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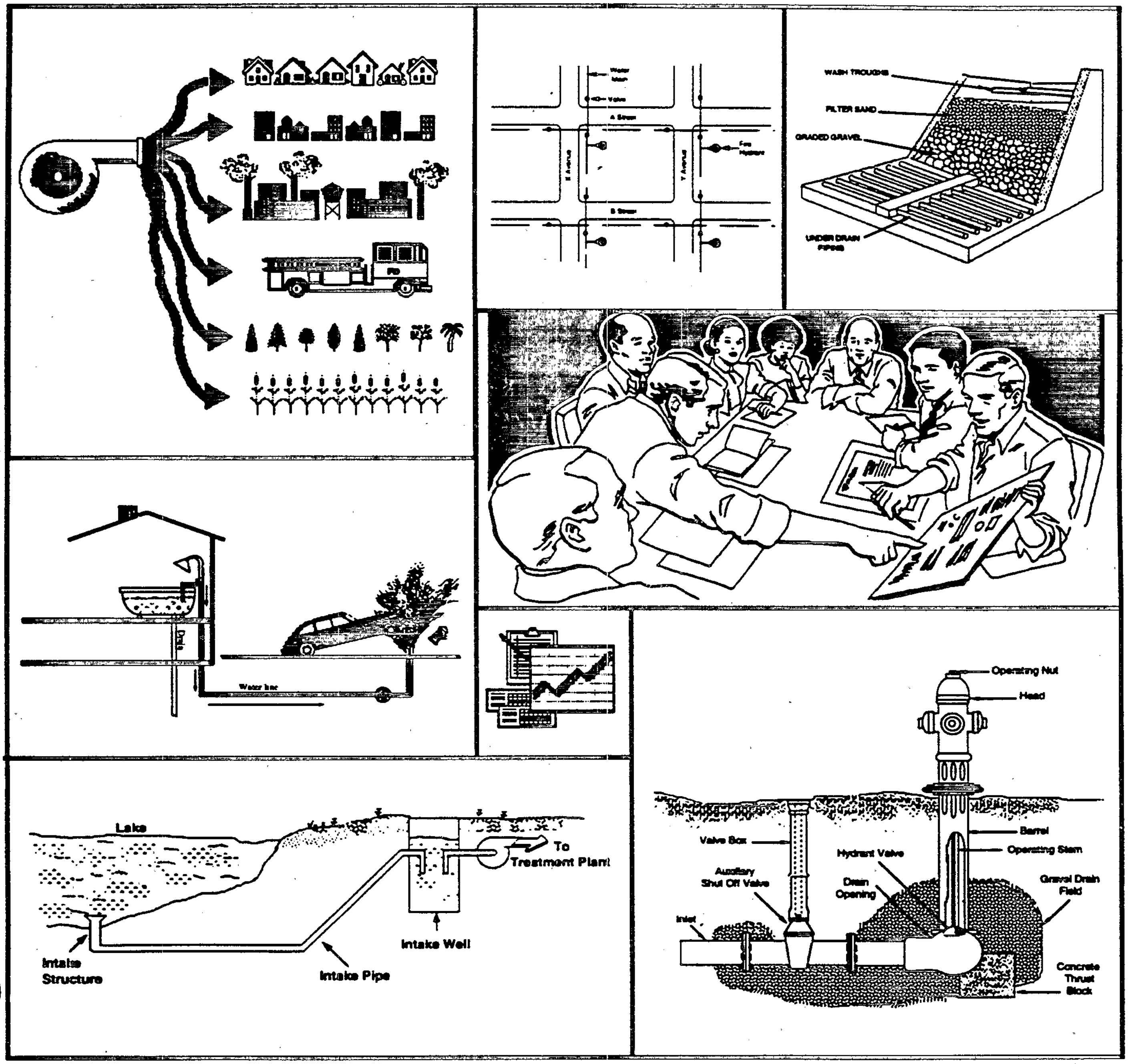
DRINKING WATER HANDBOOK FOR PUBLIC OFFICIALS



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Acknowledgement

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Introduction

Water is one of our country's most vital resources. It covers over two-thirds of our planet, makes up almost two-thirds of our bodies, and is present in almost every type of food and drink.

Americans rely on safe, clean water for many purposes such as cooking, cleaning, bathing and, most importantly, drinking. Adequate supplies of water are also necessary for uses such as manufacturing, agriculture, fire fighting, and sewage disposal.

Purpose Of This Handbook

About 15% of the population of the United States receives their water from private wells and springs. The rest rely on public water systems to gather, treat, and deliver safe, palatable water to their homes every day. The drinking water used by offices, businesses, schools, and recreational facilities is also usually furnished by a public water system.

Many public water systems are owned and operated by cities or other governmental bodies such as counties, townships, and water districts. The responsibility to govern and make decisions on the operation and management of these systems therefore falls on board members and other decisionmakers who generally have little training or experience in water system operations. Public officials are also often involved in providing oversight of small privately owned water systems.

