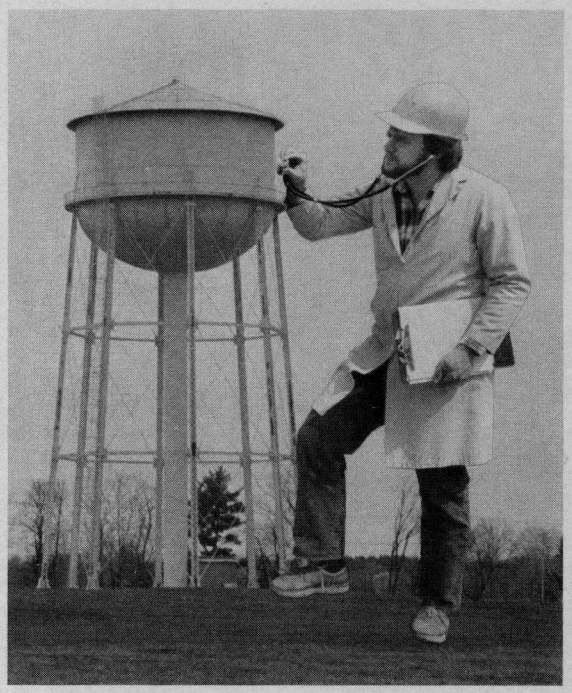
Diagnosing Water System Problems in New York . . .



PIPE DREAMS OR PLANNING?

A Report by the
New York State Senate Research Service
Task Force on Critical Problems

June 1985

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Executive Summary

Expanding the Discussion

During the past several legislative sessions, consideration of matters of "infrastructure" has been intense. The water supply aspect of infrastructure has been part of this consideration, more centrally so after the passage of transportation infrastructure bond legislation in 1983. Two characteristics of the water supply discussion led to this report.

- Concentration on Distribution--The discussion has seemed to be dominated by failures of distribution facilities, especially as they occur in the form of large pipeline breaks that disrupt service and cause flooding in parts of cities.

- Lack of Data--The evidence offered to substantiate claims of advanced deterioration of distribution facilities has been largely anecdotal, based on little direct and statistically significant observation, and/or engaged the assumption that the extent of deterioration correlates highly with age.

Distribution, in fact, is only a part of the entire task of obtaining and conveying safe and sufficient amounts of water to New Yorkers; quality and quantity are matters that are critical and, to a great extent, independent of the matter of distribution. In addition, quality and quantity are complicated subjects:

- Ascertaining and obtaining sufficient quantity involves consideration of patterns of consumption as well as available volumes.

- The quality of water affects the available volume and is related to important economic activities in many places.

The emphasis on distribution facilities will be unfortunate if it means that other water supply matters which may be more serious (e.g., groundwater pollution) do not receive the attention they deserve or if expenditure of finite public resources on one aspect of water supply limits governments' capacities to respond later to more critical problems.

A New Initiative, a Broader Focus: A Water Resources Management Strategy

Partly in recognition of limits in the water supply discussion, the Legislature passed and the Governor signed Chapter 509 of the Laws of 1984. Chapter 509 directs the Department of Environmental Conservation to prepare a water resources management strategy, which is to be implemented in 1988. This mandate, at least by implication, requires a broadly conceived approach to the subject of obtaining and conveying water to New Yorkers. It seems necessary, in order to specify measurable, achievable and worthwhile objectives for such a strategy, that its designers have data that describe current conditions and needs. Adequate data, however, are not available with regard either to the condition of distribution hardware or to the broader and overriding matters of quality and quantity. This study began, then, as an effort to:

- broaden the discussion, i.e., to suggest a context within which distribution systems must be considered; and
- suggest the need for sound evidence to:
  - ascertain the magnitude and nature of effort needed; and
  - efficiently allocate specific water supply problems among the public agencies that conceivably could address them.

And rather than simply suggesting that we need more information, the attempt in this study is to describe the kind of information that is obtainable, useful and not yet widely collected.

The Task Force's inquiry on this matter began before the enactment of Chapter 509. Presentation of this report now, however, is for the purpose of suggesting some fundamental matters which Task Force staff think a water resources management strategy, in order to be useful, should address.

The Contents of this Report

This inquiry, in part, follows the development of the water supply discussion by beginning with a narrow focus on distribution facilities. In the first part of the discussion, it is granted, for purposes of argument, that "the water supply problem" is simply one of creating and maintaining adequate distribution facilities. It is suggested, even granting this assumption, that allegations of deterioration are poorly based and inadequate for prescription

and that better information is obtainable, probably well within the working life of most of the existing distribution hardware.

Then, the effort turns to setting the matter of distribution within an appropriate context, suggesting that there are important considerations beyond the questions of whether or not distribution systems are generally deteriorated and, if they are, what should be done about it. Especially important are that:

- distribution is decidedly not the only water supply problem which demands attention--groundwater pollution, for instance, probably is a more urgent matter; and
- the lack of reliable information which characterizes the matter of water distribution seems to be characteristic of water supply matters in general.

The discussion concludes with an examination of the question of whether or not greatly improved information is affordable. The principal recommendation is that designers of the water resources management strategy give early, prolonged and vigorous attention to the feasibility, utility and specific design of a water supply monitoring and information system that would reduce the risks of overinvestment and underinvestment in water supply systems.

Water Systems:
Sizes, Financial Operations and Deferral of Maintenance

The responsibility of supplying water to New Yorkers is divided among nearly 1,800 community public water systems that are operated by various organizations--cities, villages, towns, counties, special districts, water authorities, and private companies. Some institutional characteristics may affect the condition of water systems.

- The sheer number of suppliers means that many of them are small; smaller localities, having smaller revenue bases, probably have greater difficulty in generating funds adequate to maintain and redevelop their systems.
- There is variety in financial operations. Some suppliers are free to use revenues derived from water rates for non-water-related public functions rather than water system reinvestment. Some suppliers may choose to hold water rates below the level necessary to pay for the water system's operating expenses; such suppliers can cover the

deficit with tax revenues, or they may skimp on advisable maintenance and capital activities.

Although there has been little indication that systems are not obtaining sufficient monies to pay for day-to-day operations, frequent contentions are that:

- many systems have not had the money necessary to regularly conduct the major rehabilitation and replacement work that keeps water infrastructure from generally deteriorating; and
- when such major work becomes unavoidable, it has become a larger task than it otherwise would have been, and such systems must borrow (with the effect of doubling or tripling the total cost) to pay for the enlarged task.

But while observers may claim that deferral of maintenance has been common, they have little specified how deterioration actually has happened and how far it has gone.

Deterioration of Distribution Systems: "Old" Is Not "Deficient"

It is particularly important to emphasize two points pertaining to deterioration:

- It does not appear to be accurate to regard age as a cause of deterioration. The Comptroller General of the United States has concluded that the establishment of a pipe replacement standard based upon a particular age is completely arbitrary. (1) And one consulting engineer concluded that "if a utility adopts a policy of replacing mains that are more than 100 years old, it may replace many miles of sound, useful mains while failing to replace problem segments that are 30-50 years old." (2)
- While it probably is reasonable to expect that some maintenance work in many systems has been deferred for longer than has been economically optimal and that deterioration has occurred faster than it had to, it does not necessarily follow that these systems are in terrible condition. The operating life left in existing hardware may be sufficient to permit system operators to plan a multi-year or even a multi-decade approach to maintenance and rehabilitation, rather than a crash program.

Local systems convey water through networks composed of large and small pipes, plus items (fittings, joints, valves, pumps and hydrants) that facilitate or direct the flow of water. Causes of failure are complex; a deficiency in one item can, and often does, lead to failure by another item. (3)

Nevertheless, it is possible to speak of causes of deterioration in ways other than a sequence of breakdowns; there are chemical and structural processes that lead to a failure. Processes which have been found to be significant in the development of leaks and breaks--processes which vary in the speed of their effects upon system elements without much relationship to age--include temperature changes, soil movement and settlement, improper installation, internal and external corrosion, vibrations, and excessive internal pressure. Low pressure is often a result of tuberculation, a kind of corrosion that roughens and reduces the internal surface of a pipe. Physical defects in a pipe and the material of which it is made appear to correlate significantly with speed of deterioration.

How far, then, has deterioration gone? This is not a question for which a reliable general answer has been developed.

Assessments of Redevelopment Needs: Lack of Data, Problems of Emphasis, and Limited Utility

In the past five years, several nationwide and statewide estimates of water system redevelopment needs (often with emphasis on distribution facilities) have reached the multi-billion dollar range. (4) Most of these assessments are of questionable reliability, and spending much money on the basis of their findings would be imprudent.

The chief deficiency (at this time, an unavoidable deficiency) of the nationwide and statewide assessments is the lack of data that actually describe system condition and performance. Without such data, some analysts have depended on an assumption about the relationship between age and deterioration, an assumption known to be faulty. Others have relied on operators' expressions of needs. Authors have acknowledged data problems:

- The Department of Health noted that the data in its 1983 Facilities Needs Survey "are not validated and do not result from a detailed study done by each respondent." (5)

- A 1984 report (entitled Hard Choices: A Report on the Increasing Gap Between America's Infrastructure Needs and Our Ability to Pay for Them) of the Congressional Joint Economic Committee stated that "the estimates must be viewed with caution as they are often incomplete in coverage due to a lack of data..." and "several researchers reported that there was simply no basis for any estimate of needs, revenue or both." (6)

There have been problems in addition to the data deficiency.

- There has been some reification: estimates or speculations, once published, have been repeated in subsequent research as if they were basic facts and without reference to misgivings about those findings expressed by the originating analysts.

- Often ignored, also, has been that some needs are more pressing than others, and the affordability of meeting a need depends partly on how fast it must be met. Simple quotation of large amounts of money can be alarming: It can give the impression that crisis is imminent when, in fact, almost all of the major capital recommendations of the various studies involve a time frame of 20-30 years for implementation. Some of the Corps of Engineers' findings--the only ones among the reviewed New York State studies that are based on actual observation and testing of water systems--in selected localities suggested quite clearly that not all recommended improvements are necessary for adequate moderate-range system performance.

There are several risks in using the surveys as bases for enacting multi-billion dollar programs.

- To fix old water system hardware is not necessarily to fix that which needs fixing; it would waste money and effort and leave many real problems uncorrected.

- Beginning programs of redevelopment too quickly would not easily permit the re-evaluation of management methods and institutional arrangements that may be the ultimate causes of deterioration and that would result too soon in recurrence of those water system problems that do exist.

- A perception of crisis could cause suppliers to unnecessarily borrow massive amounts of money for redevelopment, bringing a much higher cost of redevelopment than if planning occurred with a longer time frame and with commensurately greater estimates of system revenues.

Analysts employed by the President's Intergovernmental Water Policy Task Force were careful about the utility of their 1980 findings. Speaking of

their extrapolation from a review of ten urban water systems, they noted that:

> A sample of this size is unable to capture the full diversity of characteristics and is statistically inadequate for use in national extrapolations with accuracies greater than an order of magnitude. An estimate with only order of magnitude accuracy provides little assistance to budget-minded legislators and decision-makers. (7)

Further, they noted that:

> The apparent scale of these problems strongly supports the need for a more detailed and thorough study of the nature and dimensions of both the problem areas themselves and the available avenues of solution....a closer determination of distribution system rehabilitation and replacement practices and requirements is essential.... (8)

"Observing" Distribution Systems: Improvement is Possible

We have seen that age is inadequate as a criterion for making repair decisions and developing estimates of the scale of redevelopment needs; deterioration is, instead, a result of a complex interplay of materials and physical and chemical forces. Recent assessments of redevelopment needs have been distorted in quotation and are, sometimes by authors' admission, unreliable for prescription because they are the results of limited observation and/or limited sampling. It is possible, however, to develop data that would yield not only more reliable estimates of the amount of redevelopment need, but also more reliable specification of the items and locations needing attention.

Water distribution systems are complicated networks of many miles of pipes, joints, pumps and valves, and they are located underground and, therefore, difficult to observe. Despite these difficulties, engineers have developed several methods that make it possible to replace rules of thumb (such as age) with information that is more directly descriptive. The methods, which are reviewed in Chapter 4, include water accounting, leakage survey and detection, main break analysis, and various techniques which might generally be called flow appraisal.

The use of these modern methods of water system diagnosis requires the collection and storage of what may seem to be a large volume of data, such as

figures describing production and consumption, a system inventory and a record of pipe breaks. For many local systems, especially the smaller ones, it may be difficult to maintain the data necessary for these kinds of analyses. (Chapter 5 reviews the nature of water supply data which local officials directly or indirectly report to the State Department of Health, Public Service Commission, and Office of the Comptroller.) One engineering consultant, however, suggests that such data can facilitate savings:

> The cost of replacing a mile of water main is $200,000-$500,000 in 1980 dollars....Replacement decisions should be based on the physical condition of mains, not on their age. A geographically oriented information system will cost $50-$150 per mile to develop and $10-$20 per mile per year to update with routine records. The monetary gain from improved main replacement decisions is several orders of magnitude greater than the cost of the information system. (9)

The Context: Uncertainty Regarding Water Supply in General

Large pipe breaks and the resulting damage and disruption of distribution can be spectacular, but the condition of distribution facilities is only one aspect (and not necessarily the aspect in most urgent need of attention) of the broad task of obtaining water supply.

The lack of reliable information which characterizes the matter of water distribution seems to be characteristic of water supply matters in general. For instance:

- Total water use 20-50 years from now is uncertain because of seemingly unavoidable error in predicting both population trends and per capita use.

- Estimates of supply also are problematic, and not only because of limits in estimation methodologies. While raw water seems plentiful, precipitation and streamflow vary from year to year, legally required minimum releases from reservoirs to downstream rivers reduce the amount of water available to some systems, and water quality problems, especially on Long Island, place health-related limitations on the use of some water supplies.

So, as important as water is to the state's economy and the well-being of its citizens generally, the somewhat surprising fact is that it is far more

difficult than it might be to fully answer several fundamental questions:

- What water supply problems do we know to exist, and how serious is each relative to the others? That is, what are the kinds and probabilities of water supply-related risks that New Yorkers must assess?
- Which of many alternative technological and institutional approaches to the solution of water supply problems are feasible and most efficient in New York State as a whole and among its regions?
- By what criteria should entire efforts or parts of efforts to solve water supply problems be allocated to local, regional or state levels of government?

While inexactitude in water supply matters is not totally avoidable, it can and should be minimized. The risks of:

- failing to recognize which problems are more serious than others;
- investing in inappropriate solutions; and
- inefficiently allocating public resources

are risks that are maximized when critical public decisions are approached without the means of answering such questions. Observers, however, have pointed out that certainty is unobtainable and that choices and risks of some kind are therefore necessary.

> What degree of risk are we willing to accept in municipal water supply? For instance, in the 1960-67 drought a crisis arose and the water supply managers were called upon to meet a situation that wasn't counted on. The fact of the matter is that with some recourse to extraordinary measures, the basic water needs of [New York City] were met even during this very critical period. <u>What degree of risk are we willing to accept?</u> [One] position is that we proceed on the basis that we accept no degree of risk. In other words, based on past experience we build capacity and systems so that we always meet projected needs without taking extraordinary measures. We build for the rare occurrence. This simply means that we build a tremendous overcapacity which will seldom be used. (10)
>
> The 60's drought...had a statistical return period of once every 400 years. We thought that the early thirties drought was once in 100 years but it turned out to be one in 20. When an elected official's reputation is involved, we can expect he will want the degree of risk to be as close to zero

> as possible....[But] we can save literally millions of dollars by introducing in the mix a reasonable risk factor. (11)
>
> An elected official that wants a zero risk is often taking another risk of increased taxes for the cost of a system that is grossly overdesigned. There are two sides to every coin. What kind of tax burden are people willing to pay for the risk? It is obvious that zero risk is expensive and difficult. (12)

Any strategy to correct actual or projected water supply deficiencies will involve demand reduction and/or supply augmentation. Possibilities, some more realistic than others, are reviewed in Chapter 7.

The Price of Uncertainty and the Price of Information

Over-reaction, Under-reaction, and Risk Reduction

It has been suggested that a lack of data and, to some extent, a lack of theoretical knowledge characterize our water supply concerns. Future water supply development, therefore, will involve choices, and any choice will involve some risk. It is important, at this point, to explicitly state and develop another contention which has been implicit in the study: the lack of data is considerably remediable, and the amount of risk in development decisions therefore can be reduced.

Abstractly stated, potentials of uncertainty are both over-reaction and under-reaction.

- Over-reaction would involve:
  - investment of finite public resources on development of water supply capacity that will very rarely, if ever, be needed;
  - fixing system elements that do not need fixing (and incidentally failing to fix elements that are the ultimate causes of a malady); and/or
  - unnecessary borrowing that would entail the payment of interest rates that double or triple the cost of a project.
- Under-reaction mainly would involve matters which "fall through the cracks" among local jurisdictions and between local and state jurisdictions. Such problems might be of an unprecedented nature or

scale, may pose staggering economy-of-scale problems, or require a degree of cross-local cooperation that is hard to obtain.

Some might ask whether or not it is worth the time, effort and expense necessary to reduce the uncertainty before engaging in significant further development. The answer depends on whether or not:

- the information that can be acquired will reduce risk very considerably; and
- there is sufficient time to generate the information before having to engage in major development.

In other words, what can we know, and how soon can we know it? It is futile to expect to achieve certainty before taking actions, and it would be dilatory to suggest that we should. On the other hand, it may be foolhardy to not take the time to generate that information which would be useful and obtainable, for instance, in less than a decade.

Studies vs. Monitoring: The Benefits Of Continuity, and the Cost of Obtaining It

More detailed data could give water system operators and policymakers a greater capacity to monitor. Monitoring--continuity of observation--would be in contrast to the too-common situation in which suspicions of serious problems result in sporadic and quick (though not necessarily inexpensive) studies that, as Chapter 3 reviews, even the authors acknowledge as unreliable. Most often, a sound system of monitoring would render the observations for which analysts are asking when they recommend further study.

The idea of monitoring, however, means not only that operators and policymakers will have more adequate information at the time they decide that something needs to be done; it also means that the perhaps subtle signals of deterioration, generally or in particular systems, will be recorded and that problems, therefore, will not grow to points of crisis or seeming-crisis before they are at least perceived.

It is conceivable that the water resources management strategy could include the development of a feasible and more useful water supply information system. It would be necessary, however, for strategy developers to address

questions that are perhaps more difficult and certainly more elemental than have so far received attention.

(1) What do we need to know about a water supply system in order to ascertain how deteriorated or otherwise inadequate it is?

(2) If a system is in a state of advanced deterioration or otherwise grossly inadequate, what do we need to know in order to ascertain how it became so? (13)

(3) What do we have to do to generate that information?

Would the savings facilitated by a detailed and extensive information/monitoring effort be worth the money and time it would take to develop it? With regard to distribution systems, for instance, adequate information could ensure that the items to be repaired or replaced are the items which have caused the water supply problems--recurrence of the problems would be minimized. And spot repairs facilitated by more detailed information would cost less than wholesale excavation and replacement.

Would such savings justify the expense of monitoring? Certainly some observers doubt it, if the persistence with which some localities avoid installation of meters is any indication. Many--probably most--professional and academic water supply experts regard metering to be worthwhile; some regard it as essential for sound management. To those who are persuaded of the value of user metering, the amount of metering among the state's municipal systems might seem inadequate. It appears that about 31 percent of the systems have no residential metering, and even though more than 90 percent of the systems that serve 10,000 or more have metering, it may be that as much as half of New York's population is not residentially metered. Among the larger systems that have little or no residential metering are those serving Rome, Schenectady, Buffalo, and New York City. The number of people served in these places alone constitutes about 40 percent of the state's population, and a full summation of unmetered residences would have to incorporate also the populations of the many smaller systems that are not metered.

But to the consideration of savings vs. repair/replacement costs it is necessary to add another consideration: the value of water itself. The cost of producing water probably is not often apparent in the rates charged for it; subsidization of water rates, at least through deferral of maintenance, is com-

mon, and water is generally regarded as plentiful. Developments may change this situation.

- If the necessity of austerity in government budgets continues, there will be a decline in governments' capability to subsidize rates at the same level (or perhaps at all). This would be true even if the cost of producing water was not rising, generally with other government and utility operations and specifically as a result of safe drinking water standards.

- Groundwater pollution could conceivably make supplies scarce in certain localities, regardless of whether or not that scarcity resulted in higher rates.

In judging the advisability of the development of a broadened monitoring capacity, then, it is necessary to consider not only a strict comparison of the cost of monitoring and the repair/replacement savings, but also whether or not trends in the cost and actual availability of water, in and of themselves, warrant the kind of care that a monitoring capacity represents.

A Minimal Recommendation: Consideration of Monitoring

The chief recommendation deriving from this inquiry, then, is that the designers of the water resources management strategy give early, prolonged and vigorous attention to the feasibility, utility and specific design of a water supply monitoring and information system that would include the kinds of data explored in Chapter 4 and elsewhere in this report. Whether or not it would be possible to collect and use data of such detail as implied in Chapter 4, it probably is reasonable to:

- try to obtain far more information than has been brought to bear in past assessments of redevelopment needs; and

- expect that such an increment of information would make future assessments considerably more reliable.

The minimal nature of this inquiry's recommendation is not meant to suggest that the draft strategy should necessarily be limited to the matter of monitoring. The matter of monitoring capacity is just one of the several aspects of "the water supply problem" which, at least implicitly, call for the development of criteria for allocating the resources of local and state government among

those various aspects. (14) The designers of the strategy may wish to attend to specific policy considerations such as:

- whether or not rates and other water-generated revenue should be adequate for all system investment needs;
- the applicability of reserve budgeting ideas to water supply redevelopment and to water supply operations generally;
- the cost-effectiveness of complete user and flow metering and ways by which localities without such metering might be induced to install it;
- regional arrangements for emergency or routine supply needs; and
- any jurisdictional overlap or gaps that may exist among the state agencies concerned with local water supply.

Recommendations for specific redevelopment actions would be no more reliably based as a result of this report than they have been as the results of previous research. Current efforts to develop information specifically on local financial capabilities and water use could enable policymakers to address those matters more confidently, and it seems likely that findings will seem mixed to most observers. For instance, the following points might simultaneously be true:

- Water losses through breaks and leaks, and the potential for further damage, make it advisable to accelerate efforts to rehabilitate distribution system hardware.
- This acceleration need not occur at a breakneck pace: Five or ten years is not a major amount of time in the total life of system hardware, and it is possible in that amount of time to develop much information that would make large-scale rehabilitation efforts far more efficient than they could be now.
- Local governments have the resources to achieve such an acceleration, but for some of them, it would involve a painful decision to raise and dedicate water rates or otherwise generate revenues for the effort.
- Certain problems of water supply are huge and unprecedented and may require quick, continuing and great state involvement. Long Island's groundwater problem is the best example.
- Conservation conducted in fairly painless ways has the potential for great dividends. Specifically, potential savings through conservation methods such as those surveyed in Chapter 7 could help the state and its localities to avoid the necessity of large-scale, expensive

and probably acrimonious projects such as construction of dams and conveyance of water from far rural areas to urban users.

Such a set of findings is a reasonable expectation, and it probably already has proponents and opponents. Their debate, however, is based far more on assumptions and far less on reliable data than is fitting for such a critical subject as water supply.

It may seem inappropriate for the state to be concerned with such details as leakage, break incidence and low pressure in individual systems. Such matters have in the past received scant attention from the state as it concentrated on matters--chiefly water quality--that can more obviously and directly threaten human well-being. Recent proposals that the state specifically and actively help to fund massive water infrastructure redevelopment, however, make those distribution system details more pertinent to state considerations: It is the absence of reliable data on those details that has defeated efforts to assess the amount of deterioration and thereby to credibly project how much money is necessary and whether or not the state's assistance is needed.

With regard to monitoring of distribution systems, it is important to note that the methods of obtaining data (as reviewed in Chapter 4) are well enough established and regarded that they could be considered to be part of (rather than prerequisites for) state-of-the-art maintenance. More sophisticated water supply monitoring, then, would improve not only the state's attempts to ascertain the magnitude and nature of water system development needs statewide, but also the efforts of local water system operators. In the act of generating data, the operators would be engaging in routines (water accounting, leak detection, break analysis, pressure surveys) that would enable improvements in maintenance, service and the working life of facilities, regardless of state involvement. Designers of the state's water resources management strategy, therefore, might well consider whether or not the state should provide an incentive to ensure that local suppliers regularly employ these routines, even if the local suppliers do not report the results to the state.

DEC's Mandate and Regard for the Long Run

We wish to be clear: We do not know whether or not strategy designers, upon consideration, would find the cost of a more detailed monitoring system to

be justifiable. We recognize, however, that if the effort to create a water resources management strategy is to be very useful, it will not be possible for its designers to ignore:

- the information deficiencies that have so far made studies unreliable, especially for prescriptive purposes; and
- the conditions--matters relating to local capabilities and will and to how much the state should mandate or do itself--that make it difficult to change those information deficiencies.

The Department of Environmental Conservation's mandate prior to completion of a draft water resources management strategy does include studies of conditions and financial capacities. However, the lack of basic data that has been a problem in previous studies is not likely to be ameliorated in 1985 or 1986. What may be more important for the Senate and other interested observers to attend to, then, is whether or not the draft strategy, to be completed in 1987, either:

- presents a way of correcting, as much as is feasible, the deficiency in information which so far has characterized consideration of water supply development and redevelopment; or
- demonstrates why it is unfeasible or not worthwhile to correct this deficiency.

Without developing a means of more detailed monitoring of water supply-related phenomena:

- definitions of problems and specifications of their relative magnitudes, at least until matters approach great seriousness, will continue to be unreliable; and
- the allocation of public capacity toward the solution of the problems will continue to run a higher-than-necessary risk of being inefficient.

Publicity surrounding several water supply-related matters--pollution on Long Island, the City's third water tunnel, multi-billion dollar estimates of distribution system redevelopment needs, recent fears of a drought--has, whether or not all of these matters represent real jeopardy, been alarming. This has sensitized us to the real value of water and the probability that we should not--perhaps cannot--any longer take water for granted to the extent we have

historically. Greater care for this indispensable resource now is not only advisable, but probably necessary. A water resources management strategy will manifest our recognition of this necessity.

A short-term view is likely to result in feelings that broader water supply-related monitoring would require an unrealistic enormity of effort. It probably would not be possible to develop such a monitoring capacity by 1988, when the strategy is to become effective. But the strategy will be subject to biennial review, and the planning and implementation of an informational component could be incrementally incorporated into the strategy. Monitoring implies continuity in our concern, and continuity of effort would be necessary even to make broader monitoring possible.

Strategy designers should actively, explicitly and publicly consider whether or not such a monitoring capacity would be worthwhile. The answer will depend on predominant views of the economic and other values of water. Whatever the outcome of this consideration, however, a basic proposition should be recognized at the outset: If the proper time is taken and effort is made to develop the water resources management strategy from its most basic element--information--then perhaps New York State can create a continuing capability to recognize, predict and prepare for its people's water needs rather than spend its resources and efforts simply developing physical and too-temporary solutions to today's particular problems.

Introduction

Recent Concerns and a New Initiative

The Impetus: Deficiencies in the Discussion

During the past several legislative sessions, consideration of matters of "infrastructure" has been intense. The water supply aspect of infrastructure has been part of this consideration, more centrally so after the passage of transportation infrastructure bond legislation in 1983. Two characteristics of the water supply discussion led to this report.

- Concentration on Distribution--The discussion has seemed to be dominated by failures of distribution facilities, especially as they occur in the form of large pipeline breaks that disrupt service and cause flooding in parts of cities.

- Lack of Data--The evidence offered to substantiate claims of advanced deterioration of distribution facilities has been largely anecdotal, based on little direct and statistically significant observation, and/or engaged the assumption that the extent of deterioration correlates highly with age.

The Task Force and other Senate staff believed that both of these characteristics constitute serious deficiencies in the discussion and create considerable possibilities for waste.

- The emphasis on distribution facilities will be unfortunate if it means that:

  . there is an inadequate recognition that distribution facilities are part of an interrelated set of water supply-related matters;

  . other water supply matters which may be more serious (e.g., groundwater pollution) do not receive the attention they deserve; and/or

  . expenditure of finite public resources on one aspect of water supply limits governments' capacities to respond later to more critical problems.

- And regardless of whether or not there are water problems other than distribution, the offered evidence of distribution facility deterioration, while good for discussion, is very indirect and is insufficient for ascertaining the cost of rehabilitation or the location of deteriorated facilities.

This study began, then, as an effort to:

- broaden the discussion, i.e., to suggest a context within which distribution systems must be considered; and
- suggest the need for sound evidence to:
  - ascertain the magnitude and nature of effort needed; and
  - efficiently allocate specific water supply problems among the public agencies that conceivably could address them.

And rather than simply suggesting that we need more information, the attempt in this study is to describe the kind of information that is obtainable, useful and not yet widely collected.

Recent legislation indicates that the Legislature and Governor already have recognized some problems in the discussion. One provision of Chapter 509 of the Laws of 1984 directs the Department of Environmental Conservation to prepare a water resources management strategy, which is to be implemented in 1988. The Task Force's inquiry on this matter began before the enactment of Chapter 509. Presentation of this report now, however, is with the intention of suggesting some fundamental matters which Task Force staff think a water resources management strategy, in order to be useful, should address.

This Report is Both Broad and Technical

The attempt to suggest a context for consideration of the deterioration of distribution facilities has resulted in this report being somewhat of a synthesis or overview of water supply matters. On the other hand, the attempt to demonstrate deficiencies in the evidence so far offered, and to explore possible remedies, has resulted in parts of this report being quite technical. Chapters 2 and 4, especially, treat matters usually considered only by engineers and water system operators. We have attempted to represent these technical matters in a readily understandable manner, but in any case, they are subjects which cannot be ignored if assessments of distribution system needs are to be realistic. Furthermore, we did not wish to suggest the need for more information--a suggestion

which sometimes is regarded as nothing more than dilatory--without exploring also the specific nature of such information.

Contents of the Report

Here is a preview of the contents of this report.

Part I contains two chapters which set forth some basic information about the study's subject, water systems.

- Chapter 1 describes the institutional setup through which the function of water supply has been conducted, and it touches on the possible relationship between, on one hand, economies of scale and variations in modes of funding the water supply function and, on the other hand, deterioration of facilities.

- Chapter 2 is a discussion of the nature and causes of deterioration of distribution system hardware. The chapter describes the development of pipeline breaks, leaks and pressure problems, and discusses a common misconception: that the age of an element of hardware can be reliably used to indicate its condition.

Part II explores the nature of water system information regarding both what some people have suggested that we know and what is possible to know.

- Chapter 3 is a review and critique of major nationwide and statewide assessments of water supply needs. It notes problems of sample and theory and quotes the authors' own misgivings about the generalizability and policy utility of their assessments. Pervading most studies so far has been a lack of the kind of data that results from direct observation of distribution system hardware.

- Chapter 4 is a review of some of the arduous methods by which the basic data deficiency noted in the previous chapter might be corrected. The reviewed methods are water accounting, leakage surveys/detection, break analysis, and flow appraisal (including pressure modeling). These methods could render the information which has been needed to reliably assess water supply redevelopment needs.

- Chapter 5 describes the nature of data that local suppliers currently report to state agencies, points out that the extent of metering may be inadequate, and asks some basic questions about the value of better data.

Part III constitutes a major shift in focus. Part II, in effect, suggests that even if we granted that deterioration of distribution facilities is the major water problem facing the state, decision-making without further obtainable information is unnecessarily risky. Part III, on the other hand,

places the problem of distribution facilities in a context of larger water supply questions of which distribution is only one aspect; it suggests that failure to consider the problem of distribution within this larger context could result in a misallocation of the limited resources of the state and its localities.

Chapters 6 and 7, then, relate to the other chapters only loosely and present considerations which should not be ignored when addressing the matter of distribution.

- Chapter 6 describes persisting uncertainties regarding projection of water demand and ascertainment of raw and available supply (including the effect of groundwater pollution on available supply).
- Chapter 7 reviews some of the demand reductive and supply augmentative alternatives for obtaining an adequate balance between supply and demand.

Part IV, consisting of Chapter 8, is the conclusion and is essentially a question: Is the information that is obtainable worth the expense and time it would take to generate it? The answer depends on:

- how imminently and how greatly water supply is in jeopardy; and
- a comparison of the cost of generating the information with the possible costs of making redevelopment decisions without it.

One point that receives special attention is the idea of monitoring, i.e., a continuity of concern and observation that is in contrast to the sporadic and quick studies which have so far characterized consideration of the matter of water infrastructure.

Most fundamentally, the report concludes that design of a useful water resources management strategy should attend not only to the questions of "what is the condition of water infrastructure?" and "how did it get that way?" but also to "what information is necessary to reliably answer those questions, and what do we have to do to develop that information?"

It seems very likely that if such questions receive attention, it will become apparent that a resource as valuable as water deserves the greater care that monitoring implies. And this conclusion will hold regardless of whether the data that results from the monitoring is reported to the state or simply becomes part of local maintenance routines.

The implication, then, with regard to the development of a water resources management strategy is noted at the end of this report:

> Strategy designers should actively, explicitly and publicly consider whether or not such a monitoring capacity would be worthwhile. The answer will depend on predominant views of the economic and other values of water. Whatever the outcome of this consideration, however, a basic proposition should be recognized at the outset: If the proper time is taken and effort is made to develop the water resources management strategy from its most basic element--information--then perhaps New York State can create a continuing capability to recognize, predict and prepare for its people's water needs rather than spend its resources and efforts simply developing physical and too-temporary solutions to today's particular problems.

PART I.

Water Systems: What Are We Talking About?

Photo: Courtesy of New York City Municipal Archives

Chapter 1.
Who Delivers Water, and How?

Recent discussion regarding all kinds of infrastructure, whether it be roads, buildings or pipes, has popularized the term "deferral of maintenance." The essential idea is that instead of conducting repairs and other maintenance procedures when they become advisable, operators of infrastructure save money by waiting until a subsequent fiscal year to conduct these repairs and procedures. A series of deferrals, occurring because the money allocated to an infrastructure operation in a public budget is inadequate to cover all advisable expenditures, results in deterioration at a rate that is faster than necessary.

The actual incidence of this phenomenon is not clear, although it is popular to suspect that it is common. This chapter describes some of the characteristics of water supply institutions in order to develop some basic ideas about why deferral of maintenance may be more common than many observers think wise. Some of the most important inferences are that:

- responsibility for water supply is divided among many local suppliers, and some of them are small and therefore have difficulty in generating money every year for all maintenance needs; and
- revenues obtained from water charges may sometimes be diverted for use in other local operations unrelated to water supply.

Water Systems: Numerous, Local and Diverse

The water and sewer industries combined represent the third largest American industry in terms of capital investment (after electric utilities and petroleum). Nationwide annual investment in new facilities comes to more than $5 billion, 80 percent of which was locally funded in 1978. (1)

In New York State, too, the supply of water has been mainly a local concern. Nearly 1,800 community public water systems serve more than 16 million of the state's residents. (2) Most of the systems are quite small. The largest 235 systems, while constituting only 13 percent of all systems, provide water to 92 percent of the state's population served by public water systems. (3) Table 1 and figure 1 show a breakdown of public water systems by population served.

Table 1

Public Water Systems by Population Served

POPULATION RANGE	NO. SYS-TEMS	TOTAL POPULATION SERVED	% OF SYS-TEMS	CUM.% OF SYS-TEMS	% OF POP.	CUM.% OF POP.
under 25*	176	365	9.9	9.9	0.0	0.0
25 - 100	225	14,359	12.7	22.6	0.1	0.1
101 - 250	227	39,962	12.8	35.4	0.2	0.3
251 - 500	232	87,140	13.1	48.5	0.5	0.8
501 - 750	141	87,835	8.0	56.5	0.5	1.3
751 - 1000	122	108,603	6.9	63.4	0.7	2.0
1001 - 2500	267	442,786	15.1	78.5	2.7	4.7
2501 - 5000	144	534,836	8.1	86.6	3.3	8.0
5001 - 10000	91	673,533	5.1	91.7	4.1	12.1
10001 - 25000	74	1,183,596	4.2	95.9	7.3	19.4
25001 - 50000	38	1,315,365	2.1	98.0	8.1	27.5
50001 - 75000	14	856,630	0.8	98.8	5.3	32.8
75001 - 100000	1	88,709	0.1	98.9	0.5	33.3
100001 - 500000	14	2,915,454	0.8	99.7	17.9	51.2
500001 - 1000000	2	1,383,312	0.1	99.8	8.5	59.7
over 1000000	1	6,552,718	0.1	99.9	40.2	99.9

All population figures are populations as known by the Department of Health.
* Includes water systems with unknown populations.

Source: Department of Health, Bureau of Public Water Supply Protection, August 14, 1984.

Approximately 40 percent of the state's water suppliers purchase all or part of their water, leaving about 1,080 systems which rely solely on their own supplies. Such purchases are commonly arranged between a water system which sells water on a wholesale basis and a water system operating a local distribution network. New York City, for example, sells water to municipalities in counties in which City reservoirs are located. Over 600,000 non-City residents are served by the City's water.

The state's water systems can be classified also by ownership. Most people in New York are served by government-owned water systems. Investor-owned systems supply 1.7 million people and range in size from small subdivisions serving as few as 25 people to decidedly large concerns such as the Jamaica Water

Figure 1

Public Water Systems by Population Served

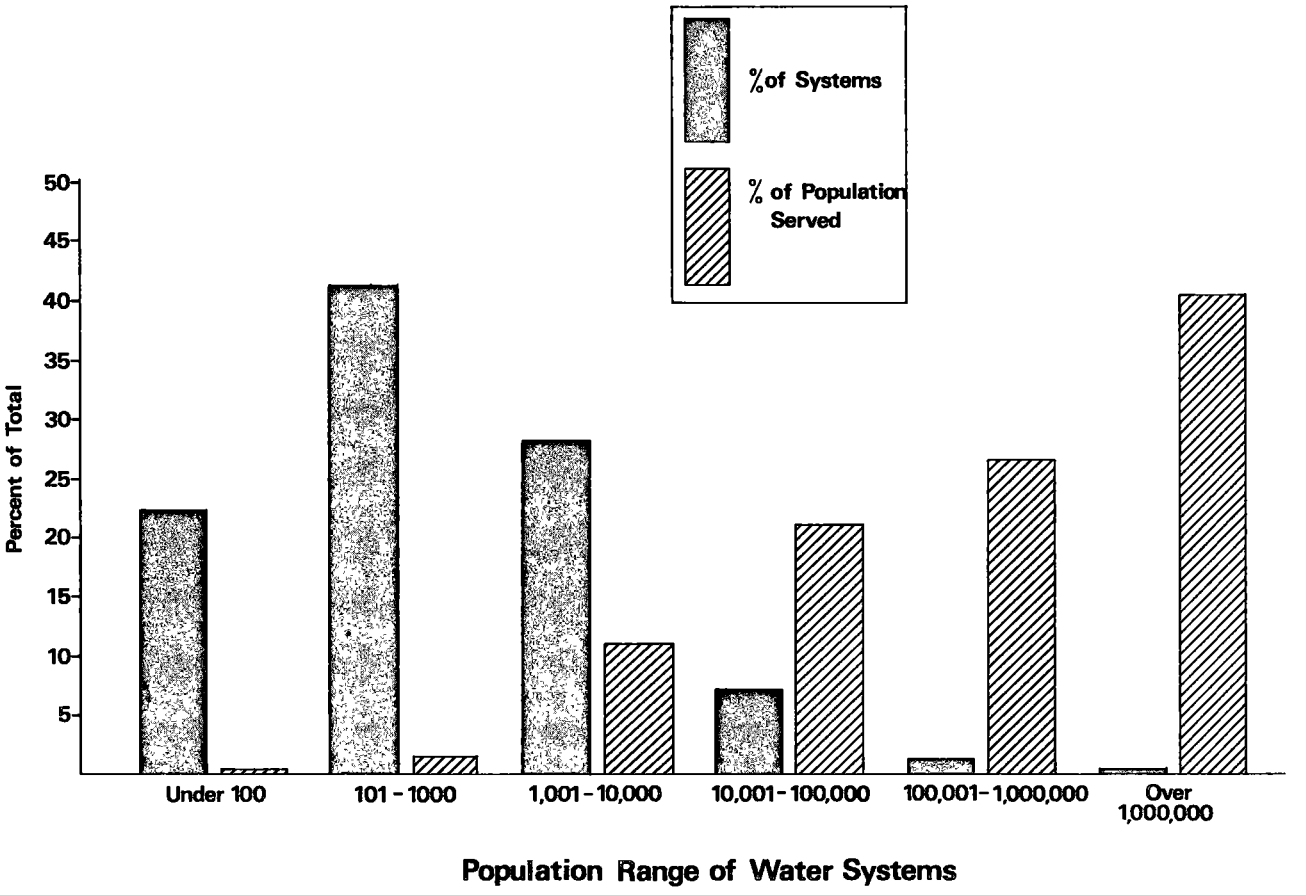


Figure adapted from Table 1.

Supply Company, which serves over one-half million residents in Queens and Nassau Counties. Table 2 shows a breakdown of water suppliers by type of supplier.

The service area of a water supplier is partly determined by the type of supplier. The service areas of private companies are limited only by the permission of the areas served. A private company may operate in any municipality in which it receives permission, although it need not serve the entire municipality. Private water companies may even be interstate: the Spring Valley Water Company in Rockland County is a subsidiary of United Water Resources, which

Table 2

Types of Water Suppliers

Type of System	No. of Systems	Population Served
City	60	9,017,571
Town or Town District	917	2,493,287
Village	414	1,386,368
County	5	3,548
Authority	4	1,670,000
Company-owned towns	2	525
Private	361	1,722,119
Indian Reservations	6	1,785

Notes: Townwide water supplies and town districts are grouped together by the Department of Health. Population figures are as known by the Department of Health. Some suppliers have unknown populations, and some double counting may result from separate entities supplying different services to the same population. For example, one entity may treat water while another distributes it.

Source: Department of Health, Bureau of Public Water Supply Protection, August 14, 1984.

serves areas of New Jersey as well as New York. Public water distributors, on the other hand, generally serve areas within a single county (seven villages do cross county lines). Distribution of a single publicly owned water supply in more than one county is accomplished by purchase agreements between separate suppliers. Among the public systems:

- City and village water systems are limited to areas within city and village boundaries.
- Two or more municipalities may enter into contracts for joint water supply, provided that each municipality take the same procedural steps which it would be required to take were it acting alone. In such cases, each participating municipality purchases water in bulk and distributes to its own customers. (4)
- A town may establish a district which serves part(s) of its area or serves the entire town outside of village boundaries through a consolidated district or as a town function. A town may also acquire any existing water system, or part of it, within its county or an adjoining county in order to provide for the town's water supply. (5) Villages may be included in town service areas if approved by a majority of village ballots cast in a general election.

- Counties may establish districts serving all or parts of cities, towns and villages. Such districts must, with the exception of Suffolk County, serve areas of more than one municipality. (6)

- The service areas of water authorities are defined in each enabling act. The four active water authorities in the state all serve areas within a single county.

The powers among the different kinds of public water systems are somewhat varied. All types of local governments (cities, villages, towns and counties) may supply water, as may state-created special water authorities. The various types of publicly owned water systems evolved according to the needs of the times, and new types of entities appeared when needs could not be met by existing institutions.

Appendix 1 is a description of the various levels and types of government as they relate to water supply. This appendix contains discussions of:

- the derivation of the different kinds of local governments, with special attention to the financial and administrative characteristics that limit and abet their water supply efforts;

- state agency involvement--quality monitoring by the Department of Health, source permit functions executed by the Department of Environmental Conservation, oversight of private water companies by the Department of Public Service, and other agency activities; and

- the federal effort, which is minor with regard to capital construction and more substantial with regard to quality safeguards.

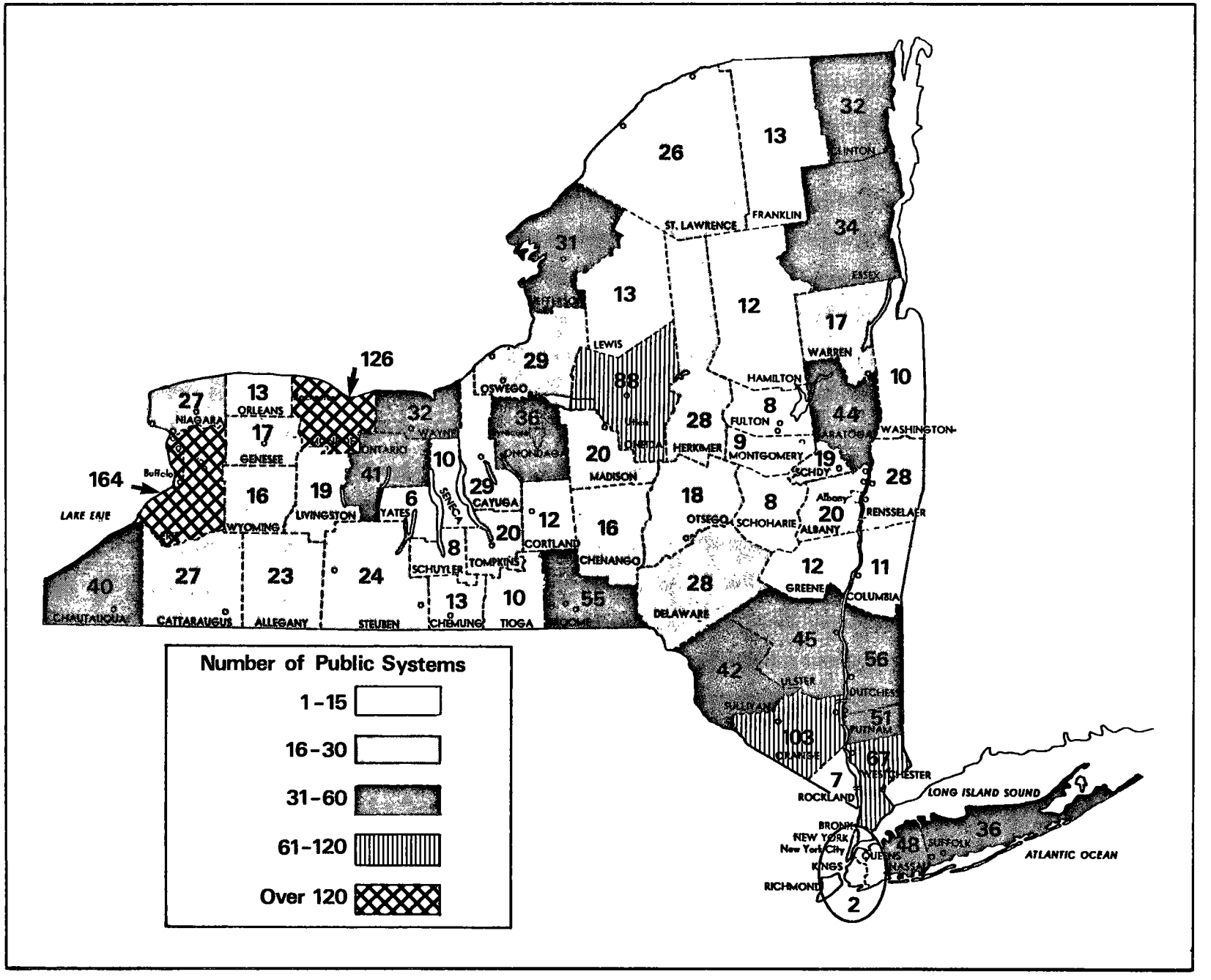
It is clear that water supply in New York State has been and continues to be primarily a local responsibility, and it is through examination of the distinctions among the powers of the different types of local suppliers that ideas about maintenance differences should be sought.

Some Financial Distinctions

There is variation among the systems with regard to several important financial/managerial features:

- the relationship between revenues and expenditures, i.e., whether or not they must be equal and whether or not water system revenues can be diverted to the support of other public services;

Figure 2.
Community Public Systems by County



- the legal and practical constraints on users' water rates; and
- the mode of financing repairs and improvements.

Revenues and Expenditures

Compared to the other suppliers, cities and villages have a great deal of discretion and flexibility in water system operations, including financing. Individual city charters spell out the organization of each city's water system; some may limit expenditures to budget appropriations or estimated income. The city legislative body or village board of trustees may choose to restrict the use of water rents to water system expenses, but no external controls exist over the setting of rates or the use of city or village water revenues. Some cities and villages choose to extract a revenue surplus from their water departments, while others subsidize their systems from the city or village budget. One observer's impression is that the incidences of subsidy and surplus extraction are about equal. (7)

New York City is especially noteworthy with regard to use of water revenues for other public purposes. The City returns only 80 percent of its water rate-supplied revenue to its system, compared to an average of 97.4 percent for the state's other publicly owned water systems. (8) It has been estimated that the City in 1972 generated a surplus of $120 million from its water rates and transferred it to the general treasury. (9) Similarly, the Buffalo water system contributes $4 million annually to the city general fund, as mandated by local ordinance. The city regards this as a rental fee for city offices. (10)

Other types of suppliers are more constrained. In town and county districts, all money collected from water services must be used for water services. Water districts are required to allocate revenues first to system maintenance and operation, and then to debt service. Any deficit must be covered by special assessments on properties within the district. Districts may not produce excess funds for diversion to other uses, and they may not run deficits to be covered by general revenues. With the exception of the establishment of specific reserve funds, revenues must equal expenditures over succeeding years. Any annual surplus must be liquidated in the following year by an adjustment of rates or service levels.

Similarly, in towns which have dissolved special water districts and provide water services as a town function, all water rate revenues must be allocated to system maintenance, improvements and expansion, and to system debt service. (11) Any costs not covered by water revenues must be covered by property assessments, either in proportion to benefits received or equally upon all property in the town outside of villages.

Among the special water authorities, revenues must be sufficient to pay all debt service and expenses for operation and maintenance. Rates and charges must also be sufficient to fund reserves for depreciation, maintenance, contingencies and debt obligations. Money may not be transferred to local governments except by contract in exchange for goods and services.

Private water companies are profit-oriented, but because they provide a vital public service, their rates and service levels are subject to approval by the Public Service Commission. The Commission must ensure that adequate and safe service is provided at a reasonable price. Because revenues include profits, companies do not receive tax exempt status. Many of the smaller companies are not independent entities, but are part of land or development companies which provide water service as a part of a larger function.

Rates

The amount of money a system obtains for its product depends on its rates. Sales may be based upon a flat rate, which disregards volume of use, or upon various types of unit rates. (The different kinds of rate structures are reviewed in more detail in Chapter 7.) The setting of water rates, mainly, is constrained by little other than actual revenue needs and local political concerns. Article IX of the State Constitution provides local governments with the right to a fair return on their local utility operations.

The state, then, does not require any specific link between water rates and water system expenditures in cities and villages. Rates are set according to the judgment of local elected officials. Inasmuch as higher costs for any service usually are unpopular, city and village water rate hikes probably have been constrained to the effect sometimes of lower system expenditures and/or deficit operations.

In town districts and in towns which provide water as a regular town function, water rates are set by the town board. Rates in county districts are set by an administrative head or body subject to confirmation by the board of supervisors. Although water revenues in town and county districts must be used

for water system expenses (with shortages made up by property assessments), it is nevertheless possible to underestimate expenses or decrease maintenance budgets in order to temporarily avoid rate increases.

