Water Use and Management in an Arid Region (Fort Collins, Colorado and Vicinity)

By

J.W. Anderson, C.W. DeRemer and R.S. Hall.

Colorado Water Resources Research Institute

Information Series Report No. 26

Colorado State University

WATER USE AND MANAGEMENT
IN AN ARID REGION
(Fort Collins, Colorado, and Vicinity)

by

John W. Anderson

Craig W. DeRemer

Radford S. Hall

Submitted to

The Water Resources Planning Fellowship
Steering Committee
Colorado State University

in fulfillment of requirements
for AE 795, Special Study in Planning

September 1977

COLORADO WATER RESOURCES RESEARCH INSTITUTE
Colorado State University
Fort Collins, Colorado 80523

Norman A. Evans, Director


Drought, City restricts lawn watering
Drought, ire Threat
Drought
LONG-TERM SOLUTIONS SOUGHT
irrigation
water shortage
Water Curb
Water Shortage
THE DESE... LOSING IN
Drou...t Eroding West's ...timism
Water S...rtage Battle
...ENCY PLANS
DROUGHT CO...
Tips
Lawn-Preservation
Water-Saving
reservoir con...
'77 Drou...
Water Wastrels
Water Quality Down In Drought-Hit Areas
Seeding
pushes r...
Water Shortage Not Crucial—Yet
Drou...
Denver, Colo.—Climate Capital of the World—
Drought Aid

ACKNOWLEDGMENTS

The assistance and helpfulness of the many local officals and private citizens who were contacted during the preparation of this paper is gratefully acknowledged. A special word of thanks is extended to the staff of the Fort Collins, Colorado Water Department without whose assistance much of the information essential to this report might not have been gathered.

The guidance and assistance of the Water Resources Planning Fellowship Steering Committee is also acknowledged and appreciated. The committee consists of Norman Evans, Director of the Colorado Water Resources Research Institute and Chairman of the Committee; Henry Caulfield, Professor Political Science; James Meiman, Dean of the Graduate School; Kenneth Nobe, Chairman of the Department of Economics; and Everett Richardson, Professor of Civil Engineering.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

FIGURES

APPENDICES

SECTION I

INTRODUCTION

Water consumption and allocation have historically been controversial issues in the arid west. These issues have traditionally intensified during periods of prolonged drought as is presently being experienced throughout the west. This report is directed toward examining these issues and presenting an overall perspective of water consumption and means of conservation with respect to the Colorado Front Range, with emphasis on Fort Collins, Colorado and the surrounding area.

Through a cursory reflection on the development of western water policy and observations on current municipal and agricultural water use, the report will examine the need for more efficient water use in the Fort Collins area.

The vast majority of water use in the area is by agriculture. The report will discuss a few of the major items of concern with respect to agriculture irrigation. This, however, is a highly technical and specialized subject, and it appears that the greatest overall need may be for additional area-specific research to determine efficient irrigation techniques. Water in the past has been viewed as plentiful enough that efficiency has not been considered as vital as it may be in the future.

Although agriculture is the largest user at the present time, municipal water demands are increasing due to the rapidly growing population in the area. Water For Tomorrow, Colorado State Water Plan states:

> "In the market place, irrigated agriculture is able to pay substantially less for water than can be paid by some of the other productive uses, such as municipal and industrial development. In the past, this situation

> has resulted in many irrigation water rights being converted or transferred to other uses, and in the future, the ultimate result is likely to be a significant decline in overall irrigated acreage and in livestock production from irrigated hay and pastureland. This decline will occur more rapidly if cities have prescriptive rights to the water they need for expanding populations." (Water For Tomorrow, 1974).

It also appears that the mood for water conservation is set in the urban areas. Thus, the report will concentrate upon the identification of a range of urban water management measures available to local urban areas for water conservation programs. The discussion of these measures will, when applicable, document the effectiveness, problems and degree of public acceptance experienced through actual implementation of the measures by other municipalities.

SECTION II

HISTORIC FACTORS

Causes and Effects

Before discussing possible causes and effects of drought conditions, it is important to know what is meant by drought. Arid and semi-arid regions are usually defined in terms of the number of inches of annual precipitation occurring there. While there is no fixed number for these types of areas, regions with less than ten inches of precipitation (rain and snow included) per year are generally classified as arid, and those with ten to twenty inches per year are classified as semi-arid. The Fort Collins area has, with about 90 years of record, an average of some 14 inches per year, making it, like the rest of the Front Range of Colorado, a semi-arid region. The section on local precipitation history will discuss variations in yearly and monthly amounts.

Drought, unlike arid and semi-arid, cannot be defined precisely as a reduction of a given number of inches of precipitation per year or even a percentage decrease. A decrease of ten inches per year over a several year period would be disastrous in areas such as Fort Collins, while having an almost negligible effect in an area receiving, say, 50 inches of rain per year. It should be noted that parts of the U. S. receive well over 200 inches per year, and most of the U. S. east of the Mississippi receives 30 to 40 inches per year. Also, the need for volumes of water varies according to types of industry, agriculture, and social habits of the region.

Drought can, however, be defined in at least two useful ways. Some would agree that drought exists where the reduction in available water is such that significant economic and social impacts are felt. Others believe drought is better defined as a similar reduction in naturally occurring water supplies. The distinction turns on whether such projects as water diversion (e.g., Western Slope water to Eastern Slope) and storage facilities or cloud seeding and similar techniques should be considered separately from drought conditions. The effects of low precipitation are felt less severely where diversion and storage facilities are available and where, in an appropriation doctrine legal system, extensive water rights are held, separate from the land. Marin County, California with few storage facilities or alternate water sources is one area greatly affected in a short time by lack of natural water sources, whereas Fort Collins has many more sources, although these are not infinite. However, the use of water and the populations and economic developments needing water tend to rise to (or above) the level of water availability. Thus, even if current water sources exceed water demand today, even in precipitation-short periods, the future situation will be far more serious, unless per unit consumption and population stabilizes. New water sources and storage facilities are limited (see Water Supply Development in Section VI), and therefore the number of users and the amount of user consumption will be limited, either through planning or through hardship or even disaster. This will surely occur even if agricultural changes take place in the region, freeing more water for urban use (see Agriculture, Section V).

The precise cause or causes of drought is, as yet, not well understood. Indeed, many experts argue that there is no consistent or discernible cause other than arbitrary fluctuations of weather and climatic patterns. We do know, however, that there is great variability in precipitation locally, and that this variation calls for preparation for the water-short periods. Some of the possible physical causes of drought periods and their potentially cyclic nature, are discussed in the following section.

Drought is even more an expected climatic event in Australia than here. Yet it has only been recently that the government has begun to accept that drought "forms part of Australia's 'normal' weather pattern" (Lovett, 1973). There are now more efforts in preparation by the national government down to the individual on a continuing basis. Dams and irrigation, land use and community planning, tax and bond inventives and aid, extension service activities, grain reserves, promotion of a national drought institute, nation-wide education, and more vigorous climatological studies are all mitigating against the drought effects.

Because of physiographic, population, economic, and social differences, the situation in Australia cannot be related precisely to ours in the United States. However, the recurring pattern of drought, need for planning and management, and development of new attitudes and behaviors toward natural and stored water are similar.

An Australian farmer said "City people have criticized farmers for not conserving water, but I have stood in a city street and watched water (from sprinkling) flowing down the gutters." (Campbell, 1968.) This urban wastage is recognized in Australia as a psychological problem for the agricultural community. If agricultural water conservation is desired by the urban dweller, then this person must also show a commitment to water conservation. For urban and rural dweller alike, the recognition and acceptance of drought is a psychological and emotional problem. The dry period is seldom recognized physically until it is well underway, and the possibility of further precipitation is always a hope. A moderate rainfall may convince the population the dry spell is over, when there may be a much longer continuing lack of precipitation just ahead. Lovell (1973) cites the need for continuing education to create a realization of the reality of the problem and then to motivate a change in the public. An example, which could apply as readily to other natural and social hazards, is given in a drawing (Figure II-1) by the Texas Water Education Office. It depicts the 'hydro-illogical' cycle wherein the hazard increases concern so long as it lasts, then is forgotten once it is temporarily over.

Drought History and Cycles

The history of drought in the United States goes back to the first settlement by the white man. With settlement negligible in the Great Plains until the late 19th century, reports of drought conditions are largely in the east, and follow the movement of the country west. As early as the 1740s and again in the 1760s, the northeast suffered through drought conditions.

From 1860 to 1864 a drought in the midwest, beginning to have larger population influx, caused extensive crop damage. In the 1880s the east was severely hit by drought, and this in part helped the move to the Great Plains by eastern farmers.

From about 1886 to the present we have adequate precipitation records, which were sketchy before. These records allow us to chart accurately the

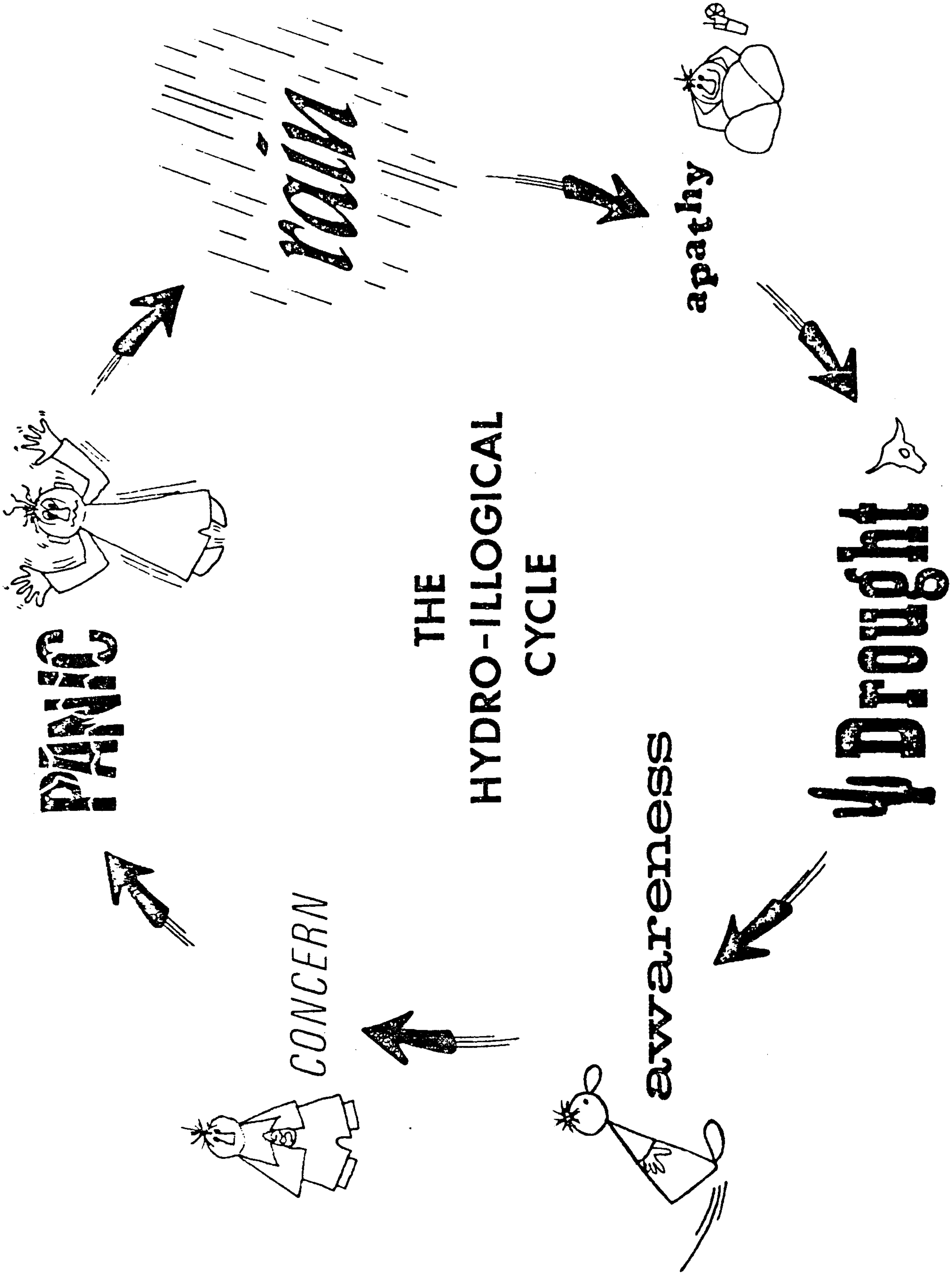

THE
HYDRO-ILLOGICAL
CYCLE
rain
apathy
Drought
awareness
CONCERN
PANIC

FIGURE II-1

the drought periods. Occupation of the Great Plains for agriculture began in the same period. Rainfall was plentiful until 1894 when a drought caused almost complete crop failure. Up to 90 percent of the settlers in some areas abandoned their land.

By the early 20th century, the rains had returned and with World War I raising grain prices, large scale farming with tractors took place. After 1915, however, the overly wet years ended and the normal dry state caused increasingly greater problems for farmers. Instead of a respite, the dry conditions became drought, and the famous Dust Bowl era of the 1930s was upon us. The combination of poor soil conservation measures and climatic conditions turned the drought into a catastrophic situation.

The drought was starting to ebb by 1936, but the devastation wrought by dust storms, grasshoppers, and erosion by wind and water made the area low in productivity into the 1940s (Tannehill, 1947). New management practices with soil protection, crop rotation, and wind breaks began to cut losses in dry periods. Still, the use of more and more land for agriculture, including marginally productive areas, made the losses in the drought of the early 1950s even greater than the 1930s (Farm Journal, 1976). This was also due to the lack of moisture at the critical times for agriculture. This evidences the fact that timing, as much as amount, affects the impact of drought periods.

Saarinen (1966) discusses three types of droughts; meteorologic, from lack of precipitation locally; hydrologic, from stream and groundwater sources diminishing; and agricultural, where due to timing, volume, or both, the crops do not develop properly. The definitions chosen depend on the purpose of the study; for our purposes the social and economic damages are key, no matter the type of criteria adopted.

The oceans are known to have their greatest impact on the world environment as climatic regulators. As the key source of water and with vast area, their motion and variation impacts globally. The exact effect on precipitation is not absolutely certain, but the seasonal movement of the warm and cold water currents (see Figure II-2) is known to affect seasonal rainfall on and near coastal areas.

At this time, the largest Pacific Ocean currents are much farther from the coast of the United States than normally. This may be the immediate cause of the lack of moisture getting to the continent. Other factors which may be impacting on the currents include sunspots and magnetic activity of the earth which has been extensively studied by Dr. Walter Orr of the University of Colorado. Dr. Orr has long promoted a theory that there is a 20-year cycle of drought which corresponds to sunspot activity. Recent evidence from tree-ring analysis has confirmed that there is roughly a twenty year cycle, although the length and intensity of the droughts vary. In fact, as Figure II-3 shows, the amount of drought in the last one hundred years is less than earlier times. The peaks show the intensity of the droughts, the size of the dark area shows the extent.

The relation of this drought cycle sunspot activity, magnetic changes, or even ocean currents is not conclusive, however. It is a reasonable hypothesis that varying radiation from the sun may affect the ocean activity, indirectly changing precipitation on the continents. Also, varying radiation may affect the amount of precipitation from those clouds that do form and vary the evapo-transpiration and winds which will impact on local

Figure II-2

World Wide Ocean Currents

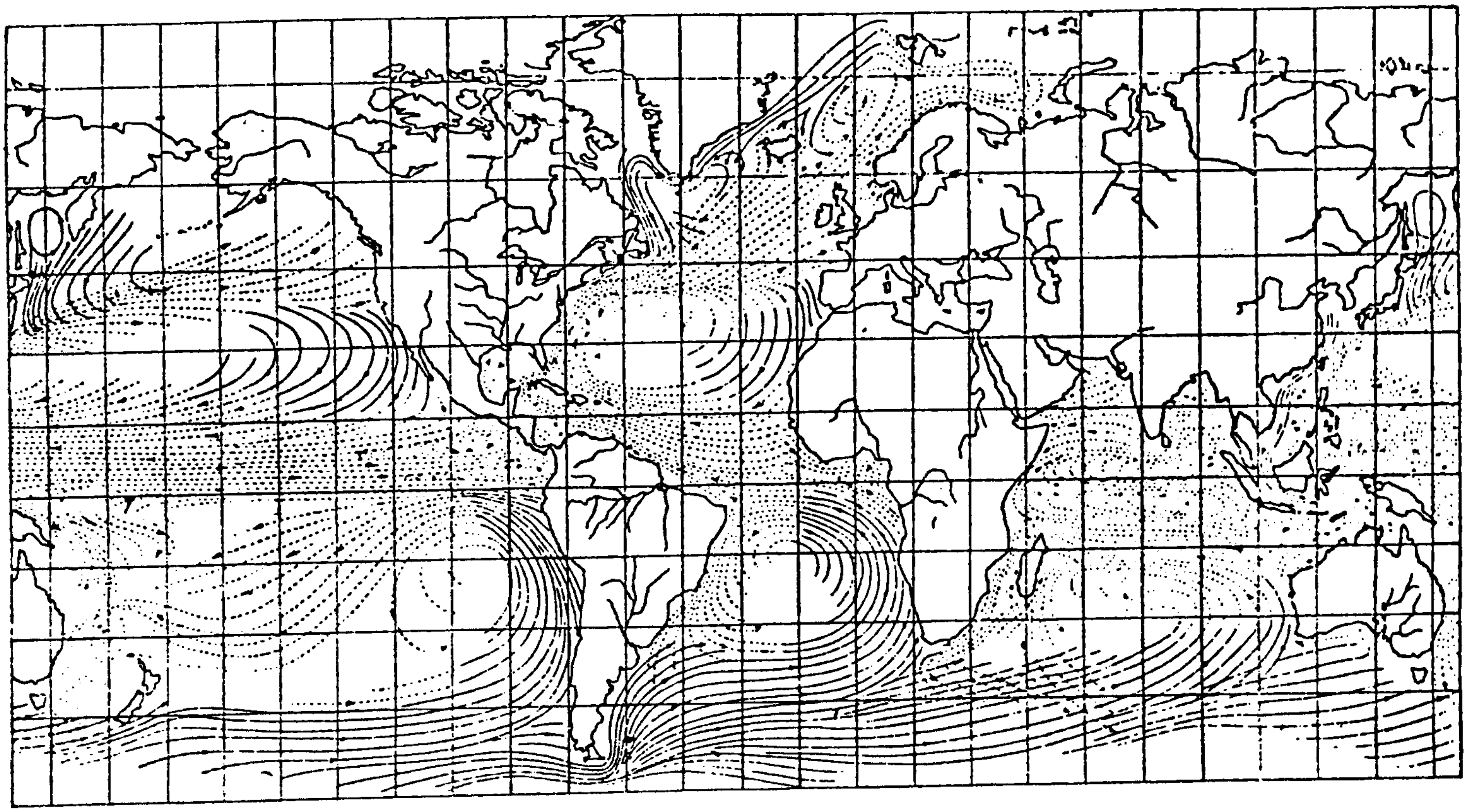
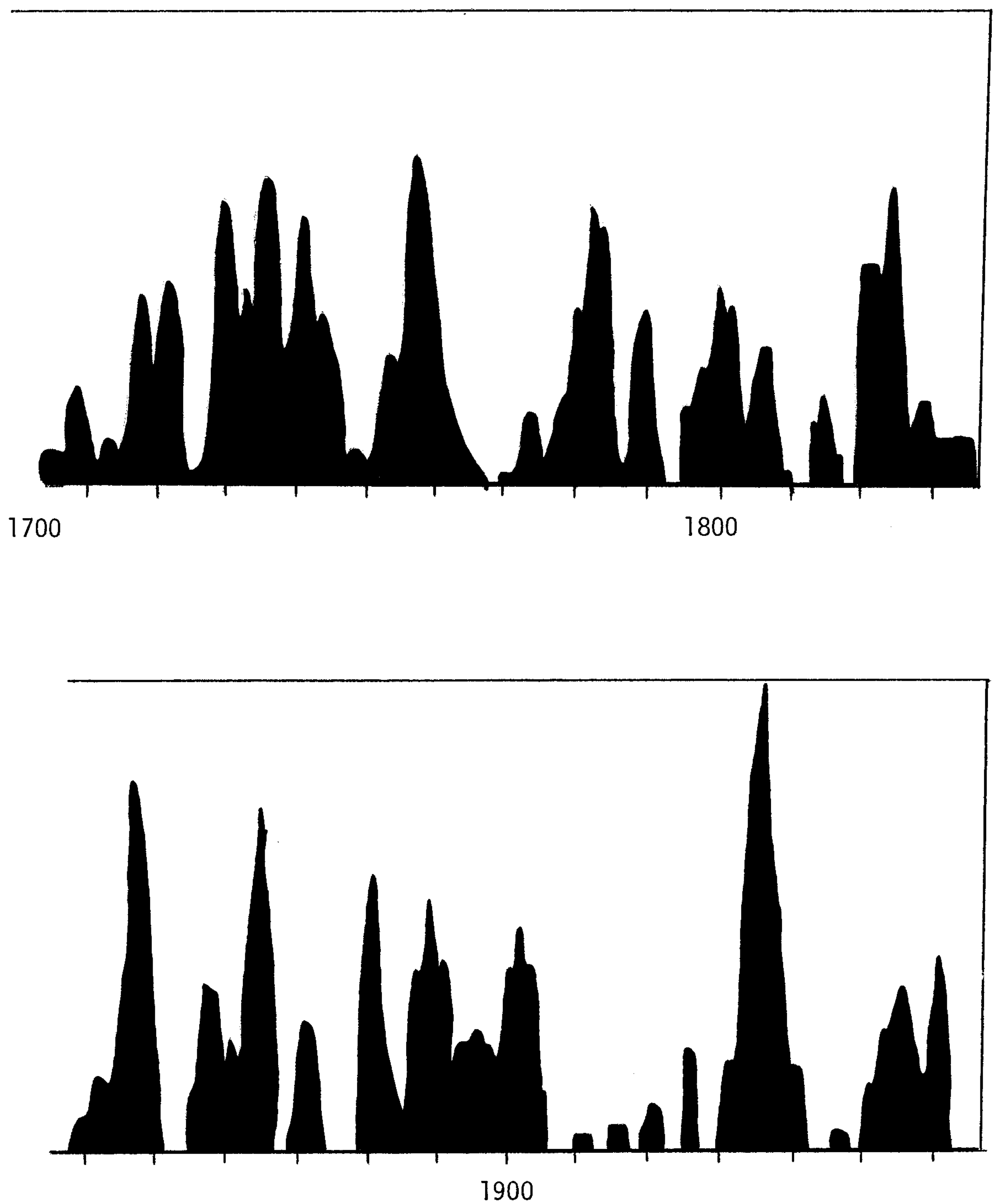


FIGURE II-3

Western Drought History Based
on Tree-ring Data



climatic conditions. The effects of increased air pollution, nuclear fall-out, carbon dioxide, and changes in the ozone layer are much less certain and will certainly complicate an already very complicated system.

In summary, although certain factors are being identified which may help create drought conditions, we are a long way from understanding, much less controlling, this global system. The only certainty, and the one which can and must be planned for, is that there will be more dry periods, some longer and more severe than so far experienced.

Local Precipitation History

Appendix A details the total precipitation history of the Fort Collins area from 1898 to the present. There are records available even earlier than this. The primary thing to see from these records is the variation from year to year and comparison by month from year to year.

Since 1898, the annual precipitation (rain and snow included) has varied from 28.42 inches to 7.34 inches, with a current average around 14 inches. The average in 1930, however, based on records to that time was closer to 15 inches. As more history goes by, the extremes and the averages are certain to change.

It was mentioned earlier that certain times of rainfall are as important as amount for the agricultural community. The variation is amazing. For instance, in May, 1966, only .27 inches of precipitation fell (against an average of 2190 inches). In May, 1967, 4179 inches fell. This variation certainly makes it difficult for consistent planning in the agricultural economy.

Only irrigation, due to storage and diversions of water have allowed any stability for farmers. However, as urbanization continues, there will be more use for this water in cities, which can develop and transfer the water more economically. More importantly, droughts can become quite extensive as the last year has shown. When snowfalls are low and precipitation is down at the diversion sources, even water development projects cannot solve the scarcity dilemma.

If prediction of precipitation is improved, better planning for dry periods will be possible. Even with better knowledge, however, planning and management of our activities is needed to maintain the lifestyle we desire.

Predicting Precipitation Patterns

Management decisions must be made regarding water use with some factual base. There is at present no accurate way to know what precipitation will be. However, there is some validity in assuming that the precipitation patterns of the past will be the same, generally, in the future. Gifford, et al, (1967) developed tables for the western region of the United States based on the 30-year period from 1931 to 1960. The tables (see Appendix B) give the probability of the occurrence of a given amount of precipitation over one, two and three week periods.

The probabilities are less reliable, unfortunately, in arid regions such as the Fort Collins area. Also, local topographic and meteorological influences will vary the amounts of precipitation on a specific site. Nonetheless, if the precipitation level which is critical for a certain decision is known, these tables can help the decision-makers determine whether certain actions should or should not be taken.

As an example, perhaps a certain activity would be inhibited by less than .4 inches of rain in one particular week. By looking at the one-week table, the probability of .4 inches or more in that week can be ascertained. For Fort Collins, in the week of May 10, it would be 49 percent; in the week of November 8, it would be 10 percent. The manager can then decide if the probability is such that there should be protective or alternative measures taken together with other considerations.

The authors do stress the locational nature of the data and the influence of geographic and topographic proximity to measuring stations. Also noted is the problem of type of precipitation and the number of occurrences during the week. A review of actual precipitation since 1960 with a computer analysis of variance from the predicted amounts would help validate the method and its utility as a management tool.

REFERENCES

Campbell, D., Drought: Causes, Effects, Solutions, F. W. Chesire, Melbourne, Australia, 1968.

Gifford, R. O.; Ashcroft, G. L.; and Magnuson, M. D., Probability of Selected Precipitation Amounts in the Western Region of the United States, Univ. of Nevada Agricultural Experiment Station, October, 1967.