Acquainting public officials with how water systems should be properly operated and managed is becoming increasingly important. Federal and state regulation of public water systems has become much more stringent and complex in recent years. Further, the technology being used for water processing and the demands of the public for better-quality water at the lowest cost have complicated water system operation and management.

This handbook has been created especially for public officials to assist them in understanding water system operations. Explanations are provided from the standpoint of a decisionmaker, how public water systems work and why they must be properly constructed, maintained, and operated.

Water Quality Concerns

Many individuals are concerned about the safety of their tap water. Media reports frequently tell of newly identified drinking water contaminants and often dramatize a particularly bad situation that has been found. Customers often want to know if these problems might threaten their water system and what system managers are doing to ensure that their drinking water is safe.

Some current issues concerning contamination of drinking water are:

Lead Poisoning—Lead was widely used for water service pipes and in solder used for joining pipes for many years. New findings indicate that lead can dissolve into drinking water and create a health danger.

Chemical Contamination—Well water can no longer be assumed to be pure. New chemical tests show that many public water system wells have been tainted by industrial and agricultural chemicals. Recent toxicological information indicates that exposure to these chemicals at levels as low as a few parts-per-billion could have the potential to cause cancer, illness, or damage to the human body.

Ground Water Protection—Widespread contamination of ground water has been caused by carelessness in the handling and disposal of manmade chemicals. Among the principal causes of ground water contamination are leaking underground storage tanks, leachate from landfills, agricultural chemicals, and improper disposal of toxic wastes. To prevent further contamination of ground water and protect the public, new regulations have recently been established governing the handling and disposal of chemicals. Regulations also govern well sites and in some cases limit activities on the ground surface over well recharge zones.

Radioactivity—Some public water system wells are contaminated by naturally occurring *radium* and *uranium*, at levels that are considered a danger to public health. *Radon* gas has also been detected in a great number of wells at levels considered unacceptable.

Disinfection By-products—It has recently been found that hazardous by-products are formed when water treatment disinfectants react with substances in the source water to form chemicals that may be hazardous to health. *Trihalomethanes* (THMs) are cancer-causing chemicals that are formed by chlorination in some water systems.

Biological Agents—There are a number of disease-causing microbiological forms found in water sources that can contaminate drinking water unless care is taken for proper treatment and handling of the water. Of particular concern are *Giardia* cysts, viruses, *Legionella*, various bacteria, and *Cryptosporidum*.

Public officials must keep abreast of the new drinking water quality concerns and consider their effect on local water systems. They should ensure that the system is in compliance with state requirements, that water samples are regularly analyzed and that plans are promptly made to make system improvements when required.

Legal Responsibilities

Public officials should also be aware of legal responsibilities which can apply to water system owners, public officials, managers and operators. These may occur from two different causes: *failure to comply with specific regulations*, and *general common law negligence*. The greatest potential for liability comes from the violation of federal, state, and local laws and regulations.

Ensuring water safety is becoming increasingly complex. The number of different types of disease organisms and toxic chemicals that are identified as potential drinking water contaminants continues to increase. This threat of contamination places increased responsibility on system operators and managers to monitor and test water quality, maintain specific treatment methods and take prompt and appropriate action whenever contamination is identified.

State laws often place direct responsibility on the owners and/or operators of a public water system to ensure that all laws are adhered to and good operational practices are followed. *Enforcement action* for failure to meet regulations is usually directed against the responsible officials of a water system, water district, municipality, or company. These responsible officials must also answer to their stockholders, employers, or constituents for the embarrassment and financial cost of their neglect.

Managers, officials, and employees of a water system may also be exposed to *civil suit* for damages if the improper or negligent operation of the system results in injury or property damage. Although municipalities were once considered immune from suits, the courts are increasingly sympathetic to claims where the cause can be shown to be negligence or failure to employ generally accepted operating practices.

Moral Obligations

The primary purpose of a public water system is to provide adequate quantities of water that are palatable, safe, and reliable. Providing this service places the owners, managers, and operators of the system under a moral obligation to meet the purposes to the best of their ability.

Customers dissatisfied with the service provided by a private- or investor-owned system can usually obtain improved service by appealing to the company indivdually or as a group. If the company does not correct the problem, the public has the option to appeal to the State Public Utility Commission for restrictive action against the company.

Customers dissatisfied with the service of a water system operated by a city or other governmental body may ask that system employees be censured or replaced if the problem is being caused by their inefficiencies. When the problem is being caused by incompetence or lack of leadership from the public officials responsible for the water system, the public can act to replace them. In states where the state Public Utility Commission has some control over these systems, an appeal can be made to the Commission to restrict the system's future requests for rate increases, or take other action.

Information Presented In This Handbook

This handbook is intended to provide an overview of water system operation and management. The principal subjects covered are:

- General information about water systems.
- Regulations affecting water systems.
- Sources of water.
- Water treatment methods.
- Distribution of water to customers.
- Operation and management of water systems.

Sources Of Additional Information

There are many publications that detail public water system design and operation. Specific references have not been included in this handbook due to the large number involved and the frequency of revision. Regulation and technology are rapidly changing in the water supply field. Readers should keep in mind that publications that are more than a few years old may no longer be accurate.