Water authorities operate independently of local governments and set rates according to their own determinations. Elected county officials appoint authority commissioners, but commissioners are then free to operate without interference. Water rates are set to meet operation and maintenance expenses, debt management needs, and reserves. Authorities must submit annual reports to county boards, but need not otherwise answer to county officials.

Private water company requests for rate increases must be approved by the Public Service Commission, which also monitors all aspects of company operations in order to ensure fiscal soundness.

Financing of Repairs and Improvements

Two ways of developing monies for repairs and improvements are borrowing and the establishment of reserve funds into which payments are regularly or occasionally made.

Debt--In addition to using income derived from water sales, suppliers are entitled to borrow to finance water system improvements. While the state's municipalities have constitutional limits placed upon total debt, a 1905 constitutional amendment excludes all water supply-related indebtedness from debt limits. (12) However, the period of contracted indebtedness must not exceed the period of a capital asset's probable usefulness, as set forth in law.

All such indebtedness in cities, villages, and town and county districts is backed by the full faith and credit of the locality concerned. Water districts may not incur debt of their own, but may utilize the bonding capacity of their town or county.

Most public water suppliers, then, must use general obligation bonds. Only the state-established water authorities may use revenue bonding. General obligation debt traditionally incurs lower interest rates than revenue bonds due to the broad revenue-raising abilities of municipal governments. The State Constitution also provides, in the event a municipality fails to make necessary appropriations, that general obligation debt service be paid out of the first received revenues. (13) Nevertheless, there is some thought that the limitation of local governments to the use of general obligation bonds has served to limit their access to the bond markets, where buyers often prefer offerings which exhibit specific revenue sources to retire bonds. This lessened access may have

occurred despite the fact that a municipality can, for instance, pass an ordinance pledging water receipts to bond retirement.

Private water suppliers must use the private bond market, and they rely upon the Public Service Commission to approve rates sufficient to meet bond obligations.

Reserve Funds--An alternative or supplement to borrowing is the maintenance of reserve funds established from water revenues. There are two major kinds of reserve funds:

- Capital reserve funds are for construction, reconstruction, or acquisition of specific improvements.
- Repair reserve funds are for capital and equipment repairs recurring less than annually.

Of limited use, also, are general reserve funds.

Counties, cities, villages and towns may establish capital reserve funds; municipal corporations (i.e., counties, cities, villages and towns) and improvement districts may establish repair reserve funds. General reserve funds are available only to suburban towns. (14) (15) Cities and villages are free to appropriate monies into the funds from any unobligated revenues coming into their general funds. Other suppliers, in general, would allocate a portion of their water revenues.

Capital reserve funds are greatly restricted in use. Funds may be used to finance all or part of the cost of capital improvements or the acquisition of certain items of equipment. They cannot be used by special improvement districts, nor can they be used to defray improvement costs which must be borne by special assessments. Expenditures from capital reserve funds may be made by authorization of the local governing board only for designated specific improvements or acquisitions. After a project has been completed or abandoned, surplus monies may be transferred only to another capital reserve fund. No monies may be used for repairs or operating expenses, nor may they be transferred to the general fund.

Repair reserve funds contain fewer restrictions. Town or county improvement districts as well as municipalities may establish repair reserve funds. Any revenues provided by budgetary appropriations and not required to be paid into any other fund may be deposited in a repair reserve fund. The fund may be used for repairs of capital improvements or equipment, provided that such repairs recur less than annually. Emergency expenditures may also be made if

they are approved by two-thirds of the governing board; any such expenditures must be repaid within the two subsequent fiscal years. An emergency is defined as an unexpected occurrence causing damage to a capital improvement or equipment and requiring immediate repair. (16)

Repair reserve funds may be put to uses otherwise covered by the general fund. Municipal corporations (but not special improvement districts) may divert repair fund monies to a capital reserve fund or to a tax stabilization reserve fund upon authorization by the corporation's governing body and after a public hearing. Money in a tax stabilization reserve fund may be appropriated (subject to a permissive referendum) for the local share of home relief, for the acquisition of equipment not eligible for debt financing, or street, highway, or parkway maintenance.

Suburban towns may use general reserve funds to finance all or part of the cost of a town object or purpose with an authorized period of probable usefulness of at least five years. Such expenditures from general reserve funds may be made only after referendum, but fund monies may be borrowed for any purpose for which bonds, capital notes or urban renewal notes have been authorized.

Improvement districts in suburban towns may establish general reserve funds to finance all or part of the cost of specific objects or classes of objects which may be constructed, acquired or provided by or on behalf of the district. A referendum is necessary to establish such a fund, but not to expend monies once the fund is established. Unobligated balances may be transferred to any other reserve fund created for the district.

The foregoing reserve fund requirements are not applicable to private water companies. Private water suppliers, however, are free to establish reserve funds in the same manner as is any private company.

Multiplicity, Financial Operations and Conditions

Some Institutional Characteristics and Their Effect on System Conditions

Two general characteristics and points of difference among New York's water systems are obvious:

- There are many suppliers--primary responsibility for water supply is divided among as many as 1,800 local entities.

- There are differences in financial operations--any particular system may present a distinctive combination of interrelated financial features such as:

  . flexibility in extracting surplus water revenues for other local uses or, on the other hand, subsidizing the water system;

  . water sales rates that more or less reflect the cost of producing the water; and

  . employment of borrowing vs. reserve funding to make repairs and capital improvements.

These characteristics--multiplicity and specific differences in generating and spending money--might reasonably be thought to have significant implications for operating costs and system conditions.

Maintenance and Scale--The implications of multiplicity for costs and conditions have to do with economies of scale. The more people a given set of hardware serves, for instance, the less each person will have to pay for the service and, on the other hand, the more money the system will be able to raise at any given level of rates in order to make repairs and improvements. We might reasonably expect, therefore, that systems which serve a small number of people would be more likely than larger systems to be unable to maintain their hardware and upgrade it. More specifically, and in addition:

- for smaller bond issues, the ratio of transaction costs (the set costs of legal fees, underwriting expenses and printing) to the size of the issues is higher than for the bond issues of larger systems. Such costs not only make it more expensive and more difficult for a smaller system to borrow money, but may effectively exclude it from the market. (17)

- The smaller systems have less capacity to hire specialized personnel to manage their hardware and sources, and there are indications that quality monitoring is more often substandard in small systems.

It may not be unreasonable, then, to expect that deferral of maintenance might happen in small systems simply because the capacity to raise revenue for public purposes is limited by the small population. (Appendix 2 contains further, more detailed observations on problems of small systems.)

Maintenance and Financial Flexibility--Cities and villages are free to generate surpluses and run deficits in their water supply operations. They may choose to use surplus money to pay for other kinds of services and not reinvest a like amount in water system maintenance, and they may hold water rates below the

level necessary for the system to generate revenues sufficient for maintenance and operations and improvements. (18) Other kinds of systems, while perhaps in practice being able to keep water rates below the level necessary for total system needs, are more constrained--they are generally required to balance revenues and expenditures and to use all revenues for system purposes.

The greater flexibility which characterizes cities' and villages' control of water revenue and expenditures may, it has been suggested, have a deleterious effect on the water systems. One observer suggests that by operating water systems with general fund monies, water supply needs are forced to compete with other municipal needs in the annual budget. Money is often diverted from water systems, maintenance is deferred, and professional management is buffeted by political or bureaucratic concerns. (19) In the special districts, revenues are dedicated to water system operations and must balance disbursements, and it is very conceivable that this would result in sounder maintenance.

This distinction--flexibility--does not per se constitute a factor that will distinguish whether or not a system obtains and spends enough revenue to cover maintenance, operations and improvement needs. A city might, for instance, keep rates low, finance water operations out of its general fund, and annually appropriate ample monies for maintenance of a sound system. Nevertheless, analysts for the President's Intergovernmental Water Policy Task Force did suggest that, whatever the precise local arrangements, "the revenues available from water rates and other sources should be sufficient to support sound capital investment and operation and maintenance practices for the water supply utility." (20)

Water rates and system investments are found to vary regionally and between private and public suppliers, as seen in table 3 and figure 3. It appears that:

- larger (urban) systems charge less than smaller (rural) systems, perhaps due to economies of scale;
- urban public systems return smaller percentages of income to the water supply effort; and
- private utilities charge considerably more than publicly owned systems. This reflects a variety of differences between public and private systems. Private water companies:
    - traditionally have a higher cost of borrowing;
    - are more closely regulated by the state, which may require

Table 3

Average Water Rates per User and Percent Revenue Returned to Water System (1981)

	AVERAGE WATER RATES PER YEAR (dollars per user)		PERCENT RETURNED TO WATER SYSTEM	
	Public	Private	Public	Private
Urban	54.25	95.90	94.3	98.4
Rural	62.88	108.46	98.1	95.6
State excluding New York City	61.20	108.27	97.4	95.8
Long Island only	35.85	132.84	98.6	98.3
New York City	38.38		80.0	

Notes: "Urban" systems are those serving 10,000 people or more, but exclude NYC. "Rural" systems are those serving under 10,000 people. Long Island figures are included in urban, rural, and statewide figures. Rates are averaged by system and not weighted by population.

Source: Table developed from data contained in Department of Health, Bureau of Public Water Supply Protection, Facilities Needs Survey of Community Public Water Systems, April 1983, pp. 49-50.

improvements that other suppliers may defer;

- are often older than their public counterparts (especially on Long Island) and may have encountered critical maintenance costs earlier;

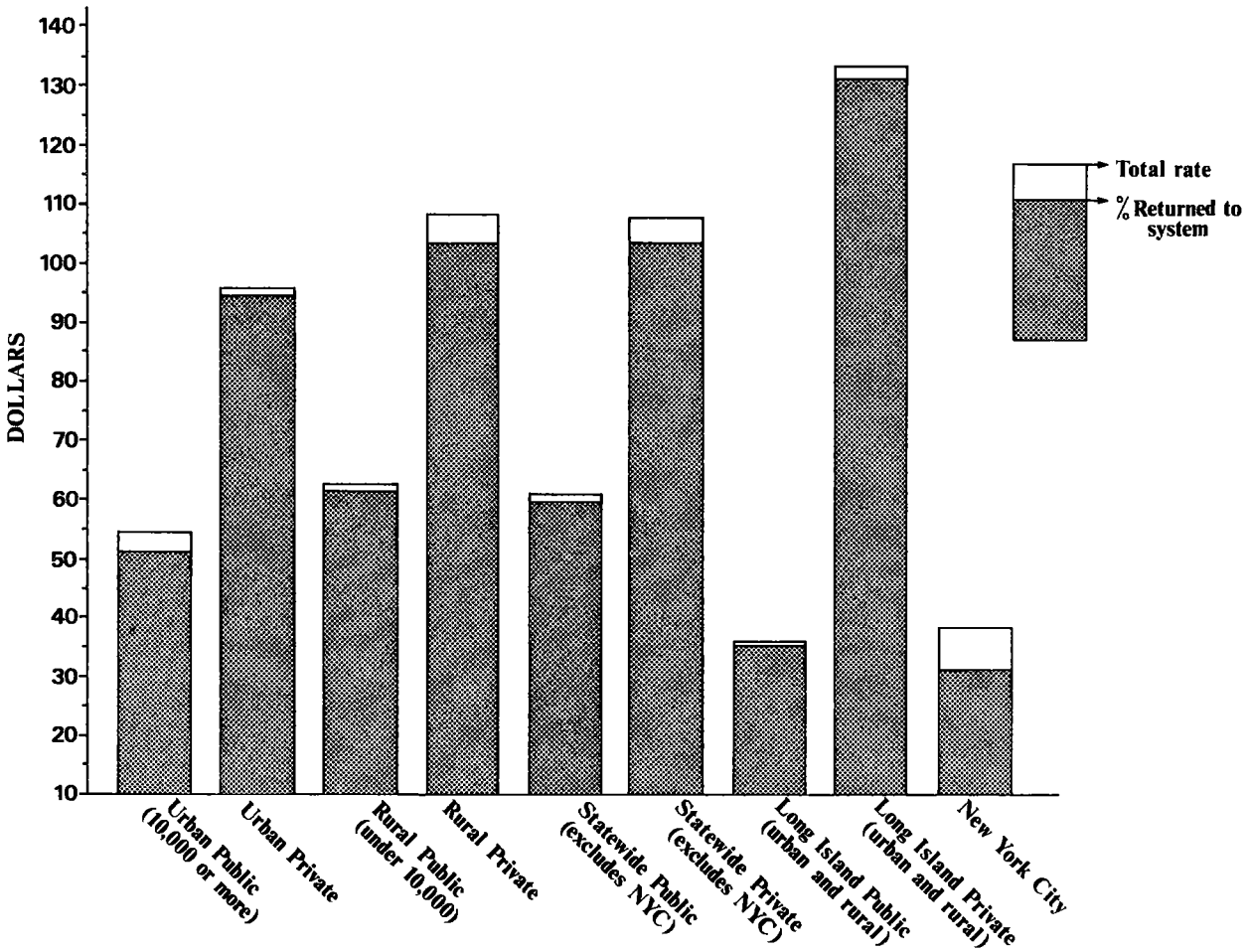
- reflect in their rates a return on investment, a cost to which public systems are not subject; and

- must pay local property taxes as well as state and federal taxes. One-third to one-half of private water company rate revenues on Long Island go toward payment of local property taxes. (21)

A striking indication is that public suppliers in New York City and other urban places have lower rates than rural systems and yet return smaller percentages of revenues to the systems. While lower rates partially reflect economies of scale and fixed paid-up assets, it does imply that it might be possible to increase annual investments in many urban public water systems without necessarily raising water rates.

Figure 3

Average Water Rates per User and
Percent Returned to the Water System (1981)



Data Source: Department of Health, Bureau of Public Water Supply Protection, Facilities Needs Survey of Community Public Water Systems, April 1983.

Money and Deterioration

Both multiplicity and financial flexibility, then, may affect the amount of money available for water system needs. There has been little indication that systems are not obtaining sufficient monies to pay for day-to-day operations, but frequent contentions are that:

- many systems have not had the money necessary to regularly conduct the major rehabilitation and replacement work that keeps water

infrastructure from deteriorating (the presence or absence of capital and repair reserve funds are pertinent in this regard); and

- when such major work becomes unavoidable, it has become a larger task than it otherwise would have been, and such systems must borrow to pay for the enlarged task. Increases in interest rates in recent years have made for particularly unwelcome effects from borrowing for any kind of major capital work--State Comptroller Edward V. Regan has pointed out that $10 million in bricks and mortar may end up costing $30 million. (22)

No one has argued that deferral of maintenance has not occurred, but there has been little specification of how common it is. Perhaps even more important, however, is that there is disagreement on how deterioration actually happens and how far it has gone. It is to those subjects that the inquiry turns in Chapters 2 and 3.

Chapter 2. Deterioration of Distribution Systems

What is it that makes a water system fail, and how fast does deterioration happen? Assumptions about the answers to these questions have been highly important in raising concerns about the condition of distribution systems generally. In order to judge the validity of recent assessments of system conditions and, if necessary, to develop new ways of assessing conditions, it is necessary to try to set forth the actual nature and causes of system deterioration as engineers know it.

Local systems convey water through networks composed of:

- water mains--larger pipes--and smaller service pipes, plus
- items--pipe fittings and joints, valves, pumps and hydrants--that facilitate or direct the flow of water through the pipes.

(Appendix 3 is a more detailed description of these system elements.)

There are chemical and physical processes that place stress, both internal and external, on each element; the speed of the effect on each element varies greatly with such characteristics as size and material. Faced by the complexity of this variation, observers of systems often depend on indirect indicators to make the task of condition assessment managable. Diagnoses based on indirect indicators, however, can be mistaken, and maintenance decisions--decisions both on total expenditures and specific repairs--can be poorly fitted to what is actually ailing a system.

Two Common Indicators: Age and Unaccounted-for Water

Age Is Not Predictive

There is a common perception that the older a water system is, the greater is the need for major repair and replacement. A review of the technical literature, however, indicates that age is at best a minor indicator of the condition of a water pipe. In some cases the reverse of expectations is true: some pipes laid more recently have been found to experience higher failure rates than some older varieties. This is especially true of the early samples of

centrifugally cast iron pipe, which prior to standardization had a higher breakage rate than older pit cast iron pipe.

Several studies and examples indicate that variables other than age play a greater role in water main failures:

- The literature review for a Corps of Engineers-authorized study of water main breaks in Manhattan found no evidence of pipes wearing out after a set number of years and indicated that no useful life span can be specified for cast iron pipes. The Manhattan survey of 2,500 main breaks over 24 years revealed no clear pattern of break rates increasing with age. (1)

- A section of cast iron mains installed in New Orleans in the 1940s has experienced failures at a higher rate than older pipes due to less rigorous specifications used by the installing authority at that time. (2)

- A Louisville study of main breaks found that mains installed from 1926 to 1930 failed at nearly four times the rate of those installed between 1862 and 1900. (3)

- In Indianapolis, 85 percent of main breaks in 1978 occurred in mains installed between 1939 and 1969. Pipes installed between those years comprise only 52 percent of the system. (4)

- A Corps of Engineers-funded study of the Binghamton water system included a statistical analysis of main breaks. The analysts concluded that while age and main breaks were positively correlated, the level of correlation indicated that factors other than age may be more significant. (5)

- The Severn-Trent (England) Water Authority reports that "spun cast iron installed since 1952 had break rates much higher than mains installed from 1890 to 1920." (6)

- The Ontario Research Foundation concluded that "cast iron mains in Metropolitan Toronto soil will have a very long life in the order of 700 years." (7)

The Comptroller General of the United States concluded that the establishment of a pipe replacement standard based upon a particular age is "completely arbitrary." (8) While age may be an appropriate consideration in identifying water pipes in need of attention, other factors must also be considered. Greater attention should be paid to particular stocks of pipe which may be causing problems. One consulting engineer concludes:

> If a utility adopts a policy of replacing mains that are more than 100 years old, it may replace many miles of sound,

> useful mains while failing to replace problem segments that are 30-50 years old. (9)

Similarly, it has been observed that:

> Rather than say that older mains wear out after a certain specified number of years, it is more productive to examine the type of pipe in the ground and the conditions of its environment. (10)

A basic problem with making such detailed observation rather than using age as a criterion is that so much of the hardware is underground. There are, however, methods by which distribution systems may be "observed." The methods require time and some expertise to use, but the complexity of causation of system failures and the risk of waste through mistakes in maintenance can make such observation a highly worthwhile investment. Chapter 4 will discuss such observation, diagnosis and maintenance decision-making in more detail.

Unaccounted-for Water

A Complicated Indicator--One of the techniques that will be reviewed in Chapter 4 is water accounting, by which analysts derive a figure called unaccounted-for water. One component of unaccounted-for water is actual leakage, but it is important to note that "unaccounted-for water" means more than physically lost water. As a matter of general definition, unaccounted-for water is the difference between the amount of water recorded as entering the distribution system and the sum of the volumes of water recorded as being received by consumers or otherwise leaving the system.

Water, which costs money to produce, usually is supposed to produce revenue to pay for its production; unaccounted-for water is water that produces no revenue. Like electricity and cable television service, water can be stolen or "lost" through faulty bookkeeping, so "What is happening to the water?" is a question in which the local treasurer is interested. But it is also a query about general system conditions, for if a high percentage of water cannot be accounted for, there is reason also to strongly suspect that it is leaking from joints and cracks in the distribution system.

Besides breaks and leaks, through which water is physically lost,

factors which contribute to unaccounted-for water include:

- inaccurate master meters;
- inaccurate industrial, commercial and domestic meters;
- unauthorized water use;
- water used from fire hydrants (this includes, in addition to fire-fighting use, water used for street cleaning, water and sewer line flushing, and unauthorized hydrant openings);
- erroneous billing and accounting practices;
- inaccurate system controls (e.g., faults in the valves which control overflows from water storage facilities); and
- public uses such as those in municipal buildings or parks. (11)

Much unaccounted-for water results from inaccuracies in water meters. Meters can overregister or underregister; the percentage of underregistration error reflects a percentage of distribution system "losses." Domestic meters are the most neglected part of the water system in many cities. (12) Up to 23 percent of all domestic water use occurs at flows of less than one gallon per minute; such flows often underregister on domestic meters. (The literature suggests that to ensure accuracy, domestic meters should be checked every ten years (13), and meters supplying large industries or commercial establishments should be tested annually.) (14)

Authorized fire hydrant use is actually a small component of total system use, accounting for about one percent of the total. (15) Unauthorized use of fire hydrants can be significant--the unauthorized opening of a hydrant can produce a loss of 1,000 gallons per minute. (16)

Much unauthorized use of water is not deliberate. For example, a building's fire lines may be used without the knowledge that the building's meter may be circumvented in the process. Circumventing of water meters, whether deliberate or not, is difficult to detect. During the 1981 drought, however, New York City achieved some decrease in unaccounted-for water by shutting down services to abandoned buildings.

The Leakage Component of Unaccounted-for Water--Much unaccounted-for water, then, represents a problem in metering and bookkeeping. Nevertheless, some water is physically lost through leaks, even in the best of systems. Optimal leakage rates in municipal systems in the United States range from 10 to 12

percent of daily flow, although some systems leak up to 40 percent of their supply. (17) A 1970 survey of 778 utilities in 48 states by the American Water Works Association found that the systems, which served a total of over 85 million people, had leakage losses averaging 23 percent per system. (18)

An American Water Works Association committee report gives its water loss standards as follows:

> Good performance is generally indicated by a metered ratio (accounted for water as a percent of total water) of 85 to 90 percent where the use of water is between 100 and 125 gallons per capita per day. Where large industrial use causes a higher per capita use, the ratio may approach 100 percent. The difference between the metered ratio and 100 percent is unaccounted-for water. This may vary from 10 to 15 percent in a well operated system where the consumption is between 100 and 125 gallons per capita per day. (19)

Unavoidable leakage is the component of lost water which would cost more to locate and repair than the amount lost would justify. Many formulas have been used to calculate appropriate unavoidable leakage based upon the length of pipe and the number of service connections. One writer quoted a researcher as stating that:

> A discharge of one drop per second from each joint, five drops from each hydrant and stop valve, and three drops from each service pipe, including tap and unit cock, represents a fair measure of the average undiscoverable leakage in a well constructed distribution system. (20)

The writer extrapolated this observation:

> On this basis and with the assumption that on the average there are 504 pipe joints, 12 hydrants, 10 stop valves and 100 service pipes per mile of distribution pipe, the leakage will amount to 2742 gallons per day per mile, or in round figures, say, from 2500 to 3000 gallons per day per mile. (21)

Leakage that exceeds this rate probably is not rare. Army Corps of Engineers' estimates of leakage in some places have exceeded 27,000 gallons per day per mile. (22)

The Complexity of Causes

Each of the major distribution system elements can, in and of itself, be a problem: When a pipe or joint breaks, interruption of service and flooding result, and even minor leaks constitute losses of water which a system's users pay to produce. When valves are inoperable, it may be impossible to halt or regulate the pressure of flows into particular districts. When a pump fails, the pressure necessary for fire fighting may be unavailable.

More important to understand, however, is that one kind of deficiency can lead to another, and often does. For instance:

- The excess pressure which results from an inoperable valve may place stress on a weakened, but still serviceable joint such that a break occurs which, had the valve been functioning correctly, would not have occurred.

- A leak not only constitutes a loss of water, but a cause of damage. Leaks saturate and cause compaction or washing away of the soil bedding which supports pipes; when the pipe's weight exceeds the weakened bedding's capacity to support it, the pipe bends and sometimes breaks.

- Internal corrosion roughens the internal surface of a pipe and may partially clog it, thereby reducing the efficiency with which the pipe carries a particular volume of water. This results in lower pressures for a particular area of users, and it may then be necessary to use a pump to boost pressure for greater amounts of time than was contemplated when the pump was installed. In addition to other effects, this increases pumping costs and wear and tear on the pump itself.

The system failures that catch our attention because of the inconvenience and damage they cause, then, may simply be the most noticeable part of a sequence of failures by system elements. One of the repair-related ramifications of this fact is the possibility of treating symptoms rather than causes, with the attendant probability of a recurrence of the symptoms.

Nevertheless, it is possible to speak of "causes of deterioration" in ways other than a sequence of breakdowns; there are chemical and structural processes that lead to a failure. The major kinds of distribution system failures are leaks, breaks and persistently low pressure. The chief system elements involved in discussions of leaks, breaks and low pressure are pipes and joints,

but two points should be remembered during such discussions:

- The chemical and structural processes in systems' environments that affect pipes and joints also damage other system elements. For instance, corrosion damages pumps; corrosion and freezing damage valves; and meters are easily damaged not only by corrosion and freezing, but also by excess pressures.

- Such damage to system elements other than pipes and joints, and the simple mechanical wearing out of valves and pumps, may contribute to the overall stresses that lead to failure of pipes and joints.

The following is a review of some of the chemical and structural properties of systems that actually make maintenance necessary and are the ultimate causes of system failures.

The Nature Of Leaks And Breaks

Engineers differentiate between leaks and main breaks. Leaks occur when joints or service connections loosen. Breaks occur when a main fractures. In common practice, a large leak may be considered a break and small fractures--cracks--in pipes may permit the escape of water in amounts small enough that such losses are regarded as leaks.

Leaks not only constitute losses of water, the product of a system's and its users' investment; they also damage the bedding of pipes and joints, which may cause further deterioration, including pipe breaks. The pressurized force of the leaking water forms voids in the surrounding soil through erosion or compaction. These voids, in combination with saturation of the soil and other material which support pipes, permit soil movement and consequently unequal stress on the pipes. These stresses can in turn cause structural failure of the pipe system.

Structural failure is exhibited by identifiably different kinds of breaks. A circumferential (or beam action) break runs around a pipe; a longitudinal break runs along its length. A third kind of rupture is called a blowout. (23)

Causes of Leaks and Breaks

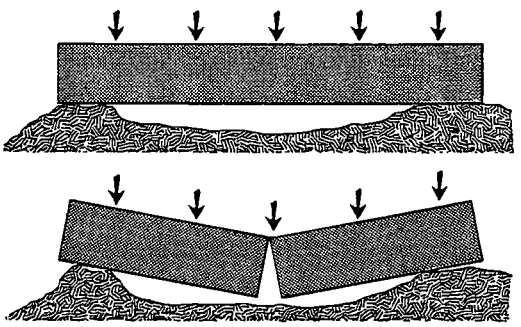
Several chemical and physical factors may create the conditions which cause breaks and leaks. When such factors cause or permit internal and/or

Figure 4

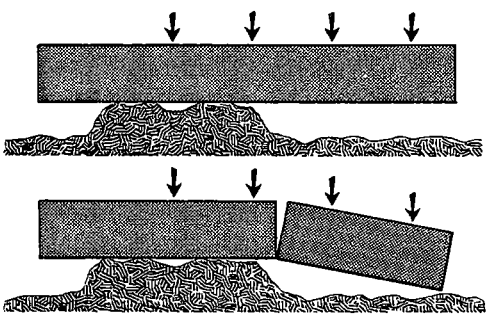
Examples of Circumferential Breaks

Some examples of beam action breaks are described below.

If blocks are used near the ends of the pipe, such as those used in the past at many New York pipe installations, and the backfill is not properly tamped, the load placed on the pipe tends to bend it downward in the middle. If failure occurs with this type of loading, the break will be opened wider at the bottom than at the top.



If the bottom of the trench is wavy with deep and long bell holes, the pipe is supported in the middle and comparatively free at the ends. Earth loads may cause the pipe to bend downward at the ends and if failure occurs, the break will be opened wider at the top than the bottom.



In either of these cases, the pipe breaks straight across near the middle of a length.

If a pipe is laid so that it rests on a rock, other pipe, a conduit or other unyielding object, the earth load may cause the adjacent segment of pipe to settle. This may cause beam failure in small pipe, and in larger pipe could easily cause pipe crushing.

From Betz-Converse-Murdoch, Inc., New York City Water Supply Infrastructure Study, Volume I: Manhattan, prepared for the U.S. Army Corps of Engineers, New York District, May 1980.

external forces acting upon a joint or main to exceed the strength of the joint or main, a break or leak will result.

Temperature is Most Significant--In cooler parts of the country, temperature may be responsible for more main breaks than all other reasons combined. (24) Temperature change is an important cause of soil movement. It directly causes soil expansion and contraction, and cold temperatures permit frost penetration, which expands the soil further and thereby increases forces exerted upon the pipes. Frost penetration of only two feet can nearly double the external soil loading on a pipe. (25)

Temperature changes also expand and contract the pipe itself. The pressure of such expansion against a relatively rigid joint or against structures in contact with water lines may result in damage to the pipe and/or joint. Flexible bell and spigot joints reduce excessive stresses by allowing pipes to expand and contract.

Another effect of low temperatures on a water main is a decrease in its ductility (i.e., the ability to slightly change shape in order to better bear an increase in stress). When cold conditions inhibit ductility, stress becomes localized and a crack may start and continue to develop into a break.

Due to the combination of temperature-induced changes in soil load and direct effects of temperature on pipes, up to 70 percent of main breaks in the northern states occur from November through February. (26)

- A study of main breaks in Binghamton found that a majority occur in winter months and can be attributed to permeable local soils which permit a high degree of frost penetration. The resulting soil movement increases the load on pipes by up to 100 percent. (27)

- Between 1969 and 1978, the percentage of annual main failures occurring between October and March was 68 percent in Boston and 65 percent in Troy. (28)

- In Indianapolis, main breaks in 1977 were 70 percent above the previous five-year average, an increase which local officials attributed to that winter's severe cold. During 1976 and 1977, Cincinnati experienced a 50-percent increase in main breaks over that city's five-year average. (29)

- In New York City, 35 percent of main breaks over a six-year period were found to occur between December 15 and March 15. In Washington, a 1968 study of six years of failures indicated that the city exhibited an increase of failures in the winter months. (30)

Soil Movement and Settlement--The natural process of organic soil settlement contributes to uneven pipe support and causes leaks and breaks in some localities. This is the major cause of main failures in New Orleans. (31) In addition, soil may shift and settle because of earthquakes and tremors, slope movement, storm water erosion, and the pressure of leaks themselves.

Improper Installation--The improper laying of water mains or backfilling of trenches may cause uneven support of pipes and joints. When a pipe's and/or joint's bedding is no longer uniform, small sections of the pipe may end up supporting its entire weight, resulting in localized pressures which may exceed the pipe's strength. (32)

Internal Corrosion--Internal corrosion most typically involves the buildup of a rust that is produced by the chemical reaction between pipe material and relatively "aggressive" water. Some of the characteristics which make water more or less aggressive are its acidity and alkalinity and the amounts of oxygen, carbon dioxide, halogen, sulfate, phosphates, calcium and other solids dissolved in it. Temperature and flow rates can affect the speed at which water's characteristics bring about corrosion, and different kinds of pipe materials have varying degrees of resistance to corrosion. (33)

Perhaps the most common manifestation of internal corrosion is tuberculation, the attachment of knoblike mounds of rust to the internal surface of a pipe. Another effect of internal corrosion is pitting of mains and service pipes. Pits may eventually penetrate the pipe wall and permit water to escape. (34) Home plumbing piping often is composed of materials that are less corrosion-resistant than are a system's non-service mains, so the pitting effect of internal corrosion is more common in the smaller pipes. (35)

External Corrosion--One form of external corrosion is graphitization, an electrochemical reaction between a metal and its environment. Graphitization often is caused by stray electric currents. Corrosion is also caused by impurities introduced in the manufacturing process, by contact with acids or bacteria or by chemical compounds produced in the soil.

Sometimes a graphite film develops over an entire pipe. The film layer in turn prevents further corrosion, and no problem results. This is called surface corrosion. Plug corrosion occurs when a piece of graphite develops in the pipe wall; this plug constitutes a weakened spot. The spot may blowout from internal pressure, and it may break from external pressure. Complete corrosion happens when all iron in a pipe is replaced by graphite. Eventually, only a graphite shell remains. (36)

In general, external corrosion is not regarded as an important cause of failures. Under non-corrosive soil conditions, no significant metal loss is expected for 80 to 150 years. (37) Soil type is the major determinant of corrosive conditions, and highly corrosive soils are geographically limited in the United States. The Cast Iron Pipe Research Association surveyed over 120,000 miles of grey and ductile cast iron pipe and concluded that 95 percent was unaffected by external corrosion. (38) A survey by the Comptroller General of the United States of 15 water systems throughout the nation found external corrosion to contribute to main failures in only five cities and to be a major factor only in Indianapolis. (39)

It has been suggested, however, that while other stresses are correctly regarded as the causes of failure, they more easily have their effect on corroded spots than on other places in systems. (40)

Vibrations--Vibrations caused by street and subway traffic and by construction contribute to loosening of joints and subsequent leaks. Vibrations can also cause soil movements which may result in improper pipe support. In Manhattan, which has a greater concentration of traffic (especially subways), six-inch mains break 6.9 times more frequently than in the other four boroughs. (41)

Other Factors: Excessive Internal Pressure, Pipe Material and Physical Defects, and Pipe Size

Excessive Internal Pressure--Pipes and joints are manufactured in different sizes to accommodate different volumes of water. If a segment of a system is required to convey more water than can easily flow through the pipe, the resulting pressure may damage the seal between pipe and joint or the pipe itself at locations where it has been weakened by corrosion. Excessive pressure may be chronic (when, for instance, only some of the system elements have been enlarged to accommodate the population of an area that has grown more than was expected when the pipes were laid) or sporadic (because, for instance, of faulty valves which permit momentary surges called water hammer). (42)

Pipe Material and Physical Defects--The pipe material, defects in the material, and the diameter of a pipe may correlate with leaks and breaks. In Los Angeles, for instance, most of the 2,300 main breaks each year occur in steel mains even though only 15 percent of the piping is steel. (43) A comparison of spun iron and cast iron pipes in the Binghamton system showed "that the sand spun mains had a significantly higher break rate than the pit cast mains even though

the sand spun mains were much newer. The earlier manufacturing of sand spun mains was not as good a process as the old pit cast techniques." (44)

Pipe strength may be decreased by notching of welds or by gouges in the pipe. An existing crack will decrease the pipe's strength at the tip of the crack, and persisting stress can then lead to an increase in the size of the crack and to a break.

Pipe Size--The case with regard to the significance of pipe diameter is less clear. The Binghamton study found that "pipe diameter was not a significant variable except for large diameter (20-24 inch) pit cast iron pipe." (45) Observers of Manhattan's network, on the other hand, found that six-inch mains had a break rate higher than the average among all mains. (46)

The Causes Of Low Pressure

The inability of water to pass through a pipe in adequate volume may result from relatively obvious features such as weak pumps, sediment in the pipeline and/or leakage. Low pressure results also, however, from internal corrosion.

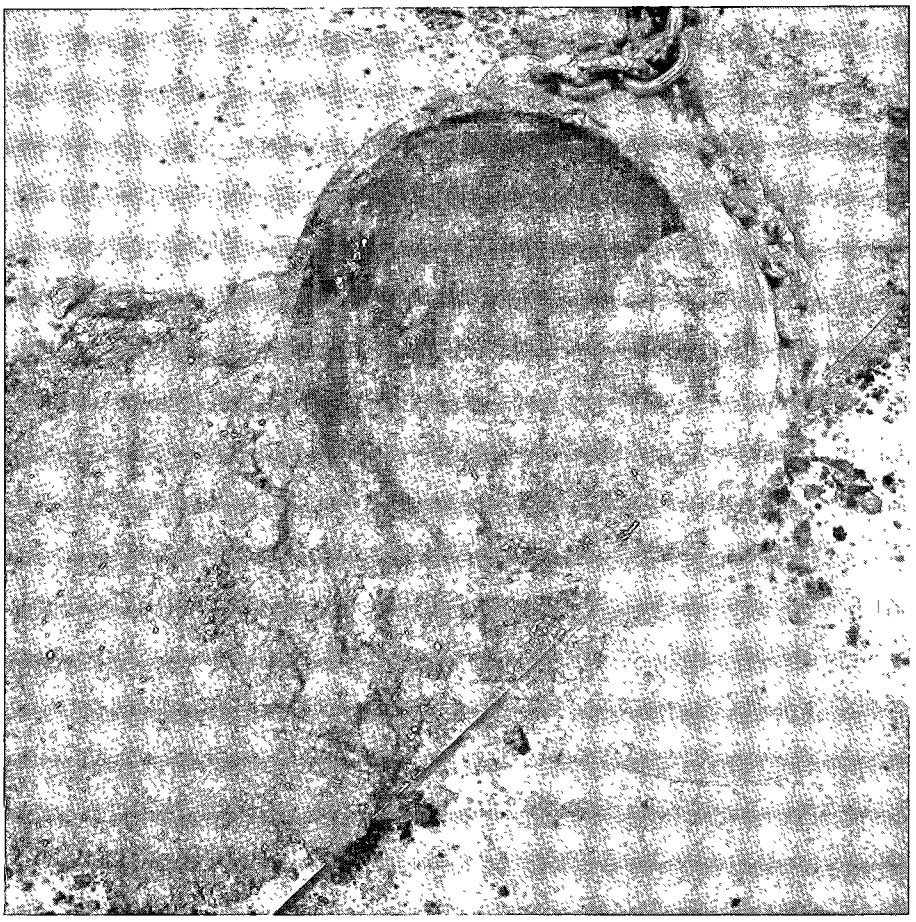
As has been noted, internal corrosion most typically involves tuberculation, the buildup of mounds of rust on the internal surface of a pipe. This roughens the internal surface, and the less smooth a pipe is, the more friction is experienced by the water passing through it. This slows the passage of any specific volume of water through the pipe, thereby lowering pressure. In extreme cases, tuberculation can clog a pipe.

It should be noted that low pressure and the previously discussed pitting effect are not the only problems caused by tuberculation. Discolored water may result when sudden increases in pressure or changes in direction of flow causes rust to flake off. And corrosion can increase compounds carried in the water to the extent that it fails to meet health standards. Substances especially notable in this regard are lead and cadmium, but also iron, copper and zinc. (47)

Maintenance Routines, Deterioration, and Actual Conditions

The Problem of Optimal Maintenance

Deterioration of water system hardware is inevitable, but the speed



A Tuberculated Water Main

(Photo: Courtesy of Ameron Inc.)

with which it occurs and the length of time it takes for system operators to react to it are variable and related. Generally speaking, at some point after installation of a set of hardware, inattention will permit deterioration to accelerate, and the eventual cost of repair/rehabilitation/redevelopment will be greater than if ameliorative action had occurred sooner.

It would not be sensible, however, to conduct maintenance activity as fast as is theoretically possible. Maintenance--monitoring, repair, upgrading--also is an investment, and if it is too constant and too early, maintenance over a period of decades theoretically could cost more than would simply permitting a system to deteriorate to a point at which total replacement is required. The rate of maintenance to be sought, therefore, is the one which ensures reliable service at that cost which is optimal between ongoing maintenance activity and total replacement.

There are procedures which affect the speed of deterioration, and there is a general perception that many systems, rather than employing those procedures, operate on an emergency repair basis (i.e., amelioration occurs only upon serious disruption of service). More routine maintenance procedures have to do with monitoring, prediction and selective repair and replacement which are in addition to emergency repair and which, it is hoped, permit the system to avoid emergencies. Here are a few examples of maintenance procedures which might be useful routines.

- Exercising valves and monitoring hydrant condition--The tuberculation which can prevent valves from working can be retarded through periodic manual opening and shutting of valves. Hydrants are more likely to give good service if, periodically, screw threads are greased, pressures recorded, valves checked and stem nuts oiled. (48)

- Flushing lines--Bursts of water and chemical treatments can remove some encrustation. (49)

- Lining pipes--Over the past century, there have been great improvements in techniques for lining the insides of pipes with materials that are more corrosion-resistant than the pipe material. Most important are cement linings, which can be placed inside already-laid pipes of as little as four inches in diameter. Lining can add as much as 50 to 100 years to the service life of a pipe at one-half the cost of replacement. (50) Other pipe rehabilitation methods exist to fill cracks, provide a smooth finish, correct uneven sections and add strength. (51) Decisions to line pipe must consider the resulting reduction in the pipe's diameter.

- Corrosion control--Water can be tested to ascertain its corrosion potential. If the primary water supply is highly aggressive, the use of corrosion-inhibiting chemicals could slow the occurrence of the health-related, aesthetic and pipeline damage which corrosion can cause. Careful selection of pipe materials can be effective. For conveying highly corrosive water, cement-lined, ductile iron, copper, brass and plastic pipe may be advisable. (52)

- Finding and fixing leaks--As has been noted, minimizing leakage conserves water which costs money to produce, and it reduces the damage which escaping water can inflict on pipe bedding.

These procedures can be cost-effective. For instance:

- Arlington, Massachusetts, a residential community of about 50,000 people, developed a leak detection program which lowered its per capita daily consumption rate from 131 gallons to 100 gallons. Table 4 shows in more detail the results of four years of surveys. (53)

- It was noted that lining pipes can add 50 to 100 years to the service life of a pipe at one-half the cost of pipe replacement. Prices of

Table 4

Leak Detection Savings: Arlington, Massachusetts

year	leaks detected	gals saved per year	cost saved per year	cost of survey
1975	16	116,800,000	$30,000	$3,750
1976	23	170,294,400	$40,800	$3,500
1977	29	172,000,000	$41,280	$3,850
1978	26	255,000,000	$61,200	$4,300

Source: Raymond A. Ouellette, "Town of Arlington, Massachusetts Annual Water Leakage Survey and Report on Reduction of Per Capita Consumption," Journal of the New England Water Works Association, 94, March 1980.

lining vary by site, size of pipe, population density, and type of surface paving. In Boston, for instance, the price of cleaning and lining pipe in 1970 was $56 per foot, whereas the cost of replacement was $122 per foot. (54)

There have been serious attempts to develop economic methodologies for making the choice of replacing vs. repairing a pipe. (55) One method involves comparing the annual cost of replacing a main over the finance period with the expected annual cost of repairing defects over the same period. The decision to replace water mains must also consider the cost of local damage caused by breaks.

A 1975 American Water Works Association manual suggests that water mains should be replaced if more than three breaks occur per 1,000 feet of pipe. The manual contains no explanation of this rule of thumb, nor does it indicate what time period should be considered when counting the number of main breaks. (56) One researcher, however, has concluded that "it is not economical to replace...pipe before it is at least 100 years old even if it has experienced previous breaks." (57)

Capacity and Priority

The general perception, mistaken or not, regarding most kinds of public infrastructure seems to be that:

- maintenance has been too much deferred;

- consequently, deterioration has progressed far and is accelerating greatly; and

- the bill for restoring soundness will be greater than it would have been if routine maintenance had been more frequent and/or extensive.

If this is indeed the case with regard to water systems, it probably has been the result of economic and political conditions which affect both the capacity of a system to conduct routine maintenance and the importance which maintenance is accorded in the system's locality.

Certainly there have been general economic and external developments that have made it more difficult for localities to allocate money sufficient to routinely maintain and upgrade water systems. For instance, high interest rates have made long-term capital improvement financing expensive, federal grant programs and proposals (regardless of the kind of infrastructure being supported) may generally have emphasized new construction, and the flight of the middle class to the suburbs has diminished many central cities' tax bases.

Limitations on capacity, however, are not unrelated to local choices. Some would observe that deferral of maintenance occurred, at least in part, because local officials were reluctant to raise water rates. The level at which a rate is adequate, however, is not always easy to specify.

> Because of the long-term nature of the business, systems can avoid operating deficits on an annual basis for many years, and yet not cover all of the true costs. This results from not keeping abreast of the reinvestment requirements of the distribution system and not planning for the large 'chunks' of capital often required for treatment capacity additions or developing new sources of supply. Even if depreciation expense is covered by revenues, these funds alone are not adequate for replacement costs because depreciation is based on historical replacement cost and the lower acquisition cost. Therefore, the level of revenues which is adequate for covering all costs over the long run often becomes obvious only after the revenues have been too low for an extended period of time.
>
> Another qualification relates to the dynamic nature of revenue adequacy--particularly for a system with revenues that are currently adequate but have not been high enough historically. If the rates had been as high in the past (sufficient to cover operating costs and to provide for reinvestment needs), the current level of rates might be adequate. However, to avoid falling further behind the reinvestment requirements and at the same time "catching up"

> on accumulated shortfalls, will require, in some cases, revenue levels that are higher than some communities are willing to pay. (58)

The fact that required revenue levels may be "higher than some communities are willing to pay" implies that politics, ultimately, might be the culprit. State Comptroller Edward V. Regan reflected upon his days as a Buffalo City Councilor, when he was told by a fellow Councilor that rather than raising taxes to fix potholes, more political mileage could be gained by waiting for the street to approach collapse and then bonding for a new street. The effect is to convert routine maintenance and repair expenses into capital costs, which spreads the expense out over 20-30 years (at perhaps triple the total cost), but eliminates an immediate impact on the budget. Eventually, the Comptroller asserted, the buildup of interest charges led to the 1970s financial crisis in New York State. (59)

Consultants writing in Consulting Engineer agree with Mr. Regan:

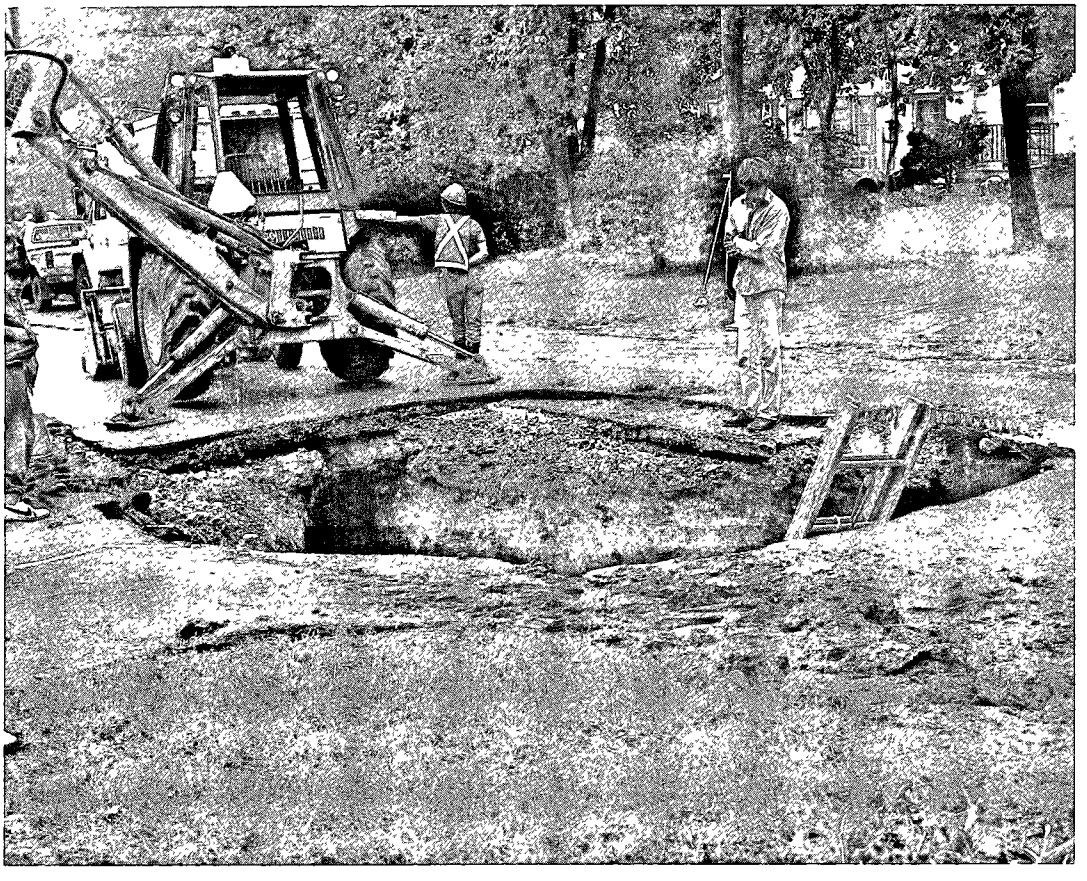
> This circumstance is not a product of the economic recession. Even in affluent times, city officials found that they could more readily gain acceptance for highly visible new construction than for maintaining hundreds of miles of sewers. There are no ribbon-cutting ceremonies for fixing valves, piping, doors, floors, roofs, wiring, and plumbing. After some years, the cumulative effects have become visible. (60)

Does Acceleration of Deterioration Mean Inadequacy of Condition?

It is probably reasonable, then, to expect that some maintenance work in many systems has been deferred for longer than has been economically optimal and that deterioration has occurred faster than it had to. This does not necessarily mean, however, that these systems are in terrible condition. It may be that while deterioration has occurred at a faster rate than was wise, the operating life left in existing hardware is sufficient to permit system operators to plan a multi-year or even a multi-decade approach to maintenance and rehabilitation, rather than a crash program.

How far, then, has deterioration gone? As the next chapter indicates, this is not a question for which a reliable general answer has been developed.

PART II.



Distribution Systems: What Has Been Observed, and What Is It Possible To Observe?

Photo: Courtesy of Washington Suburban Sanitary District

Chapter 3. What Has Been Observed?

Some Questions of Emphasis and Accuracy

The public infrastructure includes not only water supply, but also transportation (roads, bridges, mass transit, airports), solid waste management facilities, sewers, and even public buildings. One important difference between water systems and most other forms of infrastructure is that water systems, being located mostly underground, are more difficult to observe and test. Measurements of condition must be less direct and/or more costly.

Nevertheless, there have been some attempts to develop estimates of water supply redevelopment needs, both nationwide and statewide. Partly because of the observation problems relating to water systems, the redevelopment cost projections display a considerable range: nationwide estimates run from $75 billion to $160 billion (1); New York statewide estimates have ranged from $4 billion to $12 billion or more. (2)

This chapter is essentially a brief review of the findings and methods of the major assessments. Several characteristics of the assessments and of the presentation of the findings will be noted.

- Accuracy--There are problems of theory and sample. Most of the studies employ age-based assumptions about system conditions or extrapolate to the entire population of systems on the basis of a very small sample. The analysts who produced one of the most important national assessments noted that:

  > Urban water systems are quite diverse in their characteristics, with each metropolitan area differing in size, topography, climate, hydrology, political setting, and social characteristics. This makes it extremely difficult to generalize and to prescribe solutions to basic problems since each urban problem possesses a unique set of characteristics. (3)

- Emphasis--The studies' findings of probable needs in the billions of dollars have received far greater notice than have concomitant findings and caveats that could reduce the alarm such figures might produce.

. The time period for making the improvements is usually at least twenty years, and often thirty years. And some projections for finishing New York City's third water tunnel are even longer. This permits some discretion in deciding how to finance the improvements, and it implies something which some of the studies state explicitly: the systems are not commonly failing to perform and generally have not reached an advanced state of deterioration. It also suggests that we have time to improve the data that will inform redevelopment funding decisions.

