor lowest daily ground-water levels provide a meaningful measure of the magnitude of drought. Both the duration and the magnitude of flow deficiency and/or moisture availability must be known in order to characterize a drought. Clearly, design of water supply system components based on drought of record begs the issue. Tree ring analyses have suggested the possible occurrence of historic droughts more severe than those readily documented by available flow records in this country. Nonetheless, we need to develop our knowledge of drought occurrence, for such knowledge is a prerequisite for effective analysis of drought management alternatives.

Equally key to the analysis of drought management alternatives are valid assessments of the costs associated with different types and durations of system failure. Several difficulties are encountered in attempting to develop generalized and transferable relationships. First, certain costs can be very site specific. Second, acquisition of firm data is difficult until a drought is encountered. Third, the average time span between significant droughts for a given system may be so long that the local economic and social patterns, and thereby the potential consequences of different types of system failure, may have changed appreciably. These obstacles should not be allowed to deter continued inquiry. Though they may work against the quantification of well-defined cost benchmarks, they do not lessen the need to develop methodological concepts to allow for an orderly process of analysis of alternative management strategies.

Proper institutional arrangements can facilitate effective management of water supplies during drought periods. Conversely, inadequate or unwieldy institutional frameworks can effectively destroy the most industrious of management efforts. Since the management of public water systems is primarily a local responsibility, research is needed on the powers local authorities require to implement effective drought management programs. In addition, legislation at other than the local level can either expedite or constrain effective management choices. Little research has been directed at the effectiveness or influence exerted by different state laws and/or subregional, state, and interstate organizational structures during droughts.

Management Concerns

A wide range of decision issues was touched upon during the formal presentations and subsequent floor discussion. They generally can be categorized as follows: appraisal of risk, choosing between relying on supplemental supplies or relying on the management of demand, social aspects of demand management, water transfers from other uses, and other regional solutions.

There was consensus that a uniform level of hydrologic risk should not be advocated as a design or decision parameter for a variety of reasons. The use of this approach in floodplain management has discouraged rational evaluation of floodplain productivity. In addition, the risk of system failure could be as sensitive to the quality of system maintenance as to variations in hydrologic events. Consideration of scale also influences this decision. That is, a small system can, from solely a logistic consideration, accept a higher risk of having to resort to emergency supplies than can a large system. Finally, site-specific considerations must be taken into account. A system with little access to alternative or emergency supplies must seek a more risk-free environment than one not so constrained. Despite lack of unanimity as to what constitutes an acceptable risk, there was general support for the need to integrate risk analysis into system planning as opposed to basing evaluations solely on the drought of record.

Without risk appraisal, quantitative comparison of trade-offs between investments in supplemental emergency sources and demand management techniques could be meaningless. Application of demand management techniques should increase as the relative risk of system failure, especially the hydrologic portions thereof, decreases. This concept is supported by the recent trend in legal liability decisions that suggest the designer or planner could well be required to keep the risk of hydrologic system failure low. There was general agreement that system planning for drought management should capitalize on the decades of evolution in trade-off analysis that has taken place in the overall field of water resources planning. A primary prerequisite is development of an orderly and systematic matrix for analysis, and a current constraint is the lack of reliable data for quantifying the consequences of system failure.

Several major considerations surfaced in the comments related to implementation of demand management techniques. First, there is little evidence these techniques will produce a continued reduction in water demand in postemergency conditions. The public obviously feels that such reductions do, indeed, adversely affect the quality of life and finds them unacceptable in the long term. Second, public cooperation in implementing demand management techniques has been shown to be excellent provided there is clear evidence of need. Third, the successful implementation of demand management techniques requires an adequate legal foundation. These factors must be understood by managers developing drought contingency plans.

Appreciable attention was directed toward the possible diversion of water from other uses, primarily agriculture, as a means of mitigating public system drought issues. The legal concept is well established via the route of condemnation, but implementation can lead to much acrimony and is often costly and time consuming. Two alternative approaches, responsive to different physical situations, were examined and found attractive.

In the case of large, rapidly growing urbanized regions, the projected transfers may be so large as to have an impact on the associated agribusiness industry. In this case, urban investment in conservation facilities for agriculture in return for the water saved has been found attractive to all three parties (i.e., the public system, the irrigator, and the related agribusiness interests). For many systems, the problem is quite different: existing sources are adequate for most years. The agricultural transfer is not needed on a permanent basis. In such cases, negotiated lease transfers wherein the irrigator is provided an initial signing bonus and then compensated for each subsequent year his water is used have proven successful.

Legal Concerns

Several legal concerns surfaced during the presentations, some of which have already been noted. Matters of primary concern to public systems confronted with drought management issues relate to questions of authority, water transfer, and constraints imposed by state or federal actions.

Several participants in the colloquium emphasized the need for public systems to have their legal house in order before the onset of drought. The point was made that, in some instances, this might require a regional approach. Of main concern is the system's ability to initiate demand management techniques involving voluntary or mandatory conservation, revised rate schedules, or imposition of penalties. For publicly operated systems, this can be handled by the pre-enactment of a drought contingency ordinance that spells out the authority granted and the actions permitted. Privately operated systems, in the absence of supporting ordinances from local government, can establish the necessary authority via contractual arrangements with individual customers.

The need for system managers to be aware of the status of their water rights, and the related state administrative and judicial procedures, was stressed. In this light, system managers should explore ways of increasing system yield within the confines of existing rights and seek administrative or legislative relief if unnecessary and ill-advised constraints are encountered. For example, conjunctive use of ground and surface waters is not widely practiced, although the practical advantage of conjunctive management is quite clear. Often its successful implementation would require a higher maximum rate of withdrawal from the ground water during the drought, although the overall demand on the ground water through the combined wet and dry cycle would be reduced. In such cases, existing administrative and legislative policies may prohibit implementation of a conjunctive use pattern. Public system managers need to move to lessen such constraints.

There is every reason to believe that an increasing number of water supply problems will be resolved via water transfers. Again, the point was made that these solutions may need to be appraised in a regional context. This phrase "water transfer" may relate to change of use or to change of location or both. Public system managers need to know about the legal controls relating to such transfers. Where the need for transfer is of limited duration, the use of leases as described above deserves exploration. The competition for water has prompted the enactment of various state statutes concerning both intrastate and interstate transfer of waters. Judicial interpretation of these statutes is undergoing rather rapid evolution. Similarly, recent decisions citing the public trust doctrine may have an impact on water allocation issues. These several matters deserve continued examination.

Conclusions

1. There is substantial need for continued research on drought and its impact on the management of public water systems. Key research topics include (a) cause of drought, (b) development of effective drought alert

mechanisms, (c) probability analysis of drought, (d) quantification of the consequences of system failure during drought, and (e) identification of the institutional environment necessary for successful implementation of drought management plans. Federal agencies, universities, the water supply industry, and private foundations should all support research in these areas.

2. Sizing of the physical facilities of a system should not be based solely on full-service requirements during the drought of record, nor should such facilities be sized by the arbitrary specification of hydrologic risk. The reasons are many and range from the inadequacy of existing records to individual system characteristics. Instead, the measure of facility adequacy should be established by orderly comparison of incremental facility requirements versus the use of demand management techniques over the range of probability conditions. As the risk of system inadequacy decreases, the relative advantage of demand management techniques can be expected to increase.

3. The key to adequate drought management of public water systems lies in predrought preparation. This consists of a variety of actions best typified as drought contingency planning, including (a) a good system maintenance program, (b) periodic assessment of system capacity and the relative balance among all system components (source, transmission, treatment, and distribution), (c) identification and appraisal of the reliability of emergency or supplemental sources of supply, (d) analysis of the probable effectiveness of demand management techniques and determination of criteria for implementation, (e) development of the framework of public information programs needed to implement drought management measures, and (f) establishment of the legal foundation necessary to implement emergency source plans and projected demand management techniques.

BACKGROUND PAPERS

1

DIMENSIONS OF DROUGHT MANAGEMENT FOR PUBLIC WATER SUPPLIES (Colloquium Keynote Address)

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Among the several hazards to which public water supply management is subject, drought imposes a few distinctive problems as well as shares in others common to most natural resources use. It comes on very slowly, its losses are particularly amenable to short-term mitigation by individual consumers, and it has a unique spatial pattern of appropriate remedial or preventive measures.

The facets of the problems involved are so numerous that individual ones must be touched on only briefly if all are to be identified in a balanced and comprehensive fashion. Accordingly, this chapter deals with numerous dimensions of public water supply and drought without exploring any one in depth. Out of the rapid, broad review may emerge a perspective on the detailed chapters to follow.

DIMENSIONS

In beginning a more detailed examination of drought causes and occurrences, management options, the notion of acceptable risk, and their institutional implications, it may be helpful to place that management in perspectives of time, place, and quality. Drought is only one of the shocks that may disrupt the range of public services provided by a city. While thus far defying precise forecasting, it has a long period of onset with special problems of uncertainty. Its possible severity differs greatly from one area to another according to climate, ground-water availability, and competing water uses. A good deal is known about the modes of economic analysis requisite to choice of efficient options. Much has been learned in recent years about the behavioral and legal constraints on mitigating action. Nevertheless, it appears that effective means for cities to cope with drought are handicapped by a few deficiencies in data and in analytical methods, and that public perspectives and legal constraints on drought management are changing and may be expected to continue to change. This report is intended to illuminate the gaps in sight.

The term "drought" is used in this context to mean a period of time during which, as a result of abnormally low precipitation, the supply of surface water and water in shallow aquifers is reduced below that safe yield expected in most years, the recurrence interval being set by hydrologic analysis or the vulnerability of water supply systems. It does not have the precision of agricultural definitions of drought, such as the Palmer index, in which deficiencies of precipitation are determined by relations to evapotranspiration, soil moisture, and crop needs.

WATER AMONG OTHER PUBLIC SERVICES

The provision of water is only one of the services most municipalities regard as essential, whether supplied by public or private agencies. It competes with sewerage, electricity, gas, streets, trash collection, fire fighting, police, and welfare aims in seeking funds and managerial attention. This is important to remember in explaining why water improvements and planning in some cities may seem to be neglected in favor of more dramatic or complicated programs to control crime or speed up traffic or dispose of waste.

DROUGHT AS ONE HAZARD AMONG MANY

Drought is only one of the wide range of natural and technological hazards to which a public water supply is vulnerable. On the natural side, many urban systems are subject to severe shocks to supply, treatment, or distribution as a result of floods, hurricanes, and earthquakes (Burton et al., 1978). (Landslides, tornadoes, volcanic eruptions, and cold spells are on the whole less threatening to entire systems.) On the technological side, the dangers of ground-water contamination, explosions, chemical spills, large fires, and equipment breakdown are well recognized. Possibly a more severe and widespread hazard is that of short-sighted, incompetent management that fosters, often complacently in the face of supplies that seem to be satisfactory and cheap, deferred maintenance and shoddy planning.

Comparing these several hazards in Table 1-1, it is clear that drought, while of low frequency, has a much longer onset time and duration than the others, thus providing greater opportunity for preparations to cope with its effects and to carry out such measures on a sustained basis.

Taking into account the physical characteristics of the drought hazard and the economic and political consequences of sudden disruptions of water systems, it can be seen that managers faced with allocations of meager funds for improvement may be inclined to rate the drought as less important. For example, a waterworks

TABLE 1-1 Characteristics of Selected Hazards to Public Water Supplies

	Characteristics		
Hazard	Frequency	Onset (days)	Duration (days)
Natural			
Drought	rare	slow (> 730)	long (> 750)
Flood	medium	rapid (0.1-10)	short (0.1-4)
Hurricane	medium	rapid (2-5)	short (0.1-1)
Earthquake	very rare	instantaneous (0.001)	very short (0.5)
Technological			
Explosion	very rare	instantaneous	short to med.
Chemical spill	very rare	instantaneous	short to med.
Equipment failure	very rare	instantaneous	short to med.
Ground-water contamination	medium	slow	long (> 750)

operator in a town along the Wasatch Front in Utah may judge the overnight destruction by an earthquake of aqueducts, well pumps, and distribution reservoirs as more serious than the slow dwindling of streamflow and reservoir capacity over three years. Or, a waterworks operator drawing on a Delaware River supply may fear the panic and interruptions resulting from disclosure of new, carcinogenic substances in the storage reservoir or an epidemic of giardiasis more than the prospects of drought. Similarly, an Albuquerque city council could be more profoundly disturbed by a discovery that its aquifer is contaminated by organics linked with disease prevalence, than that a drought might occur.

TIME

Looking broadly at the temporal dimension, it would appear that drought has claimed national attention in three major periods, and is the object of two sets of speculation, one historical, the other prospective. The first widespread appraisal of public water supply shortages attributable to drought was stimulated by the great drought of 1934 and 1936. A first canvass of state sanitary engineers in suffering communities was made by the American Water Works Association (White, 1935); the U.S. Geological Survey and U.S. Public Health Service later began more penetrating reviews.

Notice again was taken of difficulties with supply beginning in 1953-1954, and USGS analyses were extended (Wolman, 1955). The Eastern Seaboard drought of the 1960s inspired a series of more detailed appraisals of water supply adequacy in the event of persistently low precipitation. These included the Corps of Engineers Northeastern United States Water Supply Study (U.S Corps of Engineers, 1975) and the pioneering appraisal of adjustment alternatives by Russell et al. (1970). Coming along with earlier, 1950s advances in economic analysis of water resources investments by Kneese (1959), McKean (1958), Eckstein (1958), Hirshleifer et al. (1960), Krutilla and Eckstein (1958), Maass et al. (1962), and others, the methods of examining the benefits and costs of investment options were specified for the first time.

The notion of alternatives in water management had gained wide acceptance between the late 1950s and 1960s, so that by the fresh drought episodes of the 1970s there began to be systematic reviews of the great variety of measures to increase supply or reduce consumption (Davis, 1968; Committee on Water, 1966). Russell et al. investigated 15 types of adjustments made by 39 communities (see Table 1-2).

It remained for the long dry spells of the 1970s to set off a series of investigations of the precise conditions in which consumers would adopt water conservation measures. D. D. Baumann, J. H. Sims, J. J. Boland, W. H. Bruvold, and many others began to look at individual and community response to drought-restricted water supplies. Water conservation methods were evaluated in 1979 and 1982, and demand forecast approaches were appraised (Baumann et al., 1979; Boland et al., 1981 and 1982). They carried this a further, reasonable step to the specification of methods by which community planners could effectively canvass and compare their options with an eye to public acceptance of unconventional supply and demand management measures (Sims et al., 1982).

During recent years the time horizon has extended backward and forward. Using tree-ring, clay varve, and

TABLE 1-2 Adjustments to Drought Made by 39 Massachusetts Communities (Percentage Adopting)

To Decrease Withdrawals		To Increase Supply	
Restrictions		New sources	
Domestic	87	Reservoirs	13
Industrial	59	Ground water	49
Price	15	Improve existing	
		Reservoir	26
Meter	8	Ground water	16
Leak repair	8	Emergency supplies	
		Surface	26
		Ground	23
		Purchase	18
		Weather modification	2

SOURCE: Russell et al. (1970).

archeological findings, it has become apparent that the disappearance of the Anasazi civilization of the Southwest during the thirteenth century A.D. coincided with a drought of greater duration and depth than those in recorded history. Regardless of any possible causal relation between the two, the lack of established change in climate patterns since that period supports the suggestions that the Southwest region, including the Colorado Basin, may again experience a similar episode and that it would be prudent to plan for that recurrence. Such an event could be thought of as the ultimate test for drought management in that region.

Looking ahead to a drought period in the twenty-first century when the climate warming induced by buildups of carbon dioxide and other gases in the atmosphere might begin to increase temperatures and change precipitation patterns, it is now speculated that a chronic condition of moisture shortage might unfold (Revelle and Waggoner, 1983). It might not be cyclical if it were to take place; a new base on which drought deviation might be calculated then would be established.

From both the historical and the futuristic speculations, the severity of possible future droughts is increased. It should be observed, however, that the social effects upon cities in the Southwest are not as likely to disrupt the social fabric as would similar magnitude events in the humid eastern regions. This would be because of the prevailing patterns of urban population, water use, and ground water (Engelbert and Scheuring, 1984).

SPACE

At least four spatial dimensions of the urban water supply situation interact to affect in quite different ways the vulnerability of cities to drought. These are population size, rates of growth or decline, ground-water availability, and agricultural use of water.

Records of past drought episodes suggest that, with notable exceptions, it is the smaller municipalities and those with poor planning and meager surface water supplies that have higher probabilities of suffering shortage. Even where ground water of potable quality is physically available, towns may encounter shortage through poor management. A study of small Colorado towns illustrates this relationship (White et al., 1980).

It is sometimes argued that rapidly growing cities are more vulnerable to distress induced by drought than cities with no growth or very slow growth. Over periods of a few years this may be true, but over decades the opposite might hold. Cities not faced with early expansion may neglect planning for increasing supply or improving management (Ellinghouse and McCoy, 1982). Those who already foresee a limit to available supply may be obliged to give explicit consideration to the probability that projected additional supplies may fall short of demand in dry periods.

Those with access to good quality ground water often find ways of improvising in times of shortage or of providing in advance for reserves to be available. Thus, cities located in the glaciated Central Plains may be more likely to provide reserve or emergency supplies when surface sources attenuate than those in the unglaciated Central Plains (Heath, 1984). Growth in ground-water withdrawals for public supply has been modest in comparison with that for agricultural uses (Solley et al., 1983). Major increases in such withdrawals have been in the western states, particularly the Great Plains states. A comparison of ground-water availability with proportions of supply currently drawn from surface sources would give a first, rough delimitation of areas where the ground-water alternative might be promising.

Of basic importance is the availability of water in agricultural uses. Passing over, but not dismissing, the legal barriers to transfer of water rights, it is possible in large areas of the country practicing irrigation from collective distribution systems that, in the event of water shortage, water could be diverted from agriculture to municipal and industrial uses. Temporary loans during dry years are made by farmers without suffering distress. The Asilomar Conference developed the general argument that the expanding needs from urban users in the western states could be met by transfers from irrigation without crippling U.S. agriculture and with only local areas of social dislocation (Engelbert and Scheuring, 1984). In areas where cities favor permanent acquisition of irrigation rights rather than developing new sources, the effects on prime land however, may be destructive (Anderson et al., 1976).

The statistics on national water withdrawals and consumptive use by main sectors of the economy are well known (U.S. Water Resources Council, 1978). Aggregated national figures are not meaningful, but the regional data on consumptive use as a percentage of renewable supply show those areas where reductions in irrigation use could remedy temporary shortages in urban supply (USGS, 1984). Public supplies account for only a small proportion, less than 7 percent of withdrawals and 5 percent of consumption.

ORGANIZATION

Institutional and administrative dimensions can be thought of as falling into four classes: organizational competence, legal and administrative capacity, technical skill in analysis, and basic data for analysis. Organizational incompetence already has been noted in connection with size of cities. No doubt the smaller ones as a class are most likely to display it, but even the largest U.S. city at one period suffered dramatically from inadequate planning. It may be asked whether the prevailing flows of information and federal-state-local planning arrangements provide assurance that such crises will not recur.

On the legal and administrative fronts, the exploration of the opportunities and constraints inherent in state water law and federal claims is going forward rapidly. Spurred by recent Supreme Court decisions, the possibilities for interstate transfers of water rights are receiving searching attention. Assertions of Native American and federal reserve claims are troubling communities that might have considered their supplies as certain. Largely at the initiative of environmental advocacy groups, pioneering efforts have been launched to promote water conservation measures in the Imperial Valley and to manage demand as a substitute for structural measures in the Denver metropolitan area.

Less conspicuous but possibly as significant is the evolution of regional or district institutional machinery to plan and operate water and waste disposal systems encompassing several cities. There now is sufficient time, for example, to appraise the effectiveness of the Delaware Basin compact accords and organization in dealing with the current low flows.

The Clean Drinking Water Act of 1974 complicated the planning of community response to temporary supply shortage. By requiring states to exercise regulation of quality and to provide information on current water quality, it made it more difficult for communities to turn to substitute supplies or to justify continuing with supplies that have been impaired by contamination and concentration.

Although there is high sophistication in some of the methods available for weighing the economic effects of options in managing supply and demand, there also is challenge in trying to make those practically useful to city officials and consultants. The Baumann group made such a down-to-earth effort (Planning and Management Consultants, 1980 and 1981.) The Purdue examination of the acceptability of water conservation and associated wastewater measures to government officials and their publics was another step in helping specify the conditions in which community planning to prevent shortage can gain financial support (Potter et al., 1978). Federal attempts to promote water conservation launched in 1978 continue on a reduced scale (U.S. GAO, 1983). Reviews of promising management techniques are available (U.S. OTA, 1982). In a broad sense, every improved method of identifying and evaluating choices in multiobjective water planning may further that end.

But the more traditional economic analysis is not often harnessed with behavioral investigations of the circumstances in which public officials and consultants use new information, of consumer attitudes and action toward water conservation measures, of the long-time effects of pricing policies, and of the costs and benefits of undertaking no mitigation actions.

As a matter of record, no U.S. city has gone without drinking water in the face of crippling drought. None, like the Anasazis, has moved away. All sorts of emergency measures are being or may be taken, including rationing, temporary supplemental sources, intermittent service, and hauling water. In Colorado during the 1970s drought, the most ineffective municipalities resorted to such measures and were rewarded by receiving state and federal emergency financial assistance. We lack full, discerning estimation of the whole set of effects of taking emergency measures on public health, on financial stability, and on the political stances of officials and legislators in time of emergency.

It has been suggested that agreement on some acceptable level of risk from drought, such as the analogous setting of the one percent chance flood for design of flood insurance and other floodplain management measures, might be beneficial. However, the wisdom of adopting such criterion for drought is doubtful. For certain areas and in circumstances in which a blanket national system of flood insurance is imposed hastily, it may be warranted. In the long run, however, it discourages evaluation of the particular combination of resources use gains and flood losses that affect the productivity of a given floodplain, and it encourages a false sense of security in areas subject to less frequent floods. Surely there are more suitable means of establishing acceptable drought risk, area by area.

CONCLUDING REMARKS

By way of conclusion and as a means of generating discussion of some of the conventional wisdom in the field, I offer a few observations about the state of the science--and the art--of drought management.

The long onset times and duration of droughts should make it possible to refine the forecasts of moisture shortage so as to render them more useful to waterworks operators. The experience with forecasting of the probability of hurricane landfall might offer lessons as to pitfalls and opportunities.

The provision of suitable data and technical assistance to municipal governments lacking the competence or willingness to anticipate drought currently is far from effective, and there is question as to how it might be enhanced.

The innovation and testing of new legal and administrative devices to permit municipalities to join in water management, to operate a market for water rights, and to share experience in planning and gaining public acceptance for water conservation measures deserve vigorous support beyond what is already under way.