Appendix A of this manual lists organizations that have additional information available on various aspects of public water system operation and management. Public officials are urged to call or write these organizations to obtain current publications lists and copies of publications relating to their water system and current interests. Many organizations have manuals on specific subjects available, which are easy to read and understand and available at nominal cost. There is also a growing number of video tapes available that can be purchased or sometimes obtained on loan through either the organization headquarters or from the state section of the organization.

Appendix B lists the addresses of the U.S. Environmental Protection Agency offices and the states within their region.

Appendix C lists the addresses of agencies having responsibility for public water supply overview in each state. Public officials should contact their state agency for a copy of all regulations, and other available information on water system operations.

Information on water system operations and management can also be obtained from officials and water supply professionals in larger water systems, consulting engineers, state public water supply program personnel, and local water operator groups.

Suggested Reading

Public water system officials and decisionmakers are urged to make use of all the information in this handbook in order to obtain an overall understanding of the water supply field.

For those who wish only to acquaint themselves with specific subjects, the following guide lists appropriate chapters by subject:

Local Water System Facilities	*Chapters*
Water is obtained from another supply, and your system provides only distribution to customers.	1, 5, 6, and 7
Your water system obtains water from *wells* and provides distribution of the water to customers.	1, 2, 4, 5, 6, and 7
Your water system obtains water from a *lake or river* and provides distribution of the water to customers.	1, 3, 4, 5, 6, and 7

Chapter 1

General Water Supply Considerations

Classification Of Systems

There are several ways to divide water supply systems into groups with similar characteristics. It is helpful to understand these groupings before discussing water supply operations.

Type Of Customer

The Safe Drinking Water Act enacted by Congress in 1974 provides a definition of a "public water system" that must be used throughout the United States. A *public water system* is a system that supplies piped water for human consumption and has at least 15 service connections or 25 or more persons who are served by the system, 60 or more days each year. The U.S. Environmental Protection Agency (EPA) is directed by Congress to implement the Act, and they have further divided public water systems into three categories based on the number and type of customers served.

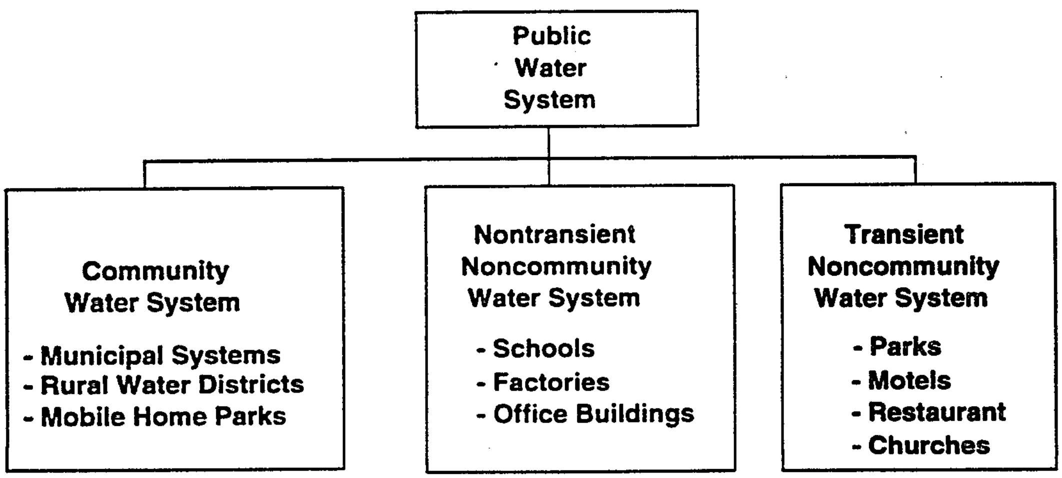
- *Community* public water system: a system where the customers are full-time residents.
- *Nontransient-noncommunity* public water system: an entity having its own water supply, serving an average of at least 25 persons who do not live at the location, but who use the water for over six months per year.
- *Transient-noncommunity* public water system: an establishment having its own water system, where people visit and use the water occasionally or for short periods of time.

Community and nontransient-noncommunity water systems are required to meet certain operating requirements and to do extensive monitoring to detect possible contamination. This is because customers are using the water over a long period of time and could have adverse health effects from the continuous exposure to relatively low levels of contamination. The requirements for transient-noncommunity systems are not as stringent because the water system customers use the water only occasionally.

EPA has also divided public water systems into general size classes as follows:

- *Very small systems* serving less than 500 persons.
- *Small systems* serving between 500 and 3,300 persons.
- *Medium-size systems* serving between 3,300 and 50,000 persons.
- *Large systems* serving over 50,000 persons.

Classification of Public Water Systems With Examples of The Types of Customer Served



Some federal regulations differ slightly for systems in each size class. In many cases, smaller systems are also given a longer time to implement new requirements.

