CHAPTER 8

DROUGHT ADJUSTMENT: THE RESPONSE TO SHORTAGE

Before moving on to the business of measuring the economic impact of water shortages, we should pause to consider some of the ways in which a community may react to impending trouble. In addition, it will be useful to see how the study communities actually did react during the 1962–66 drought.

We concentrate in this chapter entirely on active responses to potential shortage. It is, of course, possible (if not politically feasible) for a community to react passively; that is, to do nothing out of the ordinary, supplying all customary uses at customary prices and suffering the relatively spectacular consequences when there is no water left for anyone. This type of behavior is, understandably, not often observed; and we feel safe in assuming for the sake of exposition that a town with reasonably accurate knowledge of its position will make some active response or set of responses. In general, such responses may be chosen from two alternative groups: those adjustments to the normal state of affairs which aim at increasing (even if only temporarily) the available supply of water; and those adjustments which aim at restricting the level of withdrawals from that supply.

ADJUSTMENTS THAT REDUCE CONSUMPTION

Adjustments that reduce water withdrawals are directed toward a more efficient utilization of the present water supply. Such adjustments include changes from flat-rate to commodity charges through metering, changes in the price where meters exist, restrictions on the use of water, and reuse of water.

Changes From Flat-Rate to Metered Supply

One of the major factors affecting the consumption of residential water is whether or not the distribution system is metered. As Table 16 shows, water use in metered areas is significantly lower than in flat-rate areas, primarily because of the impact of metering on lawn-sprinkling. Note also that peak demands, hourly and daily, tend to be very much lower in the metered areas, a fact that is not directly relevant to this study but is obviously of great importance for the planning of water systems. Household use (inside uses such as flushing and cooking) is relatively constant as between metered and flat-rate areas.[1]

TABLE 16. WATER USE IN METERED AND FLAT-RATE AREAS (OCTOBER 1963–SEPTEMBER 1965)

(gallons per day per dwelling unit)

	Metered areas	Flat-rate areas
Annual average		
Leakage and waste	25	36
Household	247	236
Sprinkling	186	420
Total	458	692
Maximum day	979	2,354
Peak hour	2,481	5,170

Source: Charles W. Howe and F. P. Linaweaver, Jr., "The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure," *Water Resources Research*, I (1965), 14.

The literature is replete with examples of the impact of universal metering on the use of water. In Kingston, N.Y., a universal meter installation program was initiated in 1958. By 1963, with 98 percent of the system metered, average water use had decreased from 5.47 to 4.0 million gallons per day (mgd) even though the number of services had increased from 7,800 to 7,935.[2] When Philadelphia completed universal metering between 1955 and 1960, demand for water declined from 370 to 327.8 mgd (11 percent). In 1955, approximately 73 percent of the water services were metered; hence, metering was estimated to have reduced demand among the unmetered users by at least 28 percent.[3] Another example is Elizabeth City,

[1] See also, F. P. Linaweaver, Jr., John C. Geyer, and Jerome B. Wolff, "Final and Summary Report on the Residential Water Use Research Project" (The Johns Hopkins University, Department of Environmental Science, June 1966), pp. 48–49.

[2] E. T. Cloonan, "Meters Save Water," in *Modern Water Rates* (New York: Buttenheim Publishing Co., 1965), pp. 12–13.

[3] Ibid., p. 14.

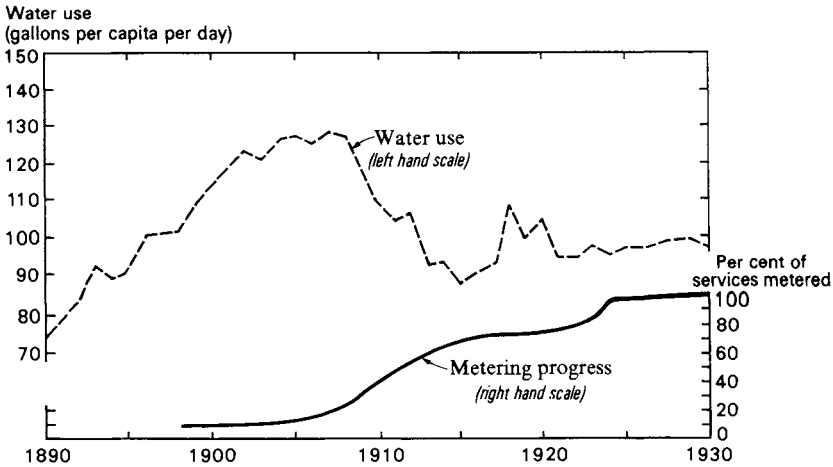

Figure 14. Effect of introduction of metering on water consumption by Metropolitan District Commission customers.

N.C., where, in 1931, universal metering of an originally flat-rate system reduced average consumption from 1.8 to 0.3 mgd. Although demand later increased slightly, per capita consumption as of 1946 was still lower than for the period prior to 1931.[4] Figure 14 shows how average per capita daily consumption of water by customers of Metropolitan District Commission reacted to metering.

The scope for this particular form of adjustment is somewhat limited, however, in that most municipalities in the United States have already installed individual water meters.[5] There are some notable exceptions. For example, only 25 percent of the water users in New York City are metered, though in a recent report, the former Water Commissioner of the city estimated that complete metering would reduce consumption by 125 mgd, or approximately 10 percent of average daily use in the early sixties.[6]

Increases in Price of Metered Supply

Where systems are already metered, it is, of course, possible to reduce the level of water withdrawals by increasing the charge per gallon. In principle, the economist would look in this direction for a method of

[4] "What Water Meters Did for Elizabeth City, North Carolina," *American City*, 61 (1946), 9.