. Some of the analysts acknowledge the inadequacy of data to perform their mandate. For instance, the Congressional Budget Office noted that "because no comprehensive nationwide assessment has been made of the physical condition of community water supply systems or of their need for capital improvements over the next decade, generalizations cannot be made with any confidence. Anecdotal reports on the physical condition of water supply systems suggest...types of problems, but no consensus has been reached regarding the severity of these problems." (4)

- Reification, or Turning the Speculative into the Definite--A frequent characteristic of both academic and government research is that estimates or speculations, once published, are repeated in subsequent research as if they were basic facts and without reference to misgivings about those findings expressed by the originating analysts.

The lack of actual, widespread observation of systems in order to develop information about their conditions is a pervasive deficiency. Expressed reservations about the assessments, however, should decidedly not be construed as negative commentary on the analysts' efforts. The analysts have acknowledged the research problems and done as well as is possible without the basic data, and their findings may indeed be better than no evidence whatsoever.

Nevertheless, when proposals that would cost billions of dollars ensue from the research, it is necessary to consider the extent to which the findings should be thought reliable. That depends partly on how long it would take to more closely examine the problem and, disregarding any immediate remedial action, on how far in the future we can reasonably expect huge system failures to be. As will be observed again, the possibility of developing sound information--information that not only will document the scale of need, but will also be prescriptive--is probably well within the remaining performance life of the state's water distribution systems.

National Assessments

The President's Intergovernmental Water Policy Task Force

In June of 1978, President Carter established an intergovernmental water policy task force, within which an urban water supply subcommittee was formed. The subcommittee report, released in June of 1980, is perhaps the most often cited nationwide assessment of water system needs. (5)

The subcommittee's examination, which was mainly financial and institutional in nature, focused on the 756 urban water systems which serve a minimum of 50,000 people. The report identified a capital expenditure need of $75-110 billion over the next twenty years, including $50-80 billion for replacement and rehabilitation of water distribution and treatment facilities, $5-8 billion to service new growth, $0.5 billion to upgrade drinking water quality, and $20-25 billion for new source development.

The study compared expenditures and revenues and concluded that 80 percent of the systems have the capacity to finance their needs, while 20 percent of the systems would experience capital investment shortfalls. One-half of the shortfall was attributed to distribution system needs and one-third to new source development. While suggesting that the total shortfall could amount to $10-$13 billion, the report noted that "uncertainties involved in the estimating procedure imply that a $5 billion to $26 billion shortfall range is not unreasonable." (6)

The Task Force's findings were based heavily on a study which it commissioned private consultants to do. (7) The consulting team conducted:

- an overview of the urban water systems in order to develop a "fundamental data base" regarding ownership, age, funding mechanisms, investment requirements, and delivery costs relative to other kinds of community services; and

- a more intensive look at a sample of ten systems (Boston, Chicago, Denver, Eugene, Indianapolis, Manchester (NH), Newark, Salt Lake City, Shreveport (LA), Tallahassee). The consultants visited the ten systems and wrote case histories in order to identify "successful and unsuccessful practices" of water systems.

The shortfall estimate was an extrapolation of investment shortfall projections for three of the ten systems--Boston, Newark and Shreveport. The

Task Force's notation of "uncertainties" was based on the consultants' statement that:

> because of the uncertainties in each step of the analysis, care should be taken to avoid inferring too much precision in the figures. They represent a 'most likely' estimate with a range extending approximately from one-half the estimated shortfall to two times this amount. (8)

The consulting team noted the need for further study because the sample size of the intensive part of the study made it statistically inadequate to provide much assistance to legislators and decisionmakers. (9)

The Report of the Comptroller General

The Comptroller General of the United States surveyed three water systems--Boston, Washington, and New Orleans--which have generated a great deal of attention due to stories of their inability to meet maintenance needs. (10) Data were collected also for twelve other cities to provide a national perspective. The examiners did not review all aspects of distribution systems and, instead, concentrated on water mains, unaccounted-for water and system financing. They reviewed records and documents of the three systems and interviewed system officials. In addition, they interviewed and obtained data from system operators in Cincinnati, Indianapolis, Louisville, Seattle, and Troy (NY). They also interviewed officials of the American Water Works Association, the National Association of Water Companies, the Ductile Iron Pipe Research Association, the National Association of Regulatory Utility Commissioners, four water main rehabilitation companies, and one leak survey engineering firm.

The study found that the incidence of main breaks and leakage was low in Boston, moderate in Washington, and high in New Orleans, but also that breaks and leaks are "not, in and of themselves, a good measure of system condition." (11) The examiners concluded generally that the systems in Boston, Washington, and New Orleans were not without problems, but that the findings in these cities nevertheless were "contrary to the popular impressions that older distribution systems are already past the point of no return." (12)

- Reports of 50-percent water leakage in the Boston system are no longer accurate, as the city has undertaken a comprehensive program to replace or rehabilitate all mains over 100 years old by the year 2000. With the exception of a small amount of borrowing for "extensions and improvements" rather than "renewals and replacements,"

Boston will have spent $113 million through 1989 for capital improvements financed entirely by user fees. (13)

- New Orleans experiences an extremely high rate of water main failures caused by soil settlement, but "Sewerage and Water Board Officials saw no need for a comprehensive main replacement program and expected to be able to cope with future failures." (14) New Orleans finances all operations plus a large waterworks improvement plan through user fees.

- Washington, D.C., officials viewed their situation as satisfactory at present, although staffing and funding cutbacks present the possibility of a bleak future. The Comptroller General suggested that by setting rates at levels sufficient to cover improvements, as has been done in Boston and New Orleans, system needs could be met and improvements could be made entirely from user fees within user capacities to pay. (15)

The Report of the Congressional Budget Office

The Congressional Budget Office (CBO) joined the discussion with a 1983 report which addressed the entire range of public infrastructure components. (16) The "Municipal Water Supply" chapter of the CBO report is essentially a projection of the findings of the President's Intergovernmental Water Policy Task Force. Extrapolating the figures for the 756 urban systems to all community systems, the CBO estimated a total replacement and rehabilitation requirement of $100-160 billion by the year 2000. The figure is higher if it is combined with the needs for servicing new growth and new source development.

The Report of the Congressional Joint Economic Committee

Another attempt to assess the nation's infrastructure needs was undertaken by the Subcommittee on Economic Goals and Intergovernmental Policy of Congress's Joint Economic Committee. (17) The Subcommittee requested the Graduate School of Public Affairs of the University of Colorado to prepare an analysis of state infrastructure conditions. The school, in turn, obtained the services of researchers in 23 states to produce infrastructure assessments. (New York was among the 23 states.)

> The estimate of needs and revenues were aggregated for the case-study states, which combined account for 64 percent of the nation's population. These totals were extrapolated to the nation assuming other states' needs and revenue expectations were the same on a per capita basis as the average for the studied states. (18)

The Subcommittee's report, dated February 25, 1984, projected nationwide water supply needs at $96.2 billion through the year 2000. Revenues were estimated at $54.5 billion over the same period, or about $3 billion per year. An additional $2.3 billion per year, or a total of $5.3 billion per year would be required to meet the total need. (19) The report noted that "this study's estimate of investment needs falls substantially below one calculated by the President's Water Policy Task Force in 1980 for urban water systems." (20)

New York State Assessments

There are, so far, two important statewide estimates of water supply redevelopment needs.

- The Department of Health conducted a Facilities Needs Survey of Community Public Water Systems; the report was released in April 1983.
- New York was one of the case study states included in the infrastructure needs analysis of the Joint Economic Committee of Congress.

Noteworthy, also, is a series of studies of individual systems which the U.S. Army Corps of Engineers has performed or for which it has contracted.

The Department of Health's Survey

In an attempt to develop a cost estimate of capital investments needed by the state's community water systems, the Bureau of Public Water Supply Protection of the Department of Health in 1983 gathered data by surveying and interviewing the state's public water suppliers. (21) Operators of the 38 largest water systems in the state and a random sample of 25 others were interviewed. A mail survey was sent to the remaining public water suppliers. Of these, 40 percent responded to the questionnaire. The report notes that the systems for which data of some kind was gathered supply 86.5 percent of the people served by the state's public water systems. The number of systems responding to the survey, however, was somewhat less than half of the total number of systems in the state.

The survey queried operators about total needs, needs priorities, cash-flow needs, water rates, metering, water production, and expenditures for maintenance and operations. The Bureau preliminarily notes that "the information presents suppliers' estimates of funding needs and how funds would be spent. No

attempt was made to validate these data...." (22) In the main text, the Bureau states that "It is to be emphasized that the data are not validated and do not result from a detailed study done by each respondent. The results are actually informed opinions given by those in each system in a position to determine what the needs are." (23)

Operators were asked "How much money would be needed in 1980 dollars to correct all problems within your system in the following categories if you could fix them all tomorrow?" (The categories were source, transmission, treatment, storage, distribution, and "other.") The Bureau projected the responses to this question to all of the state's water systems and derived a total statewide need of $6.8 billion, of which $4.2 billion was for New York City. (24) The preferred spending priority was for distribution system improvements; behind that preference, treatment, storage and source improvements were approximately equal. Immediate needs were projected to be $2.95 billion statewide and $1.39 billion outside New York City. (25)

The New York State Component of the Joint Economic Committee Report

New York was one of the 23 states included in the Congressional Joint Economic Committee's nationwide assessment. The New York component, covering more than 150 pages and surveying wastewater treatment and collection and transportation as well as water supply needs, was developed by Professor Rae Zimmerman of New York University. (26)

Professor Zimmerman noted that statewide water resources planning has concentrated on supplies, "with little attention to a comprehensive assessment of needs. Thus, total needs have to be pieced together from a variety of sources." (27) The water supply part of this document, then, is mainly a wideranging compilation of previous assessments (some of them of specific localities, rather than statewide) and, from that, a projection of needs and calculation of probable investment shortfall. The study sets forth the basic data sources, including:

- the Corps of Engineers' local studies;
- the Department of Health's Facilities Needs Survey;
- a water treatment system data base (SAFWATER) maintained by the Department of Health;

- information developed to support the Department of Environmental Conservation's (DEC) Substate Strategy for Water Resources; and
- DEC's water dam safety inventory.

Additional citations include Department of Health Water Supply Fact Sheets, New York City Planning Commission figures, an Ohio River Basin Commission water conservation survey, and an independent survey of Orange County.

Professor Zimmerman concluded that the water supply needs for systems serving three-quarters of the state's population amount to about $7.2 billion (in 1982 dollars). This includes $5.9 billion for New York City, with about $4 billion going for construction of the City's third water tunnel. The study included an examination of expenditures and revenues and projected an investment shortfall of $4.1 billion during the period lasting from 1983 to the year 2000. Professor Zimmerman did, however, express doubt that a projection of shortfall for that long a period could be regarded as reliable. (28) There appeared to be more confidence regarding the 1983-87 projection of $2.52 billion in investment shortfall, but that projection was based mainly on New York City's documented capital plans, including its third water tunnel. Capital plans for other water systems were largely unavailable. (29)

The Corps of Engineers Studies

The Corps of Engineers has undertaken or contracted for surveys of selected water supply systems, including those of Buffalo, Manhattan, the other New York City boroughs, Albany, Binghamton, Watervliet, Green Island, Cohoes, Hornell, Corning, Niagara Falls, and several communities in Cortland County. The surveys, which began in 1979, were not identical. In Binghamton, Corning, Hornell, Buffalo and the Cortland County communities, for instance, entire systems were studied. This meant that attention was given to leakage and other ways by which water is unaccounted for, main breaks, pressure problems, and source adequacy. In the Manhattan study, on the other hand, attention was focused on main breaks; in Albany, it was focused on unaccounted-for water.

Table 5 exhibits some Corps of Engineers' estimates of cost requirements for selected water systems. (30)

Table 5

Corps of Engineers' Redevelopment Cost Estimates For Selected Systems

System Location	Total Cost ($millions)
Binghamton	4.90
Cortland County	4.50
Cohoes	1.42
Green Island	.89
Watervliet	1.17
Manhattan	90.50
Buffalo	171 to 313
Albany	no cost estimate

These costs would be for different kinds of improvements.

- Manhattan--The Corps thoroughly examined a 25-year period to ascertain the incidence and characteristics of main breaks in Manhattan. The essential recommendations were to replace selected portions of those sections of the distribution system that were laid before 1930, to upgrade the maintenance program with routine annual leak detection, and to implement a water main information system. Main replacement would occur over a ten-year period at a total cost of $90.5 million. The leak detection would cost an additional $2 million per year. The analysts did not judge how large a task the recommendations would be in the context of the City's revenue capacities and current water supply expenditures.

- Buffalo--The Buffalo report presented a range of water supply needs with a cost of between $171 million and $313 million. The analysts conducted a financial analysis in which they employed various assumptions about the rate of inflation over a 30-year period. They found that there would be significant deficits between expenditures and revenues under any redevelopment scenario in which inflation existed, even with substantial increases in water rates. They suggested a need for grants.

  The report also suggested, however, that facilities were basically in good shape and that rehabilitation rather than replacement of water pipes was warranted. Part of Buffalo's problems is that its population decline has lowered the revenue base. In addition, an estimated 44-56 percent of the city's water production results in no revenue, in great part because of leakage and inadequate metering. Maintenance expenditures would therefore enhance revenues.

- Binghamton--The 1980 Corps report on Binghamton's system contained capital improvement recommendations costing $4.9 million over a period of 15 years. The Corps noted the city's lack of preventative maintenance and the need for rate changes to eliminate the deficit incurred in this city operation. The study recommended an annual maintenance program which would reduce emergency repair work and prolong the life of system components, thereby justifying the program's projected annual cost of $91,000.

- Albany--The Albany study discovered that 47 percent of the 21.4 million gallons entering the system daily was unaccounted-for. The analysts listed "correctable water losses" in several categories: unmetered accounts, unrecorded connections, data processing errors, under-registration of use by meters, leakage and main breaks. The recommended corrections and improvements could result in savings of up to $600,000 per year.

- Cohoes--The Cohoes report suggests that a twenty-year bond (at 13 percent interest), necessitating a rate increase of 21¢ per 1,000 gallons (an average person uses about 40,000 gallons of water a year), would be sufficient to conduct the necessary cleaning and lining and replacement of undersized water mains.

- Green Island--The Green Island report's cost projections used a lower (nine percent) interest rate on its 30-year bond and indicated that a project of "Priority One" improvements would cost 13¢ per 1,000 gallons.

- Watervliet--The Watervliet report concluded that $1.2 million in system improvements could be financed with a rate increase of 10¢ per 1,000 gallons, assuming a 30-year, 9-percent bond.

- Cortland County--The Corps examined the systems of seven Cortland County communities (Cincinnatus, the Town of Cortlandville, Homer, Marathon, McGraw, the Preble Water Association, and the Tully Mobile Home Park). Recommended were major projects such as hydrant and pipe replacement, additional storage facilities and pipelines, and also less expensive and more maintenance-related improvements such as metering, leak detection and mapping of facilities.

  The analysts considered the financial capacities of the communities. Generally, it was judged that without grants, the major capital improvements could not be completed, but that the maintenance recommendations were within the capabilities of the communities. The language of the recommendations indicates, also, that the recommendations for the larger capital improvements do not derive from a perception of pressing needs. For instance, with regard to the actions that are deemed to be within the financial means of Cortlandville's system, "the system can achieve some benefits from their immediate implementation, including assurance of an adequate supply at all times." (31) Likewise, with regard to the actions that are deemed to be within the financial means of Homer's system, "the system can achieve some benefits from their immediate implementation,

including assurance of an adequate supply at all times, reduced operating costs, and better fire protection." (32)

Assessing the Assessments and How They Have Been Used

Data Adequacy

The chief deficiency of both the nationwide and statewide assessments of water systems' needs is the lack of data that actually describe condition and performance. This deficiency is understandable; only local operators or consulting engineers can generate such data, and for the researchers to use it, it would have to exist in a significant proportion of systems in a uniform and readily available form. Without such data, some analysts have depended on an assumption about the relationship between age and deterioration, an assumption which we know to be faulty. Others have relied on operators' expressions of needs. The Department of Health noted, however, that its survey data "are not validated and do not result from a detailed study done by each respondent." (33)

The Department of Health has not been alone in acknowledging this data problem. The report of the Congressional Joint Economic Committee, for instance, noted that:

> ...the estimates must be viewed with caution as they are often incomplete in coverage due to a lack of data and not comparable in scope from state to state....Some researchers relied on surveys of local water system officials for estimates of both investment requirements and anticipated revenues. The assumptions underlaying respondents' estimates are generally unclear. Planning time frames vary. Some estimates are revenue constrained; others are not. (34)

Perhaps most important is that "several researchers reported that there was simply no basis for any estimate of needs, revenue or both." (35) This deficiency in basic data raises doubts about statements of the size of water system repair and replacement needs. The reports probably do correctly identify the kinds of problems which exist, but for those who propose programs for quick and massive redevelopment, they offer questionable support and little guidance about spending priorities.

Given the lack of basic data, it is not surprising that the range of contentions about the statewide costs of needed water supply redevelopment--from less than $7 billion to more than $12 billion--is considerable. It is conceiv-

able that a figure on the low end of the range could be reasonably regarded as within the capacity of the current institutional structure for water supply and that a figure on the high end could be reasonably regarded as indicative of the likelihood of a fiscal and service crisis.

Reification, or Turning the Speculative into the Definite

Data which are early recognized as flawed do not always remain so recognized. It seems that once a number appears in print, it can develop a life of its own. Here are some instances:

- The 1980 report of the President's Intergovernmental Water Policy Task Force contained a clear admission that while it was suggesting that the total investment shortfall could amount to $10-$13 billion, "uncertainties involved in the estimating procedure imply that a $5 billion to $26 billion shortfall range is not unreasonable." (36) Then, in 1981, authors of an influential book entitled America in Ruins, citing the Task Force report, stated unequivocally that the nation's 756 urban areas will require $75-$110 billion over the next twenty years to maintain their water systems and that "at least an additional $10-$13 billion beyond that generated by existing user charges will be required." (37) Furthermore, the authors cited not the Task Force, but rather the Comptroller General's report, which had elaborated upon the Task Force figures.

  The disconnection of the Task Force's findings with its authors and their more complex view went a generation further when, in a 1982 article in the Journal of the American Water Works Association, a writer quoted the $75 to $110 billion needs figure and cited not the Task force nor even the Comptroller General, but rather America in Ruins. (38)

- The New York component of the Congressional Joint Economic Committee report was an essentially uncritical compilation and statistical development of earlier studies. While there was a general acknowledgement of data problems, (39) the reservations contained in publications such as the Department of Health's Facilities Needs Survey had no clear effect on the conduct and presentation of the calculations. The New York volume did not contain the broad and emphatic note of reservation that the Joint Committee's report contained in regard to the nationwide findings.

Time

Some needs are more pressing than others, and the affordability of meeting a need depends partly on how fast it must be met. Simple quotation of

large amounts of money can be alarming in two ways:

- It can give the impression that crisis is imminent and that massive and relatively quick redevelopment programs are advisable, even necessary. Billions of dollars in redevelopment costs statewide would indeed be difficult for the responsible institutions to meet in less than ten years. And in particular localities, the idea of millions of dollars of redevelopment might be just as daunting.

  The fact, however, is that almost all of the major capital recommendations of the various studies involve a time frame of 20-30 years for implementation, which gives the suppliers some leeway, for instance, to augment system revenues, wait for lower interest rates, develop cooperative arrangements with other systems that could reduce per capita costs, and otherwise develop new financing schemes.

- Some of the identified needs are not as pressing as are others. The Department of Health's projection of needs was based largely on responses to this question: "How much money would be needed in 1980 dollars to correct all problems within your system...if you could fix them all tomorrow?" The definition of "problems" is pertinent here: Operators understandably might have specified improvements which might greatly enhance the efficiency of their systems, but it is not necessarily true that their systems would be in (or accelerate into) a state of serious deterioration without those specific improvements.

  Some of the Corps of Engineers' findings--the only ones among the reviewed New York State studies that are based on actual observation and testing of water systems--in selected localities also suggest quite clearly that not all improvements are necessary for adequate moderate-range system performance. This was most evident in the Cortland County studies.

The Case for Better Data

It is important to note again that the surveys we have reviewed are not "bad" studies. (This is obviously true with regard to the Corps of Engineers' studies. The Corps' studies generated the kind of direct observational data which we have lacked, but they have been conducted in a relatively small sample of localities.) These studies are probably the best that can be done given the lack of direct observation of conditions in a reasonably large sample of systems. But with such research limits, should the surveys be depended upon as authoritative indications of need? There are some important risks in so using them.

- To fix old water system hardware is not necessarily to fix that which needs fixing. Programs based on an assumption that "old" means

"deficient" would waste money and effort and leave many real problems uncorrected.

- Beginning programs of redevelopment too quickly would not easily permit the re-evaluation of management methods and institutional arrangements that may be the ultimate causes of deterioration and that could result too soon in recurrence of those water system problems that do exist.

- A perception of crisis could cause suppliers to borrow massive amounts of money for redevelopment. If crisis turns out to not be imminent, the cost of redevelopment would unnecessarily be much higher than if an institution had planned with a longer time frame and employed commensurately greater estimates of revenues available before work must be completed.

Analysts employed by the President's Task Force were likewise careful about the utility of their findings. Speaking of their extrapolation from a review of ten urban water systems, they noted that:

> A sample of this size is unable to capture the full diversity of characteristics and is statistically inadequate for use in national extrapolations with accuracies greater than an order of magnitude. An estimate with only order of magnitude accuracy provides little assistance to budget-minded legislators and decision-makers. (40)

Further, they noted that:

> The apparent scale of these problems strongly supports the need for a more detailed and thorough study of the nature and dimensions of both the problem areas themselves and the available avenues of solution....a closer determination of distribution system rehabilitation and replacement practices and requirements is essential to a more detailed understanding of this largest component of systems' investment needs.... (41)

If nothing else is clear from this review, then, it is that it would be better if there were more data that directly described the conditions of a significant sample of systems. This might permit a reliable assessment of statewide need and a prescription of specific kinds of redevelopment. Such a data set is not inconceivable, and as it turns out, it would not only permit reliable assessment, but also facilitate sound routine maintenance. The next chapter will be an exploration of the nature of such a data set and its derivation.

Chapter 4. What Is It Possible To Observe?

The Problem of Looking Underground: Replacing Rules of Thumb With Information

Among the indications of the previous two chapters are that:

- age is inadequate as a criterion for making repair decisions and developing estimates of the scale of redevelopment needs;
- deterioration is, instead, a result of a complex interplay of materials and physical and chemical forces; and
- recent assessments of redevelopment needs have been distorted in quotation and are, sometimes by their authors' admissions, unreliable for prescription because they are the results of limited observation and/or limited sampling.

The intention in this chapter is to specify the kinds of data that are obtainable and not often used and that could be employed not only to more reliably estimate the amount of redevelopment needed, but also to more reliably specify the items and locations needing attention.

Facilities for conveying water have two characteristics that make it difficult not only to confirm or deny contentions about deterioration, but also to efficiently treat those deficiencies that do exist:

- They are complicated networks of many miles of pipes, joints, pumps and valves; and
- they are located underground and, therefore, difficult to observe.

Despite these difficulties, engineers have developed several methods that yield reliable measurements of the general condition of a system and that can be used to locate specific problems. Use of these methods appears to be somewhat sporadic, perhaps occurring most often in special studies by consulting engineers. In addition to producing voluminous diagnoses and prescriptions regarding distribution system problems in specific localities, such consulting engineers in recent years have developed these methods of observation into models for prediction, for instance, of pipe failure and the costs of repair vs. replacement. (1)

The chief benefit to be derived from the employment of these methods is the replacement of rule-of-thumb maintenance and rehabilitation judgments (such as those based on age) with decisions that are based on reliable observation of the hardware to be maintained and rehabilitated. (2) Methods developed by consulting engineers permit local managers to be more exact than do rules of thumb. For instance, more directly descriptive information permits a manager to:

- specify which problems are the biggest and compare current problems with apparently imminent problems, and thereby schedule maintenance and repair jobs;
- more exactly ascertain the location of a hardware deficiency instead of excavating a large area to find it; and
- judge whether or not deterioration is so advanced that replacement rather than repair is the appropriate remedy.

The principal risks in using rules of thumb rather than more directly descriptive data are considerable.

- There is direct waste if the items most in need of work are not the ones identified as such.
- Problems will recur unless the source of the difficulty is correctly identified. The complexity of distribution systems is such that a problem that is apparent to the user often is actually caused by a system condition distant from the user. For instance, a leak in a joint which services a set of residences might have been caused by water hammer, a pressure surge which can result from a malfunctioning valve located some distance from the joint. Repairing such a joint without correcting the valve problem could result in recurrence of the leak.
- Overexpenditure often results when replacement occurs while repair would be adequate.

Following is a review of some methods and data which can help water system managers to avoid the risks inherent in the employment of rules of thumb in maintenance and rehabilitation decisions. As has been noted, these methods are generally put to use through contracts with consulting engineers. One point to consider during and after the ensuing review is the extent to which the use of these methods can be made more common and more efficient through their linkage with routine maintenance procedures.

The methods, which vary with regard to the directness and comprehensiveness of the distribution system observation they facilitate, are:

- water accounting;
- leakage survey and detection;
- main break analysis; and
- various techniques which might generally be called flow appraisal.

Water Accounting: Discovering How Water Is Lost

The basic question addressed through water accounting is, "What is happening to the water once it has been conveyed from the source?" As was noted in Chapter 2, the reasons for answering this question are that:

- water, which costs money to produce, is supposed to produce revenue to pay for its production, and unaccounted-for water is water that produces no revenue; and
- while the existence of unaccounted-for water does not necessarily imply a hardware deficiency, a high percentage of unaccounted-for water suggests that there may be significant leaks in the distribution system.

Reliably ascertaining the amount of unaccounted-for water requires metering, at least at the source. A flowmeter at each water source (or at the treatment works) can record the amount pumped; user meters can record the amount used. Some water supply systems--most notably, New York City's and Buffalo's--are not metered for residential use. When use is unmetered, observers must somehow estimate it as a percentage of production. An estimate is often partly the result of calculations which reflect relative use in selected and studied systems that have complete metering.

Basically, unaccounted-for water is the difference between the flowmeter record and metered use. This difference, by itself, might be the basis only for another rule of thumb. Water accounting, however, usually involves specifying the modes and respective volumes by which water escapes the recording mechanisms. In its study of the Albany system, for instance, the consulting firm noted that unaccounted-for water can be attributed to a number of factors, including inaccurate meters, leaks or breaks, unmetered public uses, unauthorized

connections, erroneous accounting practices, improper meter reading, and/or inaccurate system controls, such as faulty valves. (3)

Determining how much unaccounted-for water is attributable to each of these factors is not simple. For the Albany study, for instance, the consultant proceeded through the following sequence of tasks.

1. A statistically reliable sample of customer meters was tested for accuracy at various flow rates.

2. Based on the results of the meter testing and national water use profiles, an estimate of unaccounted-for water attributable to meter underregistration was developed.

3. An estimate of water consumption in unmetered municipal buildings, schools, and hospitals was made based on occupancy and other data provided by the City.

4. An estimate of hydrant use for firefighting was made.

5. A computerized address-match between billing files of the Water Department and the Niagara Mohawk Electric Company [sic] was performed to identify potential unrecorded connections to the water system.

6. The City's billing system was analyzed to determine any recording procedures which inadvertently add to the quantity of unaccounted-for water.

7. City records concerning main breaks and leaks were reviewed to quantify the water associated with these occurrences. (4)

This sequence of tasks requires considerable effort, and results will include an element of uncertainty. It is obvious that water accounting is more easily and more accurately conducted in a system that is completely equipped with well-working meters.

The inferences that result from water accounting usually are very important. For instance:

- If metering and/or billing inaccuracies are resulting in a high amount of unaccounted-for water, water supply managers might embark on programs to correct meters or install new ones and revise billing practices, both of which probably would enhance revenues.

- If water accounting ascertained that leakage was a major reason for a system's unaccounted-for water and that it exceeded a minimum acceptable percentage (e.g., 15 percent), the manager might wish then to conduct or contract for a leakage survey. If the water

accounting indicated that there was little leakage, then a leakage survey might be considered deferrable.

Water accounting, then, might be regarded not only as indicative (very generally, and somewhat indirectly) of the condition of a water supply system, but also as preliminary to decisions about using other diagnostic procedures to examine the distribution system. In many cases, much of the unaccounted-for water will be attributable to leakage, and it will be advisable to find the leaks.

Leakage Surveys and Leak Detection

Why Find Leaks?

There are several reasons, some already noted in Chapter 2, for which managers might wish to find and/or stop leaks.

- Loss of Investment--One reason is that pumped water constitutes a local expenditure, and pumped water which leaks through the distribution system provides no compensating revenue. One writer has noted that a 1/2-inch diameter hole at 50 psi (pounds per square inch) can leak 38,000 U.S. gallons per day (gpd), "sufficient to keep a village of 300 people in water, at an average consumption of 125 U.S. gpd per capita. It would not be surprising to find several leaks of similar magnitude in most small distribution systems." (5)

- Damage to Bedding--Leakage, already indicative of some degree of deterioration, can cause further deterioration, including damaging breaks and loss of service at the point of the leak and elsewhere in the system. For instance, water seeping into the ground around pipes damages the bedding that supports the pipes and makes them more susceptible to stressful bending. And in order to deliver an adequate quantity of water through a leaky pipe to the users, it may be necessary to pump more water at higher velocity. This increases the internal stress on the leaky pipe and on connecting pipes and valves and can, therefore, exacerbate the leak and cause new ones.

- Big vs. Little Leaks--Every distribution system will have some leaks, and the cost of repairing them--the costs of personnel, use of equipment, new pipes, excavation and interruption of water and other services--is considerable. Some leaks are so small, doing so little damage, that restoring the pipes and valves to a nonleaky condition is not worth the expense of doing so. A manager who knows that a segment contains leaks, but does not know which are the significant ones, may excavate in the wrong area. Leak detection can help him/her avoid such waste.

Diagnosing and Locating

Leak survey/detection techniques commonly involve two procedures, each of which can be useful in itself, but each of which is most useful when complementing the other. The first procedure is to divide the system into districts and successively test each of the districts to determine flows in excess of observed consumption. When a district with excessive loss of flow has been identified, it can be further divided for additional testing in order to reduce the distance of pipe that will require more intensive attention.

The next stage might be considered "pinpointing." After the survey of districts has indicated which of them may have significant leaks, those districts are further examined through visual inspection and sonic detection techniques.

The use of sound to detect leaks sometimes occurs without being preceded by a district-by-district flow-and-consumption analysis. Leaks in water pipes produce distinctive sounds which can be discerned by a variety of amplification instruments, the best of which are electronic devices akin to microphones.

> The search identifies areas of leakage by listening at direct contact points of the system, such as hydrants, main line valves, curb valves, and meters. Once a leakage noise has been identified by direct contact, the leak is bracketed. Bracketing involves comparing sonic values in the area of the leak to predict the approximate location of the leak. (6)

The skillful use of this detection equipment, especially in specifying how large a leak is, requires sensitivity to sonic differences caused by particular kinds of pipes, soils and leaks. Sonic methods are an important way of pinpointing leaks, but there are alternatives, most notably the use of tracer gases.

Sonic detection probably produces better results when preceded by flow-and-consumption analysis. Metering is important for ascertaining flow. (7) Two of the most popular instruments used to provide a measure of waste are pitot tubes and meter-masters. Pitot tubes are flow meters installed in pipes through openings as little as one inch. Meter-masters convert regular meter register action to a rate of flow. (8)

Sonic detection of leaks is a service for which a local water supply manager usually will contract. In order for such a service to be successful, however, good records must exist, not only with regard to flow and consumption, but especially with regard to the system's layout (i.e., the locations of mains, valves, pumps, etc.).

Break Analysis

The reasons for main breaks vary from locality to locality, and careful observation and record-keeping of the characteristics of main breaks over a period of years can yield information that helps local water supply managers to predict where breaks might occur in the near future and to spend pipe replacement money in the most effective manner.

Breaks as Results of Stress and Pipe Characteristics

Chapter 2 contained a review of some causes of breaks. It was noted that causation can be complex; break analysis, therefore, also is complex. The locations of pipes make them subject to different kinds of stress, and different kinds of pipes will react differently to a particular kind of stress.

To briefly review material covered in more detail in Chapter 2: Stresses on pipes are both internal (e.g., water hammer, tuberculation) and external (e.g., soil weight, traffic impact, large temperature changes, external corrosion). The way a pipe reacts to these stresses depends in great part on characteristics of the pipe itself, including pipe material, pipe diameter, and thickness of the metal. (9) Any particular configuration of kinds of stress and pipe characteristics probably will produce breaks that are distinctive in number, locations and types (longitudinal, circular, blowouts).

Specifying the Causes of Breaks

The analysis of breaks over a period of time can result in a reliable description of the nature of a locality's particular configuration of breaks. It is especially in the case of main breaks and pipe replacement decisions, regarding which age is often used as a criterion, that careful analysis offers great opportunity to substitute experientially based information for rules of thumb.

Once again, good record-keeping is necessary. The basic information required for a break analysis is:

- an inventory of the system of pipes and valves; and
- a record of breaks covering a period of several years.

Most water suppliers have some kind of system map. If a map is adequately detailed, it could constitute the most basic kind of system inventory.

However, for the purpose of statistically associating stress and pipe characteristics with break incidence, it is preferable to divide the map into segments that can be compared. Each length of pipe (usually several hundred meters) is assigned a unique numerical identity, as is each valve and joint. The lengths of pipe are sometimes called links, and the points at which they connect with each other are called nodes. Then, for each segment, pertinent information is recorded with the numerical identity. Pertinent information would include:

- general descriptive data--location (e.g., the nearest street intersection), date of installation, pipe diameter, pipe length, number of hydrants linked to it, pipe material and pipe thickness; and
- a record of breaks that have occurred in each segment. The record should include the date, location and type of break. (10)

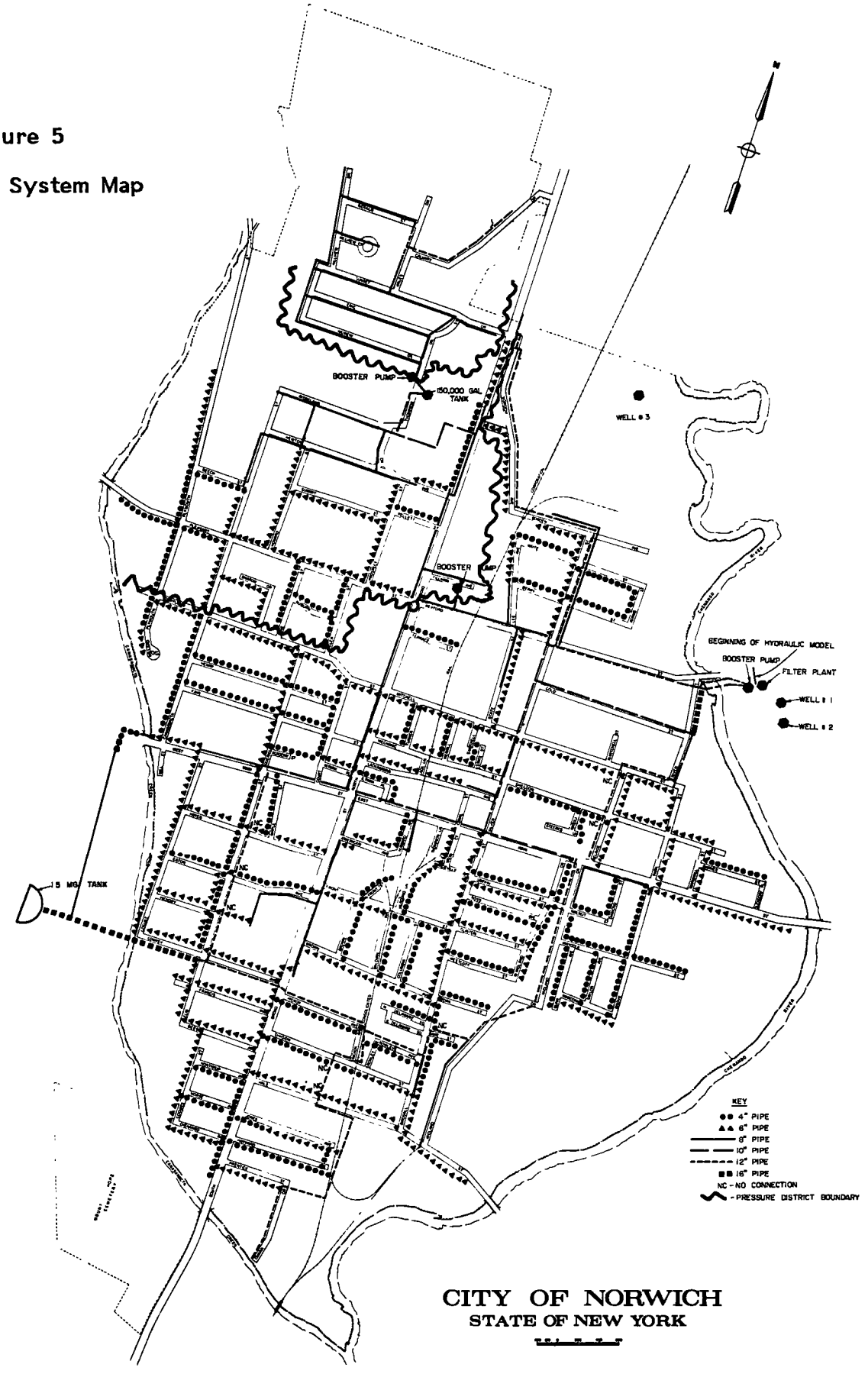
There is no specific limit to the amount of general descriptive data that might be useful. In addition to characteristics of the hardware itself, this data category could include information describing traffic pressure, soil conditions and chemical characteristics of the water. Techniques for measuring and predicting corrosion, for instance, are becoming more sophisticated. In fact, the U.S. Environmental Protection Agency has promulgated, in connection with the Safe Drinking Water Act, (11) requirements for the monitoring of corrosivity characteristics. (12) The requirements include a survey of construction materials and water quality analyses which use a variety of accepted indicators of acidity and alkalinity. Also available for corrosion investigations are laboratory analyses such as:

- weight loss tests conducted by immersing pipe in water typical of the system;
- visual inspection (sometimes with the help of a microscope) of tested materials to ascertain if the corrosion is the kind that results in pitting;
- examination of scales that accumulate on pipes; and
- use of electrochemical probes to measure corrosion rates. (13)

In order to account for the fact that water in an actual system is moving, investigators sometimes construct "pipe loops" which use appropriate metals and convey

Figure 5

A Water System Map



Source: Susquehanna River Basin Commission, Water Distribution System Infrastructure Study, City of Norwich, NY, 1983.

the water typical of a locality and in which they can then observe corrosion as it happens in a system.

Clearly, then, there is potential for a great deal of explanatory information to be recorded. Even without gathering data on soil and water conditions, data sufficient for worthwhile break analysis probably would be voluminous. Computers, although not essential, are of great help in both recording and analyzing these data. The larger the system, the more help computer analysis can be. The statistical task is to produce meaningful associations between the descriptive characteristics and the incidence of breaks. Such associations can tell local managers not only geographic locations where break incidence is high (many would notice that without such an analysis), but which particular kinds of pipes are breaking and, by inference, what particular conditions are causing breaks. Rather than replacing most mains in a large geographic section of a city where break incidence had been high, for instance, a manager might find that it will be much less expensive and just as effective to replace only the sand spun pipes of less than 24 inches in diameter. Or, he/she might find that replacement or repair will be futile if the soil bedding which supports a particular pipe segment is not strengthened.

Some analysts have used such data and statistical associations not only to ascertain types of pipes, locations and conditions characteristic of main breaks, but also to ascertain when replacement is preferable to repair, and vice versa. Their methods involve the linkage of:

- the probability of further breaks in a particular segment; and
- the cost of repairing that segment (plus the cost of damages caused by a main break)

to specify an "optimal replacement age" for that particular segment. (14) Two consultants found in their study of the Binghamton system that:

> ...it is not economical to replace...pipe before it is at least 100 years old even if it has experienced previous breaks. [But] while...it is not generally economical to replace entire pipes, it may still be economical to replace sections of the pipe that have experienced a number of breaks. (15)

Flow Appraisal

Evaluation of Whole Systems and Typical Service

Flow appraisal, often identified by the terms hydraulic network analysis and pressure modeling, has to do with the adequacy of the amount and pressure of water that passes through a system to all users. More than any other kind of assessment, flow appraisal examines the system from the user's point of view. The basic question it addresses might be stated as follows: Regardless of leakage and other disruptions--i.e., when the system is working routinely, about as well as it can--is a sufficient amount of water delivered to each place in the system in a timely manner? An additional question which flow appraisal can be used to address has to do with planned changes of the system: Will it deliver sufficient water to each place in a timely manner if it is expanded or altered in a particular way?

Answering such questions requires a definition of "adequate service." Very often, and very generally stated, the criterion of adequacy at any location within the system is an amount of water (measured in gallons per hour or gallons per day) that meets or exceeds the daily peak of consumer demand plus the amount necessary to fight a sizable fire with adequate water pressure.

Requirements and Design Choices

Ideally, then, the designers of a system, in order to attain "adequacy" of service at any particular point in the system, had to predict the demand: What is the maximum amount of water that users would require at each location in the system? After making a projection to answer that question, the designers had to decide how large a pipe, with how fast a flow of water, would be needed to transport the projected volume to each location.

Different combinations of pipe size and pressure can satisfy a specific flow volume requirement. (16) A smaller pipe with greater velocity could supply the same volume of water as a larger pipe with lesser velocity. Smaller pipes, however, increase the frictional resistance to flow, and this could require more pressure to deliver adequate volume.

While there is, theoretically, a range of combinations of pipe size and pressure that can satisfy a specific flow volume requirement, certain design

considerations make some combinations more practical than others. For instance:

- Excessive pressure often will convey more volume than necessary, causing waste by water fixtures and starting or increasing leakage in mains.

- Excessive velocity can scour and cause erosion in corrosion-weakened pipes, and it can also result in water hammer when valves are closed too quickly.

- Below a minimum velocity (2 to 2.5 feet per second), silt in the water will be deposited in the pipe, thereby decreasing the pipe's effective size.

- Pipe constrictions and enlargements along the route increase the amount of pressure required to initiate and sustain flow velocity and to overcome energy losses.

- Deposits of rust caused by internal corrosion reduce the carrying capacity of a pipe by reducing its area and increasing its roughness, thus increasing friction. This necessitates increased pressure to overcome the friction and increased velocity to convey adequate volumes. A pipe which had once been sufficiently large, then, through corrosion can be effectively rendered no better than a smaller pipe in new condition. (17)

Within the range of pipe sizes and velocities of flow which can convey a necessary volume, it is possible to select an optimum size to minimize costs. For instance, the smaller the pipe diameter, the greater will be the frictional resistance to flow, and the higher will be the cost of pumping to increase pressure. A larger pipe will reduce pumping costs, but the initial capital cost will be higher. Comparing the costs for various pipe sizes can result in the selection of an optimal size. Tuberculation, however, complicates the comparison: The larger is the diameter of the pipe relative to the amount of water it must convey, the slower will the tuberculation process make the pipe's carrying capacity inadequate. The system designers must decide whether the reduction in the carrying capacity of a particular pipe over time is sufficiently high to warrant the greater capital expense of using a larger pipe.

Such considerations are pertinent not only to system designers' considerations, but also to system managers' work. A manager monitoring deterioration in his/her system will want to know the particular locations at which the system is routinely failing to meet the criteria of adequate flow. Once such a location has been identified, the reasons for the failure can be suggested on the basis of the characteristics of that location. Failure at any particular loca-

tion may result from a distinctive combination of characteristics such as leakage, breaks, long-term increases in demand, reduced carrying capacity, and deficient pumps.

Direct Tests

Of the methods of directly appraising a system's flow, two--pressure surveys and fire flow tests--are more common than the others.

- Pressure Survey--A pressure survey measures the system's efficiency in meeting the routine requirements of users. It is conducted by attaching a pressure gauge to the hose nozzles of a succession of hydrants and opening each hydrant valve to permit the normal pressure of the water flow to fill the barrel of the hydrant. The pressure is recorded on the gauge. A reasonably large sample of hydrants will produce enough readings to reliably characterize the pressure throughout the system in general. (18)

- Fire Flow Test--One of the ways in which pressure surveys are limited is that they do not assess the adequacy of pressure at times of special demand stress. Special demand stress often is caused by the need to use one or several hydrants for fire fighting. Fire flow tests (also known as hydrant flow tests) can compensate for this limitation. To state it generally, "fire flow tests consist of discharging water at a measured rate of flow from one or more fire hydrants and observing the corresponding pressure drop in the mains through another nearby hydrant." (19)

  For fire flow testing, the system's hydrants are grouped on the basis of how closely the underlying pipes interconnect them. Within each group, then:

  > one of the outlet caps on the residual hydrant is replaced with a pressure gage...and the initial water pressure reading is recorded. The surrounding hydrants are then opened and discharge is measured using pitot gages. A pitot tube centered in the flow stream from a hydrant nozzle measures the pressure exerted by the velocity of the flowing water. (20)

  The great importance of this procedure lies in the fact that fire department hoses require a minimum amount of pressure to operate (50 to 75 psi if the hoses are connected directly to hydrants, and 20 psi if fire department pumpers are used to create the water stream). (21)

Direct appraisals of a system's flow are sometimes aided by two other methods of analysis:

- Hydraulic-Gradient Test--This procedure records flow pressure at several points along a specific route and permits graphic representation of the change in pressure along that route. The analyst desig-

nates a particular set of pipes that run from the water source to an outlying section of the distribution system and measures pressures along that line at times of normal peak demand. Generally, there will be a decline in pressure from the beginning to the end of the line. By plotting the observed pressures along a horizontal distance scale and connecting the points, a curve will be formed. Where the curve declines very steeply between two points, pressure losses are acute, and those areas might be considered the trouble spots along the route. (22)

- Coefficient-of-Roughness Test--A coefficient-of-roughness test is an attempt to infer the internal condition of a pipeline. It was earlier noted that the roughness of a pipe's internal surface is a determinant of its carrying capacity, i.e., the rougher is the internal surface, the more velocity it will require for a particular volume of water to pass through the pipe. An analyst makes an inference regarding roughness in the following manner:

  . A section of pipe is isolated by closing interconnections between the beginning and end of that section; and

  . a measured flow of water is transmitted through the pipe and the hydraulic gradient (see the preceding discussion) is observed.

  The observed loss in pressure is used in one or more of several formulae which hydraulic scientists have developed over many decades to yield a coefficient which indicates how rough the pipe is relative to new pipes. The formulae (the most often-used of which is called the Hazen-Williams formula) employ, in addition to the pressure readings, the diameter, length and number of constrictions and enlargements in the length of pipe. (23)

These, then, are the direct tests that a manager can apply to obtain an understanding of how deteriorated his/her system might be and to ascertain the points at which the deterioration is resulting in inadequate service.

Indirect Tests: Importance

There is a practical problem with direct testing: The systems that serve most people have many miles of pipes and hundreds or thousands of points of junction, turns and valves. Direct testing is intensive, requiring many man-hours; the size of a typical system makes it impossible for direct testing to be both frequent and exhaustive.

It is for this reason that indirect testing, via computer-aided simulation, has proved to be so valuable. While direct testing perhaps yields more reliable information, indirect testing is more economical and, therefore, gives a manager more opportunity for exhaustiveness. In general, an optimum between

exhaustiveness and reliability can be obtained by combining a system-wide simulation with a sample of direct tests to ensure that data used for the simulation are realistic and to verify the results of the simulation.

Simulation permits not only system-wide evaluation and diagnosis, but also prediction of the effect of system expansion or other alteration. The computer programs developed for this kind of flow appraisal permit a manager to predict the effects of a variety of hypothetical changes (e.g., increased demand, new installations of pumps or pipes) in any part of a system on the adequacy of flow to all locations in the system.

Indirect testing, then, facilitates the following practical managerial benefits:

- closer-to-exhaustive identification of locations where flow is inadequate or would be inadequate upon an alteration of the system;
- specification and simplification among the inevitable variety of possible reasons (e.g., undersized pipes, wrong pumps, too many hydrants) for inadequate flow to any location;
- generation of alternatives for correcting the deficiencies causing inadequate flow;
- comparison of the relative effectiveness of the alternative corrective actions;
- prioritization of system improvements within a limited capital budget; and
- preparation of operating procedures for different kinds of emergencies (e.g., partial loss of supply source, main break, fire).

Indirect Tests: How They're Done

The basic items required for such simulation are:

- several kinds of data--a system inventory, some direct tests to ensure that input data on hydraulic functioning are realistic, and measurements or estimates of demand; and
- use of a computer with the necessary programming.

The system inventory is essentially the same as that necessary for break analysis, i.e., a representation of the system as an interconnected collection of links and nodes, with data regarding pipe lengths and diameters. Such an

inventory is usually a major task, but:

- it is largely a one-time effort--it is unlikely that system alterations would be so vast as to make updating the inventory more than a small job; and
- it is reusable for periodic break analyses and flow appraisal.

The inventory actually used by the computer is a system representation that is somewhat less than complete. For instance, in a simulation study of the Watervliet system, the consultants used only 71 percent of the water mains, but these included 96 percent of the mains with diameters of eight inches or more. (24) Small service pipes and the valves attached to them do not appreciably affect the major hydraulic factors and overall performance of a system; excluding them from the simulation considerably reduces both the amount of data that must be entered into the computer and the amount of computer time needed for analyses and predictions.

The system inventory constitutes the data necessary to describe the structure of the system. Measurements or estimates of daily demand provide data on the volume of water that should reach the users. Hydraulic data are necessary to describe the current condition of the system. Already-completed pressure, fire flow, hydraulic gradient and coefficient tests typically constitute the hydraulic data. (Most often, analysts do not actually conduct coefficient-of-roughness tests, but instead estimate carrying capacity on the basis of pipe age, pipe size, pipe material and chemical properties of the water being conveyed.)

After all these kinds of data are entered into the computer, a preliminary calibration must occur: Test simulations are run in order to generate flow and pressure figures for the system as it exists. The purpose is to ascertain whether or not the computer model produces results that match the results of those direct tests--e.g., flow/pressure figures for a few locations in the system--that do exist. If the simulations produce different figures for those points for which direct tests exist, there is something wrong with the inventory and/or the other data, and they must be altered. Early runs often exhibit such a mismatch, and inasmuch as the carrying capacity coefficients usually have been estimated, they are the data item that most often undergoes alteration in order to obtain flow and pressure readings that fit the known system performance.

After calibration provides a reasonable fit with system performance as it has been directly measured in the past, analysts sometimes verify the model

with a few new direct tests. They consider this necessary especially when the existing test results are quite old.

The several computer programs for conducting these hydraulic simulations are elaborations of pencil-and-paper methods that existed before computers were available. The high speed of computers makes it possible to use more complete data and to do new simulations with corrected assumptions. Both the pencil-and-paper methods and the computer programs represent specific physical relationships between the amount and direction of water flow and the head loss (head loss can be understood as a decline in available water pressure that occurs as the water travels through a conduit). (25)

How Feasible?