Lovett, J. V., The Environmental, Economic, and Social Significance of Drought, Angus and Robertson, Sydney, Australia, 1973.

Millan, Jaime, Drought Impact on Regional Economy, Colorado State University Dissertation, 1972.

Saarinen, T. F., Perception of the Drought Hazard on the Great Plains, Univ. of Chicago Dept. of Geography, Research Paper 106, 1966.

Tannehill, I. R., Drought, Its Causes and Effects, Princeton Univ., 1947.

SECTION III

WESTERN WATER POLICY

General

Throughout the history of the American west, water has played a critical role. The early expeditions of Zebulon Pike in 1810 identified the west beyond the 98th meridian as an arid land and labeled it the "Great American Desert" (Pike, 1810), However, it remained for John Wesley Powell, Chief of the U.S.G. and G. Survey, Rocky Mountain Region, to provide the first definitive description of the western lands.

Powell's report, submitted in 1878, and entitled A Report on the Lands of the Arid Region of the United States, with a more detailed account of the lands of Utah, identified the arid lands of the west as having significant differences from those eastern lands familiar to the public of that time. Powell's work would ultimately be recognized as one of the most important books ever written about the west. As Stegner (1962) in his introduction to Powell's report states; "Essentially, Powell's Report on the Lands of the Arid Region was a sober and foresighted warning about the consequences of trying to impose on a dry country the habits that have been formed in a wet one." Powell, who defined an arid land as receiving less than 20 inches of precipitation per year, proposed a number of radical departures from then existing policies for dealing with the arid lands. Among these were revision of the 160-acre homestead and modification of the rectangular system of land surveys. These he felt were not appropriate to dry lands where either more or less land was needed and boundaries should more accurately reflect drainage areas. Powell also recommended revision of the agency structure dealing with these policies. Of particular interest to this paper was another of Powell's significant recommendations, that being that the "right to use water should inhere in the land to be irrigated, and water rights should go with land titles." His fear was that water would become a property independent of the land, and this property would gradually be absorbed by a few. Thus, his contention that in the arid lands the right to water be acquired by priority of utilization but the user right should attach to the land were used, not to the individual or company constructing the canals by which it is used. These proposals were radical and strongly opposed by powerful interests of that time, and as may be seen by existing policy and water law, were essentially not adopted, possibly to the detriment of western development. As stated by Stegner, "Powell was willing to look at what was, rather than what fantasy, hope or private interest said there should be." This was unique in 1878 and as this paper will attempt to show continues to be unique one hundred years later as a western water policy.

There was no disagreement from the beginning that water was a critical limiting factor to development of the west. This essential character of western water resources caused it early on to be viewed as principally an economic rather than natural resource in terms of management and law. From this basis, a western water institution, "the appropriation doctrine" evolved which treated water as a separate property right or economic resource as compared to the natural resource nature of the riparian doctrine common to the more water abundant humid areas of the east. Nowhere was this concept more intensively applied than in the inter-mountain region located along the continental divide.

Throughout the past century, this inter-mountain region as well as the remainder of the west has encouraged the provision of complex water resource development programs. The reasons for these programs and the needs to be met have been many. The area has developed vast agricultural resources through irrigation and it has accommodated large amounts of population and urban centers providing a lifestyle not unlike that found in the humid east from which many of the new residents originated. The deserts and arid regions were made to bloom, as intensive water resources provided the vast amounts of water needed and not available through the natural ecosystem.

It is now becoming apparent that throughout the inter-mountain region continued development of additional water resources may be limited. This view is based upon several factors: current water resource developments are aimed at the last remaining undeveloped sources; rivers are fully or even substantially over appropriated and even during years of high precipitation supplies are not adequate to fulfill all water rights; the appropriation doctrine is being questioned as the most appropriate means to allocate scarce water supplies; and the environmental and social costs of further water resource projects are given high consideration and serve to limit further development and beneficial uses of water other than development and use (i.e., instream) are receiving greater importance.

While the above limitations are becoming increasingly restrictive, the lure and image of the west continues to attract new residents. Water demands continue to grow from both the increased urbanization resulting from new population growth and the ever increasing demands made by agriculture, industry, and existing development which ultimately results in increased requirements for water.

Thus, it can be seen that in the arid west, water continues to be a critical factor and may indeed be becoming the most critical factor in the future of the inter-mountain area and the remainder of western America. The decisions to be made to adequately deal with future questions of water use and development in the west may require substantial alteration of currently held attitudes regarding water. To evaluate the nature and magnitude of these changes and impacts, it may first be desirable to reflect upon some historic and current public attitudes toward water in the inter-mountain area in general and Fort Collins in particular.

Historic

Although identified by Powell as arid and having restricted potential and specific limitation on development, most who came to the west brought with them the notion that the lifestyle enjoyed in the east could be maintained. With the initially small population existing in the west and most settlements and farms located near major water sources, the available supplies seemed great. Thus, the scarcity of the resource as examined by Powell was not immediately apparent. Cyclic periods of drought which Powell anticipated served to provide warnings of the limitations but by and large supplies of water were adequate.

As communities grew, settlement of the west continued and irrigated acres increased; the demand for water also increased ofttimes beyond the immediate availability of water. Typically additional supplies were developed in advance of this demand eliminating the scarcity of water as a limiting factor. This process evolved through community action and

Federal policy such as the 1902 Reclamation Act by which Federal reclamation projects were designed to encourage growth and settlement of family farms in the west through provision of adequate and inexpensive water supplies. Ultimately major region-wide development projects were designed and completed, providing the vast water supplies needed for massive irrigation.

Concurrent with this water resources development evolved the legal western water foundation of the appropriation doctrine. This is the "first in time, first in right" approach to water usage commonly known, in which water is considered to be a vested right. This economic approach to water rights was based on perfecting a right through beneficial usage. Until recently, beneficial usage required diversion and consumptive use with the ultimate conclusion that for total beneficial use, the supply should be totally utilized or, in other words, the stream dried up. This doctrine, which is critical to any study of western water development, directed that the ultimate goal be full productive use of all western water resources. It should be noted also that under the appropriation doctrine water rights may or may not be attached to the land as was recommended by Powell. California as an example adopted the former procedure while Colorado adopted the latter or separate independent right concept.

It is not difficult, therefore, to envision a prevailing historic attitude toward western water. While water was known to be a scarce resource and identified as such by the economic and beneficial use approach represented by the appropriation doctrine, the continued development of available supplies served to provide an adequate supply for continued growth and the water resource was not viewed as a limiting factor.

Thus, the stage was set for those arriving in the west to continue to hold an attitude toward water use similar to that held in the water rich eastern areas of their origin. While in the late 1800s and early 1900s it may be seen that agriculture and urban areas tended to adopt the native landscape of the arid west, the provision of adequately developed water supplies quickly allowed duplication of the lush green vegetation of the water rich east.

The dust bowl days of the 1930s were a painful reminder that possibly the artificial agricultural and urban environment could not be maintained in the semi-arid west; however, with the return of normal rainfall following the droughts and the development of ever more complex water resources systems, those warnings were quickly forgotten.

<u>Current</u>

Throughout most of the past two decades, with some minor periods of drought, water development has kept pace with demand and water scarcity has not been of critical concern to those living in the arid or semi-arid inter-mountain west. That is not to say that a great deal of planning, engineering and policy making has not been directed toward water resources. The continued availability of adequate supplies in the face of ever increasing demands is ample evidence of the magnitude and success of this effort toward water resources development in recent times.

Coming to the 1970s considering the history of water in the west, the prevailing attitude of the general population of the arid and semi-arid west is understandable. That is, that sufficient water is available to maintain the known standard of life which includes a predominance of eastern green shade tree landscaping, water intensive irrigated agriculture and in general a lifestyle suited to an abundant supply of water. The public prior to recent events was unaware and justifiably unconcerned that possibly this lifestyle was artificially supported by water supplies provided by major water resource developments.

For several reasons which were alluded to earlier, there are indications that the situation may be changing. These changes, if indeed they are eminent, may have profound impacts upon attitude and lifestyle in the inter-mountain west. To evaluate this possibility we shall consider the following indicators or events which may provide images or clues to future conditions.

Drought: Powell in his Report on Arid Lands predicted that in the identified arid lands (20 inches rainfall or less per year) many droughts will occur and their effects on agriculture would be significant due to the marginal conditions even during normal years. Powell himself observed this during the decade of drought that began in 1887. As stated in another part of this paper, subsequent serious droughts were experienced during the 1930s and the 1950s in the arid lands. With more extensive development of irrigated lands and increasing population, the effects of these droughts increased with time.

California in 1976 began to experience a new period of drought. The remainder of the arid west including the inter-mountain region began to experience drought conditions during the winter of 1976-77, with the drought extending to the present time. The advent of new drought conditions has required sacrifices by all elements of the west, and has served to bring once again the concept of arid lands to the attention of the government and the public.

Water Resources Development: During and following periods of previous drought, it was possible through major water resource projects to develop new supplies through existing sources or transport. This availability of water supply through developed sources removed water as a limiting factor and helped to reduce the impact and concern over drought. As discussed by Vlachos and Hendricks (1977) the current water resources development projects are attempting to utilize the last remaining undeveloped supplies. This is evidenced in many ways; one is the often heard fact that all the good dam sites have been utilized already. In Colorado, with the exception of the Yampa River, all rivers are over appropriated and the possibility of developing additional supplies is limited. Thus, the continued resolving of the problems of the arid lands through water development or the technological fix method may be impossible or at best substantially reduced.

Social and Environmental Values: Since the late 1960s or early 1970s, an environmental or preservationist movement has been active in the west and the remainder of the country. Many aspects of this movement have been directed at western development and growth. Whereas water resources development has historically been controversial, in the past the issues have been mainly regarding water rights and use. Presently the controversy surrounding water resources development relates less to questions of rights and more to social and environmental values. These values were officially recognized through passage of the National Environmental Protection Act of 1969 (NEPA). Thus, even the development of the last remaining supplies through planned projects is threatened by the consideration of these social and environmental values. This point was clearly made with the introduction of the Carter Administration water project "hit list," and is being reinforced by the evolving Carter Administration National Water Policy currently under review (Federal Register, July 15, 1977).

Other indicators such as the argument that certain instream uses (recreation, fishery habitat) be considered beneficial use under the appropriation doctrine and the controversy concerning the application of the Federal Reservation Doctrine also provide evidence that possibly the western water attitude and policy is at a point of change or modification.

Local Area

Stegner in his review and discussion of Powell's arid lands report states the following:

> "Apparently one of the hardest things for a wet-country man to credit is the persistent fact of insufficient rain. That single fact, as Powell told the nation in 1878, and kept telling them until his death in 1902, and has been telling them through converts and disciples ever since, is enough to make impractical and even destructive a whole inherited culture, a whole body of law and custom and political organization."

Prior to the most recent drought conditions (1976-77), local area attitudes of the Larimer County, Colorado could be expected to follow somewaht this inherited culture and custom with respect to water. Lupsha, Schlagel and Anderson (1975) and Cotter and Croft (1974) reported on attitude and practice of western populations with respect to water use. These two reports which represent the most definitive writing on the subject available address water use within the State of New Mexico.

The reports present factual data and survey results too extensive to be repeated here; however, it is of value to consider a few overall findings. As might be expected from the preceding discussion, in general respondents to the survey viewed water supply to be only a minor problem or no problem at all. Respondents by a large majority favored green landscaping over native landscaping but also favored a progressive rate structure (i.e., the more you use the more you pay). Several theories on water use were evaluated such as new residents having a higher per capita use than older or native residents, and use being dependent upon place or origin. These and other hypotheses such as ethnic or cultural backgrounds were rejected as not having any consistent effect upon water use nor per capita use. The one outstanding characteristic which was identified was that of increased water use with increasing household income. This appeared to involve relationship of income to residential lot size, type of landscaping, number of water using appliances, number of bathrooms per residence and similar income oriented factors. It is also of importance to note that most of the residential units sampled in these studies were individually metered.

Based on the preceding discussion and findings, it can be seen that prior to 1976 a model of western water attitudes might involve a lack of concern over water supplies, a preference for lush green landscaping, and a highly water demanding lifestyle depending to some degree upon income. Admittedly this model relates most closely to urban residents; however, its application to agricultural or rural lifestyles may not be unacceptable. A non-metered region such as the City of Fort Collins would tend to reinforce this model by decreasing even further the even minimal concern over the amount of water used per capita or per household.

The advent of drought conditions in the west beginning in 1976 appears to have had at least a temporary significant effect upon this model. This impact while being general in nature appears to relate directly to the severity of the drought conditions being experienced in the specific local area. In Marin County, California for example, which is a critically affected area, water supply awareness is universal among the population and significant changes in lifestyle have been incorporated. Indeed as the following quote from the Denver Post (Drought Eroding West's Optimism, July 20, 1977) indicates the drought may be altering concepts of many natural resources:

> "What has happened in California is more than a drought. It is a change in the fundamental mind-set of a people who acted as if they believed that the supply of water, energy, shoreline, fish, wildlife, crops and forests were inexhaustible."

In Denver, Colorado the present impact is less severe and thus the alteration of the model is somewhat less. Water supply awareness is increasing and minor modifications to the lifestyle are evident, yet their remains some doubt that indeed the water shortage is even real (letter to the Editor, Denver Post, June 12, 1977). However, most residents, by virtue of water restrictions, have an increased awareness of water supply limitations and have altered their lifestyles accordingly as the following quote from a Denver resident indicates, "After all, a brown lawn is the status symbol this year," (Water Restrictions Changing Some Aspects of Living, Denver Post, July 6, 1977).

This heightened awareness of natural resources limitations in general and water supply in particular is further documented by an ongoing study of public policy preferences in the southwest. Known as the Southwest Policy Research Project, the study being conducted by Helen Ingram involves the cooperative efforts of selected universities in the states of Utah, Arizona, New Mexico and Colorado. Some preliminary results of surveys conducted in conjunction with the study have shown, for example, in Arizona 69% of voters and 83% of legislators felt water shortages represented a serious problem (Arizona Speaks, Fall, 1976). In another finding of a study survey Colorado voters identified environmental issues as the most important problem facing the state, and in general the study trends tend to indicate increasing concern among both the public and the elected representatives with respect to water and other natural resource uses.

In Fort Collins, Colorado, the actual area of interest for this paper, the situation has been rapidly changing. The City, through wise planning and acquisition of water rights, has maintained an apparent abundance of municipal water supplies which appeared to be sufficient to maintain existing policy without restriction through the drought period. Informal surveys (Fort Collins Journal, June 20, 1977) and numerous newspaper articles indicated that the public in Fort Collins was becoming aware of drought conditions elsewhere in the region and while thankful for the apparent adequate supplies within the city would be supportive of restrictions and conservation if such measures should become necessary.

While it was to the credit of those responsible for water planning within the City of Fort Collins that supplies were adequate, in light of the general alternation of widely held views regarding western water use brought on by the drought and other elements discussed earlier, the continuance of "business as usual" at best seemed unrealistic and possibly damaging. In light of changing attitudes and voluntary or enforced conservation among surrounding regions and communities it seemed difficult to justify continuation of the highly water demanding lifestyle for any selected community regardless of the adequacy of present supplies. Strongly worded editorials (Triangle Review, Fort Collins, Colorado, June 8 and June 15, 1977) questioned the impact upon adjacent agricultural communities and individual agricultural interests who were experiencing severe shortages of water and adopting both voluntary and enforced conservation measures when faced with the apparent unaltered attitude and lifestyle of the local urban area.

Numerous local newspaper articles indicated that perhaps the municipal supplies available to Fort Collins were not fully adequate and that conservation measures should be instituted in anticipation of an extended period of drought (Fort Collins Journal, February 25, 1977; Triangle Review, April 20, 1977). Such contentions appeared to be largely ignored until early July 1977 when it became apparent that through a series of problems, miscalculations, drought related shortages and higher than anticipated agricultural uses the expected reserves could not be maintained. Thus the water department staff and subsequently the Water Board recommended to the City Council that water conservation measures be instituted to achieve a 10-15% reduction in water use. The City Council on July 12, 1977 follollowing the recommendation of the Water Board adopted a program of watering restrictions aimed at achieving a 20-25% reduction in water use

(Fort Collins Coloradoan, July 13, 1977). Thus, the residents of Fort Collins in like manner to residents of many areas of the west have come to acknowledge through enforced limitations on water use at least a temporary alteration of lifestyle and attitude with regard to water use within the arid west.

REFERENCES

Cotter, Donald J. and Croft, Don B. Water Application Practices and Landscape Attributes Associated with Residential Water Consumption. Las Cruces, New Mexico, New Mexico Water Resources Research Institute and New Mexico State University, (November 1974).

Ingrahm, Helen. Southwest Policy Research Project, (a study of public policy preferences in the Southwest), Utah State University, Logan, Utah, University of New Mexico, Albuquerque, New Mexico, University of Arizona, Tucson, Arizona, Colorado State University, Fort Collins, Colorado (1976)

Lupsha, Peter A., Schlegel, Don P., Anderson, Robert U. Rain Dance Doesn't Work Here Anymore or Water Use and Citizen Attitudes Towards Water Use in Albuquerque, New Mexico, Albuquerque, New Mexico, The University of New Mexico (December 1975).

Pike, Zebulon. An Account of Expeditions to the Sources of the Mississippi and through the Western Parts of Louisiana in 1810.

Stegner, Wallace (editor), Report on the Lands of the Arid Region of the United States (with a more detailed account of the lands of Utah) by John Wesley Powell, Cambridge, Mass. Belknap Press of the Harvard University Press (1962)

University of Arizona, Arizona Speaks, Tucson, Arizona, Institute of Government Research, (Fall 1976)

United States Government, Federal Register, Water Resources Policy Study, Issue and Option Papers, Water Resources Council, Vol. 42, No. 136 - Friday, July 15, 1977.

Vlachos, Evan and Hendricks, David W. Technology Assessment For Water Supplies, Fort Collins, Colorado, Water Resources Publications, (1977)

Wengert, Norman. Fragile Lands - People - and Politics: Some Questions for Policy Decisions, paper presented at the Fragile Lands Workshop, Lamar, Colorado (March 24, 1977)

SECTION IV

OBSERVATIONS OF CURRENT WATER USE

General

As is true throughout Colorado, there is more water used by farm irrigation in Larimer County than by municipalities. For this reason, there will be a brief discussion on some of the problems involved with reducing amounts of water needed for agricultural irrigation. However, as stated earlier, the mood seems to be set in urban areas concerning the value and resulting use patterns of water. Also, as the Front Range grows, municipal use will become more and more important since it will obviously continue to increase in intensity while agricultural use will be forced to decrease proportionately. The overriding reason for this situation as pointed out in Water For Tomorrow, Colorado State Water Plan seems to be cities' ability to pay more for water than irrigated agriculture can (Water for Tomorrow, 1974). Fort Collins was recently reported as the 3rd most rapidly growing city of its size in the U. S. According to a July 13, 1977 article in the Fort Collins Coloradoan, 1977 will be a record year for construction throughout the area. There is, therefore, evidence that conversion of agricultural water to urban use will occur as rapidly here as anywhere else in the arid West. In the introduction to the proposed Larimer County Policy Plan drafted November, 1976, it was stated by the County Planning Department:

> "To meet the needs of new and expanded industries and businesses and those of an expanding population, farm and ranch land is converted to industrial parks, office parks and service facilities. These changes will alter the original scenic value of the county, necessitate the conversion of agricultural water to domestic and industrial uses . . ." (emphasis added)

Water for Tomorrow, Colorado State Water Plan, under Critical Issues and Problems, states:

> ". . . in some cities along the South Platte River, especially near the Front Range, the municipal and industrial water supply is becoming critical and in the absence of other alternatives, agricultural water rights have been purchased. There is a danger there that the basic agricultural economy will be destroyed."

So it seems that urban water use in the Colorado Front Range is not only an issue due to its sociopolitical implications, but it is becoming more important in terms of amounts of water used as the area becomes more urbanized.

Agricultural Water Use

Agricultural irrigation accounts for about 79 percent of Colorado's estimated 5.3 million acre feet per year water depletion (Water for Tomorrow, 1974). Therefore, the greatest potential for actually saving water in most areas of Colorado appears to lie within the science of farm irrigation efficiency. Furthermore, as cities such as Fort Collins continue to purchase more agriculture water to convert to urban use, it will become necessary for farmers to operate using less water to produce the same crops. Agricultural irrigation is a highly technical subject and will not be discussed in detail in this paper. However, there are some obvious actions which need to be undertaken technically to help improve the overall water outlook.

It seems obvious that farmers in the area of Fort Collins, Colorado would not want to purposefully waste water, since their livelihood depends upon irrigation of their land. Furthermore, individual farmers have to pay for irrigation water, and tend to be more aware of its value than individual city dwellers who pay a flat rate as is the case in Fort Collins.

Even though farmers do not wish to waste, procedures are not available to them to know precisely the right amount of water to apply at the right time in order to conserve water while producing maximum crop yield. Often water is applied a few days earlier and for longer periods of time than is absolutely necessary to produce the maximum attainable crop. The greatest need to help farmers become aware of optimum irrigation applications is additional research in irrigation techniques and methods. Because farmers don't have the extra time and money to develop their own research and development data, this must obviously be done through governmental agencies such as Soil Conservation Service, Extension Service and Agricultural Research Service and through universities. In an Agricultural Research Service report entitled Soil Water Air Sciences Programs it is stated:

> "Irrigation and drainage technology has evolved over centuries, growing more or less out of the need in arid areas to apply water to crops to stabilize production or to avert crop failures, and the need in humid regions to protect crops from excess water. Much of the "art" of managing waters has come directly from experience of farmers and land and equipment developers. In the past half century, a major effort has been made by agencies and institutions to convert irrigation and drainage from an art to a science." (Soil Water Air Sciences Programs 1976).

According to this report limited information is available on optimizing the production per unit of water in relation to climatic conditions where supplies are limited. Further it is reported that the technology of applying fertilizers in irrigation water is not adequate. Safeguards are needed to help prevent fertilizer waste and pollution of groundwaters and streams. Compaction is another area which presents a problem of inefficient irrigation applications. Research on compaction would help in determining water conservation measures.

The report goes on to explain that "many irrigation distribution systems have become outmoded." The high irrigation efficiencies required in today's agriculture cannot be attained with these older systems, due to their lack of ability to adequately control water. Advances in water management for crop production in the next 15 years should come from integration of components and subsystems into overall or total water management systems. To achieve this, data systems are envisioned including computerized measurements of such parameters as soil moisture and other soil-plant variables which will be fed back to operate water input-output systems. Telemetry, remote sensing, computers, and automation are expected to be important components in the operation of such overall systems.

It is emphasized in the ARS report that it is important to recognize that irrigation and drainage requirements are site specific. Many of the research reports that farmers have had to rely on in the past have not even been area specific. For instance, a report done for Region 7 of the Bureau of Reclamation (which includes Fort Collins) entitled Use of Water on Federal Irrigation Projects, 1970). While much of the data might be useful to farmers and agriculture agents in and around Fort Collins, it would be more valuable if done in this area. Soil characteristics and rainfall most likely are different enough to make optimum irrigation procedures in the Fort Collins area different from those in the study areas. In addition to being area specific, research should be conducted on a scale relative to that at which actual farming occurs. It was pointed out in the aforementioned summary report by the Bureau of Reclamation that data normally available to the irrigation planner and designer consist mainly of operational records from existing farms or from small research plots. However, poor or no records are often kept by farm irrigation operators. On the other hand, data kept by researchers are generally accurate, but done on too small a scale to relate to an actual farm situation. While trickle or center pivot irrigation systems may prove very efficient on a small research plot, the cost of installation and maintenance of such systems necessary to irrigate many acres may not be apparent. Furthermore, to reiterate the point regarding area specificity, if the research plot is in an area with 15 to 20 inches of rainfall per year, the data may not be adequate to use on a farm in an area receiving 9 to 13 inches of rainfall per year.

Colorado State University located in Fort Collins, would be a logical institution to conduct area specific irrigation research for the Fort Collins area. However, CSU has been critized by the Director of the Colorado Water Conservation Board for doing a "miserable job" in helping farmers learn how to conserve water in their irrigation practices (Fort Collins Coloradoan, July 15, 1977). The Director's complaint was that irrigation engineers are not placed in the field by the school to help the farmer. As stated by a CSU official in the same article, the school would have such a program if funds were available. However, the institution's Extension Service has been unable to get legislative support for water resources programs." As cities throughout the front range expand, and as larger production demands are made on area farmers, legislative support for such programs will become even more vital.

Richard A. Warrick in Drought Hazard in the United States: A Research Assessment suggests many research programs to aid in the management of agriculture in order to be better prepared for droughts (Warrick, 1975). One of his suggested programs is irrigation and water supply protection in which he includes the subjects of technical aspects of water supply conservation, user efficiency, and water laws/institutions.

In the area of technical aspects of water supply conservation, Warrick points out the need for better technology in canal lining, evaporation control, and the control of evapo-transpiration losses by way of the control of phreatophytes. In an article in the June 19, 1977 edition of the Fort Collins Coloradoan it was pointed out that bentonite, a natural substance found throughout the Rocky Mountains can be used very inexpensively to line irrigation ditches. Additional research may turn up more such natural substances which are just as useful. However, bentonite has been known for quite a number of years to be a good ditch liner, but either the knowledge of the technology for using it or the recognized need to line ditches have not been sufficient to encourage its use. Perhaps dissemination of information about known technical water supply conservation is just as important as new research.

Research which will help to increase user efficiency, Warrick says, is needed "at an annual funding level of five person years for five years." This work would be a continuation of research on crop yield-water requirement relationships, along with technological research on improving efficiency in water application systems. He adds that there is a need to direct research toward gaining a fuller understanding of the factors influencing the adoption of water conservation techniques.