[5] Jack Hirshleifer, James C. DeHaven, and Jerome W. Milliman, *Water Supply: Economics, Technology and Policy* (Chicago: University of Chicago Press, 1960), p. 44; and American Water Works Association, *Water Rates Manual* (New York: The Association, 1957).

[6] *Report on Universal Metering* by Armand D'Angelo submitted to Hon. Robert F. Wagner, Mayor of New York City, October 7, 1964 (mimeo.), p. 6.

rationing the available water so as to minimize the welfare loss from the shortage. However, in practice, the pricing policies of most systems are so widely at variance with even roughly optimal policies,[7] and so little is known of the shapes of the existing demand functions, that it is not clear that even a second-, third-, or *n*-th best solution could be found. Virtually the only solid evidence available on water demand functions concerns residential use and suggests that the demand for sprinkling water is relatively elastic, that for other domestic uses relatively inelastic.[8] As a drought adjustment, the use of a temporary surcharge equal to several multiples of the normal price might be applied to all water used above some minimum. Since sprinkling use is the more elastic, and since a drastic temporary increase is envisioned, such a plan could result in a sharp decrease in use during summer months. There are, however, significant administrative problems: in particular, the infrequency of meter readings might make it difficult to devise a fair base use and would tend to destroy the immediacy of the price increase for customers. Perhaps even more important are the practical political difficulties involved.

In addition to reducing the use of water directly, the introduction of metering and increases in prices may indirectly have the same tendency by increasing customers' sensitivity to leaks and by making leaks in the distribution mains easier to find.[9] This may be quite important, for as noted earlier, as much as 15 percent of water withdrawn from the source may be lost in distribution. To this must be added an unknown, but probably fairly large, leakage after water is delivered to the customers' meters.

Restrictions on Water Use

Restrictions on water use can be very effective in reducing a community's withdrawals, and it is to restrictions that system managers very frequently turn when confronted with a potential shortage.[10] One of the great ad-

[7] See American Water Works Association, "Determination of Water Rate Schedules," *Journal of the American Water Works Association*, 44 (1954), 188; and Gordon M. Fair, John C. Geyer, and Daniel A. Okun, *Water and Waste Water Engineering* (New York: Wiley, 1966), I, Ch. 13, p. 14, which states that ". . . rates are obtained by dividing the system costs by the volume of water delivered. . . ."

[8] Charles W. Howe and F. P. Linaweaver, Jr., "The Impact of Price on Residential Water Demand and Its Relation to System Design," *Water Resources Research*, I (1965), 13–32, and certain other studies cited therein.

[9] John Simmons, "Economic Significance of Unaccounted for Water," *Journal of the American Water Works Association*, LVIII (1966), 639–41.

[10] Glen D. Heggie, "Effects of Sprinkling Restrictions," *Journal of the American Water Works Association*, XLIX (1957), 275; and Dwight F. Metzler, "Recommended Action Against Effects of Severe Droughts in Kansas," *Journal of the American Water Works Association*, XLVIII (1956), 1003.

vantages of this strategy is its flexibility. Restrictions may be voluntary or legally imposed; they may be based on hours of use or types of activity; they may be confined to peak demand periods or be more general. Indeed, in some communities, restrictions have been imposed on *all* uses, the water being shut off for all except a few hours each day.[11]

Certainly, from a review of the literature, it appears that communities, when faced with a potential shortage, are quick to formulate and impose programs of water-use restrictions. For example, at least 64 of the 75 communities in Illinois that suffered shortage at some time during the drought of 1952–55 enacted restrictions on use.[12]

One drawback, however, to reliance on restrictions is that their effectiveness appears to be severely limited unless the people of the town are convinced that there is, indeed, a crisis situation.[13] It might be that publicity for the cost implications of system failure would increase public tolerance for and cooperation with restrictions.[14]

Reuse of Water

Although the reuse of water for domestic purposes has recently become more attractive and viable, few communities in the United States have recycled effluent from sewage treatment plants subsequent to filtration,

[11] Symposium, "Eastern Water Shortage and Drought Problems," *Journal of the American Water Works Association*, LXVII (1955), 203–29.

[12] The other 11 communities may also have had water-use restrictions, but the data on restrictions were reported for 1953 only. A community was considered to have a shortage if restrictions on water use were imposed or if less than 6 months' supply was available for systems with surface-water supplies. H. E. Hudson, Jr., and W. J. Roberts, *1952–55 Illinois Drought with Special Reference to Impounding Reservoir Design*, Illinois State Water Survey Bulletin No. 43 (Urbana: Illinois Department of Registration and Education, 1955), p. 1.

[13] "Publicity in Water-Waste Prevention Work," *Journal of the American Water Works Association*, VI (1919), 8.

[14] It has been suggested that one rational and effective way of dealing with the problem of customer acceptance both of restrictions and of the idea of a planned failure rate for a municipal water supply would be to publish, in advance, lists of planned restrictions to be applied under various threatened levels of shortage. Thus, for example, the system's customers would know that in the face of a 10 percent potential shortage, all outside use of water (sprinkling, car-washing, etc.) would be forbidden during July and August, no non-recirculating air conditioners would be permitted to operate, and no water could be served in restaurants. If the potential shortage were 15 percent, swimming pools could not be refilled. A shortage as large as 30 percent might involve slowdowns or shutdowns of local water-using industries. This suggestion deserves a practical test in one or more cities, perhaps in combination with the temporary surcharge scheme outlined above.

purification, and dilution.[15] Because of a serious drought, Chanute, Kans., reused its water an average of 8 to 15 times from October 1956 to February 1957.[16] Although the taste and odor of the drinking water became esthetically disturbing to many consumers, the U.S. Public Health Service minimum standards for drinking water were never violated during the 5-month period. In a study concerning the feasibility of a 100-mgd waste-water purification plant utilizing secondary-treatment sewage, it was estimated that potable water could be produced at approximately 16¢ per 1,000 gallons.[17] Frankel and others have demonstrated that groundwater recharge of treated sewage is economically superior to conventional methods of providing water and sanitary services which use a stream both as source and as receiver of effluent, with treatment at both ends of the municipal "pipe."[18]

The obstacles to reuse appear to lie primarily in the minds of system managers and customers for whom the reuse of water is esthetically unacceptable.[19] Our study indicated that this was certainly true of Massachusetts: system managers uniformly avoided this alternative in discussing steps they could take in the face of potential shortage; and in a small public opinion poll only 46 percent of those interviewed indicated a willingness to drink recycled domestic water. (Over 70 percent indicated such a willingness in Kansas and Illinois.)[20] These attitudes could probably be significantly changed by an educational campaign.