These, then, are some of the important techniques of system evaluation that are more direct than are the methods upon which most nationwide and statewide assessments have so far been based. Ideally, these methods would be applied (or would have been applied as part of local maintenance routines) to a carefully selected and reasonably large sample of systems in order to obtain a realistic overall estimate of redevelopment needs. And whether or not these methods had been used to make overall estimates, their use prior to making actual repair and rehabilitation decisions in any particular system would greatly enhance the efficiency of the work.

Methods which are useful, however, are not necessarily feasible. In particular, smaller systems which have limited financial resources may be unable to hire the expertise and collect the data necessary for use of modern diagnostic procedures. Chapter 5 will explore the state of knowledge about local data collection, with special attention to deficiencies in the metering of water consumption.

Chapter 5.
What Do We Know About Local Data Collection?

Data Gathering and Organization: Needs, Capacities and Benefits

There is little definite knowledge about the nature of local water system data collection. The extent to which systems monitor water use with meters is known, and they do report information regarding some system operations to state agencies. Mainly, however, ideas about the volume and organization of local data result from impressions and unverified inferences.

The use of the modern methods of water system diagnosis requires the collection and storage of what may seem to be a large volume of data.

- For water accounting, the basic data are figures describing production and consumption. Meters are enormously useful in generating these data. Most systems will have meters at their production facilities; metering of use, however, is not so often present. Some systems do not have any metering of use. Others may meter residential, commercial and/or industrial use, but not public uses.

  The more gaps that exist in the metering of water flow, the more estimation must be used to generate the data necessary for water accounting. Procedures for such estimation would include examination of billing records, surveys of users and application of assumptions derived from studies of other localities.

- For leakage surveys, the basic data include those necessary for water accounting plus a system inventory, at least in the form of a map. The map would show pipes (including sizes and the respective directions of flow), valves and pumps, and it would facilitate the division of the system into districts for loss-of-flow testing.

- For break analysis, it is necessary to have a system inventory plus a record of breaks. An excellent system inventory would show not only the locations of system elements and pipe lengths and diameters, but also pipe materials, dates of installation and number of hydrants for each length. Ideally, there would be some description of weight and traffic stress and soil types. The break record would include the dates, locations and types of breaks.

- For flow appraisal, a system inventory constitutes the minimum data. A record of any pressure surveys and fire flow tests conducted in the

past would be helpful, but not necessary inasmuch as new ones can be conducted.

What amount of data collection, organization and analysis can reasonably be expected of water supply systems? Many local systems, especially the smaller ones, may employ only enough water system personnel to very basically operate the system--e.g., monitor quality, keeps pumps repaired, and respond to flow problems such as frozen or broken lines. For such systems, it may be difficult not only to conduct these kinds of analyses, but even to maintain the data necessary for them.

For a system in which the staff spends most of its time responding to emergencies, the inability to collect sufficient information and perform strategic analyses may present a dilemma: To the extent that deterioration is the cause of the emergencies, those data-related activities may be necessary to escape an emergency mode of operation, and they almost certainly are necessary if the system is to do so in the most economical way. When a system's personnel are forced to spend most of their time treating symptoms, causes may go undiscovered and untreated. Without dealing with causes, old symptoms often will recur with increasing frequency, and new ones will develop. For instance, a segment of a system may be experiencing a high frequency of main and service pipe breaks because excessive pressure is causing leaks and otherwise placing inordinate stress on some pipes. If the staff has time only to fix breaks (but not to analyze the system), the operator may be unable to identify a feature that is causing the excessive pressure or even to identify excessive pressure in part of the system as the cause of the breaks. He/she may simply continue to repair the breaks as they occur. And as the continuingly excessive pressure further weakens joints, places stress on pipes, exacerbates leakage and thereby damages bedding, the break frequency will increase.

Local operators, many of whom have training in engineering, know the consequences of treating symptoms rather than causes, and they bring much analytical and intuitive capacity to their jobs. But in systems in which repairs occur mainly or solely on an emergency basis, a sound data base and more frequent testing very often would considerably assist an operator in his/her efforts to escape an emergency mode. While operators recognize the value of treating causes rather than symptoms, specifying the "right" cause can be almost impossible without the right data.

For instance, a low-pressure problem caused by leakage and/or an inadequate pump might be readily diagnosed by an operator, who may have seen signs of leakage (e.g., depressions, wet pavement) and who may be aware that the number of service connections to a main has increased greatly in the last five years. He/she could decide whether it would be less expensive to install a more powerful pump or repair leakage. On the other hand, a low-pressure problem could result from the flow of water into parts of the system that do not have users (e.g., a set of pipes that was laid for future development of an area in which the development never occurred). The low pressure could have developed when main gates to that area corroded sufficiently to permit flow; or, they may never have been closed, but the pressure problems did not become significant until connecting parts of the system became heavily used.

It would be reasonable for the operator, who has never had to even think about the never-used mains, to not consider them in his attempts to deal with the low-pressure problem. In order to identify them as the causes, he/she would need the resources to do a flow-loss analysis. If, as has happened, those mains were never included on the system map and knowledge of them perished with the departure of a previous operator, even a flow-loss analysis would result in mystery. And the leak repairs and pipe installations that would occur in efforts to improve pressure might be only minimally effective.

Reported Data

Local officials directly or indirectly report data to the Department of Health (DOH), Public Service Commission (PSC), and Office of the Comptroller.

Reports to the Department of Health

DOH obtains information on local water system operations through three reporting procedures. (1) They are:

- monthly reports;
- annual inspections; and
- five- and ten-year detailed evaluations.

Monthly Reports--Water system operators file monthly reports with county or district health offices. The amount of required data varies somewhat

depending on whether a system is a community system (a system with at least five service connections used by year-round residents or which regularly serves at least 25 year-round residents) or non-community system and on whether it has a small and simple treatment operation or a large treatment operation. Most of the monthly report data relate to quality-monitoring, including figures describing temperature, acidity, amounts of chlorination and other chemical treatments and microbiological sample results. However, a few items on the report forms do pertain to other matters of system functioning.

- There is a "yes or no" query about whether or not an emergency occurred in any part of the system. The definition of emergency is a disruption of routine delivery for four or more hours.

- There is a query about the volume of production. For community systems, production is expressed in thousands of gallons of treated water per day. For noncommunity systems, production is expressed as the number of gallons pumped. All the larger systems, and many of the smaller ones, have source meters. Some of the noncommunity systems, however, must estimate production (e.g., by observing the number of hours the main pump ran), and some leave this report item blank.

- For systems with large treatment operations, there is a query about whether or not there were pressure problems in the distribution system. The standard to be maintained is a minimum of 33 psi at all locations in the system, but it is not necessary to report a pressure deficiency unless it drops below 20 psi.

- The forms contain space for "comments and/or remarks" so that the operator can elaborate on any of the foregoing or other problems.

Local health officials forward parts of the reports to DOH for entry in DOH's computer data bank, and DOH periodically prints summary reports based on the monthly reports.

Annual Inspections--Once per year, local health officials meet with water system operators to ask them for basic organizational, structural and operating descriptions. Prior to such an interview, DOH sends printouts with the previous year's data to the local health officials, who check them against the operators' responses in order to update the records.

Again, much attention is given to water quality. Operators are asked about sampling frequency for organic and inorganic matter, supply inspection routines and treatment routines, and they must supply an inventory of treatment facilities. More than in the monthly reports, however, there are questions pertaining to other aspects of system operations.

- Operators are asked for an inventory of sources and figures describing:
  - safe yields;
  - population served;
  - average daily production;
  - average daily consumption;
  - maximum daily consumption; and
  - storage capacity.
- There are "yes or no" queries about:
  - emergency procedures;
  - pressure maintenance; and
  - modifications of the system.
- Community system operators are asked to supply data on the percent of industrial, commercial and residential customers that are metered.

Detailed System Evaluations--DOH conducts detailed system evaluations on systems with their own water sources once every five years; for systems which purchase all their water, this evaluation occurs once every ten years. Each evaluation is made by a DOH inspector--an engineer--in consultation with local system operators. The form used for an evaluation is ten pages long, and there is a seven-page addendum for systems in which springs and surface water serve as sources. The information is not stored for computer analysis, but the forms are retained as information sources on specific systems. Regarding system aspects other than distribution, the content of the form includes the following areas of inquiry:

- personnel;
- sources, including general description and safe yield figures;
- wells, including protection and maintenance;
- source transmission main information, such as size and number of pipes and valves and cleaning routines;
- types of treatment, with special detail on disinfection;
- treatment plant maintenance and safety;

- emergency preparations;
- pump stations and their maintenance; and
- storage, including total capacity and number of facilities.

The distribution system-related areas of inquiry include:

- average daily production and consumption;
- normal maximum and minimum pressure;
- chronic low pressure problems and adequacy of fire flow;
- maintenance of an adequate map and a card system for locating system elements;
- flushing and valve-exercising programs;
- pipe replacement or relining programs;
- availability of replacement parts;
- unaccounted-for water; and
- general condition of the system.

Reports to the Public Service Commission

Article 4-B of the Public Service Law places private water companies (more than 300 of them) under the regulatory jurisdiction of the Public Service Commission. As part of its regulatory activities, the PSC requires annual reports of these companies. (2)

In section 561.1 of its regulations, the PSC has divided waterworks utilities into classes on the basis of their annual operating revenues:

Class A - $250,000 or more

Class B - $100,000 or more, but less than $250,000

Class C - $40,000 or more, but less than $100,000

Class D - $15,000 or more, but less than $40,000

(Smaller companies--those with less than $15,000 in operating revenues--are sometimes referred to as "Class E" companies.)

The PSC has one report form for Classes A and B, another for Classes C and D, and a third form for Class E companies. The form for classes A and B

exceeds 100 pages while the form for Classes C and D is approximately 50 pages long. They cover the same categories of information, but there is somewhat less detail required on the form for Classes C and D. The form for the smallest companies is only six pages long.

Most private companies are small. (3) The number of reports filed in a recent year, by type of form, are:

Classes A and B	19
Classes C and D	40
Class E	256

A great deal--perhaps the preponderance--of the reports is financial. Areas of required information in the forms for classes A, B, C and D include:

- tax payments, depreciation, and stock issues;
- number and structure of funds;
- debt service and amortization/balance statements regarding all parts of the system;
- personnel data, including employee protective plans and salaries and wages;
- financial details of construction plans;
- revenues, including sales of water (in gallons and dollars) described by whether or not they are metered and kinds of customers (general, fire protection services, public authorities, irrigation);
- rate schedules;
- expenses for operations and maintenance, with breakdowns for supply, pumping, treatment, transmission and distribution, customer accounts, sales and administration;
- charges for professional and consultant services; and
- notations of energy use and conservation programs.

Parts of the reports, however, do pertain to actual system description. These items include statements of:

- territory served;
- production, consumption and flow losses by month;

- metered and unmetered consumption;
- flow losses attributable to pumps, transmission mains, other distribution mains and other appurtenances; and
- inventories of:
    - sources of surface supply, including statements of amounts of draft and specifications of dams, intakes and reservoirs;
    - sources of groundwater supply, including daily yield;
    - pumping equipment, including capacity and age;
    - pumping station and fire service statistics, including capacity, actual performance, fuel consumption and fire demand;
    - treatment facilities, including type, capacity and age;
    - mains, including diameter, length and material;
    - service pipes, including material and length;
    - customers' meters, including type; and
    - fire hydrants.

The six-page forms for the smallest companies--those with operating revenues of less than $15,000--have space only for cursory statements of basic financial information, operations and maintenance expenditures, rates, personnel information, organization of the company, officers and territory served.

Reports to the Office of the Comptroller

The Comptroller requires periodic financial reports of all local governments, including special districts, and these reports have sections which describe water supply expenditures and revenues. These data are transcribed for computer storage. Reports from special districts are combined by town for the purpose of computer storage and analysis, but the physical reports from each district are retained.

Dollar statements exist for water supply system revenues (metered sales, unmetered sales, service charges, interest and penalties on water rents, federal aid for water capital projects) and for expenditures (administration, source power and pumping, purification, transmission and distribution, common water supply, miscellaneous and total water operations).

What Data Do Localities Collect?

Little Inference From Reported Data

A description of those data which localities must report may constitute only a partial description of their water system record-keeping. So, while the reported data do not completely facilitate use of the reviewed diagnostic methods, it is not necessarily true that the local systems do not collect the needed data. Nor do the limits on the usability of the State agency data imply that those data sets are deficient. The main function of the agencies' data sets is not detailed system diagnosis, but rather oversight of the systems' water quality and financial conditions.

It is understandable and sensible, then, that reports to DOH and, especially, to the Comptroller describe little about actual operations and distribution system condition. While some reported data do describe distribution system characteristics, they simply identify whether or not some classes of problems are present. For instance, there is space in the five-year evaluation form for little more than a "yes/no" indication about the existence of chronic low pressure problems; there are no requirements for system descriptive data that would permit a determination about the adequacy of pipe sizes compared to volume of water flow. And the answers to the "yes/no" queries depend greatly on the responding operators' definitions of adequacy (e.g., there is a "yes/no" item which inquires if there is an "adequate map"). Data reported to the PSC are more complete, containing inventories of distribution systems, but the companies reporting to the PSC constitute only about one-fifth of the state's water systems.

Suspected and Demonstrable Deficiencies

What, then, can be said about the quality of local water system record-keeping? While there appears to have been no systematic evaluation of such record-keeping, consulting engineers and others who have tried to use local records to study local systems occasionally have noted their impressions. Some observers have suggested that there is a problem of reliability. Analysts who conducted a pilot study on the Capital Region's water needs noted that:

> Although the Department of Health's Annual Inspection Reports include data entry spaces for served population, average and maximum day water production, and average day consumption,

> many of the reports contain incomplete or questionable information. (4)

The Capital Region pilot study, in fact, contained several expressions of reservation:

> Data on inflows to water supply reservoirs and reservoir operation data are not available or incomplete for most of the systems. Therefore, the accuracy of safe yield estimates is compromised. Also, there is little information on groundwater aquifer yield except for the Schenectady Great Flats Aquifer where yield data are known.
>
> Although there are some extant information sources and there has been an attempt to systematically collect data on municipal water system operations, few carry a high degree of completeness, accuracy, reliability, or timeliness. Also, safe yields of sources and system capabilities are not available for most of the small systems.
>
> Specific information on industrial/commercial and agricultural water supply and use is minimal or non-existent.... (5)

Consulting engineers with whom local systems contract for leakage and breakage studies and flow appraisals generally assume that a lot of "front end time" (i.e., time used to gather and sometimes estimate and organize data) will be necessary. They spend a portion of this time assembling a system inventory through examination of maps and interviews with personnel. There is among consultants and other professionals a perception that system maps too often are incomplete. (6)

Much time, too, is spent developing an understanding of consumption. Metering is enormously helpful--some would say essential--for understanding consumption.

Metering in New York State--Most localities have production metering, but user metering is much more variable and erratic. DOH's 1984 Inventory--Community Water Systems contains data from which statewide figures on user metering can be developed.

- Overall--Among 1,799 municipal systems, somewhat more than 300 did not report in the metering categories. Of the systems that reported in each category, about 31 percent have no residential metering, about 44 percent have no commercial metering, and about 53 percent have no industrial metering.

- Larger Systems--Most of the municipal systems are small; only about 140 serve populations of 10,000 or more. Among the smaller systems,

commercial and industrial presence is probably proportionately smaller than among the larger systems, so a lack of commercial and industrial metering in the smaller systems is perhaps not very significant. By examining the systems serving 10,000 or more, one makes the figures for commercial and industrial metering more meaningful while still accounting for the preponderance of the state's population. Among municipal systems serving 10,000 or more, the approximate percentages that have no user metering whatsover are 5 for residential use, 2 for commercial use and 4 for industrial use. The approximate percentages that have less than 51-percent metering are 9 for residential use, 2 for commercial use and 5 for industrial use. One of the systems without residential metering, however, is New York City's, which serves about 6.5 million people. Other large systems with little or no residential metering are those of Buffalo, Schenectady, and Rome. (7)

Is This Enough Metering?--What can be observed regarding the adequacy of user metering in New York State? An answer depends partly on the value of metering.

- Conservation--The most obvious argument for user metering is conservation. User metering would facilitate water billing methods that would provide for a close correspondence between amount used and amount paid. The conservation argument is that under such a billing method, a user would be less wasteful inasmuch as his/her bill would reflect wasteful use. However, there is some dissent among economists that users would respond to such billing in a conserving way (i.e., there is doubt that the demand for water is "elastic"), and in any case, metering only facilitates--not necessitates--such billing.

- Other Management Values--A less debatable, and perhaps more compelling argument for user metering has to do with its management values other than conservation. Reliable measurement of current use--measurement which is important in projecting needs and assessing a water system's capacity to meet those needs--requires user metering. In addition, user meter registrations are of great value in monitoring flow through small segments of systems and, therefore, can greatly reduce the amount of time it takes to diagnose water loss and locate leaks.

A judgment that the current proportion of user metering is or is not adequate depends on whether or not the observer regards the uses of meters to be worth the cost of installing and maintaining them. There are several questions which are difficult to answer absolutely and specifically.

- Regarding the conservation-related value of meters:

  . Are there places where the raw supply is so small in relation to current and/or projected demand that conservation is necessary even to ensure that there will be enough water?

. Is the cost of producing water--capturing, treating and pumping it--high enough to warrant greater care in its conveyance, or is it so cheap that wasting it costs less than metering it?

- Regarding management values other than conservation: Are the costs of:

  . leak damage and leak location;

  . the extra time required for research on water demand; and

  . the planning errors that can result from inadequate understanding of demand

  higher or lower than the cost of installing, maintaining and reading meters and then using the data?

Many--probably most--professional and academic water supply experts regard metering to be worthwhile. Some regard it as essential for sound management. To those who are persuaded of the value of user metering, the amount of metering among the state's systems might seem inadequate. The number of systems that have metering and that serve 10,000 or more is comfortingly high, exceeding 90 percent of systems of that size. Less comfort, however, is to be found in this finding: Even though more than 90 percent of the systems that serve 10,000 or more have metering, it appears that as much as half of New York's population is not residentially metered. It has been noted that among the larger systems that have little or no residential metering are those serving Schenectady, Rome, Buffalo, and New York City. The number of people served in these places alone constitutes about 40 percent of the state's population, and a full summation of unmetered residences would have to incorporate also the populations of the many smaller systems that are not metered.

Concerns about metering, however, are not limited to the subject of how many systems have it. The perceptions of consultants are that meters are too often not in good working order and that better programs of repair and replacement are advisable. Meters that do not work well usually underread the amount of consumed water. This not only deprives a system of due revenue, but also means that the meters are unreliable as management/planning and conservation devices.

Inattention to meter condition may derive partly from the perception that the cost of a meter inspection program would be greater than the cost of unmetered water. Trends in the cost of producing water may change that percep-

tion, but in any case, this stance ignores the value of metering in diagnosing leakage and controlling the damage which leaks inflict.

Other Front-End Time Tasks--System inventories are usually available in the form of maps, but often they have not been updated with all system alterations and discoveries of artifacts which did not appear on the original maps. Often, in order to obtain a complete inventory, consulting engineers must repeatedly interview knowledgeable local personnel in order to obtain information about some pipes and flow directions that does not appear on the local maps or in other records.

Leakage surveys, pressure surveys and flow tests, because some localities conduct them sporadically and infrequently, are sometimes outdated.

Such characteristics of local water system record-keeping increase the amount of front-end time necessary for analyses. Data-readiness, however, does vary among localities, and size seems to be a considerable factor. Those systems with an engineer--and even more, those systems with an engineering department--are more likely than are others to have the resources necessary to create and carefully maintain data sets. (8)

The Fundamental Needs

Shortening analytical front-end time may seem an inadequate reason for a local system to invest more resources in data gathering and data organization, especially if diagnostic analysis has been sporadic and rare. The cost of any data operation, and even of gathering any particular piece of data, ought to be paid only after its value has been considered. And the value of better local data collection and organization depends on perceptions that:

- the analyses they facilitate are worthwhile; and
- local data efforts are crucial for those analyses.

Some may regard the cost-effectiveness of improved data operations to still be questionable, and they will be persuaded only if the unnecessary costs of imprecise repairs and the cost of producing water continue to increase. Regarding the crucial importance of local data efforts in making diagnostic analyses at least possible, however, statements can be more definite. Consulting

engineers must depend on local documents and the knowledge of local operators for several indispensable kinds of information:

- System maps--the basic information for the system inventory--can reasonably be updated accurately only by local officials who conduct and monitor system alterations, including addition or closure of pipelines and changes of pipe sizes (plus discovery of distribution system parts that were not included in the original maps). Without an accurate system inventory, it is much more difficult, and sometimes impossible, to solve pressure problems and find leaks and otherwise account for lost water.

- Main break records, likewise, cannot be created by a consultant, but must be maintained by the people on the scene.

- While production and consumption can be observed after a project begins, one-year or five-year trends can be known only if local operators have accurately monitored and reported the data. At best, the data will be the result of metering rather than estimation.

Consultants would find the results of recent years' pressure surveys, leakage studies and flow appraisals to be valuable in their efforts to diagnose a system's problems and prescribe optimal solutions. In the absence of such previously collected information, however, they can generate these data so long as an accurate system inventory exists.

Some observers suggest that sound local data gathering and organization can facilitate more than consultants' work; they suggest, rather, that local operators could perform some of the diagnostic analyses. (9) Pressure-and-flow simulations and leak detection are intensive analyses that, because of the amount of time, special equipment and expertise required, usually necessitate the use of consultants. Many localities with engineering departments, however, could well find that water accounting, break analyses and leakage surveys are within their capacities. And as the costs of consultants' fees, producing water and repairing facilities increase, localities will increasingly find it cost-effective to conduct such monitoring activities. In order to do so with accuracy, however, they will need the kind of data gathering and organization that has been suggested here.

One consulting engineer, in describing the data required for pipe replacement decisions, noted three requisites for data bases to be directly useful to local operators. Such data should be:

- the result of routine operations;

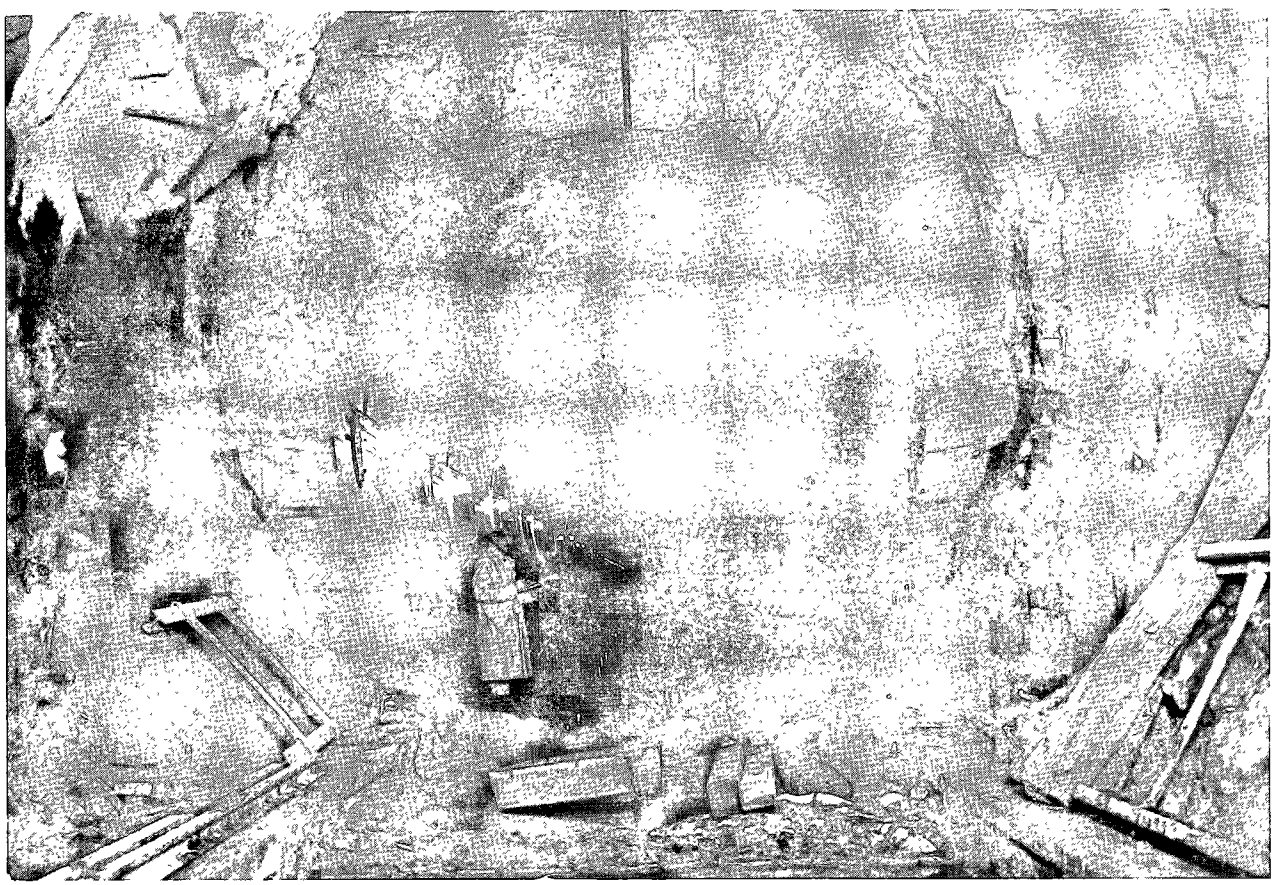
- geographically oriented (i.e., each element and descriptions of it should have an accurate address, and the system should be divided into districts and each district described and periodically tested); and

- designed for use by water utility personnel rather than data processing personnel. (10)

The writer also emphasized the value of such a locally organized and locally used data base:

> The cost of replacing a mile of water main is $200,000-$500,000 in 1980 dollars....Replacement decisions should be based on the physical condition of mains, not on their age. A geographically oriented information system will cost $50-$150 per mile to develop and $10-$20 per mile per year to update with routine records. The monetary gain from improved main replacement decisions is several orders of magnitude greater than the cost of the information system. (11)

PART III.



The Context: The Matter of Water Supply in General

Photo: Courtesy of the American Society of Civil Engineers

Chapter 6.
Overall Demand, Supply and Uncertainty

"The Water Supply Problem": Comments Introductory to Part III

A Broader Focus

The Emphasis Has Been on Distribution--In Part III, this study departs from an assumption employed in Parts I and II. In the foregoing discussion of deterioration and infrastructure redevelopment needs, it was assumed, for purposes of argument, that "the water supply problem" is mainly one of building and maintaining adequate distribution facilities. It was suggested, even granting this assumption, that allegations of deterioration are poorly based and inadequate for prescription and that better information is obtainable, probably well within the working life of most of the existing distribution hardware.

In Part III, the assumption that distribution is the central water supply problem is given some attention. Participants in the discussion have not been unaware that the full range of water infrastructure components includes not only distribution, but also sources, treatment facilities and storage facilities. But in press reports, some political rhetoric, and even some research, the distribution system has received the most notice.

- Because broken pipes result in lost service, local flooding and sometimes damage to streets and buildings, newspaper coverage understandably gives main breaks more dramatic exposure than it gives, for instance, a planner's projection that a locality's supply in twenty years might be somewhat less adequate in drought conditions than it is currently.

- Likewise, distribution system breakdowns provide more dramatic justification for immediate approval of rebuilding proposals than do problems with more subtle or distant ramifications.

- Some surveys and studies have found among local water professionals a particular concern with distribution system problems. The State Department of Health, for instance, surveyed spending preferences among a sample of water supply operators and found that "statewide, distribution system improvements received the highest priority, with treatment, storage and source a nearly equal second." (1)

There Are Other Problems, But Finite Capacity--We saw in Parts I and II that actual observation of the deterioration of distribution system components is, from a statistical standpoint, slight and that, other than that "systems are old," there has been little explanation of the specific causes of such deterioration as does exist. But there are some important considerations beyond the questions of whether or not distribution systems are generally deteriorated and, if they are, what should be done about it.

- Distribution is decidedly not the only water supply problem which demands attention--groundwater pollution, for instance, is another highly important matter; and

- aspects of water supply are interrelated such that a choice of action on one aspect affects the choice of action on another. For instance, it has been traditional in some localities to substitute cheap new supply--pumping more water--for improvement of system efficiency. Conversely, reducing the amount of water escaping through system leaks would decrease the necessity for developing new supplies.

This multiplicity and interrelatedness mean that it will not be sensible to concentrate finite public capacity on one aspect of water supply and that it will be necessary, instead, to develop optimal solutions to the range of water supply problems which may exist.

Preventing loss of water through leaks and breaks in distribution facilities is one way of augmenting supply that could help New Yorkers avoid the necessity of large-scale projects such as construction of dams and reservoirs, and redevelopment of distribution facilities therefore should be pursued. But even if distribution facilities were in perfect condition, there would be other aspects of water supply requiring the expenditure of public resources. It is therefore important, since public capacity is finite, to not spend more than is necessary or cost-effective on distribution problems, and it would be wise to attempt to rationally allocate responsibility for solving the problems among the many water supply-related governmental actors within New York State.

Only An Indication, Not a Detailed Prescription

Part III differs from Part II in another way: Part II is essentially a logical sequence of chapters that, taken as a whole, stand as an argument regarding the need for and obtainability of better distribution system information.

Part III, in contrast, is essentially an inventory: it simply surveys existing water supply problems and choices in order to substantiate that there is a larger context within which distribution or any other specific problem of water supply should be considered in order to sensibly allocate public capacity toward its solution.

The descriptions in Chapters 6 and 7, then, are not attempts to present detailed, definitive analyses of the several problems involved in obtaining and maintaining water supply. Rather, these descriptions constitute a cursory review that, it is hoped, will render an accurate idea of the complexity of "the water supply problem." These chapters will indicate that:

- the deficiency of data and knowledge regarding water supply problems in general parallels the deficiency of data and knowledge regarding distribution system conditions in particular;

- at least one of the fundamental conditions identified in the distribution discussion is pertinent in other water supply matters--fractionalization of responsibility among jurisdictions hinders attempts to control causes of quality problems and to integrate use of common sources; and

- choices are unavoidable. For a supply to be regarded as adequate, it must be sufficient to meet demand. But there are various ways to reduce demand and augment supply, and different combinations of reductive or augmentative actions will be differently efficient in obtaining balance between demand and supply. Costs of inefficiency could include expenditures for unnecessary supply development or inadequate supply for future needs.

The choices will not be easy. To develop supplies to the maximum is inadvisable because:

- we cannot be certain how severe a future drought will be, so the possible necessity of conservation cannot be ruled out even on a theoretical basis;

- public investment resources are finite and must be used also for other purposes; and

- development for particular places and needs can frustrate other demands for water, such as wetlands protection, navigation, hydroelectric generation, recreation, and downstream industrial and municipal use.

Therefore, while alarm is not in order, the time for better planning

regarding so vital a resource has probably been upon us for awhile. And good planning requires both:

- sensitivity to the interrelatedness of all water supply problems, even though their daunting complexity might make us wish to continue to treat them individually and sequentially; and
- much better information than we have so far taken care to generate and collect.

Much Water, Much Uncertainty

It is possible to recite an impressive list of numbers pertaining to New York's water resources. The state contains 4,000 freshwater lakes and ponds, covering 3.5 million acres. More than 70,000 miles of rivers and streams transport 50 billion gallons of water daily. The state is bounded by over 350 miles of fresh water shoreline. Some wells can produce up to 2,000 gallons of water per minute without depleting the underground resource. Salt water bodies along the state's shores provide 8.5 billion gallons a day to cool electric generating plants, according to federal estimates. Fresh water withdrawals statewide in 1980 for all purposes were estimated at about eight billion gallons a day, far below the 50 billion gallons available just in rivers and streams. (2)

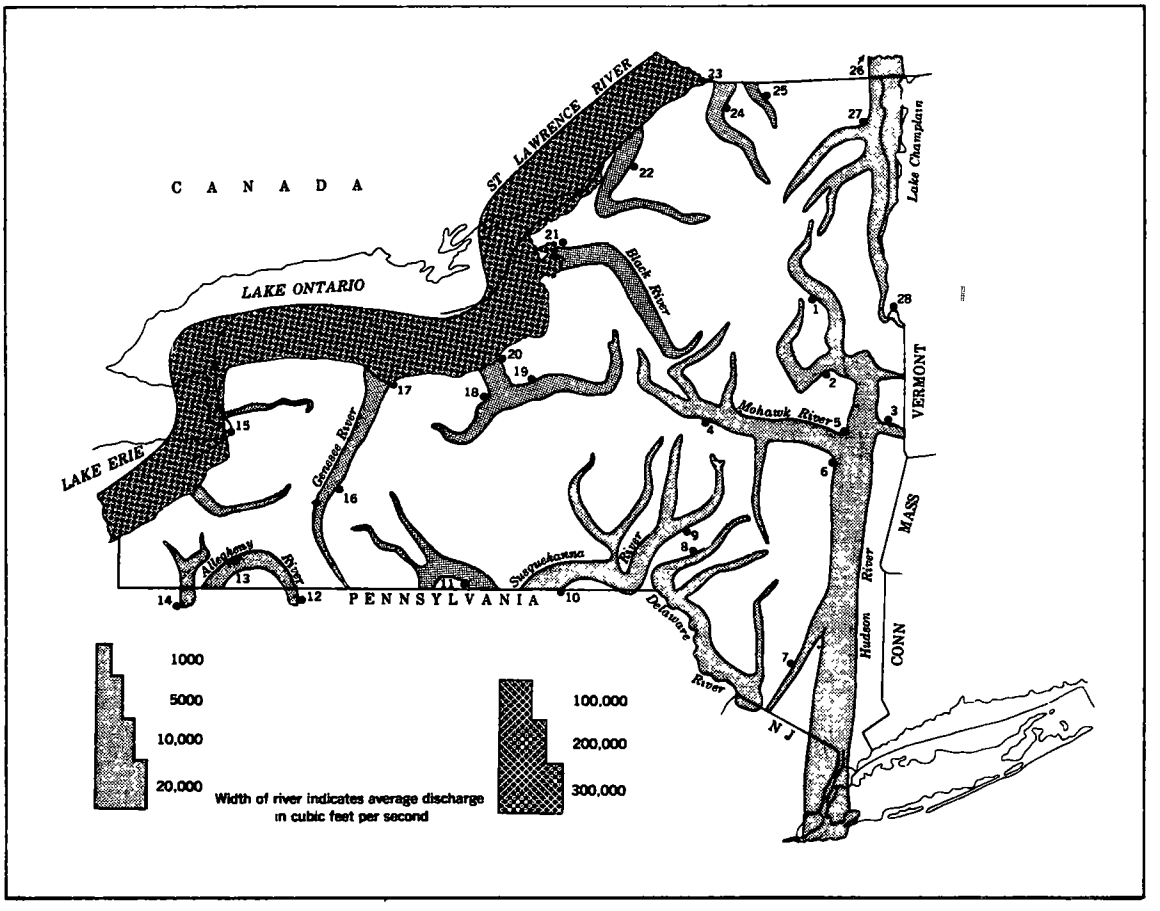
This abundance of raw water, however, does not assure an adequate supply of usable water.

- Large sources of water do not necessarily lie where the demand is.
- There is some competition for water use. For example, over 40 percent of the state's surface water is required just to maintain navigation in the Barge Canal system. (3) Hydroelectric generation in New York requires an estimated 310,000 million gallons a day of river flow. (4) Surface water is needed also for recreation, environmental protection, and aesthetic purposes.
- Pollution may render an available supply useless for public consumption.

It is clear that there is considerable uncertainty about total water use in the state. For instance: The greatest single use by far is for cooling of thermal electric power plants. In this category, DEC estimates for 1975 exceed USGS estimates for 1980 by 67 percent and 41 percent for fresh and salt water use, respectively (see table 6).

Figure 6

Average Discharge of Major Rivers in New York



Source: U.S. Geological Survey

There are no uniform statewide data regarding power plant water use. Such use can only be estimated from power production figures. (5) This is significant, as a comparatively large amount of industrial cooling water is "consumed" due to high evaporation levels. Power plants which consume great amounts of fresh water affect other users of the resource more than does a public water supply system which withdraws water, then treats the used water and returns it to its source. An accurate account of the consumed water is necessary when planning for downstream needs, such as navigation levels, hydroelectric generation, water withdrawals, and waste assimilation (the dilution of sewage treatment plant

Table 6

Estimated Use of Water in New York
Million Gallons per Day

	DEC Estimate 1975	USGS Estimate 1980
Public Supplies		
Ground	560	350
Surface	2,200	1,900
Rural private		
Ground	150	170
Surface	13	20
Irrigation		
Ground	19	21
Surface	13	25
Electric Generation		
Ground Fresh	190	130
Surface Fresh	7,200	4,300
Surface Saline	12,000	8,500
Other Industries		
Ground Fresh	130	120
Ground Saline	3	12
Surface Fresh	1,400	980
Surface Saline	35	120
	23,913	16,648

Source of DEC figures: "State and National Water Use Trends to the year 2000," U.S. Senate Committee on the Environment and Public Works, May, 1980.

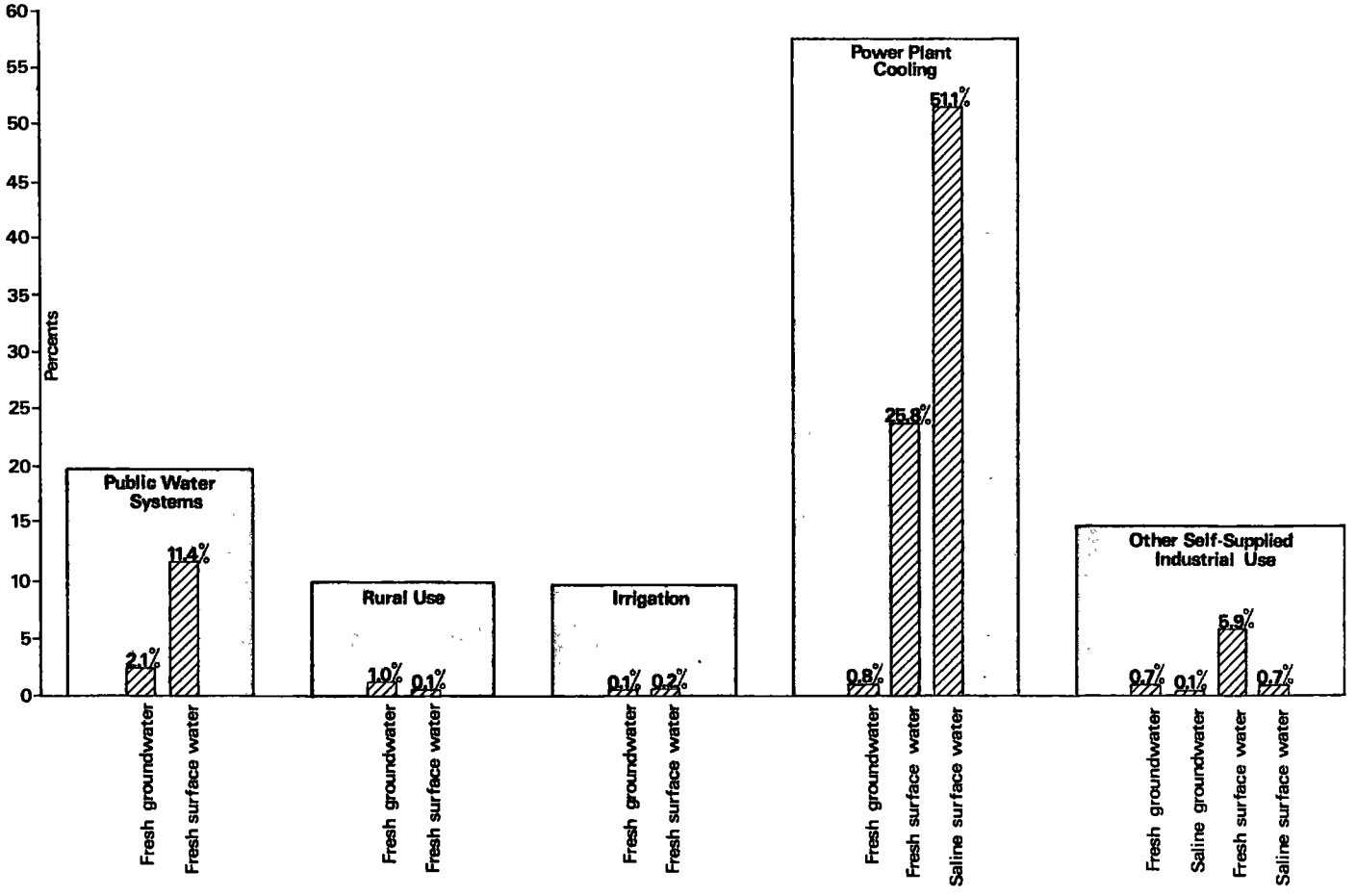
Source of USGS figures: "Estimated Use of Water in the United States in 1980," USGS Circular # 1001.

effluents). The USGS is currently developing more accurate data on the use of water by various sectors in New York. (Current USGS estimates are illustrated in figure 7.)

Other industrial use levels are also uncertain. There are no direct data on industrial water use in New York. The state maintains records of maximum industrial effluent levels through the State Pollution Discharge Elimination System (SPDES) permits. The USGS has estimated industrial water use by using the permit data and assuming that disposed wastewater approximates raw water withdrawals. There are at least three reasons for questioning the accuracy of such estimates.

Figure 7

New York Water Use by Selected Categories



Data Source: U.S.G.S., Estimated Use of Water in the United States in 1980.

- State permits allow a maximum discharge level, but records contain no measurement of discharges below the limit.
- Permits contain no indication of how much water is "consumed" in manufacturing or cooling processes and never returned to its source.
- The source of the water released according to state permits may be a direct raw water source or a piped-in public water supply.

Uncertainties remain also with regard to other kinds of water use. About three million New York residents draw water from private wells; such use

may only be estimated on a per capita basis. And municipal water demand data, for which the most useful information exists, may be seriously incomplete. In its assessment of water resources in the Capital District, DEC found that:

> Although the Department of Health's Annual Inspection Reports include data entry spaces for served population, average and maximum day water production, and average day consumption, many of the reports contain incomplete or questionable information. Generally, information on various types of water uses such as residential, commercial, industrial or agricultural is not available anywhere. Although many municipal systems are metered, and there are separate accounts and charges for public, commercial and residential uses, the information is not summarized or reported on a monthly or annual basis. (6)

Estimates of water use which are presented in documented reports therefore rely upon per capita estimates, which may in turn be based upon seriously limited knowledge. The USGS is currently attempting to develop a statewide water use data base through existing DOH records, estimates of agricultural use and individual well users, and industrial surveys. This effort is part of a national attempt to standardize water use data.

Water Demand Forecasts: Sophistication and Confusion

Forecast Methodologies

The major goal of every water supply entity is the provision of an adequate supply of potable water to its service population for the foreseeable future. Because major water supply additions may take twenty years or more from conception to completion, water supply managers must periodically assess supplies and demands and plan to meet any anticipated shortages. These plans require an anticipation of demands for up to forty years into the future.

Essentially, forecasters project a level of population and a level of demand per person for a series of future years. They then multiply the projected per capita demand by the projected population to determine a total water demand. These projections are often made by simply extrapolating historical trends into the future, and they are not taken lightly: an inaccurate forecast may result in

either an overinvestment in supply or inadequate service.

The value of an accurate demand forecast has led to increasingly complex demand models. The key variable, however, remains population. Total residential water demand is often assumed to vary in direct relationship with population. (7) But it is difficult to accurately predict population for a given water supply region: local population changes are susceptible to single event dislocations, overall in- and out-migrations are particularly hard to predict, and the study region may not conform to census data regions. While population projections have increased in complexity and now include separate projections of fertility, mortality, out-migration and in-migration, results nevertheless are characterized by a high degree of uncertainty.

Projections of per capita water use have also grown more complex. Water users are now routinely classified as residential, commercial, industrial, and public. These classifications are further disaggregated into subgroups, such as residential users with and without meters or sewers. (8) Some studies have broken user components into more than 280 separate commercial, industrial, and institutional classifications. (9)

Economic forecasts have entered the projection models of raw population and sector water demands. Sophisticated techniques have linked residential demand to such variables as house value, number of persons per dwelling, and rainfall. (10) One study of water demand in commercial establishments developed a series of formulas based upon floor area for 24 shop classifications. (11) Industrial demand, accounting for 25 percent of national public water use, is difficult to forecast but has been shown to respond to raw water costs and waste treatment costs. (12)

Each demand component is projected as far into the future as is feasible, with uncertainty factors figured in. Individual components are then aggregated into a total demand projection, with adjustments for possible weather induced changes and self-supplied demand. (13)

Prediction Failures, Greater Sophistication, Continuing Error

Demand models have grown in complexity and sophistication--some even consider how often a person flushes a toilet every day. Yet the premise remains quite traditional: past trends and current use can be divided into components and projected into an unrestricted future. If water demand continued to increase at past rates, by the year 2020 the United States' daily demand could reach 2,280

billion gallons, a figure twice as great as nationwide average streamflow. (14) Obviously, supplies cannot be increased indefinitely to meet an unlimited demand. Researchers are therefore beginning to critique traditional demand projection methods, finding them unrealistic and too-often erroneous.

The traditional water supply planning and development method has been to forecast demand, determine deficiencies in the existing system, design and construct facilities to meet the deficiencies, determine the cost of the additional facilities, set water rates to meet that cost, and then observe the actual demand. (15) The demand forecast has been treated as an unbending, concrete number which must be provided for. Actually, this number is highly variable. Water demand has been shown not only to vary with estimates of population and per capita use, but to react also to government policies, income, technological developments, the cost of using water, and sociological aspects of consumer habits. (16)

The combination of all these uncertainties results in an essential lack of knowledge of probable water use forty years in the future. For instance:

- Consider whether a planner in 1945 could have anticipated the technological and economic changes which affect water use in the 1980's. Could it have been predicted that some areas would exhibit a decline of traditional textile trades and a subsequent growth of a high technology and service economy? These changes have especially affected the commercial and industrial sectors, which together account for 37 percent of national public water use. (17)

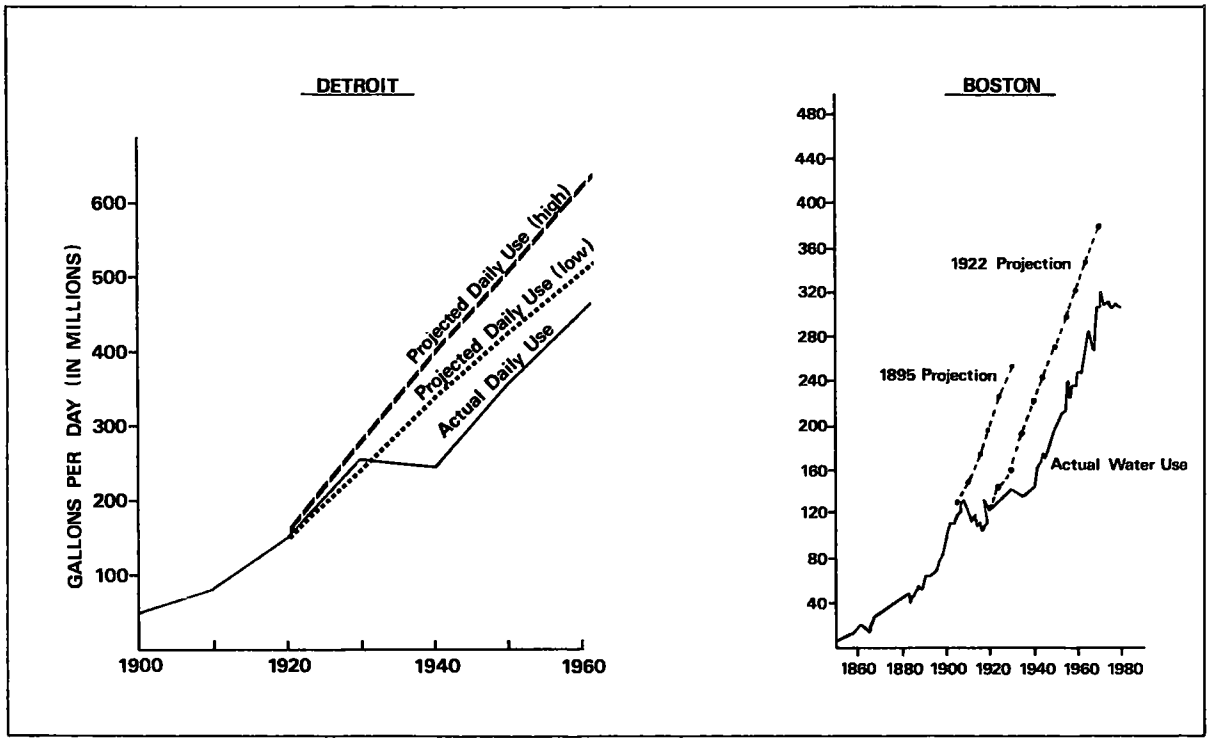
- Detroit projections from 1924 to 1960 were continually above actual use, as were projections made in 1895 and 1922 for the metropolitan Boston water system. The gap in the Boston region's figures would have been even greater had the system not doubled the number of its service communities between 1920 and 1970 (see figure 8). (18)

- More recent projections have often been based upon the high growth period of the 1960s and 1970s. A 1966 St. Louis study projected per capita use in 1980 at 300 gallons per day, while the 1978 demand rose only to 259 gallons per day. (19) A combination of lower rates of population and economic growth, greater environmental awareness, and high energy prices has lowered the rate of increasing demand. (20)

In recognition of this uncertainty, many water system planners respond by attempting to document all possibilities. The result, according to one critic, is that many planning documents "now resemble large encyclopedias which catalogue a wide variety of facts and often obscure the real trade-offs between alternative choices." (21)

Figure 8

Projected and Actual Water Use in Boston and Detroit



Sources: David Holtz and Scott Sebastian, Municipal Water Management, Indiana University Press, 1978.

Metropolitan (Boston) District Commission, Water News, Vol. 6, January 1983.

The effects of the uncertainty and errors are more than methodological. Simply providing new supplies to meet anticipated demands can be self-fulfilling: In urbanizing areas, new supplies may lead to new service regions and a resulting growth in population and demand. In existing metropolitan areas, an oversupply of water may lead to the linking of surrounding smaller communities with the system, resulting in the abandonment of local water supplies, as has happened in metropolitan Boston. The new customers may receive a short-term benefit of relatively cheap and available supplies, but old customers may be paying to provide that supply.

The Other Side of the Equation: Assessing Supply

Raw Volume

Potable water sources in New York differ greatly in type and management needs. Here is a general breakdown of supply types.

- Groundwater--There are many major groundwater aquifers scattered throughout New York. They provide water to all of Nassau, Suffolk, and parts of Queens Counties, plus several upstate areas. About three million New Yorkers who use individual private wells, and another three million who are served by public water systems, rely on groundwater.

- Large lakes--These are lakes with very large surface and/or drainage areas, and include Lake Erie, Lake Ontario, Cayuga Lake, Seneca Lake, Lake George, and Chautauqua Lake. About 30 suppliers serve 1.7 million people from these sources.