Individual homes and water systems having fewer than 25 customers that have their own well, spring, or surface source of water are referred to as *private* or *non-public* water systems. Non-public systems are not covered by the requirements of the Safe Drinking Water Act. States and/or counties usually have separate requirements that apply to these water systems.

Private vs. Public Ownership

Some public water systems are owned by *private interests* such as an individual, partnership, or investor group. Others are owned by a *unit of government* such as a city, water district, or association. From the standpoint of federal and state drinking water regulations, no distinction is made between private and publicly owned systems. Both types of systems must meet the same requirements for monitoring, operation, and water quality.

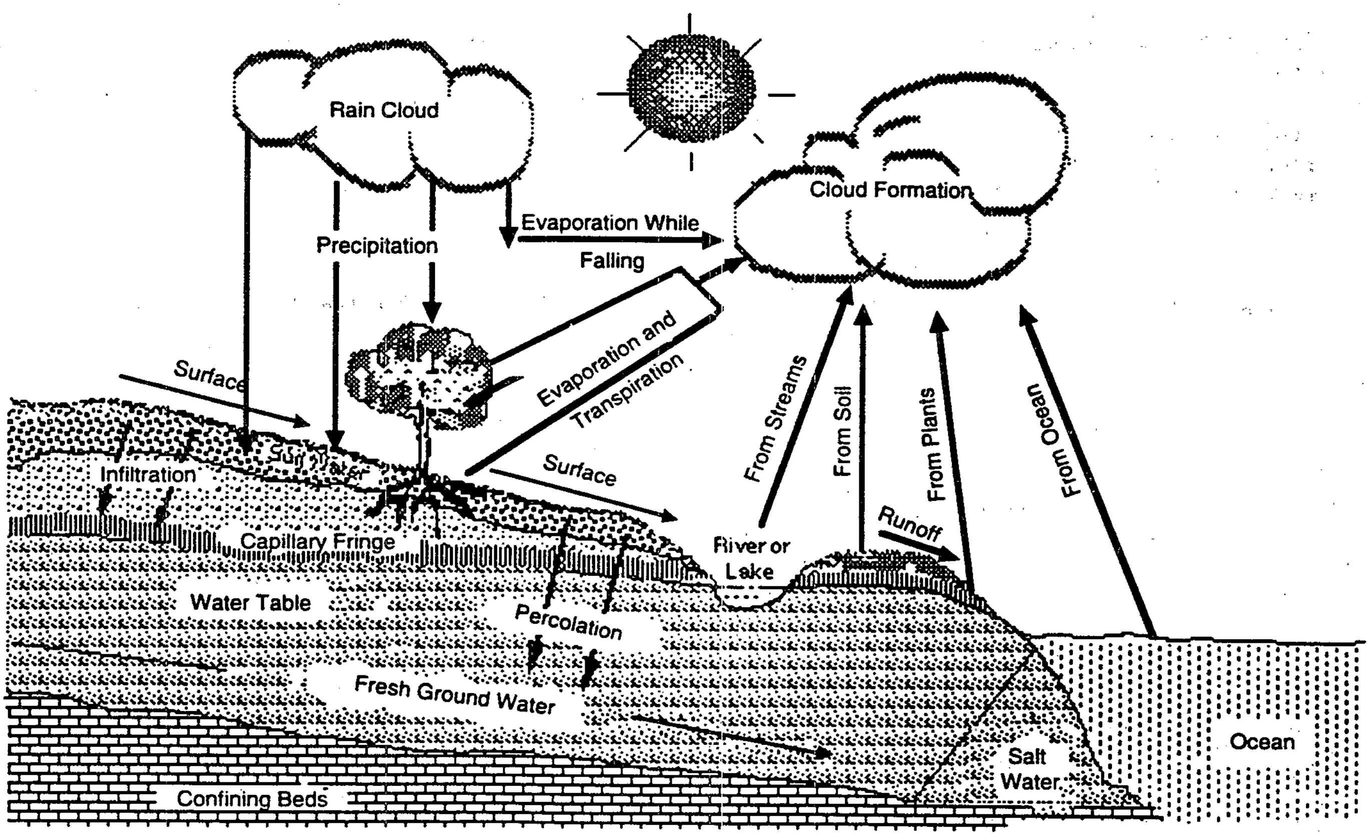
Water Sources

The hydrologic cycle continuously replenishes and redistributes the water on earth through precipitation, runoff, and percolation into the soil, evaporation, condensation, and precipitation again. This continuing cycle makes adequate amounts of fresh water available in most parts of the world as either ground or surface water.

Public water systems are generally classified by their water source since it has considerable bearing on quality of the water, the amount of water available, and the kind of treatment needed before distribution to the public.

Ground-water sources fall into the general categories of wells, springs, and infiltration galleries. Ground water is not typically subject to contamination by disease-causing microorganisms, but contamination by man-made chemicals is often possible. The water from most ground water sources is of acceptable quality with little or no treatment, but the quantity available for public water system use is often limited.

The Hydrologic Cycle



Fresh *surface water* is available in most of the world from rivers and lakes. Large rivers are important sources of water for public water systems, but smaller streams can also be used as long as the flow is reliable. Although water from some lakes and rivers is quite clean, surface water must frequently be treated to remove sediment and disease organisms before public use. When compared to ground water, surface sources usually require a larger investment in treatment facilities and have higher operating costs.