[15] Recirculation of water within a single water-using activity such as an industrial plant or even a city is clearly a means of reducing withdrawals by that activity. Recirculation which involves use of natural mechanisms, as in artificial recharge of groundwater aquifers with treated waste waters, might be characterized under methods of increasing the available supply. The appropriate definition would depend on our view of the physical system of water resources being considered as potential supply. For our purposes, all types of recirculation are classified as means of reducing withdrawals.

[16] Bernard Berger, "Public Health Aspects of Water Reuse for Potable Supply," *Journal of the American Water Works Association*, LII (1960), 599–606.

[17] Leon W. Weinberger, David G. Stephan, and Francis M. Middleton, "Solving our Water Problems—Water Renovation and Reuse," *Annals of the New York Academy of Sciences*, 136 (1966), 143. "The suggested plant employs aeration, chemical coagulation and sedimentation, carbon absorption and chlorination to purify the effluent from a secondary sewage treatment plant. If the product water is mixed with water from other sources in a large system no further treatment is necessary."

[18] See, for example, Richard J. Frankel, "Water Quality Management: Engineering-Economic Factors in Municipal Waste Disposal," *Water Resources Research*, 1 (1965), 185, 186. See also Frankel, "Water Quality Management: An Engineering-Economic Model for Domestic Waste Disposal," Ph.D. thesis, University of California, Berkeley, January 1965.

[19] Dwight F. Metzler and Heinz B. Russelmann, "Wastewater Reclamation as a Water Resource," *Journal of the American Water Works Association*, LX (1968), 101: "The challenge of acceptance is greatest with water utility managers."

[20] The Massachusetts poll involved 177 respondents in 6 towns. In Kansas and Illinois 271 persons were interviewed.

ADJUSTMENTS THAT INCREASE SUPPLY

In contrast to the above strategies, which attain their goals by impinging more or less directly on consumer choice and behavior, a second set of adjustments relies primarily on technology and aims to increase the available supply through construction of new sources of supply, use of emergency sources, weather modification, evaporation and seepage control, and desalination of salt or brackish water. Observation of past behavior suggests that communities faced with persistent long-term shortages of water have looked more often to the development of new or improved sources of supply than to such relatively new alternatives as weather modification and desalination. In cases of short-run shortages, we have very little evidence on the choices among adjustments other than the development of an emergency source of supply.

Provision of Emergency Supplies

Emergency sources of water supply have alleviated shortages in many drought-stricken communities. Simple chlorination of nearby ponds, quarries, and polluted streams, and utilization of abandoned wells have enabled communities to withstand serious droughts. During the Illinois drought of 1952–55, of the 75 communities that experienced shortages, 8 hauled in emergency water, 8 supplemented existing supplies with groundwater sources, and 13 laid pipelines to reach emergency sources of surface water. Except for specific accounts in the more popular journals, little is known concerning the frequency with which communities rely upon emergency supplies or about the nature of those supplies.

Weather Modification

Twenty years have elapsed since the Langmuir and Schaeffer cloud-seeding experiments. Since that time, the study of weather modification has emerged as a scientific discipline; the social and economic consequences of modifying the weather are being studied; and federal recognition has been translated into research funds.[21] Cloud-seeding techniques have been observed to increase average precipitation by 10 to 15 percent under appropriate weather conditions.[22] And it is predicted by some that

[21] Thomas Malone, "Weather Modification: Implications of the New Horizons in Research," *Science*, 156 (1967), 897.

[22] National Academy of Sciences—National Research Council, *Weather and Climate Modification: Problems and Prospects*, Final Report of the Panel on Weather and Climate Modification (Washington: U.S. Government Printing Office, 1966), p. 23; Peter H. Wycoff, "Evaluation of the State of the Art," in *Human Dimensions of Weather Modification*, W. R. D. Sewell, ed., Department of Geography Research Paper No. 105 (Chicago: University of Chicago Press, 1966), p. 31; and U.S. Department of the In-

with continued research "weather modification as a means of increasing the water supply will be possible" by 1975.[23]

Protecting Supply Sources

In conjunction with plans to increase public water supplies, techniques to reduce evaporation and seepage in reservoirs have been implemented, without great success, especially in the Southwest where evaporative losses are nearly three times greater than in the Northeast. Monomolecular film has been successful on small ponds, although the cost is rather high.[24] The construction of deep reservoirs (relative to volume) has also aided in the reduction of losses to the atmosphere by reducing the water surface area from which evaporation can occur.