- Major rivers--These include the Chemung, Genesee, Hudson, Mohawk, Niagara, St. Lawrence, Seneca, and Susquehanna Rivers plus major St. Lawrence and Lake Champlain tributaries. One-half million people are served by 28 suppliers which draw unimpounded water from these sources.

- Multiple-use lakes and reservoirs--These are natural and manmade lakes between 2.5 and 20 square miles in area. They are used for recreation, hydropower, and flood control as well as water supply. There are about 850,000 people served by 19 suppliers from these sources.

- Single-use lakes and impoundments--These are small manmade reservoirs specifically built for water supply, and they serve about 400,000 people outside of the New York City system.

- Small lakes and ponds--About 160,000 people are served by 46 suppliers drawing from lakes and ponds smaller than 2.5 square miles. Most of these sources are actually under one-quarter square mile in size.

- Minor streams are any streams not classified as major rivers. There are 83 suppliers serving about 690,000 people from these unimpounded sources.

- New York City supplies seven million people, including 600,000 in 60 upstate communities, using a complex network of 19 reservoirs in three separate drainage basins (Delaware, Hudson, and coastal drainage) in eight counties. (22)

Table 7 displays the number of users by type of source. The state can be broken geographically into several general source areas. The Long Island aquifer system supplies all of Nassau and Suffolk Counties and parts of Queens.

Table 7

Sources of Public Water Supplies

Type of Source	# of Supplies	Population Served
Groundwater		
Long Island and Queens	81	2,100,000
All others	679	1,000,000
Large natural lakes	29	1,763,000
Multiple use lakes and reservoirs	19	862,000
Single use lakes and impoundments	30	411,000
Small lakes and ponds	46	162,000
Major streams	29	501,000
Minor streams	83	691,000
Source unknown	18	5,000
New York City	1	7,300,000

Note: Although there are 1,800 community public water systems in the state, table 4 lists only 1,015 sources. This is because many systems purchase all of their water from other suppliers, which in turn use the documented sources.

Source: State University of New York, College of Environmental Science and Forestry, Water Supply Source Protection Rules and Regulations Project: Final Report, 1981.

The New York City system serves most of the five-borough area, plus 600,000 people in counties where City reservoirs are located. Upstate rural areas which are not served by public suppliers generally use groundwater from private wells. Upstate cities in the eastern part of the state mostly use either artificial impoundments or groundwater, while many central and western cities use natural lakes and rivers.

Raw water seems plentiful. Unfortunately, the actual available supply of usable water in the state is limited by more than the amount of raw water.

- Precipitation and streamflow vary from year to year, i.e., droughts limit the dependability or "safe yield" of water supplies.
- Legally required minimum releases from reservoirs to downstream rivers reduce the amount of water available to some systems, particularly the New York City system.
- Water quality problems place health-related limitations upon the use of some water supplies.

Central and western parts of the state generally have few raw supply problems, even during drought periods, and are mainly concerned with maintaining adequate water quality. The raw supply concerns in the state exist mainly in the large southeastern population center and in scattered areas using small reservoirs or confined aquifers.

Real Supply: Safe Yields

The discussion of water supplies for a particular area often leads to consideration of the "safe yield." When water use exceeds a system's safe yield, visions of dry reservoirs loom and water managers begin planning to increase the supply. There is a tendency to present the safe yield number as the absolute scientific limit to water use, and this deserves some discussion.

In General--The most common general definition of safe yield is the amount of water which can be continuously supplied through a critical drought. (23) The safe yield of a groundwater system is the amount of water which can be taken from the system without resulting in a net loss. (24) Two methods are used to measure the safe yield of a reservoir.

- A graphical technique known as the Rippl Method, developed in 1883, uses calculus to estimate streamflow, reservoir capacity, and the safety of various levels of demand based upon cumulative streamflow changes. (25)

- A simulation method, the other commonly used technique, is essentially a water bookkeeping method. In-flows are added to a monthly water balance, and water taken out is subtracted. The highest constant level of monthly demand which does not deplete the reservoir during the lowest streamflow period on record is considered the safe yield. (26)

The term safe yield is somewhat misleading and is in reality a risk figure rather than a concrete limit to supply. By using the most severe drought on record to determine the safe yield, water managers assume that it is necessary to plan to meet existing demand through the course of a drought of that magnitude.

The New York City experience raises some questions about this assumption. Before the 1960s drought, the accepted safe yield of the City's reservoir system was 1,665 million gallons a day, derived from a 1930s drought. (27) The 1960s drought was much more severe, and the new record lowered the safe yield figure to 1,290 million gallons a day. Through the 1970s, consumption in the

City's supply system (1,550 mgd) constantly surpassed the new safe yield figure. This did not affect the supply during normal rainfall periods, but in 1980 and 1981 a new drought occurred and reservoir levels fell rapidly. Rather than running out of water, however, the City began a campaign to reduce water losses and the consumers responded. City demand fell 71 mgd within 12 days and eventually approached the 1,290 mgd accepted safe yield figure. This flexibility of demand suggested that a higher average demand may be considered "safe".

Such a difference between accepted safe yield figures for a system may be the difference between regarding a reservoir system as adequate and calling for millions of dollars in supply expansions. For instance: The recurrence probability of the severe drought that affected New York City in the 1960s is estimated at once in 250 to 400 years, or between .25 and .40 percent per year. If a 100-year (1 percent) drought is used as the planning basis, the safe yield of the system could increase by 25 percent to over 1,600 mgd. (28) Considering that the City's population is decreasing and plumbing code changes should reduce the growth rate of per capita demand, system expansion for City use alone might reasonably be regarded as unwarranted. A former City Commissioner of Environmental Protection agreed in 1981 that it would be a waste of capital assets to build a new supply which would seldom be needed. (29)

Groundwater Yields--The determination of the safe yield of an aquifer system is more complicated than for surface water. Complex geological and hydrological systems must be understood, including the complex linkages between groundwater and surface water. A hydrologist can directly measure groundwater only at test wells, through which he/she can ascertain the water table and aquifer bottom at only one point. The number of test wells is limited by expense, so conditions between wells can be determined only through interpolation. To accurately calculate water table elevations in order, in turn, to assess the direction of flow and the volume of an aquifer, diverse variables must be considered, including:

- Aquifer boundaries
  - Elevation of bottom of aquifer
  - Location of impervious materials at edges and inside aquifer
  - Location and surface elevation of large surface water bodies
- Aquifer material characteristics, i.e., hydraulic conductivity (the rate at which water may flow through a material)

- Recharge
  - Amount of recharge from precipitation at land surface (including any storm water channeled to recharge basins)
  - Amount of septic tanks and other sewage facilities
  - Net amount from streams entering the recharge area

- Pumpage, i.e., locations and pumpage rates of major wells (30)

Any well will draw down the water table immediately surrounding it, creating a "cone of depression" (see figure 9). If an aquifer contains sufficient water and porous material, surrounding waters will flow to the well. If a well or series of wells pumps too fast, the cone of depression will not be refilled, the water table will drop, and the safe yield will have been exceeded.

Real Supply: Reservoir Releases

Some rivers provide water to users who reside not only in different jurisdictions within the state, but also in other states to the south. Arrangements to assure adequate supplies downstream can affect upstream supply limits and the way the supply is managed.

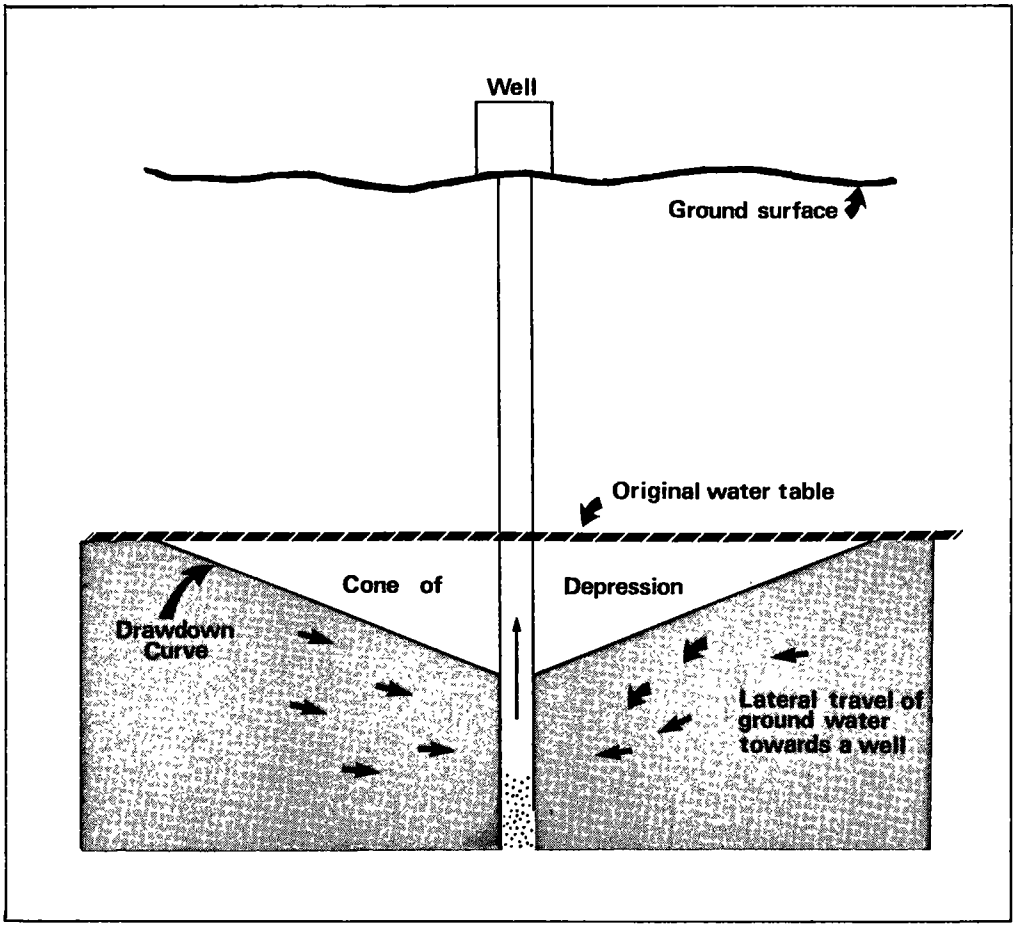
Reservoir managers are legally required to release certain amounts of water downstream. These releases place a limit on available water storage and are required by state, interstate and federal agencies for recreation, environmental protection and downstream user allocations. State release requirements (under Article 15, Title 8 of the Environmental Conservation Law) authorize the Commissioner of Environmental Conservation to regulate releases from reservoirs of over one billion gallons of capacity within seven southeastern New York counties. The law was passed to enhance fishing and recreation downstream from the major New York City reservoirs. (31)

Of greater concern to the management of the New York City reservoir system is the 1954 Supreme Court decree which limits diversions from the Delaware River basin to New York City in order to assure minimum downstream flow levels. (32) The court decision was in response to a suit by the State of New Jersey over New York City's plan to expand its reservoir system into the northern tributaries of the Delaware River. The court limited City diversions to an annual daily average of 800 million gallons. The City was required to increase its reservoir releases during low flow periods to maintain a flow of 1,750 cubic feet per second (1131.1 mgd) at Montague, New Jersey.

The decision also included an excess release requirement which, in

Figure 9

A Simplified Cone of Depression



effect, prevents the City from storing water beyond its immediate needs. The City is required to release from its Delaware system a quantity of water equal to 83 percent of the difference between its annual water consumption and the system safe yield, which was then considered to be 1,665 mgd. The safe yield figure was lowered to 1,290 mgd after the 1960's drought, which essentially erased the release requirement for the present, as City demand currently exceeds this safe yield figure. However, should the safe yield figure be revised upward, or should conservation lower the system's average demand to below 1,290 mgd, the City would be required to release 83 percent of its savings. This removes much of the incentive for the City to decrease its water demand.

The Delaware River Basin Commission has certain authority over the management of basin waters as a consequence of the Supreme Court decree. Because it was impossible to maintain the minimum flow requirements during the 1960s and

the 1980-81 droughts, the commission has sponsored negotiations between the parties to the decree in order to reach a compromise between the water supply needs of New York City and northeastern New Jersey and the flow requirements of the lower basin. The commission has recommended a schedule of phased reductions in diversions and releases, as set forth in table 8 (also, see figure 10). The commission is also seeking to coordinate water releases from other basin reservoirs in order to relieve some stress on the New York City system.

Outside of the New York City system, water release requirements are not as specific. The federal-interstate Susquehanna River Basin Commission has review authority over all projects affecting that basin's water resources. The commission may require minimum release programs and schedules. Federal agencies such as the Environmental Protection Agency, the Department of the Interior's Fish and Wildlife Service, the National Marine Fisheries Service, and the Corps of Engineers may express concern about river flows in their areas of interest. These agencies may request flow standards as part of federal project review activities.

Table 8

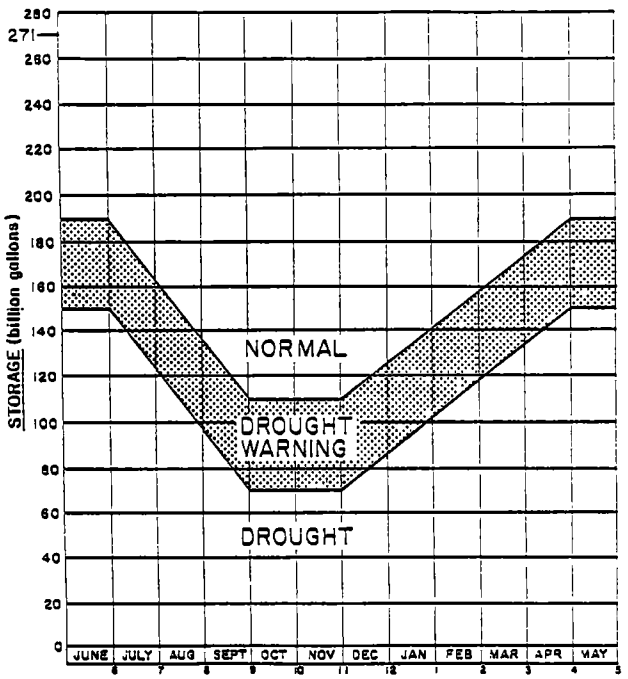
New York City Drought Releases
Delaware River Basin Reservoirs

NYC Storage Condition	NYC Maximum Diversion (mgd)	Montague, NJ flow objective (cu. ft. /sec)	Trenton, NJ flow objective (cu. ft. /sec)
Normal	800	1750	3000
Upper half drought warning	680	1635	2700
Lower half drought warning	560	1550	2700
Drought	520	1100-1650	2500-2900
Severe drought	to be negotiated based on conditions		

Source: Delaware River Basin Commission, "Interstate Water Management: Recommendations to the Parties to the U.S. Supreme Court Decree of 1954 to the Delaware River Basin Commission Pursuant to Commission Resolution 78-20," November 1982.

Figure 10

Operation Curves for New York City's Delaware River Reservoirs



Source: Delaware River Basin Commission, "Interstate Water Management: Recommendations to the Parties to the U.S. Supreme Court Decree of 1954 to the Delaware River Basin Commission Pursuant to Commission Resolution 78-20," November 1982.

Real Supply: Raw Water Quality

Discussion of water quality is usually concerned with public safety. In recent years, however, there have been allegations of pollution so vast as to make the matter of quality pertinent not only to safety, but also to sheer volume. Groundwater pollution on Long Island, in fact, has become a concern of such seriousness that the Legislature has since 1980 had a Commission on Water Resource Needs of Long Island. The Commission's annual reports serve as increasingly detailed descriptions of the problem and of alternatives for dealing with it.

Considering that about one-third of the state's population relies on groundwater for its drinking supply, the amount of detailed information available on the potential yields, quality, and threats to the quality of the state's groundwater systems might be thought insufficient. About three million groundwater users rely on private wells for which there are no requirements to monitor

quality. (33) Many upstate aquifers lack the detailed geological assessments necessary to determine water volumes and directions of flow which are in turn needed to assess threats to groundwater quality. While Long Island gets most of the publicity for its groundwater problems, about half of the state's groundwater users are in upstate areas.

Individual groundwater areas differ considerably in terms of size, yield, recharge, and underground flow. A general breakdown can be made into two kinds of aquifers.

- Shallow aquifers occur in sand and gravel deposits, lie close to the surface, and are closely connected with surface water systems.
- Confined aquifers lie beneath or between impervious layers of rock or clay. (34)

Water in confined aquifers is often subjected to great pressures and can be removed by artesian wells with little or no pumping required. Such systems are less prone to contamination from the surface. Once contaminated, however, they may take 1,000 years to cleanse themselves, due to very slow rates of water movement.

Shallow aquifers are of greater importance in the state. They lie in prehistoric river valleys which have been filled with glacial debris, along the plains adjacent to huge prehistoric lakes, and within the 2000-foot-thick deposit of glacial outwash debris which created Long Island.

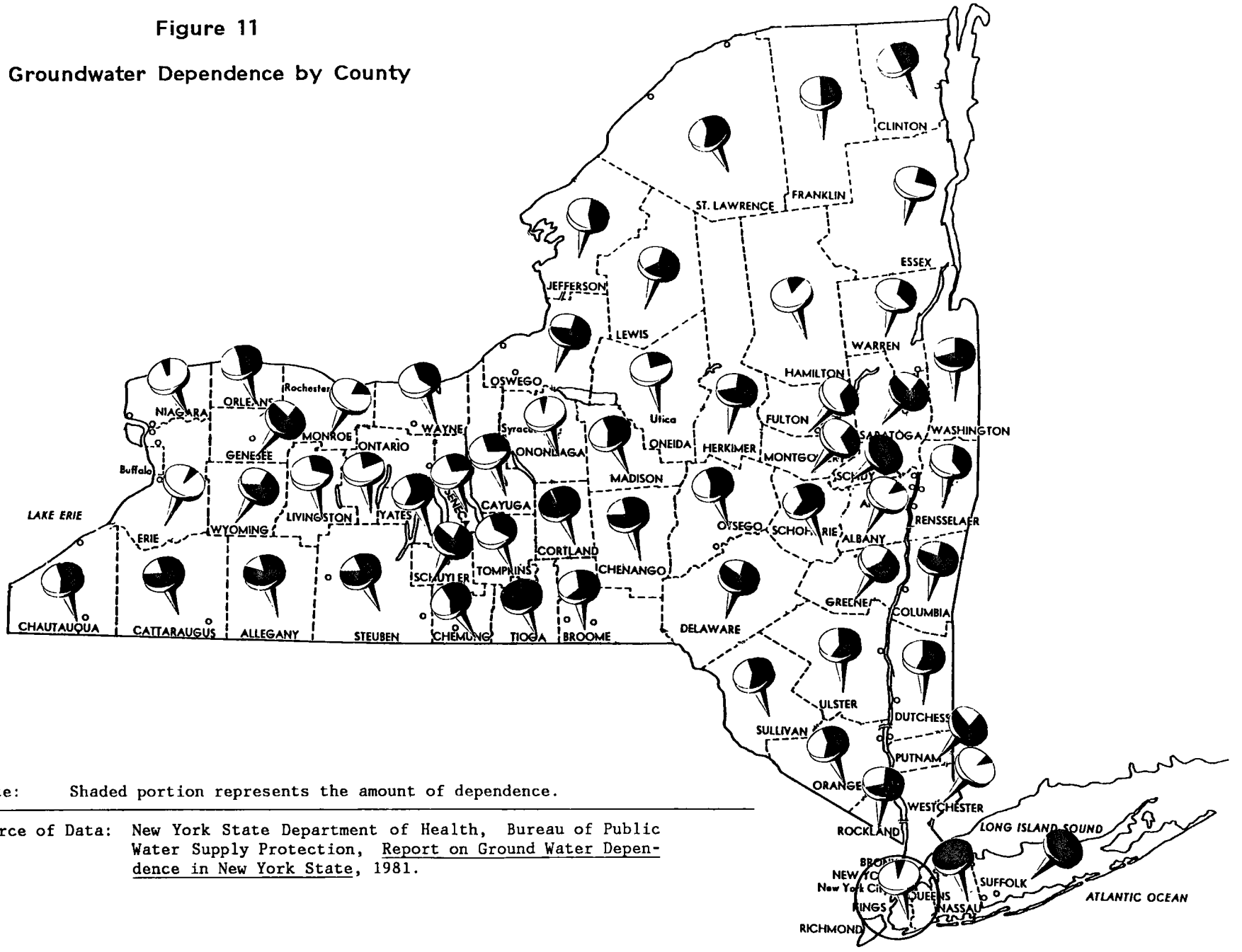
Interrelated Usage and Quality Problems--The state's aquifers provide an enormous volume of water storage, with no dams required and no environmental disruption. (Figures 11 and 12 show groundwater dependence and primary aquifer locations throughout the state. Primary aquifers are those which supply water to at least 8,000 people through community water systems.) The water is stored with no evaporation, at low temperatures, and with relative immunity to most droughts. Yet, the problems of using groundwater are increasing.

- Water quality has deteriorated in many areas--hundreds of wells have been closed. (35) Private well users have long recognized that sewage from their neighbor up the hill may be contaminating their well supply due to an insufficient leaching system. Only recently, however, have public suppliers of groundwater paid a great deal of attention to the link between land surface activities and groundwater quality.

  . Urbanization prevents precipitation from entering the ground, and water runs off through storm drainage systems instead.

Figure 11

Groundwater Dependence by County

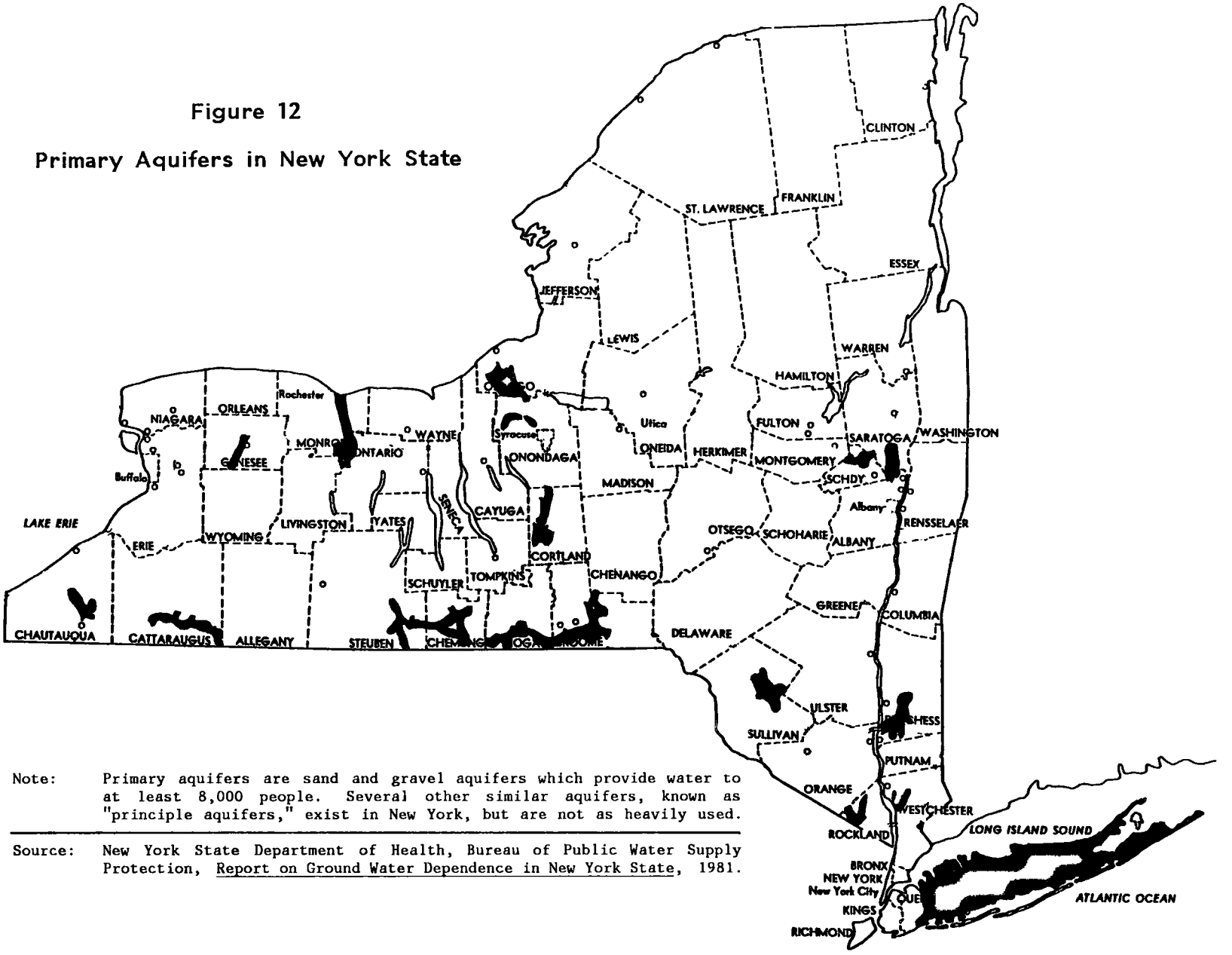


Note: Shaded portion represents the amount of dependence.

Source of Data: New York State Department of Health, Bureau of Public Water Supply Protection, Report on Ground Water Dependence in New York State, 1981.

Figure 12

Primary Aquifers in New York State



Note: Primary aquifers are sand and gravel aquifers which provide water to at least 8,000 people. Several other similar aquifers, known as "principle aquifers," exist in New York, but are not as heavily used.

Source: New York State Department of Health, Bureau of Public Water Supply Protection, Report on Ground Water Dependence in New York State, 1981.

. Materials that are placed on or in the ground may leach toxic or hazardous materials into groundwater supplies.

- "Mining" (using groundwater faster than its recharge rate) may lead to salt water intrusion along the coast, disastrous sinkholes in certain areas, and decreased streamflow. (36)

- Lowering of water tables results in increased energy use for pumping, and depletion of supplies may eventually lead to economic disruptions. (37)

- Individual private groundwater users are not regulated, and estimates of such use are based upon educated guesses.

Groundwater is out of sight, which has tended to keep it out of mind until a problem develops. Although problems are now being recognized, the source is resistant to efforts to manage quality and quantity.

- The slowness of groundwater flows, in combination with a lack of oxygen, results in an extremely slow natural purification process. Groundwater pollution is thus difficult to treat or remove once it occurs.

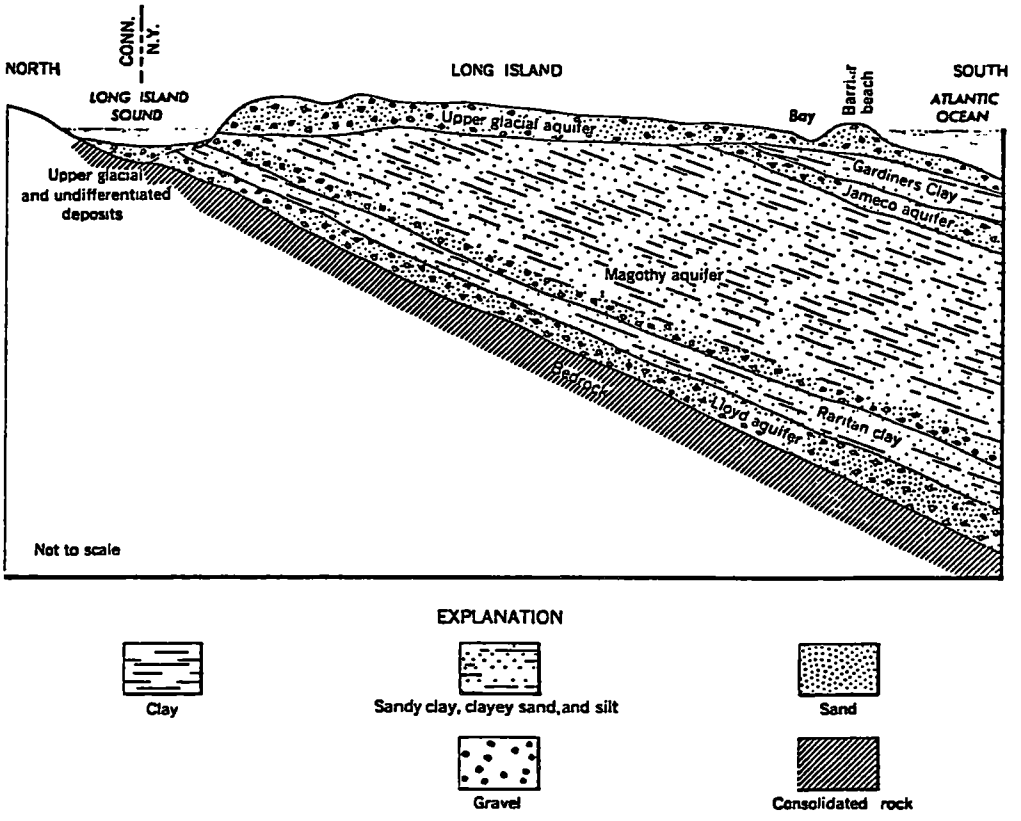
- It is both difficult and expensive to determine groundwater quantities. (38)

The Long Island Case--Nassau and Suffolk counties, with populations of about 1.3 million each, are almost completely dependent on groundwater. The island has three major aquifer layers which together form an interconnected water system that runs the length of the island (see figure 13). The upper Glacial aquifer is closest to the ground surface and has been mostly abandoned due to contamination. It is considered usable only in eastern Suffolk County. The middle Magothy aquifer is the predominant source of the island's water supply. The deepest layer--the Lloyd aquifer--is not in heavy use except along the south shore, where shallow aquifers have been contaminated by seawater. The source of the island's groundwater supply is precipitation which seeps in from the ground surface. The aquifers together are estimated to contain 60 trillion gallons of water (39) and are recharged at an average of one million gallons a day per square mile of land surface. (40)

Long Island was once known for the purity of its groundwater. Much of the water in the aquifer system fell as rain or snow hundreds of years ago.

Figure 13

Cross Section of the Long Island Aquifer System



Note: The vertical dimension is not drawn to scale. The deepest aquifer is an average of 500 feet below the surface.

Source: Reprinted from Progress Report of the New York State Legislative Commission on Water Resource Needs of Long Island, 1982.

Groundwater hydrologists estimate that it takes up to 800 years for water seeping into the Magothy aquifer to reach the ocean. In the deeper Lloyd aquifer, it may take up to 3,000 years for the water to completely replace itself. (41) With 350 years of water stored in the ground at present usage rates, (42) a high recharge rate, and an underground resource which originated hundreds of years before the advent of pollution, the island at a glance would appear to be in good shape. However, the density of population, loss of prime water recharge areas, lack of coordination among the region's dozens of water suppliers, and polluting activities have brought national recognition of Long Island as a region with serious water supply problems.

More than 80,000 wells pump over 170 billion gallons of water annually from Long Island's aquifers. (43) While Suffolk County has no shortage of water except in some limited coastal areas, Nassau County suppliers are mining water in certain areas. When many large wells are concentrated around population centers, craters are formed in the water table, streams and wetlands are dried up as water is drawn down into the underground gap, and contaminants may be drawn to the water intake area. Along some coastal areas, salt water is being drawn into the former fresh groundwater zone.

A 1980 Nassau County groundwater master plan contained the estimate that the safe yield of the county's water supply, or the amount which could be drawn without lowering the water table, was 180 million gallons a day. (44) That year, actual pumping in the county amounted to 194 million gallons a day. In addition, it was estimated that 10 million gallons of water a day flow from Nassau County across the line into Queens as a result of groundwater pumping there. If current practices continue, estimates are that by the year 2020 there will be a deficit of 21 million gallons a day, and the water table may be lowered by up to 75 percent. (45)

Exacerbating the problem is the fact that Nassau County has lost most of its water recharge area. Development covers 84 percent of the county's land area. (46) When land is covered by buildings or other impermeable surfaces, water cannot seep into the ground and instead runs off through the storm drainage system, eventually out to the ocean. The sewering of Nassau County, while serving to protect water quality, has also decreased the amount of water available to the aquifer. Water which formerly seeped from septic systems back into the ground is now routed through sewage treatment plants and out to the ocean. Protecting the remaining open land (and possibly using artificial groundwater recharge techniques) could preserve the water table, but the choice to do so will not be painless since remaining undeveloped land in Nassau County is increasing in value and development pressure.

The glacial moraines which form the hills that run the length of Long Island are also home to much of the remaining pine barrens, which are essential groundwater recharge areas. The sandy surface soils of these regions permit rapid water infiltration, which continually replenishes the underground resource. In eastern Long Island, 110,000 acres of pine barrens remain, most of which are in Brookhaven, Southampton, and Riverhead. (47) While more expensive alternatives do exist, some observers would assert that the protection of these areas

requires banning certain potentially polluting activities and restricting development to a low density.

In much of Long Island, groundwater is threatened with contamination from pesticides and herbicides, industrial chemicals, cleaning materials and solvents, landfill leachate, and fuel spills. Organic chemicals were first discovered in Long Island water in 1976. Once in the groundwater, such chemicals, because of the lack of oxygen, do not deteriorate. Water moves through the aquifer very slowly so that a well area, once contaminated, can be considered useless for human consumption for the foreseeable future. Currently, the upper Glacial aquifer is extremely contaminated. The worst contamination is identified as the Hempstead-North Hempstead town line area. (48) Of 450 public water supply wells in Nassau County, 54 have been abandoned or deepened due to contamination. (49) Only since the 1970s has it been widely recognized that groundwater problems are directly related to land use. (50) From this perception have grown the contentions that it is essential to protect land surfaces in order to protect groundwater and that such protection in the long run is more effective and economical than treating contamination after it occurs.

Other Places--The Jamaica Water Supply Company, the last private water supplier in New York City, draws well water from eastern Queens and western Nassau Counties and serves 520,000 Queens residents in addition to 130,000 Nassau County residents. (51) Eleven of the company's wells have been shut down since 1979 due to contamination, and overpumping has resulted in the danger of salt water and pollution intrusion.

Some residents of the area are looking toward City water as the only alternative, but connecting the City system with the company's water lines would cost at least $188 million, according to engineers' studies. (52) Complete City service in the area would require completion of a $1 billion extension of the City's third water tunnel. Questions also remain concerning the City's ability to continuously provide the 63 million gallons a day needed to replace the Jamaica supply. The City Department of Environmental Protection has projected that the City currently can maintain adequate water supplies for an average of 88 years out of each 100. If the Jamaica Water Supply Company service area was added to the City system, the projection would decline to 84 years out of 100. (53) At present, the City is planning to provide up to 15 million gallons a day to the Jamaica system and is negotiating an outright purchase of the company's Queens assets. (54)

Upstate areas also have concerns about their groundwater supplies. For instance:

- The Village of Clifton Springs in the Finger Lakes region received notice from the Health Department in 1971 that its well supply contained nitrate levels exceeding the maximum allowed by the State Sanitary Code. State and federal funds enabled the village to contract the services of the Cornell University Center for Environmental Research. Analysts found that nitrate levels had been steadily increasing since the 1930's, correlating with a significant increase in cropland. The researchers were able to identify the farm most responsible, and the farmer agreed to change fertilization practices in order to decrease excess nitrogen runoff. Even so, groundwater movement is so slow as to require 25 years to return wellfield nitrate levels to an acceptable range, forcing the village to develop an alternative groundwater supply. (55)

- The Big Flats Aquifer lies in a broad, flat-bottomed valley between Elmira and Corning and supplies water to 6,000 people. Higher-than-average nitrate levels were discovered in new public water supply wells in the mid-1970's. The Cornell Environmental Research Center surveyed the area under a DEC contract to determine ways in which the aquifer can be protected against further contamination. The contamination is a result of land uses, such as agricultural fertilization. By assessing historical land use changes, taking soil core tests, and mapping underground water flows, an approximate source of contamination may be determined. (56)

Actions--Cornell University analysts have noted that protection of groundwater requires extremely difficult management decisions.

> It will involve control of land uses, which are the source of the contamination. Can this be done when the exact boundary of the recharge area may be difficult to define? It may also be necessary to resolve the legality of imposing controls over some residents and not others for groundwater supply protection, in a situation where the precise source of potential contaminants cannot be determined. (57)

Such difficulties notwithstanding, the State has considerably developed groundwater protection. The Department of Environmental Conservation is responsible for aquifer classifications and effluent standards and limitations to protect groundwater. (58) The Department maintains effluent standards to protect existing groundwater quality. (59) These standards apply to the direct release of effluents into the ground. Pollution may, however, enter aquifers from "non-point" sources such as urban storm water runoff and runoff from agricultural land which may contain fertilizers and pesticides.

Several 1983 state laws were passed in an attempt to strengthen groundwater protection measures.

- Chapter 951, the "Incompatible Use Law," restricted the use of hazardous wastes or substances in Long Island's primary groundwater recharge areas. (Chapter 968 of the Laws of 1984 extended the incompatible use law to state-designated recharge areas in Brooklyn and Queens and to the Schenectady County Great Flats Aquifer.)

- Chapter 613 strengthened control over bulk storage of petroleum, and Chapter 901 prohibited the improper disposal of waste oil.

- Chapter 299 provided for the phasing out of landfills over Long Island's deep flow aquifer recharge areas.

- Chapters 662 and 663 provided for notification of applications for and violations of State Pollution Discharge Elimination System (SPDES) permits in Long Island to all public water suppliers within a three-mile radius of the discharging facility. (60)

Currently, DEC is working to strengthen its approach to statewide groundwater protection. Aquifers which provide water to at least 8,000 people have been defined as primary aquifers, 18 of which have been identified. (61) More than three-quarters of a million people are served from these aquifers. There have been suggestions to extend the Long Island incompatible use law to cover these primary aquifers. DEC is studying proposals to prohibit or regulate certain potentially polluting activities based upon three primary aquifer zones: the wellhead area, critical recharge areas, and tributary areas contributing water to aquifer systems.

Even with more protective standards, limits to groundwater protection remain. Certain aspects of groundwater hydrology require more study. In particular, it is difficult to determine the direction of localized flows within an aquifer. Some uses may be allowed over aquifers where waters flow away from well areas. There are several other considerations:

- Certain use prohibitions may be judicially overturned as unlawful property takings.

- Total prohibitions of certain uses over entire aquifer areas may be infeasible. For example, the entire City of Corning overlies its aquifer. It probably would not be possible, for example, to ban all gas stations from the city.

- Even if potential contaminants are totally monitored, which could be prohibitively expensive, actual detection of all contamination may not be possible.

In Sum: Pervasive Uncertainty and Choices

The lack of reliable information which characterizes the matter of water distribution seems to be characteristic also of the general matter of water supply. Estimates of available supply are problematic because of inherent limits in the estimation methodologies and complicating factors such as pollution. And total water usage 20-50 years from now is uncertain because of seemingly unavoidable error in predicting both population trends and per capita use.

Some of this uncertainty may be irremediable insofar as near-term planning efforts are concerned, and this means that development choices, though the alternatives may be plentiful, will be difficult. For instance:

- Planners and users may wish to allocate enough investment for any circumstance that may occur, but some of them realize that population growth may be so slow that such a wish, brought to fruition, may result in an overcapacity that was expensive to obtain and that was purchased at the cost of other public development needs.

- The extent of groundwater pollution and, even more, its practical effects are unclear. Uncertainty about groundwater dynamics makes it difficult to know whether or not entire aquifers upon which millions of users currently depend may already be unsalvageable. Deliberations comparing the costs of deferring urban or suburban development with the costs of radical alterations in water supply to serve such development are therefore likely to be so highly hypothetical as to seem speculative.

Whether or not the participants have acknowledged it, discussions of distribution system redevelopment occur within the context of such large-scale water supply uncertainty. Distribution, of course, is a requisite of any water supply system, and the assurance of adequate distribution should be pursued. But this pursuit should not occur without recognition that some kinds of water problems are more serious than others--e.g., groundwater pollution has more dangerous ramifications than do main breaks, even if the breaks are frequent. Finiteness of public capacity means that not all development possibilities can be simultaneously pursued with equal vigor--choice is unavoidable. The next chapter will simply review the kinds of water supply development possibilities that may exist.

Chapter 7.
A Survey of Large-Scale Choices

Facing Risky Business

The Cost and Illusion of Certainty

Because water supply planning involves projection of future needs, some risk is unavoidable. Developing new supplies or facilities in many places may prove to be an unnecessary expenditure. But the risk that more commonly concerns planners is that any particular amount of development will prove to be insufficient to satisfy needs. The evaluation of that risk is based on drought experience and is usually quite conservative (i.e., tends toward "worst case basis" planning).

Some of the testimony in 1972 before the Temporary State Commission on the Water Supply Needs of Southeastern New York is illustrative and instructive regarding this matter of risk. To the commission panel's inquiry about safe yield, the chief engineer of the New York City Board of Water Supply gave this response:

> ...the quantity of water defined as the safe yield is the least quantity of water based on historical record that can be produced by the system rather than the average. Up until 1961 the period of least historical yield had been in 1930 and -31. This experience was thought to have a return period of one in 100 years. In other words, based upon a statistical analysis, you would expect that the experience of 1930-31 would be repeated once in a hundred years. (1)

A "100-year drought" is a statistical idea. Droughts sometimes defy probability, and a "100-year drought" may not occur for 200 years, or it may occur repeatedly within a few years. And in fact, New York experienced an even worse drought in the 1960s; statistical analysis--practically the only method we have for planning in this matter--was an inadequate guide. Despite the unplanned-for severity of the 1960s drought, however, the City's water supply proved to be sufficient. Later in the chief engineer's testimony, then, a panel

member raised the pertinent question with regard to the adequacy of the City's supply:

> What degree of risk are we willing to accept in municipal water supply? For instance, in the 1960-67 drought a crisis arose and the water supply managers were called upon to meet a situation that wasn't counted on. The fact of the matter is that with some recourse to extraordinary measures, the basic water needs of the city were met even during this very critical period. What degree of risk are we willing to accept? If I understand the city position, it is that we proceed on the basis that we accept no degree of risk. In other words, based on past experience we build capacity and systems so that we always meet projected needs without taking extraordinary measures. We build for the rare occurrence. This simply means that we build a tremendous overcapacity which will seldom be used. During the drought by measures such as a public education campaign, leakage control in the system, instituting the Chelsea pumping station, you managed to come through a tough period without collapsing. I think it was a tremendous performance. So I come back to the question. What degree of risk are we willing to take in this situation? (2)

The occurrence of a drought of greater severity than that planned for results in pressures to develop greater water supply capacity so that, it would seem, "it doesn't happen again." But inasmuch as it is impossible to specify the ultimate drought, a certain amount of risk must be chosen. As others at the Temporary State Commission hearings noted:

> The 60's drought...had a statistical return period of once every 400 years. We thought that the early thirties drought was once in 100 years but it turned out to be one in 20. When an elected official's reputation is involved, we can expect he will want the degree of risk to be as close to zero as possible....[But] we can save literally millions of dollars by introducing in the mix a reasonable risk factor. You have got to get the public to accept the fact that once in 100 years or so you may run into a tough water supply situation that might require some public discomfort. (3)
>
> An elected official that wants a zero risk is often taking another risk of increased taxes for the cost of a system that is grossly overdesigned. There are two sides to every coin. What kind of tax burden are people willing to pay for the risk? It is obvious that zero risk is expensive and difficult. (4)

The necessity of the assumption of some level of risk changes the determination of safe yield from an engineering decision to a policy choice.

Sometimes, economic analyses are used to help make the decision. For instance, the U.S. Institute of Public Administration recommends an approach that compares the cost of a water shortage of an assumed probability of occurrence with the cost of avoiding the shortage. (5)

Choices

Any strategy to correct water supply deficiencies will involve demand reduction and/or supply augmentation. Increasing the efficiency of distribution seems to fit into both categories. Reduction of leakage, for instance, means that more of the water pumped from a source will reach the users, and this will forestall demands for more capacity; in that way, leak control is demand reductive. Looked at another way, however, leak control is supply augmentative: the water that escapes the pipes before reaching users can be thought to be a supply of water to which users do not have access.

Other methods of demand reduction and supply augmentation are more easily classified as one or the other. The rest of this chapter is a review of some possibilities which could conceivably be used singly or in combination. Specifying a particular combination as most sensible--a specification which would vary depending on what local water conditions permit--would be complex because the feasibility of all possibilities is not clear. As will be noted more emphatically later, consideration of such choices again calls to our attention a lack of information, and perhaps policy, that is only partly irremediable.

Demand Reduction Alternatives

Some Methods

Growing attention is being paid to the idea that the demand part of the water supply/demand balance can be reduced. Reduction methods range from voluntary conservation to physically or legally limiting water use. These methods have varying degrees of acceptability, depending on concerns about limiting economic development, restricting personal freedom, or unfairly allocating costs and responsibilities. There are also debates about the total cost and effectiveness of various reduction programs. System management possibilities of reducing waste were reviewed in Chapter 4. Several approaches, however, are more user oriented.

Education and Voluntarism--Promoting public awareness of water conservation methods and benefits is the most frequently used and least controversial conservation technique. The public must believe that voluntary conservation is beneficial before it becomes effective. The education process can occur through brochures, mailings, or public service announcements which explain the need for conservation and ways to reduce or eliminate unnecessary water use.

Results can be dramatic. New York City cut its water use by 71 million gallons a day within twelve days during the 1981 drought. (6) Total water consumption for the City system eventually dropped by 196 million gallons a day from the previous year. (7) In most areas, consumption returns to pre-drought levels after the emergency. Californians, however, maintained a per capita usage decline of 20 percent a year after the 1977 West Coast drought. (8)

In-House Leak Detection--A dripping faucet can waste gallons of water a day. Reducing these leaks will result in some energy savings to the consumer and a slightly reduced total demand on the system. The customer's incentive to act may be perceived water and energy cost savings.

Plumbing Changes and Pressure Management--Various plumbing code changes and water saving devices can result in a direct and permanent reduction in water use. Savings can result from toilet tank inserts or new low-water-use toilets, faucet and shower flow reducers, insulation of hot water lines to reduce waiting time for hot water, and pressure reductions. A pressure of 80 pounds per square inch (psi) is common in a residential water system. A reduced pressure of 50 psi may be sufficient for household use (9), while some household water-using appliances may require only 20 psi. (10) Pressures can easily be reduced by flow restrictions for service areas or individual services, and savings can be dramatic.

Changes can be brought about gradually through building and plumbing code changes (as have been implemented in New York), free or low-cost distribution of conservation devices, or promotion of full cost installation. Even free distribution of devices by water suppliers has been shown to reduce system costs. Money saved by lower treatment and pumping costs may exceed the cost of distributing the devices. (11) Caution, however, is warranted: experience with water saving devices has shown that some varieties may actually lead to increased water use if consumers compensate for uncomfortably low pressures by taking longer showers.

Pricing and Metering--Considerable debate has surrounded the issue of using water pricing and metering to manage demand. Water rates usually are set

to cover the historic cost of providing water, with little continuing attention paid to anticipating future costs or relating price to demand.

Rate structures have evolved in complexity: they range from flat rates independent of use, to gradual fixed rates based upon physical features like house size, to fixed rates per unit of water used, to block rates. Block rates involve the charging of different unit rates for successive "blocks" of water use and are often based on the assumption that it costs less per unit of water to supply a large user than a single small household user. Water bills are often broken into:

- fixed costs for customer services such as reading meters and processing water bills, plus
- base costs which vary with quantity used, plus extra capacity costs (block costs). (12)

Table 9 displays the "decreasing block rate" pricing system used in Batavia in 1971.

The effects of rates on demand have been the subject of disagreement. Some researchers have argued that residential demand is not at all responsive to water price. They contend that a minimum amount of water is used for life and hygiene regardless of cost, and water costs have such a small impact upon household budgets that consumers may not adjust use to reflect cost. (13) One study, for instance, rejected the hypothesis that price has any impact on commercial

Table 9

Quarterly Water Rates, Batavia, New York, March 1971

	Quantity			Rate
fixed rate	first	10,000	gal	$6.10
base rate	next	30,000	gal	.53/1000 gal
block rates	next	160,000	gal	.48/1000 gal
	next	800,000	gal	.43/1000 gal
	next	2,000,000	gal	.38/1000 gal
	next	2,000,000	gal	.30/1000 gal
	all additional water			.26/1000 gal

Source: John H. Galligan, "Municipal Water Rates in New York State: Conference of Mayors and Other Municipal Officials," New York Conference of Mayors, Report #72-b, 1972.

water uses because such uses are mostly for personal hygiene and users are not directly responsible for the price. (14)

On the other hand, a growing volume of literature suggests that demand is indeed responsive to price. As early as 1926, a published report reviewed 29 water systems and concluded that those with higher rates experienced lower levels of consumption. (15) More recent reports have suggested that price has a significant impact on certain types of water demand. Demand may be inelastic until a threshold cost is reached, at which point demand will respond to price until conservation possibilities have been exhausted. (16) Several studies suggested that while indoor household residential use may be relatively unresponsive to price, outdoor use (e.g., lawn watering) responds significantly. (17, 18)

Sewage or wastewater treatment costs can be considered as water-related costs which can affect demand. Industries often implement water saving technologies as a result of water treatment requirements or metered sewage disposal rates. (19)

Several pricing methods have been proposed as demand management techniques:

- Real or marginal cost pricing would set rates based upon the cost of providing the next unit of demand. In this way, investments for new supply are figured into the pricing structure.
- Increasing block rates set unit prices at higher levels for successive "blocks" of water use, keeping rates low for low-volume users and encouraging conservation by high-volume users.
- Flat rate pricing simply eliminates decreasing block rates and charges an across-the-board price per unit.
- Seasonal pricing is the setting of higher summer rates to discourage excessive outdoor use.
- Excess use pricing involves charging a penalty fee for use beyond a certain level.
- Extra connection fees can be used to deter additions onto the system.

No unit pricing system can be implemented without meters to measure water use. Meters provide other use-related benefits as well. Installing meters may have a psychological effect on consumers, making people more aware of their water use and encouraging some conservation regardless of price. Metering facilitates more equitable pricing and provides information to identify high-use customers, areas of increasing use, and high leakage areas. (20) Metering also

tends to promote more uniform usage, smoothing demand peaks and in turn lowering storage and pumping needs. (21) The U.S. Army Corps of Engineers has estimated that Buffalo could save 32.4 gallons per capita per day, or 11.4 million gallons a day by metering. The Corps estimated also that New York City could save 125 million gallons a day by implementing a universal metering program. (22)

Some system operators are reluctant to install meters. Metering involves a high ($150 to $300 per unit) installation cost and ongoing operational costs, though expenses may be offset by water savings. (23) Metering can lead to an uneven revenue flow: Because revenues are based on water usage, changes in use patterns result in changes in revenue. A further difficulty is that older meters may under-register by as much as 25 percent of household flow, resulting in faulty information and unequitable charges.

Water Reuse--The idea of reusing wastewater is commonly met with distaste. Nevertheless, any intake of river water includes a certain amount of upstream waste. About one-third of the United States population uses water with at least a 1-to-30 ratio of previously used water. (24) As pure water supplies in some areas become more precious, the idea of reusing water gains a measure of respectability.

This does not mean that we will be drinking our effluent. In fact, less than one percent of the nation's water use is actually for human consumption. (25)

Several reuse possibilities exist.