Many water systems are in a third class termed *purchased water systems*. These systems purchase water, that is usually already treated, from another water system or water authority. Their only business is to distribute the water. In some instances, the purchasing system can distribute the water directly to its customers. More often though, it must supply supplemental disinfection, additional storage, and re-pumping.

Both EPA and the states have, in recent years, strongly recommended "regionalization" of water systems. There are many advantages in operating one large water system over several small ones, such as lower operating costs and improved reliability of service. The advantages are even greater if there is a high cost in obtaining the water, or if it requires expensive treatment. In some cases, regional water systems take over the responsibility for both furnishing water and operating the distribution system in all of the member communities.

Water System Operating Considerations

Three aspects of public water supply operation that must be considered when managing and operating a system are *quantity, quality,* and *system reliability.*

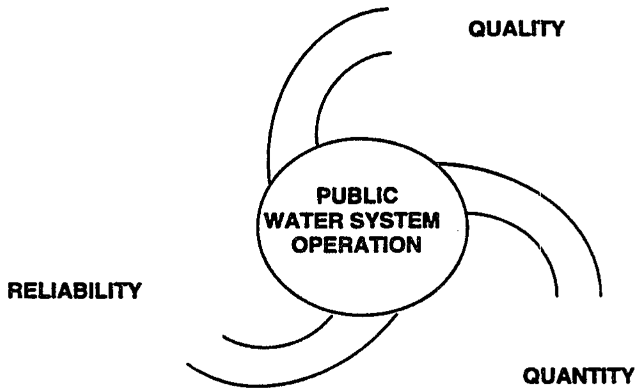
Water Quantity

A public water system must be capable of meeting all customer *quantity* demands under any conditions. Water use by customers generally falls into several categories.

Domestic use is the consumption by private homes and other living facilities and usually fluctuates by the time of day, day of the week, and time of year. On a normal day, there is a moderately high use in the early morning, much higher use in the evening, and relatively low water use through the night.

Commercial use is the water used by stores, offices, and other businesses. A few businesses such as laundries and greenhouses use larger quantities of water, but most commercial customers use relatively little water.

Operating Considerations



Industrial use is the water used by factories and industries. Many factories do not use water in manufacturing, so only require water for drinking, sewage disposal, and cleaning. A few industries use great quantities of water for cooling, cleaning, or incorporation into the product that is being manufactured. Industries frequently have fire sprinkler systems, which require a water service adequate for drawing large quantities of water in the event of a fire.

Industrial use is usually predictable but varies with the number of shifts worked and days of the week. In some cases, industries have wells or surface water sources for use in the plant processes, and only use water from the public water system for drinking and sanitary purposes.

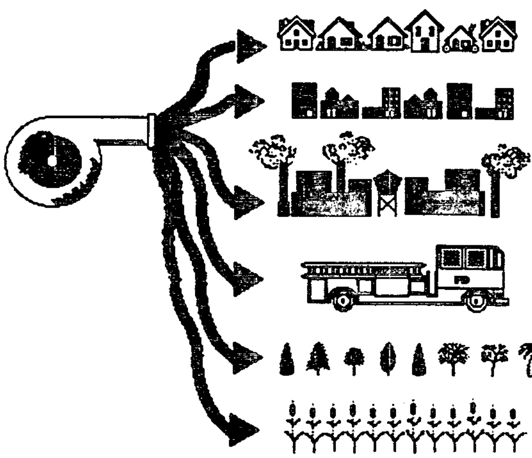
Irrigation use is the water used for lawn and garden care. While the billing for irrigation water is usually a part of the charge to domestic, commercial and industrial customers, this use requires special considerations by most water systems. Water systems in arid regions have almost a continual demand for irrigation water. Even in areas with normally plentiful rainfall, water demands on some systems may be three or four times greater than normal during dry months.

If source water is plentiful and the treatment facilities adequate, water systems generally try to supply as much water as customers want to use for irrigation. This requires that the system make investments in facilities that can meet the heaviest demands, but are then underutilized for most of the year. Where the availability of source water is limited, irrigation use is often discouraged by high water rates or sprinkling restrictions. If there is an extreme shortage of water, irrigation use may be banned.

Agricultural use of water from a public water system is not usually practical except where small quantities are required. In rural areas, where no other water source is available, water from a public system may be used for irrigating small areas of crops and fruit trees and watering livestock.

Fire use capability is the ability to furnish adequate amounts of water for fighting fires. The amount of water required for fire protection must be in addition to the domestic, commercial, and industrial use. A reserve ability to furnish adequate amounts of water in the event of a fire is achieved by maintaining additional pumps or wells or reserving treated water in storage.

Water Use



Water Quality

The *quality* of water is considered in two ways: the presence of contaminants that might cause adverse health effects and the aesthetic properties of the water.

Adverse health effects from contaminants in drinking water include many types of sickness, permanent body damage, or death. This may be caused by the presence of disease organisms or harmful chemicals in the water.