Desalination

A final and rather dramatic alternative, one mentioned frequently during the recent Northeast drought, is the desalination of salt or brackish water. But, because of the time required for construction of facilities, desalting is not a realistic alternative for a community faced with a shortage and in need of an immediate boost in supply. Even over a longer time horizon, desalting is not yet competitive with conventional sources. For a large (300 mgd), dual-purpose seawater desalting plant for New York City, the average annual costs were estimated to be approximately $77,000 per mgd of safe yield. In contrast, it was calculated that use of Hudson River water would cost about $37,000 per mgd of safe yield.[25]

DROUGHT ADJUSTMENT IN MASSACHUSETTS

Among these possible alternatives, what were the choices of the communities in Massachusetts during the recent drought? In particular, did the town tend to take on the burden of reducing shortages by obtaining

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terior, Bureau of Reclamation, Office of Atmospheric Water Resources, *Plan to Develop Technology for Increasing Water Yield from Atmospheric Sources* (Washington: U.S. Government Printing Office, 1966), p. 27.

[23] U.S. Senate Select Committee on National Water Resources, *Water Resources Activities in the United States: Weather Modification*, Committee Print No. 22, 86th Congress, 2nd Sess. (Washington: U.S. Government Printing Office, 1962), p. 45.

[24] For a review of the state of the art see C. W. Lauritzen, "Water Storage-Seepage, Evaporation, and Management," paper presented at Symposium on Water Supplies for Arid Regions, Committee on Desert and Arid Zones Research, Tucson, May 1967.

[25] U.S. Department of Commerce, Northeast Desalting Team, *Potentialities and Possibilities of Desalting for Northern New Jersey and New York City* (Washington: The Department, 1966).

emergency supplies, or was the impact primarily felt by customers through the instrument of restrictions on use?

Of the 48 communities in which interviews were conducted in the course of our study, 39 adopted one or more drought-related adjustments at some time during the 1963–66 period. The most common response to the drought was the imposition of restrictions on water use. But other measures to reduce the level of demand were rarely taken. Efforts to obtain new sources, to improve existing sources, and to provide emergency supplies were, on the other hand, all quite popular strategies. (See Figure 15.)

For the towns included in the mail survey, the water superintendents were asked to rate their system as adequate or inadequate during the drought period. In over 50 percent (82 of 150) of the mail-survey communities, the existing water supply was considered inadequate at some time during the drought. Restrictions on water use were imposed in all but 2 of these places, with more than 50 percent of the restrictions being compulsory. Emergency water sources were used by 50 of the systems classified by their managers as inadequate. (The mail-survey data on adequacy and adjustments are summarized in Table 17.)

It should also be noted that, of the 68 communities served by systems classified as *adequate* by their managers, 8 enacted restrictions and 4

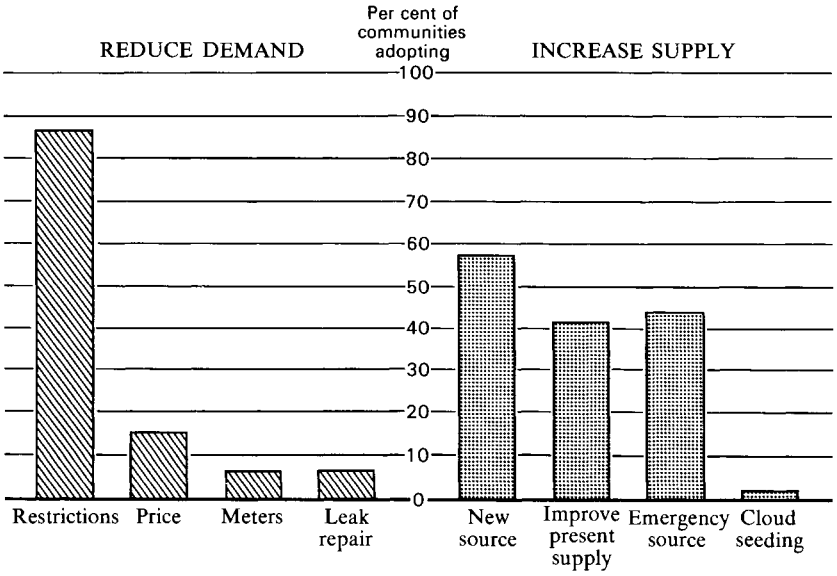


Figure 15. Nature of adjustments made by 39 Massachusetts communities during 1963–66 drought.

TABLE 17. MAIL-SURVEY COMMUNITIES: ADJUSTMENTS TO DROUGHT[a]

Status and adjustments \ Characteristics of systems	Groundwater systems			Surface-water systems			Combination systems			Total systems		
	Number of systems	Percentage of groundwater systems	Mean index of inadequacy[b]	Number of systems	Percentage of surface-water systems	Mean index of inadequacy[b]	Number of systems	Percentage of combination systems	Mean index of inadequacy[b]	Number of systems	Percentage of total systems	Mean index of inadequacy[b]
Total adequate	52	54%	0.48	13	45%	0.56	3	12%	0.61	68	45%	0.50
Restrictions	6	6	0.39	2	7	0.49	—	—	—	8	5	0.41
Voluntary	4	4	0.42	2	7	0.49	—	—	—	6	4	0.45
Compulsory	2	2	0.34	0	0	—	—	—	—	2	1	0.34
Emergency supply	3	3	0.54	1	3	0.54	—	—	—	4	3	0.54
Planning	21	22	0.47	5	17	0.62	—	—	—	26	17	0.48
Total inadequate	44	46%	0.52	16	55%	0.72	22	88%	0.77	82	55%	0.63
Restrictions	43	45	0.51	15	52	0.65	22	88	0.77	80	53	0.60
Voluntary	31	32	0.51	5	17	0.51	14	56	0.70	50	33	0.62
Compulsory	20	21	0.54	11	38	0.66	15	60	0.67	46	31	0.62
Emergency supply	29	30	0.52	13	45	0.70	8	32	0.68	50	33	0.59
Planning	37	39	0.53	14	48	0.78	18	72	0.78	69	46	0.62
		Percentage of total sample			Percentage of total sample			Percentage of total sample				
Survey totals	96	64.0	0.50	29	19.3	0.65	25	16.7	0.75	150	100	0.57

[a] System "adequacy" was determined by system managers. Systems were listed under both voluntary and compulsory restrictions if both types were imposed.