- Industries can, and often do, use non-drinkable water in industrial processes.
- Sewage may be used for irrigation or for groundwater recharge.
- A dual water system may be established in newly developing areas to provide both potable and non-potable water for appropriate uses.
- Sewage can be treated to reach drinking water standards and recirculated directly into a water supply.
- A household "grey water system" can use dishwashing, bathing and laundry water for toilets and lawn watering.

All possible systems have costs and problems to be overcome. For instance:

- Some pollutants cannot be completely removed and may build up within a recirculating system. This may require periodic flushing of the system, with potentially adverse environmental consequences.

- Certain contaminants limit the use of wastewater for land application. Lead, long-living viruses, and newly developed synthetic substances may create long-term health dangers if spread on the ground or added to the water supply.

The health risks of any reuse system must be ascertained, and the product must be monitored to eliminate risk and minimize liability damages. For a reuse system proposal to be viable, it must be acceptable to the public, and the cost of the system (minus possible sale values of water and sewage by-products) must be comparable to or less than the cost of providing "new" water. A system that is safe may nevertheless present problems of odor or appearance, which would hamper public acceptance.

Use Limits and Prohibitions--Restrictions on total use or types of use are a last-resort response to water shortages. Restrictions can be voluntary or legally imposed and may be enacted in stages. This is a flexible response to a crisis, but cannot be considered a long-term conservation measure.

Demand Reduction: Expectations And Doubts

As already indicated, it is impossible to design water supplies for the ultimate drought. Climatologists have documented the occurrence of extreme weather changes over short geologic time periods. Within human history, lakes and rivers have appeared, changed and disappeared, glacier coverage has expanded and contracted, and ocean levels have risen. Some extreme events have occurred within relatively recent history, such as the "mini-ice age" of the 1600s, and the "year without summer" in the early 1800s. The drought of the 1960s was without precedent for public water suppliers in the Northeast. It is conceivable, though unlikely, that more severe droughts may occur, turning reservoirs into dry, cracked earth.

To provide water at normal demand levels during "the most severe possible drought," or even during more common droughts, would necessitate a capital expense beyond the means of any level of government. Once built, such facilities would rarely be used. A certain amount of demand management is therefore required in every system to minimize stress during a shortage. The National Conference of State Legislatures recognizes the necessity of this minimum standard of demand management: "The costs of developing excess supply capacity may be greater than costs associated with a water conservation program to meet emergency needs." (26)

Emergency conservation, however, is reactive. Long-term conservation is predictive and will decrease the number and seriousness of supply shortages by stretching existing supplies. This will, in turn, decrease the expense and hardship associated with more stringent demand reduction methods during shortages and the need for expensive supply expansions to meet demand during droughts.

Decreasing overall demand also results in other financial savings for water and sewer systems:

- Some of these savings are related to energy costs associated with water pumping and to water and sewage treatment costs.
- Pressures on the infrastructure may be reduced, especially through reductions of peak demand. This increases the efficiency and lifetime of water distribution components.
- Existing supplies may become available for new users without the need for new supply expansions.

One estimate of the economic benefits of water conservation measures indicates that well-managed conservation programs can realize from $5 to $50 in savings for each dollar spent. (27)

Customers as well as systems stand to gain monetarily. For instance, Boston's Prudential Center complex realized savings of two million gallons of water and 500,000 pounds of steam a year from a 1973 program to retrofit toilets and sinks. (28) Industrial users save on treatment and energy costs. Homeowners can save from $197 to $385 a year in reduced water bills, sewage fees, and especially water heating costs. (29) The federal Department of Energy estimated that by installing flow control devices in 80 percent of American homes, energy savings would be the equivalent of seven percent of nationwide oil consumption. (30)

Sewage systems are generally managed separately from water supply systems, but costs and savings for both systems should be considered. The New England Interstate Water Pollution Control Commission listed the following benefits of water conservation for local sewer systems:

- The size of proposed wastewater conveyance systems may be reduced, saving five percent on construction costs.
- Sewage flows may be reduced by up to 15 percent, decreasing hydraulic pressures on sewers, which could in turn extend the life expectancy of pipes by up to 20 years.

- Savings from reduced wastewater pumping may reach $350 for each one million gallons saved.

- Sewage treatment plant construction costs may decrease by 7.5 percent, and up to 20 years may be added to the lives of existing plants. (31)

The environment itself may benefit from reduced water demand. Less sewage is discharged into water bodies. Because the contaminants in wastewater are more concentrated, the wastewater treatment process may become more efficient. Possible dangers from groundwater overpumping, such as land settlement and salt water and pollution intrusion, may be reduced. More water may be saved for environmental requirements, such as waste assimilation and fish and wildlife habitat preservation, within streams and lakes. Some doubts remain regarding water conservation:

- Consumers must respond to conservation initiatives and must be convinced of the benefits of conservation for voluntary measures to succeed.

    . Some may resist conservation-related rate changes or other expenses related to conservation even if long-term savings are realizable. Water is often regarded as "free", like the air. Any attempt to treat water as an economic good is certain to generate opposition. Some may regard conservation as a lowering of their standard of living.

    . A debated point is whether or not conservation savings prove to be permanent. Consumers may decrease demand as the result of a perceived crisis or a conservation campaign, and then later revert to old habits.

    . For systems using unit rates, reduced water consumption results in reduced revenue. This may necessitate base rate increases in order to assure minimum required revenues. Rate increases may in turn generate opposition to a conservation program.

- Considerable debate has concerned the effectiveness of water prices to reduce demand, as has already been noted. Price structures may affect economic development, especially if connection fees are high. A change in the price structure may involve discussions of rate subsidies for low-income users and broader discussions of which segments of society are actually paying for the water system.

- A barrier to conservation efforts is the high initial cost involved in certain techniques. The cost of metering the New York City system was estimated at $94 billion in 1973. (32) Current costs would be significantly higher, but metering is needed before many conservation measures can be implemented. Costs for leakage control amount to about $50 per million gallons a day (mgd) saved, and metering

costs about $1,000 per mgd saved. However, the costs for developing new supply systems (in 1977 dollars) are about $2,000 per mgd. (33)

- Should conservation be undertaken by utilities facing no water shortfall? Buffalo, for example, takes Lake Erie water and will never face a shortage of raw supply.

- The benefits of decreased distribution and sewage costs would have to be weighed against the costs of conservation. Concentrating sewage effluents in a lower volume of water may require some adjustments at waste treatment plants.

- Some conservation methods may overlap with others. For example, pressure reductions and faucet devices are two ways to save water, but if pressure has already been reduced, faucet devices may no longer be useful.

Some Conservation Experiences

Following are some descriptions of notable examples of actual water conservation activities around the country.

- Boulder (Colorado) adopted a uniform commodity charge and quickly metered the city in 1961. A permanent 36-percent reduction in water use resulted over a six-year period. Outdoor watering use dropped nearly 50 percent. (34)

- Philadelphia adopted universal metering between 1955 and 1960. Per capita water use decreased 28 percent. Pennsylvania law now requires universal metering within all public utility commission jurisdictions. (35)

- In the Boston Metropolitan District, per capita use declined from 130 gallons per capita per day (gpcd) to 100 gpcd over the course of a metering program from 1900 to 1930. (36)

- Kingston (NY) reduced water use 20 percent as a result of a 1958-63 metering program. (37)

- East Brunswick (NJ) adopted a flat rate and then an increasing block rate pricing structure in the mid-1970s. Consumption was reduced 8 percent by 1978, and the 1981 drought period saw a 19-percent reduction in use. (38)

- The Washington Suburban Sanitary District in Maryland adopted an increasing block rate structure with 100 price blocks in 1978. Before adopting the new rate structure, the district had engaged in a conservation media blitz and door to door distribution of flow reduction devices. The system also reduced water pressures to 60 pounds per square inch. Per capita use decreased between 7 and 15 percent from 1977 to 1982. (39)

There are some examples of success with wastewater reuse. Most existing reuse systems involve using municipal wastewater for agricultural irrigation; by 1979, there were 470 such projects nationwide. Of the 536 wastewater projects of all kinds existing in 1979, 244 were in California, 125 in Texas, 36 in Arizona, and 22 in New Mexico. California may meet up to 60 percent of its projected water shortages over the next 20 years with treated municipal and industrial wastewater. (40) No current reuse system in the nation uses wastewater for direct potable supply, although several systems mix wastewater with new supplies. Here are descriptions of some experiences.

- North of San Francisco, treated wastewater is being used to reclaim a marshland, resulting in an increased wildlife habitat and in water quality and quantity benefits to supplies fed from the marsh. (41)
- Fairfax County (Virginia) discharges ten million gallons a day of treated sewage into a water supply reservoir. The system cost, however, has been high. (42)
- Denver has established the largest reuse project in the nation, adding one million gallons of treated sewage a day directly to the water supply pipe system. (43)
- Orange County (California) injects treated sewage into the ground to form a barrier against salt water intrusion. (44)
- Malibu (California) has had some success growing tomatoes and cucumbers in secondary effluent. Trace metals have been found in stems and leaves, but not in the fruit. (45)
- St. Petersburg (Florida) has been using a dual potable and non-potable water distribution system since 1977. Much lawn watering is done with reclaimed water. (46)

In New York, wastewater reuse possibilities have received attention on Long Island. A federally funded demonstration project in Wantagh treated up to four million gallons of residential sewage a day and returned the treated effluent to the ground via wells and basins. The United States Geological Survey has been monitoring test wells near the recharge sites to ascertain the applicability of such a project. Results of the experiment had yet to be determined as of this writing.

State-level Initiatives

State policymakers and agencies have not been unaware of the value of conservation.

- Connecticut now requires a conservation implementation plan as a condition for required state permits for all new water withdrawals or diversions in excess of 50,000 gallons per day. (47)

- Florida is divided into five regional water management districts which issue permits for water use. The districts are required to formulate water shortage plans. (48)

- Arizona requires conservation plan implementation for four designated management areas: the cities of Phoenix and Tucson, and Prescott and Pinal Counties. (49)

- California initiated a vigorous water conservation program in 1976, emphasizing urban and agricultural conservation and in-school water conservation education. The program has included distribution of water saving devices, landscape design demonstration projects, encouragement of additional metering and conservation-oriented price structures, a leak detection grant program for small- and medium sized utilities, and the imposition of water conservation measures on all agencies receiving state grants for sewage or water supply treatment plants. (50)

- Maryland plumbing codes call for toilets using 3.5 gallons per flush (rather than the conventional 7 gallons per flush) and showerheads using 3.5 gallons per minute. (51)

New York State, too, has developed some water conservation measures. The state plumbing code has been amended to provide for lower-flow toilets, faucets and showers in new construction. (52) DEC established an ad hoc drought task force in response to the 1981 drought. The Department issues drought warnings for six regions.

The Department of Health (DOH) coordinates the State's water-related emergency equipment such as temporary pipe connections. In 1981, DOH asked the State's communities to submit drought emergency plans, including information on water levels, criteria for local drought warnings and water restrictions, emergency sources, specific emergency actions, and available resources. (53)

A DOH report, issued in April 1982, detailed the drought preparedness plans of all water suppliers within the 22-county region affected by the 1980-81 drought. (54) It revealed that emergency sources are available with the exceptions of New York City's and Westchester and Rockland Counties' systems. It was further found that state emergency equipment stockpiles are inadequate to meet community needs during a more severe drought. An eleven-point series of recommendations was developed, including increased source monitoring, new source developments, universal metering, emergency source sampling and rehabilitation, and emergency equipment stockpiling by the State Office of Disaster Preparedness.

Interstate Efforts

A portion of southeastern New York falls under the jurisdiction of the Delaware River Basin Commission, a federal-interstate compact commission. New York City lies outside the basin, but gets about half its water from basin reservoirs. For the purpose of protecting downstream users, the commission has a detailed drought operation formula which imposes use restrictions on in-basin users and which limits New York City's water allocation during times of short supply. The three-stage formula is triggered automatically when City reservoirs fall below warning levels for five consecutive days. Specific use restrictions within the basin are mandated, while New York City may manage its reductions as it sees fit. The commission has adopted water conservation policies which are required for any new projects larger than one million gallons per day. A commission task force was formed in 1983 to formulate an overall use reduction program. (55) The adjacent Susquehanna River Basin Commission requires conservation and metering plans as conditions for approval of water withdrawal applications.

Supply Side Possibilities

As the following review will indicate, the technology available for supply augmentation seems considerably less developed than the technology available for demand reduction. (56)

Augmenting Existing Supplies

Certain management techniques are available to water suppliers to increase the yield of a water source without tapping new sources. Watershed management techniques may increase runoff into storage reservoirs and decrease storage losses. Storage reservoirs themselves may be increased in volume. Experiments have been undertaken to decrease reservoir evaporation and to increase precipitation, but results are not promising. Several separate supply sources can be managed conjunctively to improve the efficiency of water allocation. Especially appropriate for parts of New York may be the conjunctive management of surface and groundwater supplies.

Watershed Management--Most water supply reservoirs in the Northeast are located in forested areas. Lands surrounding reservoirs were commonly planted with softwood stands to reduce erosion and sediment buildup in the reservoirs. The softwoods are easily managed and produce a fine, erosion-resistant forest

floor. (57) The forest also prevents a large amount of water from reaching streams. By a process known as "evapotranspiration" (loss of water from a land area through transpiration by plants and evaporation from the soil), about 71 percent of total forest land precipitation is consumed before it reaches streams. (58) Runoff into surface water supplies may be increased by selective tree cutting and by complete removal of trees in favor of open grassy areas in limited locations. Open spaces thus created can increase snow retention and decrease vegetation demands on water during the growing season.

Such a program must be carefully managed to maximize benefits while avoiding harmful environmental impacts. It may be possible to return 20 percent of the water lost to evapotranspiration to the surface runoff system, at a cost of between $13 and $424 per acre-foot of water produced. (59) The price of the operation varies according to timber values. The harvested timber may be sold commercially and for firewood. A variable tree stand with a mixture of tree types and age and with some open areas can provide a healthier forest and a healthy and diverse wildlife community. Indirect recreation and fire control benefits may also accrue. Care must be taken, however, to avoid losses of groundwater recharge and to minimize erosion and sedimentation.

Another watershed management technique is snow fencing, especially in high elevations. Fences can create massive piles of drifted snow, which can extend the snow melt season by up to three weeks. The longer melting season can decrease the amount of water lost over a reservoir's spillway, thus increasing water available for storage. The method has aesthetic disadvantages and must be undertaken with care to avoid impeding the movement of wildlife.

Increasing Reservoir Capacity--In some places, it may be possible to increase the storage at existing reservoirs to increase yields. The effective life of any artificial impoundment is limited because of the natural sediment which all streams carry; the amount and type of sediment are based upon upstream geology and the flow and gradient of the stream. When a stream is impounded behind a dam, the suspended sediment load is allowed to settle out and accumulate at the bottom of the lake. This slowly but steadily chokes the reservoir's storage capacity. Within a century, many artificial lakes can fill completely with deposited muck. For this reason, it is necessary not only to minimize upstream erosion, but occasionally to dredge an old reservoir.

Dredging may also be used to increase the total capacity of a reservoir. The process, however, is expensive and has environmental complications. Lake bottom sediments may contain hazardous material accumulations, presenting

disposal problems. The dredging process could stir up the lake bottom, resulting in increased turbidity in the lake and downstream areas. This may in turn threaten water quality standards and impact fish habitats.

A more accepted way to increase reservoir storage is to raise the height of the dam. In the New York City system, a metal gate flashboard is being installed on the Cannonsville Dam in the Delaware River system. For a relatively low cost, the maximum water level will be raised eight feet. An additional 13 billion gallons of storage capacity will be added, providing 25 million gallons a day of added yield. The project will not increase the City's maximum system yield, which the U.S. Supreme Court has restricted to 800 million gallons a day from the Delaware system. The extra storage will, however, provide for the maintenance of downstream release requirements and provide some added protection against drought conditions.

Many reservoirs are, of course, limited by topography to a certain maximum level. Raising a dam where it is possible would immerse additional acreage, which could create controversy over land use rights.

Reducing Evaporation--Evaporation of surface water storage is a process to which those in the arid western states are highly sensitive. But even humid areas experience significant evaporation losses. The amount of evaporation from surface waters is a function of water temperature, solar energy, air temperature, relative humidity, and wind. The average evaporation rate in the United States is 50 inches per year. (60)

Scientists have attempted to decrease evaporation by developing films to spread on water surfaces; a film acts as a barrier between the water and the atmosphere. Such films are a single molecule thick and must be non-toxic. Results have yet to be encouraging. Experiments have resulted in the films breaking up in the wind. (61) A more feasible method of reducing evaporation is to provide windbreaks along lake shores. (62) Small reservoirs, however, are generally lined with trees anyway, and large reservoirs will get windy regardless of such efforts.

Cloud Seeding--The idea of seeding clouds to increase precipitation comes up from time to time during droughts. Cloud seeding involves spreading tiny particles over clouds; water molecules attach themselves to the particles, creating rain drops. Seeding has been attempted with some success on winter clouds which form over mountains when air is forced to rise. Experimental results have ranged from precipitation increases of 200 percent to decreases of 45 percent. (63)

Two Westchester County legislators reportedly proposed cloud seeding during the 1981 drought. (64) It was not attempted due to some uncertainties: increases in rainfall are not inevitable, and rainfall downwind may actually decrease (the latter phenomenon has not been proven conclusively). Lawsuits resulted from a 1940s and 1950s cloud seeding experiment over the Catskills. A resort owner claimed that a loss of business resulted from a possible increase in rainfall, and several communities claimed that flooding resulted. (65) There have generally been, then, too many uncertainties involved to very optimistically consider a cloud seeding program at present.

Integrating Water Sources--The idea of integrating sources has to do both with interlocal arrangements and kinds of sources. Several areas of New York are served mainly by small systems; the very characteristic of smallness may make a system especially vulnerable to certain possibilities.

- Small water supply systems are especially threatened when drought or contamination occur.
- State regulators are reluctant to restrict the use of a partly contaminated source if no alternative source exists.
- Small systems may suffer unusual financial burdens during shortages even though a nearby source may have an adequate supply.

It is conceivable that by linking smaller systems into regional systems, economies of scale could be realized. Improvements could be more effectively carried out, more professional personnel hired, and water resources more efficiently distributed. Regional systems might increase the adaptability of water supply distribution to unexpected shifts in demand. And the linking of systems could increase management options during droughts, as various water source areas respond to drought periods at different rates due to physical and meteorological differences among watersheds.

The coordinated use of surface water and groundwater is another possible management tool. Groundwater reserves are less affected by drought conditions than are surface waters. It may be possible in some areas to store excess surface waters in aquifers to maintain groundwater levels and to use the groundwater supplies during drought periods. By this method, new surface source projects may be postponed, pumping costs would be saved by maintaining groundwater tables, and evaporation losses would decrease. Total costs would decrease, as the cost of developing a new groundwater supply is a tenth the cost of a corresponding new surface development. (66)

Subjects of some practical difficulty with this kind of coordination are the determination of legal rights to groundwater reserves, the need to allocate costs between the owners of surface supplies and less expensive groundwater supplies, and the necessity of excess surface water supplies available for recharge. (67) In addition, the efficacy of such coordination is not proven: groundwater and surface water in the same area tend to be interconnected, so studies would be necessary to determine if the method would actually increase a system's overall dependability.

The most interesting suggestion to integrate sources combines interlocal arrangements with source coordination. The Corps of Engineers' Northeastern U.S. Water Supply Study (NEWS) in the early 1970s suggested the possibility of integrating Long Island groundwater supplies with the New York City surface water system. During periods of surface water surplus, the City would pipe water to Nassau County to recharge groundwater supplies. In return, Long Island groundwater reserves could be used by the City during drought years. (68) Total supply would be expanded by the use of floodwaters which currently spill from reservoirs. Connection facilities would have to be constructed, and it would be necessary to complete the City's third water tunnel to provide transmission capabilities.

Current proposals do not call for such a project. The 1972 report of the Temporary State Commission on the Water Supply Needs of Southeastern New York recommended expanding upstate supplies to provide water to Nassau County through the New York City system. There was no recommendation, however, to supply Long Island groundwater to the City system during drought periods. The Legislative Commission on Water Resource Needs of Long Island recommends a comprehensive effort to interconnect neighboring water suppliers and to negotiate water sales from Suffolk to Nassau County, but excludes New York City as an option for satisfying future water needs. (69) The idea of linking City and Long Island supplies may resurface, however, if future evaluations of Nassau County's water supply suggest that broader interlocal arrangements are necessary.

Developing New Supplies

Once possibilities of minimizing water demand and improving the use of existing supplies have been exhausted, water suppliers may be forced to undertake the expensive process of developing new supplies. When urban areas exhaust their local supplies, they often turn to diversions of water from distant basins. These attempts tend to create divisive political battles between the source

areas, where such diversions are regarded as surrenders of control over a vital resource, and the importing cities.

New Reservoirs--Under present political and economic realities, the development of new surface water supplies is likely to be a last resort to balance supply and demand. Currently, the only proposal for a new reservoir in the state is that of the Spring Valley Water Company of Rockland County. (DEC is expected to reach a decision on the Spring Valley proposal in 1985. (70)) However, the next drought is certain to bring renewed calls for supply system expansions, particularly in southeastern New York.

Just as certain is that reservoir construction proposals will touch off complex debates over needs, legal rights, competing interests, and environmental impacts. Water law in the eastern states is based upon the riparian doctrine, which was passed down from English common law. Under the doctrine, owners of riparian land, or land adjacent to streams and rivers, "are entitled to water undiminished in quantity and unimpaired in quality except for reasonable use by other riparian owners." (71)

The "reasonable use" clause generates much confusion. Courts have developed a multitude of definitions depending upon the demands of water users. As a result, the right to water tends towards vagueness, and state water laws have become a patchwork of responses to specific situations. Theoretically, riparian owners have a right to undiminished streamflows, but as cities have outgrown their local water supplies, increasing amounts of water have been diverted out of the source river basins. Legal responses have been to guarantee rights of sufficient water for all reasonable uses, including instream water needs. This is hardly a clear-cut policy, especially where water quantities cannot meet all "reasonable" demands.

Where conflicts have occurred, institutions occasionally have been developed to satisfy competing claims. Two such arrangements are the Delaware and Susquehanna River Basin Commissions, which were created by federal-interstate compacts to manage the waters of their respective basins. Comprehensive basin-wide plans were developed by the commissions as compromises among competing water needs. In the Susquehanna basin, for instance, commission approval is required for projects on or crossing state lines or affecting another signatory state, diverting water out of the basin, or affecting the comprehensive plan. (72)

Former DEC Commissioner Flacke suggested that an allocation system within the state may be necessary. (73) Such a system might include:

- a statewide assessment of the availability of water;
- the assurance and allocation of water within existing constraints;
- contingency plans for water loss or drought mitigation; and
- the determination of methods to increase supply and reduce demand.

According to the National Conference of State Legislatures, the data necessary to develop such an allocation system include:

- the impacts of different use levels and diversions upon flows, safe yields, and water quality;
- minimum flow levels necessary to maintain instream requirements;
- the impacts of surface water use on groundwater quality and quantity; and
- increased information on groundwater geology and hydrology. (74)

Flood Skimming--Flood skimming is a concept growing in popularity as new reservoirs become less feasible. The idea is to skim water directly from a major river during periods of peak spring flow. This is the only active proposal to increase the yield of the New York City system. Proposals call for an average of 100 million gallons a day to be pumped from the Hudson. (75) Because pumping would occur only during high water periods, the rate of pumping would be much greater during times skimming actually occurs.

Even this seemingly harmless proposal has an environmental impact. Flood skimming can decrease water storage in freshwater marsh areas, which are vital to certain plants and wildlife. Groundwater recharge is reduced, and water quality may be affected. In its review of proposals by the Commonwealth of Massachusetts to skim flood waters from the Connecticut River, the Connecticut Department of Environmental Protection made the following comments:

> One of the primary hydrologic functions of a river or stream is recharge of its banks and flood storage areas so that in times of low flow, reversal can occur resulting in stream flow augmentation. Out-of-basin diversion through flood skimming removes runoff water which would otherwise overflow

the channel and infiltrate into the groundwater system. This overflow process also serves to improve water quality: silt, heavy metal, toxins and other water contaminants are deposited or adhere to deposits and are thereby removed from the stream. (76)

Desalination--An often mentioned and generally discarded notion is the manufacture of potable water out of seawater. Seawater contains 35,000 parts per million of salts, while drinking water standards are 500 parts per million. (77) Most desalination methods are highly energy intensive and have not received widespread acceptance in the United States. Distillation produces a high quality product, but at great energy cost; it can utilize solar energy for small scale plants. Freezing salt water to create fresh ice crystals requires less energy, but further research. Membrane methods are cheaper, but produce a lower quality product. Electrodialysis is a method which separates salt from fresh water by an electric current, but is not economical for the salt concentrations found in seawater. With all methods, a salty brine remains, presenting disposal problems.

Eventually, desalination may become feasible for part of Long Island's supply. The technology is likely to decline in price, and a new method may become feasible. The Princeton University Center for Energy and Environmental Studies has conducted experiments using snow-making machines with seawater. When frozen salt water melts, the salt melts off first, leaving drinkable fresh water at a relatively low cost. A working project exists in Saskatchewan, where brackish groundwater is rendered potable. The Greenport Village Board (Long Island) is considering a plan to produce 250,000 gallons of drinking water per day by freezing seawater in a plastic-lined pond during winter months. (78)

Desalination, then, may warrant further consideration should the state's coastal areas face further supply or quality crises in the future. Another possibility for Long Island is to partially desalinate seawater and then inject it into aquifers near the coast to form a barrier against salt water intrusion.

New York City--Most upstate cities have adequate water supplies nearby, but the New York City metropolitan area presents a unique issue. Under present conditions, the City water system is probably adequate. However, the problems of surrounding areas may result in searches for more water supplies from more distant locations.

- Pollution of the aquifer underlying the Borough of Queens may require New York City to take over the Queens County assets of the Jamaica

Water Supply Company, and the City might want additional upstate sources to serve the added population.

- Ongoing concerns regarding water quality in Nassau County may result in proposals for a New York City supply line hookup.

- Out-of-state problems may also be of concern. The U.S. Army Corps of Engineers NEWS study recommended flood water skimming in the Hudson River to benefit northern New Jersey. (79) While the state is likely to oppose any out-of-state diversions, it is possible that the federal government may eventually force the issue.

The Temporary State Commission on the Water Supply Needs of Southeastern New York in the early 1970s suggested a wide variety of possible new supplies for the City system. The suggestions included flood skimming from the Delaware and Catskill systems, Susquehanna River diversions, and diversions from Adirondack and Lake Ontario sources.

All new interbasin transfer proposals would create legal, environmental, political, and economic problems. Many Adirondack rivers are part of the state's Wild, Scenic, and Recreational Rivers System, preventing new dam construction along those reaches. Great Lakes or Lake Champlain diversion proposals require international agreement. Northern New York diversions to the southeastern part of the state are thus unlikely in the foreseeable future. Susquehanna diversions would require agreement from the Susquehanna River Basin Commission, and this may also be unlikely. (Further diversions from the Delaware Basin would violate provisions of the 1954 Supreme Court decision (347 U.S. 995) which limits basin diversions to New York City.)

Any interbasin diversion proposal must consider the complex balance of costs, water rights, needs, and environmental protection. Many values--e.g., aesthetics, in-stream environmental needs, recreational opportunities--are difficult to quantify. A major disincentive to increased diversions from upstate is the increasing local value of upstate resources. Any diversion would necessarily include some form of reimbursement to the impacted communities for the loss of a local resource.

Toward Planning?

As important as water is to the state's economy and the well-being of its citizens generally, the somewhat surprising fact is that it is far more

difficult than it might be to fully answer several fundamental questions:

- What water supply problems do we know to exist, and how serious is each relative to the others? That is, what are the kinds and probabilities of water supply-related risks that New Yorkers must assess, locality by locality?

- Which of many alternative technological and institutional approaches to the solution of water supply problems are feasible and most efficient in New York State as a whole and among its regions?

- By what criteria should entire efforts or parts of efforts to solve water supply problems be allocated to local, regional or state levels of government?

These are not unimportant questions, and although inexactitude in answering them is not totally avoidable, it can and should be minimized. The risks of:

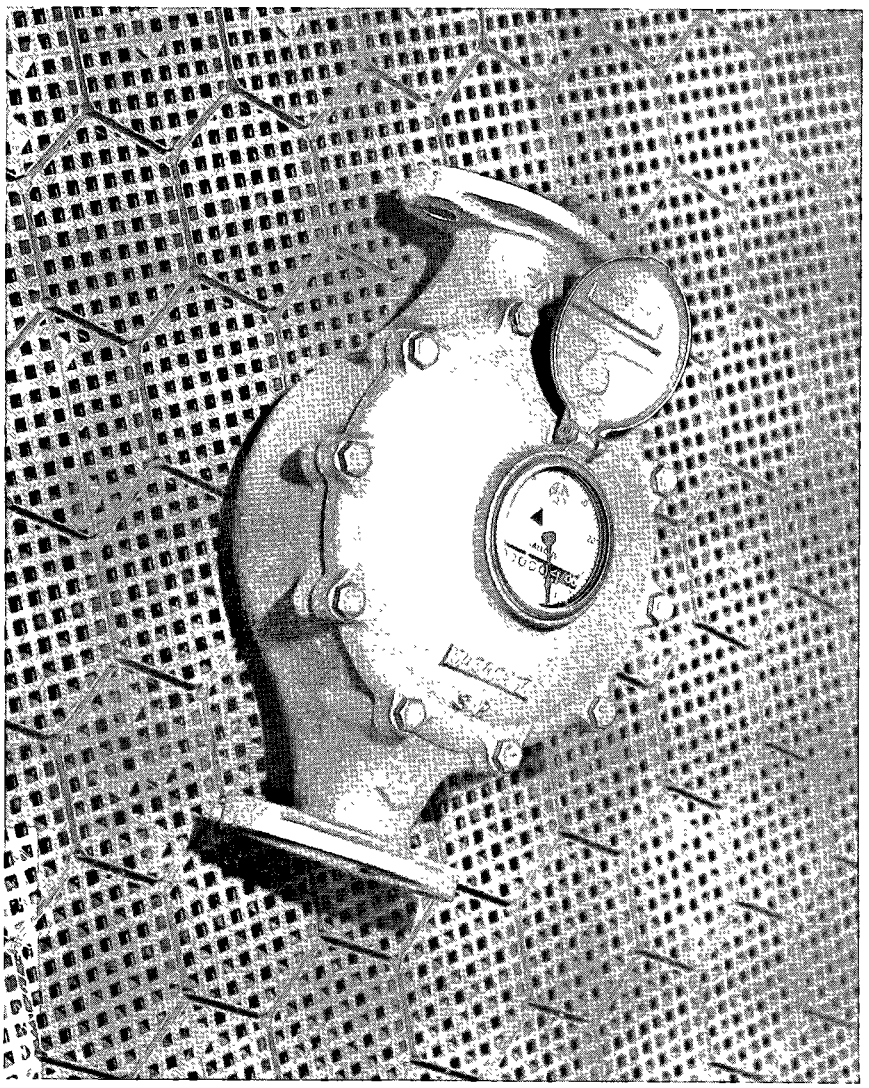
- failing to recognize which problems are more serious than others;

- investing in inappropriate solutions; and

- inefficiently allocating finite public resources

are risks that are maximized when critical public decisions are approached without the means of answering such questions. Fortunately, it does not appear that a water-related crisis is so imminent that generating the necessary means--information and analysis--would be an effort for which there is insufficient time. What, then, should be the nature of such an effort? It is this question that the last chapter, in part, addresses.

PART IV.



Conclusion

Photo: Courtesy of Washington Suburban Sanitary District

Chapter 8.
Monitoring and Strategy

The Price of Uncertainty and the Price of Information

Over-reaction, Under-reaction

Some basic contentions developed so far in this report might seem cantankerous or gloomy. It has been suggested that:

- a lack of data and, to some extent, a lack of theoretical knowledge characterize our water supply concerns;
- future water supply development will inevitably involve choices; and
- any choice will involve some risk.

It is important, at this point, to explicitly state and develop another contention which has been implicit in the study: the lack of data is considerably remediable, and the amount of risk in development decisions therefore can be reduced.

Some might ask whether or not it is worth the time, effort and expense necessary to reduce the uncertainty before engaging in significant further development or large-scale rehabilitation. The answer depends on whether or not:

- the information that can be acquired will reduce risk very considerably; and
- there is sufficient time to generate the information before having to engage in major development.

In other words, what can we know, and how soon can we know it? It is futile to expect to achieve certainty before taking actions, and it would be dilatory to suggest that we should. On the other hand, it may be foolhardy to not take the time to generate that information which would be useful and obtainable, for instance, in less than a decade.

Matters about which we lack data include some basic observations, such as:

- usage--power plant cooling requirements are huge, but not actually

measured, and many water systems (including New York City's and Buffalo's) have little or no residential metering;

- supply--the safe yields of many reservoirs are unknown;

- distribution system conditions--it seems that leakage and pressure surveys in many systems are sporadic, and system inventories are often not up-to-date; and

- quality--for some large aquifers, the number of sampling stations may be too few for obtaining very detailed pictures of the extent of pollution. And many small water systems test their water infrequently; quality problems, therefore, may persist for months before being discovered. (1)

Such deficiencies of basic observation are at least technically remediable. There is uncertainty also, however, with regard to matters of theory, such as:

- projecting demand--available methods have exhibited significant error; and

- measuring raw supply--e.g., there are no generally accepted and reliable methods of ascertaining safe yields of large aquifers.

Such uncertainties about theory are not technically remediable at this time; they represent research problems which, conceivably, will not be solved for decades. If adequate supply seemed in serious jeopardy, it probably would not be sensible to defer action in order to wait for the generation of this kind of information.

Uncertainty poses a basic problem for prescription: Without detailed knowledge of the nature and scale of specific water supply deficiencies, it is difficult to be confident that specific proposed actions are adequate in magnitude or addressed to the real causes of the deficiencies, and it is difficult also to be confident that the entity in charge of dealing with a deficiency has the capacity to do it. For instance, are pipe replacement necessities so extensive and imminent that very few localities could afford it? If so, some financial help from the state and federal governments might be warranted. If not, state and federal aid for such activity would constitute the expenditure of public resources on a problem that could have been otherwise solved and would make those public resources unavailable for solving bigger problems.

Potentials of uncertainty, then, include both over-reaction and under-reaction.

- Over-reaction would involve:

  . investment of finite public resources on development of water supply capacity that will very rarely, if ever, be needed;

  . fixing system elements that do not need fixing (and incidentally failing to fix elements that are the ultimate causes of a malady); and/or

  . unnecessary borrowing that would entail the payment of interest rates that double or triple the cost of a project.

- Under-reaction mainly would involve matters which fall through the cracks among local jurisdictions and between local and state jurisdictions. Such problems may be of an unprecedented nature, may pose staggering economy of scale problems, or require cross-local cooperation that is hard to obtain. For instance, groundwater pollution on Long Island, had the state not recognized its importance, could have been an example of a major problem which was met by under-reaction.

What is the Current Mandate?

Policymakers have not been unaware of this line of reasoning regarding uncertainty and risk. Chapter 509 of the Laws of 1984 requires not only water supply studies, but also the development of a water management strategy. More specifically, Chapter 509:

- requires creation of a Water Resources Planning Council of 15 members, including various state department commissioners, the Secretary of State and seven appointees; and

- directs the Department of Environmental Conservation (DEC) to:

  . produce, in consultation with the Department of Health, an inventory of existing significant deficiencies (including matters of supply, distribution, transmission, and hazardous materials and waste) in water supply systems by July 1, 1985;

  . review laws and identify constraints pertaining to local water finance by January 1, 1986;

  . compile, also by January 1, 1986, a list of places that cannot afford to correct their significant deficiencies; and

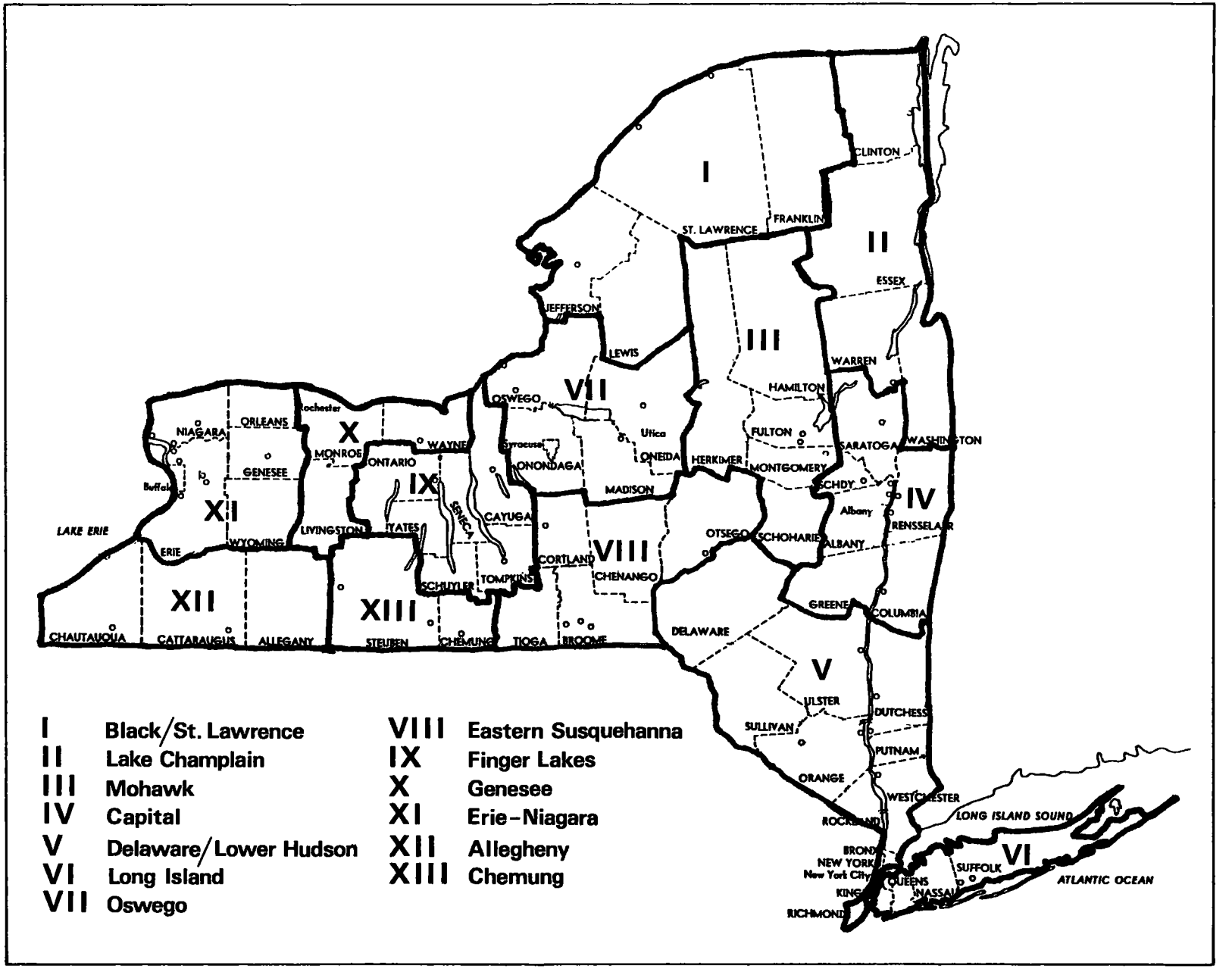
  . develop a water resources management strategy, including strategies for substate regions, by January 1, 1987.

Chapter 509 also requires a review of the water resources management strategy at least once every two years.

The tasks to be completed in 1985-86 address the question of "what is wrong?" In his memorandum upon signing the bill into law, the Governor noted

Figure 14

Water Resources Management Strategy Substate Areas



Source: NYSDEC Water Bulletin, August 1984.

that "this process will identify capital needs throughout the state." As the review in Chapter 3 indicates, such an inquiry is not unprecedented, and while most studies completed so far were attempts to produce overall capital needs estimates rather than inventories, they have demonstrated a significant lack of the basic information needed to produce either overall estimates or inventories. One result has been a considerable range of contentions--from less than $7 billion to more than $12 billion--about the statewide costs of needed water supply redevelopment.

Under this circumstance of basic data inadequacy, it is questionable that the inventory of deficiencies which DEC is to produce by July 1, 1985 can be of greater reliability than the previous studies. It appears that it is not enough to inquire about "what is wrong" or, pursuant to that inquiry, "what capital development actions should we take?" If answers are to be reliable for prescription--if they are to be useful in reducing the risks--it is necessary to first ask, "How can we better describe the situation?" and then take action to develop the means by which the necessary and obtainable data can be generated.

Studies vs. Monitoring: The Benefits Of Continuity

It is conceivable that the water resources management strategy could include the development of a feasible and more broadly useful water supply information system. But to do so, it would have to be more than an amalgamation of already completed, in-progress, or soon-to-be contracted studies of the kind reviewed in this report. Rather, strategy developers would have to address questions that may be more difficult and certainly are more elemental than have so far received attention.

(1) What do we need to know about a water supply system in order to ascertain how deteriorated or otherwise inadequate it is?

(2) If a system is in a state of advanced deterioration or otherwise grossly inadequate, what do we need to know in order to ascertain how it became so?

Identification of conditions pertains fairly simply to observation of supply, usage, quality and facilities. Explaining the derivation of conditions, however, requires subtle analysis regarding incidence and ultimate causes of such phenomena as overconsumption, deferred maintenance and pollution. Identified causes from locality to locality are likely to be highly varied, ranging, for instance, from such explanations as "inadequate leak control" to the fiscal

reasons behind a locality's inability to install a leak control program. Such matters of derivation are perhaps dauntingly complex, but it is important to explore them because effective prescription--prescription that will be efficient and avoid quick recurrence of a problem--depends on a correct understanding of the derivation of the problem.

Once those two questions about the nature of the needed information are addressed, there is a third question to be faced:

(3) What do we have to do to generate that information?

With regard particularly to distribution facilities, Chapter 4 surveyed some of the kinds of observational procedures (water accounting, leakage surveys and detection, break analyses, pressure surveys) and tools (e.g., meters, system inventories) that:

- are technically feasible and underused; and
- would yield data that was sufficiently direct to permit analysts to be confident about specifications of the locations and severity of system ailments.

Such information would facilitate thoroughly realistic explanations of at least the technical origins of deficiencies. It would explain, for instance, how many of a set of pressure problems were caused by leakage and how many by tuberculation and if there was some combined effect of leakage and tuberculation. It would not, however, specify the political, institutional, managerial, and/or fiscal reasons that prevented a locality from having the up-to-date system inventory and meters that would have facilitated more frequent and more efficient leakage surveys over the last five years. As an aid to prescription, therefore, such information would be highly useful; it would enable better ascertainment of the size of the repair and rehabilitation efforts needed and it would assure that the technical causes of physical problems are the items being addressed by repair and rehabilitation efforts. Specifying more ultimate causes of problems, however, would require some judgment regarding local capabilities and will.

Perhaps the most basic and most important thing to say about a proposal to develop a more detailed data set is that it could give water system operators and policymakers a greater capacity to monitor. Monitoring--continuity of observation--would be in contrast to the too-common situation in which suspicions of serious problems result in sporadic and quick (though not necessarily inexpen-

sive) studies that, as Chapter 3 noted, even the authors acknowledge as unreliable. Most often, a sound system of monitoring would render the observations for which analysts are asking when they recommend further study.

The idea of monitoring, however, means not only that operators and policymakers will have more adequate information at the time they decide that something needs to be done; it also means that the perhaps subtle signals of deterioration, generally or in particular systems, will be recorded and that problems, therefore, will not grow to points of crisis or seeming-crisis before they are at least perceived.

When is Information Worth the Cost of Obtaining It?

It seems reasonable to expect that developing an information capacity of the kind that would correct the deficiencies in the current data would be a large, complicated and even expensive task. Some cities have initiated computer assisted efforts that incorporate the kinds of activities and level of informational detail reviewed in Chapter 3, (2) but such an effort on a larger geographic scale probably is unprecedented. We can be confident that:

- although it is clear that much information that is obtainable could greatly reduce the risks inherent in development decisions, certainty (especially with regard to the supply-demand equation and, perhaps, with regard to the extent of groundwater pollution) is highly unlikely; and

- the cost of better information will, at least in the beginning, be much higher than the cost of the information we currently generate.

Would the savings facilitated by a detailed and extensive information/monitoring effort be worth the money and time it would take to develop it? It is difficult to say in a way that uses dollar figures. It is worthwhile to repeat here an earlier-used quote from an article by an engineering consultant:

> The cost of replacing a mile of water main is $200,000-$500,000 in 1980 dollars....Replacement decisions should be based on the physical condition of mains, not on their age. A geographically oriented information system will cost $50-$150 per mile to develop and $10-$20 per mile per year to update with routine records. The monetary gain from improved main replacement decisions is several orders of magnitude greater than the cost of the information system. (3)

That is one consultant's conclusion regarding a locally developed and operated information system for improving pipe replacement decisions. He has managed to attach actual dollar figures to his contention that such an information system would be worth the investment. The ways in which savings would occur can be stated less abstractly (there has been allusion to them at various points throughout this report). With regard to distribution systems:

- Adequate information could ensure that the items to be repaired or replaced are the items which have caused the water supply problems; recurrence of the problems would be minimized.

- Spot repairs facilitated by more detailed information would cost less than wholesale excavation and replacement. This would reduce the amount of money that a supplier would have to spend in order to improve or maintain the infrastructure. And the smaller was a job of rehabilitation, the less would be the amount necessary to borrow and the less, therefore, would be interest payments. Precise knowledge of the nature of necessary rehabilitation might even permit a locality to schedule much work in a regular manner through a capital budget that avoids borrowing.

- The procedures (reviewed in Chapter 4) to obtain diagnostic information on hardware as it exists, once the capacity to regularly use them was established, could be used on both current and new hardware so that working life would be lengthened.

Would such savings justify the expense of improved monitoring? Certainly some observers doubt it, if the persistence with which some localities avoid installation of meters is any indication. To the consideration of savings vs. repair/replacement costs, however, it is necessary to add another consideration: the value of water itself.

The cost of producing water probably is not often apparent in the rates charged for it; subsidization of water rates, at least through deferral of maintenance, is common, and water is generally regarded as plentiful. Developments may change this situation.

- If the necessity of austerity in government budgets continues, there will be a decline in governments' capability to subsidize rates at the same level (or perhaps at all). This would be true even if the cost of producing water was not rising, generally with other government and utility operations and specifically as a result of safe drinking water standards.

- Groundwater pollution could conceivably make supplies scarce in certain localities, regardless of whether or not that scarcity resulted in higher rates.

The more expensive it is to produce water, presumably, the more incentive there will be to not waste it. And increased control of the loss of usable water through breaks and leaks, as well as through pollution, will require some form of improved monitoring.

In judging the advisability of the development of a broadened monitoring capacity, then, it is necessary to consider not only a strict comparison of the cost of monitoring and the repair/replacement savings, but also whether or not trends in the cost and actual availability of water, in and of themselves, warrant the kind of care that a monitoring capacity represents.

A Basic Problem of Strategizing: Matching Responsibilities and Capacities

We wish to be clear: We do not know the answers to the foregoing questions, nor are we prone toward one or another resolution. The potential risks of over-reaction and under-reaction, just reviewed, are serious. On the other hand, the cost of developing a detailed monitoring capacity would be high, probably so high that many systems could not afford it without greatly increased water rates or other revenue sources. We recognize, however, that if the effort to create a water resources management strategy is to be very useful, it will not be possible for its designers to ignore:

- the information deficiencies that have so far made studies unreliable, especially for prescriptive purposes; and
- the conditions--matters relating to local capabilities and will and to how much the state should mandate or do itself--that make it difficult to change those information deficiencies.

The matter of monitoring capacity is just one of several aspects of "the water supply problem"; a useful strategy would indicate how to allocate the resources of local and state governments among those aspects. Stated another way, there should be an attempt to specify usable criteria, at least for purposes of discussion, by which any water supply problem could be designated as routine--to be handled by the water supplier--or as warranting extraordinary attention by the state or some other entity that does not have primary responsibility for supplying water.

What, in general, would such criteria be? What characteristics of a particular water supply problem would require that the state or some other interlocal or supralocal entity play the major active role in its solution? Several sometimes interrelated possibilities come to mind. Such a problem could involve:

- economy of scale considerations, where most localities did not have the resources to deal individually with the problem they had in common without, for instance, raising water rates to unacceptable levels;

- cross-local considerations, where the problem affecting a locality derived from occurrences or practices in another locality;

- unprecedented nature, where the problem was one that had not been encountered before and therefore required, at least in the early stages of its solution, the greater research capabilities of the state government; and/or

- large stakes, where the possible effects of not resolving the problem might reasonably be expected to be calamitous.

By most of these criteria, deterioration of distribution facilities, for instance, would be regarded as routine. It is certainly not of an unprecedented nature; techniques of diagnosis and repair are well established. Distribution hardware, in contrast to raw water supply, is unlikely to be affected by the practices of neighboring localities. And the occasional disruption of service and the property damage that result from main breaks are minor in comparison with the awful possibilities of pollution of entire aquifers on which millions depend.

Economy of scale considerations, however, might be limitedly pertinent: There are about 1,800 suppliers, and the small ones have far less opportunity to generate revenue than do others. This means that small systems might, in order to maintain their systems in the coming decades, have to raise rates far higher than would other systems, perhaps to a point that would be regarded as unreasonable.

It would not be sufficient, however, to simply specify some ratio of distribution system deterioration to system size, i.e., to say, in effect, that "systems with 'x' amount of service disruption and with no more than 'y' amount of population qualify for aid." Rather, fairness would require strategizers to consider the question of what constitutes a reasonable local effort: What level of water rate monies or other revenues generated by a local water system implies

that the users and operators are doing that which is feasible to keep their system in good working order and yet are unable to keep up with costs? One small locality may have a sound set of hardware because it has spent more than has another identically sized locality which is having disruptions. The former locality may have always had higher water rates or higher taxes through which it has steadily funded critical hardware replacements and hired expert management.

Should a locality qualify for assistance, there would also be a reasonable question regarding the most efficient form of assistance. Possible alternatives range from outright grants, to loans, to aid in obtaining loans, to technical advice. But whatever the form of outside assistance, there frequently would be the potential of this criticism: "Why should the taxpayers in one town, who may be paying water rates calculated to pay all expenses, subsidize a federal or state grant to improve the water system of a neigboring town?" (4) (Appendix 4 contains more extended comments on problems and existing efforts regarding adequacy of local water revenues and cross-local (i.e., "regional") considerations.)

This suggests how complicated the development of the water resources management strategy (if not the actual document itself) must be if it is to be useful. It seems reasonable to expect that there are indeed problems of water supply, now and yet to occur, that will warrant large-scale action that the state sponsors, coordinates or fosters, and that there are other problems which the suppliers can handle themselves.

Time To Care

DEC's Mandate and Regard for the Long Run

DEC's mandate prior to completion of a draft water resources management strategy includes studies of conditions and financial capacities. A series of studies can be useful, perhaps by incrementally improving the exactitude with which we define a problem. When examining DEC's study findings, however, it will be important to bear in mind that the lack of basic data that has been a problem in previous studies is not likely to be ameliorated in 1985 or 1986.