There is a lot of overlapping and inconsistency of laws, regulations, and administrative policies of various levels of government regarding water supply and distribution. This has caused the prevention of efficient management of water resources, and therefore research on water laws and institutions is necessary (Warrick, 1975). Warrick states that an interdisciplinary research approach is necessary to define the nature of existing institutions, their deficiencies, and alternative models of water supply management to overcome related problems.

One water resource problem which falls into all the aforementioned areas of irrigation research is ground water management. While there is probably room for improvement of technical knowledge about underground water storage and how to use it, the most needed research lies in the area of management and control of the resource. As pointed out in a Colorado State University Experiment Station bulletin entitled "Colorado's Ground-Water Problems," ground water development is accomplished largely by individual effort and private funds (Colorado's Ground Water Problems, 1967). This creates much less opportunity for control than does surface-water development which occurs through efforts and financing of groups such as irrigation companies, municipalities, and governmental agencies. New institutions are needed to direct ground water planning and management in a way that will conserve the resource and at the same time facilitate optimum use to irrigators and other users.

Another problem which should receive research effort is prioritization of prime agricultural land. If farm irrigation water is to be converted to municipal use, and it is inevitable that it is, it should be taken from less productive lands. Some legal instrumentation is needed so this can be done.

While the need for farm irrigation research is great, the major step in stepping up research programs and in gaining the acceptance of the results of such research lies mainly in the overall attitudes of the people involved.

Municipal Water Use

There are several rural water districts in the surrounding areas of Fort Collins, each with their own water systems and rate schedules. Each of these districts has had its problems due to water availability and system inadequacies. The Fort Collins system, on the other hand, appeared to have an adequate supply even in the midst of the 1977 drought due to ownership of surplus water shares. Not until early July, 1977, did the City realize it needed to limit lawn irrigation in order to conserve water. The fact that the City felt that it had an adequate water supply while many areas close by did not raises many interesting questions, some of which are: should a city be an autonomous water user while contiguous areas experience shortages; is it wise to plan for the future by buying up water rights that aren't currently needed; should a city be allowed to purchase agricultural irrigation water thus taking land out of productivity; should there be a more cooperative effort on the part of people within and outside of city boundaries to assure adequate water supplies. As one question is considered, it raises others. Hopefully, a look at the way water is normally used within the City of Fort Collins will reveal whether it is used wisely. Perhaps more water could be made available to others outside the city for domestic and agricultural use. Even more important is the possibility that better use patterns could be established so that more equitable water distribution to everyone would be possible during drought. Even though they appear to occur only periodically, drought periods should be planned for. The lack of preparedness for water scarce periods has been a continuing problem. Water supplies should be managed in Fort Collins and throughout the arid West as if the next year was going to be a drought year.

Fort Collins municipal water use was analyzed using 1925 through 1976 monthly total water consumption figures furnished by the Municipal Water and Sewer Department. As concluded by Linaweaver in A Study of Residential Water Use, "except for small amounts of leakage, water use during December, January, and February is almost all domestic use" (Linaweaver, 1967). Even though lawn sprinkling may be observed in Fort Collins in any one of these months in any given year, the water consumed during this time was considered normal household domestic and industrial use. An average was taken in these months for each year, and multiplied times the remaining number of months (nine) to determine normal household domestic and industrial use for the lawn irrigation season (March-November). The difference between this normal use and the actual use was identified to be lawn irrigation. This includes treated water used for irrigation of parks, medians, etc., by the city. While it is true that cars are washed and some swimming pools are used during the spring and summer months, it was assumed that the absence of approximately 70% of the Colorado State University students from mid-May through mid-August each year would more than offset this use. All CSU domestic consumption is supplied by the City of Fort Collins, while the school's lawn irrigation is supplied by its own irrigation lakes. Since system leakage has been determined by the Municipal Water and Sewer Department to be approximately 10%, a factor of .9 was applied to each year's irrigation consumption for years 1960-1977 to determine the approximate number of gallons applied to lawns per year. System leakage was no doubt occurring prior to 1960. However, it cannot be determined what that leakage may have been. Since present lawn irrigation trends seem to have begun around 1960, and the system was no doubt old enough to have substantial wear, the leakage coefficient was applied beginning with that year. Figure IV-1 shows percentage of total treated municipal and industrial water consumption used for lawn irrigation from 1925 through 1959 (no system leakage considered). Figure IV-2 shows percentage consumption used for lawn irrigation from 1960-1976. Note that 1961 and 1967 were low irrigation years and that rainfall in both those years was over 20 inches. The average percentage of domestic and industrial consumption used for lawn irrigation from 1969 through 1976 is 38.1. This compares with the average throughout the Front Range in normal years.

Figure IV-3 shows the rise in total municipal and industrial consumption and the rise in lawn irrigation use. Note that while lawn irrigation increases are not directly proportionate to increases in total consumption, the increases follow a very similar pattern. Figures IV-1 and IV-2 seem to indicate that percentage use for lawn irrigation is not necessarily affected by slight variations from the approximately 14.5 inches of annual rainfall. However, extremely high rainfall seems to lower lawn irrigation appreciably (note 1951, 1961, and 1967). The effect of extremely low rainfall seems to be dependent upon whether or not the rainfall periods are during the summer months. Rainfall data was not available for the years 1974 or 1975.

Lawn irrigation represented approximately 37.7 percent of total consumption on 1976. Since this was very close to the 69-76 average, it was the most recent year, and related data was available; a monthly breakdown of 1976 lawn irrigation was compiled. The private lawn irrigation

FIGURE IV-1

% Municipal and Industrial Water
Consumption Used for Lawn Irrigation

1925-1959

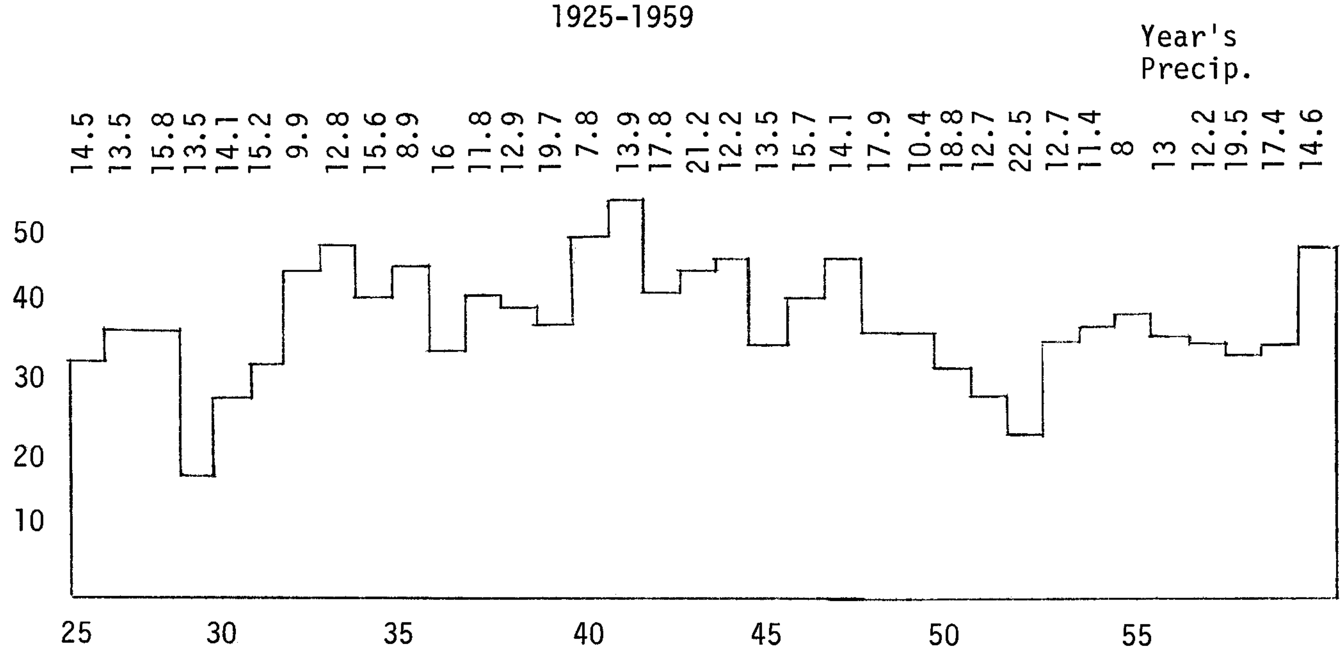


FIGURE IV-2

% Municipal and Industrial Water
Consumption Used for Lawn Irrigation

1960-1976

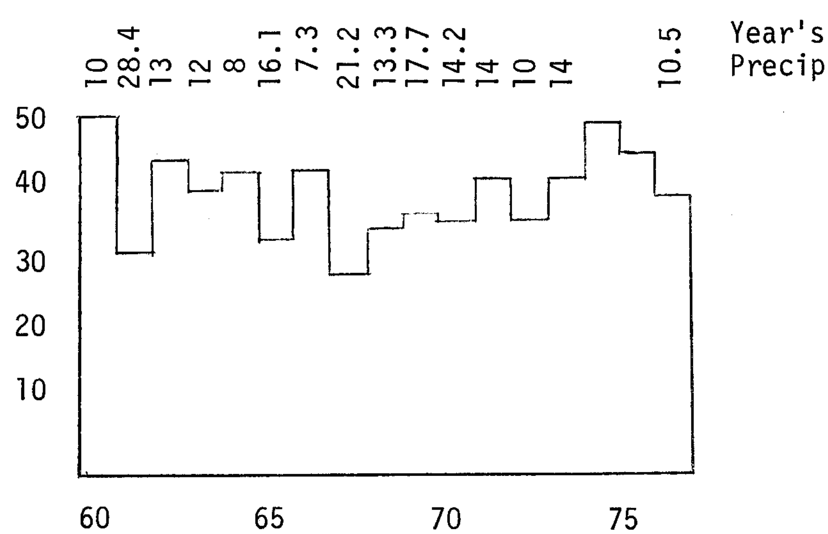
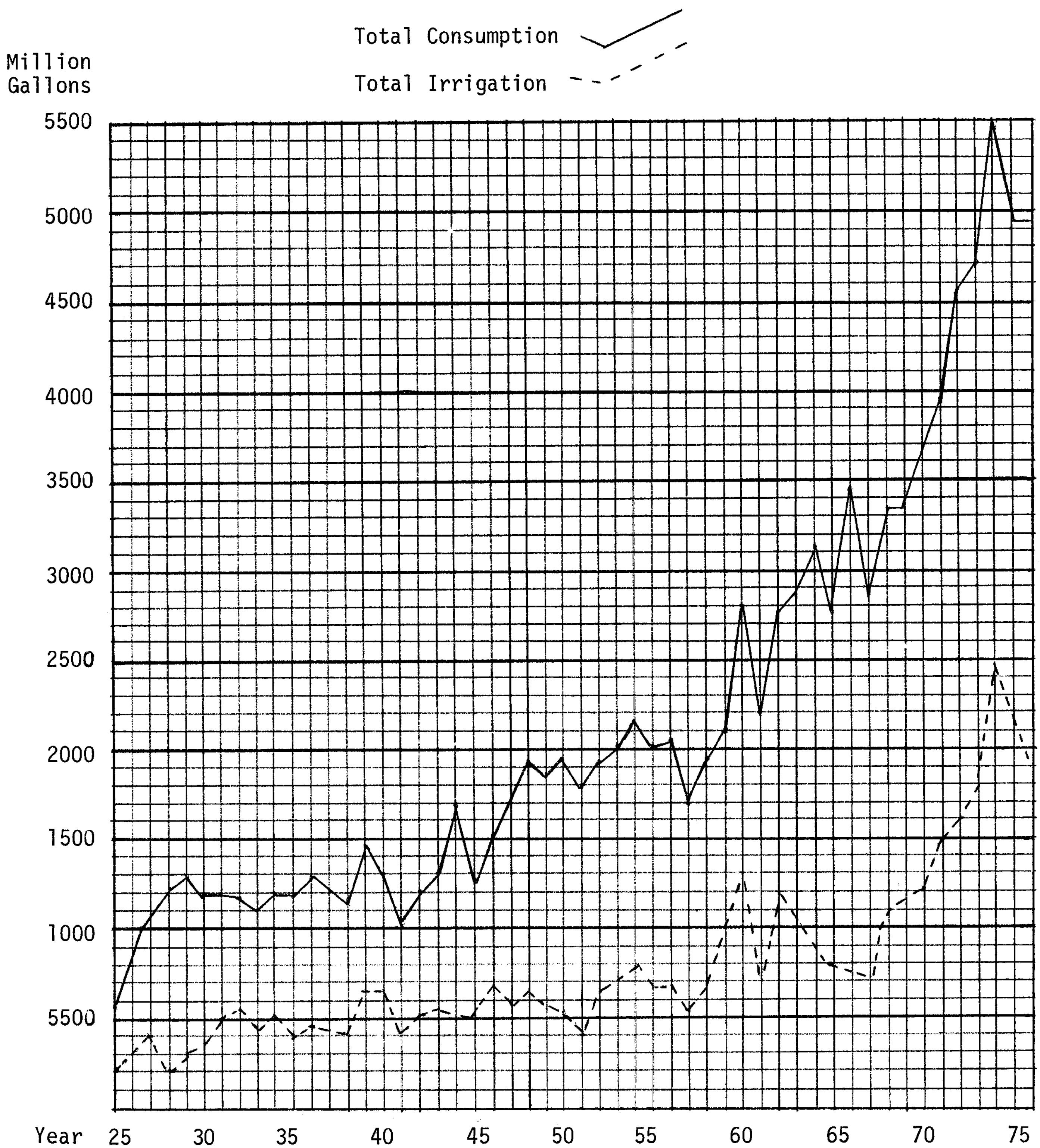


FIGURE IV-3

TOTAL YEARLY CONSUMPTION AND LAWN IRRIGATION



was determined by subtracting irrigation by the city. Private irrigation for 1976 was determined to be 1,981,602,000 gallons. The monthly percentage of total irrigation (municipal and private) occurring in that month was applied to this figure for each month to determine the private irrigation for that month. Each month's total was divided by irrigable residential acreage (2439) to determine a monthly per acre total. Each monthly per acre total was divided by the number of days in that month, then multiplied by seven to determine gal/ac/wk for that month. This was divided by 326,000 to determine acre feet/wk., which was converted to inches per week by multiplying by 12. A factor of .9 was applied to each weekly inches total to allow for system leakage. Figure IV-4 shows the monthly breakdown for the year. Note that the highest irrigation use occurs in July at 1.73 inches per week. Since this is based on all residential acreage it is reasonable to assume that many homeowners use less than this and some use more.

Lawn irrigation is the most visible and single most consuming water use in Fort Collins. Much of this water is lost through evaportranspiration. The rest either runs off and is collected in the sewer system which flows into the river, or percolates into the ground and eventually winds up in a stream or underground aquifer.

The major reason for concern with lawn irrigation is that it could be reduced, not only in drought years, but as a regular practice. One way to reduce lawn irrigation is to reintroduce native plants which survive on small amounts of moisture. Since this may not be realistic as an immediate measure due to the desire at present by so many people in Fort Collins to have lush green lawns, the next best thing may be to "harden" lawns to take

FIGURE IV-4

CALCULATION OF MONTHLY BREAKDOWN, 1976 LAWN IRRIGATION

Average normal domestic and industrial monthly use	=	239,100,000 gal.
Mo. normal use, Mar.-Nov.	=	2,151,900,000 gal.
Actual use for Mar.-Nov.	=	4,222,800,000 gal.
Difference - lawn irrigation	=	2,070,900,000 gal.
City used (parks, medians, etc.)	=	89,298,000 gal.
Total private irrigation	=	1,981,602,000 gal.

Month	% Total Used for Irrigation	Gallons Private Irrigation
Mar.	.8	15,852,816
Apr.	7.0	138,712,140
May	8.6	170,717,770
Jun	22.5	445,860,450
Jul	28.5	564,756,570
Aug.	17.3	342,817,140
Sep	10.0	198,160,200
Oct	4.0	79,264,080
Nov	1.3	25,760,826

Breakdown of City Residential Acreage*

Type Unit	Acres Occupied	# Units
Single Family	2,366	11,130
Duplex	105	1,074
3-6 Family Apts.	91	1,304
7-13 Family Apts.	48	955
Over 14 Family Apts.	124	2,935
Mobile Homes	104	837

Avg. single family unit	=	1,500 sq. ft.	x	11,130	=	383 acres
Avg. duplex unit	=	1,000 sq. ft.	x	1,074	=	25 acres
Avg. apt. unit: 3-6 family complex	=	500 sq. ft.	x	1,304	=	15 acres
7-13 family complex	=	500 sq. ft.	x	955	=	11 acres
14 + family complex	=	333 sq. ft.	x	2,935	=	22 acres
Mobile homes	=	750 sq. ft.	x	837	=	14 acres
Total area occupied by dwellings						470 acres

Total Residential Acreage	2,909 acres
Occupied by dwellings	470
Acreage to be irrigated	2,439

*Information furnished by Planning Department, City of Fort Collins

FIGURE IV-4 (Cont'd)

March

15,852,816 gal + 2,439 ac = 6,500 x .9* = 5,850.0 gal/ac

April

138,712,140 gal + 2,439 ac = 56,873 x .9 = 51,185.7 gal/ac

May

170,417,770 gal + 2,439 ac = 69,872 x .9 = 62,884.8 gal/ac

June

445,860,450 gal + 2,439 ac = 182,805 x .9 = 164,524.5 gal/ac

July

564.756,570 gal + 2,439 ac = 231,553 x .9 = 208,397.7 gal/ac

August

342,817,140 gal + 2,439 ac = 140,556 x .9 = 126,500.4 gal/ac

September

198,160,200 gal + 2,439 ac = 81,246 x .9 = 73,121.4 gal/ac

October

79,264,080 gal + 2,439 ac = 32,499 x .9 = 29,249.1 gal/ac

November

25,760,826 gal + 2,439 ac = 10,562 x .9 = 9,505.8 gal/ac

		da	gal/ac/da	gal/ac/wk	gal/ac/ft	ac/ft/week	in/wk
Mar	5,850.0 +	31 =	188.7 x 7 =	1,320.9 +	326,000 =	.0041 x 12 =	.05
Apr	51,185.7 +	30 =	1,706.2 x 7 =	11,943.4 +	326,000 =	.0366 x 12 =	.44
May	62,884.8 +	31 =	2,028.5 x 7 =	14,199.5 +	326,000 =	.0436 x 12 =	.52
Jun	164,524.5 +	30 =	5,484.2 x 7 =	38,389.4 +	326,000 =	.1178 x 12 =	1.41
Jul	208,397.7 +	31 =	6,722.5 x 7 =	47,057.5 +	326,000 =	.1443 x 12 =	1.73
Aug	126,500.4 +	31 =	4,080.7 x 7 =	28,564.9 +	326,000 =	.0876 x 12 =	1.05
Sep	73,121.4 +	30 =	2,437.4 x 7 =	17,061.8 +	326,000 =	.0523 x 12 =	.63
Oct	29,249.1 +	31 =	943.5 x 7 =	6,604.5 +	326,000 =	.0203 x 12 =	.24
Nov	9,505.8 +	30 =	316.9 x 7 =	2,218.3 +	326,000 =	.0068 x 12 =	.08

*Leakage factor

less water and still maintain a nice green appearance. Peter H. Dernoeden in his thesis, Variety Tolerance to Drought in Kentucky Blue Grass, relates a procedure in which he was able to apply water to various varieties of blue grass only once every three weeks while it maintained what he described as a quality appearance (Dernoeden, 1976). According to Dernoeden, quality turf in the arid United States may require as much as 18 to 20 inches of water in addition to natural rainfall. Recommendations of up to an inch and a half of lawn irrigation per week have been made in some publications to maintain a lush green lawn (Conserve, 1977). At this rate, a person in Fort Collins would sprinkle 36 inches of water on his lawn in a six-month irrigation season, and 42 inches in a seven-month irrigation season. This means the people of Fort Collins may over-irrigate from 44 to 52 percent if they sprinkle their lawn at 1-1/2 inches per week. As shown earlier, if 1976 is a normal year, over 1-1/2 inches is applied some summer weeks, but the average for the summer months is about 1.4 inches. As stated earlier, a logical way to cut down on the need for lawn irrigation would be to plant native materials. Another way would be to cut down on the amount of yard area containing plants. A study done in New Mexico showed that homeowners with 90 to 100% of the yard in plant materials apply 88% more water per home than where only 50 to 70% of the yard is in plants (Chavez, 1973). If people insist on having green grass lawns, and indications are that they will, the knowledge of how to attain such lawns with less water should be disseminated to the public. Many of the things that Dernoeden found in his research could be related to Fort Collins and throughout the arid west, for that matter, by way of a short, concise pamphlet containing instructions on how to "harden" a lawn. Lawn hardening is discussed in more detail in Section VI.

Even though lawn irrigation makes up such a large part of municipal and industrial water use, it is by no means the only area of concern. Although Linaweaver concluded that in-house domestic water use was about the same whether users are metered or not (Linaweaver, 1967), S. Hanke disagrees. In a 1969 study of Boulder, Colorado, Hanke found that meters installed in Boulder in 1962 and 1963 caused household domestic use to drop thirty-six percent (Hanke, 1969). He found further that this reduced consumption remained constant from then on. Not many studies of this type have been done, but this finding should at least indicate that a reduction of household use is indeed possible.

We have come to take water for granted in our homes. We think nothing of letting the water run unnecessarily while we go about washing vegetables, brushing our teeth, shaving, etc. No known estimates have been made as to how many gallons could be saved if people were more careful to use only the water necessary for such things, although recent conservation programs in California recommending such practices as well as other methods have shown significant savings. Very simple arithmetic will reveal that if each person in Fort Collins had saved one gallon of water per day by being more cautious, there would have been a savings in 1975 of 20,376,125 gallons of water. This is enough water to last one person three lifetimes (230 years) using the per capita use rate for Fort Collins in 1975 (243 gpd). It is very difficult to convince a person that the one gallon he or she might save is a necessary part of such a savings.

It has been shown that one leaky faucet can waste as much as 2,200 gallons of water per year (<u>Conserve</u>, 1977). A city such as Fort Collins with one leaky faucet in each of its approximately 18,000 households could waste as much as 39,600,000 gallons per year. Surprisingly enough, this would be an approximately 90% savings considering the present leakage in the system. The Fort Collins Water and Sewer Department did a leakage study by monitoring water use between the hours of 1:00 a.m. and 4:00 a.m. with all known users being metered. They found a leakage of about 10 percent, or 1 million gallons per day, most of which they attributed to leaks in private homes. This leakage would amount to approximately 365 million gallons per year. It is interesting to note that Hanke mentioned in his study that the reduction in household consumption when Boulder installed meters may very well have been partly due to individuals repairing leaks in their plumbing systems.

Plumbing fixtures such as toilets can develop leaks which may go undetected. With water available at low cost, and especially at a flat rate there is little, if any, incentive to correct such a leak given the cost and time involved to do it. Even when a toilet is working correctly, it will use three to seven gallons each time it is flushed. The toilet unfortunately is often used as a trashcan, and ways should be sought to reduce the number of times it is flushed in a day. Of course, water saving devices such as bricks or water-filled containers may be used to reduce the amount of water necessary for the toilet's operation. Showers can be fitted with a low volume head and low volume toilets are available. Dishwashers and other luxury appliances should be used wisely; for instance, washing only full dish and clothes loads to make use of the minimum amount of water. Garbage disposals could be used when full rather than each time waste is placed into them. Cooking may be done with lids on pans so that extra water doesn't have to be added. Cars could be washed with a minimum amount of water, and rinsed only after the car is completely washed so the water won't run continuously. When cleaning in the house, water need not be left running. Insulating hot water pipes would preclude having to run large amounts of water waiting for it to turn hot. Driveways and sidewalks should be swept with a broom rather than washed off with a water hose. While it is doubtful that anyone in Fort Collins would deliberately defy any of these suggestions so as to waste water, the fact remains that there is little incentive to do any of these things to save water. This is especially true if the conservation measures cost money, since saving water will save no money. Only those concerned with saving water for saving water's sake will go to any trouble or expense to do so without further incentive.

Fort Collins Water Restrictions, Summer 1977

As this report was being prepared, a change occurred in the water use in Fort Collins. The Fort Collins Water Board had not planned to restrict water use throughout the summer of 1977 due to what appeared to be an adequate water supply. They had hoped to achieve a 10 to 15 percent reduction in use by way of a promotional volunteer program. At the end of April, a 16 percent savings in water consumption had been realized. However, by June only 4 percent had been saved. According to the City's water utilities director low precipitation, an increase in population, and a 700 acre feet water loss due to treatment plant construction problems were all factors contributing to the availability of less water than what was planned for (Fort Collins Coloradoan, July 10, 1977). However, good planning involves trying to prepare for the unexpected. The water board had planned to store about 4,000 acre feet in high mountain reservoirs for next year since predictions have been made that 1978 may be the worst year of the drought. Chambers Lake and Long-draw Reservoir are being used for this storage since the City has no storage space of its own. Approximately one-half of the storage has been accomplished, but to save an additional 2,000 acre feet the water director predicted water use through early October would have to be reduced 25 percent below normal. In order to do this, the City would have to limit lawn watering to one day a week (Fort Collins Coloradoan, July 10, 1977). The board considered this as an alternative. They also considered limiting watering to twice a week on a rotation system alternating various sections of the city. They proposed to the City Council, as the best alternative, to simply restrict lawn watering between the hours of 10:00 a.m. and 4:00 p.m. and between 10:00 p.m. and 4:00 a.m. daily. City Council decided to enact the alternative restricting watering to twice a week on a rotation system combined with limiting the legal watering times to between 4:00 a.m. and 10:00 a.m. and between 6:00 p.m. to midnight. According to the City water director this could result in a 25 percent savings over the remaining months and thus make possible the additional 2,000 acre feet of storage (Triangle Review, July 13, 1977). The lawn watering restrictions went into effect on July 15, 1977. A newspaper article in the Fort Collins Coloradoan on the next day reported that the City had found some violations of the restrictions, but that most residents had been cooperating. On July 18, 1977, the same newspaper reported that on July 14, the day before the restrictions went into effect, the supply in the City's water tanks had dropped to the four and one-half foot level. Water pressure becomes critical below the nine foot level.