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2

CAUSES AND OCCURRENCE OF DROUGHT

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Droughts are indiscriminate in terms of geography, climate, and political boundary. Each and every region of the United States has experienced conditions of below normal rainfall and streamflow runoff at some time. As noted by Buchanan and Gilbert (1977), "Hydrologists can pragmatically report on recorded data which show that almost every year, some area of our country experiences the conditions which constitute a drought."

Many climatologists have noted a significant increase in the variability of the weather during the past two decades (CIA, 1974; Fritz, 1977; Schneider, 1977; Wallis, 1977). It is now apparent that the years 1956 through 1971 constituted an abnormally stable period in terms of temperature and precipitation fluctuations, and that the disastrous worldwide weather conditions of 1972 heralded the end of that area. As Mitchell (1977) states, "It appears that we're returning to normalcy, and that means greater variability in the weather than we're used to." This trend toward increased variability in the weather may be due either to a random fluctuation in the complex weather-generating processes or to a large-scale climate change. Unfortunately, the brevity of available hydrologic records makes it virtually impossible to distinguish between these two possible causes (Lettenmaier and Burges, 1978). Nonetheless, the present increase in meteorological variability should cause a corresponding increase in the occurrence of hydrologic droughts, at least in the immediate future. Hence from these considerations it is apparent that the study of droughts is an extremely relevant and essential aspect of water resources analysis.

A surprisingly limited amount of attention has been given to hydrologic drought events in the literature

(Whipple, 1966). A cursory survey of the Water Resources Abstracts substantiates this claim, it is found that the ratio of papers indexed under "Floods" to those indexed under "Droughts" exceeds 6 to 1 in all cases, and was nearly 10 to 1 in 1976. In addition, many of the "drought" entries actually refer to meteorologic droughts or low flows rather than to hydrologic drought events.

DEFINITION OF DROUGHT

What is a drought? It brings to mind extreme pictures of emaciated humans, hunger, and famine, or simply empty reservoirs, parched fields, and dusty roads. However, a precise definition of drought is difficult to obtain (Dracup, 1980a). The difficulty in devising an objective definition of drought is fourfold. One source of confusion is the unavoidable diversity in the ways in which various fields of study view drought events. A water resource engineer views drought as a problem in supply and demand. He may state "there is no drought in the ocean," meaning, of course, that without a specified demand no drought can occur however severe the precipitation shortage may be. Thus the engineer views drought as a shortage in streamflow runoff and water storage.

The geophysicist's view of drought will include climatology, meteorology, hydrology, limnology, and oil physics (Yevjevich, 1967). The farmer and agriculturalist view drought as a function of the specific crop under cultivation. Others may view drought as a function of the impact the drought has on institutional and human activity and on their response during the drought.

A second factor militating against an objective drought definition is the variety of connotations given to the term "drought" in different parts of the world. For instance, in Bali any period of 6 days or more without rain is considered a drought, while in Libya droughts are only recognized after 2 years without rain; in Egypt before construction of the Aswan Dam, failure of the Nile River to flood constituted a drought, regardless of rainfall (Hudson and Hazen, 1964). In Britain an "absolute drought" has been defined as a period of at least 15 consecutive days without 0.01 inch of rain on any one day, whereas a "partial drought" is taken to be a period of 20 consecutive days for which the mean daily rainfall does not exceed 0.01 inch (Rodda, 1965). Other examples exist in the literature (Tannehill, 1947) that serve to demonstrate that definitions of drought events are strongly related to the climatological and geological traits of a particular locale.

The third problem in drought definition from the point of view of the hydrologist is that a drought event is manifested in terms of both a precipitation deficiency and a streamflow deficiency. Hence a thorough and complete definition of drought events requires consideration of both rainfall and runoff. However, due to constraints of time, economic resources, and professional expertise, most drought studies have focused on only one aspect of the drought event. Thus two drought definitions are often specified, one based on precipitation and the other based on runoff.

Finally, there is a curious lack of uniformity in the conventional terminology relating to different hydrologic events. For instance, since the term low flow denotes an annually occurring minimum flow of short duration, one would expect the annually occurring maximum flow of short duration to be called a high flow; however, this is usually termed a flood event. In addition, because the term high flow may be used to refer to extended periods of above mean discharge, one would expect extended periods of below mean discharge to be called low flows; however, these are usually termed drought events. This lack of symmetry in hydrologic terminology is shown schematically in Figure 2-1.

It is in this context that general definitions of drought events have evolved. These definitions have, of necessity, been broad in scope so as to apply to as wide a variety of particular drought manifestations as possible. An extreme example of this is the drought definition offered by Matalas (1963): "A drought is defined, in a broad sense, as an extended period of dryness." In addition, most definitions describe drought in relation to some locally determined water requirement. For instance, the U.S. Weather Bureau defines drought as a "lack of rainfall so great and long continued as to affect injuriously the plant and animal life of a place and to deplete water supplies both for domestic purposes and for the operation of power plants, especially in those regions where rainfall is normally sufficient for such purposes" (Havens, 1954). A typical

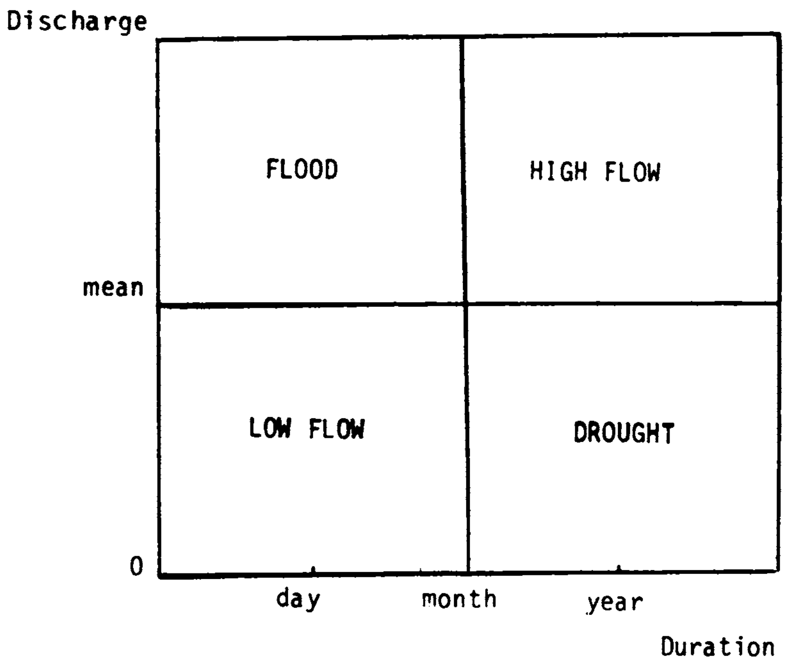


FIGURE 2-1 Classification of hydrologic events.

textbook definition of drought is given by Linsley et al. (1982): "a period during which streamflows are inadequate to supply established uses under a given management system." A less subjective definition is offered by Whipple (1966): "the term drought will refer to prolonged periods of runoff, averaging less than the long term mean." The generality of these definitions clearly leaves them open to subjective interpretation by individual researchers, a situation that has often provided a barrier to the advancement of the state of the art of drought analysis.

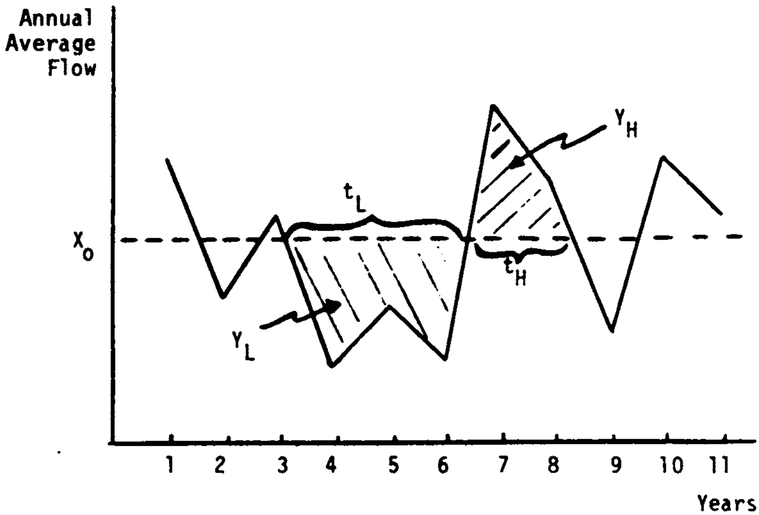
In the midst of this ambiguity and complexity, one potentially satisfying drought definition has emerged in the past decade as being objective and yet flexible enough to be applicable to a wide variety of drought concepts. In effect the proposed approach merely systematizes the intuitive intentions of the various definitions mentioned above.

The drought definition of interest has been proposed by Yevjevich (1967), and is based on the branch of statistical analysis known as the theory of runs. This is a method of analyzing a sequential time series of stochastic or deterministic variables, and hence is well suited to the study of hydrologic event. The fundamental parameters of the runs of an annual hydrologic series are shown in Figure 2-2. The parameters best suited to drought definition are t_L (drought duration) and y_L (drought severity). In the terminology of the theory of runs, t is referred to as a run-length and y as a run-sum. A third parameter may be identified by forming the ratio of y to t; this represents the average magnitude of the drought event.

The selection of x_0, the base value index by which all other values of a hydrologic variable x are described, is an important decision. Figure 2-2 indicates that the run-sum and run-length are determined by the choice of x_0. Some candidates values for x_0 are the mean of the x series, the median of the x series, or an expression such as

$$x_0 = x_m + e \cdot s_x,$$

where x_m is the series mean, s_x is the series standard deviation, and e is an elective scaling factor. It is noted that x_0 need not be a constant; it may be a stochastic variable, a deterministic function, or any synthesis of the two.



Runs Parameters:

Y_H = Run-sum above X_0

Y_L = Run-sum below X_0 (drought severity)

t_H = Run-length above X_0

t_L = Run-length below X_0 (drought duration)

Y_L/t_L = Drought magnitude

FIGURE 2-2 Parameters of the runs of a hydrologic series.

Once the desired value of x_0 has been stipulated, the time series is divided into upper (above x_0) and lower (below x_0) sections. A primary advantage of using runs to define droughts is that the run-sum and run-length series of the upper and lower sections are amendable to statistical analysis in order to determine properties such as time dependence, probability distribution, or serial correlation. These properties may be determined analytically or by a suitable data generation approach (e.g., the Monte Carlo method). In the case of drought events this implies that the statistical properties of drought duration, magnitude, and severity may be assessed (Dracup et al., 1980b).

The objectivity of this method of drought definition is one of its strongest advantages; if a number of analysts select the same value of x_0 to be applied to a particular hydrologic record, then each should derive identical statistical properties for duration, severity, and magnitude. The method's flexibility is due to the freedom allowed in the choice of x_0; the hydrologist may use mean annual flow, while the agriculturalist may prefer seasonal soil moisture. The combination of these two characteristics in an approach to drought definition and description is particularly attractive because of the wide variety of drought concepts held throughout various scientific disciplines.

CAUSES OF DROUGHT IN TEMPERATE LATITUDES

The material covered in this section concerns the statistical, synoptic, and physical aspects of drought on time scales of a month to several years. The current literature reveals that the causes of drought are complex and are not yet completely understood by meteorologists and climatologists. Namias (1985) states

> . . . it should be made clear that there are many unsolved "mysteries" of drought. While some physical understanding has been achieved for droughts that last for a month to a season, spells of years characterized by drought are poorly understood, and thus remain on the agenda for research climatologists.

When studying the factors responsible for drought, one is struck by the "chicken and the egg" analogy, that is, which of the processes actually occurs first? Perhaps a gradient of sea surface temperatures (SST) first is formed between the warm eastern Pacific and the cold central and western Pacific. This process may cause high-pressure cells in the mid-troposphere to emerge and persist. This in turn causes subsidence (sinking) or warm, dry air in the middle troposphere, which then causes adiabatic heating, low relative humidity, and a reduction in the growth of cumulus clouds. The result is a reduction of precipitation. The reduced cloud cover and precipitation in turn increases insolation, drying out the soil and increasing its albedo, thus further aggravating the process. Let us investigate each of these phenomena in turn.

Recently, it has been suggested that there are important teleconnections (relationships between two phenomena that are physically hundreds or thousands of kilometers apart) within the atmosphere-ocean system (Namias, 1978a). As shown in Figure 2-3, there appears to be a teleconnection between a warm SST anomaly and the continental high-pressure cell.

It is well known that high-pressure cells exist over drought-affected regions and that companion oceanic high-pressure areas exist simultaneously. As shown in Figure 2-4, strong high-pressure areas exist over the Atlantic and the Pacific as well as the continental United States. These high-pressure areas help shape the upper-level long-wave westerlies. In turn, the positioning of these long-waves determine to a large extent climatic variations. During drought periods there is a general northward shifting of pressure zones. Therefore the westerlies are displaced northward over the continental United States during droughts, bringing stronger than normal winds to the high latitudes as shown in Figure 2-5.

The result of these atmosphere anomalies is the presence of (relatively) warm, dry air in the middle troposphere. In drought regions, the warm air aloft subsides at the rate of several hundred meters per day. The sinking of the dry air and the attendant adiabatic heating of it inhibits precipitation through the suppression of the growth of cumulus clouds. The subsidence of the warm, dry air aloft is caused by air flowing out of the bottom boundary layers of the high-pressure cells. This air is replaced by the further sinking of air masses aloft. The warm air aloft resulting from the subsidence is shown in Figure 2-6.

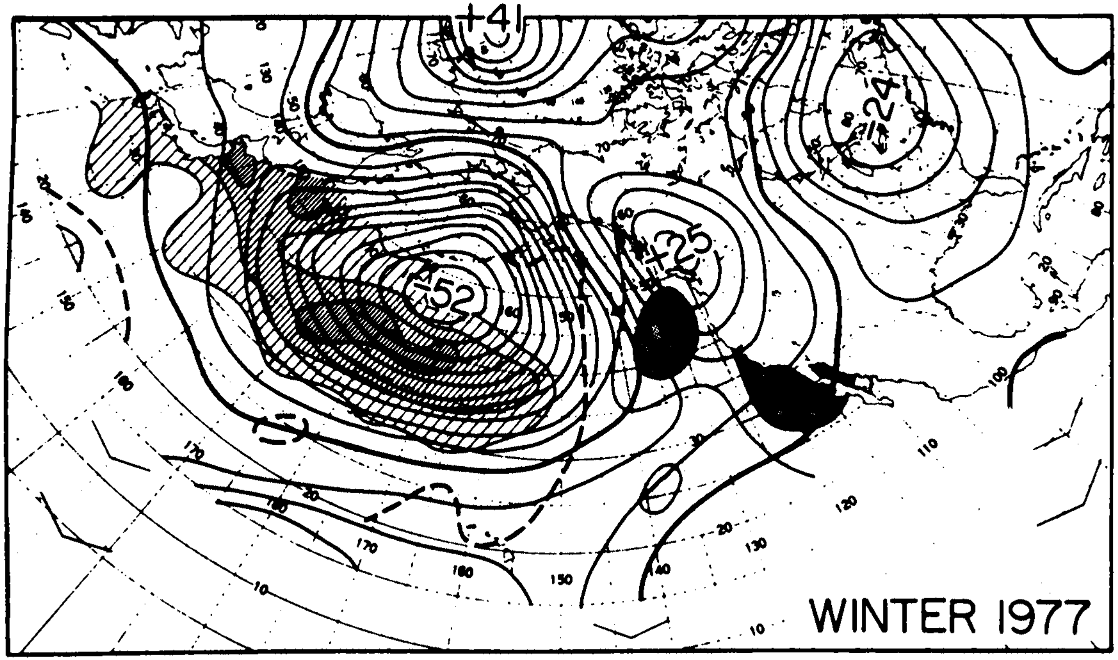


FIGURE 2-3 Sea surface temperature anomalies and isopleths of 700-mb height anomalies (intervals of 50 ft) in winter 1977. Stippling indicates 1°F or more above normal. Slant shading indicates 1°F or more below normal.

SOURCE: Beran and Rodier (1985). Permissions granted World Meteorological Organization and UNESCO Press.

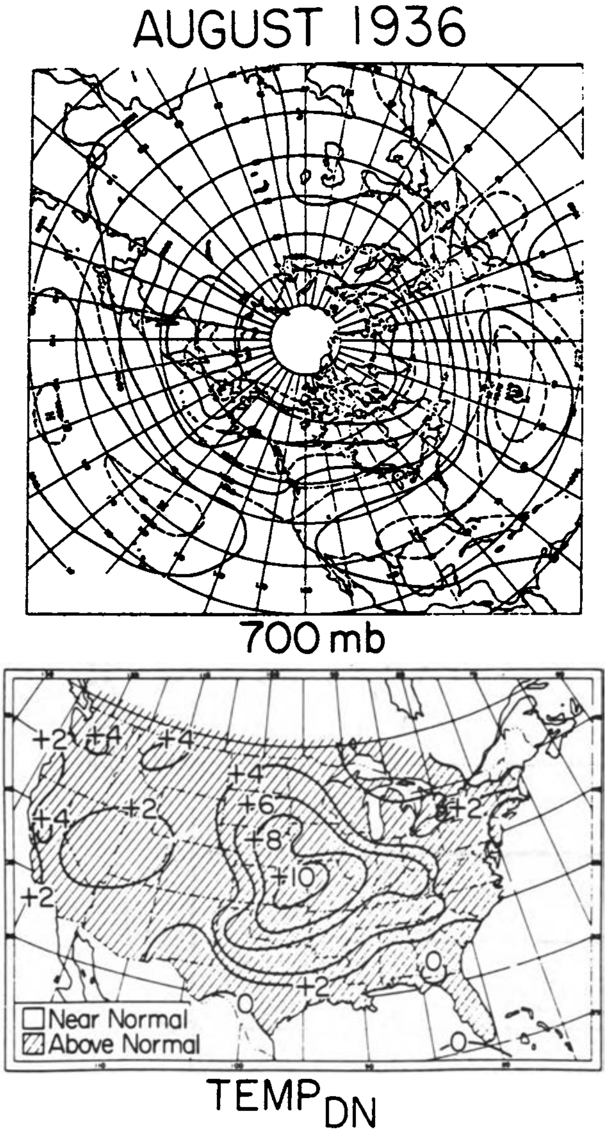


FIGURE 2-4 (Top) Average contours of the 700-mb surface for August 1936, a drought month. (Bottom) Average temperature departures from normal (°F) for August 1936. (DN: departures from normal).

SOURCE: Beran and Rodier (1985). Permissions granted World Meteorological Organization and UNESCO Press.

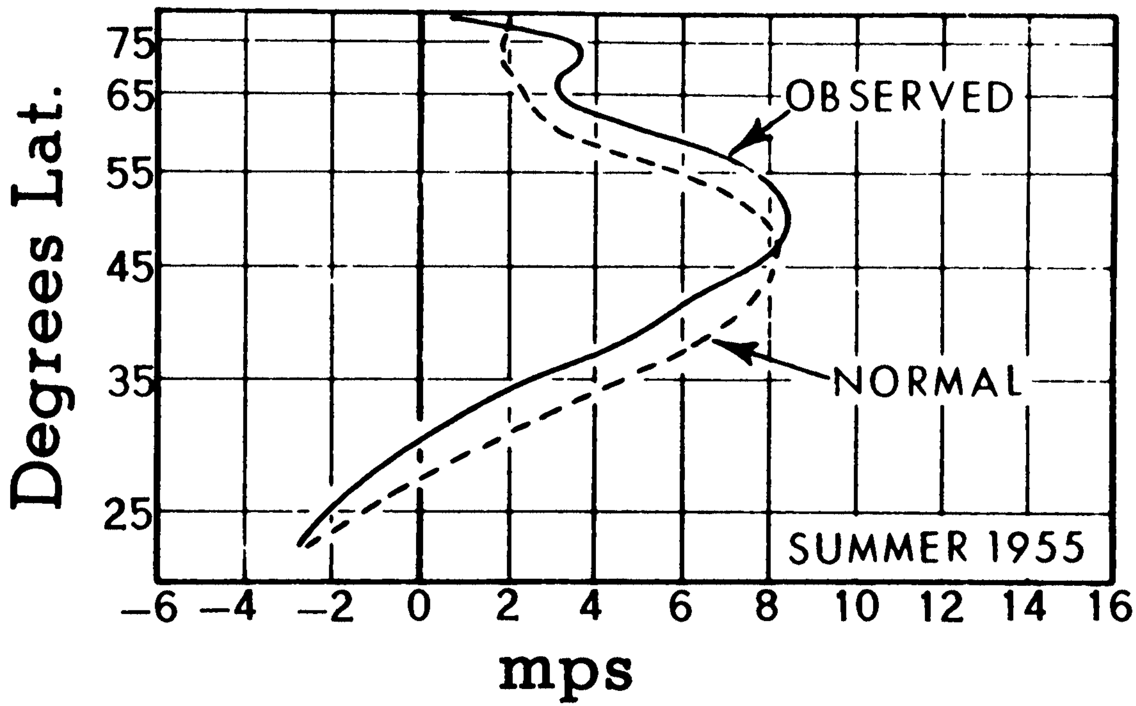


FIGURE 2-5 Main 700-mb zonal wind speed profile in the Western Hemisphere (0° westward to 180°) for August 1955.

SOURCE: Beran and Rodier (1985). Permissions granted World Meteorological Organization and UNESCO Press.