What may be more important for the Senate and other interested observers to attend to, then, is whether or not the draft strategy, to be completed in 1987, either:

- presents a way of correcting, as much as is feasible, the deficiency

in information which so far has characterized consideration of water supply development and redevelopment; or

- demonstrates why it is unfeasible or not worthwhile to correct this deficiency.

The draft strategy could include specifications regarding a broad variety of matters such as land use and pollution, supply and demand, and deterioration and maintenance. It does appear, however, that without developing a means of more detailed monitoring of water supply-related phenomena:

- definitions of problems and specifications of their relative magnitudes, at least until matters approach great seriousness, will continue to be unreliable; and

- the allocation of public capacity toward the solution of the problems will continue to run a higher-than-necessary risk of being inefficient.

Strategists, however, must encounter the problem of allocating capacity even before defining and measuring specific real problems. Detailed monitoring of the kind suggested by Chapter 4 probably represents a greater effort than many systems can make with current levels of revenue. In proposing a monitoring system, then, strategists would (implicitly, at least) have to make judgments (i.e., develop and apply criteria) about the scale of current efforts and about whether, on one hand, revenue supplementation for such an effort could be derived reasonably from local sources or, on the other hand, state monies would be necessary.

More Monitoring: Is It Acceptable? Is It Feasible? Is It Dispensable?

The vision of a large, integrated information system is, per se, one to which many people object, regardless of its function or how the information is collected. At very least, such a proposal, probably involving local monitoring and reporting to regional or state agencies, carries with it the threat of another mandate to which localities will object unless there is commensurate fiscal assistance. It is not clear, however, that more extensive reporting would constitute a qualitative difference from current procedures whereby local water suppliers, directly or indirectly, do report to public health officials and

other agencies. Whether or not such reporting would be odious might best be considered in the course of the hearings which DEC will hold during the development of the strategy.

It may seem inappropriate for the state to be concerned with such details as leakage, break incidence and low pressure in individual systems. Such matters have in the past received scant attention from the state as it concentrated on matters--chiefly water quality--that can more obviously and directly threaten human well-being. Recent proposals that the state specifically and actively help to fund massive water infrastructure redevelopment, however, make those distribution system details more pertinent to state considerations: It is the absence of reliable data on those matters that has defeated efforts to assess the amount of deterioration and to credibly project, thereby, how much money is necessary and whether or not the state's assistance is needed.

With regard to monitoring of distribution systems, it is important to note that some methods of obtaining data (as reviewed in Chapter 4) are well enough established and regarded that they could be considered to be part of (rather than prerequisites for) state-of-the-art maintenance. More sophisticated water supply monitoring, then, would improve not only the state's attempts to ascertain the magnitude and nature of water system redevelopment needs statewide, but also the efforts of local water system operators. In the act of generating data, the operators would be engaging in routines that would facilitate improvements in maintenance, service and the working life of hardware, regardless of the state's involvement.

Designers of the state's water resources management strategy, therefore, might well consider whether or not the state should provide an incentive to ensure that local suppliers regularly employ these routines, even if the local suppliers do not report the results to the state. (5)

A Minimal Recommendation

The chief recommendation deriving from this inquiry is that the designers of the water resources management strategy give early, prolonged and vigorous attention to the feasibility, utility and specific design of a water supply monitoring and information system that would include the kinds of data explored in Chapter 4 and elsewhere in this report. Whether or not it would be possible to

collect and use data of such detail as implied in Chapter 4, it probably is reasonable to:

- try to obtain far more information than has been brought to bear in past assessments of redevelopment needs; and
- expect that such an increment of information would make future assessments considerably more reliable.

Recommendations for specific redevelopment actions would be no more reliably based as a result of this report than they have been as the results of previous research. Current efforts to develop information specifically on local financial capacities and water use could enable policymakers to address those matters more confidently, and it seems likely that findings will seem mixed to most observers. For instance, the following points might simultaneously be true:

- Water losses through breaks and leaks, and the potential for further damage, make it advisable to accelerate efforts to rehabilitate distribution system hardware.
- This acceleration need not occur at a breakneck pace: Five or ten years is not a major amount of time in the total life of system hardware, and it is possible in that amount of time to develop much information that would make large-scale rehabilitation efforts far more efficient than they could be now.
- Local governments have the resources to achieve such an acceleration, but for some of them, it would involve a painful decision to raise and dedicate water rates or otherwise generate revenues for the effort.
- Certain problems of water supply are huge and unprecedented and may require quick, continuing and great state involvement. Long Island's groundwater problem is the best example.
- Conservation conducted in fairly painless ways has the potential for great dividends. Specifically, potential savings through conservation methods such as those surveyed in Chapter 7 could help the state and its localities to avoid the necessity of large-scale, expensive and probably acrimonious projects such as construction of dams and conveyance of water from far rural areas to urban users.

Such a set of findings is a reasonable expectation, and it probably already has proponents and opponents. Their debate, however, is based far more on assumptions and far less on reliable data than is fitting for such a critical subject as water supply.

A New Appreciation

The minimal nature of this inquiry's recommendation is not meant to suggest that the draft strategy must be limited to the matter of monitoring. It is possible to explore important ideas even while awaiting more complete information. The designers of the strategy may wish to attend to specific policy considerations such as:

- whether or not rates and other water-generated revenue should be adequate for all system investment needs;
- the applicability of reserve budgeting ideas to water supply redevelopment and to water supply operations generally;
- the cost-effectiveness of complete user and flow metering and ways by which localities without such metering might be induced to install it;
- regional arrangements for emergency or routine supply needs; and
- any jurisdictional overlap or gaps that may exist among the state agencies concerned with local water supply.

Publicity surrounding several water supply-related matters--pollution on Long Island, the City's third water tunnel, multi-billion dollar estimates of distribution system redevelopment needs, recent fears of a drought--has, whether or not all of these matters represent real jeopardy, been alarming. This has sensitized us to the real value of water and the probability that we should not--perhaps cannot--any longer take water for granted to the extent we have historically. Greater care for this indispensable resource now is not only advisable, but probably necessary. A water resources management strategy will manifest our recognition of this necessity.

A short-term view is likely to result in feelings that broader water supply-related monitoring would require an unrealistic enormity of effort. It probably would not be possible to develop such a monitoring capacity by 1988, when the strategy is to become effective. But the strategy will be subject to biennial review, and the planning and implementation of an informational component could be incrementally incorporated into the strategy. Monitoring implies <u>continuity</u> in our concern, and continuity of effort would be necessary even to make broader monitoring possible.

Strategy designers should actively, explicitly and publicly consider whether or not such a monitoring capacity would be worthwhile. The answer will depend on predominant views of the economic and other values of water. Whatever the outcome of this consideration, however, a basic proposition should be recognized at the outset: If the proper time is taken and effort is made to develop the water resources management strategy from its most basic element--information--then perhaps New York State can create a continuing capability to recognize, predict and prepare for its people's water needs rather than spend its resources and efforts simply developing physical and too-temporary solutions to today's particular problems.

Appendices and Notes

Appendix 1. The Government Roles

The Suppliers: The Local Entities

Towns and Counties

New York's 62 counties and 932 towns originally served essentially as local agents of the state and rendered services under a relatively severe constraint: they could provide services only through single-purpose districts with separate elected commissioners. The growth of demand for local services outside the boundaries of cities and villages, however, brought changes in town powers. Since 1932, special town districts, including water districts, can be created under the jurisdiction of a town board. The establishment of a new district may be initiated by town board resolution or by petition subject to town board approval. Both methods are subject to a permissive referendum. Districts are funded through property taxes within district boundaries. By 1979, 6,550 districts (an average of about seven per town) existed in the state and provided such services as lighting, water, sewerage, drainage, parks, parking, and refuse collection. (1)

While many town water districts remain, all towns now may provide water service on a townwide basis (outside of villages). Existing water districts may be dissolved by town board resolution or public petition, both subject to local referendum. Water systems are then operated as a direct town function. (2)

Counties were given the authority to create special single-purpose water, sewer and drainage districts in the 1950s as expanding population clusters grew beyond town boundaries. Districts may be established by a county board of supervisors subject to a referendum. They may consist of two or more noncontiguous areas and (except for Suffolk County) may not consist wholly of territory within one city, village, or town outside a village. Different zones of assessment may be established within districts to reflect different service levels. A county district is under the jurisdiction of the county legislature, and the county backs all district bonding obligations. Only Westchester and Niagara Counties have established county water districts.

In 1959, counties were given greater authority and discretion. Charter

counties may be created with executive forms of government and increased professional capabilities. County charters may be adopted according to Article 4, Part 1 of the Municipal Home Rule Law. Such charters specifically assign executive or administrative functions, powers and duties to elective or appointive officers and may, subject to referendum, transfer functions or duties of the county or of a city, town, village or district within the county to county agencies or offices. For example, water supply services in charter counties may be provided by a countywide public works department. Only in Westchester County has any water service been provided by the county without a special district or independent authority. The Westchester County Joint Water Board operates a water treatment plant which then sells water to participating municipalities. (3)

Cities and Villages

The state's 62 cities and 556 villages were formed by local petition and operate under a relatively broad grant of power to provide local services and to raise money for that purpose. Cities exist independently of towns. Villages, on the other hand, while formed to provide those services which towns formerly did not provide, are subject to some town board jurisdiction. Water supply was the service for which villages most commonly were formed.

Cities and villages operate their water systems as departments of local government. City systems may be managed through a city public works department, a separate water department, or directly through the city legislative body. The village board of trustees may create a board of water commissioners to manage the local water system.

As town functions have grown, village incorporations have decreased. Few villages have been incorporated since 1940, and six have been dissolved since 1970. (4)

Independent Authorities

Fragmentation of the water supply function among different kinds of localities in an area has sometimes been thought to be inefficient; independent water authorities are one response to such fragmentation.

Authorities are corporate instrumentalities of the state, each created by special legislation for the purpose of establishing and managing public improvements. Authorities are not subject to the Local Finance Law's constraints

on the use of debt, and state and local governments are not liable for authorities' debts. Authorities can overcome local boundaries that typically constrain the development of more expansive systems, and they are financially independent of general purpose governments. Nevertheless, they have the tax-exempt status of a public corporation. (Specific operating conditions depend considerably on the provisions of the enabling acts.) Authority commissioners are generally appointed by the county supervisors.

With the exception of Suffolk County, the state's water authorities were established to provide service to suburban areas surrounding central cities. New York State has had five water authorities, one of which (the Great Neck Water Authority) was never activated. The four active water authorities, which operate in Erie, Monroe, Onondaga and Suffolk Counties, have been the only water suppliers in New York State entitled to issue revenue bonds. (Legislation signed in 1984 (Chapter 510) provides a general statute for the creation of local water authorities with revenue-bonding powers. Another 1984 act (Chapter 513) established a New York City Municipal Water Finance Authority with the power to issue revenue bonds, but provided that management of facilities would remain with the City water agency.)

Private Water Companies

Most private water companies are small, established to serve new housing or commercial developments. Five or six large ones exist in southeastern New York. A private company operates under authority of the Transportation Corporations Law and must secure the consent of each municipality in which it proposes to operate. The law provides that companies must supply "pure and wholesome water at reasonable rates." The Public Service Commission has supervisory authority over all private water corporations.

The State Role

While local entities have primary responsibility for building and managing water supply systems, the state and federal government do have some involvement. The federal role has been particularly limited. The state role, however, is important, especially with regard to safety.

The Agencies

Several state agencies have responsibilities pertaining to New York's water supplies. The waters of New York State are legal properties of the state held in trust for the benefit of the people. (5) The Water Resource Law of 1960 notes that it is the state's "sovereign duty to conserve and control its water resources for the benefit of all inhabitants of the state." (6)

The Bureau of Public Water Supply Protection in the Department of Health is the predominant state agency concerned with local water systems. The Bureau is responsible for assuring that public water is safe to drink, and to that end, it has developed protective water supply rules and regulations. In 33 counties, health services are carried out by full-time county health agencies. In the remaining counties outside of New York City, district offices of the State Department of Health provide services.

The Bureau occasionally undertakes or commissions studies of the status and needs of the state's water systems, and it maintains and regularly updates computer files containing various data collected from the state's 1,800 community water systems. Data on sources of water, treatments utilized, violation of quality standards, populations served, number of service connections, gallons delivered, emergency interconnections and supplies, and system yields are all maintained in the Bureau's computers. There are limits to the reliability and completeness of the Bureau's data set. For instance, many suppliers do not know the capacities and safe yields of their systems. (7) And the data describe only public water systems; self-supplied users, such as large industries or private well users, do not provide data. It is estimated that electric power plants alone account for over three-quarters of the state's water use, but actual measurements are nowhere to be found. (8)

Between 1964 and 1974, the Health Department undertook a comprehensive water supply study for the state, as authorized by 1963 legislation. (9) Studies of each county were completed to serve as county master plans and as guides for state and federal agencies. The studies were wide-ranging, covering such matters as service economies, changing local conditions, and inter-municipal cooperation. Recommendations were made for each county to increase total system efficiencies. A former Bureau director wrote that the pace of implementation of the study recommendations was not encouraging. (10) More recently, the Bureau conducted a facilities needs survey of community public water systems. (This survey is reviewed in Chapter 3.)

The Department of Environmental Conservation (DEC) has a broader responsibility regarding the state's water resources. DEC issues permits for new reservoirs and for other plans for additional water supplies by public water systems. The Department also registers most water supply wells on Long Island. Other DEC activities include the regulation of certain reservoir releases and protection of sole source aquifers through the prohibition of certain activities in aquifer recharge areas. DEC may allocate water resources between competing interests, both public and private, for municipal supply, irrigation, small watershed protection districts, and regional multi-purpose water projects.

During 1984, DEC generated a water resources strategy for the six-county Capital region in cooperation with the Department of Health. (11) The study is structured as a pilot regional water resource management strategy to encourage full protection and utilization of water resources while providing information for public financial investments. The intention has been to extend the study procedure to thirteen substate planning regions, and the state appropriated $800,000 to complete the process as part of the development of the statewide water resources management strategy. Completion of this work could provide an update of the Health Department's county water supply studies. The pilot study identified, for the six counties, $163 million in total needs, broken into distribution, transmission, treatment, storage, and source development components.

Another state agency concerned with water supply is the Environmental Facilities Corporation (EFC). The EFC was created by Chapter 744 of the Laws of 1970, which reconstituted and continued the former Pure Waters Authority. The EFC is empowered to borrow money to lend to municipalities, state agencies or private corporations for construction of water management facilities. It may offer technical assistance to state agencies, municipalities, or private water companies, a purpose for which it reportedly has been underutilized. (12)

The Public Service Commission (PSC) has regulatory responsibility over all private waterworks corporations. It receives annual reports in great detail for systems with over $250,000 in assets, and in lesser detail for systems with less than that amount. The PSC may determine and prescribe just and reasonable rates, charges, and classifications, and set standards for property, equipment, and appliances. The PSC maintains a water division staff of 35 to monitor 450 water companies which serve 1.7 million residents.

In some parts of the state, river regulating districts exist as munici-

pal corporations under state law to construct, maintain and operate reservoirs for the purpose of regulating streamflow "when required by the public welfare, including public health and safety." (13) The Department of Environmental Conservation establishes a district after public hearings and upon petition of persons or localities with land within proposed district boundaries. Members of district boards serve five-year terms upon appointment by the Governor, and district costs are met through local assessments on benefitted properties. District concerns generally include navigation, flood control and power generation. Other pertinent state agencies include:

- the Department of Transportation, which operates and maintains the Barge Canal system (including regulating reservoirs and feeding channels);
- the Office of Disaster Preparedness, which may respond to water supply emergencies;
- the Department of Agriculture and Markets, which oversees agricultural practices (including the use of pesticides) which may impact water supplies; and
- the Department of Audit and Control, which has some authority over local government finances. In addition, permission of the State Comptroller is required for the creation or expansion of town water supply, water storage and distribution, or improvement districts. (14)

Also, the Legislature in 1980 established a Commission on Water Resource Needs of Long Island, and this Commission has issued several reports describing Long Island's water problems and suggesting solutions.

Several interstate agencies also have an interest in New York water resources.

- The International Joint Commission is a United States-Canada entity concerned with the management of the Great Lakes.
- The New England Interstate Water Pollution Control Commission trains personnel employed at water pollution control facilities and serves as a forum for water quality concerns in the river basins which cross the New York border with the New England states.
- The Great Lakes Basin Commission is an interstate compact agency primarily concerned with navigation issues on the lakes.
- The Ohio River Basin Commission is concerned with water quality in

tributaries of the Ohio River, including the Allegheny River in western New York.

- Two federal-interstate compact commissions--the Delaware and Susquehanna River Basin Commissions--have wide-ranging planning and regulatory jurisdictions over their respective basins.

An Expanded Role, and Some Changes in Local Powers

In 1984, the Legislature passed and the Governor signed several bills pertaining to the state's water systems.

- Chapter 509 calls for the enactment of a statewide water resources management strategy.

- Chapter 510 provides for the establishment of local water finance authorities upon their creation by legislative action.

- Chapter 513 creates a New York City Municipal Water Finance Authority to assist with revenue bond financing of the City's water and sewer facility needs.

- Chapter 622 authorizes towns to create water quality treatment districts to protect private well water by providing treatment devices and water testing and by implementing measures to reduce water contamination and protect future water sources.

Also, Chapter 512 authorizes the Environmental Facilities Corporation to finance and construct dams and reservoirs in addition to other water supply components. Following is a more detailed review of Chapters 509, 510, and 513.

Chapter 509--A statewide water resources management strategy should be implemented by 1988, according to a new Title 29 of the Environmental Conservation Law. The strategy is subject to approval by a 15-member Water Resources Planning Council which will operate within DEC. Two steps are to precede the submission of the statewide strategy.

- By July of 1985, DEC is to complete a statewide inventory of significant deficiencies in water supply availability, system component improvement or rehabilitation needs, and threats to water systems by hazardous wastes.

- By January of 1986, the Department must complete a review of statutory and constitutional provisions regarding the financing of water supply systems, including a report on cases in which the remediation of difficulties is beyond local financial capacities.

The Statewide Water Resources Management Strategy must be prepared by DEC and submitted to the Water Resources Planning Council by January of 1987. The strategy is to be composed of "substate...strategies which recognize the natural boundaries of the water resource basins, watersheds, and aquifers...." Matters to be addressed include supply deficiencies; recommended practical water supply organizations and regional management strategies; future demographic, economic, natural resource, water quality and conservation requirements of the state's water systems; and recommendations for modification and implementation of strategies by state and local agencies and districts. The Council may then approve, modify, or disapprove the strategy. A disapproved strategy must be revised and resubmitted. Once the strategy is approved, it is to be adopted by pertinent state agencies (including the Departments of Health and Environmental Conservation) and reviewed and amended or updated at least once every two years.

Chapter 510--The New York State Water and Sewer Authority Act is a generic statute which allows municipalities or groups of municipalities to operate local water and sewer authorities upon establishment by legislative action. Chapter 510 creates a means by which revenue bonding may be used for water and sewer financing at the request of concerned municipalities. (The State Constitution forbids general purpose local governments or special districts to use revenue bonds.)

The public benefit corporations would be empowered to incur indebtedness and charge for services. The statute provides the basic framework for the organization and operation of such authorities. Sponsoring municipalities may request special enacting legislation similar to that by which industrial development agencies or public housing authorities are created. Members of authority boards would be appointed by the municipal governing body, or, in cases of authorities serving two or more municipalities, by inter-municipal agreement. Once established, such authorities may enter into contracts or agreements, negotiate with government officials, borrow money, purchase and sell water, and establish and collect fees. Bonds may be general obligation, secured by the faith and credit of the authority, or special obligation, payable out of particular revenues.

Chapter 513--The New York City Municipal Water Finance Authority is a means for the City to finance water and sewer system improvements with revenue bonds backed solely by user fees. The Authority, which is a finance agency only, would enter into a financing agreement with a newly established New York City

Water Board (as enabled by Chapter 515). The Board would set and collect water and/or sewage fees in amounts sufficient to pay debt service on the Authority bonds and meet operation and maintenance costs. The Board would be established subject to a special act of the Legislature at the request of the City and may assume title to the City's water or sewer system. The City, the Water Board, and the Authority may then enter into agreements for the financing and operation of City water and/or sewer facilities.

The Federal Role

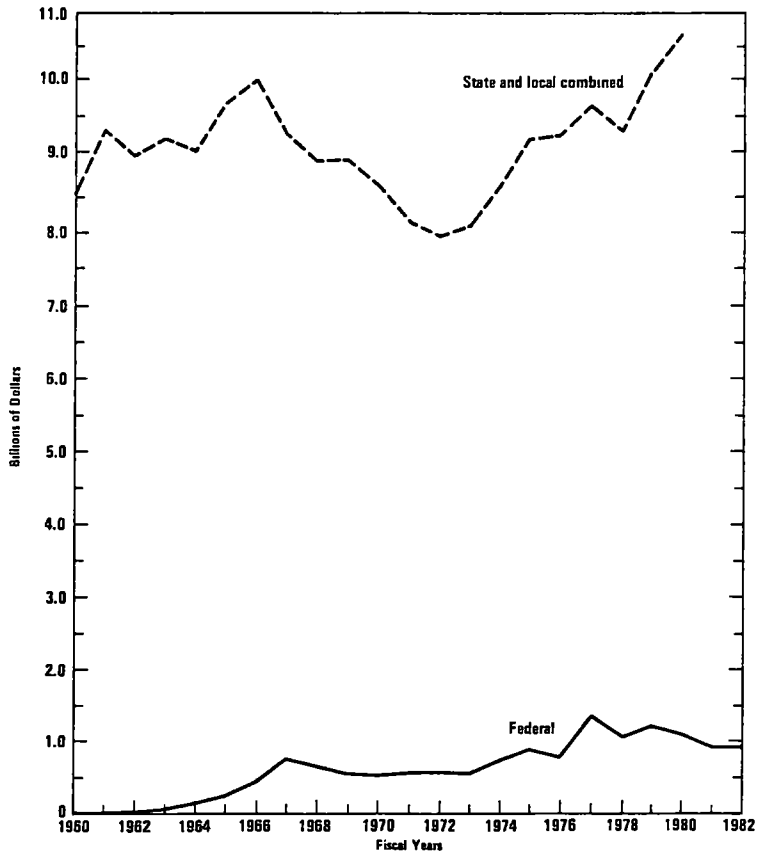
The federal government plays a minor role in the provision of New York's water supply. The nationwide federal expenditure for municipal water supply was estimated at $900 million in 1982, compared to the combined state and local expenditure that year of $11.6 billion. (15) In recent years, the federal expenditure has been falling, while state and local expenditures have increased (see figure 15). The major federal program pertinent to New York is the Farmers Home Administration grant and loan program for communities of under 10,000 population. (16) While federal water supply expenditures are made for municipal water supply storage at the multi-purpose reservoirs of the Army Corps of Engineers and the federal Bureau of Reclamation, no such projects exist in New York. A small portion of General Revenue Sharing, HUD and Economic Development Administration funds are spent on municipal water supply.

There have been attempts in Congress to increase the federal role in municipal water supply. Congress has not passed a bill authorizing large-scale water projects since 1976. In 1984, the House of Representatives passed an $18 billion omnibus water resources authorization bill which would have included a loan program of $800 million annually for municipal water systems and which would have increased user fees for water project beneficiaries. The Senate passed a smaller bill. Negotiators failed to reach a compromise over cost sharing provisions and the bill subsequently failed. The Congressional Quarterly suggested that the bill failed due to its large size, late timing, and lack of consensus on cost sharing. The journal concluded that "their size, a result of their something-for-everyone approach, was supposed to make them invulnerable. But...they were too unwieldy to maneuver...." (17)

A larger federal role exists in the areas of water pollution control

Figure 15

Federal and Nonfederal Spending on Municipal Water Supply, 1960-1982



Data Source: Congressional Budget Office from U.S. Census information. Graph reprinted from CBO study, "Public Works Infrastructure: Policy Considerations for the 1980s," p. 128.

and drinking water quality. The 1972 Federal Water Pollution Control Act and its amendments establish criteria for nationwide water quality standards and enforcement, effluent permit systems, sewage treatment plant grants, and planning and management activities. (18) The Safe Drinking Water Act of 1974 explicitly addresses the subject of drinking water. (19) The Act sets maximum acceptable contamination levels for public water systems and offers grants to state agencies to help meet the standards. In most states, the state and the water suppliers maintain primary responsibility for ensuring that water supplies meet the quality standards.

Under the Safe Drinking Water Act's Sole Source Aquifer program, the federal Environmental Protection Agency may designate certain aquifers which serve as a community's only available drinking water supply. Any party may petition EPA to include a particular aquifer in the program. All federal activities which may adversely affect the quality of a designated aquifer must be reviewed by EPA, which can deny discretionary federal funds for projects with negative impacts.

The Long Island aquifer system was long the state's only aquifer to be designated as a sole source. Under the program, the Long Island Regional Planning Board reviews projects in accordance with a memorandum of understanding with EPA. The board attempts to resolve problems with projects. When resolution is not obtained, the board conveys its concerns to EPA, which then performs a

full-scale study. Several projects have undergone changes or have been blocked. (20)

Attempts to add the Schenectady County and Binghamton area aquifers to the program were pending with the Environmental Protection Agency for two years. (21) Early in 1985, both aquifers were formally added to the program by EPA. (22)

Appendix 2.
Some Problems of System Smallness

Particular Difficulties

Raising Money

For small systems, paying for improvements can be particularly difficult because capital construction costs represent a much larger portion of system finances and local budgets than for larger systems. This is true not only because of the ratio of hardware costs to the revenue base, but also because of differences in financial/administrative efficiencies. For instance, small bond issues carry a higher proportion of transaction costs due to the set costs of legal fees, underwriting expenses and printing. These costs may effectively exclude small bond issues from the market. (1) Recent cutbacks in traditional external funding sources, such as the federal Farmers Home Administration, have increased the burden on local system revenue. (2)

Capital expenditures usually are initiated by citizen requests, subject to approval by local legislative bodies. Formal capital programs usually are nonexistent. A Cornell researcher found that the bottleneck in efficient management of small systems was often the town or village board's reluctance to spend money for maintenance. (3)

Quality Problems

Many rural water systems operate in areas of heavy tourist traffic. Such systems are often forced to meet high seasonal demand peaks which strain their resources. In addition to personnel and financial limitations deriving from their small size, these systems may exhibit unusual water quality problems. Sources for some are lakes which are surrounded by summer cottages with septic systems. Although the temporary residents perceive a pristine natural environment, septic systems may be creating a bacteria problem in their drinking water.

The small supply systems frequently do not adequately treat water taken from such surface sources. Two-thirds of the public systems and over one-half of the private ones surveyed by the Cornell group failed to meet federal coliform bacteria standards at some time over a six-year period. During one sample year

(1982), 10 percent of publicly owned systems and 16 percent of the private ones failed to meet the bacteria standards. (4)

Many of the surveyed small systems failed to test their water at required intervals. About half of the publicly owned plants and at least a third of the private ones failed to test for inorganic chemicals (a $500 procedure) at the state-required interval. And while publicly owned systems were found to meet coliform testing requirements, privately owned systems performed only 72 percent of their required tests. (5) Infrequency in testing means that unsafe water may be delivered for long periods of time before it is discovered. The Cornell group contended that although the State Department of Health has moved to fill the monitoring gap, it concentrates upon larger systems.

Specialists and Equipment

Small water systems are hampered by a lack of professional expertise. The Cornell study found that 15 percent of the Adirondack region's municipal water system operators, and 55 percent of the private operators, lacked certification by the State Department of Health. (6)

The private systems, many of which were formed as parts of housing cooperatives or to encourage local land sales, often lack professional staffs. Of those surveyed, 35 percent had no designated operator. (7) Interviews with both public and private system operators indicated that a knowledge gap exists with regard to system design capacities and degrees of stress within systems. Although most operators rated their systems as fair to good (private) or good to perfect (public), (8) researchers discovered that 25 percent of private suppliers and 33 percent of public systems were at times unable to meet volume demands. Five percent of private suppliers and 13 percent of public systems reported at least one all-day system shutdown during the previous year. (9)

Further inhibiting small system management capacity is the fact that many small systems do not meter their customers, and many lack even master system meters. As discussed in Chapters 2 and 4, it is difficult to efficiently monitor or maintain a water supply system if volumes and system losses are not known.

Particular Needs

The cost of new debt and other diseconomies suffered by small scale water systems, then, present major management difficulties, but it is not neces-

sarily true that local suppliers have reached the reasonable limit of water charges. The Cornell group found that although less than one-third of the surveyed Adirondack water systems were in debt, average annual water charges amounted to only $50, and many systems had surpluses of over 25 percent. (10) The researchers, however, did emphasize the need for local government cooperation in obtaining needed expertise and in providing an enlarged municipal resource base, full-time operating personnel, and enhanced financial capacity. (11)

One observer, in fact, noted that the greatest need is for technical assistance and personnel training. (12) More particularly, such assistance today should include not only standard subjects of system management, but also computer use law and accounting procedures. (13)

Appendix 3.
A Brief and General Review of the Major Elements of Distribution System Hardware

Local systems convey water through networks composed of:

- water mains--larger pipes--and smaller service pipes, plus
- items--pipe fittings and joints, valves, pumps and hydrants--that facilitate or direct the flow of water through the pipes. (1)

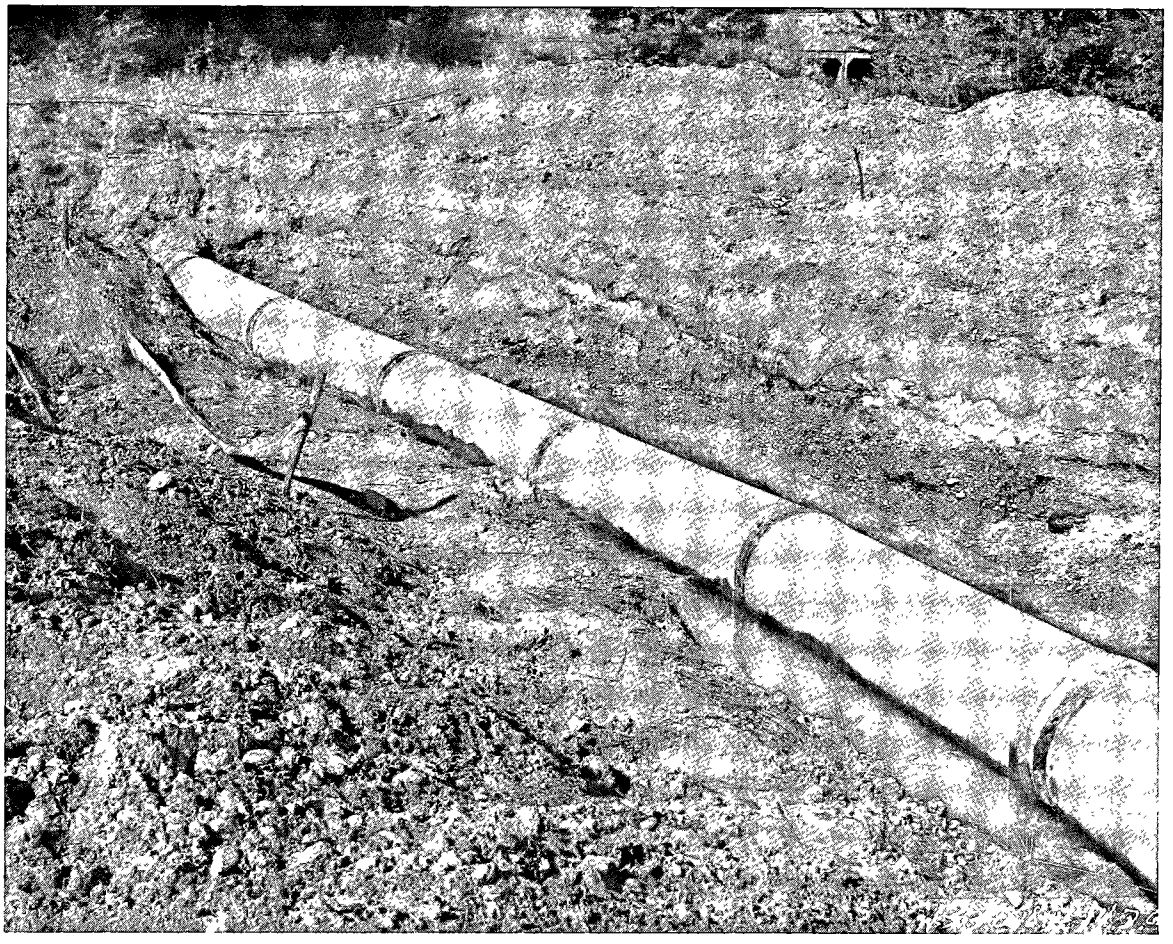
Engineers over the decades have made several improvements in each kind of element in order to better deal with some constant problems of water distribution hardware (e.g., reaction of material to freezing, thawing, soil movement and internal water pressure; resistance to weight, impact and corrosion; ease of joining the components together). Improvements in construction and design have occurred faster than existing hardware has worn out, so the components within each system vary in the extent to which they are state of the art.

Water Mains

Usually, the term main is reserved for the large pipes that act essentially as a water distribution system's arteries. Mains ranging from 6 inches to 48 inches in diameter convey large amounts of water throughout the territory occupied by the network. Smaller pipes, called service mains or service pipes, connect to the mains, and it is through the smaller pipes that users receive water at their homes and places of business.

Cast Iron--About 90 percent of water mains of more than four inches in diameter in the 100 largest American cities are made of cast iron. Philadelphia began laying cast iron pipes in 1804, and they came into widespread use in America in the 1830s. Europeans have been using them even longer. A cast iron pipe installed in Langensalza, Germany, in 1562 still supplies water to two fountains. In Versailles, a 16-mile cast iron main laid in 1664 is still in use. (2)

Early cast iron pipes were manufactured in horizontal sand molds in lengths of four to five feet. This limit on pipe length was necessary because of a common structural defect: The molding process characteristically resulted in a



(Photo: Courtesy of Washington Suburban Sanitary District)

sagging at the core of the mold such that the pipe wall had an area that was thinner than the rest of the pipe wall. If the pipe was too long, its weight would easily cause a break at the thin spot.

Around 1800, tilted molds came into use. This change decreased the sagging and permitted pipe lengths of up to nine feet. A further improvement came around 1850 with the introduction of vertical casting (better known as pit casting), which essentially eliminated the core sagging problem and permitted pipe lengths of sixteen feet.

Of the 100 largest American cities, 28 have some cast iron water mains over 100 years old, and many of those still provide satisfactory service. (3) The derivation of new methods and use of new materials, however, turned some characteristics of pit cast iron pipes into disadvantages. A section of cast iron pipe is heavier and shorter than are pipes constructed with newer methods

and materials, and it has a rougher internal surface. The relatively short lengths require more joints per mile of pipeline than do pipes made of newer materials, and because water is more likely to leak through joints than through the mains themselves, the older cast iron mains exhibit greater leakage than do some of the more modern pipes. The rougher internal surface means that it is harder to move a given amount of water through it than through pipes made of smoother materials.

Spun Iron--While vertical pit casting eliminated the problem of sagging, some variation in wall thicknesses persisted. Greater symmetry became possible in the 1920s with the development of centrifugal casting. In this method, iron is poured into rotating sand or metal molds. The centrifugal force produced by the rotation distributes the metal evenly over the interior of the mold, producing a symmetrical pipe with tensile strength greater than that of pit cast pipe.

Symmetry, however, was not in itself an adequate criterion of design. Some early centrifugally cast pipe had walls which did not bear the pipe's weight well, and breaks were common. By the 1940s, stress tests had been developed to ascertain the optimum ratios of thickness to length and diameter. (Tests have shown that some mains purchased in the 1920s and 1930s performed less adequately than those purchased before or after.)

Ductile Iron--The late 1940s brought the development of ductile iron pipes. The controlled introduction of magnesium produced a form of iron that has the superior strength, flexibility and impact resistance of steel while maintaining the relative corrosion resistance of cast iron. Ductile iron pipes are the modern standard for water mains.

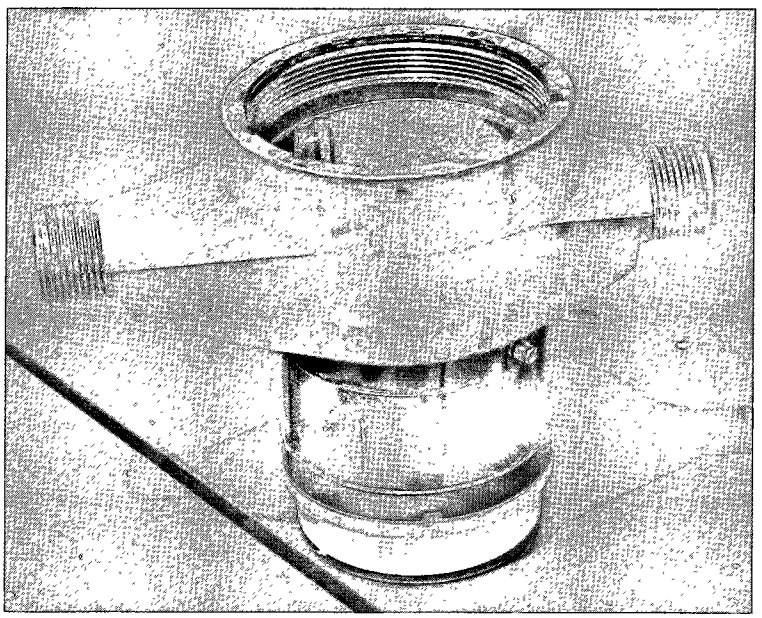
Non-iron Materials--There has been mixed success using materials other than iron.

- Prestressed concrete pipes came into use in the 1950s for water mains smaller than 16 inches in diameter and have been found to exhibit no signs of corrosion or diminished water carrying capacity. Such pipes have some disadvantages: they lack the beam strength of iron; they are non-metallic and therefore difficult to locate with standard pipe detection instruments; and they are more easily damaged during excavations. (4)

- Asbestos cement pipes were used from the 1940s until around 1970. They are corrosion-resistant, but rather brittle. Some asbestos cement pipes laid in New England were found in 1980 to have vinyl linings which were releasing a suspected cancer-causing chemical. The literature does not indicate how extensive this problem may be.

- Steel pipes are smooth and strong, but expensive and easily damaged by corrosion.

- Plastics--light, smooth, flexible, easily joined, virtually non-corrodable--are sometimes expensive and easily damaged. Plastic is more often used for the smaller, service pipes.



(Photo: Courtesy of Washington Suburban Sanitary District)

Pipe Fittings

Fittings are short pipes that have been cast or otherwise made to have special shapes--e.g., curves, Y's, and T's. When installed between two sections of pipe, fittings facilitate changes in direction of water flow.

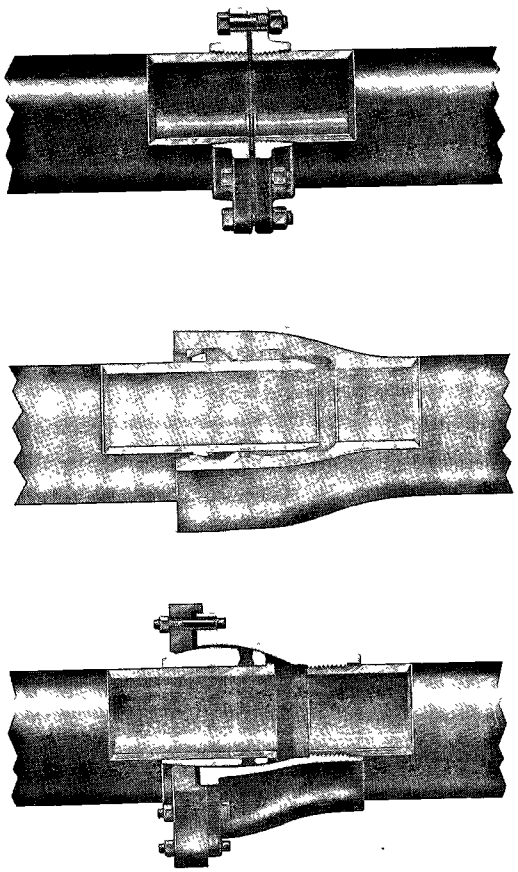
Service Connections

Smaller pipes--frequently 1 to 2 inches in diameter--connect the user's house or place of business with a water main. Devices exist to permit tapping of a main by a new user without stopping the flow of water through the main. Copper is the standard material for service piping, but cast iron and, recently, plastic are also common. Plastic is less expensive than copper. For service pipes of greater than two inches, cast iron often represents the optimal combination of cost and durability.

Some service piping has been made of lead and steel. Use of lead was discontinued after the 1930s. Galvanized steel was used during World War II due to copper shortages; it has been particularly susceptible to external and internal corrosion.

Joints

Whatever the weaknesses which pipe walls exhibit, they are not as generally troublesome as are the pieces which join lengths of pipe. The joints are subject to the same stresses--soil weight and movement, freezing, thawing, traffic impact, corrosion, internal water pressure--as are pipes. In addition, the weight and any movement of the pipes themselves are exerted against the joining



(Photo: Courtesy of The American Cast Iron Pipe Company)

point. A joint must, therefore, be durable and attach tightly to the ends of pipes, but it must do so without damaging the pipes.

Engineers have developed many kinds of joining pieces. Criteria that determined how much each kind of joint has been used include not only its success in dealing with the problems of joining, but also its cost and ease and reliability of installation. Despite improvements, it appears that water losses from distribution systems have more commonly occurred through joints than through pipes.

The earliest cast iron pipes had flanged ends and leather gaskets. Bell and spigot joints were invented in 1785 and were commonly used until 1935. The straight (spigot) end of a pipe was inserted into the larger (bell) end, and the space between was caulked with lead.

A typical problem with bell and spigot joints was that pipe movement caused the lead to work loose. In the mid-1800s, bell and spigot joints were formed with grooves to better hold the lead. Later, lead substitutes, the most common of which is called leadite, were developed to reduce cost and weight and avoid the necessity of caulking during installation. Some of the new sealing compounds, while cheaper and easier to use than lead, formed joints that were very rigid and therefore contributed to main breaks.

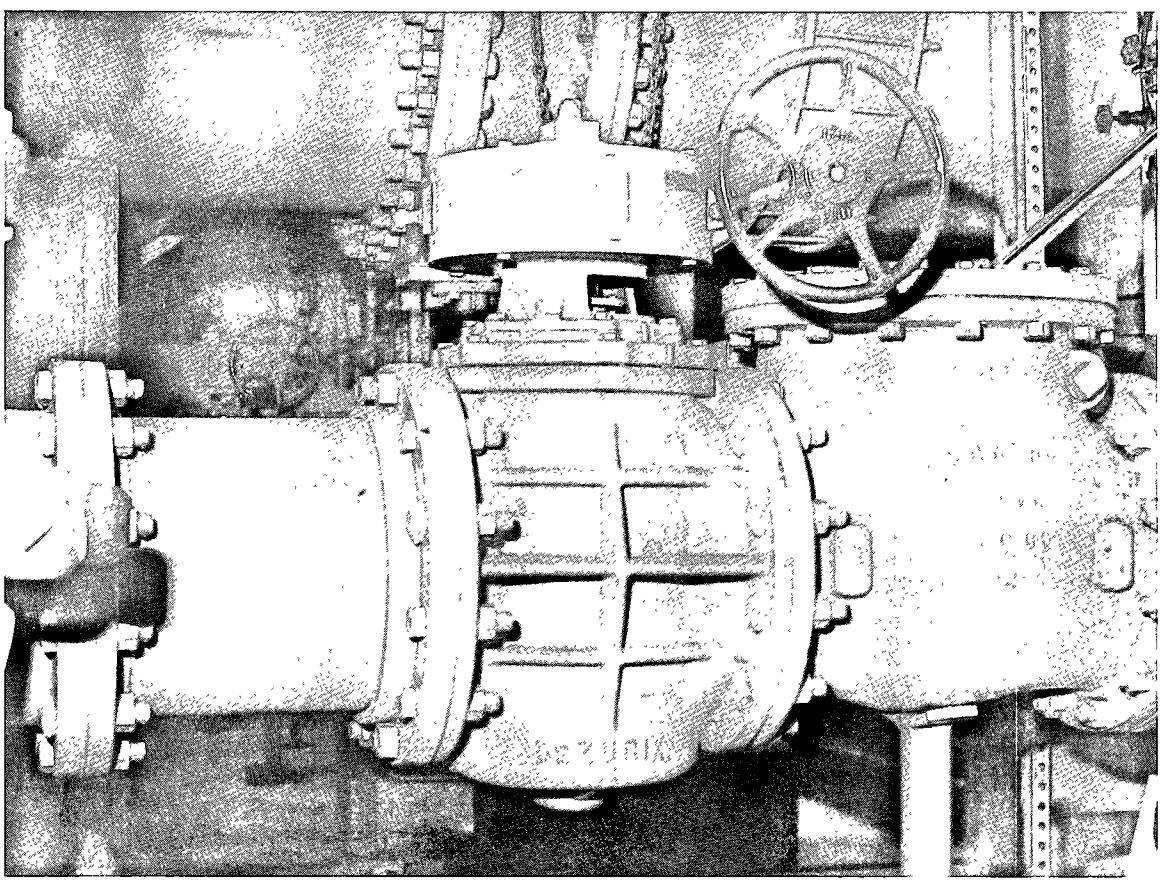
Bolted mechanical joints developed by the natural gas industry were used on some water mains beginning in the 1920s. Rubber ring gaskets were developed in the 1950s and began to replace lead or sulfur caulking on bell and spigot pipes. Push-on (slip) joints, made possible by the rubber ring gaskets, create a pressure-tight seal with a simple assembly procedure. A flexible joint, which itself moves and thereby permits some pipe movement without stressing the

joint, facilitates the laying of pipelines on riverbeds. The new ductile iron pipes come with rubber gaskets which fit in a groove over the bell, creating a watertight flexible joint. Welding is also used to join large diameter mains. (5)

Valves

The general purpose of a valve is to restrict or regulate the flow of water. The specific kinds of restriction and regulation, however, are various, and the structures of valves differ accordingly.

One of the most common kinds of valve is the gate valve, which shuts off the flow of water to particular districts of a pipe network, usually for the purpose of repairs. The more gate valves that are installed in a system, the smaller is the area controlled by each valve and the smaller, therefore, is the



(Photo: Courtesy of Washington Suburban Sanitary District)

number of users whose service is disrupted when shutdowns are necessary. A gate valve, essentially, is a sliding, flat, metal disk which, when it is not being used, rests in a case adjacent to a pipe. When necessary, the disk is moved (by use of a screw-operated stem) into the pipe, within which the disk fits snugly, across the path of water flow.

Check valves permit one-directional flow of water and are used, for instance, to prevent backflow of water when a pump has been stopped. Altitude valves close the supply line to elevated storage tanks when the tanks are full. Air-and-vacuum and air-relief valves permit the expulsion of air (which may impede flow) from a water pipe. Regulating valves are used to reduce pressure, for instance, in areas where gravity might cause water to rush so fast that the resulting pressure would be too high for the size of pipe installed in those areas.

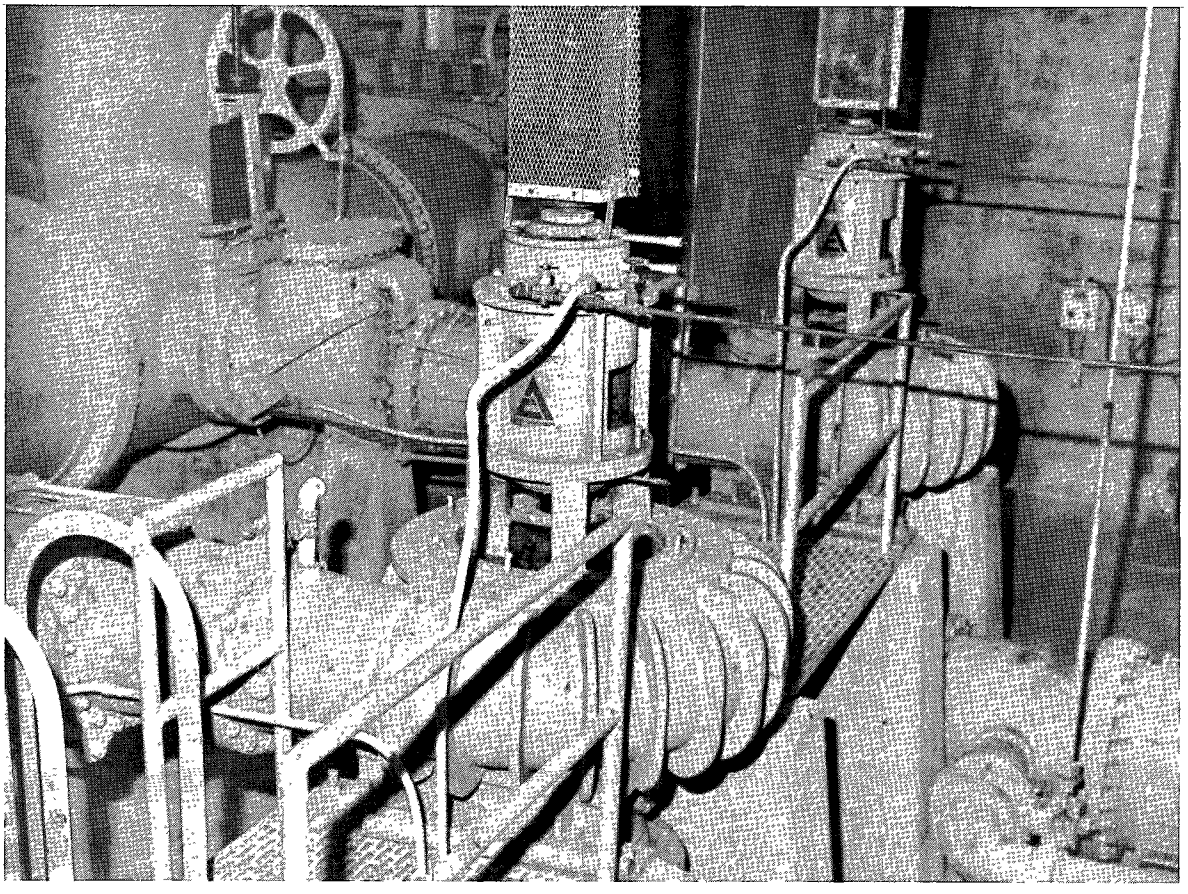
This listing does not exhaust the inventory of kinds of valves included in a typical water system, but it does give some indication of the variety. Some valves, such as gate valves, are used infrequently and therefore are operated manually. Other valves, especially those used to regulate flow, operate automatically through hydraulic action. The criteria of good performance by a valve include tightness of closure, size, ease of access for use and maintenance, and durability against corrosion and water pressure. (6)

Pumps

If a water source is located at an elevation higher than that at which the users reside, a water system can transport the water to (and sometimes through) the distribution system simply by directing the natural downward flow. More common, however, is the location of sources--lakes, rivers, reservoirs, wells--at elevations below the elevation of the users' residences. In this circumstance, it is necessary to purchase, install and operate pumps in order to propel the water upward to the users.