On July 15, no watering was allowed at all, and the water level rose to the maximum level of 22 feet. As of July 18, the level had not dropped below nine feet since the imposition of the restrictions. Preliminary data was reported as showing that consumption for July 15-17, 1977 was thirteen percent below that for July 15-17, 1976.

REFERENCES

Chavez, F., 'A Study of Water Used in Urban Landscapes', Horticultural Science, period 73:319, 1973.

City May Limit Yard-Watering Time, article, Fort Collins Coloradoan, newspaper, July 10, 1977.

Colorado's Ground Water Problems, Bulletin 504-S, Colorado State University Experiment Station, Fort Collins, Colorado, March, 1967.

Conserve, pamphlet prepared by Cooperation Extension Service, Colorado State University, Fort Collins, Colorado, March, 1977.

CSU 'Is Doing Miserable Job' of Teaching Water Conservation, article, Fort Collins Coloradoan, newspaper, July 15, 1977.

Dernoeden, P. H., Variety Tolerance To Drought In Kentucky Bluegrass, thesis for Master of Science, Dept. of Horticulture, Colorado State University, Fort Collins, Colorado, 1976.

Hanke, S. H., The Demand for Water Under Dynamic Conditions: A Study of Boulder, Colorado, Center for Urban Engineering Studies, University of Colorado, Boulder, Colorado, 1969.

Linaweaver, F. P., Jr., Geyer, J. C., and Wolff, J. B., A Study of Residential Water Use, report for the Federal Housing Administration, Department of Housing and Urban Development, Johns Hopkins University, Baltimore, Maryland, U. S. Printing Office, February, 1967.

Soil Water Air Sciences Programs, U. S. Department of Agriculture, Agricultural Services Research Services, 1976.

The Boom is Back, '77 Area Construction Tops $51 Million, article, Fort Collins Coloradoan, newspaper, July 13, 1977.

Use of Water on Federal Irrigation Projects 1965-1969, Summary Report, Department of Interior, Bureau of Reclamation, Region 7, May, 1970.

Warrick, R. A. with Trainer, P. B., Baker, E. J., Brinkman, W., Drought Hazard in the United States: A Research Assessment, Institute of Behavioral Science, University of Colorado, Boulder, Colorado, 1975.

Water for Tomorrow, Colorado State Water Plan, Phase I, U. S. Department of Interior, Bureau of Reclamation in Cooperation with the State of Colorado, February, 1974.

Watering Restrictions Mark Sharp Policy Change, article, Triangle Review newspaper, July 13, 1977.

SECTION V

AGRICULTURAL WATER MANAGEMENT

General

As has been previously pointed out, water in the west goes predominantly to agriculture. Depending on the region, economy, and other factors, the percentage ranges from about 35 percent to about 97 percent. In the semi-arid sections of Colorado, the irrigation of crops accounts for some 80 percent of the water use in the region.

Those in agriculture hope to keep or increase this water use, while some urban interests would like to reduce the agricultural 'take' in order to provide more water to domestic and industrial uses. As agricultural land has been urbanized, it has been found that the amount of water used for irrigation is about the same as that used for the same area under urban conditions. Thus, some cities, such as Fort Collins, require the water rights held by a farmer to pass with his land should it be annexed. This will provide, then, the water needed by the urbanizing areas. However, as non-municipal urban areas grow and as the pressure increases to maintain agricultural areas, the water supply problem will multiply. Given the economic pressure for use of water for energy resources recovery, in this area also, the outlook is very serious.

Of all areas of farm and ranch management, the one least studied and most open to new innovation, is clearly irrigation. Water is usually applied as liberally as it is available and by the easiest, most economical methods available, not those allowing most conservation. There are exceptions, of course, with certain dryland farming methods and during periods of scarce water. Yet even then the most common technique is the reduction in the number of irrigated acres and pressure for additional water development projects for more water sources.

Conservation and management of water in agriculture has the potential of providing an amount of water for urban use, or wider agricultural use, which is equal to the amount of water currently used in urban areas along the Front Range of Colorado. Whether the cost and effort required to provide this is made worthwhile will need careful economic, social and environmental study. Points of view range from those who believe that the urban areas should pay all such costs of agricultural water conservation including any future crop losses, to those who believe that the best way to get farmers to conserve water is to withhold it from them.

Whatever sanctions may be imposed from outside, there are many potential actions that can lower the total water use in agriculture and make far more efficient the farm. The following section discusses various methods, potential implementation and the benefits and detriments of the methods. With sufficient tax and subsidy incentives, many of these could be adopted in the immediate future.

Management Techniques

In the area of education and information, programs can be instituted to create an atmosphere for water conservation programs. Water conservation districts, county, state and federal groups, and educational institutions can promote attitude readjustment providing means and rationale towards conservation methods. News media, especially within the agricultural community, can provide technical, economic, and other information. Pamphlets, brochures, and other publications through extension services, departments of agriculture, and other sources, can provide specific action possibilities. Many of these programs can be underwritten or supported by government funds from various levels and from educational institutions. In the area of technology transfer, too, mechanisms are needed to meet with research the needs of the farmers, and then to pass this information on to them.

Incentives are needed in all the programs to be discussed so as to facilitate their implementation quickly where there is not immediate economic benefit to the farmer. Special financing, grants, tax breaks, supports, and other measures are possible.

Institutional changes include special large-scale programs for farmer assistance. There can be immediate efficiency gains by this, but the state and federal costs can be very high. Changing the pricing structure for water has legal and social difficulties, but would enable use of the free market system or other allocation means to determine where the water goes. This may well encourage conservation due to outright need. Changing the water laws will entail state and federal law and often Constitutional changes. Recommendations in this area have been strongly promoted, however, and though the political process would be long, the long-range planning benefits will potentially benefit all competing forces.

As to direct conservation techniques, irrigation, which uses the greatest amount of water by far in agriculture, can be much more efficient. While more study is needed for specific site application, upgraded irrigation systems could reduce use by three to five percent (White House, 1977). More efficient sprinklers, drip systems, better design of gravity systems, and improved drainage can all contribute to better efficiency. Crop yield would also go up, percolation and evaporation losses would go down, and soil compaction and disease could be lessened. There is high capital cost for much of this, however; drip systems, for instance, can cost $700 to $1200 per acre to install. Drainage and gravity systems are less to upgrade, about $100 to $300 per acre. Another consideration is the tradeoff between possible increased energy costs and reduced water consumption. Proper maintenance of irrigation systems is less costly, but may be prohibitive without incentives where profits are currently marginal. Inspection, repair, and cleaning of sprinkler systems, ditches, and other structures will have small immediate gains, but are also least costly.

Management of the total farm system is another area to improve water conservation. Adjusting the acreage and crops on both a long and short range basis can cut farm losses at the same time water is conserved. The timing of such crops, the influence of the market, and other factors do make such changes difficult. Study of exact moisture needs for certain periods can be studied and publicized. Evaporation data has been published this year (see Figure V-1) which aids the farmer in calculating the most effective irrigation scheduling. Finally, encouraging irrigation of only fertile fields can improve the crop/water use ratio. The determination of 'prime' lands, however, is fraught with legal and social problems.

Control of water loss in seepage and evapo-transpiration can be obtained by a variety of methods. Lining of canals and ditches can reduce withdrawals of water by at least three percent and consumption by one to two percent. Concrete lining is expensive, however, about $500 per acre, depending on irrigation distances and extent. There are natural linings,

FIGURE V-1

Crop Water Use Data

Weekly ET (inches)

DATE	DAY	CORN	SUGARBEETS	FIELD BEANS	ALFALFA
JULY	6-12	2.45	2.25	2.09	2.75

The tasseling-silking stage is here for some of the early corn. Moisture stress in the plant at this time will delay silking and cut yields drastically. Pinto beans can stand moisture stress at any early stage but moisture is needed at early bloom. Alfalfa and sugar beets will continue to use water at higher rates.

also, which may prove to be less expensive. Bentonite is a natural substance found locally which has been shown in research to be very effective. Other clays and similar materials can also be used. Seepage control of subsurface drainage can increase productivity, although it will probably show no net water conservation. Anti-transpirants can be sprayed on crops to reduce water loss, but they are expensive, reduce photosynthesis, and may cause environmental and health problems. Water storage areas can be covered with a monolayer of chemicals such as hexadecannol and thereby reduce evaporation by up to ten percent. These techniques are, however, still low in reliability, high in cost ($10 to $40 per acre foot), and potential environmental and health hazards.

Control of weeds and phreatophytes in agricultural areas, in reservoirs and impoundments, and canals and ditches would provide small local gains immediately, and would reduce losses to nonessential plants. The long term effects on wildlife, erosion, and other systems makes such action of limited and local use only. Such activities are also very labor intensive, which can be benefit or disbenefit depending on the labor market.

Whichever of the above techniques may be undertaken, they must be conducted with the complete involvement of the farmers, and with a view to improving the agricultural situation as well as an improvement in the water conservation situation on farms. To the extent to which such programs are economically beneficial to the nation and/or less costly than the water conserved, they will be both acceptable and successful.

REFERENCES

Millan, Jaime, Drought Impact on Regional Economy, Colorado State University Dissertation, 1972.

Saarinen, T. F. Perception of the Drought Hazard on the Great Plains University of Chicago Department of Geography Research Paper 106, 1966.

U. S. Department of Agriculture, Impacts of Weather: Farming, Forestry, Food, and People, (Working Materials) 1977.

White House Drought Study Group, Drought Appraisal, March 1977.

SECTION VI

URBAN WATER MANAGEMENT

Water Rationing

The various forms of water rationing represent the most widespread and perhaps most effective means of urban water conservation. Almost without exception, local governments when faced with a need to reduce local water consumption will initially institute a program involving water rationing. Water rationing exists in a myriad of forms, dependent to some extent upon the nature of the problem, the specific region involved and the degree of reduction required.

Two basic types of water rationing exist. The first and also the most widely used is in reality not rationing per se, but rather restrictions upon the manner in which water may be used or upon the time in which water may be used. This type of rationing technique is most commonly used in conjunction with reducing outside of the house forms of water use such as lawn irrigation and/or automobile washing, etc. The other basic form of water rationing is through actual limitation of the volume of water which may be used by a household or business either through restriction or reduced deliveries. This means of rationing is generally a more severe approach and is most effective where the amount of water consumed per residence or business is metered through some physical device. The following paragraphs will discuss each of these techniques in greater detail.

In its most basic form, the restrictive type of water rationing consists of a total ban upon some form of water use for a specified period of time. Generally this approach is used to respond to some short term emergency situation, such as represented by the following two newspaper quotes:

> "A water crisis occurred July 7, 1977, when the Fort Collins City Council ordered all lawn watering halted for two days, running from 6 a.m. Friday to 6 a.m. Sunday because of continued depletion of stored water in the city's three reservoirs" (Fort Collins Coloradoan, July 13, 1977)

> "A 48-hour ban on lawn watering has been instituted in the East Larimer County (ELCO) Water District beginning at 4 p.m. today. The ban is necessary because storage tanks are dangerously low, according to Ira Miller, manager of the District. If we had a fire right now, we'd be in trouble." (Fort Collins Coloradoan, July 13, 1977)

This technique which is effective in quickly replenishing storage, is also quite drastic and acceptable to the public for only infrequent short emergency periods.

On a longer, less immediate emergency situation, such as is produced by drought conditions or lack of adequate delivery systems, the more commonly known periodic lawn watering restriction technique is normally used. Through this means, some restrictions are placed upon the time period in which the individual homeowner may apply water to lawn areas. This may be accomplished through a number of restrictive measures. Typically the restriction applies to lawn watering, which as is shown in this paper represents the most easily reduced portion of summer per residence water use. The restriction is generally placed upon hours or days of lawn watering with some identified means of selecting which residences may water at specific times. Two current local examples demonstrate the variances in method. First in Denver, Colorado watering restrictions were instituted on June 1, 1977. Under these restrictions, each residence is allowed to water lawns for three hours every third day only. To stagger this watering, based on the last two digits of the residence address each residence is identified as a circle, triangle, or square with these shapes relating to specific dates (i.e., every third day). Thus, by marking a calendar or consulting the newspaper the home-owner can determine the shape applicable to the day, and knowing the shape for the household then can identify the days on which the three hour watering is permitted.

In Fort Collins, Colorado watering restrictions were adopted and began on July 15, 1977. These restrictions limited lawn watering to 6:00 p.m. to midnight and 4:00 a.m. to 10:00 a.m. on specific days. To identify what residences could water on each day, the city was divided into four zones and each zone given two days on which it could water each week during the watering hours.

During earlier periods of drought in Colorado similar restrictions were placed on lawn watering using a different form of application. For example, in 1952 in Fort Collins watering was limited by even numbered houses being permitted to water on even numbered days and odd numbered houses on odd numbered days; almost an identical system was also used in Denver during water shortages of the 1950s.

The second major water rationing technique as mentioned earlier is that of actual limitation of water volume used or delivered to each residence. Generally this is a more drastic measure than hourly restrictions, and as is obvious is most effective in areas with water meters or some means of water supply control.

The most significant use of this latter technique has been during the existing drought in California. As most California cities are metered and the drought situation is critical, this has been found to be an effective means of reduction. To implement the process, some means of allocation of an identified volume of water to each user must be determined. The most common means and the one used most extensively in California is to base the allocation on the previous year's use by the same residence. An example of this method as used by the North Coast County Water District (NCCWD) of northern California is as follows: (reproduced from notification card distributed by the NCCWD).

> "This is your water allotment in hundred cub. ft. month by month, for the duration of the water shortage. (Subject to change if drought becomes more severe)."

1976 Consum.			Your 75% Allotment
Jan.	11		8
Feb.	10		8
March	10		8
April	13		10
"	"	(con't by month)	"
Nov.	13		10
Dec.	11		8

A variation upon the allotment method is to base the allotment not upon previous use but rather upon the number of persons residing in the household and/or the lot size of the residence. Regardless of the allotment method used, it can be seen that this form of rationing tends to produce water conservation throughout the household rather than limiting it to only lawn watering or outside the house water uses. This results from the limitation on the total water used rather than just the lawn water used.

If the above mentioned measures do not achieve the desired reduction or if water scarcity worsens, cities may impose stricter water controls, including more limits upon irrigation, prohibition of all uses except domestic and certain commercial and industrial uses, and finally, limited domestic use.

Critical to the success of any water rationing or restrictive program is enforcement. Generally with the restrictive form of water rationing, through public education and awareness the attempt is made to achieve voluntary compliance with the program. In addition most programs have a monitoring regulatory component included to aid in enforcement. The following description of the Denver program is typical of this form of enforcement:

> During the initial phase of the program, water department personnel were told to issue warnings and give informational material on the limitations to violators in the service area. Special attention will be given to flagrant violators. The first violation by a resident will bring a $10 fine. A second violation will prompt installation of a restricting device on the water tap. A $50 fee will be charged for removal of the device. In addition, violators who receive water on a flat rate basis and do not have meters will have a meter installed at their own expense.

Similar enforcement programs are used in the area; for example, Thornton, Colorado has a fine structure of $15 for the first violation, $25 for the second, and disconnection and a $50 reconnection fee for the third and future violations. Fort Collins, Colorado violators are subject to one oral warning, a written warning and then a situation which could lead to a $300 fine.

In most cases, however, the maximum penalties are rarely if ever used. Societal pressures are generally sufficient to maintain compliance, as most programs have established means for the public to report violations which have been observed.

Within the allotment or allocation form of rationing, enforcement follows similar techniques. However, as the amount allotted to each user is identified and the amount actually used measured by a water meter, the determination of violations is quite straightforward. Generally a series of warnings and/or fines are initially levied against the violator with the final enforcement being a complete cutoff of water service when the allotment for the residence has been fully used.

With all forms of rationing, some means of variance or exception from the restrictions must exist. Normally these exceptions relate to hardship cases, larger than normal lot sizes or numbers of occupants, and those having individual well water or other sources of water. These variances must be applied for and, if awarded, generally a notification to the effect that an exception exists must be posted on the property to avoid unwarranted complaints.

When adequate and factual information regarding the nature of the problem is provided the public, water rationing receives good public acceptance and cooperation and can be an effective means of reducing water use. The Denver Water Board has reported reduced water consumption by 25 per cent (323 million gallons a day to 238 million gallons) since restrictions went into effect on June 1, 1977 (Denver Post, July 6, 1977). And while it is difficult to evaluate the Fort Collins program at this early date it appears that the restrictions are are achieving approximately the desired rate of reduction. As reported on July 20, 1977 the Fort Collins program had achieved a 13% reduction over the previous year's usage, with seventy warnings issued and 220 variances granted mostly for hardship cases (Triangle Review, July 20, 1977).

As with any program aimed at restricting public use of a needed natural resource through enforced conservation, problems do exist. In both Colorado and California, instances of illegal water acquisition or "water rustling" have been reported at storage facilities. Other reports have indicated losses of conserved water due to the activities of vandals (Fort Collins Coloradoan, June 15, 1977).

Problems may also be encountered in conjunction with the means of limitation selected. The original program used in the Fort Collins area which based watering days on four identified sections of the city was found to cause a severe pressure drop in the water system due to the excessive use by each area during the watering hours. Thus, sufficient pressure was not available to accomplish the watering and perhaps more importantly the city's fire fighting capacity was diminished. To eliminate this problem, the program was revised to allow specific daily watering based upon the end digit of the house number, which while allowing one third of the city to water at one time will distribute the water use throughout the whole water system and reduce the pressure drop.

Problems have been encountered in the allocation program when basing the allotments on previous years' usage. Under this system, it can be seen that if excessive use existed during the preceding year, then based on a percentage of that use, the residence obtains an inordinately large allotment under the conservation program. Likewise, if efficient use of water was made during the preceding year or if for some reason (vacation, members of family absent, etc.) water use was minimal, the percentage allotment may be unduly restrictive for current conditions. Thus, the exception program must be appropriate or the allotment should be based on other factors such as were mentioned (family size, lot size, etc.).

Water Meters

It may seem strange that a city such as Fort Collins, in an area where water has never been considered plentiful, could have developed into a city of approximately 60,000 people with flat water rates and no water meters. Nevertheless, that is exactly how it was developed. To install water meters at this point would be a very costly undertaking.

According to the Fort Collins Water and Sewer Department it would take approximately three years at a cost of approximately $2.8 million to fully meter the city given its present size and physical makeup. This is based on the cost of $350 per installation of each meter at locations having no previously prepared meter housing unit. This includes completely resodding and restoring the lawn after meter installation. Beginning July 1, 1977, all new water taps will be required to have a meter stub. This stub includes a housing unit in which a meter can be placed at a later date. Meters installed in these units will cost only $80 per installation.

It is not hard to see how water meter opponents can present a reasonable argument on the grounds of installation costs. This is a very easy argument to use as a "smokescreen," however, when opposition may actually stem from a desire to keep the city's grass and trees green or the hope of keeping a flat rate system to attract more economic growth. Actually, economics is a fairly poor argument in opposing water meters, especially considering Fort Collins' present rate of growth and the limited water resources. Federal funds are available to cover part of meter installation costs. Canon City, Colorado, received $1.2 million in federal drought relief ($514,000 an outright grant, and the remainder a loan at 5% at 40 years) to be used for construction of a water tank and the purchase and installation of water meters (Denver Post, June 30, 1977).

If the external costs of supplying water to Fort Collins were borne by each water user, $350 may not sound like such a high cost per user to reduce water consumption. Some of these external costs are those related to depletion of agricultural land due to acquisition by the City of irrigation water; the cost of water depletions on the Western slope due to the water diverted through the Colorado Big Thompson project; the ground water depletions due to a lack of recharge from water consumed in the City. Most of these costs are realized by the farmers from whom irrigation water is purchased, those living on the Western slope including wildlife, and those who would use the ground water if it were there. By installing meters, and charging for water by volume, these costs should become more individually internalized.

Actually, meters do nothing to save water unless they are properly used. In other words, meter installation by itself is not a management measure. Theoretically, meters could be installed and a flat rate continued, thus not altering water use at all. Meters are, however, very effective tools with which various management measures can be instituted.

The monitoring of volumes of water with meters is not simply necessary for rate purposes alone. During times of water rationing in Fort Collins, users could be monitored to assure they were not exceeding their ration. Also, incentive programs could be instituted by using meters. Water customers could be charged an increasing rate with increasing use. A flat fee could be charged for water up to a certain amount and then a very high per 1000 gallon rate thereafter. Tax incentives could be offered based upon low water use. Before any of these things could be done, however, meters would be necessary to monitor use.

The data which would be available through metering would also be very helpful. As it now stands, no one can tell with any assurance if a person in one part of town uses more water than someone in another part. It can't be determined if lower income users use more or less water than those with high incomes. This information would be very helpful in deciding what management alternatives might be needed. If high income users consume more water, perhaps it might be appropriate to charge them a higher rate. Possibly rates should be based on square feet of lawn space. With the difficulty of collecting data in these various situations as is now the case, it would be hard to make such decisions. With meters the data would be readily available.

According to Linaweaver in A Study of Residential Water Use, the use of meters doesn't curtail household domestic consumption. He states:

> "Apparently consumers use the amounts of water necessary to meet household needs in a reasonably efficient manner. This leads to the conclusion that whether consumers are metered or on a flat rate basis, their domestic use differs but little.
>
> The difference in sprinkling use is very significant... Apparently sprinkling is very inefficient in flat rate areas. As a result the peak demands, both maximum day and peak hour, in flat rate areas are more than twice those in metered areas" (Linaweaver, 1967).

Linaweaver's conclusion about lawn sprinkling should be reason enough to seriously consider metering. In addition to that, though, S. Hanke, in a case study of Boulder, Colorado, concluded that not only was lawn sprinkling greater in Boulder when it was on flat rates, but household consumption dropped substantially after meter installation. Hanke states:

> "The conclusions with regard to domestic use are similar to but more unexpected a priori than those of sprinkling demand. The domestic consumption is reduced sharply upon the introduction of meters as people alter their activities in response to a positive water price. The average use in the metered rate period for all of the routes being considered was thirty-six percent lower than that in the flat rate period" (Hanke, 1969).

It can be concluded, then, that there is a strong possibility that water consumption would be reduced in Fort Collins if meters were installed and rates were based on volume used. This possibility is extremely strong since Fort Collins is in the same general area as Boulder, and it has similar growth characteristics, similar climate, and its water users would no doubt have the same water consumption habits (Figure VI-1).

FIGURE VI-1

Johns Hopkins' Comparison of Metered Versus Flat-rate Average Annual Use*

Area	Domestic use (gpd/du)	Sprinkling use (gpd/du)	Leakage (gpd/du)	Total use (gpd/du)
Denver (4 flat-rate areas)	238	544	44	826
8 flat-rate areas	236	421	35	692
Metered areas (10 in Western U.S.)	247	186	25	458

*Source: F. P. Linaweaver, John C Geyer, and Jerome B. Wolff. Final and Summary Report on the Residential Water Use Research Project. A Report to the Federal Housing Administration, Prepared by The Johns Hopkins University, Baltimore, MD, 1966, pp. A-2 and A-3. Adapted from (Bryson, 1969)

Hanke concludes that the larger household consumption decrease is probably a once-and-for-all change that accompanies the introduction of a positive incremental charge. The same would probably hold true in Fort Collins. He further states that one reason for such a drastic change may have been caused by repairing leaks in the domestic plumbing system and by using such conservation methods as using a stopper or dishpan when washing dishes instead of using a constant flow. These types of changes were found to have occurred in Boulder by obtaining information through field interviewing. To illustrate what such measures by water users can do Hanke states:

> "The correction of one leak 1/32 inches in diameter will reduce consumption by an amount slightly greater than the average quantity of water used per dwelling per month after metering. Various other conservation practices can and do yield substantial reductions in domestic water use. Using a stopper while washing dishes instead of permitting the continuous flow of water reduces consumption approximately thirty gallons per wash for the average family." (Hanke, 1969).

Hanke concluded that lawn sprinkling fell substantially and stabilized at the lower rate after meter installation. He said that sprinkling habits exist, but are weak.

In a 1973 study (Bryson) water savings estimates were made of around 190 gallons per day per dwelling unit or in excess of 17 million gallons per day for the City of Denver when approximately 90,000 one and two family residences with flat-rate water charges were changed to metered billing. The total cost for meter installation was $27 million or approximately $300 per unit.

Given the above information concerning Boulder and Denver, it would most likely be wise for Fort Collins to consider metering. Even though the expense would be sizeable, since water is a limited resource, it only makes sense that people should pay for the amount they use. No other utility is furnished on a flat-rate basis. When a person can save by using just what he or she needs that person is likely to do just that. On the other hand, when nothing is at stake there is very little incentive to conserve. A twenty-year bond program as well as higher monthly rates would be imminent if metering was adopted by Fort Collins. It is doubtful that the citizens would vote for such a raise in taxation unless they thought it was the only way the water supply could be managed. This may very well be the case within the next ten to twenty years if Fort Collins continues to grow at its present rate.

Incentives and Taxation

Most water conservation management measures currently in use involve some form of rationing program which attempts to obtain public compliance through an enforcement program. As has been previously discussed these enforcement programs involve some form of penalty such as fines and/or service termination. An alternate means of encouraging participation in water conservation measures or in obtaining funding for required actions is that of incentive and/or taxation.

Perhaps the most obvious and effective incentive would involve a revised rate structure for metered water service. That is, a structure in which water becomes more expensive the more one consumes. It has been shown in agricultural use that as the cost of water increases, the efficiency of use increases likewise with a subsequent decrease in the amount used. Thus, as in other resources and public utilities, the idea of making over-use cost more may offer the greatest incentive to conserve.

Quite the opposite appears to be occurring today. In many localities currently under water rationing, the lower use combined with the fixed operating costs of the water service system have made the cost of water rise as the effectiveness of the conservation program has increased. This obviously creates confusion among the public and is a strong disincentive to active participation in the program. Such contradictions in policy should be avoided by whatever means necessary. To avoid such a situation monies might be diverted from other less critical government operations to cover the operating expense of the water system during the restriction program.