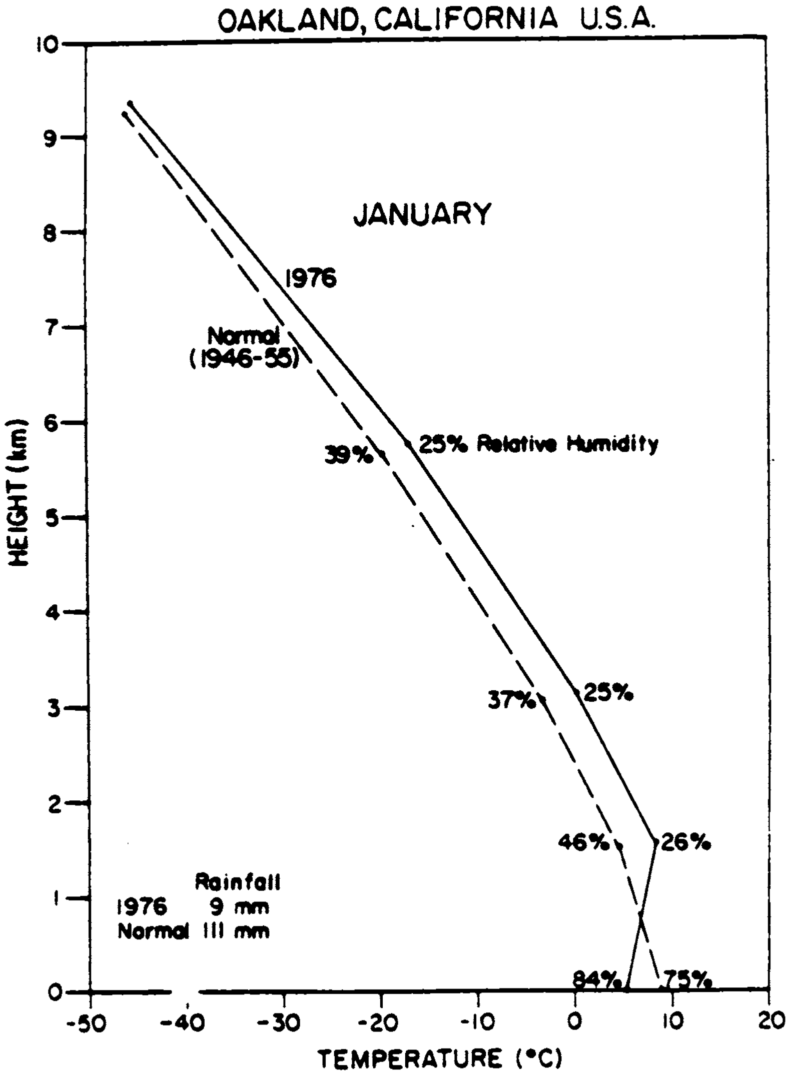


FIGURE 2-6 Upper-air temperatures in the core (Oakland) of the California drought for January 1976 and the normal temperatures. Numbers beside temperature plots give relative humidities. Rainfall amounts are given in the lower left.

SOURCE: Beran and Rodier (1985). Permissions granted World Meteorological Organization and UNESCO Press.

Here the increase in temperature at any given height is evident.

Once the high-pressure cells are formed and the drought is initiated, there is a self-perpetuating mechanism that continues the process. One theory holds that the land, rendered hot and dry during drought, further heats the air above it and thereby enhances the regional high pressure zone. A second theory states that drought causes an increase in fine dust particles in the air, which lead to high concentrations of very small cloud droplets whenever cumulus clouds form and thus make it more difficult for precipitation to form (Twomey and Squires, 1959). A third theory suggests that high albedo in dry areas creates a mechanism that produces warm air aloft (Charney, 1975). Whatever the mechanism, there is statistical evidence that hot, warm springs over the plains of the United States are followed by hot, dry summers and these tend to persist from one year to the next (Namias, 1960).

In reviewing the literature in meteorology on the causes of drought, one is struck by the many different mechanisms that in themselves are well understood. That is, SST anomalies, high-pressure cells, long-wave westerlies, warm air subsidence, increased albedo, and so on, are all understood by atmospheric scientists. However, the interrelationships between these variables, and how their interrelationships cause a persistent drought, are not well understood.

POTENTIAL FOR DROUGHT FORECASTING

A scientific forecast of a geophysical event such as a drought must include four vital components. These are the event's time of occurrence and its magnitude, duration, and location. For example, the essential elements required for the prediction of an earthquake must include the expected time that the earthquake will occur, along with its expected magnitude (i.e., Richter scale value), duration, and location. In the case of a drought, forecast must include location (i.e., areal extent), duration, and magnitude. The product of duration and magnitude result in the determination of drought severity.

The forecasting of any catastrophic event is fraught with difficulties, and droughts are no exception. This section summarizes the current state of the art of long-range forecasting. For a more extensive review the reader is referred to Namias (1953, 1968, and 1978b). The forecasting procedures can be divided into meteorological methods and hydrological methods.

The meteorological methods include analogues, linear regression models, teleconnections, statistical and kinematic models, air-sea interactions, statistical time series forecasts and extrapolation in time using cyclicities (Beran and Rodier, 1985). Only teleconnections and air-sea interaqtions will be discussed here.

Teleconnections are shown on charts that specify conditions remote from the area being forecasted. As indicated on Figure 2-7, the correlation coefficients for all grid points are specified at the 700-mb level.

Other examples of teleconnections include the following:

1. Links between SST and continental weather (Namias, 1963; Shulka et al., 1977).
2. Wind in East Africa and monsoon in India (Findlater, 1977; Raghaven et al., 1975 and 1978).
3. General circulation and sea surface "signature antecedent to deficit seasons in Brazil, Central America, and Africa" (Hastenrath, 1976 and 1978).

The use of air-sea interactions first involves measuring the macroscale thermal character of the sea surface. The second step is to determine the atmospheric circulations that are compatible with the SST anomalies. Correlations are then made and teleconnections are used to translate these data into circulation patterns, temperature, and precipitation over continental areas (Namias, 1976).

The hydrological methods of forecasting drought include streamflow-regression-based methods, regression methods, the analysis of cycles in annual streamflow, and other statistical analyses of historical streamflow events.

Probably the most widely used method of hydrologic forecasts is the regression method. A linear regression equation of the form

$$Y = b_0 + b_1X_1 + b_2X_2 + \ldots b_nX_n$$

may be used for drought and/or streamflow forecasting where Y may be the pressure, temperature, or streamflow

700mb SUMMER MONTHS
TELECONNECTIONS (CROSS-CORRELATIONS)

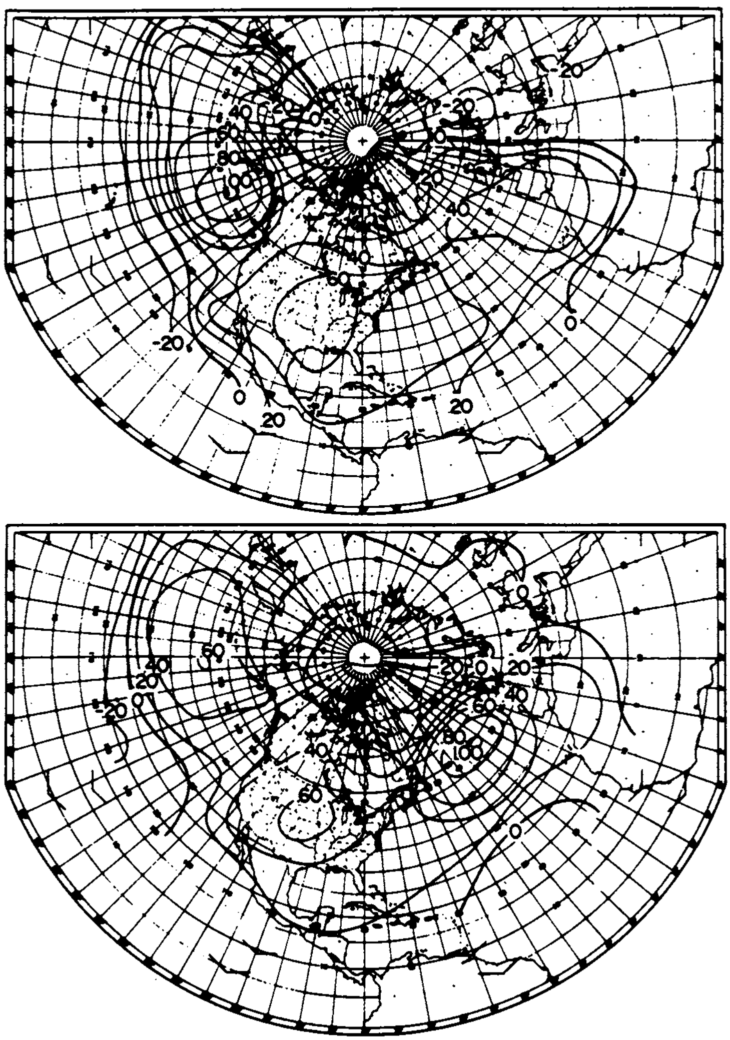


FIGURE 2-7 (Top) Teleconnections between 700-mb heights over the field as correlated with a point in the North Pacific (labeled 1.00). (Bottom) Same with a point in the North Atlantic (labeled 1.00). Note in each case the positive correlation with 700-mb heights over the central United States.

SOURCE: Beran and Rodier (1985). Permissions granted World Meteorological Organization and UNESCO Press.

at a point. The variable Y may take the form of an index summarizing the total weather situation derived using the principal components method. The forecasting X variables must be observable at the time the forecast is to be made and like the Y variable can include prior values of pressure and temperature, summarizing indices, sea surface temperature, wind, ice extent, and even sunspot number or some other cyclic variable. The estimation of the coefficients b_0, b_1, etc., is by least squares and makes use of a run of back data, typically 30 years for seasonal or annual forecasts.

In the case of streamflow, soil moisture and climatic factors such as precipitation and temperature are used as the independent variables.

CURRENT OPERATIONAL DROUGHT FORECASTING TECHNIQUES IN CALIFORNIA AND THE WESTERN UNITED STATES

The current operation drought forecasting techniques as presented here are divided into meteorological methods and hydrological methods.

Meteorological Forecasts

The Scripps Institute of Oceanography (SIO) provides the California State Department of Water Resources (CDWR) with seasonal temperature and precipitation forecasts as shown in Figure 2-8. Namias (1984) states that these forecasts are

> physically based using statistical and synoptic methods which employ large scale fields of Northern Hemisphere atmospheric geopotential height and Pacific Ocean sea surface temperatures.

The forecasts are made in equally likely tercile classes, light (L), moderate (M), and heavy (H). The forecasts are called "experimental" and are part of ongoing research at SIO aimed at improving long-range-forecasting techniques. A total of four forecasts is made each year starting in September. The fall forecast is for September, October, and November. In December, the winter forecast is for December, January, and February. Similarly, three-month forecasts are made for the spring and summer months. In addition

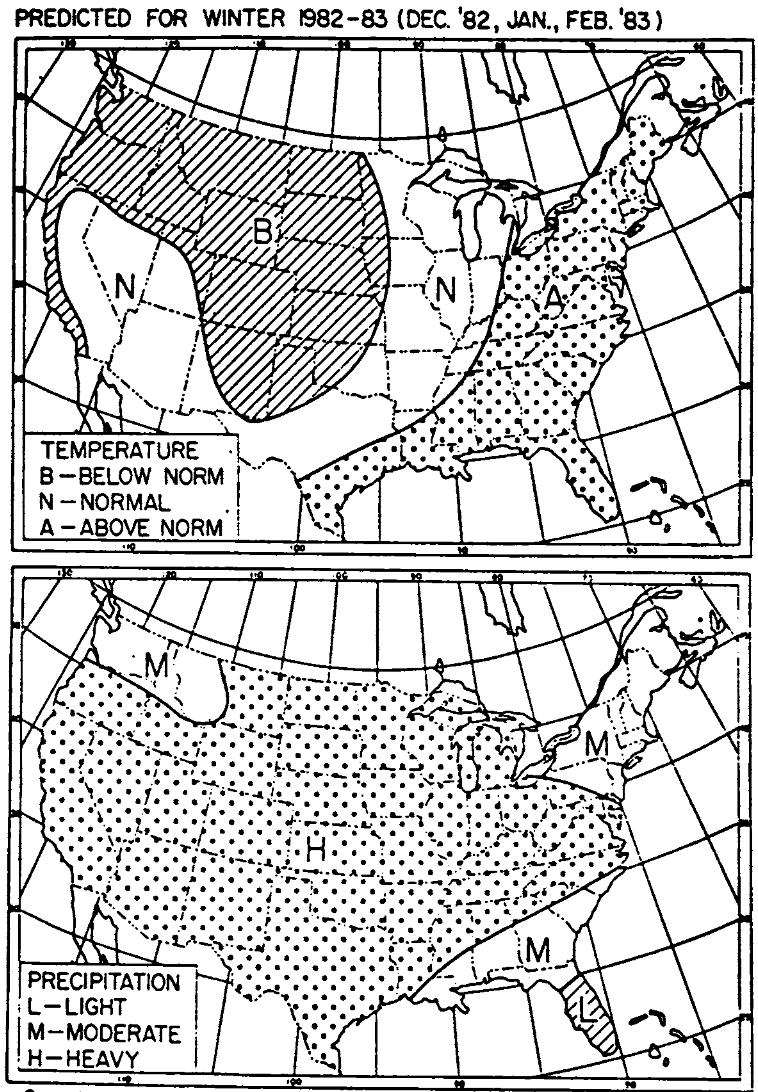


FIGURE 2-8 Forecasts of temperature and precipitation for winter 1982-1983.

SOURCE: Namias (1984).

to the precipitation forecasts, the movement of various upper level winds and storm tracks also are predicted as shown in Figure 2-9. In addition to pictorial forecasts, an annual report is furnished (Namias, 1984). The report contains a discussion of results of the project forecasts to date and an analysis using a "skill score."

The CDWR translates these forecasts into California Water Supply Outlook report (1985) and a State Water Project Water Delivery Rule Curve and Criteria for 1985 report. These reports are mainly used to operate reservoirs throughout California mainly for irrigation supply deliveries (agricultural irrigation accounts for 87 percent of water supply deliveries in California).

Hydrologic Forecasts

The National Weather Service (USDC) and the Soil Conservation Service (USDA) jointly publish monthly reports on Water Supply Outlook for the Western United States for five months beginning on January 1 of each year. Similarly, the CDWR publishes a report entitled Water Conditions in California. These reports contain streamflow forecasts for the entire water year (October through September), streamflow forecasts for specific irrigation periods (April to September), and data on current reservoir storages. It is important to note that these forecasts are for unimpaired flows. Similar reports are published throughout the United States.

The meteorologic and hydrologic forecasts are principally used to allocate irrigation water supplies to senior and junior irrigation districts with appropriative rights in California and throughout the West.

The only "drought index" used in California is the "Four River Index," which comprises the sum flows of the Sacramento River, the American River at Folsom, the Yuba River at Smartville, and the Feather River inflow to Oroville Dam. This index is published in Water Conditions in California (Bulletin 120-85) and is primarily used as a means to meet salinity standards in the Sacramento Delta. Other input to the Water Conditions in California report include snowpack measurements, precipitation, reservoir storages, and streamflow runoff.

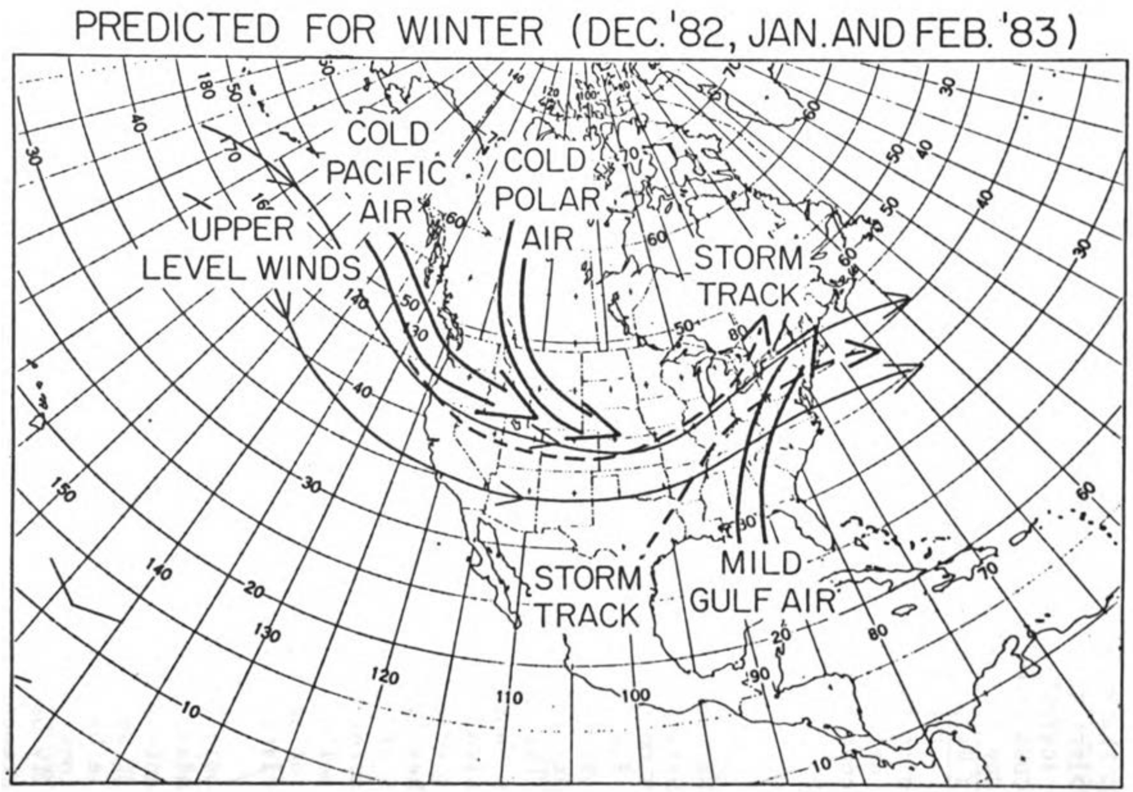


FIGURE 2-9 Forecasts of winds aloft and major storm movements for winter 1982-1983.

SOURCE: Namias (1984).

FORECAST ACCURACY

In Thomas Heggens classic play Mister Roberts (1946), he describes life aboard a cargo ship during WWII:

> Now in the waning days of the second World War, this ship lies at anchor in the glassy bay of one of the back islands of the Pacific. It is a Navy cargo ship. You know it is a cargo ship by the five yawning hatches, by the house amidships, by the booms that bristle from the masts like mechanical arms. You know it is a Navy ship by the color (dark, dull, blue), by the white numbers painted on the bow, and unfailingly by the thin ribbon of the commission pennant flying from the mainmast.

Heggens goes on to state:

> It has shot down no enemy planes, nor has it fired upon any, nor has it seen any. It has sunk with its guns no enemy subs, but there was this once that it fired. This periscope, the lookout sighted it way off on the port beam, and the Captain, who was scared almost out of this mind, gave the order: "Commence firing!" The five-inch and the two port three-inch guns fired for perhaps ten minutes, and the showing was really rather embarrassing. The closest shell was three hundred yards off . . .

Hopefully, meteorologic and hydrologic forecasts are currently doing better than the guns of the USS Reluctant.

Namias evaluates his meteorological forecasts for California and the western United States using the following skill score equation:

$$\text{Skill} = \frac{\text{Correct Forecasts} - \text{Correct Forecasts Expected by Chance}}{\text{Total Forecasts} - \text{Correct Forecasts Expected by Chance}}$$

For the time period 1975-1976 through 1981-1982, skill scores of approximately 0.67 were experienced. However, during the 1982-1983 water year a skill score of only +0.25 (6 out of 12 correct forecasts) was achieved, and during the 1983-1984 water year a skill score of 0.00 (4 out of 12 correct forecasts) was achieved. These recent results raise the question of the actual value of these long-range forecasts.

The determination of streamflow forecast accuracy is somewhat more difficult in that the measured streamflow has to be converted to unimpaired flows. An analysis of 29 streamflow stations in the Colorado River Basin (Dracup et al., 1985) reveals correlation coefficients ranging +0.52 to +0.88 depending on the correlation technique utilized and the region being analyzed. It appears therefore that these streamflow forecasts are a valuable input to water resource planners.

POTENTIAL PROBLEMS IN DROUGHT FORECASTS

Any discussion on drought forecasts would be incomplete without at least some mention of the problems that arise when geophysical forecasts are in error. For example, a drought forecast made in January of 1977 by the U.S. Bureau of Reclamation on the Yakima River (Glantz, 1982) resulted in a $20 million lawsuit against the U.S. government. The plantiffs in the case are farmers who allege that errors occurred in the forecasts. Annual irrigation allocations to farmers are based mainly on snow melt runoff forecasts. In 1977, the USBR forecasted that the farmers would only receive 7 percent of their normal annual allocation. Based on this forecast, the farmers then made adjustments (e.g. sold land, drilled wells, changed crops, etc.) which were documented to equal $20 million. However, due to both an erroneous forecast and subsequently discovered errors in the forecast calculations, these farmers actually received 70 percent of their normal water allocation. Therefore their earlier expensive adjustments proved to be unnecessary. The courts have yet to determine if the federal government is libel for these forecasts.

Similarly, a volcano forecast warning for the Long Valley Caldera in California resulted in plummeting real estate values in the nearby resort area of Mammoth Lakes. Also, the widely publicized meteorological forecast for the Georges Bank fishing area for November 21-22, 1980, resulted in the only lawsuit against the U.S. government that was decided for the plaintiffs (Honour Brown et al. v. U.S.A.) (Siegel, 1985).

These and other problems raise such questions as who is using these forecasts, what are their actions as a result of the forecasts, and do the long-term benefits exceed the potential short-term costs? That is, can many years of benefits be countered by a single lawsuit from a single faulty forecast? Or should these forecasts be made by the private, rather than the public, sector, which would assume liability via a corporate structure?

CONCLUDING REMARKS

This chapter, which focuses on the causes and occurrence of droughts, deals with the technical aspects of this subject. However, in considering this topic and the broader issue of drought management and its impact on public water systems not only the engineering and technological aspects of the problem should be analyzed, but also the areas of economics, finances, legalities, politics, society, and the environment. For example, suppose an elaborate international network for drought prediction were developed, which included ground sensors, report collection stations, telemetering satellites, simulation models, and information dissemination centers. Such a system would be required to answer such questions as do the benefits exceed the costs, who will finance such an enterprise, is such a system completely legal under present laws, is it supported politically, will society accept the end results, and is it environmentally feasible? Only if such a drought prediction system can successfully pass each of these feasibility tests will it actually be established.

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3

WHAT ARE ACCEPTABLE RISKS FOR PUBLIC SYSTEMS?

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The subject of drought management in the context of risk assessment is a relatively new concept in terms of urban water supply planning. Simply stated, the concept of drought management would be to plan for a water supply that would be available at all times except during droughts with some calculated recurrence interval, say once in 50 years or once in 100 years. Determining an appropriate drought recurrence interval for water supply planning is extremely difficult due to the highly unpredictable nature of droughts. This discussion briefly describes some of the problems associated with this type of risk analysis and examines some practical drought management strategies in the context of past experiences and necessary future planning.

FLOOD MANAGEMENT PLANNING

Although risk assessment has been applied to flood damage mitigation for many years, there is no simple formula, such as one percent chance of exceedence, that can be applied to all situations. The planning of flood mitigation facilities is far more complex and rightly so.

For example, along California's largest intrastate river, the Sacramento, some agricultural lands are inundated every two or three years by flood waters that overflow at seven control structures, thus reducing the cost of flood control along the river. There is also in the Sacramento-San Joaquin Delta area a complex of below-sea-level islands protected by levees. These delta islands, composed of primarily agricultural lands with some urban development, experience flood perhaps every 20 years. Although most urban flood control facilities are designed to accommodate a 100-year flood, certain other structures, such as dam embankments and spillways, are often designed to safely pass the probable maximum flood that approximates a 1000-year recurrence interval. Because of the potential of catastrophic loss of life and property damage associated with dam failure, particularly in urban areas, public policy dictates that special consideration be given to the construction of dams.