The *aesthetic qualities* of drinking water include characteristics that make the water unpalatable or bothersome to customers. Examples are hardness, taste, odor, color, and the tendency to discolor plumbing fixtures. Industrial users of water are often concerned with water quality as well, particularly if the water is incorporated into a product. The quality of water used for medical purposes, such as for dialysis, must also be monitored and closely controlled.

System Reliability

Water system reliability is absolutely essential. Losing pressure in the water distribution system for even a short time creates the possibility of the water being contaminated by disease organisms. Following a loss of pressure, the state will usually require the system manager to issue an order to the public to boil their water as a precaution until the distribution system can be flushed, sterilized, and tested safe.

The failure of treatment equipment while a water system is in operation also presents an opportunity for disease-causing organisms to contaminate the system. Adequate controls must be provided to make sure that water furnished to the public is properly treated at all times.

Public Water Supply Regulations

Regulations for the operation and monitoring of water systems serving the public were developed by states during the early 1900s, with policies and the degree of enforcement varying among states. Monitoring of water quality, technical assistance to water system operators, and enforcement of regulations were generally performed by the State Health Departments under individual state regulations.

Prior to 1974, federal involvement in drinking water consisted only of the development of drinking water standards by the U.S. Public Health Service. These standards suggested bacteria and chemical limits for public water systems. Although the standards were not federally enforceable, they were incorporated into the regulations of most states.

The Safe Drinking Water Act

During the 1960s and early 1970s, scientists and public health experts discovered previously unrecognized potential for harmful disease organisms and chemicals in drinking water. There was also increased pressure by the public and legislators to create uniform national standards for drinking water to ensure that every public water supply in the country would meet minimum health standards.

Accordingly, Congress passed the original *Safe Drinking Water Act* (SDWA) in 1974. The Act directs EPA to establish standards and requirements necessary to protect the public from all known harmful contaminants in drinking water, and asks the states to accept primary enforcement responsibility for enforcing the federal requirements.

The Act was re-authorized and amended in 1986. In doing so, Congress emphasized that EPA must set standards to keep abreast of the very latest knowledge of harmful contaminants and direct more rigid enforcement against water systems that violate the federal requirements.

A few of the more important federal requirements established under the SDWA are:

- *Primary drinking water standards* are established by EPA for microbiological and chemical contaminants that may be found in drinking water and could have adverse health effects on humans. The maximum concentration that is allowable is called the *Maximum Contaminant Level (MCL)*. All states must make their regulations at least as rigorous as those established by EPA. The primary standards are *mandatory* and must be complied with by all public water systems.

- *Secondary drinking water standards* established by EPA set recommended, non-enforceable, maximum contaminant levels for contaminants that affect water's taste, color, odor, or appearance.

- *Public notification* (PN) is required by the Act as the first step of enforcement against all public water systems that fail to comply with federal requirements. Systems that violate operating, monitoring, or reporting requirements or exceed an MCL, must inform the public of the problem, and explain the public health significance of their violation.

- *Formal enforcement* with stiff monetary fines may be leveled against systems that do not comply with the federal requirements.

Other Federal Regulations

The *Wellhead Protection Program* is a federal requirement that is not a direct part of the public water supply program, but will impact most water systems using ground water sources. This program was established after it was realized that many wells throughout the country have been contaminated by chemicals and substances spread, dumped, or leaked on the ground, or injected into the ground near wells.

Under the requirements of the Wellhead Protection Program, each state must develop a strategy for protecting wells from future contamination by limiting surface activity near vulnerable wells and selecting safe sites for new wells. Some of the prime considerations are the depth of the aquifer to be tapped, the area geology, and the types of human activity in the well recharge zone.

The *National Pollution Discharge Elimination System* (NPDES) is a program established under the *Clean Water Act* requiring that all waste water discharging to waterways meet federal effluent standards. Under the NPDES requirements, water system treatment plant wastes must meet effluent standards before discharge to a waterway, or another method of disposing of the wastes must be used.

The *Resource Conservation and Recovery Act* (RCRA) regulates hazardous waste production, transportation, storage, treatment, and disposal. Some chemicals used by water treatment plants must be stored and handled in accordance with RCRA requirements.

State Drinking Water Programs

The intent of the SDWA is for each state to accept primary enforcement responsibility (primacy) for the operation of the drinking water program within their state. To be delegated primacy, a state must establish all requirements, standards, and programs required by EPA. In return, the state receives a federal grant to supplement state funds to operate the program.

In states that agree to accept primacy, EPA delegates operation of the program to a state agency designated by the governor. In many states it is the State Health Department. In others it is delegated to a state environmental department such as the Department of Natural Resources, Pollution Control Agency, or state Environmental Protection Agency. When a state does not accept primacy, the EPA regional office ensures that federal drinking water requirements are met by public water systems in the state.

Under the provisions of the primacy delegation, each state must establish requirements for public water systems at least as stringent as those set by EPA. States occasionally establish some requirements more stringent than the federal regulation. As the federal requirements are periodically changed or expanded, each state must, within a prescribed period of time, make similar changes in their regulations and begin implementation and enforcement.