Other incentives involving public recognition of those effectively instituting water saving measures as well as periodic press releases informing the public of the status of the conservation measures, the water supply and the effectiveness of the program aid in assuring active public participation.

Taxation may be used either to fund necessary improvements in the system needed to effect water conservation or it may be used as an additional form of water saving incentive. In the first case, a per capita or per residence tax could be levied to obtain funding necessary to install water meters in a community currently using a flat rate unmetered system. In many cases new construction is subject to such a taxing program to provide the funds to meter all new water hookups. Generally, such direct taxation of the public is unpopular, as it usually relates to property owners, who alread see their tax burden as excessive. Thus, as a practical alternative it may not be politically feasible except in the most critical situations.

Tax incentives for water conservation might well be an effective step, however, as water saving devices are not as well identified and as major an investment as, say, energy-saving devices. It is difficult to foresee any major tax incentive programs on a large public scale. In new construction it is not uncommon to offer some tax incentive to home constructors for installing water saving appliances and low volume toilets and showers.

Conservation Measures Inside the House

A review of the history of domestic water use reveals that some societies have used more water than others, and it was not always related to water availability. The water consumption of Roman times decreased through the Middle Ages and was about the same until the last 100 years. By 1912, the per capita water use of London was equal to that of Roman times, and today many cities in the western United States, including most of the Front Range, use four to five times that amount.

In order to continue our lifestyles and maintain water and other resources, conservation measures are needed. Some of these can be technological innovations in appliances, but change of habits and conceptions of water will also have to change.

Residential water use can be divided into indoor and outdoor use very readily, and thus we have separate sections for these two areas in our report. As a rule of thumb, toilets use about half of indoor water in the average household. About one third goes to bathing and personal use, another one fifth to laundry and dishes, and a very small amount (about five percent) to drinking and cooking.

There are many existing and even more in-development technical solutions being promoted, this in response to the increased demand for such products. A list of major companies and distributors offering these devices is found in Appendix C of this report.

Toilets, as the greatest in-house water user, have many possible adaptations. These range from the placing of objects in the tank to displace water, smaller tanks, pressure systems using less water or air or even oil, in-house recycling of the water. The more simple methods can be readily and inexpensively adapted. To provide incentive for more expensive systems, aid and promotion must be made for the construction industry in new housing and in the plumbing industry for replacements.

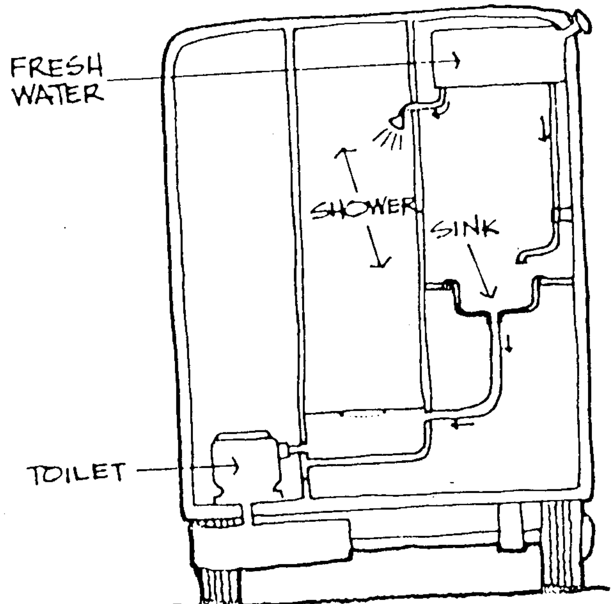
Figure VI-2 depicts two possible bathroom water reuse systems, wherein water used first for one use goes on to another use instead of being immediately discharged to the sewers. These sorts of systems can be adapted to many indoor areas. In Marin County, California and other areas such reuse of bath and dishwater for toilets, watering plants, etc., has become standard, at least for the duration of their extreme water shortage.

Water saving appliances in the kitchen, too, are becoming better known. Leakless faucets, foot-controlled faucets, computerized temperature mixing mechanisms, water-saver dishwashers and disposals, etc., will become even better known and more competitive as their need increases.

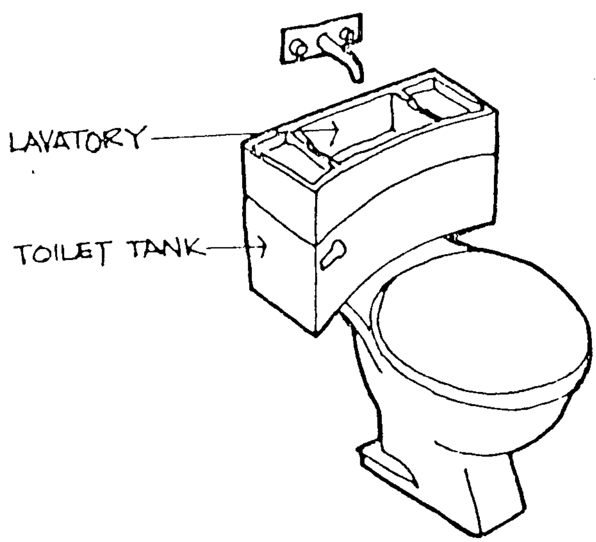
Of even more note than the technological innovations have been the socio-cultural and institutional changes proposed. Education has already changed some behaviors, and workshops, programs, literature and other methods will continue to have the greatest long-range impact on the attitudes toward and behavior with water use. The costs for this are

FIGURE VI-2

Bathroom Water Reuse Systems



REUSE SYSTEM (STAN. PROD., 1971)



LAVATORY-TOILET TANK COMBINATION
(CARFORA, 1972)

large, of course, and there is a need for political commitment to see such programs through, but they can promote community cohesion, involvement, and support as well as reducing water consumption.

Personal habits are stressed in most literature and as a shortrun as well as a long-run approach it is beneficial. There are immediate results, and where metering is available the reduced cost of water often makes the effort seem miniscule. Reducing flushing can save 5 gallons or more per person per day, reuse of once used water can save up to 25 gallons per day, and using full dishwashers and dryers can save ten to 15 gallons per day.

It must be remembered that the in-house use of water is not a large percentage of our total water use, but the attitudes acquired within the house where the results and problems are very visible provides an atmosphere for carrying on such programs where there is much greater water use, and where the water wastage is also greater.

In order to promote any of the above plans, economic and institutional changes are mandated. Pricing controls for water, with increasing cost for increasing use, seasonal rates, tax incentives for fixtures and recycling, and block grants to support research, construction, enforcement, and monitoring of systems and programs, can all aid the water conservation effort. Changes in laws for plumbing codes, building codes, and appliances will increase the chance for their installation. Equally important is rigorous and fair enforcement and monitoring of programs. Although costs for monitoring and enforcement are high in monetary and manpower terms, these actions are vital to maintain morale and support of adopted programs. It has been shown that, while voluntary measures can help save water, only mandatory regulations or pressures economically will have any long-range effects of great extent.

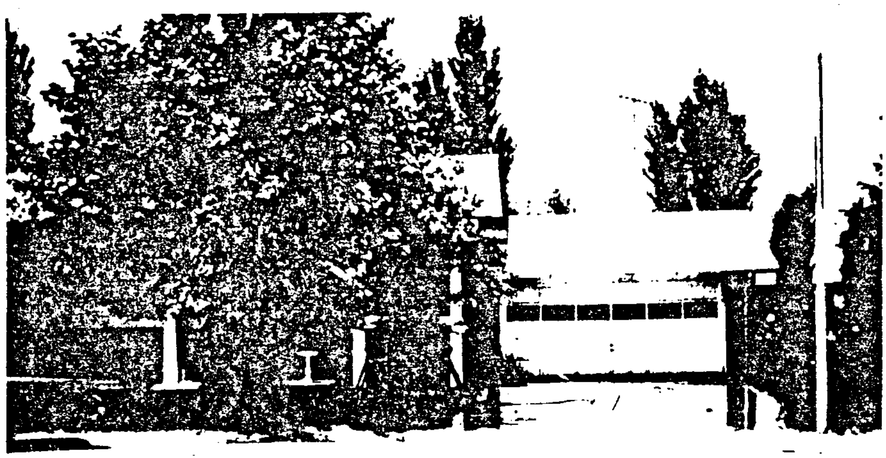
Conservation Measures Outside the House

The most logical out of house domestic use to reduce in and around Fort Collins is that of lawn watering (see Figure VI-3). This use accounts for an average of about 38 percent of all municipal and industrial use within the city (1969-1976 average). The most water consumptive aspect of lawn irrigation, which is watering turf grass lawns, could be reduced by planting native vegetation or landscaping with rock or bark and widely dispersed xeric plants. This could be encouraged by holding seminars and workshops on landscaping and how to care for native plant materials. Such a program could be set up in cooperation with the local Extension Service. Regulations could also be passed which mandate that a certain portion of each yard contain native plant materials. This would no doubt be difficult to enforce and would not be received as readily as a voluntary program. Publicity in the lawn and garden sections of the newspapers could illustrate the good points of native plant landscapes. Also incentive programs such as tax breaks could be offered for converting old lawns or establishing new ones which were made up of native plant materials.

The area of space containing plant materials can make a substantial difference in the amount of water needed to irrigate a lawn. F. Chavez found that in New Mexico 88 percent more water is applied to yards made up of 90 to 100 percent plant materials than yards made up of only 50 to 70 percent plants (Chavez, 1973). Plant area reduction could also be encouraged via publicity and education programs or mandated by way of regulation. Again, it would most likely be received much better if left on a voluntary or incentive basis. Tax breaks could be offered based upon

FIGURE VI-3

Wastage Resulting from Careless Lawn Watering



Here an oscillating sprinkler was set in the middle of the driveway in order to water a small strip on each side. Such practices can be seen throughout Fort Collins during a normal summer.

(Original photos not available for a clearer reprint).

the percentage of yard area containing no plant materials. Methods are available to develop yards with very few plants. Rock or bark can be used with a black plastic layer underneath to cover areas of ground where plants aren't desired. Pathways can be constructed to afford access through the yard. One very attractive feature of such a landscape is that it requires very little attention, thus allowing free time for the home and no need for energy consuming lawn mowing (see Figure VI-4).

A tax incentive program might encourage the planting of native materials, low density planting, or a combination of both. Homeowners might be given an incentive to convert old lawns to such a landscape with the city's help in setting up a market in which individuals' sod could be sold. Advertising and transportation could be coordinated by the city in order to encourage the sale of sod to people in other parts of the country where rainfall is sufficient to sustain it. Revenue could go to the home-owners to help defray the cost of converting their lawns.

A program as drastic as discussed above would most likely only occur if the situation got to the point that little or no water was readily available for lawn irrigation. As long as water is readily available, or at least perceived to be, less drastic measures are likely to be taken. Kentucky bluegrass is very popular as a turf in and around Fort Collins, and this situation is unlikely to change. A very realistic conservation measure would be to teach people how to have a green lawn while using less water to irrigate it. Herbert C. Gundell, CSU Extension Horticulturist for Denver and The Denver Post Garden Editor has published a pamphlet entitled "Good Lawns with Less Water" made available by the Denver Post and Western Federal Savings which gives several hints on how to save water

FIGURE VI-4

Example of an Alternative Landscape

A large portion of the yard contains bark with widely dispersed trees and shrubs, thus reducing the need for lawn watering.

(Original photos not available for a clearer reprint).

(see Appendix D). Also, the Cooperative Extension Service at CSU has published a pamphlet entitled "Conserve" which lists several ways to save water in and out of the house (see Appendix E). Cities should support such publications and help distribute them. Such publications could be enclosed with each water user's bill.

According to P. H. Dernoeden, in his thesis Variety Tolerance to Drought in Kentucky Bluegrass, bluegrass can be "hardened" or made more drought tolerant (Dernoeden, 1976). According to Dernoeden, the most widely accepted factor contributing to drought resistance is the ability of grass protoplasm to endure dehydration. Less drought resistant grasses' protoplasm, it is said, ruptures as a result of drying out and remoistening. It is possible to "harden" the protoplasm of Kentucky bluegrass by restricting irrigation in the early spring when transpiration rates are low. Other drought-hardy characteristics are promoted by doing this also, such as increased root mass and root branching, extended root hair zone, and deep rooting. It should be noted that Kentucky bluegrass hardens swiftly as compared to other turfgrasses. In his thesis, Dernoeden relates the procedure in which he was able to apply water to bluegrass only once every three weeks after a summer of "hardening" it, and the grass retained a quality green appearance. This procedure could be publicized so that people throughout the arid West could take advantage of it. Furthermore, incentives might be offered by cities to encourage such a procedure.

Besides hardening the protoplasm, Dernoeden says that turf growers should avoid the application of nitrogen in the spring. Nitrogen stimulates rapid shoot growth, and causes other reductions in drought hardiness. Complete fertilizers should be applied in the fall to stimulate root and rhizome development. Also, grass can stay green using less water when mowed at a height of about 1-1/2 inches than if mowed shorter. The mower blade should be sharp. Frequent and severe mowing generally produces low carbohydrate reserves and a weak root system (Dernoeden, 1976).

It is interesting to note that in Fort Collins watering occurs heavily in the spring rather than being restricted as Dernoeden found would help lawns become more drought resistant. This heavy watering prevents proper gas exchange which normally stimulates root development. Also, heavy watering helps cause soil compaction, thus greater evaporation and leaching. In addition to heavy watering, nitrogen fertilizers are used quite heavily in the spring in the Fort Collins area. This may be due in part to the heavy advertising and marketing campaigns to sell such products by area lawn and garden sales companies each spring. So actually, rather than being made drought resistant, lawns throughout Fort Collins are made water dependent.

Area residents generally do not realize how drought tolerant Kentucky bluegrass is. Actually, it has many characteristics which will bring it successfully through a drought. Its seeds, as with many turf grasses, are able to withstand extended periods of exposure to dry air conditions without significant loss in viability. Also, dormant buds on rhizomes and stolons are drought hardy (Dernoeden, 1976).

Lawn hardening would be a very helpful water saving program. It would be more successful, however, if coupled with a program to establish better subsoils. Due to the hard clay beneath the surface soils, the subsoil throughout the Fort Collins area needs to be treated before sod is placed on top of it. Peat moss, sewer sludge, compost material, animal manure, or other such enriching moisture holding material should be tilled into the soil before sodding. This allows a better root system to develop so that grass can live on less moisture and thus be more easily "hardened." The standard procedure now is to scrape off the top soil, then place sod right on top of the subsoil. This leaves virtually a thin layer of top soil within which roots can establish. Regulations are needed to require contractors to establish a better sub-soil. This could be added as a stipulation for passing a building inspection. Incentives could be established by reducing contractors' fees if they met minimum criteria in establishing sub-soils.

Another significant water use outside the house is car washing. The use of automatic car washes should be encouraged since many of these establishments recycle their water using less per car than individual washing. Citizens should be made aware of this. The city might go so far as passing laws limiting washing cars at home. Care would have to be taken so as not to create an unreasonably high market for car washes under such a situation. The number of new car washing establishments as a result of the new demand should take care of this. If car washing at home continues to be allowed it should be limited to washing with a bucket and rinsing with a low volume head on the hose allowing no free running hoses. This is a restriction which has been successfully used in California.

Educational programs, incentives, or laws should be instituted to also combat using water to wash down sidewalks and driveways. This is a waste since sweeping with a broom will do the job just as effectively.

Mulching around trees and gardens should be encouraged, making less irrigation necessary. Moisture meters could be used to detect the soil's need for water. Also, measuring methods should be encouraged so that people might know when they have watered enough. One such method suggested by Mr. Gundell in Good Lawns With Less Water (Appendix D) is to place coffee cans so as to measure the amount sprinkled. This type of information could be disseminated by the City.

While saving all the water used for outdoor household consumption would not cure the problem of water being in short supply, such measures as discussed would make an impact on people's attitudes toward water use. People are more aware of their impact on a resource when they feel the effects of the supply of that resource.

Public Education

To modify the water use habits of the public, it is necessary to make full use of all education, communication and media opportunities available. Facts must be communicated properly and more importantly, long term impact upon attitude and belief is vital to insure continuing water conservation behavior.

There are many opportunities through education, communication, and the media. With limited financial means, however, it is important that the methods employed have a strong impact for the money spent.

Printed and electronic media provide wide dispersal of information, usually at little or no cost, through news reporting. One problem is, of course, the tendency for the most dramatic situations to be stressed and for conflicts to be focused on. This can bring doubt and confusion into the mind of the public, leading to a lack of trust in officials or the sources of information. Also, the editorial stance of the particular publication often reflects a certain set of values which may serve to color the reporting of the situation in an undesirable manner. For instance, strongly growth oriented communities may in water-scarce times call for development of more water supplies to the exclusion of water conservation means. Nevertheless, the media can be an effective source of information dissemination for the water manager. Evidence of this in the case of Denver, Colorado, was provided by a letter to the editor of the Denver Post newspaper from the manager of the Denver Board of Water Commissioners. In that letter, the Board by resolution, publicly thanked the press, radio and television for "the assistance in making certain that the citizens are aware of the conservation program," (Denver Post, July 18, 1977).

Printed brochures, newsletters and other techniques can be effective, especially for use by schools. In addition to showing the problems of the hydrological cycle, specific means of water conservation may be promoted. This method was used in a cartoon brochure initiated in the San Francisco, California area and which has subsequently distributed through the Denver Public Schools. Such brochures can often be promoted free of charge by newspapers, radio and television, as well as by educational institutions. An example of this type of brochure is given by Figure VI-5.

Motion pictures and other visual aids are another means of educating the public on water conservation. Films dedicated to water conservation and emphasizing the seriousness of the water shortage exist and are generally available for showings without charge to schools, civic groups and other interested groups. The Denver Water Board, for instance, has produced such a film entitled "Water Follies" which is available locally through several sources (Triangle Review, July 27, 1977, "Film on Water Available").

Figure VI-5

CONSERVE

Prepared by
Cooperative Extension Service
Colorado State University
Fort Collins, Colorado

Use the smallest amount of water possible in cooking. Most frozen vegetables require about 1/2 to one cup of water, not half a saucepan.

A tight-fitting lid on a pan saves water from boiling away and also cooks food faster, thereby using less energy.

Using syrups and juices from canned goods saves water and makes foods taste better.

Use a pan of water when peeling and cleaning vegetables and fruits rather than letting the sink tap run.

When washing dishes by hand, use a stopper in the sink and don't rinse with running water.

When use of a garbage disposal is necessary, save food scraps and run the disposal once to conserve water. You can use the disposal even less by saving food scraps for a compost pile.

A bottle of drinking water kept cold in your refrigerator saves running the tap to get cold water.

CONSERVE

All Around the House

Faucets, throughout your house, should be checked for drips. Sixty drips a minute can waste up to 2,200 gallons of water a year.

When washing the car, use a bucket filled with warm, soapy water and use a running hose only for a quick, final rinse.

Use a broom, not the hose, to clean the garage, the sidewalks and the driveway.

The tap water should not be left running when doing normal cleaning of cabinets and appliances. Wet a sponge or cloth and rinse it when necessary, preferably in a bucket of water.

Insulate the hot water pipes under your house. Having to clear the line of cooled water is wasteful.

Forums at meetings, in schools, on the radio, or on television also can put the problem before the public. Far less impact is usually obtained by these meetings/discussions, but they do provide a place for like-minded persons to share views and organize for other actions.

Workshops can be of utility, especially where there is specific information, techniques, or strategy to be taught or shared. Workshops may be among educators, political leaders, school children, special interest groups, or combinations of these groups. Methods and purposes vary, of course, and are related to the goal of the particular workshop. Means of conducting these and other meetings are detailed in many sources, including an Institute of Water Resources publication (IWR 75-R4).

Surveys, by mail, in person or via media are valuable in assessing the current beliefs and knowledge of the public. Newspapers often report these, and if done properly can be very useful. They may aid in determination of what management techniques will be more readily accepted and what information needs to be better communicated.

Public facilities, such as restaurants, can also educate via the service of water only upon request, having brochures available and advertising their own management practices (Figure VI-6).

Again, the methods employed in the educational process depend upon the information to be communicated, the types of publics to be reached, funds available and time. It is always most effective to have a feedback, or inter-play two way process with the public rather than a one-way communication channel.

Land Use

Land use and land use planning can and do have a significant impact upon water use and water conservation management. Likewise, restrictive

FIGURE VI-6

**We're Proud of our Service
As a Restaurant in
Fort Collins**

**We're Also Concerned about the Continued
Supply Of Water in the Fort Collins Area**

Therefore

**We Will Be Happy To Serve You
Water If You Request it.**

Sponsored by
Ft. Collins Chamber of Commerce

water use and supply controls can directly affect land use. Typically water service has been viewed as being similar to a public utility in that the service was provided to meet existing and projected demands. It was not viewed to be the responsibility of the water supplier to evaluate nor attempt to modify these demands but only to provide the necessary capacity. Evaluation and justification of growth and added water demand was considered to be the responsibility of local government and planning agencies rather than the utilities.

Recently, and most notably in northern California (Marin County) as a result of the environmental movement and a desire for effective growth control, water service was used in an attempt to restrict growth. Through election to positions on local water boards and alteration of water policy with regard to development of new supplies, it was assured that the service capacity of the local water supplies was reached. Once this capacity was fully utilized, and no additional supplies available, no further water tap permits were issued, thus effectively stopping further growth in the community. Initially such policy appeared to have wide support; however, with the advent of serious drought conditions and the system at capacity, critical shortages quickly developed and public pressure for creation of additional capacity became evident. Such use of water service for growth control and ultimately land use control is generally unacceptable to those involved in the provision of water services; however, it should be recognized that if growth control pressures are intense, such means may be a viable alternative for those advocating control.

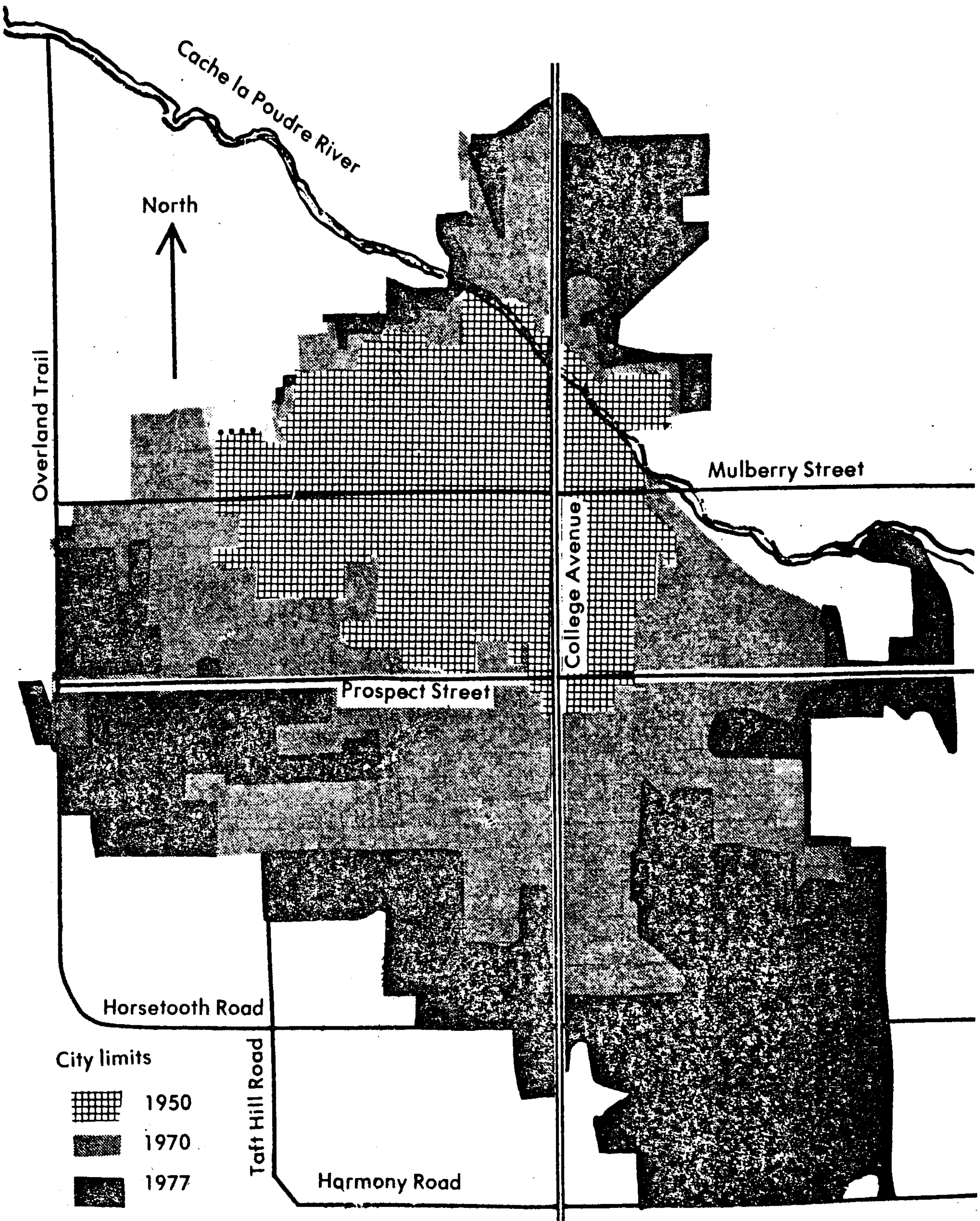
The argument is often heard that provision of excess water capacity to meet projected growth tends to foster such growth. While specific studies addressing this question are not available, it appears to most that with regard to urban growth the availability of water, while representing one consideration, is not generally the limiting factor either from a restrictive nor a positive standpoint.

Provision of water service may properly affect land use planning by directing urban growth to existing service areas. Planning urban or residential growth toward existing service areas is most efficient in terms of reducing the costs of service by limiting the need for additional and lengthy water lines and required pressure increases to serve dispersed areas. Dispersed and scattered population densities result in an inefficient use of water services and may result in a duplication of services. Lower densities mean more water lines which must be spread over a greater area.