Similarly, no set recurrence level can be used for drought planning. The impossibility of predicting how and when a drought will unfold and the problems of applying uniform measures to deal with the drought make risk assessment very difficult.

During drought periods, various management strategies have been employed to allocate an inadequate water supply among competing users for that supply.

AGRICULTURAL DROUGHT MANAGEMENT

One example of drought management applied to agricultural water users is the U.S. Bureau of Reclamation's Central Valley Project in California, which serves almost 3 million acres of land. The Central Valley Project has "firm" water or Class 1 water available in most years, and in addition has Class 2 water that is available on a "less firm" basis. In dry years, when little or no Class 2 water is available, the farmers have the option of reducing their irrigated acreage of annual crops or increasing their production from alternative supplies such as individual wells.

The Bureau's system, in general, works well; however, the example above does not fit the typical urban situation, since most urban water users neither make an explicit annual decision on their needs for domestic water or water-using vegetation nor do they have the option of turning to individual wells. Also, while a contract system might work fine for a few hundred to a few thousand agricultural water users, it has some obvious limitations for an urban setting with hundreds of thousands of small customers.

THE GREAT CALIFORNIA DROUGHT OF 1976-1977

From November 1975 through November 1977, California experienced its most severe drought of this century. Although most of the urban and farming areas are accustomed to the almost total absence of precipitation during the growing season from April through October, in 1976 and 1977 the winter periods experienced only one-half and one-third of normal precipitation, respectively. The result was California's fourth driest and driest years of record, successively. Most surface storage reservoirs were substantially drained in 1976, with the result that there were widespread shortages when 1977 turned out to be even drier.

Many dramatic and imaginative programs were implemented by federal, state, and local officials, as well as private companies, farmers, and individuals to cope with the water shortage. In general, the public response and cooperation were outstanding because the evidence of shortage was clear and uncontrovertible--bare ski slopes in the winter and empty lakes and reservoirs in the summer. Southern California with its access to the giant Colorado River reservoirs at Lake Mead and Lake Powell was less hard hit than the normally wetter areas of Central and Northern California (interestingly, the Colorado River also experienced its driest year in recorded history in 1977). As a result, Southern California was able to give up substantial quantities of its contracted rights to water from the State Water Project to assist the San Francisco Bay area (approximately 40 billion gallons) and the San Joaquin Valley farmers (approximately 100 billion gallons).

The cost of the two-year drought has been estimated at $2.5 billion, with those hardest hit economically being businesses directly dependent on precipitation--cattle ranches and recreational facilities, particularly ski resorts. Also hard hit was hydroelectric generation in Northern California (only 38 percent of normal), with replacement made up at much higher cost from burning increased quantities of fossil fuels at Southern California plants for export to Northern California. The impact on farm production, other than range cattle, was substantially lessened by the increased use of ground water with accompanying higher costs. It has been estimated that up to 10,000 new wells were drilled or deepened to provide replacement agricultural water.

(See Table 3-1 for a comparison of agricultural production in 1977 with the previous three years.)

Much media attention was received by the urban water conservation programs in California during the drought, and in particular, the programs in Marin County, where, due to a particularly severe supply deficiency, water use was reduced by approximately 65 percent to only 45 gallons per person per day. However, other urban water customers throughout California also enthusiastically cut their water use as can be seen on Table 3-2. Public opinion polls in water-short areas during 1977 determined that city dwellers had substantial sympathy for the plight of the farmers and frequently stated the opinion that the urban water user could more easily conserve than the farmers.

TABLE 3-1 Agricultural Response to Drought

Year	Field Crops	Fruit- and Nut-Bearing Crops	Vegetables and Melons	Total
Acreage				
1974	6,520,300	1,508,010	861,320	8,889,630
1975	6,602,000	1,571,440	921,660	9,095,100
1976	6,590,000	1,634,540	829,466	9,054,006
1977	6,359,000	1,673,890	914,652	8,947,542
Production (tons)				
1974	24,986,000	8,702,700	11,820,750	45,509,450
1975	28,566,000	9,794,800	13,312,050	51,672,850
1976	28,965,000	9,626,600	11,051,650	49,643,250
1977	25,009,000	9,673,700	13,037,750	47,720,450

This table displays the harvested acreage and production of the principal crop groups in California during the drought of 1976-1977 as compared with the two previous years. These figures include both irrigated and dry farm acreage and production. As indicated, acreage and production actually increased in the drought year 1977 for fruit- and nut-bearing crops, vegetables, and melons.

SOURCE: From The California Water Atlas (1978).

TABLE 3-2 Urban Response to Drought Municipal Water Use (millions of gallons)

City	Jan. 1, 1976–June 30, 1976	Jan. 1, 1977–June 30, 1977	Difference	Difference in Percentage
Eureka	694	546	-148	-21
Redding	938	816	-122	-13
Alturas	153	140	-13	-8
Chico	2,471	1,969	-502	-20
Subtotal	4,256	3,471	-785	-18
Sacramento	13,156	10,760	-2,396	-18
San Francisco	18,859	13,564	-5,295	-28
San Jose	20,808	15,495	-5,313	-26
East Bay MUD	39,553	25,161	-14,392	-36
Alameda Co. WD	4,912	3,458	-1,454	-30
Stockton	4,828	3,565	-1,263	-26
Contra Costa Co. WD	18,414	14,633	-3,781	-21
Santa Clara	3,789	2,921	-868	-23
San Mateo	2,302	1,492	-810	-35
Daly City	1,440	1,025	-415	-29
Hayward	2,737	1,756	-981	-36
Sunnyvale	3,963	2,859	-1,104	-28
Marin MWD	3,934	1,848	-2,086	-53
North Marin Co. WD	1,160	717	-443	-38
Santa Rosa	2,263	1,424	-839	-37
Subtotal	142,118	100,678	-41,440	-29

TABLE 3-2 (Continued)

City	Jan. 1, 1976– June 30, 1976	Jan. 1, 1977– June 30, 1977	Difference	Difference in Percentage
Fresno	10,297	7,658	-2,639	-26
Bakersfield	7,539	6,087	-1,452	-19
Modesto	5,016	3,887	-1,129	-23
Merced	2,043	1,385	-658	-32
Monterey Bay	2,652	1,414	-1,238	-47
Sonora-Jamestown	267	200	-67	-25
Subtotal	27,814	20,631	-7,183	-26
Los Angeles	94,983	82,335	-12,648	-13
Long Beach	10,873	9,148	-1,725	-16
San Diego	25,344	23,584	-1,760	-7
Anaheim	8,479	7,530	-949	-11
Riverside	6,755	5,919	-836	-12
Santa Barbara	2,376	1,926	-450	-19
Oxnard	2,802	2,649	-153	-5
Ventura	3,463	2,799	-664	-19
San Luis Obispo	1,041	924	-117	-11
Santa Maria	1,297	1,068	-229	-18
Subtotal	157,413	137,882	-19,531	-12
Total Reported	331,601	262,662	-68,939	-21

SOURCE: From The California Water Atlas (1978).

DEVELOPMENTS SINCE 1977

Because of the dramatic urban water conservation achievements during the drought there was, during 1977, substantial debate regarding whether the per capita water use assumptions for water planning should be substantially reduced to reflect an enlightened new "urban water ethic." Unfortunately, water use habits of Californians, from both the north and south, have proved difficult to modify. Table 3-3 shows that per capita water use has returned to near predrought levels in most cities, even though many cities continue with water conservation programs.

A recent news article reported that even though water use in Marin County had returned to predrought levels, the public perception was that they were still conserving. In one survey, 45 percent of the people responded that they were already doing all that they could do to conserve. Another survey in California determined that 80 percent of respondents felt that substantial water could be conserved, but only 30 percent believed that they personally could conserve water.

Another interesting development relates to the public's growing recognition that 85 percent of the water used in California is used for agriculture and that less than 15 percent is used for all urban purposes. Much attention has focused on the alleged waste of water by the Imperial Irrigation District, the largest agricultural district in California. As a result of continuing pressure, preliminary approval has been given to a plan to conserve 100,000 acre feet per year (approximately 90 million gallons per day) by lining canals and reducing water losses. The conserved water would be made available to urban Southern California, which would reimburse Imperial $10 million annually to develop the conservation programs. This proposed transaction has stimulated a growing debate regarding the need for developing a "free market" to permit water to be sold to the highest bidder, just as any other commodity.

WATER PLANNING IN CALIFORNIA

Most urban areas of California, whether the San Francisco Bay area or Los Angeles or San Diego, depend

TABLE 3-3 Water Use in California Cities (Gallons Per Person Per Day)

City	Calendar Years 1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
EBMUD (Oakland, etc.)	178	190	115	138	146	164	163	175	159	180
Fresno	241	240	194	215	244	230	226	208	266	297
Humboldt Bay (Eureka, etc.)	134	136	118	135	146	148	146	141	141	144
Los Angeles	170	174	149	147	159	163	170	159	173	185
Marin Municipal	143	109	49	99	115	126	130	132	135	144
Modesto	345	330	293	304	332	327	358	313	353	390
Riverside	222	258	197	204	224	222	233	216	211	269
Sacramento	279	306	258	276	289	309	310	285	259	283
San Diego	178	193	180	173	175	185	192	192	176	189
San Jose Waterworks (private company, serves most of the San Jose area)	173	184	142	158	165	167	172	165	188	209
Santa Barbara[a]	170	165	145	141	148	155	164	160	174	183

[a]Fiscal year starting May 15.

NOTE: Figures are based on total water sales and total population served, fiscal year starting July 1.

for most of their water on long aqueducts from either the Sierra Nevada, the Sacramento Delta, or the Colorado River. In addition, there are 9 million acres of irrigated lands that are also supported by similar aqueduct systems moving water great distances (see Figure 3-1).

The management of California water systems involves all levels of government--federal, state, 20 different special districts, counties, cities, the other six states of the Colorado Basin, and even Mexico. The abundance of water in the rural north and the need for water in the more arid areas from San Francisco south gives most major water planning activities a statewide character. For that reason, the state legislature has been the focal point of three major efforts in the last eight years to develop a statewide program to complete the State Water Project, which voters approved narrowly in 1960 and which today can meet only one-half of its contractual commitments. Although one of these legislative proposals was approved by 60 percent of the legislators in 1980, it was subsequently repealed in a statewide referendum, which 60 percent of southern voters approved but which 90 percent of northerners rejected.

The extreme difficulty of achieving a statewide consensus on water development in the face of continued population and economic growth, together with the future loss to Arizona of more water than is used by the City of Los Angeles, raises the specter of more frequent drought shortages in the years ahead. There is little question that all aspects of drought management will get increasing attention from water professionals, environmental organizations, and government leaders, but how the decision-making will take place is difficult to forecast.

POTENTIAL CONSEQUENCES OF URBAN WATER SHORTAGES

Serious consideration needs to be given to the potential magnitude of the urban water shortage in order to consider which decision-makers should be involved in deciding what constitutes acceptable risk for shortages. For example, if the shortage is to be one of limited duration or severity that can be accommodated by short-term conservation programs (such as odd and even days for lawn watering), perhaps such decisions could be

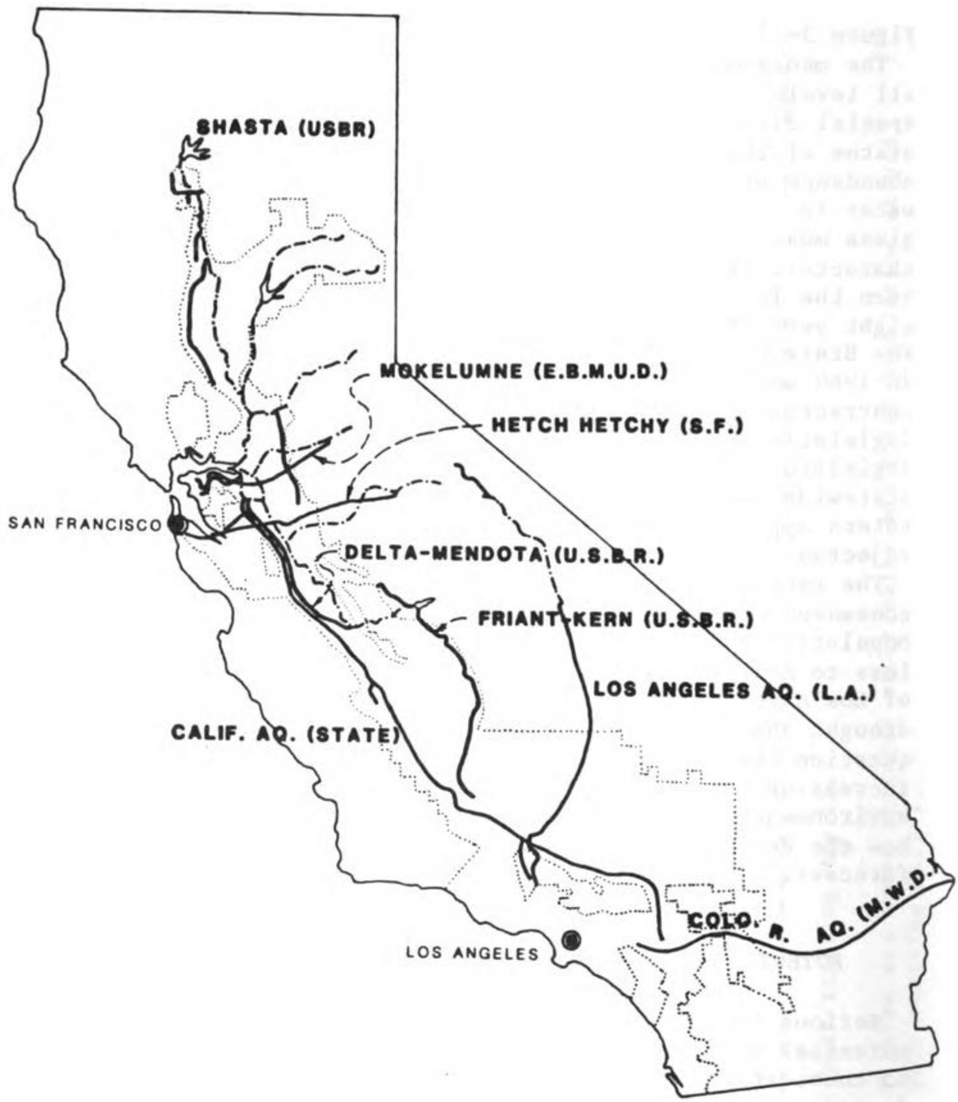

FIGURE 3-1 California water transfer facilities.

made by the local water utility board. On the other hand, if the potential water shortage would necessitate "Hong Kong" type rationing, where the public water supply system would operate only a few hours per day to conserve a very limited resource, the decisions should be made by general government and elected officials, since important public safety considerations are involved. (Profound impacts on the public include diminished fire protection and greater contamination threats because of backflow potential into unpressurized water mains.) Even if the potential water shortage is well short of a "Hong Kong" type of shortage, local government should almost certainly be involved in the planning stages, since many of the drought management options require the leadership of top elected officials to convince the public of their necessity. Other options require the exercise of police powers, which are available to local general government, but which are usually not available to the local water utility board.

URBAN AND AGRICULTURAL COMPETITION AND COOPERATION

Following the drought of 1977, there developed some support for the notion that urban water users are more able to conserve than farmers and perhaps contractual provisions which require agriculture to take the first shortages should be reversed to require urban users to accept initial shortages.

As discussed above, urban users developed substantial sympathy for water-short farmers during the 1977 drought. Whether this sympathy would have continued into 1978, if it had been a third dry year, is very uncertain particularly if urban users had become generally aware that total irrigated acreage slipped very little in 1977 and that productivity actually increased in several major areas (see Table 3-1).

In normal water supply years, over 10 million acre feet per year of water is used to irrigate alfalfa and cotton. Some critics of California water development have suggested that, since these crops have a gross value of only about $1 billion per year or about $100 per acre foot, during drought periods alfalfa and cotton production could be curtailed to provide water (at a profit to the alfalfa and cotton farmers) for urban users and higher valued agricultural commodities. These simplistic proposals, however, fail to consider that while such financial transactions might be very appealing, they do not usually suggest any form of compensation to third parties such as farm workers, crop dusters, farm equipment dealers, and the myriad other support businesses and employees. Even local governments have their concerns because of potentially reduced tax levies and increased welfare costs.

A more likely, near-term, scenario of urban and agricultural cooperation would be expansion of the above-mentioned pending transaction between the Imperial Valley and the Metropolitan Water District of Southern California. The concept of using urban dollars to increase the efficiency of agricultural water use while maintaining farm production provides a win-win-win solution including benefits, not detriments to virtually all third parties including workers, support businesses, and even local tax collectors.

PUBLIC COMMITMENT

As discussed, the success that urban areas in California achieved in reducing water use (see Table 3-2) has lead to speculation that sharp reductions in urban use could be easily achieved again in the future. Water planners and those involved in public policy development in this area should keep in mind that mandatory conservation and rationing programs lasted a relatively short time. By early November 1977, when heavy statewide precipitation mercifully arrived, most urban water customers and public officials were growing weary of the problems and nuisances of living with the water shortage. For example, in the City of Los Angeles, which had implemented water rationing for the first time in the 75-year history of the municipal water system, 85 percent of the water customers were meeting their water conservation goals; however, this still left approximately 100,000 different residential, commercial, and industrial customers who were in violation. Under the City's Emergency Water Conservation Plan (see Appendix A), these 100,000 customers were scheduled to have flow restrictors installed on their service lines during November and December of 1977 at a minimum charge of $25 per customer. The logistics of such an effort and the enormous customer relations problem associated with it would almost certainly have forced the Los Angeles City Council to modify this portion of the emergency plan, and of course any weakening of the plan would bring loud complaints from the 85 percent of the customers who were, at some expense and inconvenience, meeting the plan's requirements. The experiences with emergency water ordinances in Marin County, San Francisco, and dozens of other California communities were very similar to that being experienced in Los Angeles. One can only speculate on the political, administrative, legal, and other problems that would have resulted if the drought had extended through 1978.

As discussed above, it is very likely that the continuing high rate of agricultural water use in California would eventually have come to the attention of urban areas and very likely undermined the enthusiasm of urban areas for maintaining the increasingly less popular restrictions.

The success of urban water conservation in 1977 was undoubtedly due to the public recognition of a real and widespread problem and the perception that water restrictions and penalties were being fairly administered. Public commitment to water conservation would likely erode quickly if financial penalties and other restrictions were perceived as not being enforced. For example, water agencies in New Jersey experienced substantial public backlash a few years ago when financial penalties imposed during the drought on a number of large customers were waived upon easing of the drought.

WATER AGENCY RESPONSIBILITY

If the public feels that water agencies are managing water supplies responsibly and efficiently, they will be more likely to support proposed conservation measures in emergency situations. The ability to extend supplies during water-short periods is important to public confidence.

One important way to extend water supplies and increase flexibility during emergency situations is through the increased use of ground-water storage basins. Additional wells and distribution lines can be constructed to give greater ability to pump ground water when other sources grow scarce. Conversely, pumping can be curtailed in wet periods and recharge programs can be expanded to ensure that basins will be adequately full to handle emergency situations.

FINANCIAL AND INSTITUTIONAL PROBLEMS

In California, with its multitude of different levels of water agencies, there are major legal and contractual problems associated with drought management planning. In Southern California, there is a large wholesale water agency, the Metropolitan Water District of Southern California (MWD), which provides supplemental water to Los Angeles, San Diego, and 24 other cities and water districts. The MWD Act provides that each member agency has a preferential right to purchase water based on the proportion of property taxes paid by each member agency. When the 1977 drought occurred, the City of Los Angeles had a preferential right to 30 percent of the MWD supply, and San Diego County had a right to 10 percent of that supply. (Normally, Los Angeles uses only 2 percent of the supply, and San Diego uses 25 percent.) However, during 1977 for a variety of complicated legal and political reasons, the City of Los Angeles imposed water rationing and was able to limit its use of MWD water to approximately 7 percent of the MWD supply, or one-fourth of its legal right, whereas San Diego did not impose rationing and purchased 27 percent of the MWD supply or almost 3 times its legal right. There is no suggestion of impropriety on San Diego's part intended by these remarks, merely a statement of what took place during the 1977 drought. It is likely that the events of 1977 would receive considerable attention when a water shortage within the MWD service area occurs at some future time.

This issue remains a matter of considerable interest in both Los Angeles and San Diego, since Los Angeles continues to pay property taxes that are approximately $19 million per year, and San Diego only pays $10 million. There is also extensive debate with MWD at the present time as to whether the entire preferential right concept should be modified or abolished, given the fact that preferential rights have never been used to allocate water during a time of shortage.

Solutions with acceptable public risks for drought management are elusive. The above example has been debated for more than two decades. The hundreds of other water agencies throughout California have institutional and financial relationships of similar complexity.

DROUGHT MANAGEMENT DECISION-MAKING

Since the consequences of urban water shortages are potentially very serious and involve great numbers of people, the decision-making unquestionably must take place by the elected officials. Given the great uncertainty about the timing or severity of future droughts, water officials are understandably reluctant to "cry wolf" and urge elected officials to immediately begin development of what would have to be fairly complicated water curtailment ordinances. There is a concern that pressure by the water managers for such ordinances would be perceived as merely a poorly disguised "hype" for additional expensive water projects.

In the case of the City of Los Angeles, there is an existing Emergency Water Conservation Ordinance (see Appendix A), which was hastily developed during the spring of 1977 to deal with the water shortage of that time. Although the ordinance is far from perfect, it at least provides a standby mechanism that could be triggered in the event of some future water shortage and perhaps fine-tuned on rather short notice.

Other cities and counties that do not currently have in place such ordinances will probably do as Los Angeles did, namely, wait to implement such a plan until conditions demand such action.

Leaving the development of water curtailment ordinances to over 100 cities and counties in Southern California is clearly a fragmented approach to dealing with a regional problem; however, since the regional agency, MWD, is a special district without the police powers of general purpose government, it is difficult to conceive how regional water curtailment plans could be implemented even in the presence of a severe drought. The same is true for a statewide water curtailment program. Although the state legislature has adequate police power, the water supply issues become almost hopelessly complicated with thousands of different water purveyors with vastly different circumstances and involving both agriculture and urban water supplies.

CONCLUDING REMARKS

The experience of the 1976-1977 drought in California demonstrated that, at least over a limited period of approximately 6 months, urban areas are capable of achieving imaginative and substantial reduction in water use. It is far from clear how the achievements of 1977 can be translated into some rational quantitative risk management approach to water supply planning, given the impossibility of predicting when and how future droughts will unfold. Perhaps, the best that can be achieved is for the water managers to be familiar with the variety of strategies that succeeded and those that failed for implementation of appropriate ones on an ad hoc basis during future water shortages. As crises occur, drought management will continue to improve as we build upon past experiences.