In addition to the federal requirements, each state also establishes requirements to ensure proper water system operation and protection of public health. Principal additional requirements by most states include mandatory certification of water plant operators, cross-connection control programs, and monitoring for additional water contaminants.

Requirements of other state agencies such as air and water pollution prevention laws, standards for handling of toxic chemicals, and labor practice laws also have an effect on water system operations.

Note: Although state drinking water regulations must be as stringent as federal regulations, they are often slightly different and include additional requirements. Public officials and water system operators should obtain a copy of current regulations from the agency with primary responsibility for the drinking water program for their state. A roster of these state agencies is included in *Appendix C* of this handbook.

State Functions

The major functions performed by state primacy agencies can be divided into the following categories.

Monitoring And Tracking. All public water systems must monitor water quality in several ways. On-site testing of water quality for chlorine residual and other indicators must be routinely performed by the water system operator. Periodically, reports of these tests must be furnished to the state agency.

Water samples must also be collected and analyzed for the presence of disease-causing organisms and toxic chemicals. The analyses of these samples must be performed by a certified laboratory. Samples may be collected by a state employee, or the state will instruct the water system operator on how and when samples should be collected and shipped to a laboratory for analysis.

States also require periodic reports on the operation of many water systems. The system operator must furnish information such as the amount of water furnished to the public, details of treatment provided and types and quantities of chemicals added to the water. The state staff then reviews, records, and analyzes this information as one means of ensuring proper operation.

Sanitary Surveys. A sanitary survey is an on-site inspection of a water system's facilities and operation. The survey is usually performed by a state employee, but the state may also approve another person. Survey visits range from yearly to once every several years, depending on the water source, treatment process, and resources available to the state.

A sanitary survey usually involves a review of operating methods and records and a physical inspection of facilities and equipment. The survey is designed to note problems or deficiencies that could cause contamination of the water supply or interrupt continuity of service. Surveys also produce recommendations on needed programs and changes to improve water quantity, quality, and reliability. The observations and directives made during the survey are usually furnished in writing to the water system owner or operator.

Plan Review. The SDWA requires states to review plans for water system construction and improvement. Plans and specifications prepared by a professional engineer must be submitted for approval before work begins on the installation or replacement of pumping, treatment, and distribution system equipment.

Technical Assistance. One of the staff functions of the state drinking water program is to provide system owners and operators with technical assistance. Field staff with training and experience in water system operations and problem solving are usually available to provide advice and assistance, or recommend other sources of assistance.

Laboratory Services. Chemical and microbiological testing of water must be performed by a state- or EPA-certified laboratory. Some laboratories are certified to perform a wide variety of tests while others specialize only in certain analyses.

Most states have state-operated laboratories available to perform drinking water tests. Some states limit the number of samples that will be processed for a water system in the state laboratory, so additional required samples must be analyzed at a commercial laboratory. Some states charge for laboratory services by the sample, or as a yearly fee.

Enforcement. Because of the direct relationship between drinking water and public health, public water system operators generally do not willingly disregard state and federal requirements. Most violations of federal requirements are due to failure by the system operator to properly monitor water quality. The SDWA requires states to use enforcement actions when federal requirements are violated. The Act further directs EPA to take action against systems when a state does not properly enforce the law. Enforcement may result in substantial fines against a water system owner or operator where violations are not promptly corrected.

Chapter 2

Ground-Water Sources and Treatment

Sources Of Ground Water

In most of the United States, water can be obtained by digging or drilling into the ground. Shallow holes will produce water in some places, while in others it may be necessary to drill hundreds of feet through earth and rock to reach water. However, the quality of water obtained from a well may not be desirable or even usable for drinking water without treatment. It is technically possible to treat just about any water to acceptable quality, but it may not be affordable.