Fort Collins, Colorado is a good example of a community which is experiencing rapid growth and diversification. In 1950 the density of Fort Collins was 5,150.7 residents per square mile; in 1975, the density per square mile had decreased to 3,703.6. This lowering of the density has resulted from expansion of the city borders through annexation. The Fort Collins planning department has reported that in 1950, the city covered 2.9 square miles; in 1970, the city's area had expanded to about 10 square miles, and by the end of 1977, the city is expected to occupy approximately 20 square miles (see Figure VI-7). Fort Collins, in order to allow city water service to keep pace with this rapid expansion and diversification, requires prior to annexation of an area that the proponents of the annexation provide adequate water rights or monies sufficient to purchase adequate water rights to serve the existing and projected population of the annexed area. In the Fort Collins area, the direct

FIGURE VI-7

Map of Fort Collins Growth Pattern



(Fort Collins Coloradoan July 17, 1977)

alteration of land use from agriculture to urban appears to require little additional in respect to water service if the total water supply used for agriculture is converted to urban use. Service requirements differ, however, in that urban development requires treated water to be provided through water lines, whereas irrigation requirements may be met with raw water and ditch delivery systems. Thus, while total water demands per unit of area (acre) may be roughly equivalent for both urban and agricultural uses in the Fort Collins area, the cost involved in provision of such water may differ greatly.

Many aspects of land use in urban areas may greatly affect water demands. As mentioned earlier, density is a significant factor; water demands for dispersed large lot single family residences are generally high on a per unit or per capita basis while clustered development or high density apartment development, even though containing large green space area, may have lower water requirements on the same basis. As discussed in another portion of this paper, application of alternative or native landscaping in conjunction with land use requirements and planning can also represent considerable water savings.

Application of these land use measures would normally require inclusion in zoning ordinances, planned unit development (PUD) requirements or restrictive covenants on properties. These implementation measures do not now exist and would in most cases require local government action prior to or for their adoption.

Legal

The current Constitutional and statutory status, especially at the State level, is not amenable to many desired water management practices.

Either the practices must be limited to the legal status-quo, the laws changed or a combination be done, as seems most feasible.

Colorado is unique in that it is the only state to use exclusively the Doctrine of Prior Appropriation. This doctrine is also known as the Appropriation Doctrine and the Economic Consumption Theory. All other states use either the Riparian Doctrine or a combination of both Riparian and Appropriation Doctrines. In Colorado, under the appropriation doctrine, water rights are considered vested real property rights and not necessarily attached to the land. This fact together with the basic premise of the appropriation doctrine; that is, beneficial use is generally defined to be diversion and consumptive use, presents obstacles to any program of water conservation and management. The following statement of Karl R. Klingelhofer, Chief of the U. S. Soil Conservation Service's flood plain management and special projects branch is illustrative of this fact:

> "For the near long term, water conservation should be emphasized and implemented. But what incentive is there where water prices are low and water rights law often encourage that water be used or the right lost."

Partially in an attempt to resolve some of the legal problems involving water conservation management and to strengthen local justification for such management, revision of the Colorado State Constitution is being considered. A report of the Citizen's Assembly on the State Constitution, made up of a diverse group across the political spectrum, noted that the Colorado Constitution "is almost completely silent" concerning environmental matters.

The group recommended many constitutional changes to modernize the document. Of relevance to the water situation are, among other, the following:

> Article XVI, Sec. 6: This deals with rights to divert unappropriated waters of any natural stream. The panel recommends amending it to provide for appropriation of water for instream beneficial uses, such as fishing, wildlife, and recreation, and not require diversion for beneficial use. This is consistent with a 1973 statute which authorizes the state to appropriate water to maintain a minimum flow on streams and lakes, where essential to preserve the natural environment to a reasonable degree. Regarding the part of the same section which established certain priorities of water appropriation (domestic use, agricultural use, industrial use) the panel recommends leaving it to the General Assembly to "maintain a balanced water conservation program which will consider all uses."
>
> Article XVI, Sec. 7: This established the right of "all persons and corporations" to have private lands condemned, with compensation, for construction of canals and ditches. The panel would delete this and leave it to legislation to determine rights regarding such condemnation and construction.
>
> Article XVI, Sec. 6: Denies the legislature the power to prohibit inter-basin transfers of water. The panel would allow legislative prohibition where it deems it appropriate.

Municipalities under the priority allocation of water use referred to above in the State Constitution and under the Doctrine of Great and Growing Cities may through condemnation procedures and compensation acquire water rights sufficient to service the cities' projected fifteen year growth. Generally these supplies could be drawn from the agricultural sector. As a politically acceptable technique condemnation is normally not feasible, however the concern over such actions was sufficient to accomplish passage of HB-1555 in 1975 which is described as follows:

> The act concerns condemnation of water rights by municipalities. The act establishes a court-appointed commission of three persons to review the growth development plan of the municipality seeking the recommendation and required preparation and review of an impact statement to determine whether or not

> the condemnation is in the public interest. The court makes the final determination, based on the recommendation of the commission. If the commission determines there is a need for condemnation as proposed, hearings are to be held to determine compensation and damages accruing to the owners. Proponents feel the act protects limited water supplies in Colorado from growth-oriented communities.

Some communities such as Fort Collins have avoided this politically sensitive and controversial problem through water restrictions upon areas annexed to the city. In Fort Collins, prior to approval of annexation of adjacent areas, those proposing the annexation (developer, residents, etc.) must also provide to the city sufficient water rights or monies sufficient to purchase water rights adequate to service the expected population of the annexed areas. While this legal requirement may not ultimately avoid the problem of diversion of agricultural waters to municipal use, it does permit a more orderly transfer of water rights and removes the city from the need to utilize condemnation procedures at a later date.

Specific state and local legislative action, and administrative acts by agencies, will be a continuing source of legal support both for gaining new water storage facilities and for backing management measures. Public response to the need and the reaction to the proposed actions will be key to the strength of legislative actions taken and to the enforcement of water plans so initiated. Such laws can apply to excess water use by agriculture as well as municipalities.

There are existing laws which though not often used at present, could through vigorous enforcement, create an atmosphere more conducive to water use management. For example, the City of Fort Collins has a statute prohibiting "water wastage," such as watering streets and sidewalks. Such inundation of cement is often seen and is not conductive to a water savings program (See Figure VI-3). Laws such as this could be well publicized and enforced to demonstrate that municipalities take seriously the current water situation.

These and other laws can institutionalize a continuing program of wise water use and allow a continuation of a comfortable life style, allow some growth, and maintain needed agricultural water supplies.

Water Supply Development

The remedy for water shortages throughout the Colorado Front Range area by civilized man has been by means of water supply development. This development has been principally in the form of transmountain diversions, dams, and reservoirs. One of the largest reservoir projects to supply water to northern Colorado is the Colorado Big Thompson (CBT) project which diverts approximately 206,000 acre ft. of water annually from the Colorado River in the Pacific drainage system to the Big Thompson River which flows into the Atlantic drainage system. The diverted water is stored in reservoirs until it is used for municipal or agricultural use. There are thirty-seven such diversion projects throughout Colorado (Colorado Water, 1975). The smallest diverts around 55 acre feet per year, and the largest is the CBT. Horsetooth Reservoir, in which one half of Fort Collins' available water supply is stored, is one of the CBT system reservoirs. Approximately 10,000 acre feet per year is available to the City from Horsetooth. The remainder of Fort Collins' water comes from the Poudre River. There seems to be a danger involved with reservoir water supplies that is seldom if ever mentioned in engineering reports. This danger is that there is a tendency to plan for water availability based on normal reservoir supplies. At this writing this year's drought has apparently not caused an appreciable shortage in irrigation water delivered to farmers via the Big Thompson project. According to the May 9, 1977 edition of the Fort Collins Coloradoan, 100 percent of the 310,000 acre feet allotment of irrigation water would be available. At the time this prediction was made, Colorado Big Thompson storage was approximately eighty-eight percent of normal. What will happen if next year's precipitation is as low as this year's? Furthermore, what will occur if the drought lingers as it has in California? Diversion systems, dams, and reservoirs are important in sustaining modern society in the arid West since such means have to be used to acquire and store necessary water. However, such development can create an expectation of an adequate water supply when it is inevitable that the supply simply will not be adequate every year. These systems often simply delay the effects of drought.

Nearly all the water flowing through Colorado has been purchased or has to remain flowing due to interstate compacts. However, there are nine additional water storage projects being considered for construction. These projects are listed in Figure VI-8. On February 22, 1977, President Carter cut the funds on a list of projects he considered questionable due to environmental reasons or due to a lack of sufficient economic benefits. The projects affected by this "hit list" are so indicated in Figure VI-8. Mr. Carter's list is no doubt a result of the current ethic in our country concerning the environment and the value of such public works projects. Since the early-to-mid 1960s, concern has been growing throughout the United States as to whether or not we have been doing the right thing by building large reservoirs. The concern has stemmed from the fact that such bodies of water often create undesirable social effects and drastically

FIGURE VI-8

Proposed Reservoir and Diversion Projects in Colorado

Project	Year Authorized	Location	Volume in Acre Feet	Purpose
Fruitland Mesa*	1964	Gunnison River Basin	57.900	Irrigation & Public Works
Savory-Pot Hook*	1964	N.W. Colorado Little Snake	29.000(Col) 22.400(Wyo)	Irrigation
Animas-LaPlata	1968	S.W. Colorado	201.600	Multi-purpose
Dallas Creek	1968	S.W. Colorado	66.300	Multi-purpose
Dolores	1968	S.W. Colorado	126.000	Multi-purpose
San Miguel	1968	S.W. Colorado	122.000	Multi-purpose
West Divide	1968	W. Cent. Colo.	193.100	Multi-purpose
Narrows*	1946	N.E. Colorado	400.000	Irrigation & Recreation
Halted	1952			
Reauthorized	1970			
Closed Basin	1972	San Luis Valley	100.800	Treaty and Compact Obligations, Irrigation and Wildlife

*Indicates project on President Carter's "Hit List", future undertain.

alter the ecosystems in the inundated area. With the passing of the National Environmental Policy Act of 1969 (NEPA) on January 1, 1970, federal agencies were directed to investigate the feasibility of such projects with regard to environmental, economical, and sociopolitical effects. Since that time the general attitude of much of the public and various federal agencies seems to have become opposed to large reservoir projects, or at least skeptical of their value. It is doubtful, then, that an appreciable amount of water supply will be added throughout our country in the way of new reservoir projects. It should be noted that the few additional projects planned for Colorado are directed at developing the last available supplies.

Fort Collins is developing Joe Wright Reservoir, a small project which will actually involve the expansion of an existing reservoir. As stated earlier, the City's present water supply is obtained from Horsetooth Reservoir and the Poudre River. The water available from Horsetooth is approximately 10,000 acre feet per year, none of which can be carried over to the next year. Of course, no storage is available in the Poudre River itself. Joe Wright will have a capacity of more than 7,000 acre feet. Since the City will control it, water can be carried over to supply water in drought years. However, 7,000 acre feet is less than one-half of what was used in 1975, and less than one-third of the projected need for 1990 (see Appendix F). The cost of the project is over $5 million. It is questionable that other potential quality reservoir sites are available. If they are, it is doubtful that they would be worth the money required to develop them. It may be more economical in the long run to spend around

$2.8 million to install water meters, thus reducing water consumption and the need for more water supply (see this Section, Water Meters).

Another possible water supply development method is recycling. This involves the recycling of storm runoff and/or sewage effluent. Storm runoff in Fort Collins is very low. However, runoff from lawn sprinkling appears to be substantial in many areas, especially on the Colorado State University campus. This runoff could be collected, treated, and returned to the system. It could also be collected, left untreated, and used only for lawn irrigation. However, if this were done, a separate system would have to exist specifically for this purpose. Such a system would have to be closed, with no outlets other than retractable sprinkler heads to preclude anyone accidentally drinking the untreated water. With the amount of raw irrigation water available to Fort Collins, such a system might be feasible. Water could be used directly out of irrigation ditches, with no treatment necessary. Sewage effluent could be used in such a system. If the sewage was properly treated, there would be no offensive odor. Such a separate lawn irrigation water system would cut down the need for water treatment by about thirty-five to forty percent (see Section IV).

Possible Future Water Supply Development Measures

Cloud seeding is a method which has been used throughout Colorado in an attempt to increase water supply. This science is still developing and current knowledge is limited. Evaluation of the various cloud seeding techniques is difficult because it requires controlled study to distinguish the amount of rain induced by artificial means from that which might have occurred naturally. The difficulty in making such a distinction is due to the fact that the meteorological conditions essential for artificial rain production are similar to those leading to a natural rainfall.

Cloud seeding has been tried in Colorado by dispersing silver iodide from ground generators as well as from aircraft. A program was approved in February, 1977, authorizing $250,000 of state and local money to be used to seed clouds. The program was run from February 15 to May 15, 1977. According to the May 18, 1977 edition of the Fort Collins Coloradoan, Dr. L. O. Grant, an atmospheric sciences professor at CSU, reported that the seeding program produced snowfall thirteen to nineteen percent greater than would have fallen naturally. According to the article, Dr. Grant has consistently claimed that a ten to twenty percent snowfall increase can be realized by seeding winter storm clouds. Other experts, the article said, have said that the amount of increased snowfall produced by seeding can in no way be precisely determined.

There are definitely some problems with cloud seeding. One problem is the legal implications. No large legal issues have been pursued in court as yet, but they most likely will if cloud seeding becomes more widely used. States or their citizens in areas contiguous to and on the windward side of cloud seeding activities may very well have standing to sue on the grounds that induced precipitation would have fallen on them if left in its natural form. Also, weather patterns might prove to be changed by altering natural precipitation. This could spark action by environmental groups and wildlife societies. These legal problems have historically served to limit the development of cloud seeding technology. A major legal question is on whom the burden of proof will fall in such a lawsuit.

If seeding becomes economically feasible for private groups or cities to undertake, certainly federal control will become necessary.

It appears that more research will be funded for the science of cloud seeding. At the present time it is not a feasible measure for a city or small local government to undertake. It might be considered as a future possibility, but for now local funds probably shouldn't be spent on cloud seeding unless on a cooperative basis with the state or federal government.

Water desalinization is a measure which could relieve the prospect of ever having a water shortage. However, Fort Collins is hardly strategically located to take advantage of seawater for a water supply. If it were economically feasible to convey desalinized ocean water to Colorado, this might be the ultimate technological fix.

The Office of Saline Water within the Department of the Interior directs federally funded desalinization research. There are numerous desalinizing processes which produce fresh water, but at a higher cost than that produced by conventional systems. Several of the processes involve evaporation of the water and condensation of the resulting steam. Another method involves freezing the water. The ice crystals are separated from the brine, washed free of salt, and melted into water. This works due to the different freezing points of fresh and salt water. Another process is called reverse osmosis. This involves pressure which forces fresh water through a thin membrane which doesn't allow minerals to pass through it. Also electrodialysis is used to desalt brackish water. When salt dissolves in water, it splits into positive and negative ions. Electric current can be used to remove these from the water.

Smaller scale desalinization plants can use conventional fuels such as coal and oil very efficiently. However, research is being conducted on the use of atomic energy for desalinization.

Desalinization is in no way economically feasible for Fort Collins to consider at this time due mainly to the long distances over which the water would have to be transported once desalted. However, if Fort Collins and the rest of the northern Front Range is going to continue to try to attract more people, such a measure will be necessary. Otherwise, water resources may be completely depleted. While Fort Collins could not afford to pursue desalinization on their own, it might be feasible for the entire Front Range to look into it. If all the arid Western states as a group were to consider desalinization, a desalting and conveyance system serving all of them might prove worthwhile. As with any other new measure, however, the effects of such a system should be very carefully considered. Rigorour research would be required to ascertain what effects the extra water brought inland would have.

REFERENCES

Bryson, S. G., Water Metering Experiments For The Flat-Rate Denver Residences, thesis for Master of Science, Department of Civil and Environmental Engineering, University of Colorado, 1973.

Canon City to Get Federal Drought Funds, article, Denver Post, newspaper, June 30, 1977.

Chavez, F. "A Study of Water Used in Urban Landscapes", article, Hortical Science, period 73:319,1973.

Citizens' Assembly on the State Constitution, The Colorado Constitution: Is It Adequate for the Next Century?, 1976.

Dernoeden, P. H., Variety Tolerance To Drought In Kentucky Bluegrass, thesis for Master of Science, Department of Horticulture, Colorado State University, Fort Collins, Colorado, Spring, 1976.

Economic Research Service, U. S. Department of Agriculture, Our Land and Water Resources, May, 1974.

Federation of Rocky Mountain States, Summary of 1975 Rocky Mountain Land Use and Natural Resource Bills, October, 1975.

Flack, J. E., A Water Conservation Program For Denver, A Report on the Evaluation of Universal Metering in Denver, Colorado, Sponsored by the Denver Board of Water Commissioners, September, 1973.

Fredrick, K. D., A Troubled Island, article, Resources, period., published by Resources for the Future, Washington, D. C., No. 55, April-June, 1977.

Hanke, S. H., The Demand for Water Under Synamic Conditions: A Study of Boulder, Colorado, Center for Urban Engineering Studies, University, of Colorado, Boulder, Colorado, 1969.

Institute for Water Resources, Public Involvement in the Corps of Engineers Planning Process, report IWR 75-R4, October, 1975.

League of Women Voters of Colorado, Colorado Water, Denver, Colorado, 1975.

Linaweaver, F. P., Geyer, J. C., and Wolff, J. B., A Study of Residential Water Use, report for the Federal Housing Administration, Department of Housing and Urban Development, Johns Hopkins University, Baltimore, Maryland, U. S. Printing Office, February, 1967.

Milner, Murray, Residential Water Conservation, California Water Resources Center, Report 34, 1976.

White House Drought Study Group, Drought Appraisal, March, 1977.

SECTION VII

CONCLUSIONS AND COMMENTS

-- Drought is temporary, though repetitive, but the limit of water availability is certain.

The temporary water shortages due to drought may become permanent. This is due to limited supplies, urban growth, restrictions on water development, and other factors. Redirection of water from agriculture to urban use may extend the time until this occurs.

-- Consistency of policy is vital.

In order to obtain acceptance of water management programs, the policies must be based on education, accurate data, and socially acceptable measures.

-- Great sacrifices in life style need not be made for water conservation if management measures are properly selected and applied.

Green lawns, trees and modern appliances can be maintained by reducing waste in the system, developing drought resistent species, and using low consumption fixtures as well as taking personal management measures.

-- Policies are more readily changed during periods of crisis.

The tendency is to ignore resource problems until a point of crisis is reached. At that time innovative solutions and policy changes are more readily accepted by both decision makers and the public.

-- There is a definite need for drought preparedness throughout the arid west.

In the past, all drought related activities have been in response to a drought crisis. Measures should be taken and policies established in anticipation of inevitable drought cycles.

-- Incremental water savings programs are most acceptable.

> The restrictiveness of water conservation measures should be phased to correspond appropriately to the perceived severity of water shortages to assure public acceptance.

-- Planning should be directed to achieve the best tradeoffs among growth, lifestyle, and resources.

> Western development traditionally has favored maximum resource use as opposed to that necessary to achieve optimum balance among all aspects of the environment. More consideration should be given to carrying capacity of the land and other resources.

-- While technological, socio-political, and legal infrastructure exists within which to accomplish much of the needed water conservation management measures discussed in this report, further research and policy reorientation is needed to meet the demands of future growth and resouce needs throughout the arid west.

APPENDIX A

PRECIPITATION HISTORY IN FORT COLLINS, COLORADO

1898 TO PRESENT

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1898	.14	.08	.50	1.08	3.65	1.37	.50	.98	.50	.82	1.24	.17	11.03
1899	.66	1.04	1.50	1.10	1.01	1.03	4.95	.99	.21	3.23	T	.47	16.19
1900	.25	1.12	1.07	10.56	1.75	.82	1.14	.16	1.92	.24	.07	.11	19.21
1901	.19	.38	1.88	3.62	7.47	2.35	.71	.57	2.25	.36	.02	1.37	21.17
1902	.32	.15	1.50	.61	2.13	2.43	1.31	.67	7.12	1.15	.27	.77	18.43
1903	.16	1.60	1.03	1.50	.63	2.23	1.06	.86	.87	1.48	.14	.07	11.63
1904	.04	.34	.51	.89	5.37	1.68	1.99	.71	1.09	.39	.00	.12	13.13
1905	.29	.35	1.75	6.32	4.13	.64	2.17	1.25	.28	2.60	.07	T	19.85
1906	.01	.03	2.44	4.30	2.40	1.80	1.96	.80	3.08	1.59	1.35	.12	19.88
1907	.23	.36	.69	2.80	2.44	.44	2.28	1.27	.58	.08	.44	.03	11.64
1908	.11	.03	.28	.05	5.83	1.16	3.66	2.12	.52	1.80	1.06	.60	17.22
1909	.02	.90	3.35	1.34	1.06	2.59	1.98	1.45	2.10	.08	.79	.58	16.24
1910	.29	.16	.06	.42	4.75	1.04	.87	1.92	1.79	1.03	.11	.48	12.92
1911	.34	1.52	.05	1.89	.72	1.78	1.47	.59	.80	.93	.43	.37	10.89
1912	.37	1.65	1.79	.90	2.84	2.43	2.93	1.21	2.66	2.03	.59	.21	19.61
1913	.30	.94	.20	1.49	2.09	.15	2.63	.41	2.39	1.00	.17	4.08	15.85
1914	.35	.30	.87	3.23	2.73	2.01	1.68	1.27	.02	1.58	.12	.15	14.31
1915	.12	1.41	1.73	4.01	3.78	2.20	2.12	1.56	2.97	1.97	.10	.82	22.79
1916	.84	.11	.31	.86	3.85	.60	.65	.71	.70	2.92	.98	.62	13.15

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1917	.40	1.04	.99	1.22	5.82	.07	1.19	1.21	.45	.62	.40	.31	13.72
1918	.41	1.05	.14	3.72	2.95	1.18	4.83	1.91	3.23	.71	.90	.76	21.79
1919	.00	.30	1.65	.93	.45	.19	.64	.61	2.61	1.93	1.22	.39	10.92
1920	.54	.64	.14	3.60	1.95	.60	.58	1.72	.60	.50	.24	.54	11.65
1921	.96	.19	.13	1.71	1.97	3.66	1.40	2.55	.68	.37	.32	.89	14.83
1922	.35	.53	.36	2.80	.87	1.03	.80	.73	.02	.74	1.44	.31	9.98
1923	.19	1.39	2.74	2.18	4.46	6.23	4.50	.62	1.36	3.55	.10	.25	27.57
1924	.51	.54	1.83	.93	3.90	.22	.21	.05	.84	.78	.09	.74	10.64
1925	.27	.09	.58	.10	1.18	1.50	1.85	1.28	1.96	3.26	.89	1.50	14.46
1926	.25	.28	1.54	2.99	1.76	1.58	.93	.86	1.04	1.15	.36	.83	13.57
1927	.04	.40	1.87	2.69	.91	2.17	2.19	2.10	1.10	1.05	1.00	.25	15.77
1928	.26	.52	1.38	.98	3.35	2.73	.83	.69	.09	1.50	1.15	.06	13.54
1929	.21	.70	1.78	2.37	1.08	1.09	.46	2.35	2.13	.89	.93	.09	14.08
1930	.45	.07	.70	.56	4.08	1.50	1.00	5.45	.16	.36	.70	.14	15.17
Average	.42	.59	1.03	2.05	2.82	1.60	1.78	1.30	1.25	1.15	.50	.46	14.95

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1961	.21	.64	3.38	1.00	7.06	1.83	4.27	4.00	4.00	1.17	.62	.24	28.42
1962	1.17	.70	.55	1.00	2.36	2.13	2.07	.31	.41	1.75	.57	.18	12.20
1963	.67	.42	1.28	.50	.42	3.75	.13	1.69	2.10	.30	.19	.55	12.00
1964	.31	.21	.92	1.69	1.87	.54	1.04	.45	.34	.06	.46	.18	8.07
1965	.66	.31	.84	1.19	1.89	5.27	2.29	.44	2.33	.51	.00	.44	16.17
1966	.12	.60	.01	1.39	.27	1.60	.62	.63	1.16	.43	.45	.06	7.34
1967	.61	.35	.61	3.02	4.79	3.26	3.10	1.82	.93	.61	1.14	1.05	21.29
1968	.09	.60	.90	1.85	3.20	.86	2.05	2.11	.09	.65	.78	.13	13.31
1969	.59	.33	.59	1.46	3.80	2.56	.84	1.72	.63	4.85	.32	.02	17.71
1970	.06	.02	2.65	1.04	.90	2.44	2.65	.97	1.61	1.25	.54	.16	14.29
1971	.59	.50	.51	4.42	2.33	.20	.52	.19	3.55	.94	.02	.21	13.98
1972	.54	.06	.43	1.38	.55	1.40	.72	2.24	.51	.57	.91	.60	9.91
1973	.26	.02	.79	2.70	1.63	.34	2.56	.18	1.70	.43	2.29	1.17	14.07
1974	.33	.06	1.05	1.65	--	--	1.65	--	--	--	.59	.06	--
1975	.05	.54	1.57	1.53	--	1.77	.92	--	.39	.90	.70	.95	--
1976	.30	.57	.64	1.64	1.13	.95	1.03	1.88	1.94	.25	.08	.15	10.57
1977	.04	.05	.13										
Ave.	.38	.50	.95	1.86	2.90	1.73	1.15	1.53	1.20	1.08	.15	.42	14.19