California in 1985 is experiencing a year almost as dry as 1976. The hot, dry weather is causing reservoir levels to drop sharply throughout the state (with the exception of the Colorado River, which this year is above normal) causing farmers and city dwellers to wonder whether 1986 will bring the repeat of 1976-1977 drought. Perhaps by September 1986, California will have some new chapters to add to our drought contingency plans and perhaps the subject of drought management will be receiving even greater attention than it is today.

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4

DROUGHT MANAGEMENT OPTIONS

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Many municipal water systems face a risk of having major disruptions in water supply during droughts. The level of risk for any existing system can be assessed by preparing a probabilistic forecast of potential water supply deficits during a stated planning period. Such a forecast is obtained by comparing the probability distribution of the future availability of water in supply sources with the long-term forecasts of water requirements.

The systems facing a high level of risk can reduce their vulnerability to shortages by expanding the capacity of supply sources or implementing nonemergency demand management programs. If the level of risk is low or moderate, the best strategy may involve formulation of drought contingency plans to cope with actual emergencies.

This chapter summarizes the conceptual approaches to planning for droughts and presents a method for developing an optimal strategy for mitigation of water deficits caused by droughts.

THE "DESIGN DROUGHT" APPROACH

The traditional approaches to water supply planning treat the question of droughts as a part of the capacity expansion problem. Theoretically, the capacity expansion problem should be solved by balancing the cost of water supply augmentation projects against the expected damages that may result from recurrent shortages of water caused by droughts. However, the expected long-run drought damages are difficult to estimate, since both the hydrologic variability of supply sources and the economic consequences of periodic disruptions of water supply are not adequately defined. Faced with inadequate data, water resource engineers devised a compromise solution that balances the cost of additions to supply capacity against the increments in the reliability of a water system.

The term "reliability" is related to the expectation of water supply sources to sustain a stated level of supply over time. Assuming that the hydrologic variability can be described by a reasonably well known probability distribution, reliability is defined as the probability that a desired outcome (or level of supply) will take place. In relation to droughts, the desired outcome is usually defined as the "safe yield" which determines the output of a supply project (or a combination of projects) that can be maintained during a severe drought, such as the worst drought in the historic record.

In practice, the balancing of the cost of supply additions against the increments of reliability is reduced to the selection of a "design drought." In most applications, either the worst drought on record or a 100-year drought is chosen as the basis for deciding on the excess capacity of a water supply system. Since the design drought implicitly sets the magnitude of the economic losses that may be incurred, the selection of the probability of such a drought (or its recurrence interval) must assume that the incremental damages that may result from recurrent shortages of water (caused by droughts more severe than the design drought) during the planning horizon are balanced with the incremental costs of the additions to supply capacity.

Typical capacity expansion projects usually involve the construction of new facilities for water storage, treatment, and transmission. In recent years, however, a number of unconventional alternatives have also been considered. These may include the following:

1. more efficient utilization of existing water supplies (e.g., pumped storage or reduction of losses),
2. use of ground-water aquifers for storage of excess supply of surface water,
3. interbasin importation,
4. desalination of seawater or brackish ground water,
5. reclamation of waste water, and
6. implementation of cloud-seeding projects.

Using the design drought approach, the optimal combination of projects and the dates of their completion are determined by minimizing the cost of their implementation subject to the constraint that the safe yield is at least equal to the requirements for water at any time during a prescribed planning horizon.

While structural solutions to water supply planning might have been efficient in the past, the cost of some unconventional supply augmentation projects have made this "fail-safe" approach to droughts prohibitively expensive for many existing systems. As a result, water resource planners have been forced to extend their perspective to include nonstructural alternatives. A combination of supply augmentation and long-term demand management projects has the potential for affecting the position of a water system, with respect to the risk of recurrent water deficits, by not only increasing supply but also by reducing future water use. The demand management projects that can substantially reduce future water use may include the following:

1. campaigns to educate the consumers on how to modify water use habits to reduce water consumption,
2. promotion or a mandatory requirement of use of water-saving devices and appliances,
3. promotion or a mandatory requirement of low-water-using landscaping,
4. adoption of efficient marginal cost pricing, and
5. adoption of zoning and land use policies to control the number of water users served by the system.

Although the inclusion of demand management projects may reduce the overall cost of the long-term adjustments to droughts, it does not eliminate the problems associated with the arbitrary selection of the design drought. This is true in cases where the minimum-cost combination of the supply augmentation and nonemergency demand management projects is determined subject to the constraint that the safe yield is at least equal to the anticipated future water requirements with conservation at any time during the planning period. Also, the reliance on demand management projects introduces two additional sources of uncertainty that are associated with the effectiveness (water savings) and the cost of water conservation measures.

Overall, the long-term adjustments to droughts can effectively reduce the magnitude and the frequency of potential water deficits; however, the criterion of the design drought with arbitrarily established levels of acceptable severity and unknown economic consequences is inadequate for developing optimal drought mitigation plans. Due to the rising costs of supply augmentation projects, the use of the design drought approach is very likely to lead to suboptimal plans in which the incremental cost of system reliability considerably exceeds the actual cost of shortages.

DROUGHT EMERGENCY PROGRAMS

The formulation of the capacity expansion problem described in the previous section assumes that the costs of water shortage are prohibitively high and the situations in which the capacity falls below requirements are not permitted except for droughts more severe than the design drought. During an actual emergency, the knowledge of the system's safe yield is of limited value to the water manager. Since the severity (or recurrence interval) of an ongoing drought cannot be determined with a reasonable degree of certainty, to be on the safe side the manager is very likely to assume that the ongoing drought is more severe than the design drought. To keep the risk of running out of water reasonably low, the manager will always try to adjust the demand for water by imposing increasingly severe water use restrictions to forestall more severe cutbacks that may be required if the perceived shortage of water materializes at later stages of the drought.

Past drought experiences show that the actions of water managers can greatly influence the magnitude of the monetary and nonmonetary losses from the drought. Although the manager apparently has little choice but to pass (or create) water shortage to the customers, the drought literature documents a great variety of drought emergency measures undertaken in response to anticipated shortages of water. Generally, these measures fall into three broad categories:

1. demand reduction measures,
2. improvements in efficiency in water supply and distribution systems, and
3. emergency water supplies.

Table 4-1 classifies specific drought management options according to these three categories.

Each urban area has considerable potential for temporary reduction of "normal" water consumption during drought emergency without significant costs or inconvenience to consumers. However, when the emergency actions are undertaken as uncoordinated ad hoc responses to changing storage conditions, the cost of these actions may be substantial. For example, high cutbacks in water delivery may very rapidly increase the losses suffered by local economies, especially when industrial output must be reduced. Therefore planning for water deficits in the long run should begin with the minimization of the cost of short-term deficit management programs. The central question is how potential water shortages can be averted at minimum cost to the supplier or, alternately, to the region served by the water utility.

The information that would aid the most water managers in coping with water deficits during an actual drought is the following:

1. the level of deficit most likely to result from an ongoing drought if no action is taken,
2. the effectiveness of specific drought management measures (i.e., the quantity of water saved or obtained due to the implementation of the measure), and
3. the total cost of individual measures including the economic losses resulting from cutbacks in water delivery.

Given this information, the manager would be able to devise a drought emergency program that would alleviate the expected deficit at the minimum cost.

An important consideration in the formulation of minimum-cost drought emergency plans is that it is not likely that one emergency program can be optimal for all droughts that may occur during the planning period. The "best package" of various drought management measures may be different for different sizes of water deficits. Therefore in order to carry out a complete evaluation of drought management alternatives, it is necessary to develop a probabilistic forecast of future water supply deficits. Alternately, separate plans may be formulated for coping with deficits of increasing magnitudes, for

TABLE 4-1 A Typology of Drought Management Options

I. Demand Reduction Measures

1. Public education campaign coupled with appeals for voluntary conservation

2. Free distribution and/or installation of particular water saving devices:

   2.1 Low-flow showerheads
   2.2 Shower flow restrictors
   2.3 Toilet dams
   2.4 Displacement devices
   2.5 Pressure-reducing valves

3. Restrictions on nonessential uses:

   3.1 Filling of swimming pools
   3.2 Car washing
   3.3 Lawn sprinkling
   3.4 Pavement hosing
   3.5 Water-cooled air conditioning without recirculation
   3.6 Street flushing
   3.7 Public fountains
   3.8 Park irrigation
   3.9 Irrigation of golf courses

4. Prohibition of selected commercial and institutional uses:

   4.1 Car washes
   4.2 School showers

5. Drought emergency pricing:

   5.1 Drought surcharge on total water bill
   5.2 Summer use charge
   5.3 Excess use charge
   5.4 Drought rate (special design)

TABLE 4-1 (Continued)

6. Rationing programs:

   6.1 Per capita allocation of residential use
   6.2 Per household allocation of residential use
   6.3 Prior use allocation of residential use
   6.4 Percent reduction of commercial and institutional use
   6.5 Percent reduction of industrial use
   6.6 Complete closedown of industries and commercial establishments with heavy uses of water

II. System Improvements

1. Raw water sources:

   1.1 Reservoir/lake evaporation suppression
   1.2 Reduction of dam leaks
   1.3 Transfer of surplus water between reservoirs
   1.4 Pumped reservoir storage

2. Water treatment plant:

   2.1 Recirculation of washwater
   2.2 Blending impaired quality water

3. Distribution system:

   3.1 Reduction of system pressure to minimum possible levels
   3.2 Implementation of a leak detection and repair program
   3.3 Discontinuing hydrant and main flushing

III. Emergency Water Supplies

1. Interdistrict transfers:

   1.1 Emergency interconnections
   1.2 Importation of water by trucks
   1.3 Importation of water by railroad cars

TABLE 4-1 (Continued)

2. Cross-purpose diversions:

   2.1 Reduction of reservoir releases for hydropower production
   2.2 Reduction of reservoir releases for flood control
   2.3 Diversion of water from recreation water bodies
   2.4 Relaxation of minimum streamflow requirements

3. Auxiliary emergency sources:

   3.1 Utilization of untapped creeks, ponds, and quarries
   3.2 Utilization of dead reservoir storage
   3.3 Construction of a temporary pipeline to an abundant source of water (major river)
   3.4 Reactivation of abandoned wells
   3.5 Drilling of new wells
   3.6 Cloud seeding

example: 10, 20, 30, or 50 percent of unrestricted water requirements in any year of the planning period.

The critical point in the formulation of drought emergency plans is the evaluation of specific emergency actions such as those listed in Table 4-1. The purpose of the evaluation of individual measures is to prepare an array of applicable, technically feasible, and socially acceptable conservation practices together with the information on quantities of water saved and the expenditures and monetary losses associated with their implementation.

The specific steps in the evaluation of demand reduction measures must include the following:

1. determination of technical feasibility, i.e., the capability of a given measure to produce a reduction in water use upon implementation,

2. determination of social acceptability to predict the probable response to the measure of various sectors of the community,

3. analysis of implementation conditions to identify the agencies responsible for implementation and to define the temporal and sectoral coverage of each measure,
4. determination of effectiveness, i.e., the reduction in water use that can be attributed to the implementation of each measure,
5. determination of the utility's expenditures on implementing the measures, and
6. determination of the economic losses resulting from cutbacks in water delivery borne by the customers in various sectors of local economy.

The identification and evaluation of emergency water supplies must follow similar steps; however, the information sought is of different character and it includes the following:

1. availability and quality of water in potential emergency sources during persisting dry weather conditions,
2. adequacy of existing treatment facilities to produce finished water of acceptable quality when emergency supplies make up some fraction of raw water supply,
3. lead time required to construct necessary water transmission and pretreatment facilities (if required),
4. construction and operation-maintenance costs required to bring emergency sources on line,
5. forgone benefits associated with cross-purpose diversions of water from alternative uses, and
6. potential legal and institutional considerations involving permits, rights to water, or easements for transferral systems.

The descriptive data on individual drought management options produced through these steps allow the manager to formulate optimal (minimum cost) drought emergency plans corresponding to deficits of varying magnitudes occurring in different points in time during the planning period.

The selection of an emergency plan for implementation during an actual water crisis should be preceded by the determination of the expected magnitude of supply deficit. Preliminary actions of the water manager are contingent upon some indication of potential water shortage. When a shortage alert is in effect, the manager should initiate the analysis to assess the likelihood of water deficit. A probabilistic forecast of supply deficits can be developed by comparing the probable levels of supply in the short-term with short-term forecasts of unrestricted water demand. Provided with a cumulative probability distribution of water deficits that may be caused by the ongoing drought, the manager may either choose the expected deficit (expected value) or a volume of deficit with a "sufficiently" low probability of occurrence and match it with the corresponding minimum-cost shortage mitigation plan defined during the drought preparation stage. If after the implementation of the selected plan it becomes apparent that the volume of deficit will be different than predicted, the appropriate adjustments are made based on revised estimates of the supply deficit.

An alternative approach to managing of actual drought emergencies involves a sequential implementation of increasingly severe shortage mitigation measures as the supply conditions become more critical. Although this approach eliminates the need to assess the risk of shortage at the onset of a drought, the overall cost of coping with emergency may be higher, since the measures capable of providing substantial increases in supply (or water savings) at relatively low cost are not likely to be used during the critical period of the drought. When the drought emergency decisions are geared to the expected magnitude of supply deficits, the most effective measures are likely to be used at the earlier stages of the drought, and the decision as to when in the course of a drought to introduce and terminate emergency measures becomes less critical.

MINIMIZING THE LONG-RUN COST OF COPING WITH DROUGHTS

The use of the minimum-cost plans during actual emergencies does not imply a simultaneous minimization of the long-term cost of coping with shortages. It is reasonable to expect that a system that has to resort to emergency measures every year or even every five years can deal with supply deficits more effectively by expanding the capacity of supply sources and/or implementing nonemergency water conservation programs.

The need for expanding supply capacity of an existing system can be assessed by using the expected value of the cost of coping with drought emergencies during the planning period. The expected value of the coping cost is a common metric for comparing the alternative long-term adjustments to drought. For any given water supply system, the expected value of the cost of coping with emergencies can be determined on the basis of the probabilistic forecast of supply deficits and the cost of drought emergency plans. For each future year, minimum-cost drought emergency plans are determined for a range of possible supply deficits. The probability of occurrence of these deficits is assigned to the cost of the corresponding emergency plans so that higher costs associated with large volumes of deficit have lower probability. The expected value of the coping cost in each year is found by summing the products of the costs and their respective probabilities. For a specified planning period, the expected values of annual costs are reduced to a single number by finding the sum of the present worths of the expected values of coping costs in each future year. This number represents the expected value of the cost of coping with water deficits in the long run.

The expected value of the long-term costs to cope with emergencies in the supply of water allows water planners to examine the trade-offs between the short-term and the long-term adjustments to droughts. Any combination of the long-term supply augmentation and demand management projects will affect the probability distribution of supply deficits in each future year thus resulting in the new expected value of the long-term cost of coping with emergencies.

Theoretically, the optimal strategy for dealing with droughts would be determined by balancing the incremental cost of the long-term adjustments with the decrements of the cost to cope with emergencies. However, the optimal solution selected in this manner would be based on the comparison of the relatively certain costs of system expansion with uncertain expenditures and economic losses during droughts. A more appropriate approach would be to compensate for the differences in uncertainty by assigning subjective weights to each of the two cost categories.

AVAILABILITY OF ANALYTICAL TOOLS

A more complete elaboration of the drought planning approach outlined in this discussion is given in Dziegielewski et al. (1983a,b). This approach follows the concepts and decision criteria formulated by Russell et al. (1970), Young et al. (1972), and Russell (1979). The practical application of this method largely depends on the availability of analytical tools for forecasting the water supply and demand. There exists a large body of literature on forecasting water supply. The methods most relevant to drought planning are described by Stall and Neill (1963), Lampe and Smith (1982), and Sheer (1980). The methods for forecasting water demands are also available. A computerized water use forecasting system known as IWR-MAIN (Crews and Miller, 1983) is most useful for the evaluation of drought management alternatives, since it estimates water use at a highly disaggregate level based on demographic and socioeconomic characteristics of the water service area.

Although further refinement of forecasting methods can considerably improve the planning for water deficits, the most critical research needs are related to the measurement of the effectiveness and costs of various emergency actions. A complete evaluation of short-term drought management measures will allow water utility managers to make more informed decisions during crisis situations and will also result in more efficient long-term water supply planning.

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5

LEGAL AND INSTITUTIONAL ASPECTS OF DROUGHT MANAGEMENT

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When water is available at the right place and in ample quantities, almost any system of law will work. When water is not available, no system of law can provide it. However, an efficient system of water law can facilitate optimum use even during a drought.

Because the amount of water made available by nature is erratic, cities and municipal-type districts almost everywhere are confronted with periods of drought. In order to provide for adequate water during drought periods, the municipality would need to develop a water-supply system that would be in excess of its needs during normal times and substantially in excess of its needs during wet cycles. If this is not done, then during drought conditions there is inadequate water. The only available alternatives are to develop or secure additional water on a temporary or permanent basis, or to ration the use of the available water. The people on the system cannot be left to sort out the problem. Those on the lower end of the system can drain the water away from those in the higher parts of the system, leaving the latter totally without water. If there is an overdraft on the entire system, pressures drop, and the area is left without fire protection. Rationing can maintain pressures and assure that the limited water is available for the critical uses. Lawn watering, which in the West is the biggest use of water, and other nonessential uses can be either limited or totally prohibited.

Streams everywhere in the West reach their flood stage in the early spring before the heavy use period arrives in the cities. The spring runoff normally occurs in May. The peak use develops in the hot days of July and August, by which time the streamflows have receded.

Thus, heaviest use is at a time when streams are low. Then on a daily basis there are periods of peak use. These start about 4:00 p.m. and end by about 11:00 p.m. There is little use of water between 11:00 p.m. and 6:00 a.m. Direct flow water will thus waste unless there is storage. On long weekends much of the population leaves the city. The people all return at about the same time. Their lawns are dry, they need to wash their cars and take baths, and so on, and abnormal demands are placed on the system.

SYSTEM NEEDS

In the semiarid West a city needs a substantial amount of surface storage where winter water and the flood waters that are available can be stored. This storage capacity needs to be adequate not only to take care of heavy use during the hot summer months, but also--this is desirable, if not necessary--to provide enough storage capacity to permit water to be stored and carried over two or three years. With carry-over storage, the water accruing during wet cycles can be carried over to provide some water during dry cycles. The system also needs an aqueduct from the storage reservoir to the area of use with capacity to supply large quantities of water during periods of peak summer use. Generally, it is also necessary for a city to provide a water treatment facility with capacity equal to the capacity of its aqueduct. Then to make it possible to operate these facilities 24 hours a day during periods of peak use, the city needs storage for treated water so that water can be stored when use decreases. The system also needs strategically located distributional (overnight) storage reservoirs that can be filled during the period after 10:00 p.m. to help meet the heavy demands that will develop the following day.

For example, in one large district in Salt Lake County, the daily needs in January of the 450,000 people served by the district can be met with a flow of approximately 30 cubic feet per second (cfs). During periods of peak use in August the same district needs to provide a flow of 260 cfs. In all of Salt Lake County we are endeavoring to develop facilities and water supplies adequate to provide peak daily flows of approximately 1,200 cfs. A good well in Salt Lake

Valley will produce from 3 to 5 cfs and while these wells help in a variety of ways, the facilities described--a large reservoir, a large aqueduct, a large treatment plant, treated water storage, and distributional storage--are needed.

The objective of rationing is twofold; first, to cut the total amount of water being consumed; and, second, to spread out the use so that the peak demands are not so high. The power of cities and municipal-type districts to impose rationing is generally established by statute and court decision.

ORGANIZATIONS THAT SUPPLY WATER

There are various types of organizations that supply water. These include cities and towns, municipal-type water districts, privately regulated water utilities, and unregulated mutual water companies, which furnish water only to their stockholders. The source and extent of the power these organizations may exercise over the water may differ. Cities and towns have some governmental powers and by ordinance may within their legal authority enact regulations that have the force of law. In Utah, for example, the state legislature has provided:

> 10-7-12. Scarcity of water--Limitation on use. In the event of scarcity of water the mayor of any city or the president of the board of trustees of any town may, by proclamation, limit the use of water for any purpose other than domestic purposes to such extent as may be required for the public good in the judgment of the board of commissioners or city council of any city or the board of trustees of any town.

Water districts are creatures of statute with limited governmental powers. In Utah there are four types of water districts, each operating under different statutory authority. These include water conservancy districts created under the authority of Title 73, Chapter 9; metropolitan water districts, created under Title 73, Chapter 8; local improvement districts, created under Title 17, Chapter 6; and county service areas created under Title 17, Chapter 29. Generally, these statutes do not provide express power to ration water but do contain general grants of power authorizing the districts to acquire water systems and adopt rules and regulations for the use of water. These statutes would generally be broad enough to permit rationing.

For example, on conservancy districts, S73-9-28, U.C.A. 1953, as amended, provides that the water conservancy district board shall have the power to make and enforce rules and regulations concerning "management, control, delivery, use and distribution of water." S73-8-21 grants to metropolitan water district boards the power to construct and control the waterworks systems necessary for the full exercise of its power, and empowers such districts to enact ordinances, resolutions, and orders necessary for the management and control of the district's affairs. Improvement districts are authorized by S17-6-3.4 to do all things necessary in the conduct of their affairs and the operations of their properties.

Public utilities would have no governmental power. A utility's right to ration water would have to be provided for in its articles of incorporation and/or its rules and regulations, all of which would be approved and regulated by the public service commission. Mutual water companies are private water companies that furnish water only to their stockholders, and their power would be reflected in the articles of incorporation and by-laws of each company.

CONTRACT PROTECTIONS

It is also possible when the customer applies for water to have the customer enter into an agreement with the entity furnishing water to the effect that the customer will abide by the lawful rules and regulations of the city or municipal-type water district or utility. The contract can provide remedies, including the contractual right to ration in the event of shortage. The right of an individual to receive water from a public system on a nondiscriminatory basis does exist. However, every user can be required to sign an application for water service, and the essential elements of a program to adjust to drought conditions can be made a part of that contract. The entity furnishing water can adopt rules and regulations and the user can be required contractually to agree to abide thereby. Remedies for noncompliance can include an injunction, the right to shut off the water for noncompliance, and this, coupled with a turn-on fee high enough to encourage general compliance, can be imposed. The agreement can provide for attorney fees and court costs for collection or enforcement. I have created and during the early years of their existence have represented numerous water districts, mutual water companies, and public-utility-type water companies--none of which have governmental powers. These application-type contracts have been widely and successfully used by the various types of water organizations that I have represented over the past 40 years or so.