Pumps are used, then, to lift water from the source into the major transmission conduits and toward the distribution system, then to discharge it into the distribution system at the higher pressure needed for many users' purposes, and to boost the pressure within the distribution system when necessary.

Water systems use many kinds of pumps (e.g., turbine, air lift, centrifugal, rotary gear). Centrifugal pumps perhaps are the most common. They are



(Photo: Courtesy of Washington Suburban Sanitary District)

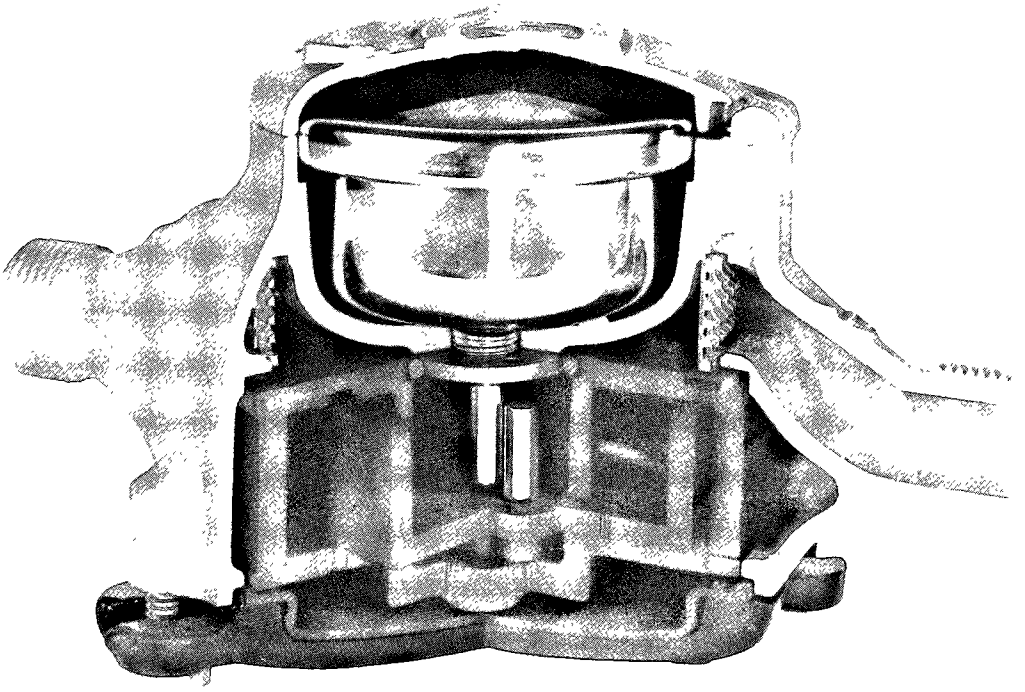
less expensive to purchase, their simple construction makes them more dependable, and they are lighter and smaller.

Pumps are most commonly powered by electric motors. Steam turbines and diesel and gasoline engines have had some use. (7)

Meters

Water meters are not necessary to deliver water, but they are an essential component of water system information gathering. They provide data necessary to monitor the performance of parts of a distribution system and to record water consumption in total and by specific users.

There are several kinds of meters which have been used to register flow (in gallons or cubic feet) generally and to register consumption. They can be fixed or portable, and they can be installed at water sources to measure produc-



(Photo: Courtesy of Rockwell International Municipal and Utility Division)

tion, at points throughout the system to measure flow through districts, and at consumers' homes and places of business to measure consumption. Meters are essentially water driven: water passing through the meter mechanism, for instance, oscillates a piston, wobbles a disk, or spins a turbine propeller which has been coordinated with a numerical registration device to record the volume of water flowing through the meter and represent the volume of water flowing through a pipe. Recent developments include electronic devices which permit the delivery of flow information to a central data receiving point through telephone lines or other connections.

Meters often are rendered inaccurate by simple wear, frost damage, water corrosion and deposits of sediment carried in the water. Most often, an inaccurate meter underregisters flow. Directing flow through a meter consumes some of the energy of a flow of water; different kinds of meters reduce water pressure to different extents.

Appendix 4.
Comments on Some Strategic Problems

Economies of Scale and Local Effort

Economies of scale may be particularly pertinent to small systems' distribution hardware problems. If designers of a strategy were to specify some minimum magnitude of such problems as warranting a program of state aid, it would be necessary to consider the question of what constitutes a reasonable local effort. That is, what level of water rate monies or other revenues generated by and reinvested in a local water system implies that the operators and users are doing that which is feasible to keep their system in working order and yet are unable to keep up with costs? Could a particular system under stress reasonably raise more revenue?

Rates and Costs

Some have argued that water rates in the United States are too low.

- The average rate in the U.S. is about $1.00 per 1,000 gallons, and average per capita consumption is about 100 gallons per day. Average European rates are closer to $2.00 per 1,000 gallons, and average per capita daily consumption is 37 gallons in West Germany, 54 gallons in Sweden, 30 gallons in France, and 53 gallons in Great Britain. (1)

- Approximately .70 percent of an average American household's disposable income pays for water and wastewater services. In the rest of the developed world, those services require closer to 2-3 percent. (2)

Whether adequacy of local efforts is defined as a simple matter of revenue vis-a-vis system needs or as a matter of per capita effort relative to other systems, there is some criticism of usual rate levels in this country. Some observers believe that too-low rates lead to high consumption, unnecessary investment in new supply (rather than conservation), and added treatment and delivery costs. A prominent water finance expert estimated that an average national rate increase of 30-40 percent would provide $50-75 for water system improvements. (3) One federal study estimated that 87-90 percent of identified water supply needs can be accommodated by at most doubling rates. (4)

The real price of urban water after inflation actually has declined in the past decade. (5) Some contend that the inexpensiveness of the commodity and the traditional reliance upon engineering approaches within the water supply industry have relegated pricing to a minor role in the water policy decision making process. (6) Actual rates around the country vary by more than 100 percent, and the American Water Works Association concluded after a survey that the systems with the greatest backlog of maintenance needs generally have the lowest rates. (7) Table 10 shows a comparison of a few water rates around the country.

How Much Help, Where, and What Kind?

Returning, then, to the matter of economies of scale, allocation of responsibilities, and assessment of the adequacy of effort by water suppliers: There is some indication that rate variation correlates with population and that lesser populated areas do indeed charge more for water. The average rate of publicly owned water systems in New York State (excluding New York City) is $61.20 per year. Rural (under 10,000 population) rates average 16 percent above urban rates. Rates for publicly owned systems in Long Island average only $35.85 per year, and average New York City rates are $38.38 per year. (8)

These figures may indicate that urban water systems' flexibility to finance improvements through water rates is greater than that of rural systems.

Table 10

Annual Residential Water Charges
Based upon 100,000 gallons per year

City	Effective date of rate	Annual Water bill
Boston	April 1, 1980	$101.00
Cincinnati	July 1, 1978	47.20
Indianapolis	January 4, 1979	135.02
Louisville	January 1, 1980	84.00
New Orleans	March 1, 1980	93.12
Troy, NY	January 1, 1980	90.00
Washington, DC	July 1, 1976	52.70

Source: Comptroller General of the United States, Additional Federal Aid for Urban Water Distribution Systems Should Wait Until Needs are Clearly Established, November 1980, p. 43.

This in itself, however, is not a clear indication of need nor, if need is indicated, of the magnitude of need. Cornell researchers found, for instance, that less than one-third of the Adirondack systems they surveyed were in debt, the average annual water charges amounted to $50, and many systems had surpluses of up to 25 percent. (9) Several observers of small systems have suggested that a technical assistance program (in contrast to a state-funded rebuilding program) operated via local public health department auspices, local planning agencies, county governments, Cooperative Extension personnel, or even through contracting with other water utilities, would be an effective way to address smaller systems' maintenance needs. (10)

Even if economy-of-scale conditions warranted state action, then, the nature of such action could be variable, ranging from advice and lending of expertise, to fostering cooperation among neighboring entities, to financial help including borrowing assistance or grants.

A Basic Complaint: Subsidy

Whatever the form of aid, helping some systems and not others on the basis of an economy-of-scale criterion would entail a problem of assessing adequacy of effort. Aid decisions probably would encounter this criticism: "Why should the taxpayers in one town, who may be paying water rates calculated to pay all expenses, subsidize a federal or state grant to improve the water system of a neighboring town?" (11) Some might make that criticism whether or not there was an explicit economy-of-scale criterion for aid. (The following cases, mostly made in the context of discussion about federal subsidies, apply generally to the matter of subsidization.)

- The American Water Works Association (AWWA), which represents the nation's water supply professionals, has stated that a water utility should receive sufficient revenue from water users to finance all operation and maintenance expenses, along with all capital costs. (12)

- The general manager of the Waukesha (Wisconsin) Water Utility wrote in the Journal of the AWWA that conditions attached to federal grants make such subsidies undesirable by restricting engineering and construction innovations and imposing costly and burdensome administrative requirements. He further argued that such a grant system would be counter-productive: A grant program may tempt local water managers to continue to defer maintenance in anticipation of outside funding which, in any event, cannot be sufficient to meet all needs. He concluded that water utilities, which provide a vital public

service and product, are capable of generating revenue sufficient to meet their own needs. (13)

- A 1979 Presidential Task Force on urban water problems adds that a subsidy program may create a sort of addiction.

> Outside assistance can, if inappropriately structured, encourage management behavior that would perpetuate a need for assistance. Further, such assistance to those who currently have an investment shortfall could, in theory, encourage those who currently do not have shortfalls to behave in ways that will create future needs for outside assistance. (14)

Others, similarly, contend that external funding may lead to the construction of higher levels of capacity than are necessary and this, in turn, could increase future maintenance needs and facilitate overconsumption. (15)

- The National Association of Water Companies, which represents private water systems, argues that government subsidies discriminate against private, taxpaying water systems. (16)

Nevertheless, the AWWA and the National Association of Water Companies agree that there is a proper role for government aid. Both groups argue that where federal programs (e.g., the Clean Water and Safe Drinking Water Acts) result in added local costs, the government should offer guaranteed loans to help meet the requirements. (17)

Another Example: Cross-Local Matters

If an economy-of-scale criterion for state aid turned out to be untenable, fiscal pressures on smaller systems could generate increased interest in the development of interlocal or supralocal water supply arrangements. In the abstract, such arrangements, by consolidating revenues, hold the promise of improving economies of scale to the effect of attenuating increases in average rates or other revenue-raising assessments. With or without economy-of-scale considerations, however, such arrangements might reasonably be proposed to deal with some water supply problems.

Long Island

While the water problems on Long Island have been recognized, and while the state has acted to protect certain areas from further degradation, some

believe that progress is hindered by the balkanization of water supply activities in the region. There are 48 municipal water suppliers in Nassau County and 36 in Suffolk County, all drawing from a common resource. (18) (About 20 of these suppliers are small investor-owned systems which, some critics claim, defy regulatory control. (19)) Enforcement of water quality standards depends considerably upon self-monitoring. Furthermore, the protection of groundwater is dependent upon certain controls over land use. The region's water supply agencies cannot control land use; this is instead the responsibility of the two counties' 13 towns, 2 cities, and 63 villages.

This balkanization has not, however, defeated all efforts at dealing with the groundwater problem. The Long Island Regional Planning Board has an active water management program in cooperation with DEC. Some towns have acted on their own. Brookhaven in 1975 rezoned 6,000 acres of pine barrens for lots of at least two acres. (20) (21) Southampton is updating its land use plan and is considering water quality in the process. The town contracted with the Cornell Center for Environmental Research, which suggested minimum residential lot zones of five acres in the most critical recharge area, a ban on certain polluting products, a study of the polluting impacts of golf courses and tree nurseries, and public education regarding the connection between land surface activities and groundwater quality. (22)

Suffolk County has taken a regional perspective through the Suffolk County Water Authority, which has been in operation since 1951. The authority supplies water to about three-quarters of the county's population. It has the power to purchase and condemn land and facilities, purchase bulk water, and construct and operate water supply facilities. (Municipal water systems may not be condemned without the consent of the municipality.) In 1974, the authority had a relatively low water charge of $56 per 100,000 gallons; it operates in the black, with excess revenues reserved for system expansions.

The authority may, with the county's permission, develop excess supplies for sale outside the county. Suffolk County has acted to prevent such sales through an untested use of the Burr Act, (23) which delegates to certain defined counties the authority to designate certain ponds or streams which are considered necessary for the supply of pure water to county residents. Designated water bodies become off limits for water withdrawals without the written consent of a majority of the county legislature. Suffolk County has passed a general resolution designating all waters within the county, effectively preventing any water sales to Nassau County. While legal opinions have questioned the

designation of groundwater under the Burr Act, the Suffolk County position has yet to be tested. (24) Should Nassau County be unable to negotiate water purchases from Suffolk County, upstate supplies via New York City may eventually be sought.

The New York City "Region"

The New York City system appears, in fact, to be our largest and oldest regional water supply arrangement. Whether it is interlocal or supralocal, however, is a matter of some disagreement.

New York City is required by the Water Supply Act of 1905 to sell water to municipalities located in counties which contain City reservoirs. (25) Westchester, Ulster and Putnam Counties are now almost totally dependent on City water. The Water Supply Act set the criteria for City water sales: Communities in counties in which City aqueducts or other water supply facilities are constructed are entitled to purchase City water. The localities bear their own connection and distribution costs, and the City is entitled to "fair and reasonable" charges set by negotiation, but not exceeding New York City customer rates. The City pays taxes on its upstate water supply properties, and these payments represent a considerable part of the tax income of several upstate municipalities.

The relationship between the City water system and the 37 upstate customer-municipalities has at times involved conflict.

- The City inhibits the creation of county water districts or authorities by refusing to recognize counties as municipalities. Separate water supply arrangements are thus negotiated with each town, city or village. This inhibition is particularly important in parts of Westchester County, where population patterns often transcend municipal boundaries and a regional water supply approach would therefore be particularly appropriate.

- Another point of contention is that the City restricts wholesale sales to each receiving community to a total per capita amount not exceeding per capita consumption in New York City. This means that the per capita usage of a population base of over seven million is being applied to small communities which may have a low population, but high water use. For example, the village of North Tarrytown contains a large General Motors plant. The plant's heavy water use causes the village to exceed the City's per capita usage limit. In the 1960s, the City attempted to impose retail water rates on the difference at ten times the wholesale rate, a retail rate which the village refused to pay. (26)

The Water Supply Act of 1905, therefore, imposed something of a regional water supply system upon southeastern New York, but some observers believe it did so without provision for adequate regional planning input from outside the City. Researchers (especially those of the Temporary State Commission on the Water Supply Needs of Southeastern New York, and also the Citizens' Union Research Foundation) have suggested the need for an explicit regional water supply entity in the New York City service region. Also suggested has been the inclusion of Nassau County in a regional plan, with the possibility of conjunctive use of upstate surface waters and Long Island (including Brooklyn and Queens) groundwater. The region's political entities have yet to seriously examine such a plan.

Contingency Planning?

It is clear, then, that suggestions for greater and more formal interlocal or supralocal arrangements are neither new nor totally unexplored. Such proposals, however, typically have induced statements of fear about loss of control by localities over local functions. Whether or not these fears are warranted, they probably would recur upon new proposals for regionalization. Not acting to develop regional arrangements, however, would not necessarily preclude a precautionary consideration of them in the water management strategy. The requirement that DEC prepare plans also for substate areas already implies recognition of the pertinence of the regional aspect of water supply activities. It may be useful to develop data that would make such arrangements, should they ever prove to be palatable or necessary, most efficient. For instance, it could be useful to have an inventory of localities which have tremendous excess capacity for which neighboring localities could contract rather than further develop their own supplies or facilities. (DEC plans to include such an inventory in the substate parts of the water resources management strategy.)

Notes

Executive Summary

1. Comptroller General of the United States, Additional Federal Aid for Urban Water Distribution Systems Should Wait Until Needs are Clearly Established, November 1980, p. 14.

2. D.K. O'Day, "Organizing and Analyzing Leak and Break Data for Making Main Replacement Decisions," Journal of the American Water Works Association, 74, November 1982, p. 594.

3. For instance: Excessive pressure which results from an inoperable valve may place stress on a weakened joint such that a break occurs; a leak not only constitutes a loss of water, but can damage soil bedding and thereby cause breaks; and internal corrosion may partially clog a pipe and make it necessary to use a pump to boost pressure for greater amounts of time than was contemplated when the pump was installed.

4. The major nationwide assessments were conducted by the President's Intergovernmental Water Policy Task Force, the U.S. Comptroller General, the Congressional Budget Office, and the Congressional Joint Economic Committee. Two important statewide assessments were the Department of Health's Facilities Needs Survey of Community Public Water Systems and the New York State component of the study done for the Congressional Joint Economic Committee. In addition, the U.S. Army Corps of Engineers has performed or contracted for a series of studies of individual water supply systems. (These efforts are reviewed in Chapter 3.)

5. New York State Department of Health, Bureau of Public Water Supply Protection, Facilities Needs Survey of Community Public Water Systems, April 1983, p. 11.

6. Subcommittee on Economic Goals and Intergovernmental Policy of the Joint Economic Committee, Congress of the United States, Hard Choices: A Report on the Increasing Gap Between America's Infrastructure Needs and Our Ability to Pay for Them, 1984, pp. 36, 37-38.

7. SMC-Martin Consulting Engineers and Temple, Barker & Sloan, Inc., An Analysis of the Nation's Urban Water Systems: Characteristics, Investment Requirements and Policy Options, Prepared for the Institute for Water Resources, United States Department of the Army, February 1980, p. 98.

8. SMC-Martin Consulting Engineers and Temple, Barker & Sloan, Inc., p. 98.

9. O'Day, p. 594.

10. Comments of Robert D. Hennigan, Executive Director, Temporary State Commission on the Water Supply Needs of Southeastern New York, Proceedings: Local Government Conferences, 1973, p. 110.

11. Testimony of Maurice M. Feldman of the New York City Department of Water Resources, Temporary State Commission on the Water Supply Needs of Southeastern New York, p. 111.

12. Testimony of E. Virgil Conway, Chairman, Temporary State Commission on the Water Supply Needs of Southeastern New York, p. 111.

13. Identification of conditions pertains fairly simply to observation of supply, usage, quality and facilities. Explaining the derivation of conditions, however, requires subtle analysis regarding incidence and ultimate causes of such phenomena as overconsumption, deferred maintenance and pollution. Identified causes from locality to locality are likely to be highly various, ranging, for instance, from such explanations as "inadequate leak control" to the fiscal reasons behind a locality's inability to install a leak control program. Such matters of derivation are perhaps dauntingly complex, but it is important to explore them because effective prescription--prescription that will be efficient and avoid quick recurrence of a problem--depends on a correct understanding of the derivation of the problem.

14. There should be an attempt to specify usable criteria, perhaps only for purposes of discussion, by which any water supply problem could be designated as routine--to be handled by the water supplier--or as warranting extraordinary attention by the state or some other entity that does not have primary responsibility for supplying water.

    What, in general, would such criteria be? What characteristics of a particular water supply problem would require that the state or some other interlocal or supralocal entity play the major active role in its solution? Several sometimes interrelated possibilities come to mind. Such a problem could involve:

    - economy-of-scale considerations, where most localities did not have the resources to deal individually with the problem they had in common without, for instance, raising water rates to unacceptable levels;

    - cross-local considerations, where the problem affecting a locality derived from occurrences or practices in a neighboring locality;

    - unprecedented nature, where the problem was one that had not been encountered before and therefore required, at least in the early stages of its solution, the greater research capabilities of the state government; and/or

    - large stakes, where possible effects of not resolving the problem might reasonably be expected to be calamitous.

    Use of such criteria would be complicated. For instance, if designers of a strategy were to specify some minimum magnitude of such problems as warranting a program of state aid, it would be necessary to consider

the question of what constitutes a reasonable local effort. Some would consider rates to be too low, and even if it was decided that a problem warranted supralocal action, the nature of such action could be variable, ranging from advice and lending of expertise, to fostering cooperation among neighboring entities, to financial help including borrowing assistance or grants. Whatever the form of aid, helping some systems and not others would entail a problem of assessing adequacy of effort and probably would not avoid this criticism: "Why should the taxpayers in one town, who may be paying water rates calculated to pay all expenses, subsidize a federal or state grant to improve the water system of a neighboring town?" (Quotation is from Robert T. Symonds, "Water Utility Financing Through a Water Bank," Journal of the New England Water Works Association, March 1982, p. 64).

Chapter 1

1. John J. Boland, "Forecasting the Demand for Urban Water," Municipal Water Systems, ed. David Holtz and Scott Sebastian, Indiana University Press, 1978, p. 91.

2. Community public water systems are defined by the State Sanitary Code as being public or investor-owned water systems which have at least five service connections used year-round or which regularly serve at least 25 year-round consumers (State Sanitary Code, 5.5-1.1, part d-1).

3. Data provided in printout by the New York State Department of Health, Bureau of Public Water Supply Protection, August 14, 1984.

4. General Municipal Law, Art. 5-b, secs. 111-116.

5. Town Law, sec. 198(3).

6. County Law, sec. 250.

7. Interview with Dr. Robert D. Hennigan, College of Environmental Science and Forestry, State University of New York, May 11, 1984.

8. New York State Department of Health, Bureau of Public Water Supply Protection, Facilities Needs Survey of Community Public Water Systems, April 1983, p. 49.

9. Interview (May 11, 1984) with Dr. Robert D. Hennigan, who served as executive director of the Temporary State Commission on the Water Supply Needs of Southeastern New York in the early 1970s.

10. U.S. Army Corps of Engineers, Buffalo District, Urban Water Study: Buffalo, New York, Volume 1, Final Report, August 1981, p. 8-12.

11. Town Law, secs. 198(d)(3), 209-r(3-a).

12. Constitution of the State of New York, Art. 8, sec. 5, part B.

13. Constitution of the State of New York, Art. 8, sec. 2.

14. Suburban towns have:

- at least 25,000 people; or
- at least 7,500 people, a boundary line within 15 miles of a boundary line of a city of over 100,000 population, and a population growth of 60 percent between 1940 and 1960 or 40 percent between 1950 and 1960.

Such designation is subject to a resolution by the town board and may require a referendum upon motion of the town board or upon public petition.

15. Sections 55 and 55-a of the Town Law contain procedures for establishing and using general reserve funds in suburban towns or improvement districts within suburban towns. Sections 6-c and 6-d of the General Municipal Law set forth the criteria for capital reserve funds and repair reserve funds.

16. New York State Comptroller, Opinion 82-159.

17. Pat Choate and Susan Walter, America in Ruins: Beyond the Public Works Pork Barrel, Council of State Planning Agencies, 1981, p. 34.

18. Villages, in practice, may have less fiscal breathing room than cities. Villages are under the jurisdiction of the towns in which they lay, and village residents must therefore pay both village and town taxes. Village officials may feel it necessary to contain village assessments if town functions and assessments have been expanding. A possible result is that village-owned and operated capital may deteriorate. (Robert Pomeroy, Productivity Improvement in New York State Local Governments: State Actions to Assist Local Governments, Cornell Agricultural Economics Research Paper, no. 83-18, Cornell University, Dept. of Agricultural Economics, 1983, p. 1.)

19. "Improving New York's Water Supply Systems," Cornell University Cooperative Extension Synopsis Series, no. 83-5, April 4, 1983. Article was adapted from a paper ("Meeting New York's Water Supply Needs: A Regional Perspective") presented by Robert D. Hennigan, State University of New York College of Environmental Science and Forestry, at the first annual meeting of the New York section of the American Water Works Association, November 1982.

20. SMC-Martin Consulting Engineers and Temple, Barker & Sloan, Inc., An Analysis of the Nation's Urban Water Systems: Characteristics, Investment Requirements and Policy Options, Prepared for the Institute for Water Resources, United States Department of the Army, February 1980, p. 10.

21. Temporary State Commission on the Water Supply Needs of Southeastern New York, Institutional Arrangements and Alternative Futures, December 1973, p. 168.

22. Testimony of Edward V. Regan, reported in New York State Assembly Infrastructure Task Force, First Interim Report on New York's Infrastructure, 1983, p. 101.

Chapter 2

1. Betz-Converse-Murdoch, Inc., New York City Water Supply Infrastructure Study, Volume 1: Manhattan, prepared for the U.S. Army Corps of Engineers, New York District, May 1980, pp. xiv-xv.

2. Comptroller General of the United States, Additional Federal Aid for Urban Water Distribution Systems Should Wait Until Needs are Clearly Established, November 1980, p. 20.

3. Comptroller General of the United States, p. 20.

4. Comptroller General of the United States, p. 21.

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51. Some of these methods are "shotcreting," "seal grouting," "compaction grouting," "sliplining," "steel plate lining," and "in-situ forming." Shotcreting is the application, through spraying, of gunite reinforced concrete. The technique is commonly used in sewers and is appropriate only for pipes of more than two feet in diameter. Grouting is the injection of grout (a thin mortar) under pressure; it can be used for both emergency and regular repairs. The material can also be used to fill voids in the soil which result in improper bedding. Lining, the insertion of a "pipe within a pipe," is an appropriate method for refurbishing extensively cracked or corroded pipe. The technology was rejected twenty years ago, but is gaining a new look in response to escalated construction costs and improved polyethylene materials. Its applicability may be limited in areas with many service connections. Where it is feasible, it results in greatly reduced frictional resistance to the flow of water.

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Henry G. Schwartz, "The Undercover Facts About Our Aging Water and Sewer Lines," Consulting Engineer, September 1983, pp. 70-74; and

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2. The term and idea of "rules of thumb" in this context is D. Kelly O'Day's, who used it in presenting his information system contentions in the article entitled "Organizing and Analyzing Leak and Break Data for Making Main Replacement Decisions," previously cited.

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7. Investigators have found that one useful comparison is the ratio of nighttime flow to daytime flow.

> In general, where minimum night rates of consumption are less than 50 percent of the average daily consumption, there is little likelihood of water waste in the corresponding district. The probability of appreciable waste varies proportionately with this percentage. For example, when the district figure drops to 30 percent or less, the likelihood of serious leakage is practically nil. Using these data, it is possible to reduce the amount of detailed investigation required to account for night rates of consumption. Normally, a number of districts will prove to have night rate-to-total consumption ratios so low that no further attention to these grids is required.
>
> Such was the case in one city where 24 of the 68 districts had low minimum night rate ratios....In these 24 areas, it was determined that further investigation was unnecessary. These districts covered 402 mi. of main, or 35 percent of the total 1150 mi. Eliminating them from detailed study materially reduced the work and time required for the overall study. (E. Shaw Cole, "Methods of Leak Detection: An Overview," Journal of the American Water Works Association, February 1979, p. 74).

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used to determine the thickness of pipe needed for a particular location: the iron strength, the pipe diameter, the internal pressure, the depth of cover, and the amount of surface truck traffic expected." (See Betz-Converse-Murdoch, Inc., New York City Water Supply Infrastructure Study, Volume 1: Manhattan, prepared for the U.S. Army Corps of Engineers, New York District, May 1980, p. 3-4.)

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24. Betz-Converse-Murdoch, Inc., Watervliet, New York, Water Distribution System Network Analysis, prepared for the U.S. Army Corps of Engineers, New York District, 1981, p. 9.

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Chapter 5

1. Copies of forms and supplementary information for this description were made available by the New York State Department of Health, Bureau of Public Water Supply Protection.

2. Section 89-1 of the Public Service Law directs municipal water systems also to submit reports to the PSC, but inasmuch as the PSC has no regulatory power over municipal systems, this reporting requirement is not enforced.

3. Figures supplied by the central filing section of the New York State Department of Public Service.

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6. See, for instance, Leonard R. Batts, "Distribution System Maps and Record-keeping," Journal of the American Water Works Association, November 1984, pp. 50-53.

7. It is clear that among the municipal suppliers, it is the great majority of smaller ones that constitute most of the unmetered proportion of systems. The Department of Health provides metering data also for non-municipal systems. These exist in such entities as mobile home parks, apartment complexes, developmental centers, state parks, nursing homes, hospitals, colleges and universities, correctional facilities and psychiatric centers. Of the 1,540 non-municipal systems listed in the 1984 Inventory, about 96 percent serve populations of 500 or less; about 55 percent serve populations of 25-100, about 20 percent serve populations of 101-250 and about 15 percent serve populations of less than 25. Only 44 (about 3 percent) of the non-municipal systems serve populations of 1,000 or more. These systems are almost devoid of commercial and industrial enterprises, so only residential metering is significant. Of the entire set of 1,540 non-municipal systems, only 35 have residential metering that exceeds 5 percent. This means that about 98 percent are essentially not user metered. Among the 44 systems that serve populations of 1,000 or more, 4 have residential metering that exceeds 2 percent.

8. Considerable portions of the information about consulting engineers' activities and needs and impressions of local records were derived from interviews with Claire O'Neill, Robert Pace and Charles Zernentsch of the U.S. Army Corps of Engineers and Robert Hennigan of the New York State College of Environmental Science and Forestry.

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3. Cornell University Center for Environmental Research, p. 2.

4. Wayne B. Solley et al., p. 30.

5. Interview with Deborah S. Snavely, U. S. Geological Survey, February 21, 1984.

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11. R. H. McCuen, et al., "Forecasting Urban Water Use," Journal of the American Water Works Association, 67, May 1975, pp. 239-244.

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13. Milliken and Taylor, p. 24.

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18. Holtz and Sebastian, p. 4. Also, Metropolitan (Boston) District Commission, Water News, Vol. 6, January 1983.

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23. G. Gordon Milliken and Graham C. Taylor, p. 53.

24. David Holtz and Scott Sebastian, Municipal Water Management, Indiana University Press, p. 39.

25. LeRoy H. Reuter, "Health Considerations in Wastewater Reuse," Municipal Water Systems, ed. David Holtz and Scott Sebastian, Indiana University Press, 1978, p. 156.

26. National Conference of State Legislatures, Office of Science and Natural Resources, Issue Brief, "Water Conservation," April 1, 1980, p. 4.

27. Blackwelder and Carlson, p. 10.

28. Blackwelder and Carlson, p. 16.

29. Blackwelder and Carlson, p. 12.

30. National Conference of State Legislatures, Office of Science and Natural Resources, p. 5.

31. Blackwelder and Carlson, p. 16.

32. Temporary State Commission on the Water Supply Needs of Southeastern New York, Water For Tomorrow: Recommendations of the Commission, 1973, p. 20.

33. New York State Department of Environmental Conservation, DEC News, December 6, 1977.

34. S.H. Hanke and J.J. Boland, "Water Requirements or Water Demands," Journal of the American Water Works Association, 63, May 1975, pp. 677-681.

35. Holtz and Sebastian, p. 32.

36. Holtz and Sebastian, p. 32.

37. Holtz and Sebastian, p. 32.

38. Morandi and Lazarus, p. 127.

39. Interview with Marjorie Johnson, Director of Public Affairs, Washington Suburban Sanitary District, February 16, 1984.

40. Morandi and Lazarus, pp. 134-135.

41. Morandi and Lazarus, p. 138.

42. Richard D. Heaton, "Potable Reuse: The U.S. Experience," Municipal Water Systems, ed. David Holtz and Scott Sebastian, Indiana University Press, 1978, p. 174.

43. Heaton, p. 177.

44. Heaton, p. 169.

45. Heaton, p. 172.

46. Morandi and Lazarus, p. 135.

47. Morandi and Lazarus, p. 98.

48. Morandi and Lazarus, p. 96.

49. Morandi and Lazarus, p. 100.

50. Morandi and Lazarus, p. 126.

51. Morandi and Lazarus, p. 126.

52. New York State Uniform Fire Prevention and Building Code, Art. 9, Pt. 900.1e.

53. News Release, New York State Department of Health, February 18, 1981.

54. New York State Department of Health, Bureau of Public Water Supply Protection, Summary Report on Drought Planning by Community Water Systems, April 1982.

55. Delaware River Basin Commission, "Eighteenth Water Resources Program," October 1982.

56. Especially noteworthy with regard to the deficiencies in available supply augmentative technologies is the matter of aquifer pollution.

At present, it appears that an aquifer, once polluted, is beyond reclamation efforts with time horizons as short as those which have succeeded regarding surface water pollution. Groundwater movement is extremely slow, from two meters a day to two meters a year. (David A. Francko and Robert J. Wetzel, To Quench Our Thirst, University of Michigan Press, 1983, p. 11) Once polluted, then, an aquifer will take many years to naturally cleanse itself. Water treatment plants may permit purification of some polluted groundwaters, but some forms of chemical pollution may be irreversible by any process we know of today. And the natural cleansing process can be retarded not only by any continuing pollution, but also by simple urbanization: recharge to aquifers decreases as ground is covered with impermeable materials such as pavement and buildings. Where soils are permeable and aquifers lie close to the surface, precipitation will replenish groundwater levels within days. But as population increases, groundwater use tends to shift to deeper aquifers, which exhibit less response to short-term weather patterns.

57. Newsletter, Water Supply Citizens Advisory Committee to the Metropolitan (Boston) District Commission, December 1982.

58. Milliken and Taylor, p. 85.

59. Morandi and Lazarus, p. 126.

60. Holtz and Sebastian, p. 29.

61. Holtz and Sebastian, p. 29.

62. United Nations, Department of Economic and Social Affairs: Natural Resources/Water Series No. 3, The Demand for Water: Procedures and Methodologies for Projecting Water Demands in the Context of Regional and National Planning, 1982, p. 43.

63. Milliken and Taylor, p. 88.

64. "Two Legislators Propose Cloud Seeding," Westchester Reporter Dispatch, January 28, 1981.

65. Westchester Reporter Dispatch, January 28, 1981.

66. Comments by Robert R. Peters in Proceedings of the Research Conference: Water Problems in Urbanizing Areas, p. 219.

67. Morandi and Lazarus, pp. 104-105.

68. Schilling, p. 29.

69. New York State Legislative Commission on Water Resource Needs of Long Island, Progress Report, 1984, pp. 32, 118.

70. Bill Vlasic, "Pond Report Pleases Opponents," Rockland Journal, March 1, 1985.

71. Morandi and Lazarus, p. 95.

72. Susquehanna River Basin Compact, section 3.10, Part 2.

73. New York State Legislative Commission on Water Resource Needs of Long Island, Progress Report, 1982, p. 164.

74. Morandi and Lazarus, p. 11.

75. George P. Fulton, "New York's Water Supply Dilemma," Public Works, 112, February 1981, pp. 55-59.

76. Connecticut Department of Environmental Protection, "Interbasin Transfers of Interstate Water: Current Authorities and Pressures," October 1973, p. 2.

77. Milliken and Taylor, p. 98.

78. New York State Legislative Commission on Water Resource Needs of Long Island, Progress Report, 1984, p. 11.

79. Schilling, p. 29.

Chapter 8

1. A 1983 Cornell University study of community water supply systems in the Adirondacks found that many of the 67 small suppliers surveyed failed to meet state quality testing requirements. Bacteria testing (required at least monthly) was conducted frequently by most of the systems, but seven systems had performed no test since 1978. More alarming is that testing for inorganic chemicals (required annually for surface water supplies) had not been undertaken by two-thirds of the systems since before 1981. (Eighty percent of the systems have at least one primary surface water source.) Regarding organic chemicals (mostly herbicides and pesticides), there were no testing records in 35 percent of the systems. Another 30 percent of the systems had not been tested for organic chemicals since 1977. (Surface water supplies must be tested for organic chemicals at three-year intervals, according to the State Sanitary Code.) (Joe D. Francis and Wendy F. Graham, Community Water Supply Organization and Performance in the Adirondacks: Assessment of Social, Economic, Political, and Environmental Influences, Cornell University Department of Rural Sociology, 1983, pp. 164-169.

2. For instance, the Corps of Engineers developed and computerized a substantial data base for Manhattan to monitor and analyze main breaks, and the City of Des Plaines (Ill.) has a computer-aided design and drafting system which uses "water audits" and a system inventory as basic data. The Metropolitan St. Louis Sewer District, in consultation with the Sverdrup Corporation, is assembling a broad data base that is to:

> encompass data on existing sewer routes, including information on age, depth, size, structural type, etc.; soil data; demographic data, focusing on both high

population density and building proximity to large combined sewers; history of sewer failures; location of water and gas mains; and information derived from aerial photographs, such as street patches on subsiding roadway surfaces along a sewer trunk line. (Henry G. Schwartz, Jr., "The Undercover Facts About Our Aging Water and Sewer Lines," Consulting Engineer, 59, September 1983, p. 70)

3. D.K. O'Day, "Organizing and Analyzing Leak and Break Data for Making Main Replacement Decisions," Journal of the American Water Works Association, 74, November 1982, p. 594.

4. Robert T. Symonds, "Water Utility Financing Through a Water Bank," Journal of the New England Water Works Association, 91, March 1982, p. 64.

5. Such an effort might be similar, for instance, to the existing program of state assistance for operation and maintenance of sewage treatment works. (Environmental Conservation Law, section 17-1905) The specific percentage of state aid given to localities under this program since its enactment in 1962 has varied; in recent years, it has been 12-15 percent of the local costs. (The statute has permitted assistance of up to one-third of costs, and the lesser amount of actual aid has been a subject of frequent criticism. It is the basic idea of the program, rather than any positive or negative judgment regarding its level of funding, that we wish to note here.) In order to qualify for assistance, a locality must meet operation and maintenance standards enforced by the Commissioner of Environmental Conservation. The Commissioner must annually inspect an aided treatment facility's "operating conditions and results, including the collection of necessary flow and analytical data...." (Environmental Conservation Law, section 17-1905 (4)(b,c)) Occasionally, localities do fail to meet the standards and therefore do not qualify for assistance.

Appendix 1

1. New York State, Department of State, Local Government Handbook, 3rd Edition, 1982, p. 115.

2. Town Law, Art. 12-C.

3. Conversation with Walter Bundy, DOH Bureau of Public Water Supply Protection, August 10, 1984.

4. New York State, Department of State, p. 125.

5. Temporary State Commission on the Water Supply Needs of Southeastern New York, Institutional Arrangements and Alternative Futures, December 1973, p. 53.

6. Environmental Conservation Law, Art. 15.

7. New York State Department of Environmental Conservation, Capital Region Water Resources Strategy, undated, pp. I-5,I-6.

8. United States Congress, Senate, Committee on Environment and Public Works, State and National Water Use Trends to the Year 2000, May 1980, pp. 146-149.

9. Chapter 250, Laws of 1963.

10. J. Bumstead, "Comprehensive Water-Supply Study for New York State," Journal of the American Water Works Association, 68, January 1976, p. 32.

11. New York State Department of Environmental Conservation, Capital Region Water Resources Strategy. The counties surveyed were Albany, Columbia, Greene, Rensselaer, Saratoga, and Schenectady.

12. Donald J. Robinson, "Public Authorities and the Financing and Management of Infrastructure," Stretching Dollars to Strengthen Infrastructure, ed. Richard Watson, speeches from a conference sponsored by the Eastern Regional Conference of the Council of State Governments in cooperation with the Southern Legislative Conference of the Council of State Governments, New York, April 29-30, 1983, p. 45.

13. Environmental Conservation Law, sec. 15-2103.

14. Town Law, sec. 194.

15. Congress of the United States, Congressional Budget Office, Public Works Infrastructure: Policy Considerations for the 1980's, 1983, p. 127.

16. Under the Rural Development Act of 1972, communities of under 10,000 population are eligible for low-interest loans from the federal Farmers Home Administration for their water and sewer systems. Funds for the water and wastewater program have been reduced and interest rates have gone up. Annual allocations for New York State have been cut from $21.6 million to $10 million for the loan program, and from $9.2 million to $3.2 million for the grant program. In 1981, interest rates were raised from 5 percent to 10.5 percent. (Source: personal communication, Donna Ryder, FmHA New York State office, July 16, 1984) Prior to the cutbacks, FmHA annually financed 30 to 40 rural New York State water projects. (Richard H. Mansfield, "Timely Financial Advice for Rural Water Systems," NYSDEC Water Bulletin, #17, August 1981.)

17. Congressional Quarterly Weekly Report, October 27, 1984, pp. 2797-2800.

18. Public Laws 92-500, 93-243, and 95-217.

19. Public Law 93-523.

20. Interview with Dr. Edith Tanenbaum, Bi-County Planning Coordinator, Long Island Regional Planning Board, March 20, 1985.

21. Interview with Donald Zizzi, Schenectady County Planning Department, August 27, 1984.

22. Daniel Halton, New York State Department of Environmental Conservation, addressing a meeting of the Water Management Advisory Committee, March 26, 1985.

Appendix 2

1. Pat Choate and Susan Walter, American in Ruins: Beyond the Public Works Pork Barrel, Council of State Planning Agencies, 1981, p. 34.

2. Small systems have traditionally employed federal Farmers Home Administration (FmHA) grants and loans for water and sewer systems. Under the Rural Development Act of 1972, communities of under 10,000 population are eligible for low-interest loans, with priorities given to: alterations to meet requirements of the Safe Drinking Water Act; systems under public or private non-profit ownership; systems undertaking regional treatment facilities or administrative services; systems serving over 5,500 people; and systems serving a low-income population. FmHA operates by purchasing municipal bonds and reselling certificates to the Federal Treasury. Funds for the water and wastewater program have been reduced and interest rates have gone up. Annual allocations for New York State have been cut from $21.6 million to $10 million for the loan program, and from $9.2 million to $3.2 million for the grant program. In 1981, interest rates were raised from 5 percent to 10.5 percent. (Source: personal communication, Donna Ryder, FmHA New York State office, July 16, 1984) Prior to the cutbacks, FmHA annually financed 30 to 40 rural New York State water projects. (Richard H. Mansfield, "Timely Financial Advice for Rural Water Systems," NYSDEC Water Bulletin, #17, August 1981.)

3. Interview with Professor Joe D. Francis, Cornell University Department of Rural Sociology, April 9, 1984.

4. Joe D. Francis and Wendy F. Graham, Community Water Supply Organization in the Adirondacks: Assessments of Social, Economic, Political, and Environmental Influences, Cornell University, Department of Rural Sociology, November 1983, pp. 115, 170, 174.

5. Joe D. Francis and Wendy F. Graham, pp. 111, 113, 174.

6. Joe D. Francis and Wendy F. Graham, p. 152.

7. Joe D. Francis and Wendy F. Graham, p. 105.

8. Joe D. Francis and Wendy F. Graham, pp. 102, 149.

9. Joe D. Francis speaking at seminar on local water supply, hosted by the Cornell University Department of Agricultural Economics, Albany, NY, February 21, 1984.

10. Joe D. Francis and Wendy F. Graham, pp. 120, 185, 189.

11. Joe D. Francis and Wendy F. Graham, Community Water Supply Organization in the Adirondacks: Assessment of Social, Economic, Political, and Environmental Influences, Executive Summary, pp. 5-6.

12. Interview with Lyle S. Raymond, Jr., Extension Associate and Water Resources Specialist, Cornell University Water Resources Program, April 9, 1984.

13. Robert Pomeroy, Productivity Improvement in New York State Local Governments: State Actions to Assist Local Governments, Cornell Agricultural Economics Research Paper, no. 83-18, Cornell University, Department of Agricultural Economics, 1983, p. 1.

Appendix 3

1. The ensuing description of distribution system elements amalgamates descriptions offered in several studies and texts:

   Betz-Converse-Murdoch, Inc., New York City Water Supply Infrastructure Study, Volume 1 Manhattan, prepared for the U.S. Army Corps of Engineers, New York District, 1980.

   G.M. Fair, J.C. Geyer and D.A. Okun, Water and Wastewater Engineering: Volume 1. Water Supply and Wastewater Removal, Wiley & Sons, 1966.

   G.M. Fair, J.C. Geyer and D.A. Okun, Elements of Water Supply and Waste-water Disposal, Wiley & Sons, 1971.

   H.W. Gehm and J.I. Bregman, ed., Handbook of Water Resources and Pollution Control, Van Nostrand Reinhold, 1976.

   Mark J. Hammer, Water and Waste-Water Technology, Wiley & Sons, 1975.

   Ernest W. Steel, Water Supply and Sewerage, McGraw-Hill, 1960.

   T.H.Y. Tebbutt, Water Science and Technology, Harper & Row, 1973.

   U.S. Army Corps of Engineers, Baltimore District, Urban Water Supply System Rehabilitation Needs Study - Binghamton, New York, 1980.

   Rodger Walker, Water Supply, Treatment and Distribution, Prentice Hall, Inc., 1978.

2. Comptroller General of the United States, Additional Federal Aid for Urban Water Distribution Systems Should Wait Until Needs are Clearly Established, November 1980, p. 8.

3. Comptroller General of the United States, p. 8.

4. Ray A. Jackson, "Keeping a Century-Old Water System Young," Journal of the American Water Works Association, 72, September 1980, p. 492.

5. Stanley T. Fletcher, "Designing and Installing Large Steel Water Mains to Prevent Failures," Journal of the American Water Works Association, November 1982.

Steel, pp. 105-108.

Tebbutt, p. 88.

6. Hammer, pp. 202, 204.

Steel, pp. 152-156.

Tebbutt, p. 90.

7. Fair et al, 1966, pp. 16-2, 16-3.

Fair et al, 1971, pp. 183-189.

Gehm et al, pp. 269-275.

Hammer, pp. 129, 186.

Appendix 4

1. Congress of the United States, Congressional Budget Office, Public Works Infrastructure: Policy Considerations for the 1980's, 1983, p. 134.

2. Presentation by Professor John Boland of Johns Hopkins University at the Annual Meeting of the Association of American Geographers, Washington, D.C., April 24, 1984.

3. Presentation by Professor John Boland of Johns Hopkins University at the Annual Meeting of the Association of American Geographers, Washington, D.C., April 24, 1984.

4. President's Intergovernmental Task Force estimate, quoted in Congress of the United States, Congressional Budget Office, p. 135.

5. Patrick C. Mann and Paul R. LeFrancoise, "The Real Price of Urban Water," Journal of the American Water Works Association, 74, January 1982, p. 22.

6. According to Mann and LeFrancois.

7. Cited in "State Water Chiefs Insist Financing Help is Needed," Engineering News Record, 210, April 14, 1983, p. 13.

8. New York State Department of Health, Bureau of Public Water Supply Protection, Facilities Needs Survey of Community Public Water Systems, April 1983, p. 49.

9. Joe D. Francis and Wendy F. Graham, Community Water Supply Organization and Performance in the Adirondacks: Assessment of Social, Economic, Political and Environmental Influences, Cornell University Department of Rural Sociology, November 1983, pp. 185-189.

10. Interview with Lyle Raymond of the Cornell University Cooperative Extension Water Resources Program, April 9, 1984.

Also, interview with Robert Hennigan, State University of New York College of Environmental Science and Forestry, May 11, 1984.

11. Robert T. Symonds, "Water Utility Financing Through a Water Bank," Journal of the New England Water Works Association, 91, March 1982, p. 64.

12. According to Joseph H. Kuranz, "Federal Aid for Aging Distribution Systems: Tempting But Unwise," Journal of the American Water Works Association, 72, June 1980, pp. 12, 48.

13. Kuranz, p. 48.

14. Subcommittee on Urban Water Supply, The President's Intergovernmental Water Policy Task Force, Urban Water Systems: Problems and Alternative Approaches to Solutions, 1980, p. IV-3.

15. Harry P. Hatry, Maintaining the Existing Infrastructure: Current State of the Art and Practice of Local Government Planning, The Urban Institute, 1981, p. 7.

See also: Congress of the United States, Congressional Budget Office, pp. xiv, 31.

16. Comptroller General of the United States, Additional Federal Aid for Urban Water Distribution Systems Should Wait Until Needs are Clearly Established, November 1980, p. 41.

17. Comptroller General of the United States, p. 41.

18. New York State Department of Health, Bureau of Public Water Supply Protection, Inventory - Community Water Systems, New York State, Volume I, Municipal, 1984, pp. vi, vii.

19. Temporary State Commission on the Water Supply Needs of Southeastern New York, Institutional Arrangements and Alternative Futures, December 1973, p. 168.

20. Larry B. Morandi and Greg H. Lazarus, Water Resource Management: Issues and Policy Options, National Conference of State Legislatures, November 1982, p. 48.

21. The United States District Court upheld the zoning change in Omnie Properties, Inc. vs. Town of Brookhaven (Docket #77-C-574, 12/26/79):

> The central objectives sought to be achieved by rezoning the subject property and its environs to 2 acre residen-

tial use were to minimize the density of population in that area and to maintain undisturbed as much of the area as possible in order that the quality of drinking water and groundwater might be maintained...Both of these objectives are legitimate and proper governmental purposes. (Morandi and Lazarus, p. 48.)

22. Henry Hughes and Keith Porter, Land Use and Ground-Water Quality in the Pine Barrens of Southampton, Cornell University Center for Environmental Research, Water Resources Program, November 1983.

23. Chapter 942 of the Laws of 1896. The Burr Act was passed in response to concerns by Suffolk County that New York City would eventually claim Suffolk County water. As written, the law only applies to surface waters. The county has claimed all of its water under the law, but no judicial test has occurred. While New York City has long abandoned any plan to tap Long Island water supplies, the situation in Nassau County may result in a reexamination of the Burr Act.

24. Temporary State Commission on the Water Supply Needs of Southeastern New York, Institutional Arrangements and Alternative Futures, pp. 126-127.

25. Title K, Ch. 51, Administrative Code of the City of New York.

26. The problem has since been resolved by negotiation, but it appears that other upstate communities have had similar conflicts. (Interview with David Benson of Westchester County Department of Environmental Facilities, July 20, 1984.)

PUBLISHED REPORTS OF THE TASK FORCE ON CRITICAL PROBLEMS

Oil - It Never Wears Out. It Just Gets Dirty. A Report on Waste Oil. October, 1974. 39 pages.

Insurance and Women. October, 1974. 30 pages.

The Other Side of Crime...The Victim. January, 1975. 18 pages.

No Deposit, No Return... A Report on Beverage Containers. February, 1975. 106 pages and Appendices.

Subsistence or Family Care...A Policy for the Mentally Disabled. March, 1975. 37 pages and Appendices.

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One in Every Two...Facing the Risk of Alcoholism. February, 1976. 101 pages.

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The Three Billion Dollar Hurdle...Information for Financing Education. April, 1976. 66 pages.

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Accused and Unconvicted...A Brief on Bail Practices. Janaury, 1978. 77 pages.

Office of Business Permits...A Business Permit Assistance Program. March, 1978. 79 pages.

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Old Age and Ruralism...A Case of Double Jeopardy. May, 1980. 260 pages.

The 1980 Census...Where Have All the People Gone? November, 1980. 50 pages.

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E+S=$^{2}...Energy in Schools Costs Too Much. June, 1982. 182 pages.

Bolstering New York State's Human Services...ANY VOLUNTEERS? October, 1982. 134 pages.

A Report on the Problems of New York State's Beginning Farmers...FOOD FOR THOUGHT. March, 1983. 136 pages.

Educational Partnership: Nonpublic and Public Elementary and Secondary Education in New York State. October, 1983. 166 pages.

Tending the Vineyards: Renewed Growth for New York's Grape/Wine Industry. April 1984. 112 pages.