APPENDIX B

PRECIPITATION PROBABILITIES IN FORT COLLINS, COLORADO

FORT COLLINS, COLORADO 053005
PRECIPITATION MEANS AND PROBABILITIES FOR 1-WEEK PERIODS

PERIOD BEGINS	MEAN PCPN	PROB 0-T	PROBABILITY (PERCENT) OF RECEIVING AT LEAST THE FOLLOWING AMOUNTS (IN) OF PRECIPITATION 0.06	0.10	0.20	0.40	0.60	0.80	1.00	1.40	2.00
MAR 01	.16	22	63	53	33	12	4	2	1		
MAR 08	.23	19	67	58	40	18	9	4	2		
MAR 15	.25	25	64	56	41	21	11	5	3		
MAR 22	.19	30	59	52	39	21	11	6	4	1	
MAR 29	.31	27	61	55	44	28	18	12	8	3	1
APR 05	.44	21	70	64	53	36	24	16	11	5	1
APR 12	.37	19	73	68	56	38	25	17	11	5	1
APR 19	.47	20	73	68	58	40	28	19	13	6	2
APR 26	.48	17	76	72	62	45	33	24	17	10	4
MAY 03	.75	13	78	74	64	49	38	29	23	14	7
MAY 10	.69	14	76	72	63	49	39	31	25	16	8
MAY 17	.66	12	76	71	60	46	35	28	22	14	7
MAY 24	.54	7	80	74	63	46	34	26	19	11	5
MAY 31	.62	9	80	74	63	46	34	25	18	10	4
JUN 07	.47	19	73	68	57	40	28	20	14	8	3
JUN 14	.33	23	67	62	50	33	21	14	9	4	1
JUN 21	.32	26	61	55	43	26	16	10	7	3	1
JUN 28	.21	29	56	49	36	20	12	7	4	2	
JUL 05	.21	25	57	49	34	17	9	5	3	1	
JUL 12	.18	18	64	55	38	19	10	6	3	1	
JUL 19	.34	17	68	60	44	25	15	9	6	2	
JUL 26	.29	21	65	59	47	31	21	15	11	6	3
AUG 02	.64	22	62	57	46	32	23	18	14	9	5
AUG 09	.24	20	61	54	42	27	18	13	10	5	3
AUG 16	.29	19	61	54	40	24	15	9	6	2	1
AUG 23	.27	22	59	52	39	24	15	9	6	3	1
AUG 30	.26	29	52	46	36	23	16	11	8	4	2
SEP 06	.35	37	47	42	33	21	15	11	8	4	2
SEP 13	.14	40	47	42	32	19	12	8	6	3	1
SEP 20	.30	41	48	43	34	21	13	9	6	3	1
SEP 27	.22	47	45	41	32	20	13	9	6	2	
OCT 04	.17	51	41	37	30	20	13	9	6	3	1
OCT 11	.41	46	46	42	34	24	17	13	9	6	3
OCT 18	.27	42	49	44	35	22	15	10	7	4	2
OCT 25	.14	40	48	41	29	15	8	4	2	1	
NOV 01	.14	38	48	41	26	11	4	2	1		
NOV 08	.13	41	45	38	24	10	4	2	1		
NOV 15	.12	40	42	34	20	7	3	1			
NOV 22	.07	39	40	31	16	5	2	1			
NOV 29	.11	47	37	29	17	7	3	1	1		
DEC 06	.10	54	31	26	17	8	4	2	1		
DEC 13	.06	61	25	20	13	6	3	1	1		
DEC 20	.07	64	24	20	13	6	3	1			
DEC 27	.08	59	30	25	15	5	2	1			
JAN 03	.08	53	35	27	14	3	1				
JAN 10	.05	50	35	25	10	1					
JAN 17	.05	43	40	29	13	3	1				
JAN 24	.16	37	44	34	18	7	3	1			
JAN 31	.06	37	44	34	20	7	3	1			
FEB 07	.16	33	49	39	22	7	3	1			
FEB 14	.09	30	51	40	22	7	2	1			
FEB 21	.13	28	54	43	24	7	2	1			

FORT COLLINS, COLORADO 053005
PRECIPITATION MEANS AND PROBABILITIES FOR 2-WEEK PERIODS

PERIOD BEGINS	MEAN PCPN	PROB 0-T	PROBABILITY (PERCENT) OF RECEIVING AT LEAST THE FOLLOWING AMOUNTS (IN) OF PRECIPITATION 0.06	0.10	0.20	0.40	0.60	1.00	1.40	2.00	4.00
MAR 01	.40	7	83	75	58	34	20	7	2		
MAR 15	.45	6	86	80	67	46	31	15	7	2	
MAR 29	.76	3	91	87	77	59	44	24	13	5	
APR 12	.84	2	95	93	85	69	56	34	21	10	1
APR 26	1.24	2	96	94	87	75	63	44	30	17	3
MAY 10	1.36	2	95	93	87	75	65	47	34	21	4
MAY 24	1.16	2	95	92	86	73	61	42	29	16	3
JUN 07	.81	4	91	87	79	63	50	30	18	9	1
JUN 21	.53	5	85	80	67	48	35	18	9	4	
JUL 05	.40	6	84	78	64	43	29	14	7	2	
JUL 19	.63	7	85	80	68	50	37	21	12	6	1
AUG 02	.89	7	84	79	69	53	41	25	16	8	1
AUG 16	.56	9	79	74	64	48	37	22	14	7	1
AUG 30	.62	15	73	67	57	42	32	18	11	5	1
SEP 13	.44	21	69	63	53	38	28	15	8	4	
SEP 27	.39	23	68	63	53	38	28	15	8	4	
OCT 11	.68	20	70	64	53	37	27	16	10	5	1
OCT 25	.29	16	73	66	50	30	19	8	5	2	
NOV 08	.25	17	70	61	44	22	11	3			
NOV 22	.19	24	60	52	35	17	8	2			
DEC 06	.17	36	48	41	29	14	8	2	1		
DEC 20	.15	38	47	40	27	12	6	2			
JAN 03	.14	27	58	48	30	12	5	1			
JAN 17	.22	16	69	58	38	15	6	1			
JAN 31	.22	13	73	63	43	18	7	1			
FEB 14	.22	10	78	69	49	23	11	3	1		

FORT COLLINS, COLORADO 053005
PRECIPITATION MEANS AND PROBABILITIES FOR 3-WEEK PERIODS

PERIOD BEGINS	MEAN PCPN	PROB 0-T	PROBABILITY (PERCENT) OF RECEIVING AT LEAST THE FOLLOWING AMOUNTS (IN) OF PRECIPITATION 0.06	0.10	0.20	0.40	0.60	1.00	1.40	2.00	4.00
MAR 01	.66	1	95	92	81	60	41	19	9	3	
MAR 22	.95	0	98	96	89	74	59	36	22	11	1
APR 12	1.33	1	98	96	92	82	72	54	39	24	5
MAY 03	2.12	2	98	97	94	87	79	64	50	34	9
MAY 24	1.64	2	97	96	92	83	73	56	42	28	7
JUN 14	.87	3	95	93	88	74	60	39	24	12	2
JUL 05	.74	6	92	90	83	68	54	33	19	9	1
JUL 26	1.18	6	90	87	80	66	54	36	24	13	2
AUG 16	.83	4	88	84	75	61	49	33	22	12	2
SEP 06	.80	7	84	80	71	56	45	29	19	10	1
SEP 27	.80	12	82	78	70	55	43	26	16	8	1
OCT 18	.56	11	83	78	67	48	34	18	9	4	
NOV 08	.33	12	78	71	56	35	22	8	3	1	
NOV 29	.29	21	67	60	45	26	15	5	2		
DEC 20	.23	21	66	59	43	23	13	4	1		
JAN 10	.28	8	78	69	50	25	12	3	1		
JAN 31	.32	2	89	82	65	38	22	7	2		

APPENDIX C

MANUFACTURERS AND DISTRIBUTORS

OF

WATER CONSERVATION PRODUCTS

APPENDIX: MANUFACTURERS AND DISTRIBUTORS OF WATER CONSERVATION PRODUCTS

AERA-FILT SYSTEMS, INC.
P.O. Box 567
Lafayette, Indiana 47901
Sewerless toilet; diffused air, extended aeration unit

ALSONS PRODUCTS CORPORATION
525 E. Edna Place
Covina, California 91722
Hand held shower

AMERICAN STANDARD-PLUMBING/HEATING
Post Office Box 2003
New Brunswick, New Jersey 08903
Conventional toilets; conventional urinals; shallow trap toilets; conventional faucets; self closing valves; pressure balancing mixing valve; shower fixture, Aquarian (4gpm flow control Aquamizer (2.5 gpm)

AQM CORPORATION
1909 New Rodgers Road
Levittown, Pennsylvania 19056
"Aqua-miser" toilet tank insert

AQUA-DATA CORPORATION
P.O. Box 901
Carpinteria, California 93013
Drip irrigation

AQUA GUARD
3200 Valley Lane
Falls Church, Virginia 22044
Toilet tank insert (see mini-Dam)

AQUA-GUARD POOL COVERS
2801 San Fernando Road
Los Angeles, California

AQUA MISER
P.O. Box 284
Glen Ellen, California
Aqua miser toilet tank insert

ARROWHEAD PURITAS WATERS
1566 East Washington
Los Angeles, California 90054
Bottled water

BIO SYSTEM
1200 28th St., Suite 1
Boulder, Colorado 80802
Evapotranspiration home sewage treatment and disposal systems.

BRIGGS
5200 West Kennedy Boulevard
P.O. Box 22622
Tampa, Florida 33622
Conserver, shallow trap toilet; conventional toilets; bidet.

BUDERUS
6330 Wetzlar, Postfach 201
West Germany
Water saving tub

*Note: The inclusion of a company's name in this list does not in any way constitute an endorsement of its products.

CAN-TED INDUSTRIES
Process Equipment Division
P.O. Box 340
Mineral Wells, Texas 76067
Large aerobic treatment plants

CHAPIN WATERMATICS, INC.
368 N. Colorado Avenue
Watertown, New York 13601
"Micro-Dripper". Drip irrigation emitter, direct tap into polyethylene pipe.

CHICAGO FAUCETS
2100 S. Nuclear Drive
Des Plaines, Illinois 60018
Econo-flow (0.75 gpm aerator) faucet; Soft-flow flow control; Stedi-flo flow control; self-closing faucets; conventional faucets.

CHRYSLER CORPORATION
Space Division
P.O. Box 29200
New Orleans, Louisiana 70129
Oil Flush toilet

CLIVUS MULTRUN USA, INC.
14A Eliot Street
Cambridge, Massachusetts 02138
Composter toilet

COLT INDUSTRIES
Water and Waste Management Operation
701 Lawton Avenue
Beloit, Wisconsin 53511
Envirovac system vacuum toilet; Liljendahl, Electrolux.

CONSERVOCON, INC.
191 Edgewater Street
Staten Island, New York 10305
Foot controlled faucet ($9 attachment)

CONTROLLED WATER EMISSION SYSTEMS
585 Vernon Way
El Cajon, California 92022
Drip irrigation

CRANE COMPANY
17900 Skypark Circle
Irvine, California 92664
Shallow trap toilet; conventional toilet; conventional urinal.

CROMAGLASS CORPORATION
Box 1146
Williamsport, Pennsylvania 17701
Aerobic waste treatment tanks

CULLIGAN DEIONIZED WATER SERVICE
315 N. Hoover Street
Los Angeles, California 90004
Water filters

CUSTOM HOME SPA
14705 Oxnard Street
Van Nuys, California 91401
Whirlpool spa

DUPONT COMPANY
1007 Market Street
Wilmington, Delaware 19898
Drip irrigation

DEEP SEEP CAP-TOP SOAKERS
915 E. Bethany Home Road
Phoenix, Arizona 85014
Drip irrigation

DEFCO, INC.
325 North Daloson Drive
Camarillo, California 93010
Emitters for drip irrigation

L. M. DEARING ASSOCIATES, INC.
12324 Ventura Boulevard
Studio City, California 91604
Floating pool cover

DIXEL IRRIGATION SYSTEMS
17 Briar Hollow
Houston, Texas 77027
Drip irrigation - strap on emitter

DOLE (see EATON)

DUO-FLUSH PLUMBING COMPANY
610 S. Tejon
Colorado Springs, Colorado 80903
Two-way flushing valve

EATON CORPORATION
Controls Division
Plumbing & Heating Products
191 East North Avenue
Carol Stream, Illinois 60187
Dole flow controls (2,3,4, gpm); Dole shower controls (2,2.5,3,4 gpm); Dole sink faucets (1.5 to 4 gpm models).

ECOLOGICAL WATER PRODUCTS INCORPORATED (EWP)
P.O. Box 509
Dunkirk, New York 14048
Nova shower head (2.5 gpm); EWP faucet aerators (1.5 gpm).

ECODYNE CORPORATION
Smith & Loveless Division
96th & Old Santa Fe Trail
Lenexa, Kansas 66215
Aerobic sewage treatment, large units.

ECOLOGY PLUS
Box 184
Croydon, Pennsylvania 19020
Water wizard tank insert

ELECTROLUX
S-105 45
Stockholm, Sweden
Vacuum toilet

ELJER PLUMBINGWARE
Wallace Murray Corporation
Three Gateway Center
Pittsburgh, Pennsylvania 15222
Savon water-saving urinal; shallow trap toilet; conventional urinal; conventional toilet.

RICHARD FIFE INCORPORATED
140 Greenwood Avenue
Midland Park, New Jersey 07432
Spray taps; flow control built into the faucet; Rada thermostatic mixing valve.

FLUIDMASTER, INCORPORATED
P.O. Box 4264
Anaheim, California 92803
Tank flushing valve, leak signaling ballcock.

FORMULABS INCORPORATED
Fluorescent Dye Tracing Systems Division
529 West Fourth Avenue - P.O. Box 1056
Escondido, California 92025
Water saver super drip kit; toilet tank dye tablet.

FRIEDRICH GROHE ARMATORENFABRIK
5870 Hemer, Postfach 260
Grohe Wien GmbH, 1071 Wiem
Postfach 285 West Germany
Thermostatically controlled mixing valve

GENERAL AMERICA TRANSPORTATION CORPORATION
General America Research Division
7449 North Natchez Avenue
Niles, Illinois 60648
Controlled volume flush toilet

A B GUSTAVSBERGS FABRIKER
Fleminggatan 62 B, Box 12159
10224 Stockholm 12, Sweden
Composter toilet

HUMUMAT LIMITED
9403 120th Street
Delta, British Columbia
Canada V4C 2P3
Composter toilet

HYDRO-RAIN
26031 Avenida Aeropuerto
San Juan Capistrano, California 92675
Solenoid valves for lawn sprinkling and irrigation.

HYDRO TERRA CORPORATION
800 North Park Avenue
Pomona, California 91768
Automatic irrigation controller tensiometers

HYDROLON SYSTEMS, INCORPORATED
1948 Gladwick
Compton, California 90220
Water filters

INTERBATH, INCORPORATED
3231 North Durfee
El Monte, California 91732
Hand-held shower

ITT LAWLER
453 North MacQuesten Parkway
Mount Vernon, New York 10552
Pressure reducing valve house connection

IDEAL STANDARD
Postfach 549
Poppelsdorfer Allee 114, 53 Bonn
West Germany
Thermostatically balancing mixing valve.

IN-SINK-ERATOR (I.S.E.)
4700 21st Street
Racine, Wisconsin 53406
Garbage disposal; instant hot water heater.

INTERNATIONAL METAL PRODUCTS
Division of McGraw Edison
Box 20188, 500 South 15th Street
Phoenix, Arizona 85036
Evaporative air cooler

IRRI-DRIP SYSTEMS, INCORPORATED
870 East Santa Clara Street, P.O. Box AW
Ventura, California 93001
Drip irrigation

JACUZZI RESEARCH INCORPORATED
1440 San Pablo Avenue
Berkeley, California 94702
Whirlpool spa

JEF SKID
P.O. Box 2288
Rockville, Maryland 30852
Dual Flush Toilet

JEGCO, INCORPORATED
2016 Sunset Drive
Pacific Grove, California 93950
Gold-ring variable flush attachment

JENSEN GENERAL CORPORATION
1946 East 46th Street
Los Angeles, California
Chemical toilets

JKW 5000 LIMITED
10610 Culver Boulevard
Culver City, California 90231
Watergate toilet tank insert; Ny-Del shower head.

KEENE CORPORATION
Water Pollution Control Division
1740 Molitor Road
Aurora, Illinois 60507
Large sewage aerobic treatment units

KITCHEN AID
Hobart Manufacturing Company
1501 W. 8th Street
Los Angeles, California 90017
Instant hot water heater

KOHLER COMPANY
Kohler, Wisconsin 53044
Conventional toilet; conventional urinal; Water Guard shallow trap toilet; pressure balancing mixing valves; flow control shower heads (3 gpm and up); flow control faucets (2 gpm and up).

LAKESIDE EQUIPMENT CORPORATION
1022 E. Devon Avenue
Bartett, Illinois 60103
Large aerobic sewage treatment units

LAMERE INDUSTRIES, INCORPORATED
227 N. Main Street
Walworth, Wisconsin 53184
Destroilet, incinerator-toilet system.

LEISURE TIME WATERING SYSTEMS
P.O. Box 1298
Hollister, California 95023
Drip irrigation

LIFTOMATIC INCORPORATED
6445 N. Sepulveda
Los Angeles, California
Swimming pool covers

MANSFIELD SANITARY, INCORPORATED
Perrysville, Ohio 44864
Water-saver toilet flush valve; vacuum flush toilets for boats; chemical toilets.

THE MAYTAG COMPANY
107065 E. Green Drive
City of Industry, California 91744
Clothes washer

METROPOLITAN WATERSAVING COMPANY, INCORPORATED
5130 MacArthur Boulevard, Suite 106
Washington, D.C. 20016
"Little john" water closet insert.

MICROPHOR
P.O. Box 490
Willits, California 95490
Microphor pressurized flush toilet (2 quarts per flush).

MINI-DAM WATERSAVER CORPORATION
640 S. Pickett Street
Alexandria, Virginia 22304
Toilet tank insert (see Aqua Guard)

MINUSE ENVIRO-SYSTEMS, INCORPORATED
206 N. Main Street, Suite 300
Jackson, California 95642
Shower (2 quarts per minute)

MOEN
Elyria, Ohio 44036
Pressure balancing valves; shower head, Easyclean (3 gpm). Aerators

MONOGRAM INDUSTRIES, INCORPORATED
100 Wilshire Boulevard
Santa Monica, California 90401
Oil flush toilet (Magic Flush); chemical toilet

MONTGOMERY WARD & COMPANY
618 Chicago Avenue
Chicago, Illinois 60671
Appliances

MULTI-FLOW, INCORPORATED
500 Webster Street
Dayton, Ohio 45401
Recycling extended aeration filtration unit

NEPTUNE MICROFLOC INCORPORATED
P.O. Box 612
Corvallis, Oregon 97330
Community wastewater treatment

NOLAND COMPANY
2700 Warwick Boulevard
Newport News, Virginia 23607
Flow controls (plastic inserts)

M.C. NOTTINGHAM COMPANY
P.O. Box 2107
Irwindale, California 91706
Septic systems

NY-DEL CORPORATION
740 E. Alosta Avenue
Glendora, California 91740
The "Saveit' Water Closet Insert.

OGDEN FILTER COMPANY, INCORPORATED
4222 Santa Monica Boulevard
Los Angeles, California
Water filters

OSBY-PANNAN AB
28300 Osby
Sweden
Freeze toilet

OWENS/CORNING
5933 Telegraph Road
Los Angeles, California 90040
Hot water pipe insulation

PACEMAKER CORPORATION
3828 Fifth Avenue
San Diego, California 92103
Moisture indicator

PACTOSAN
Nitro Nobel Group
Box 100, S-71300 Nora
Sweden
Packaging toilet

PIPER HYDRO, INCORPORATED
1159 Fountain Way
Anaheim, California 92806
Combined domestic hot water circulation and heating system.

POLLUTROL TECHNOLOGY, INCORPORATED
32 Kearney Road
Needham Heights, Massachusetts 02194
Aerobic waste treatment

POWERS REGULATOR COMPANY
Skokie, Illinois 60076
Pressure balancing shower and bathtub valves.

PROGRESSIVE HARDWARE
P.O. Box 874
Garden Grove, California 92642
Ballcock

RAIN BIRD
Glendora, California
Drip irrigation emitters

ROKAL ARMATUREN GMBTT
4054 Nettetal -1
Postfach 1266, West Germany
Thermostatically controlled mixing valve.

RIVIERA SPA, INCORPORATED
11735 Sheldon Street
Sun Valley, California 91352
Whirlpool spa

SAVE IT OF WASHINGTON
11168 Safford Way
Reston, Virginia 22070
Toilet tank inserts (2 models)

SEARS ROEBUCK AND COMPANY
Sears Towers
Chicago, Illinois 60684
Water filters; chemical toilet; applicances, etc.

SOILMOISTURE EQUIPMENT CORPORATION
Box 30025
Santa Barbara, California 93105
Soil tensiometers

SPARKLETTS DRINKING WATER CORPORATION
3475 S. LaCienega
Los Angeles, California
Bottled water

SPEAKMAN COMPANY
Wilmington, Delaware 19899
Flow controls, Auto flow (2.5 to 4.5 gpm); spring and time faucets; shower heads, Auto flow (2.5 to 4.5 gpm).

SPOT SYSTEMS, INC.
P.O. Box 807
Redmond, Washington 98052
Drip irrigation emitters

SUBMATIC IRRIGATION
P.O. Box 2449
Menlo Park, California 94025
Drip irrigation

SUNSET POOLS
900 Wilshire Boulevard, Suite 1242
Los Angeles, California 90017
Solar circles (floating swimming pool "solar heaters" and evaporation reducers).

TE-BE ELPRODUKTER AB
Postbox 24, 561 01 Huskoarna
Sweeden
Freeze toilet

THETFORD CORPORATION
Waste Treatment Equipment Division
P.O. Box 1285
Ann Arbor, Michigan 48106
"Cycle-let" recycling flush water toilet; chemical toilets.

TURF SERVICE LABORATORY
P.O. Box 1001
Laguna Beach, California 92651
Moisture indicators, moisturometer

TYME VALUE CORPORATION
12100 E. Park Street
Cerritos, California 90701
Sprinkler control

ULTRAFLOW CORPORATION
P.O. Box 2284
Sandusky, Ohio 44870
Electrically controlled plumbing system

UTAH MARINE
459 South Seventh Street, P.O. Box 485
Bringham City, Utah 84302
Flush Gard: sink-bob dual flush device

WAICO-NORTHWEST
5920 N.W. 87th Avenue
Portland, Oregon 97220
Drip irrigation

WATER CONTROL PRODUCTS, INCORPORATED
1100 Owendale, Suite E
Troy, Michigan 48084
Flushmate pressurized tank toilet

WATTS REGULATOR COMPANY
Lawrence, Massachusetts 08142
Water pressure reducing value house connection

WALKER CROSSWELLER LIMITED
Whaddon Works, Cheltenham,
Gloucestershire, England
Spray taps (single or double handle).

WRIGHTWAY MANUFACTURING COMPANY
371 East 116th Street
Chicago, Illinois 60628
Water-saver kit (shower head and two faucet aerators).

ZURN INDUSTRIES INCORPORATED
2267 Yates
Los Angeles, California
Chemical toilets

APPENDIX D

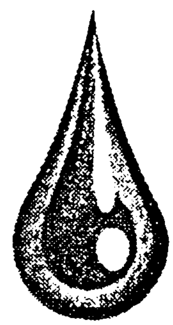
GOOD LAWNS WITH LESS WATER

BROCHURE PUBLISHED BY

THE DENVER POST

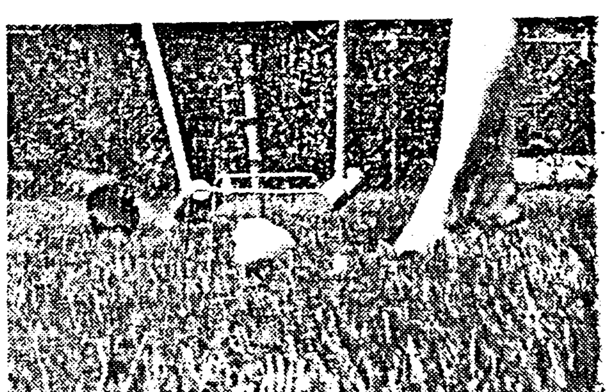
AND WESTERN FEDERAL SAVINGS

Good Lawns With Less Water



by Herbert C. Gundell
CSU Extension Horticulturist for Denve
and The Denver Post Garden Editor

This folder is made available to the public by
THE DENVER POST
and
WESTERN FEDERAL SAVINGS



Yes, you can have a beautiful lawn while using less water!

Quality of life in the semi-arid western United States can depend upon many and diverse things. As much as it is associated with blue sky and brilliant sunshine, it also depends upon shade and comfort provided by water. Water is a necessity for many forms of human recreation and enjoyment. This is why the people in the Rocky Mountain Region consider the accumulation of snow each winter of such vital importance.

THE WATERING SCHEDULE

Because of differences of soil, slope and exposure, no specific schedule works adequately for everyone. If you can hold lawn watering to 1" per week through the summer, it will keep the grass green and the roots deeper. You can spot 4 or 5 coffee cans from a sprinkler head to the outer reach of water delivery and run that hose or circuit for exactly 30 minutes. At the end, combine all the water in one can, measure and divide by the number of cans. Since you watered only 30 minutes, multiply by 2 to obtain your sprinklers' hourly delivery rate. Hold back on watering when it rains. A rain gauge will help you measure rainfall accurately.

SPOT WATERING

Let the lawn tell you when it begins to get dry. You can learn easily enough where your problem spots are located that indicate a lack of available moisture. Only the few spots that turn off-color the quickest should be watered by hand with a root-watering or water-aerating attachment to a garden hose. By doing this you can then allow the rest of the lawn to go unwatered several more days before the mottling of grayish-green becomes noticed overall. At that point it would be well to water the entire lawn to satisfy its normal thirst.