POWER TO REGULATE

A number of Utah cases have dealt with the powers of these entities to regulate the use of water. For example, in Interwest Corporation v. Public Service Commission, 29 Utah 2d 380, 510 P.2d 919 (1973), a developer had sold building lots in a relatively large development that was served by a public utility created and owned by the developer. With each building lot sale a commitment had been made for water. When all of the lots were developed, the total supply of the utility would have been committed. However, initially many of the lots were vacant. A customer on the system wanted to increase substantially the density of condominium housing units to be constructed on land that he had purchased. The utility denied the extra water. The Utah Supreme Court held that the utility had to supply the water on a first-come, first-served basis. A similar result was reached in North Salt Lake v. St. Joseph Irrigation and Water Co., 118 Utah 600, 223 P.2d 577 (1950).

In McMullin v. Public Service Commission of Utah, 7 Utah 2d 157, 320 P.2d 1107 (1958), the court held that a public service water company was not required to furnish service to property owners not reasonably within its service area, particularly where the extension of service would impair the water supply of those already connected to the system. A similar result was reached in Rose v. Plymouth Town, 110 Utah 358, 173 P.2d 285 (1946).

One of the more comprehensive discussions on the power of a municipal-type district to ration water is presented in Swanson v. Marin Municipal Water District, 56 Cal. Appl. 3rd. 512, 128 Cal. Rptr. 485 (Cal. Ct. App. 1976). There a municipal water district had by ordinance amended its rules and regulations to provide that no new water service would be granted or installed except under certain limited circumstances. The ordinance was based upon an objective finding that a threatened water shortage existed and that the ordinary demands and requirements of the water customers could not be satisfied. The new ordinance prohibited the granting of new water service where pipeline extensions would be required, but allowed new service to any person who had an existing water main fronting his property and who had applied for water service within 120 days after the enactment of the ordinance.

The trial court concluded that the district was without statutory authority to prohibit water connections or extensions to inhabitants of the water district, merely because of a dry cycle. The appellate court held otherwise, and in so holding said:

> a water district is empowered to anticipate a future water shortage and to impose appropriate regulations and restrictions where, lacking such control, its water supply will become depleted and it will be unable to meet the needs of its consumers.

The court held that the district could impose a moratorium and was authorized to impose restrictions upon the use of the district's water in any emergency caused by a threatened or existing water shortage. The court held that the district could prohibit the use of water for specific uses that it found to be nonessential and could also deny applications for new service while the shortage continued.

Sabine Offshore Service, Inc. v. The City of Port Arthur, 595 S.W.2d 840 (Texas 1979) corrected on denial of rehearing (1980), involved a water user seeking to force city officials to vacate their water rationing plan. The water rationing plan permitted Sabine, the largest user of water in the area, to use water on alternate days only. Procedure problems and the adoption of a new water rationing plan resulted in the case being remanded to the trial court for a new trial.

The curtailment program must be nondiscriminatory and cannot be arbitrary or capricious. Also, there must be a statutory "underpinnings" granting the power to curtail use. As noted, cities and towns have limited law-making power. Water districts, although generally creatures of statute, have limited governmental powers. Then, as noted, private water companies and mutual water companies have essentially no governmental powers, but they can adopt nondiscriminatory rules, regulations, and rates for the use of water. Where there is the necessary statutory authority, or contractual arrangements, rationing on a nondiscriminatory basis may be imposed. Rationing may include a refusal to make new connections and may also include rationing to existing customers.

THE NEED FOR MANAGEMENT OF DROUGHT CONDITIONS

The problem of drought in the United States was addressed by J. L. Sax, Water Law Planning and Policy (1968 Bobbs-Merrill Co. New York, New York), starting on page 22. He notes that the problem is not so much a problem of shortage as it is a problem of mismanagement.

> . . . This was dramatically emphasized by the Northeast water crisis during the summer of 1965. Drinking water was not served in New York City restaurants while millions of gallons were lost each week in leaky pipes, water ran through air conditioning units (without recycling) into sewers, the cost of wasted water through apartment faucets was zero because of unmetered deliveries at a flat rate, and the Hudson, a mighty river, ran by the city unusable because of pollution.

In Water and Water Rights (R. E. Clark, ed., Allen Smith Co., Indianapolis, Indiana, 1967), volume 7, page 184, the author, Clifton Davis, also makes reference to the City of New York. He cites People on Complaint of Begley v. Morgan, 102 N.Y.S.2d 267 (1951) and states:

> In another New York City case, defendant was convicted of violation of a municipal law prohibiting willful or malicious waste of water on testimony by a city investigator that on two occasions while he was on defendant's premises, he saw water pouring from a hose into a trench and then down a drain for periods of approximately

fifteen minutes each. Defendant was sentenced to fifteen days or a fine of $15.

Metering, so that the customer is charged proportionately to the quantity used, provides a direct economic incentive to conservation, and it, rather than criminal sanctions, is probably the most effective and most widely used method of controlling waste. In an article written before the drought of the mid-sixties ["New York Drowns Another Valley," Harpers Magazine, p. 76, Aug. 1963] Noel Perrin discusses New York City's perennial water shortage and the political problems involved in efforts to introduce universal metering. The reasons behind the city's reluctance to meter are identified as primarily political rather than economic, but Perrin concludes that New York's solution still lies in metering as a method of regulating water usage.

Another method of restricting customer usage is suggested by the Missouri holding [Filger v. Public Water Supply Dist. No. 1, 346 S.W.2d 567, (Mo. App. 1961)] that a private supplier can limit the size of the pipe that is used to tap the supply. . . .

Included in Appendix B is a rationing program actually adopted and put into operation by the Salt Lake County Water Conservancy District, which is a well-managed organization in Salt Lake County, Utah, furnishing water to 450,000 people.

Drought conditions currently exist generally in the Northern Great Plains and in the Northeast. Crop losses in one Wisconsin County alone are put at $23 million. Mandatory conservation is in effect in New York City, 218 northern New Jersey communities, and 25 communities in eastern Massachusetts. New York requires that temperatures go above 78°F before air-conditioning can be used, and buildings cooled with city water can be fined up to $500 for violation. There are also fines for leaks, washing cars and streets, watering lawns, turning on fountains using public water, illegal use of fire hydrants, and filling of private swimming pools. New Jersey imposed a limit of 50 gallons per capita per day for residential users and coupled this with an outright ban on lawn watering, hosing streets, and noncommercial car washing.

Another tool that has been constructively used to reduce the quantity of water consumed is pricing. If the system can provide 6,000 gallons of water per home per month, and thus meet the basic needs, any use above the 6,000 gallons can be discouraged by a reasonable surcharge. I had a situation where a coal mining company (with its own company town) rented employee housing and included water at no extra charge. The company developed some wells, acquired rights in an adjacent stream, constructed a small reservoir and a treatment plant, and so on. This system was not providing enough water for the town during years that were dryer than normal. The next source of available water involved a 1,800-foot pump lift and a fairly expensive reservoir and pipeline. I was retained to acquire the water rights in the adjacent stream and to file applications so that the water so acquired could be removed from that drainage area where it had been used for irrigation and permit its use for municipal and industrial purposes in the adjoining watershed. When I learned that the homes were all unmetered and water was free, I made the suggestion that instead of building the expensive reservoir, pipelines, and so on, they put individual meters on every home and price the water so that the basic water needs would be met at a relatively low monthly cost, but with a surcharge imposed for use above this basic minimum. That recommendation was followed, and it has never been necessary to build the reservoir and the rest to take water from the adjacent stream. The ability to measure and charge for the water used, coupled with a price structure that discouraged unneeded use, solved the problem. Now even in dry years the original system fully meets the needs. (See Sax's Water Law Planning and Policy, page 157, noting such a surcharge. See also The Water Works Board of the City of Birmingham v. Barnes, 448 So.2d 296 (Alabama 1983), reh'g den. (1984), where the court permitted the City Water Works Board to maintain a three-zone rate schedule.)

In Stepping Stones Associates v. The City of White Plains, 100 A.D.2d 619, 473 N.Y.S.2d 578 (N.Y. App. Div. 1984), the court permitted a municipality to set its own rates, which rates varied with usage. In City of Fayetteville v. Fayette County, 171 Ga. App. 13, 318 S.E.2d 757 (Ga. App. 1984) the court noted that "[t]he establishment of water rates by a municipality is a legislative or governmental power." Id. at 758.

The power of a city to prescribe its own rates, rules, and regulations, is not without limit. It must be nondiscriminatory and reasonable. (See Banberry Development Corporation v. South Jordan City, 631 P.2d 899 (Utah 1981); Lafferty v. Payson City, 642 P.2d. 376 (Utah 1982); and Home Owners' Loan Corporation v. Logan City, et. al, 97 Utah 235, 92 P.2d 346 (1939)).

As noted above, if a city has adequate water to meet its needs during a drought, the water rights it owns will almost assuredly provide a surplus during normal and wet years. I have by contract worked out arrangements that solved the problem during dry periods without creating these surpluses in normal or wet years.

In one instance I negotiated with farmers the right to take their water for a single season, or a part of a season, to meet urgent needs of a city during a drought. The city paid $25,000 for the privilege of taking the water whenever it wanted, but whenever it takes the water it is required to replace to the farmer the hay that he normally would have grown had he used the water. This was agreed by contract to be 300 tons of hay per season. The city would notify him that it was going to take the water. It then had to replace, at city expense, the 300 tons of hay. The farmer saved the cost of harvesting, and this was a benefit; the city was required to make a further payment of $1,000 each year it took the water; and the hay fields (although dry) produced pasture. With this arrangement the city could take the water from farmlands and use it in the city's water system. Since the farmer in question had the first priority on the stream, the city was able to divert up to 5 cfs, which was enough to meet the city's needs. The arrangement has been in operation for about 25 years. The city has only called upon the water three times. During the other 22 years the farmer has been able to go on with his farming. If the city had acquired this water permanently, it would (during each of these 22 years) have had a surplus, and the city would have had to find a lease for the water.

In another instance, a mutual irrigation company serving about 70 farms owned all the water of a stream. The farmers had no storage, and their canal system was inefficient. My client agreed to provide the money to build a storage reservoir and to line the canals. In return therefor it obtained the right to secure water to tide it over a dry cycle. Here the money advanced was utilized to improve the system. During normal years the farmers are much better served, and during a dry cycle they are willing to take care of the municipal and industrial needs, up to an agreed level.

Throughout the West the water that is dependably available and that can be appropriated at acceptable expense has long since been appropriated. There are areas where the extreme high water available in random years can be stored and carried over. For example, a project in Wyoming, which has 240,000 acre-feet of storage space, can provide a firm annual supply of only 62,000 acre-feet. This amount of water (62,000 acre-feet) is not available every year above existing rights, but water above 62,000 acre-feet is available with sufficient frequency in random years so that with 240,000 acre-feet of storage a reasonably firm supply of 62,000 acre-feet can be made available for annual use.

New projects, using water that is available only in random years, are more likely to be developed as a part of a large, multipurpose, publicly financed project. The two main federal agencies that do this kind of construction are the Bureau of Reclamation and the Corps of Engineers.

When the Bureau of Reclamation builds a project, it is normally required to make a state water filing for that project by Section 8 of the National Reclamation Act of 1902 (see California v. United States, 98 S.Ct. 2985, 440 U.S. 59, 59 L.Ed.2d 144 (1978)). The Corps makes no filing, but frequently has a local sponsor who does. The application for a permit may itself make some initial allocation of the water, simply because the data required in completing the application form require it. The application will normally name the water source, the point of diversion, the location of the impounding dam, and place and purpose of use, and so on. When the state engineer approves the application, the right is like any other water right and takes its place in the state priority system. See In re Green River Adjudication v. United States, 17 Utah 2d 50, 404 P.2d 251 (1965). When the works are completed and the water is placed to beneficial use, proof of appropriation is filed (showing the details of actual use) and the right is certificated or adjudicated, but the water allocation process only nominally takes place at this point. Generally, the project has a local sponsor, which receives the project water supply, in return for an agreement to repay the project costs. Then the local sponsor makes the ultimate allocation to the ultimate user.

WATER ALLOCATION AND CONJUNCTIVE USE

It is customary in the process of allocating water from such projects to address the problems incident to water shortage. Frequently, municipal users are given a preference. In any event, there is an opportunity in that allocation process to deal with adjustments for drought.

A significant amount of "new" water can also be "found" through better coordination of existing uses, which take maximum advantage of the short-lived high water flows. For example, in Salt Lake County there is an area that was dependent on a spring for its water needs. The area was historically agricultural and the high flows were applied to irrigation. The low flow was sufficient to provide domestic water for a small cluster of homes. As homes expanded into this area and irrigation was abandoned, the high flow (about 10 cfs) became a flood problem because there was no place to put it; the low flows of August were not adequate to fill the domestic needs of the increased number of homes in the area. The system was taken over by the Salt Lake County Water Conservancy District, which had a pipeline system large enough to take the maximum flows and put them to beneficial use. When the low flows developed, the district had other sources of water--primarily wells and surface storage--so that it could take care of the needs. The spring yields 2,000 acre-feet a year. As a part of a larger system, 2,000 acre-feet would take care of the annual needs of nearly 8,000 people. By itself, however, it could barely meet the needs of 53 homes, or about 200 people.

In Salt Lake County there are three major suppliers of water. One is the Salt Lake County Water Conservancy District, which furnishes water on a wholesale basis to many cities, districts, and water companies. Its primary source of supply is wells. The other two suppliers are interrelated--one is Salt Lake City and the other is the Metropolitan Water District of Salt Lake City. The city holds the primary rights to the mountain streams and Metropolitan has a large amount of water in storage in Deer Creek Reservoir. By statute, it must make that storage water available to the city, but by contract it sells its surplus to the conservancy district. If each of these agencies were to use water strictly in accordance with their individual rights, there would be times in the year--e.g., the early spring runoff--when Salt Lake City could not use all of the water accruing under the city's rights and flowing in the mountain streams. The unused portion would flow into Great Salt Lake unused. During this period the streams meet the city's total needs, the streams furnishing water to Deer Creek normally fill the reservoir, and it spills. If at the same time the conservancy district meets its total needs through the pumping of its wells, underground storage is depleted. By agreement Salt Lake City and the metropolitan district sell water to the county district. They provide aqueducts, treatment plants, and conveyance facilities so that the surplus water can be used. The price is about the cost of pumping the wells. They collectively use the direct flow from streams; then if the reservoir is full, they draw on it to a reasonable extent, and none of them pump wells. This permits the ground-water basin to recharge. The county district can sharply reduce its total use from the underground and thus also permit it to recharge. When they need it, all three entities pump their wells; but they do so usually from a fully recharged ground-water basin.

A similar conjunctive use was approved in Hewitt v. Rincon Del Diablo Municipal Water District, 107 Cal. App. 3rd 78, 165 Cal. Rptr. 545 (Cal. Ct. App. 1980).

In one sense, the large reclamation projects of the Bureau can firm up local supplies. The Provo River, which is a major source of water for the heavily populated Wasatch Front area, including Salt Lake City, might yield 1,500,000 acre-feet during a random wet year, 1,000,000 acre-feet during an average year, and only 500,000 acre-feet during a dry year. With Provo River storage, the use can dependably approach the average. However, to use all the Provo River water, a supplemental supply is needed. The Bonneville Unit of the Central Utah Project is developing that supply. That project will make 99,000 acre-feet of new water available from the random high flows of the Provo River for use in the Salt Lake-Provo areas, and because the project will also have large quantities of water in carry-over storage from the Colorado River, it can firm up the supply from the Provo River, if this is needed, so that cities can dependably rely on whatever water the river will yield. It is not planned to use the 99,000 acre-feet of new water every year. If we have a wet year and the local streams can meet the needs, they will be called upon to do so and the 99,000 acre-feet will all be held in storage. A 320,000 acre-feet reservoir is being built for this purpose. It is backed up by more than 1,000,000 acre-feet of new storage on Colorado River tributaries. Then, in a dry year, 200,000 or 300,000 acre-feet may be withdrawn from storage. Developing 99,000 acre-feet of new water, with storage capacity to hold it over several years, has the effect of firming up the local streams so that the dependable new supply is more in the magnitude of 123,000 acre-feet, rather than the 99,000 acre-feet of new municipal and industrial water. To make the system function this way, however, we must have management of the local supplies. The advantages of this type of management are illustrated by the voluntary operation in Salt Lake County, Utah, described above.

In 2 Kinney, Irrigation and Water Rights, (2d ed., 1912), the rule is stated as follows:

> S704. Appropriation for storage. Again, not only may a valid appropriation of the water from a natural stream be made for immediate use, but the water may be saved up and stored in times of plenty and thus saved for the ultimate purpose of using the same in times of scarcity for irrigation, or any other useful purpose.

5 Clark, Water and Water Rights (Robert E. Clark, ed., Allen Smith, Co., Indianapolis, Indiana, 1967) agrees (see S408:3):

> The storage of water for future uses has long been held to be a beneficial use. Without storage, beneficial uses would be limited to short periods of runoff during the year, and on many western streams power could not be generated except at irregular intervals.

In 1 Hutchins, Water Rights Law in the Nineteen Western States (W. A. Hutchins, U.S. Government Mass Publication No. 1206, 1971), it is stated:

> Recognition of reservoir storage as one of the chief features of water utilization appears in the water rights jurisprudence throughout the West. Storage is a means of conserving water, by capturing it when plentiful and holding it back for future use, as well as an implement in flood

protection programs. Thus, with use of upstream reservoirs, spring floodflows may not only be prevented from inundating downstream lands, but may be stored and made available for late-season use when unregulated flows are low. And they may even be carried over from so-called "wet" years to mitigate the deficiencies of "dry" seasons.

(See also J. R. Long, Irrigation S276 (W. H. Courtright, 2d ed., 1916), and 1 Weil, Water Rights in the Western States 10 page 410 (3d ed.). The court cases also support the proposition that carry-over storage is a beneficial use. See Edwards v. City of Cheyenne, 19 Wyo. 110, 114 P.611 (1911); VanTassel Real Estate & Live Stock Co. v. City of Cheyenne, 54 P.2d 906 (Wyo. 1936); A-B Cattle Co. v. United States, 589 P.2d 57 (Colo. 1979); Friends of the Earth v. Armstrong, 485 F.2d 1 (10th Cir. 1973); East Side Canal & Irr. Co. v. United States, 76 F.Supp. 836 (Ct. Cl. 1948), cert. den. 339 U.S. 978 (1950); City of Frisco v. the Texas Water Rights Commission, 579 S.W.2d 66 (Tex. Civ. App. 1979), reh'g denied.)

PREFERENTIAL USE

The acquisition of water rights and the reservation of that water for future municipal growth is generally recognized in the law. For example, under S73-1-4, Utah Code Anno. 1953, as amended, the state legislature has provided for forfeiture where the water is appropriated and then not put to beneficial use. This section permits the state engineer to grant extensions of time, but requires the applicant to show good cause as to why he has not been using the water. It identifies financial crises, industrial depression, operation of legal proceedings, or unavoidable causes, and concludes by saying, "the holding of a water right without use by any municipality, metropolitan water districts or other public agencies to meet the reasonable future requirements of the public shall constitute reasonable cause for such nonuse."

Texas law gives to cities a right to displace existing uses for subsequently arising municipal needs. This is an exception to the general rule in Texas that first in time is first in right (see Tex. Rev. Civ. Stat. Art. 74-72(54)). This section provides that allotments of water for all purposes other than municipal or domestic use "shall be granted subject to the right of any city . . . to make further appropriations of said water thereafter without the necessity of condemnation or paying therefor . . . ." We have found no Texas court cases construing the statutes and are not aware of any instance in which a Texas city has endeavored to invoke this statute.

Prather v. Eisenmann, 261 N.W. 2nd 766 (Neb. 1978) interpreted Nebraska's preference statute with regard to the domestic use of ground water between private parties.

The matter is addressed in Water and Water Rights volume 1, page 369, where the following observation is made:

> In this context a preference is a beneficial use that receives a special, or higher, priority or value than some other beneficial use. Not all beneficial uses have equal value to the community. This is the rule even in the prior-appropriation states where first in time is ordinarily first in legal right. The concept of preference was recognized in the common law by separating "artificial" or extraordinary uses from "natural" or ordinary uses which were preferred because essential to human survival. Domestic uses were preferred to the extent of allowing a riparian owner to reduce or deplete a streamflow for his household uses despite injury to lower riparian owners. In the Southwest a preference exists through the pueblo right which preserves a superior municipal claim for human uses even though prior appropriators are injured by stream diversions.
>
> Modern law separates preferences into three general classes. First is a right or high priority that may be exercised irrespective of all other rights and in the exercise of which no compensation is paid. This is sometimes called a true preference. Secondly, there are preferred uses defined by statute that are enforced by condemnation; in these cases compensation must be paid for taking another's water right. A third type of preference is found in the administrative discretion granted to public officials to choose among different uses in granting applications for permits to use water. A hierarchy of preferences is often established by statute and the official

must decide between superior and inferior beneficial uses in granting or denying the application. These statutes are not uniform in ordering all of the preferences, but all of them prefer domestic uses over other uses.

See also Jarvis v. State Land Dept., 106 Ariz. 506, 479 P.2d. 169 (1970), and statement in later case: "If it is to the State's interest to prefer mining over farming, then the Legislature is the appropriate body to designate when and under what circumstances such economic interest will prevail."

States having preferential statutes include Colorado, California, Arizona, Oregon, South Dakota, Wyoming, Idaho, and Utah.

INTERSTATE TRANSFERS

A dispute is currently pending between the State of New Mexico and the City of El Paso, Texas, arising out of an effort by El Paso to appropriate large quantities of water from an underground basin in New Mexico. The United States Supreme Court in Sporhase et al. v. Nebraska, ex rel. Douglas, Attorney General, 458 U.S. 941, 73 L.Ed. 1254 (1982), had indicated that a carefully drawn statute protecting the interests of the state of origin in the event of water shortage might be permissible, and New Mexico, after losing in the trial court, attempted to draft such a statute. The trial court's opinion (City of El Paso v. Reynolds, 563 F.Supp. 379 (D.N.M. 1983)), holding that New Mexico's embargo statute was unconstitutional, was appealed. The Tenth Circuit remanded the case to the trial court for "fresh consideration" in light of the amendments to the New Mexico statutes. The district court's decision held the New Mexico statute, which created a total ban on the interstate exportation of water, created an impermissible burden on interstate commerce. Subsequent to the entry of the district court's decision, New Mexico repealed New Mexico Statute Annotated S72-12-19 (1978) and enacted 72-12B-1, which established an application procedure requiring consideration of several factors by the state engineer when ruling on applications for the withdrawal and transportation of ground water from the state. The new statute (in contrast to the outright ban on interstate transportation of water) provided that "under appropriate conditions" the interstate transportation and use of New Mexico's "public waters" are not in conflict with the public welfare of the state's citizens. In referring to "public waters," the statute is not limited to ground water but would also encompass surface water supplies. The statute requires any person or entity desiring to export water from New Mexico to apply for a permit from the state engineer to make the withdrawal. The state engineer is required to publish notice of the application. The statute stipulates that the state engineer, prior to granting the permit, must find that the withdrawal and transportation of water outside of the state will not impair existing rights. The state engineer must also find that the proposed export is neither contrary to the water conservancy policies of the state nor otherwise detrimental to the public welfare of New Mexico's citizens.