[b] The index of inadequacy of a system was calculated from U.S. Department of Health, Education, and Welfare, *1963 Inventory of Municipal Water Facilities*, Public Health Service Publication No. 755 (Washington: U.S. Government Printing Office, 1964) as average plant output over safe yield or maximum dependable draft as appropriate. We give the means for the systems listed to the left in the particular category.

utilized emergency supplies. This observation points up the difficulties of relating a measure of inadequacy based on managerial perception with measures based on physical capability. Thus, it is quite reasonable to suppose that managers would seek to bolster or save apparently adequate supplies when surrounded by the din of crisis publicity. It is also true that in the absence of accurate measures of potential demand and available supplies, adequacy is, like beauty, in the eye of the beholder.[26]

One of the most interesting features of Table 17, however, is the extent to which even in this context, with only imperfect measures available, our concept of relative system adequacy shows up as important. We calculated a surrogate measure of relative inadequacy from the information in the 1963 USPHS Inventory,[27] using the "average plant output" as a measure of the level of demand in combination with the given features for safe yield or maximum dependable draft as appropriate. The table shows the mean of these ratios for the systems in the particular category. Examining the table, then, we can see that within each system type (by source) the "mean inadequacy" ratio for the "adequate" systems is invariably lower than is that for the "inadequate" systems. This comparison is least pronounced for groundwater systems, to which our model is not expected to apply. For surface and combined-source systems, the contrast is much sharper. The ratio of the mean inadequacy index for "inadequate" systems to that for "adequate" systems is, for each category, equal to about 1.25. Since the higher the mean inadequency ratio, the *lower* the level of relative system adequacy, we find the satisfactory result that "inadequacy" in the perception of managers (and the performance of the system as it affects that perception) corresponds to relative inadequacy, in our sense, for a given climatic event.

Adjustments to Decrease Withdrawals

Returning now to the 48 interviewed communities, in the 39 systems which adopted some type of adjustment during the drought period, the choices ranged from appeals for voluntary reduction in use to a weather modification project. (See Table 18.) Aside from the widespread community adoption of water use restrictions, very few attempts to reduce consumption were made. The emphasis was on augmenting supply through technology, while strategies requiring water use behavior modification were narrowly perceived and adopted. (See Figure 15 for a graphic summary.)

[26] See comments in Chapter 7, on the possibility of "created" shortages attributable to conservative water-management policy.

[27] U.S. Department of Health, Education, and Welfare, *1963 Inventory of Municipal Water Facilities*, Public Health Service Publication No. 775 (Washington: U.S. Government Printing Office, 1964).

TABLE 18. ADJUSTMENT TO DROUGHT MADE BY 39 COMMUNITIES

Adjustments that decrease withdrawals			Adjustments that increase supply		
Type	Number reporting	Percentage of interview sample adopting	Type	Number reporting	Percentage of interview sample adopting
I. Restrictions	34	87	I. New sources	23	59
Domestic	34	87	Reservoirs	5	13
Industrial	23	59	Groundwater	19	49
Public use	19	49			
			II. Improve existing supply	16	41
II. Price adjustment	6	15	Reservoir	10	26
			Groundwater	6	16
III. Meter adjustment	3	8	III. Emergency supplies	17	44
			Surface	10	26
IV. Leak survey/repairs	3	8	Ground	9	23
			Purchase	7	18
			IV. Weather modification	1	2

Note: Subtotals do not add because some communities used more than one.

In Table 19, we summarize the choices made among a variety of types of restrictions by the 34 cities and towns which turned to this general type of drought adjustment. We note that *every* system that used restrictions imposed lawn-watering restrictions on the domestic sector. This finding supports our expectations based on casual observation (and on exposure to irate lawnowners). The next most popular single type of restriction was that on home car-washing adopted by 76 percent of the restriction towns. Refilling of private swimming pools was restricted by 50 percent of the towns, but all outside use was restricted by only 29 percent of those introducing any restrictions.

Restrictions on the industrial (or commercial) sector were introduced by 13 of the 34 towns (38 percent). In 9 of these 13 places, the restrictions applied to the cooling water for large air conditioners; industries and commercial establishments were required to recirculate cooling water for all machines over a specified size, such as 5 tons. (Of the 9 communities, 2 extended this requirement to all cooling water. Only 1 community acted to require industries to recirculate process water where feasible.)

Other restrictions imposed on the industrial and commercial sectors took a variety of forms. Five communities took action to affect the use of water by commercial car-washes, including such measures as required recirculation and limits on hours or days of operation. One community

TABLE 19. NATURE OF RESTRICTIONS ADOPTED BY 34 COMMUNITIES

Sector applied to and description	Number of towns adopting	Percentage of all towns imposing any restrictions	Percentage of those towns imposing restrictions on particular sector
Domestic sector:	34	100	100
Lawn-sprinkling	34	100	100
Car-washing	26	76	76
Swimming pool (re)fill	17	50	50
All outside use	10	29	29
Industrial sector:	13[a]	38[a]	100
Cooling water recirculation	9	26	69
Air conditioning	9	26	69
General cooling	2	6	15
Process water recirculation	1	3	8
Restrictions on air-conditioning use (hours, temperature)	2	6	15
Car and truck washing (including commercial establishments)	5	15	38
Public sector:	19	56	100
Ponds, fountains	13	38	68
Hydrant flushing	12	25	63
Swimming pool (re)filling	6	18	32

[a] Several towns took measures with reference to the industrial sector which did not seem to qualify as voluntary restrictions for the purposes of this table. Specifically, 7 towns "requested" industries to recirculate one or more streams (generally air conditioning). Two other towns "recommended" such recirculation. If these are included, 22 towns, or 65 percent of the restricting towns, took some action with respect to industry.

imposed a restriction on the hours during which industrial and commercial establishments could operate air-conditioning equipment, allowing only 5 hours operation at mid-day. Another community prohibited operators of air-conditioning equipment from reducing the temperature inside their buildings more than 10° F. below the outside temperature. It would be interesting to know why this last, rather ingenious limitation came to be adopted and to find out how, and how strenuously, it was enforced. For while the idea of a "temperature patrol" is mildly amusing, the enforcement of this restriction seems perhaps more practical in the short run than the more common restriction requiring investment in recirculation equipment.