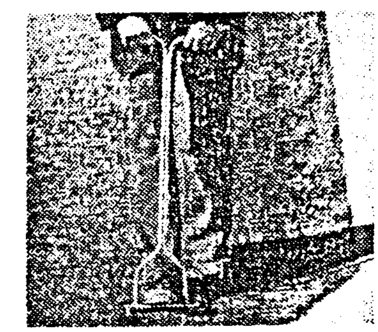
WATER-SAVING SPRINKLERS

Not all sprinklers in use were designed for efficiency or water saving purposes. Some naturally conserve water better than others. Generally, sprinklers that throw out a flat pattern of water are less prone to wind deflection than those which throw water high into the air. Sprinklers that deliver larger droplets are also more economical with water than those that produce a fine mist under high pressure.

The so-called Thompson Twin Sprinkler is one of the most effective. Its delivery pattern is quite even and round. Along sidewalks and driveway edges you can use a Thompson Half Circle very efficiently. Pulsating sprinklers like the popular rainbird also are known for their watering efficiency. Many of them can be pre-set to water only a given area. Plastic sprinkler hoses are suitable for watering of slopes. They deliver only 1/8" per hour. Just enough to avoid run-off. Oscillating sprinklers are among the poorest in watering efficiency. They may have other compensating features.

THE VALUE OF AERATION

The primary purpose of aeration is to reduce soil compaction. Western clay soils swell in summer heat, but rarely break up on their own. Aeration by removal of soil plugs can be achieved with hand and mechanical equipment. Both plugging hand aerators and water aerators are successful in opening a tight soil to better air and moisture penetration. An aerated lawn area can utilize the water we apply more efficiently and release it to grass plants at a better rate of capillarity. Any lawn could be aerated any time for immediate and quickly noticed improvement. An entire lawn is aerated most efficiently with mechanical equipment.



STARTING A NEW LAWN

A lawn is part of every home development. It controls soil erosion and creates a suitable surface for outdoor activities and play. A lawn need not be all bluegrass. It can be a combination of needed bluegrass areas with either low-moisture need grass types, ground covers, or inanimate materials. Each family must base such decisions on need.

A new lawn can be sown or sodded. A sown lawn may be more economical to establish, but requires more frequent watering and higher water use. Sod is relatively more practical and avoids the dangers of a washout or wind erosion. Colorado's front range produces some of the finest sod anywhere at a fair cost.

Whether you sow or sod a lawn, soil preparation is needed. Our native clay soils are so poor that you cannot expect much success unless you add materials to the soil that tend to improve its moisture-holding and aeration capacities. It takes approximately 2 cubic yards of animal manure, peatmoss, sewer sludge, compost or mixes of any of these to improve soil before planting a new lawn. This material should be tilled or spaded under as the sod or seed bed is prepared.

MOWING YOUR LAWN

The best time to mow a lawn is when it needs it. That occurs every time it has grown about 1/2 inch. It may occur more frequently in May and June than during the summer. This year it is recommended to set the lawn mower cut 1/2 inch higher. The height of the cut should be about 2 inches. Grass clippings may be removed or allowed to drop. The longer the clippings, the less readily they disappear.

lawn tips

FERTILIZING

A lawn should be fertilized often enough to keep it green and healthy. Most lawn fertilizers contain a higher amount of useable nitrogen, less phosphate and potassium. Analyses of 20-10-5, 24-3-3, 25-3-7 or similar are highly effective to feed a lawn properly. Some organic fertilizers also are available for lawn use. Their analysis is usually lower. Slowly released forms of nitrogen such as urea formaldehyde can be effectively used to insure nitrogen availability over a longer period up to 6 weeks or longer. Apply each product with a spreader setting recommended by the manufacturer. Some fertilizers work best when applied to a moist lawn surface. Others are applied to a dry turf. Follow the instructions on the bag. The use of iron during the summer produces better color.

WEED CONTROL

Weed control in a lawn is simple if you can follow instructions. Most herbicides work best in warm, dry weather. Apply them only on a relatively wind-free day with a temperature rise to above 70° F. Avoid watering for several days after application. The sprayer you use for weed controls should not be used for other garden purposes. Dry weed-and-feed type products must be applied with a mechanical spreader.

FUNGUS CONTROL

Often a lawn condition of spotting or browning can be the result of a lawn disease organism. Fungi are most often the cause of disease. Infrequent watering of a lawn tends to reduce the incidence of disease. The most common disease of a spring lawn is melting-out (Helminthosporium). Summertime diseases include Brown patch, Fusarium and Stripe Smut. Only after qualified analysis of a problem should a suitable fungicide be used. Follow label directions to obtain expected results. Fairy Ring fungus is also a common problem. Watering with a root feeder or water aerator in the affected areas followed by a drench of fungicide and detergent often produces good results.

CRABGRASS CONTROL

Crabgrass is an avoidable lawn weed if proper chemicals are used. The best time to control crabgrass is with chemicals before it germinates. The so-called crabgrass pre-emergence controls or preventers are highly effective. They include the basic chemicals like Dacthal, Betasan, Tupersan and others. They should be applied to a lawn before May 15. Once crabgrass commences to grow, it is difficult to control without temporary browning of the turf. Summertime controls include Methyl Arsenates and similar products. A thick lawn rarely leaves much room for crabgrass to grow.

Some good ways to "stretch" water

AVOID STEEP SLOPE WATER LOSS

Watering on a steep slope can be difficult. Aeration can increase moisture intake but not enough to avoid runoff. Sprinkler hoses put out such small water streams that runoff can be curbed or avoided. Of course, installation of retaining walls can overcome steep slopes. If you use sprinklers, apply the water from the lowest point up and turn the water off as soon as soil moisture absorption is exceeded. You can water the same slope again later in the day.

MAKE USE OF WASTE WATER

Waste water from the laundry or dishwasher is indeed suitable for garden use. The diluted detergents in the water have not been found harmful to the soil or plants in any way. If you can save this waste water, it can be applied almost anywhere in the garden. As a general rule, I would avoid using waste water in any particular spot again and again. You can spread it around and benefit different garden and lawn areas. The detergent in your waste water will increase a soil's moisture absorption rate for a short time. Chlorine products in laundry water should be thoroughly diluted before they are applied to a garden. In fact, to be safe, use water with chlorine bleach in open soil beds instead of the lawn, and then only well-diluted. Waste water from a bathtub can also be carried to the garden and used there. With a rain barrel, you can also catch a little extra water for the garden when it rains. Harmful chemicals to plants might include laundry soaps containing a high level of boron or certain fabric softeners. Water treated with water softeners may contain sodium. This, too, does not improve soils.

DROUGHT-TOLERANT PLANTS

Generally plants found native in the Eastern front range are most drought-tolerant. Unfortunately there aren't many. You can find Ponderosa Pine, a few one-seeded junipers and Pinon pine in the southern portion of Colorado. Sage, Rabbit Brush, Yucca and cacti make up the rest of dry area vegetation of value. Grasses that are tolerant of drought include Crested Wheatgrass, Buffalo grass, the Grama grasses and a few of the tall Fescue grasses. They create more of a groundcover than a lawn. Trees that can sustain some drought are Honeylocusts, Russian Olive, Montmorency Sour Cherry and native American Plums. Drought-tolerant shrubs include Mountain Mahogany, Apache Plume, Shrubby Cinquefoil, Buffaloberry and a few others.

CONSIDER GROUND COVERS

A lawn is the only ground cover you can use for outdoor traffic and play. Many other plants can be used to reduce water use, but inanimate materials are most effective. Inanimates include crushed rock, chunk bark, expanded clay products such as Turface or Terragreen, woodchips, sand and gravel — just to mention a few. They require no water at all, but are solar collectors of heat during a day. Suitable plants for low maintenance are sedums and house leeks. Other suitable ground covers are Wooly Yarrow, Goldentuft, Dianthus, Phlox, Vinca, Candytuft and Coralbell. Evergreen groundcovers include Creeping Junipers, Vinca Minor and Native Hollygrape.

Water conservation is a "must" now and in the future

You can avoid putting water on sidewalks and other concrete areas by a little timely work with the garden hose. I recommend the use of a root feeder or water aerator attached to a garden hose. Insert such a tool approximately 15 inches from the concrete and every 12 to 15 inches in progression and allow the water to run into the soil until it commences to ooze at the surface. At that point, move on 15 inches and repeat the process until the entire edge of the lawn has been serviced. When you are watering your lawn, attempt to select a time when there is minimal wind to disturb the pattern of the sprinkler's delivery. Even a 15 mile-an-hour wind with heavier gusts should cause one to stop watering.

The use of chemical detergents sold commercially to increase the moisture absorption rate of compacted soils is worthy of consideration. Although the duration of the chemical treatment may be less than a full season, it still increases the soil's moisture absorption and reduces potential waste.

Other water-saving tips

1. A vegetable garden requires only half as much water as a lawn area of similar size. Vegetable gardens frequently are overwatered. Tomatoes produce more fruit earlier with less watering.

2. Pines that have been established for several years are quite drought hardy. Among the least moisture requiring pines are Ponderosa, Austrian, Pinon, Foxtail and Lodgepole pines.

3. Lawn areas with a northerly or easterly orientation and exposure require less frequent irrigation than those sloping to the south or west.

4. Early morning hours usually are wind-free and permit more effective lawn watering. Automatic sprinkler systems may be set to water during those early morning hours.

5. Reduce the number of hanging baskets on a patio to avoid needed daily waterings.

6. Prune shrubs and trees as needed. Many shrubs are best pruned after the end of their normal flowering period. Pruning reduces the moisture needs of plants.

7. The use of mulches is recommended in open soil areas of vegetable or flower gardens. You can use lawn grass clippings, sawdust and wood chips, peatmoss and well-aged manure, garden compost and other organic mulches. Black plastic also is a moisture saver and prevents weedy growth where it is placed.

8. Composting of garden and home vegetative refuse and waste can save much water wherever the finished products is applied. A compost pit is recommended over a pile. Moisture control is important to accelerate decomposition.

APPENDIX E

CONSERVE

BROCHURE PREPARED BY
COOPERATIVE EXTENSION SERVICE
COLORADO STATE UNIVERSITY

State of Colorado
EXECUTIVE CHAMBERS

My Dear Fellow Coloradans:

As you know, we are facing the potential of one of the worst droughts in Colorado's history. We receive reports every week which indicate that all areas of the economy may experience severe water shortages.

There is a limit to what state and local government can do to alleviate drought conditions. Much more can be done by you, the individual water consumer.

Each year the average family of four in Colorado uses nearly 200,000 gallons of water. We are accustomed to using water in our everyday lives as if it were in great abundance. Such is not the case this year in Colorado. It is important that we all voluntarily try to reduce our water usage in order to avoid a major water crisis in the state.

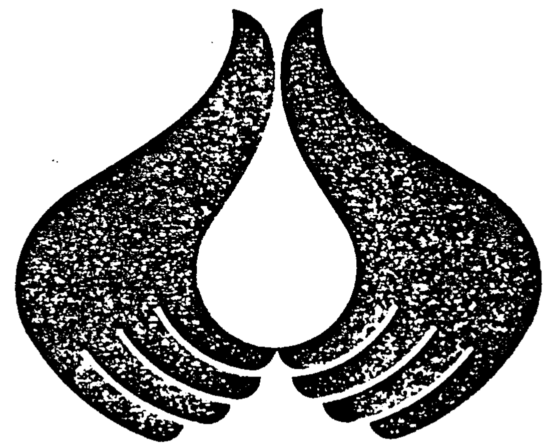
If each one of us would practice the water saving tips outlined in this pamphlet, we could easily reduce water consumption in the state by 10 billion gallons of water each year!

The water situation is serious in the state, but, by voluntarily working together we can reduce the economic loss and personal discomfort during a time of drought.

We need your help!

Sincerely,

Richard D. Lamm
Governor



CONSERVE

Prepared by
Cooperative Extension Service
Colorado State University
Fort Collins, Colorado

Key Water Facts

Your lawn and yard account for about 40 per cent of your domestic water use. Bluegrass can survive on about half the water normally applied.

CONSERVE

One leaky faucet can waste up to 2,200 gallons of water a year — enough to quench your thirst with 35,200 glasses of water (eight-ounce size).

CONSERVE

Depending on the type, your toilet uses from three to seven gallons of water. Less frequent flushing or water-saving devices in the toilet can conserve much water.

CONSERVE

Wise use of your clothes washers, dishwashers and disposals can conserve many gallons of water each day.

CONSERVE

Showers — especially those fitted with flow restrictors or low-volume heads — usually use less water than a bath.

CONSERVE

Mulching and other gardening practices can conserve water and promote healthier plants.

Added together, every little bit of water you conserve counts!

CONSERVE

Bathroom

A shower generally uses less water than a bath. Plug the tub during a shower and compare the water used with that for a bath.

Do your showering and hair washing in one step. It takes less water than doing the hair separately.

Most showers can be fitted with a flow restrictor or low-volume head to conserve water.

Turn the water off while brushing your teeth, shaving or washing your face.

A water-filled, capped bottle (quart size) in a toilet's water tank or an adjustment of the float level reduces the normal 4.1 gallons of water to flush a toilet.

A toilet leak can waste lots of water. Put a few drops of food coloring in your tank. If colored water shows in the bowl without flushing, there's a leak and repairs are needed.

Avoid using the toilet as a trash basket. Tissues should go in the wastebasket and cigarette butts in the ashtray.

CONSERVE

Kitchen

If you use a dishwasher — and more than 1/4 of our families do — wait until it is full before you run it. When buying a new one, make sure it has variable cycles which save on water in certain circumstances.

Use the smallest amount of water possible in cooking. Most frozen vegetables require about 1/2 to one cup of water, not half a saucepan.

A tight-fitting lid on a pan saves water from boiling away and also cooks food faster, thereby using less energy.

Using syrups and juices from canned goods saves water and makes foods taste better.

Use a pan of water when peeling and cleaning vegetables and fruits rather than letting the sink tap run.

When washing dishes by hand, use a stopper in the sink and don't rinse with running water.

When use of a garbage disposal is necessary, save food scraps and run the disposal once to conserve water. You can use the disposal even less by saving food scraps for a compost pile.

A bottle of drinking water kept cold in your refrigerator saves running the tap to get cold water.

CONSERVE

All Around the House

Faucets, throughout your house, should be checked for drips. Sixty drips a minute can waste up to 2,200 gallons of water a year.

When washing the car, use a bucket filled with warm, soapy water and use a running hose only for a quick, final rinse.

Use a broom, not the hose, to clean the garage, the sidewalks and the driveway.

The tap water should not be left running when doing normal cleaning of cabinets and appliances. Wet a sponge or cloth and rinse it when necessary, preferably in a bucket of water.

Insulate the hot water pipes under your house. Having to clear the line of cooled water is wasteful.

When buying a new water heater, pay special attention to the insulation qualities of the shell. Avoid buying a larger tank than is required for your needs.

Wait until you have a full load before washing laundry, or use a lower water-level setting.

CONSERVE

Lawn and Yard

A lush, green lawn requires about 1½ inches of water a week, applied ½ inch at a time, three times a week. But, in years of water shortages, homeowners will have to accept a lawn which is not as green. Experts estimate that most Colorado lawns can survive on ¾ inch of water a week, or less.

If water is rationed or otherwise restricted, lawns should receive the lowest priority for outside watering. Trees and shrubs die more quickly and are more expensive to replace.

Bluegrass lawns are fairly drought tolerant and can recover after a prolonged dry period.

It is estimated that approximately 40 per cent of the domestic water supply goes for lawn and yard watering. Wise use of water outside can save significant quantities.

Don't over-water your lawn — and don't water until the lawn needs it. When grass turns a dull grey-green, and when footprints remain when you walk across the lawn, it's time to water.

If most of the lawn still looks green and only spots or areas near concrete are grey, root-water or hand-water just the dry spots.

Hand watering should be done with a soaker or a two-pronged aerator which attaches to the garden hose, rather than a sprinkler.

Use root-watering devices on shrubs, trees, strips of grass and areas near concrete. Soakers help prevent runoff on slopes.

When watering near concrete, push a root feeder or aerator into the soil 12 to 16 inches from the concrete. Force the water jets down to a depth of four to six inches. When the grass rises like a bubble, remove spike and repeat operation 12 to 16 inches further along grass edge.

Less frequent but heavier lawn watering encourages a deeper root system to withstand dry weather better.

If a ½-hour setting with a sprinkler is what your lawn needs, keep track of the time. A sprinkler left on overtime in one spot wastes water. Set an alarm clock or timer as a reminder.

With an automatic sprinkling system, make sure it is not soaking the lawn too often and too long.

Much of the soil in Colorado is clay. This heavy soil usually can absorb no more than ½ inch of water per hour. For slopes and heavy clay soils, let the water run for 30 minutes, then come back in an hour and water for another 30 minutes.

Sandy soils need watering more often but for shorter periods of time.

If water starts to run off, turn off the sprinkler until the lawn needs watering a few days later.

Lawns should be watered during hours when the water system experiences the least demand — usually from 4 a.m. to 6 a.m.

Adjust lawn watering to the weather. Following a heavy rain, skip the regular watering schedule until the grass needs it. Know how to turn off an automatic sprinkling system until needed again.

Avoid watering when windy or in heat of day.

Delay regular watering of your grass during the first, cool weeks of spring to encourage deeper rooting.

Sunny, south sides of buildings, or slopes, or areas near sidewalks and driveways usually require watering more often. Shady or north locations need watering less frequently.

Forget about watering streets, walks and driveways. They won't grow a thing.

Keep grass length fairly long — two inches or higher. Cut lawn fairly often so that no more than 1/3 of the grass blade is cut off. Otherwise, grass blades turn yellow from excessive shock.

Taller grass provides more food for deeper rooting if deep-watering is practiced.

Sprinklers throwing large drops of water in a flat pattern are more effective than those with fine, high sprays.

Water flow can be controlled at your water outlet, by the type of sprinkler used, and by the size of the garden hose. More is dispensed faster with a larger diameter hose.

High nitrogen fertilizers stimulate lawn growth and increase water requirements.

Mulch your shrubs and other plantings so the soil holds moisture longer.

CONSERVE

Vegetable and Flower Gardens

When possible, flood irrigate your vegetable and flower gardens rather than using sprinklers. Irrigation allows deeper soaking with less water. Sprinklers result in high evaporation loss of water.

Garden irrigation is best accomplished with shallow ditches next to the plant rows or by use of a soaker hose.

Prevent irrigation water runoff and waste by damming the ends of the ditches with soil. Fill the ditch with water and let it soak in.

Polyethylene (black plastic) mulch between your vegetable garden rows conserves water. (Avoid plastic thicker than four mils as it reduces air exchange.)

Mulches which stay open and porous (leaf mold, wood chips, loosely-applied lawn clippings) conserve water and discourage weeds in your flower and vegetable gardens. Mulches such as finely-textured peat moss or sewage sludge will compact and form a surface crust which prevents water from soaking into the soil.

Certain flower and vegetable varieties can tolerate shade and thus require less frequent watering. (Consult a CSU Extension Service county agent for variety recommendations.)

Leafy vegetables (lettuce) generally require more water than root crops (beets).

Vegetables requiring more water should be grouped together in the garden to make maximum use of water applications.

Vegetables can be combined with flowers and shrubs to prevent watering a separate vegetable garden or to utilize space more effectively.

Vegetables for small families can be grown in tubs, thereby avoiding the need to water a large garden.

CONSERVE

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Lowell H. Watts, Director of Extension Service, Colorado State University. By law and purpose, the Colorado State University Cooperative Extension Service is dedicated to serve all people on an equal and nondiscriminatory basis.

APPENDIX F

TOTAL WATER CONSUMPTION

CITY OF FORT COLLINS, COLORADO

FURNISHED BY FORT COLLINS WATER DEPARTMENT

TOTAL WATER CONSUMPTION
CITY OF FORT COLLINS, COLORADO

Year	Jan.	Febr.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1925	34	28	31	66	64	57	70	55	48	44	46.5	40	583
1926	31	28	31	35	65	82	89	96	93.5	92	60.5	67	770
1927	69.5	40.5	63.7	67	138.5	119.7	158	100.8	138.8	113.7	87	91.7	1103
1928				96.5	101.2	87	147.7	150	124.5	111.7	77.5	88.5	1231
1929	76.2	83.8	87.2	91.8	119.2	154	178.5	148.5	81.5	95.8	82	80	1278
1930	74	77.5	69.8	101.2	102.8	172.8	179	115.8	102.2	76	64.2	60.8	1196
1931	60.7	50.5	58.8	79	103.5	144.8	205.2	162	123.2	80.8	68.5	61.5	1198.0
1932	53.2	51	58.5	109.5	133.5	141.5	183.8	134.2	116.8	78.5	59.2	57.5	1177.2
1933	54.2	56.2	57.2	72.2	87.2	172	182.3	116.5	88.2	91.5	65.8	60.5	1104
1934	55.2	51.2	54.8	80	144.8	160.2	202.8	151	101.5	76	60	64	1200.8
1935	67.5	62	63.2	82	74.2	117.8	179	201.5	104.5	94.7	76.7	73.3	1196.5
1936	66.5	68.5	69.5	99	143.8	156	207	155.2	114.5	68	62.5	63	1274.5
1937	64.2	59.2	56.8	55.5	121.5	114.2	169.5	202.5	138.2	86.2	70.5	64.5	1203
1938	62	56	63.7	56.5	83.2	108.2	201.5	213.5	85.5	78.5	63	66.7	1138.5
1939	62	59	62	76.2	154.8	192.2	255.2	193.5	150.2	113	77	73	1468.2
1940	54.2	50.7	55.2	99.7	152	216.5	212	199	100	70.7	66.5	55.5	1332.25
1941	49	49	54.2	57	87.5	148.2	182.0	123.7	90.5	57.7	56.0	54.2	1006.2
1942	55	49	54.2	64.5	112.5	116.2	225.0	164.5	119.2	107	67.5	64.7	1199.5
1943	56.7	51.0	56.7	98.7	81.0	141.7	225.5	196.0	138.7	77.7	56.5	58.5	1282.2
1944	60.2	51.0	54.5	56.5	108.0	155.2	165.8	235.5	146.0	97.0	72.0	66.5	1691.0
1945	62.5	57.5	73.5	64.5	144.5	133.5	224.5	115.5	149.0	85.0	75.0	71.0	1256.0
1946	69.8	67.5	105.5	177.5	128.0	208	218	201.5	98.5	108	88.2	78	1546.5

Year	Jan.	Febr.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1947	87.2	82.3	90.5	108	143	128.5	244	256	195.5	146.0	126.0	122.5	1729.5
1948	99.2	109.5	129.0	172.8	202.5	181.0	264.5	222.0	178.5	137.5	114.0	104.5	1915.0
1949	102.5	98	106.5	142.5	175	185.5	231	251.5	179.5	141	142.5	129	1884.5
1950	123	105	135.5	163	148.5	228	230.5	239	132.5	170.5	129	126	1930.5
1951	124	112	126	144	182.5	173	249	174.5	164	129.5	103	110	1791.5
1952	105	105.5	124	136	184	230	236	241	208	154	108.5	109	1941.0
1953	112.5	103	134.2	112.5	192	220.5	272.5	261.0	215	164	119.5	109.5	2016.3
1954	106	105	124	210.5	223.5	266	255.5	216.5	198.5	156.5	137	123.5	2122.5
1955	123	112	135	200	222	210	276	194.5	179	142	121	93	2007.5
1956	108.5	110.5	119.5	144.5	174.5	300.5	267	195.5	223	161	113.5	114	2032
1957	108.5	103.5	128	128.5	123.5	224	285	188.5	177.5	137	112	101	1717
1958	110	98	106	110.5	152	241.5	242	288	220.5	165	105	113	1951.5
1959	93	87	90	118.5	161	300	341.5	318.5	234	130.5	103	99	2076
1960	108.5	101.5	113	185.5	257	364	412.5	442.5	337.5	220	136	121.5	2799.5
1961	133	114.5	128.5	162	182.5	272	347.5	311.5	181	128	108.5	120	2189
1962	134	122.5	137	206.5	261.5	326.5	387	435.5	325.5	220.5	160	136.5	2753
1963	139.5	128	151.5	259.5	371	365.5	401.8	279	246.5	218.5	155	151.3	2867.1
1964	151	143	149.5	189.5	365	365.5	480.2	385.5	326.5	241	178.5	146.5	3112.7
1965	161.5	135	161	204.5	298.5	233	366.5	412.5	247	203	173.5	156.5	2752.5
1966	164	150	212.5	255.5	445.0	290	519.5	415	320	279.5	201	166.5	3418.5
1967	169	154.5	194	253.5	250.8	189.1	318.2	455.3	270	226	175	175	2830.4
1968	192	175.5	178	237.5	312	455	457.3	365.9	359.3	250	177	166.5	3326
1969	175	157.5	184.5	292	343.9	300.4	494.8	477.4	364.3	177.1	185.2	180	3332.4
1970	195	203.5	204.5	201.5	431.8	480	508.5	519.8	346.9	208	192	177	3668.5

Year	Jan.	Febr.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1971	190.5	170	209.5	240	247.1	591.2	597.2	657.4	331.6	255.0	231.0	205.5	3926.0
1972	222.9	228.5	211.4	333.9	507.5	578.0	643.3	555.4	352.9	305.7	287	227.0	4564.4
1973	239	221.5	248.7	247.4	450.0	722.3	626.1	719.5	420.2	335.6	235.5	213	4678.7
1974	220.5	201.5	231	316.4	679	758.4	859.5	794.3	509.3	379.8	269.1	259.3	5478.1
1975	267	248.5	250.5	285.2	490.2	500	773.4	671.5	556.4	409	266.8	229.8	4948.3
1976	227.5	227.2	255.5	384.9	418.1	705.5	828.4	597.1	444.1	323.1	266.1	262.6	4940.1

Year	Population	AF	Consumption	Per Capita
1930	11,489	3,670	1,196.0 MG	285.2 104,100
1940	12,251	4,089	1,332.25	297.9 108,746
1950	14,937	5,925	1,930.5	354.1 129,243
1960	25,027	8,591	2,799.5	306.5 111,859
1970	43,098	11,258	3,668.5	233.2 85,120
1975	55,825			
1980	67,225	17,164		
1990	97,796	24,959		
2000	144,607	36,814		