In making his decision the state engineer shall consider the following factors: (1) The supply of water available to New Mexico; (2) water demands of New Mexico; (3) whether there are water shortages within New Mexico; (4) whether the water that is the subject of the application could feasibly be transported to alleviate water shortages in New Mexico; (5) the supply and sources of water available to the applicant in the state where the applicant intends to use the water; and (6) the demands placed on the applicant's supply in the state where the applicant intends to use the water.

The statute also provides that by filing an application to export New Mexico water, the applicant submits to New Mexico law governing and regulating the appropriation and use of water. The state engineer is empowered to condition the granting of any such export permit to ensure that water being exported will be used in accordance with the rules and regulations imposed on in-state users.

While the remand was pending before the district court, the New Mexico legislature also enacted H.B. 12, which placed a two-year moratorium on all pending and future applications to appropriate ground water hydrologically connected to the Rio Grande River below Elephant Butte Reservoir. Judge Bratton issued an opinion on August 3, 1984, in Civil No. 81-730 (D.N.M.) addressing the constitutionality of the amended statute and the two-year moratorium. The opinion is reported at 597 F.Supp. 694 (1984). The court held that S72-12B-1 was not facially unconstitutional when applied to regulate ground-water exports generally, but that it was unconstitutional when used to regulate the export of ground water for domestic use and when used to regulate the transfer of existing ground-water rights for use out of state. He also held the two-year moratorium under H.B. 12 to be facially unconstitutional. The critical portion of S73-12B-1 provides that the state engineer must find that the "use outside the state . . . is not contrary to the conservation of water within the state and is not otherwise detrimental to the public welfare of the citizens of New Mexico" before he can approve an application for the export of water. He must evaluate the six factors identified above in making his findings.

The criteria stated above attempt to apply the conservation and public welfare considerations even-handedly at least as to new appropriations. Notwithstanding this, El Paso argued that the even-handedness is only superficial because these criteria are meaningless to in-state uses of ground water. New Mexico noted the case of Young & Norton v. Hinderlider, 15 N.M. 666, 110 P 1045 (1910) regarding the public interest or public welfare criterion and argued that the public interest criterion is not meaningless as applied to in-state uses. The court rejected this argument and in doing so held that the phrase "conservation of water within the state" referred to the waters to be conserved and did not prohibit exports. The court also rejected the argument that the second criterion directed at protecting the public welfare of New Mexico's citizens rendered that statute unconstitutional. He noted that Sporhase (above) permits a limited preference for the state's own citizens. He held that the preference must be limited to situations in which exercise would not place unreasonable burdens on interstate commerce. The court also noted that the state could not prefer its own citizens merely to protect local economic interests. A state could, however, prefer its own citizens in times of shortage. The court also indicated that a state might regulate exports to protect against future shortages to a reasonable degree. The proximity in time of a projected shortage, its certainty, its projected severity, and the availability of alternative measures were all factors to be considered in determining the reasonableness of the regulation (see page 701 of the opinion).

El Paso also argued that the six factors to be applied to evaluating applications applied only to the export of water and were therefore facially discriminatory. Again, the court rejected this argument and ruled that the six factors (which relate to supply and demand in New Mexico and the importing state) provide information required by the state engineer to determine whether New Mexico can constitutionally prefer its own citizens. Although the six criteria did not make the section facially unconstitutional, the court held that the use of these criteria to regulate the export of ground water for domestic (municipal) use and to regulate the transfer of existing ground-water rights (but not when making an in-state transfer) is unconstitutional (Id. at 703-704). The court noted that the state engineer is not permitted to consider the conservation or public welfare criteria when acting on applications to appropriate ground water for domestic in-state use, or when acting on in-state transfer applications. The court found no legitimate justification for the distinction in application and consequently held the use of the criteria unconstitutional.

The court held the two-year moratorium H.B. 12 to be facially discriminatory. It applied only to two specific aquifers in which the City of El Paso has filed applications to export water. It concluded that the only purpose of the moratorium was to prevent El Paso from obtaining ground water in New Mexico and on that basis they imposed unfairly on interstate commerce.

New Mexico argued that the statute did not violate the commerce clause because it regulated even-handedly and applied equally to in-state and export applications. The court ruled, however, that even-handedness would not validate an illegitimate purpose, which in this case was a complete blockage of the interstate movement of water. Further, even if the statute were not invalid per se, the court held it would fail because it had not been narrowly tailored to its stated purpose, which is a requirement of Sporhase.

PUBLIC TRUST

In National Audubon Society v. Superior Court of Alpine County, 33 Cal.3rd 419, 659 P.2d 709, 189 Cal. Rptr. 346 (Cal. 1983), modified on denial of rehearing, the court held that the public trust doctrine must be considered in the allocation of water resources.

CONCLUDING REMARKS

The best way to adjust to drought conditions is to plan adequately in advance. Emphasis should be placed on using direct flow waters, which can only be used as nature makes them available. If they go unused, they flow downstream and beyond the reach of the system. These supplies should be used first. Surplus surface supplies should be placed in storage with sufficient capacity so that substantial quantities of water can be carried over from wet cycles to be used during dry cycles. Generally speaking, it is desirable to use surface storage and to conserve ground-water storage. Ground water is not subject to evaporation losses. In a large ground basin, wells can be drilled near the point of use, and there is generally a lag between shortages in a surface system caused by drought and the adverse impacts of the drought on ground water. That lag also reappears during periods of recharge. The management of water supplies is critical. If the normal supply available is not adequate during a drought period, then with a proper statutory unpinning, the authority can be granted to cities, districts, private water companies, and so on, to impose rationing and to conserve water.

APPENDIXES

APPENDIX A

THE EMERGENCY WATER CONSERVATION PLAN OF THE CITY OF LOS ANGELES

and the

SUMMARY OF THE LOS ANGELES EMERGENCY WATER CONSERVATION ORDINANCE

THE EMERGENCY WATER CONSERVATION PLAN OF THE CITY OF LOS ANGELES

[Added by Ord. No. 149,700, Effective 5/16/77.]

ARTICLE I

(Rev. No. 10—1977)

CHAPTER XII

THE EMERGENCY WATER CONSERVATION PLAN OF THE CITY OF LOS ANGELES

[Added by Ord. No. 149,700, Effective 5/16/77]

ARTICLE I

SEC. 121.00. SCOPE. There is hereby established a City of Los Angeles Emergency Water Conservation Plan.

SEC. 121.01. DECLARATION OF POLICY. It is hereby declared that, because of the conditions prevailing in The City of Los Angeles and in the areas of this State and elsewhere from which the City obtains its water supplies, the general welfare requires that the water resources available to the City be put to the maximum beneficial use to the extent to which they are capable, and that the waste or unreasonable use or unreasonable method of use of water be prevented, and the conservation of such waters is to be exercised with a view to the reasonable and beneficial use thereof in the interests of the people of the City and for the public welfare.

SEC. 121.02. DECLARATION OF URGENCY. The Council of The City of Los Angeles hereby finds and declares that there exists within this City a water shortage emergency condition and that as a result there is an urgent necessity to take legislative action through the exercise of the police power to protect the public peace, health and safety of this City from a public disaster or calamity, to take effect immediately upon publication of this Ordinance.

SEC. 121.03. DECLARATION OF PURPOSE. The purpose of this Chapter is to provide a mandatory water conservation plan to minimize the effect of a shortage of water to the customers of the City and, by means of this Chapter, to adopt provisions that will significantly reduce the consumption of water over an extended period of time, thereby extending the available water required for the customers of the City while reducing the hardship of the City and the general public to the greatest extent possible, voluntary conservation efforts having proved to be disappointing as of the date hereof.

SEC. 121.04. DEFINITIONS. The following words and phrases, whenever used in this Chapter, shall be construed as defined in this section unless from the context a different meaning is intended or unless a different meaning is specifically defined within individual sections of this Chapter:

a. "City" means The City of Los Angeles.

b. "Mayor" means the Mayor of The City of Los Angeles.

c. "City Council" means the Council of The City of Los Angeles.

d. "Department" means the Department of Water and Power.

e. "Section" means a section of this Chapter unless some other ordinance or statute is specifically mentioned.

f. "Customer" means any person, persons, association, corporation or governmental agency supplied or entitled to be supplied with water service by the Department.

g. "Chapter" means the Ordinance providing for "The Emergency Water Conservation Plan of The City of Los Angeles".

h. "Officer" means every person designated in Section 5 of the Los Angeles City Charter as an officer of The City of Los Angeles.

i. "His" as used herein includes masculine, feminine or neuter, as appropriate.

j. "Process Water" means water used to manufacture, alter, convert, clean, heat, or cool a product, or the equipment used for such purpose; water used for plant and equipment washing and for transporting the raw materials and products; and water used to grow trees or plants for sale or installation.

k. "Base Period" means that period of time over which the base is computed.

l. "Base" means the amount of water used on a customer's premises during the corresponding billing period in 1976.

Any customer who was not a customer on the premises for which service was billed by the Department during the base period shall be assigned the same base for such or similar premises as provided above, and the Department shall have the further discretion to adjust such base in the event such customer's use of the premises is substantially different from the previous use thereof during the base period.

m. "Billing Unit" means the unit amount of water used to apply water rates for purposes of calculating commodity charges for customer water usage and equals one hundred (100) cubic feet or seven hundred forty-eight (748) gallons of water.

SEC. 121.05. AUTHORIZATION. The various officers, boards, departments, bureaus and agencies of the City are hereby authorized and directed to immediately implement the applicable provisions of this Chapter upon the effective date hereof.

SEC. 121.06. APPLICATION. The provisions of this Chapter shall apply to all customers and property served by the Department of Water and Power wherever situated, and shall also apply to all property and facilities owned, maintained, operated or under the jurisdiction of the various officers, boards, departments, bureaus or agencies of the City.

SEC. 121.07. WATER CONSERVATION PHASES. No customer of the Department of Water and Power shall make, cause, use, or permit the use of water from the Department for residential, commercial, industrial, agricultural, governmental, or any other purpose in a manner contrary to any provision of this Chapter or in an amount in excess of that use permitted by the conservation phase then in effect pursuant to action taken by the Mayor and the Council in accordance with the provisions of this Chapter.

A. PHASE I

1. Prohibited Uses Applicable To All Customers:

(a) There shall be no hose washing of sidewalks, walkways, driveways, or parking areas, except that flammable or other dangerous substances may be disposed of by direct hose flushing for the benefit of public health and safety.

(b) No water shall be used to clean, fill or maintain levels in decorative fountains unless such water is part of a recycling system.

(c) No restaurant, hotel, cafe, cafeteria or other public place where food is sold, served or offered for sale, shall serve drinking water to any customer unless expressly requested.

(d) No customer of the Department shall permit water to leak from any facility on his premises; failure to effect a timely repair of any leak shall subject said customer to all penalties provided herein for waste of water.

(e) No lawn, landscape, or other turf areas shall be watered or irrigated between the hours of 10:00 a.m. and 4:00 p.m.; provided, however, that the provisions of this subsection are hereby suspended until such time as the Council, by resolution, reinstates the provisions hereof when it finds and determines such action necessary in order to assist the City in achieving the necessary level of water conservation, such resolution to be effective immediately upon publication thereof. (Amended by Ord. No. 150,636, Eff. 4/15/78.)

B. PHASE II

1. Prohibited Uses Applicable To All Customers:

(a) No use of water may be made contrary to the provisions of subsection 121.07 A.

2. Customer Percentage Curtailment. No customer shall make, cause, use or permit the use of water from the Department for any purpose in an amount in excess of ninety percent (90%) of the amount used during the base period as defined in this Chapter.

C. PHASE III

1. Prohibited Uses Applicable To All Customers—

(a) No use of water may be made contrary to the provisions of subsection 121.07 A.

2. Customer Percentage Curtailment. No customer shall make, cause, use or permit the use of water from the Department for any purpose in an amount in excess of eighty-five percent (85%) of the amount used during the base period as defined in this Chapter, except that the process water may be used to the extent of ninety percent (90%) of the base period.

D. PHASE IV

1. Prohibited Uses Applicable To All Customers:

(a) No use of water may be made contrary to the provisions of subsection 121.07 A.

2. Customer Percentage Curtailment. No customer shall make, cause, use or permit the use of water from the Department for any purpose in an amount in excess of eighty percent (80%) of the amount used during the base period as defined in this Chapter, except that process water may be used to the extent of ninety percent (90%) of the base period.

E. PHASE V

1. Prohibited Uses Applicable To All Customers:

(a) No use of water may be made contrary to the provisions of subsections 121.07 A.

2. Customer Percentage Curtailment. No customer shall make, cause, use or permit the use of water from the Department for any purpose in an amount in excess of seventy-five percent (75%) of the amount used during the base period as defined in this Chapter, except that process water may be used to the extent of eighty-five percent (85%) of the base period.

F. EXCEPTION. The prohibited use of water from the Department provided for by subsections 121.07 A 1, B 1, C 1, D 1 and E 1 of this section are not applicable to that use of water necessary for public health and safety or for essential government services such as police, fire, and other similar emergency services.

SEC. 121.08. CONSERVATION PHASE IMPLEMENTATION.

A. Phase Change Initiation. The Department shall monitor and evaluate the projected supply and demand for water by its customers monthly, and shall recommend to the Mayor the extent of the conservation required by the customers of the Department in order for the Department to prudently plan for and supply water to its customers. The Mayor shall, in turn, notify and recommend to the Council the appropriate phase of water conservation to be implemented. Thereafter, the Mayor may, with the concurrence of the Council, order that the appropriate phase of water conservation be implemented in accordance with the applicable provisions of this Chapter. Said order shall be made by public proclamation and shall be published one time only in a daily newspaper of general circulation and shall become effective immediately upon such publication. The prohibited use provisions shall become operable immediately upon the effective date of this Ordinance. The customer percentage curtailment provisions shall take effect with the first full billing period commencing on or after the effective date of the public proclamation by the Mayor.

B. Exemptions. Nothing contained in subsections B, C, D, or E of Section 121.07 of this Chapter shall be deemed to require any single-family residential customer of the Department to reduce his consumption of water provided by the Department to an amount less than nine (9) billing units per month at each meter during any billing period while subsection B of Section 121.07 is in effect (Phase II); to an amount less than eight and one-half (8 1/2) billing units per month at each meter during any billing period while subsection C of Section 121.07 is in effect (Phase III); to an amount less than eight (8) billing units per month at each meter during any billing period while subsection D of Section 121.07 is in effect (Phase IV); or to an amount less than seven and one-half (7 1/2) billing units per month at each meter during any billing period while subsection E of Section 121.07 is in effect (Phase V).

SEC. 121.09. APPLICATION OF SURPLUS REDUCTION. Notwithstanding any other provision of this Chapter, any reduction in the use of water by any customer during any current billing period in excess of the amount required by Section 121.07 shall be applied as follows:

1. **Bimonthly Customers:**
Said surplus reduction shall be applied to that customer's consumption for the immediately preceding billing period. Any surplus reduction remaining after the application of the rule provided immediately above shall be applied to offset any excessive use of water by that customer during the next billing period for bimonthly customers. Such carry-forward of the surplus reduction shall operate only as an offset to excessive usage and shall not be applied to any use of water at or below the customer's allowable maximum consumption thereof.
2. **Monthly Customers:**
Said surplus reduction shall be applied to that customer's consumption for the immediately preceding three-month period. Any surplus reduction remaining after the application of the rule provided immediately above shall be applied to offset any excessive use of water by the customer during the next two billing periods for monthly customers. Such carry-forward of the surplus reduction shall operate only as an offset to excessive usage, and shall not be applied to any use of water in an amount at or below the customer's allowable maximum consumption thereof.

SEC. 121.10 FAILURE TO COMPLY (Amended by Ord. No. 150,637, Eff. 4/21/78.)

A. **Penalties.** It shall be unlawful for any customer of the Department to fail to comply with any of the provisions of this Chapter. Notwithstanding any other provision of the Los Angeles Municipal Code, the penalties set forth herein shall be exclusive and not cumulative with any other section of this Code. The penalties for failure to comply with any of the provisions of this Chapter shall be as follows:

1. For each violation by any customer of the Department of any of the provisions of subsections B 2, C 2, D 2, or E 2 of Section 121.07 a surcharge penalty is hereby imposed in an amount equal to fifteen percent (15%) of the water bill plus an additional one dollar ($1.00) for each billing unit in excess of the percentage usage of water permitted by the particular conservation phase in which the violation occurred.

2. (a) For the first violation by any customer of the Department of any of the provisions of subsections A 1, B 1, C 1, D 1, or E 1 of Section 121.07, the department shall issue a written notice of the fact of such violation to the customer.

(b) For a second violation by any customer of the Department of any of the provisions of subsections A 1, B 1, C 1, D 1, or E 1 of Section 121.07 within the preceding twelve (12) calendar months, the Department shall issue a written notice of the fact of such second violation to the customer.

(c) For a third violation by any customer of the Department of any of the provisions of subsections A 1, B 1, C 1, D 1, or E 1 of Section 121.07 within the preceding twelve (12) calendar months, the Department shall install a flow restricting device of 1 GPM capacity for services up to one and one-half (1½) inch size, and comparatively sized restrictors for larger services, on the service of the customer at the premises at which the violation occurred for a period of not less than forty-eight (48) hours. The charge for installing a flow restricting device shall be based upon the size of the meter and the cost of installation as set forth in the Water Rate Schedules and Rules but shall not be less than twenty-five dollars ($25.00). The charge for removal of the flow restricting device and restoration of normal service shall be twenty-five dollars ($25.00) if restoration of normal service is performed during the hours of 8:00 a.m. to 4:00 p.m. on regular working days. If removal of the flow restricting device and restoration of normal service is made after regular working hours, on holidays or weekends, the restoration service charge shall be forty dollars ($40.00).

3. For any subsequent violation by any customer of the Department of any of the provisions of subsections A 1, B 1, C 1, D 1 or E 1 of Section 121.07 within the preceding twelve (12) calendar months, the Department shall discontinue water service to that customer at the premises at which the violation occurred. The charge for reconnection and restoration of normal service shall be twenty-five dollars (25.00).

B. Notice. The Department shall give notice of each violation to the customer committing such violation as follows:

1. For any violation of the provisions of subsection B 2 through E 2 of Section 121.07 or for a first or second violation of the provisions of subsections A 1 through E 1 of Section 121.07, the Department may give written notice of the fact of such violation to the customer personally or by regular mail.

2. If the penalty assessed is, or includes the installation of a flow restrictor or the discontinuance of water service to the customer for any period of time whatever, notice of the violation shall be given in the following manner:

(a) by giving written notice thereof to the customer personally; or

(b) If the customer be absent from or unavailable at either his place of residence or his assumed place of business, by leaving a copy with some person of suitable age and discretion at either place, and sending a copy through the United States mail addressed to the customer at either his place of business or residence; or

(c) If such place of residence and business cannot be ascertained, or a person of suitable age or discretion there cannot be found, then by affixing a copy in a conspicuous place on the property where the failure to comply is occurring and also by delivering a copy to a person there residing, if such person can be found, and also sending a copy through the United States mail addressed to the customer at the place where the property is situated.

Said notice shall contain, in addition to the facts of the violation, a statement of the possible penalties for each violation and a statement informing the customer of his right to a hearing on the violation.

C. Hearing. Any customer against whom a penalty is levied pursuant to this section shall have a right to a hearing, in the first instance by the Department with the right of appeal to an appeal board, on the merits of the alleged violation upon the written request of that customer to the Department within fifteen days of the date of notification of the violation.

D. **Reservation of Rights.** The rights of the Department hereunder shall be cumulative to any other right of the Department to discontinue service. All monies collected by the Department pursuant to any of the penalty provisions of this Chapter shall be deposited in the Water Revenue Fund as reimbursement for the Department's costs and expenses of administering and enforcing this Chapter.

E. **Additional Penalties.** In the event the Department is unable to achieve the necessary level of conservation, the Council, by resolution, may order the imposition of the penalties provided for in subsection 2 (c) of Section 121.10 for a third violation by any customer of the Department of any of the provisions of subsections B 2 through E 2 of Section 121.07, and may also order the imposition of the penalties provided for in subsection 3 of Section 121.10 for any additional violation of the provisions of said subsections, such resolution to be effective immediately upon publication thereof.

SEC. 121.11 RELIEF FROM COMPLIANCE

A. **Administrative Relief.** Any customer who is dissatisfied with the application of any of the provisions of this Chapter as the same relate to him, may seek relief as set forth below.

The Department shall have the power, upon the filing by a customer of an application for relief as herein provided, to take such steps as it deems reasonable and to set up such procedures as it considers necessary to resolve said application for relief prior to the submission of said application to an appeal board.

In determining whether relief shall be granted, the Department and the appeal boards shall take into consideration all relevant factors including, but not limited to:

1. Whether any additional reduction in water consumption will result in unemployment;
2. Whether additional members have been added to the household;
3. Whether any additional landscaped property has been added to the 1976-based property;
4. Changes in vacancy factors in multi-family housing;
5. Increased number of employees in commercial industrial, and governmental offices;

6. Increased production requiring increased process water;

7. Water uses during new construction;

8. Adjustments to water use caused by emergency health or safety hazards;

9. First filling of a permit-constructed swimming pool;

10. Water use necessary for reasons related to family illness or health.

No relief shall be granted to any customer for any reason in the absence of a showing by the customer that he has achieved the maximum practical reduction in water consumption in his residential, commercial, industrial, agricultural or governmental water consumption, as the case may be, other than in the specific area in which relief is being sought.

No relief shall be granted to any customer who, when requested by the Department, fail to provide the Department with information whereby the services provided to him can be classified for the purpose of establishing an appropriate base or classification pursuant to the provisions of this Chapter. No relief shall be granted to any customer who fails to file an application for relief within one year of the date of the application of the provisions of this Chapter from which he seeks relief, except as otherwise provided in Section 121.10 C.

If a resolution of the application for relief is mutually agreed upon between the Department and the customer, the agreement and the fact of concurrence therewith shall be in writing subscribed by the customer. No further appeal may be taken by the customer on the same, or substantially similar, circumstances and facts.