Nineteen of the interview communities adopted restrictions on public-sector uses of water. Most common here were rules shutting down or re-

quiring recirculation for decorative ponds and fountains. Twelve communities altered or abandoned normal schedules of hydrant flushing and testing. Six communities curtailed operation of municipal swimming pools.

Restrictions and the Level of Shortage. We felt that it would be interesting to investigate the relationship between the restrictive actions taken by communities and the levels of shortage they faced; in particular, to see whether certain restrictions tended to be adopted only under the pressure of relatively great potential shortage. Are some sectors favored over others when it becomes necessary to distribute a potential shortage; that is, to ration a limited supply of water?

We chose to measure the severity of the drought's impact on a town by the estimated potential shortage faced by the town during the depth of the drought.[28] We used this in preference to a measure of shortage faced at the time of initial imposition of restrictions because almost half of the communities we dealt with in this comparison instituted restrictions in 1963, and, as we have seen, our model does not appear to perform particularly well in explaining the size of shortages in 1963. This did not seem to be a dangerous strategy; we were interested in comparisons of relative shortage levels; and, for the communities we were able to survey, no important changes in relative adequacy took place during the drought. Thus, measures of relative severity for the last years of the drought should not differ significantly from what we would find had we a good measure of relative severity for the first year.[29]

Accordingly, in Table 20 we show, for the sample of 17 communities for which we had sufficient data, the average shortages faced by communities taking a number of different restrictive measures.[30] We also include data showing how prevalent each type of restriction was within the group of 34 communities imposing any restrictions, and how prevalent within the narrower sample of 17. The agreement between these two measures is generally good, indicating that our sample of 17 is at least not

[28] For the central and coastal regions of the state, we used the average shortage faced in 1965 and 1966; for the western region, the 1965 shortage alone.

[29] One test of the validity of this claim is to compare the pattern of shortage and restriction found below in Table 20 with that computed using the shortage estimate for the first year of restrictions for towns initiating restrictions in 1965 or 1966. (No towns in the sample we were able to work with initiated restrictions in 1964.) This was done, and the two are essentially the same. The small number of such towns, however, means that for several types of restrictions, no representatives were available in the group.

[30] The earlier discussions concerning our narrowing down of the list of towns with which we could work are applicable here. We are able to include here certain towns which could not be included in the regression testing of the shortage model presented in the last chapter. This is true, for example, for towns for which we lacked safe-yield estimates, since the D/Y ratio need not be measured here.

obviously biased with respect to any particular type of restriction. The restrictions for which the comparisons are presented are those which were relatively rare in our original sample and those which seem a priori to have a relatively greater psychological impact on the public. As a base for comparisons we use the average percentage shortage associated with the towns imposing lawn-sprinkling restrictions; that is, with the entire sample of 17.

TABLE 20. AVERAGE SHORTAGE FACING COMMUNITIES ADOPTING VARIOUS RESTRICTIONS

Type of restriction	Total communities adopting this restriction of 34 adopting any	Percentage of 34	Number of communities adopting this restriction of 17 in shortage-restriction sample	Percentage of 17	Average shortage faced by those adopting
					(*percent*)
Lawn-sprinkling	34	100	17	100	8.5
Restrictions on public swimming pools	6	18	4	24	9.5
Restrictions on private pools	17	50	10	59	13.6
Ban on all outside domestic use	10	29	3	18	25.9
Compulsory restrictions on commercial/industrial sector	13	38	8	47	14.5
Compulsory industrial cooling-water recirculation	9	26	5	30	14.6
Compulsory industrial process water recirculation	1	3	1	6	22.3

Some of the conclusions suggested by the table are mildly surprising. In particular, it seems odd that use of private pools was restricted only at a higher level of shortage than was required to trigger restrictions on public pools. This, however, may simply be a manifestation of where the effective power lies. In addition, since almost every community banned car-washing and every community did restrict sprinkling, it seems odd that "all outside use" would be restricted only at such a very high average shortage. The explanation here seems to be that, in fact, water managers mentioned "all outside use" only when they had *banned* such use. This represents, then, a considerably more serious step than the mere institution of permitted hours of use, etc., for sprinkling or car-washing.

From the point of view of some of our later findings concerning the apparent differential economic impact on sectors of shortages of different sizes, the most interesting findings in Table 20 concern the levels at which restrictions are imposed on the industrial and commercial sectors. We note from item 5 that the broad range of compulsory restrictions on the water-use activities of these sectors were instituted by systems facing an average shortage of 14.5 percent, considerably higher than the 8.5 percent shortage found for domestic restrictions. The one community which attempted to force industrial recirculation of process water faced a shortage of 22.3 percent, while the level for the 5 communities confining their recirculation edicts to cooling water was 14.6 percent. This all suggests that if the potential shortage does not exceed about 10 percent, the community will probably attempt to meet it by restricting domestic (and perhaps public) use, probably supplementing these restrictions with emergency supplies, either purchased or obtained from nearby ponds and similar sources. Only when the potential shortage is significantly larger than 10 percent do the communities attempt to clamp down on industrial use, and then they attempt to avoid the more sensitive areas. This phenomenon too is presumably tied to the relatively great power wielded by industrial customers, at least in Massachusetts. It is interesting to see this finding emerge from a direct look at the types of restrictions imposed. Later, in Chapter 9, a very similar conclusion is shown to be implied by the indirect evidence of the sectoral economic impact of the drought in three Massachusetts towns.