B. Curtailment Relief Limitations. A customer may seek relief as herein provided from any application of the provisions of subsections B 2, C 2, D 2 and E 2 of Section 121.07 that adversely affect him at any time after any of such provisions are in effect. During any subsequent phase which may hereinafter be imposed, a customer may seek relief as herein provided only as to the issue of whether that customer committed the particular act or acts, or omitted to perform the particular act or acts, as alleged by the Department.

C. Base Adjustment. The Department, in its discretion, may adjust the base assigned to any customer if that customer establishes, to the satisfaction of the Department, that the base, as herein provided, would cause him great hardship for reasons including, but not necessarily limited to, technological improvements to that customer's premises since the base period, increased employment on said customer's business premises since the base period, a significant change in either the manner or the extent of use of water at the location in question since the base period, extreme fluctuations in weather conditions, increase in business volume directly related to water use, and occupancy factors occurring since the base period. Upon application therefor by a customer whose service is classified as a multiple-family dwelling, the Department shall grant an exemption of four billing units per dwelling unit per month.

D. Reclassification. The Department shall have the power to reclassify any residential, commercial, industrial, or agricultural customer to any other classification upon a showing of good cause by said customer of why all customers similarly situated should be so reclassified.

E. Appellate Relief.

1. The Mayor and the City Council shall establish such number of residential and nonresidential appeal boards as they deem necessary. Each nonresidential appeal board shall be composed of three members, one of which shall be selected from the business community, one of which shall be selected from the labor sector, and one of which shall be selected from the public at large. The residential appeal boards shall be composed of three members selected from the public at large. Appeal board members shall be appointed by the Mayor and confirmed by the Council. The Mayor and Council shall adopt such rules and regulations as they, in their sound discretion, deem reasonable and necessary to the formation, procedure and operation of such appeal boards.

2. The filing by a customer of an application for a hearing before an appeal board for any form of relief must be made within fifteen (15) days of the Departmental action complained of. This shall automatically stay the implementation of the proposed course of action by the Department pending the decision of the appeal board. No other or further stay shall be granted by the Department. Requests for relief hereunder may be filed immediately upon this Chapter's becoming effective.

F. **Wilful Misrepresentation.** Notwithstanding any other provision of law, and in addition thereto, and not in lieu thereof, any wilful misrepresentation of a material fact by any person to the Department or to any appeal board established pursuant to this Chapter, made for the purpose of securing relief from the provisions of this Chapter for any customer, is unlawful; and a violation of this subsection shall be punishable by a fine not exceeding the sum of five hundred dollars ($500), or by imprisonment in the county jail for a period not to exceed six (6) months, or by both such fine and imprisonment.

SEC. 121.12. GENERAL PROVISIONS

A. **Enforcement.** The Department of Water and Power shall enforce the provisions of this Chapter.

B. **Department to Give Effect to Legislative Intent.** The Department shall provide water to its customers in accordance with the provisions of this Chapter, and in a manner reasonably calculated to effectuate the intent hereof.

C. **Reduction in Water Supplied.** If any customer fails to comply with any provision of this Chapter, the Department may reduce the amount of water provided to that customer to the level which that customer would be using said water if he were complying with the provisions of this Chapter. The provisions of this subsection shall be applied in lieu of, or in addition to, any other penalties provided in this Chapter, in the discretion of the Department, and shall be applied without regard to the status or nature of the customer.

D. **Public Health and Safety Not to be Affected.** Nothing contained in this Chapter shall be construed to require the Department to curtail the supply of water to any customer when, in the discretion of the Department or an appeals board, such water is required by that customer to maintain an adequate level of public health and safety.

E. Reports. All commercial and industrial customers of the Department of Water and Power using 25,000 billing units per year or more shall submit a water conservation plan to the Mayor's office. These users shall submit quarterly to the Mayor's office a report on the progress of their conservation plans.

All City departments shall submit to the Mayor a monthly public report on their water conservation efforts. The reports are to present the level of performance compared to their water conservation plans.

SEC. 121.13. ENVIRONMENT. This Chapter and the actions hereafter taken pursuant thereto are exempt from the provisions of the California Environmental Quality Act of 1970 as a project undertaken as immediate action necessary to prevent or mitigate an emergency pursuant to Section 15071 (c) of the State EIR Guidelines.

SEC. 121.14. SEVERABILITY. If any section, subsection, clause or phrase in this Chapter or the application thereof to any person or circumstances is for any reason held invalid, the validity of the remainder of the Chapter or the application of such provision to other persons or circumstances shall not be affected thereby. The City Council hereby declares that it would have passed this Chapter and each section, subsection, sentence, clause, or phrase thereof, irrespective of the fact that one or more sections, subsections, sentences, clauses, or phrases or the application thereof to any person or circumstance be held invalid.

SUMMARY OF LOS ANGELES EMERGENCY WATER CONSERVATION ORDINANCE

Upon the recommendation of a Blue Ribbon Water Conservation Committee appointed by the mayor in 1977, the Los Angeles City Council approved an Emergency Water Conservation Ordinance that allows for quick imposition of mandatory water conservation measures in a drought or other emergency situation of reduced water supply. Implementation of the ordinance that year, at the height of the drought, accomplished a 14 percent reduction in water use citywide.

Different phases of the ordinance can be implemented depending on the severity of the water supply shortage and the degree of water use reduction required:

Phase 1: Prohibits the watering of lawns during midday hours and the service of water in restaurants except on request, and asks all water users to voluntarily reduce their use by 10 percent.

Phase 2: Includes Phase 1 restrictions and makes a 10 percent water use reduction by all water users mandatory.

Phase 3: Increases mandatory reduction to 15 percent.

Phase 4: Increases mandatory reduction to 20 percent.

Phase 5: Increases mandatory reduction to 25 percent or more.

Users who do not reduce their historic use levels by the amounts specified in Phases 2 through 5 are subject to surcharges and other fines, to possible installation of flow restrictors in their service lines, and in extreme cases, to service disconnection. Exemption levels of use are established in Phases 2 through 5. Customers using less water than the exemption level are not subject to penalties. The ordinance also includes an appeals process for those users who feel they would be unfairly burdened by a mandatory curtailment level.

The capability of the ordinance to achieve significant reductions in water use was demonstrated during the drought. The public recognized the presence of a genuine emergency situation and responded accordingly.

This ordinance remains a valuable tool for Los Angeles in emergency situations. The mayor and City Council can implement appropriate phases of the ordinance during water-short periods to ensure adequate conservation of the available water supply.

APPENDIX B

SALT LAKE COUNTY WATER CONSERVANCY DISTRICT RATIONING PLAN

NOTICE OF WATER RESTRICTIONS

Dear Customer:

In order to meet our water delivery demands throughout the County, it is now necessary for us to ask your cooperation in observing the following limitations in using your water this summer:

1. The use of outside water should be limited to four (4) total hours per week for residential users. This amounts to about half the water used in previous years by the average homeowner outside the home.
2. Outside watering should be limited to the hours between 8:00 p.m. and 10:00 a.m..
3. Even numbered homes may water on Mondays, Wednesdays and Fridays.
4. Odd numbered homes may water on Tuesdays, Thursdays and Saturdays.
5. No outside watering should be done on Sundays.
6. Schools, public parks, condominium projects, apartment complexes, etc., are asked to water between midnight and 8:00 a.m., where possible. Total watering hours per week should be one half of the time used in 1976.

Based on this program an even numbered home could water two (2) hours on Monday, one (1) hour on Wednesday, and one (1) hour on Friday, or four (4) hours on Monday with no watering on any other day. **THE TOTAL WATERING TIME SHOULD NOT EXCEED FOUR (4) HOURS IN ANY WEEK.**

Related to these limitations we recommend limiting new landscaping to that which can be supported within the watering schedule. Gardens are included in total outside use and must be watered accordingly.

Other uses of water such as for car washes, commercial nurseries, industries, air conditioning systems, and household use for bathing, dishwashing, etc. are not being restricted at this time but the users are encouraged to eliminate the waste of water and to conserve whenever possible.

The schedules recommended are in conformance with reductions in outside use which were outlined for the public on February 18, 1977. Discussions on March 6th indicated that as much as five hours of outside watering per week could be accommodated. Snowmelt and runnoff in the Wasatch Canyons is occurring earlier than anticipated resulting in the reduction to four hours.

Public cooperation in what is a serious condition is the key to our success. Failure to meet reduced water use requirements will bring serious water shortages this summer. Additional measures to enforce a reduction in water use such as penalty charges for excess use and ordinances restricting outside water use with civil penalties are being prepared for enactment by the Salt Lake County Commission and the City Councils if voluntary response to our problem is not successful.

The schedule for outside watering outlined will result in adequate water supply for basic needs through this summer if it is followed by everyone. Failure to conform will result in the more restrictive actions to protect public health.

WHAT DOES FOUR HOURS OF WATERING PER WEEK MEAN?

This figure is based on a limitation of 36,000 gallons of water per month for an average residence. The average monthly use inside the home is approximately 14,000 gallons per month. This leaves 22,000 gallons for outside use.

Four hours per week is recommended as an average watering time for a residential user to achieve this limitation. The following tables can be used to determine if you should water for a longer or shorter time in order to maintain the 36,000 gallons per month limit on total use. From Table 1, select the combination of sprinkling methods you use at one time in your yard and note the total flow in gallons per minute. Then in Table 2, read the hours per week you may water to stay within your watering limit, according to your total flow.

TABLE 1

Type of Watering Device	Flow in Gallons Per Minute at Average Pressure
Hand Held Hose Full Flow Without Sprinkler	12 gpm
Ring Type Sprinkler on 50 Foot Hose	8 gpm
Spray Head Sprinkler System	6 gpm per head
Rainbird Type Sprinkler on Sprinkler System or Hose	10 gpm
Rotary Head Sprinkler System	8 gpm per head

TABLE 2

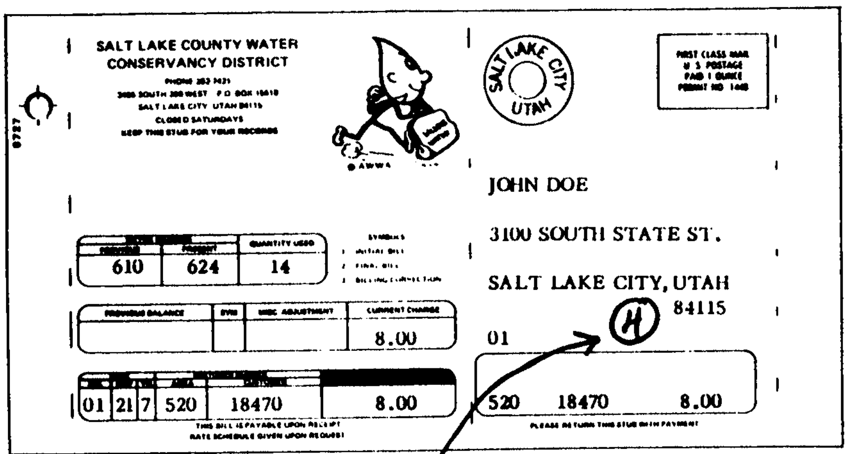
Total Flow Gallons Per Minute	Hours Per Week
5	18
10	9
15	6
20	4.5
25	3.5
30	3

Additional information on watering systems and ways you can conserve water in your yard can be obtained from your local nurseryman. Proper mulching and water use in your yard can reduce your outside water requirements by over 50 percent.

If you have any questions concerning the above information, please contact:

THE SALT LAKE COUNTY WATER
CONSERVANCY DISTRICT
P.O. Box 15618
3495 South 300 West
Salt Lake City, Utah 84115
Phone: 262-7421

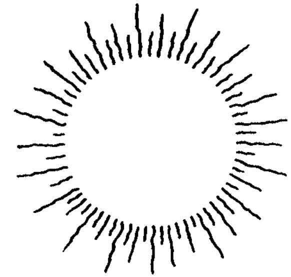
EXAMPLE:



Write the number of people living in your home or number of employees at your address here

Thank you for your cooperation. If you have any questions concerning our water situation, please feel free to call or write us for further information.

Salt Lake County Water Conservancy District
3495 South 300 West
P.O. Box 15618
Salt Lake City, Utah 84115
262-7421



Drought

Update on Water Situation

1976 Driest Year on Record

UPDATE OF WATER SITUATION

Present Water Situation

1976 is now officially the driest calendar year in recorded history for the State of Utah with 7.71 inches of precipitation as compared to the previous low of 8.10 inches in 1966 and the average of 11.36 inches in normal years. The chances of getting enough moisture in the coming weeks before spring are very slim. Arlo Richardson, State Climatologist for the Department of Agriculture reported on the thirteenth of January of this year that Utah would need nearly record-breaking moisture in January, February, and March to avoid drought conditions this summer. He reported on that date that only once in history has enough moisture fallen in Utah from January through March to equal the amount Utah now needs by April 1.

In addition, the U.S. Department of Agriculture's Soil Conservation Service states in its report entitled "Water Supply Outlook for Utah as of January 1, 1977:"

> Utah's spring and summer water supply outlook is poor, as Utah enters the new year with a record low mountain snow pack. Measurements in the last days of 1976 reported many snow courses bare for the first time in their 30 to 40 year (recorded) histories. Areas that had measurable snow were only 10 to 20 percent of their 15 year January 1 averages. Reservoir storage over the state is near January 1 averages, however, many direct inflow facilities are well below typical January 1 levels after a long, dry summer and fall.

The report goes on to state that unless the mountain snow cover improves over the rest of the winter, many areas served by stored water may well experience shortages.

Our Position

The District is heavily dependent upon stored water in Deer Creek Reservoir to meet its water demands in the warmer months of the year. The usable storage water in Deer Creek as of January 1 was 80500 acre-feet compared to an average for this date of 95300 acre-feet. These figures are a little misleading in that in a normal year Deer Creek's level would increase with the accumulation of the spring run-off. This year we are faced with a record low run-off and therefore, the reservoir level can only drop. There are steps being taken to compensate for this situation. Our District and Salt Lake City are pumping wells throughout the winter months tapping underground sources in an effort to reserve stored water for later use. Irrigators are holding their water in reservoirs for possible later sale or trade to municipalities. A complicated exchange of water from the partially completed Central Utah Project utilizing water in Strawberry Reservoir has been contemplated. Still, in spite of our best efforts and intentions, there will be, most likely, certain unavoidable curtailments in the distribution and use of water for this coming spring and summer for all of our customers.

What You Can Do

With this situation in mind water conservation becomes a matter of great importance. You can help now in a number of ways by not wasting water. Check your faucets and water connections to make sure they are not dripping or leaking. If they are, get them fixed. Don't run water unnecessarily. Shut the water off while you are brushing your teeth. Watch the length of your showers; don't fill your bathtub so full. Don't run water to cool it off when you want a drink (keep a chilled container of water in your refrigerator). There are many ways you can save water, if you will. You may not think that you or your family members alone can do much to help conserve water, but if each person in this valley could save but a few gallons each day, this small effort would result in the savings of many millions of gallons of water throughout the year when multiplied by the thousands of water users that we serve. Each person needs to do his or her part. Don't wait for summer and forced water use restrictions. Water saved now through sound conservation practices can help reduce the amount of curtailment that will be necessary this summer.

Another thing - if you have recently moved into a new home and are planning a new lawn for this year, we advise that you wait to see what the water situation will be this spring and summer before you commit yourself to costly investment that you may not be able to sustain due to the lack of water.

WILL THIS SITUATION EXIST DURING EVERY DRY YEAR?

Not if we can continue conserving our supplies and can complete the Central Utah Project. You can help in our planning for future water supply needs. Future needs are predicted on the population and the water requirements per person. We know from our records how much water is used per home but we don't have an accurate determination of the number of people in each home. Please take a minute and write down the number of persons living in your home on the stub of your bill next to your name and address, we will then have an accurate basis for determining the water use per person in various areas of the District.

APPENDIX C

BIOGRAPHICAL SKETCHES OF PRINCIPAL CONTRIBUTORS

Edward W. Clyde received a B.S. degree from Brigham Young University in 1939, and in 1942, a law degree from the University of Utah. He has engaged in private law practice in his own firm since 1945, and throughout that period has specialized in all phases of natural resources law. His geographical area of practice is generally throughout the West, with extensive work in Nevada, Wyoming, Montana, Idaho, Colorado, and Utah.

He taught mining law, water law, and other law subjects at the University of Utah Law School from 1948 until about 1960. This also included teaching a course in law for engineers and architects and a course in law for the graduating medical class.

He was chairman of the Water Law Committee of the Natural Resources Section of the American Bar Association for approximately five years; a Council member for three years; and chairman of the Section in 1976-1977. Currently, he is a member of the Board of Litigation of Mountain States Legal Foundation.

John A. Dracup is a professor in the Civil Engineering Department, School of Engineering and Applied Science, UCLA. His professional interests and expertise are in the fields of hydrology and water resource systems engineering. Recent research work has involved the statistical analysis of hydrologic droughts, the modeling of ground-water systems, the analysis of flash floods in ungaged watersheds, the optimization of energy use in urban water districts, and the hydrologic analysis of an alpine watershed under acid deposition stress.

Prior to his association with UCLA, he was a member of the faculty of Oregon State University and an instructor at the University of California, Berkeley. For the past 20 years he has served as a consultant to various federal, state, and local agencies, as well as to private companies. He has served as an expert witness in more than 30 water resource litigations. He is currently a member of the NRC Committee on Natural Disasters and the Mono Basin Ecosystem Study Committee.

Benedykt Dziegielewski, a native of Poland, has B.S. and M.S. degrees in environmental engineering from Technical University of Wroclaw, Poland, and an interdisciplinary Ph.D. in geography and environmental engineering from Southern Illinois University at Carbondale. Prior to serving as assistant professor in the Department of Geography at Southern Illinois University, he was a lecturer in the Department of Civil Engineering and the Department of Thermal and Environmental Engineering at Southern Illinois University. He has also been an instructor at the Department of Sanitary Engineering at Technical University of Wroclaw.

His Ph.D. dissertation entitled "Evaluation of Emergency Water Supplies as Drought Management Alternatives" has received the 1984 Outstanding Dissertation Award of the Universities Council on Water Resources.

Duane L. Georgeson was appointed to his present position as head of the Los Angeles Water System in February 1982, after serving in several water system management positions, including direction of the Aqueduct and Engineering Design Divisions.

A registered civil engineer, Georgeson joined the Department of Water and Power in 1959 after serving two years as a commissioned officer in the U.S. Coast and Geodetic Survey. He is an active member of the Los Angeles Area Chamber of Commerce, the Association of California Water Agencies, Town Hall, the American Water Works Association, the Association of Metropolitan Water Agencies, and the U.S. Committee on Large Dams. In November 1983, he was appointed an alternate member of the Colorado River Board of California by Governor Deukmejian.

Georgeson is a graduate of UCLA, where he received a B.S. in engineering in 1957.

Robert L. Smith received a B.S. in civil engineering and an M.S. in mechanics and hydraulics from the University of Iowa. He has served as Deane Ackers Professor of Civil Engineering at the University of Kansas, Lawrence, and in various consulting assignments in both public and private sectors. He has been a trustee and member of the executive committee, Center for Research, Inc.,; member, USGS Advisory Committee on Public Use of Water Data; chairman, ASCE Task Committee on Federal Policies in Water Resources Planning; member, Water Science and Technology Board, National Research Council; and member, Commission on Engineering and Technical Systems, National Research Council. He is a member of the National Academy of Engineering and has authored more than 50 journal articles and research monographs.

Gilbert F. White received S.B., S.M., and Ph.D. degrees from the University of Chicago. He has served as president, Haverford College; professor of geography, University of Chicago; visiting professor, University of Oxford; and professor of geography and director, Institute of Behavioral Science, University of Colorado. He is a member of the National Academy of Sciences and the American Academy of Arts and Sciences. He has served as chairman, Environmental Studies Board, National Research Council; member, Technology Assessment Advisory Council, U.S. Congress; trustee, Agricultural Development Council, Resources for the Future; president, Scientific Committee on Problems of the Environment, International Council of Scientific Unions; and chairman, Commission on Natural Resources, National Research Council.

APPENDIX D

ATTENDEES AT BOULDER COLLOQUIUM

MERLIN AHRENS, Bureau of Reclamation, Washington, D.C.

MARTIN J. ALLEN, American Water Works Association Research Foundation

WILLIAM ALLEY, U.S. Geological Survey, Reston, Virginia

JOHN J. BOLAND, The Johns Hopkins University

PAUL BUSCH, Malcolm Pirnie

CAROLE B. CARSTATER, National Research Council

HENRY CAULFIELD, Colorado State University

EDWIN H. CLARK II, The Conservation Foundation

JO CLARK, Western Governor's Association

EDWARD W. CLYDE, Attorney, Clyde and Pratt

JAMES E. CREWS, Corps of Engineers, Washington, D.C.

SHEILA D. DAVID, National Research Council

JAMES M. DAVIDSON, University of Florida

JOHN A. DRACUP, University of California, Los Angeles

BENEDYKT DZIEGIELEWSKI, Southern Illinois University

RICHARD S. ENGELBRECHT, University of Illinois at Urbana-Champaign

J. ERNEST FLACK, University of Colorado

DUANE L. GEORGESON, Los Angeles Department of Water and Power

JEROME B. GILBERT, East Bay Municipal Utility District

JAMES A. GOODRICH, U.S. Environmental Protection Agency, Cincinnati, Ohio

JACK HILL, East Bay Municipal Utility District

CHARLES HOWE, University of Colorado

CHARLES HUNTLEY, Bureau of Reclamation, Denver, Colorado

LES LAMPE, Black and Veatch Consulting Engineers

ROBERT LANKY, Bureau of Reclamation, Denver, Colorado

WALTER R. LYNN, Cornell University

DAVID LYSTROM, U.S. Geological Survey, Lakewood, Colorado

FRANCIS MAYO, U.S. Environmental Protection Agency, Cincinnati, Ohio

DAVID W. MILLER, Geraghty & Miller, Inc.

KENNETH MILLER, CH_2M Hill Consulting Engineers

WILLIAM MILLER, Denver Water Department

JEROME W. MILLIMAN, University of Florida

J. OBEYSEKENG, Colorado State University

FRANK OSTERHOUDT, Department of the Interior, Office of Policy Analysis

STEPHEN D. PARKER, National Research Council

WILLIAM RIEBSAME, University of Colorado

GARRY L. SCHAEFER, U.S. Department of Agriculture, Soil Conservation Service

KYLE E. SCHILLING, Corps of Engineers, Institute for Water Resources

DANIEL SHEER, Water Resources Management, Inc.

ROBERT E. SIEVERS, University of Colorado

ROBERT L. SMITH, University of Kansas

ROBERT SWAIN, Bureau of Reclamation, Denver, Colorado

RICHARD WAHL, U.S. Department of the Interior, Office of Policy Analysis

GARY WEATHERFORD, Watershed West, Consultants

GILBERT F. WHITE, University of Colorado

PETER O. WOLF, Consultant, London, England