Enforcement of Restrictions. The extent to which a community may enforce restrictions is governed by law. Massachusetts law provides for declaration of a water emergency with the approval of the State Department of Public Health (DPH). If the emergency is approved by the DPH, the community may impose restrictions on water use, with authority to suspend service for noncompliance. The emergency declaration also allows the use of DPH-approved emergency water sources to augment supplies. If a water emergency is not declared, a community may still enact local restrictions on water use without the approval of the DPH; however, punishment for noncompliance may not include actual suspension of supply. A third strategy a community may select, a step less severe than the two outlined above (and therefore likely to precede them), is to appeal to consumers to reduce their water use voluntarily.

The degree of enforcement of restrictions on water use varied among the 34 communities, but in none was service discontinued because of consumer noncompliance. Most (65 percent) of the communities relied on consumer cooperation and did not undertake active enforcement, thus in

effect making ostensibly compulsory restrictions voluntary. Only 35 percent of the communities instituting restrictions, then, actually felt it necessary (or were willing) to back up their rules with a strict enforcement policy, including police vigilance.

Introduction or Expansion of Metering. In only three communities were any changes in the metering system instituted during the drought: Fitchburg, Marlboro, and Woburn. But only in Woburn was metering increased (from 50 to 85 percent). In Marlboro, metering of the entire system was completed in 1963, the product of a decision made *prior* to drought. And in Fitchburg a meter-repair program was formulated. In 5 other towns the introduction or expansion of metering would probably have been very helpful in reducing demand. All of these towns had little or no metering[31] at the beginning of the drought but found it necessary to make some adjustment during the drought.

Price Changes. In light of the extensive meter coverage in the sample communities, it might be thought that increases in water rates would have been effective in reducing the quantity of water demanded, particularly if applied during the critical summer sprinkling months. Not one community, however, raised the price of water in an effort specifically to reduce the quantity demanded. In 6 towns, the price of water was raised, but in each case the decision was based on considerations other than the level of demand. In 3 of the communities, water rates were raised because of cost increases resulting from purchases of water from the Metropolitan District Commission. In the other places, the decision to raise the price of water had been made prior to the drought in response to rising costs of operation and maintenance.

Efforts to Reduce Losses from Leaks. Although, as we have indicated, the potential loss of water as a result of leaks may be substantial, only 3 communities endeavored to reduce unaccounted-for water. Of the 39 systems that made some type of drought adjustment, only 1 community hired a leak-detecting firm, and only in two other places was a greater-than-normal effort made with regular personnel to detect leaks in the distribution system.

Other Measures. Neither the reuse of domestic water nor the application of film to cut down on reservoir evaporation were even mentioned by water managers as possible adjustment alternatives.

[31] In three of these towns, domestic water use was not metered though industrial use was, and in the other two systems, less than 50 percent of total water use was metered.

Adjustments to Increase Supply

Permanent new additional sources of water supply were developed by 23 of the communities. (See Table 18.) The drilling of a well, the most common type of new source, was completed in 19 communities; and, in 5 places a new reservoir was added to the existing supply. One or more emergency sources of water supplemented the existing supply in 17 places. Emergency sources of supply included groundwater, surface sources which were not normally used, and the Metropolitan District Commission which had in its giant Quabbin Reservoir a substantial safe-yield cushion.

Even though not a single community raised the price of water to curb demand or discussed the feasibility of water reuse, one city elected to try a cloud-seeding project. With the aid of industry, 3 adjoining communities raised a total of $9,000 for a 35-day silver iodide experiment.[32] The success of the project is debatable, as is true in many weather-modification trials.

Another widespread response to the drought was the heightened interest in planning for future public water supplies. In the mail survey, 63 percent of all the responding systems indicated that they had begun, expanded, or accelerated planning activity because of the drought. Of the 48 interviewed communities, 15 indicated some drought-related planning effort. None of the water managers, however, mentioned any future plans with respect to periodic or seasonal restrictions, increases in water rates, or complete installation of meters to reduce the level, or at least dampen the rate, of increase in the demand for water. It may be possible that prior publication of planned sequences of restrictions and their probable duration would sell communities on planned failure rates and condition the consumer to a more positive reaction to restrictions, but none of our system managers appeared prepared to embark on such a course. This was the traditional response: engineering plans were formulated with emphasis on increases in safe yield. In 8 of the communities that had an adequate supply during the drought period, engineering plans called for construction of new reservoirs. Groundwater development was planned in an additional 7 communities. Data from the mail survey confirms this stress on new supplies. Seventeen percent of the surveyed systems were "adequate" and yet were planning expansion. Forty-six percent were "inadequate" and were planning increases in supply facilities.

To water system managers, the most attractive answer to the adequacy problem, then, is an increase in safe yield. When asked what their systems needed most, 34 of the interviewed managers (71 percent) stated they be-

[32] The towns were Fitchburg, Leominster, and Gardner. J. Andre Provencial, "Emergency Measures Due to the Drought—The Fitchburg, Massachusetts Story," *Journal of the New England Water Works Association*, 79 (1965), 234.

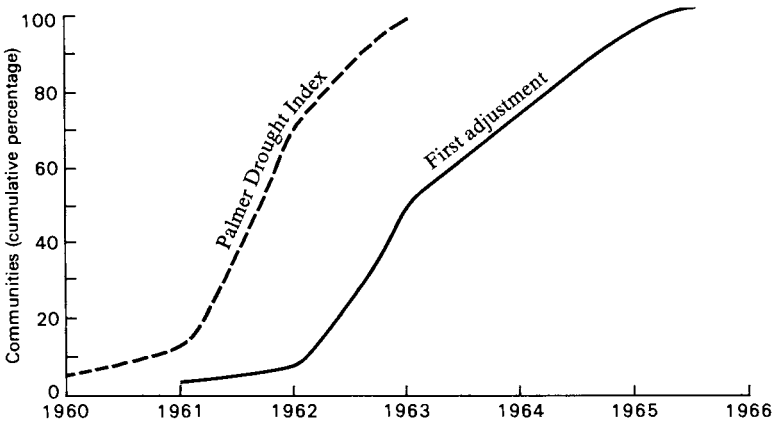
lieved new supplies to be essential either through the construction of new reservoirs or the digging of additional wells. Significantly, not one manager mentioned an improved price structure or the implementation of preplanned restrictions to curb demand. Opportunities to reduce the level of use by the introduction of metering, changes in prices, etc., will undoubtedly tend to disappear as the drought recedes in memory, and it is likely that not until serious shortages again appear imminent will such measures again receive serious consideration.

TIMING OF DROUGHT ADJUSTMENTS

Prior to 1963, very few water managers experienced an actual water shortage or foresaw an impending one. This was reflected in the absence of drought adjustments. Short-run adjustment to meet a shortage threat was undertaken in only 1 community: Northampton, which enacted restrictions in 1961. Randolph and Lenox developed new additions to their sources of water supply, but these actions were the consequence of decisions made prior to the drought.

In 1963, however, 16 communities initiated action in response to actual or expected shortages. During 1963, more communities adopted some type of adjustment to drought than during any other drought year (Figure 16). During the following year, 1964, 10 communities implemented their first adjustment to drought.

Shortly after a water manager perceived the beginning of drought, action was taken to meet the expected shortage of water. Although the data do not



Based on the 39 communities making some type of adjustment to drought.

Figure 16. Community adjustment to drought: time of first adjustment.

allow a more precise statement, analysis of the 25 communities with more complete data suggest that the average time between drought perception and employment of the first adjustment was about 6 months. In 17 communities, the water managers adopted some type of drought adjustment within 1 year. In 2 of the remaining 8 communities, adjustments were not implemented for 2 years *after* recognition of the drought.

There was a tendency for the water managers who perceived drought beginning in 1964 or 1965 to initiate action more rapidly than the managers who viewed drought as beginning 1963 or earlier. Among the former group of managers, the average time of adjustment was about 7 months; whereas, those who recognized drought in 1964–65 were able to initiate action in only 3 months. (This phenomenon may also be related to the publicity generated by that time and the consequent public pressure, as we have already noted in connection with perception itself.)

SEQUENCE OF DROUGHT ADJUSTMENTS

The first response to drought in most communities was the enactment of restrictions on water use. In 25 water supply systems, the first choice among alternatives was the implementation of voluntary or involuntary restrictions (Figure 17). Reliance on emergency water supplies or the

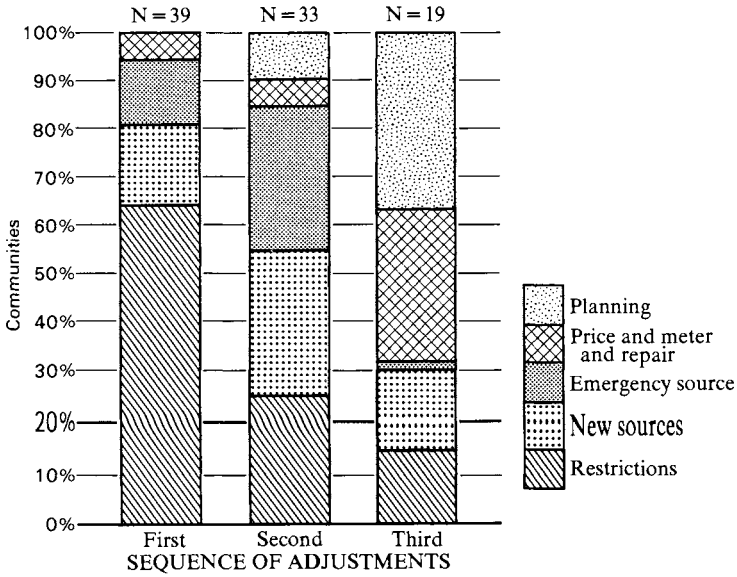


Figure 17. Sequence of community adoption of adjustments.

development of an additional permanent source of water supply constituted the response in 12 of the remaining 14 communities. In none of the communities was the emphasis upon new engineering plans a first adjustment.

Not all communities adopted more than one adjustment to the drought. Of the 39 communities that made some type of adjustment to drought, 33 tried two or more alternatives. Only 19 communities implemented three or more drought adjustments.

In the second type of adjustment adopted by the water managers, a greater emphasis was placed upon emergency and new sources of supply. These two alternatives constituted 60 percent of all second choices. Restrictions on water use were chosen in only 24 percent of the 33 communities as the second adjustment.

In the third group, the emphasis shifted to changes in price, metering, leak surveys, and planning for increases in the existing supply. These alternatives constituted the third choice of adjustment in 62 percent of the communities.

In review, a typical sequence of community adjustment to drought is: (1) enactment of restrictions on water use; (2) emergency and/or new permanent sources of supply; and, finally (3) new engineering plans and modification of consumption. As either a first or second choice, nearly every community adopted restrictions and an emergency or new source of supply. Other types of adjustment to drought were relegated to a third or fourth choice, if considered at all.

In the light of water managers' present solid preference for a few traditional strategies, it appears that some efforts to increase knowledge of alternatives in municipal water supply management and to change attitudes toward the alternatives might be exceedingly useful.