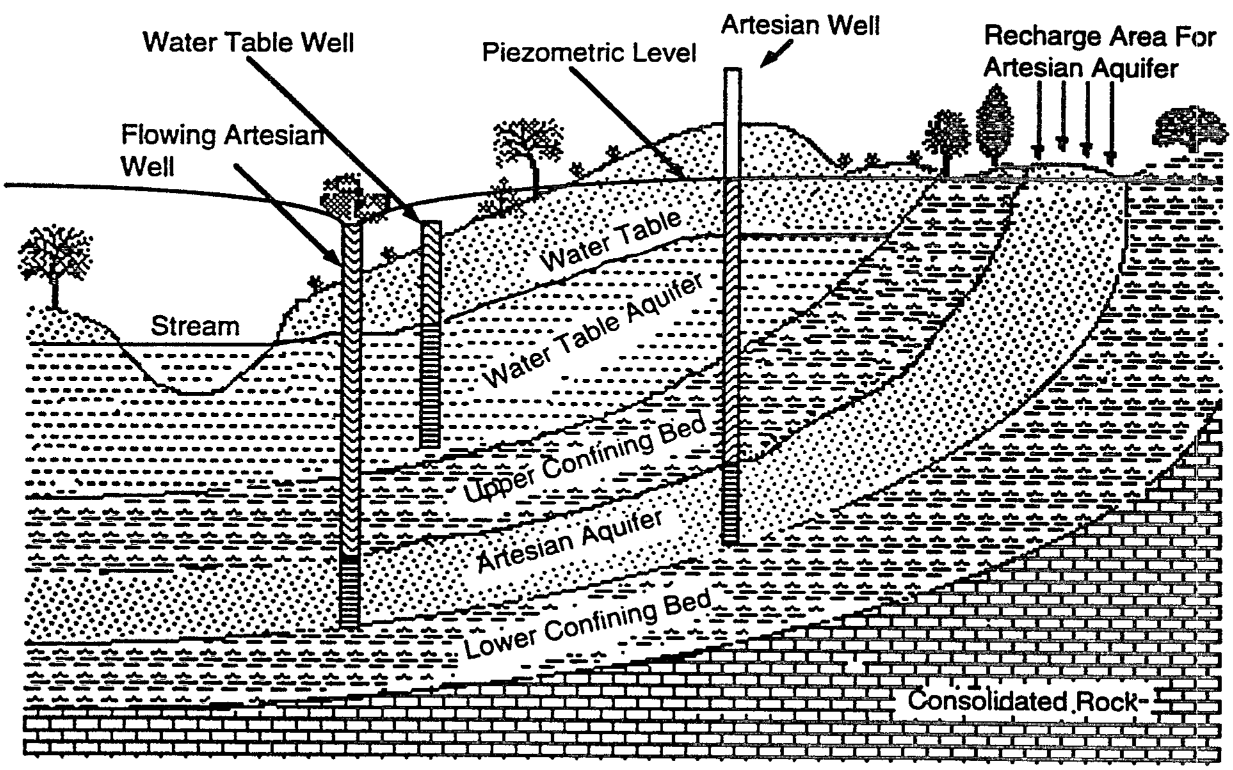
Although ground water can be found in most areas, the quantity is not always enough to meet all water supply needs. While the water available at some locations can supply individual home wells, it may not be enough to furnish the requirements of a public water system.

Aquifers

A portion of the water that falls on the earth as rain or snow seeps into the soil and flows downward by gravity until it contacts a layer of rock or other impenetrable material. It then moves in a general downhill direction, taking the path of least resistance. The layer of soil, sand, gravel, or rock through which the water moves is called the "aquifer," and the level of the water surface in the aquifer is called the "water table." In general, the level of the water table follows the surface of the ground above, although some conditions cause exceptions.

The movement of water through an aquifer is generally quite slow. Water may travel 20 feet or more a day in coarse sand. In fine sandstone it may move only a few feet in a year. In some areas only a single aquifer exists.

Ground Water Aquifers



Where there are several aquifers, each separated by a layer of material such as clay, the quantity and/or quality of water may vary greatly, so wells may be constructed to select those most suitable for public water supply use.

Sand and gravel aquifers are usually the most suitable for public water system use because of their relatively high productivity. Often the aquifer is a buried river valley or the bed of an ancient lake.

Sandstone is porous and often yields water of good quality in sufficient quantity to supply public water systems. Limestone is not very porous, but often has cracks and cavities that can provide good quantities of water. Sometimes ground water dissolves minerals in the limestone to form underground rivers or caverns that can be tapped as a public water supply source.

A spring forms when ground water flows naturally from rock or soil onto the land surface. Water flowing from a spring may travel hundreds of miles from where it seeped into the ground, or could be from a source only a few yards away. Springs should be assumed to be carrying surface water contamination unless it is proven that the water is consistently safe.

Gravity And Artesian Wells

A *gravity well* is a hole or shaft sunk from the ground surface to an aquifer that is not under pressure. Water must then be pumped from the aquifer level to the surface for use.

An *artesian well* has been constructed to tap an aquifer that is located under a confining layer, and the water is under some pressure. In some cases, the pressure is sufficient for the water to flow to the ground surface without pumping. Often, though, after an artesian well has been used for a period of time, the pressure reduces until the water no longer flows to the surface.

A well is still called artesian if the water level rises in the column above the top of the aquifer. For instance, a well 1500 feet deep may tap an aquifer having sufficient artesian pressure for the water to rise to within 500 feet of the surface. In this case, the water would only be pumped 500 feet to the surface for use.

Ground Water Protection

Environmental protection has only recently been directed to the problem of ground water contamination. New chemical tests and more complete sampling of well water has revealed a large number of public water supply wells contaminated by careless use and disposal of man-made chemicals.

Each state is now implementing strict regulations to protect underground sources of water. Some actions being taken are:

- New requirements for installation and testing of underground storage tanks.
- Increased regulation for handling, use, and transportation of toxic chemicals to reduce the possibility of spills.
- Greatly increased regulation of landfills and other waste disposal locations.
- Closer control of the use of pesticides and agricultural chemicals.
- Sampling and monitoring of identified ground water contamination locations, and in some cases, action to remove the contamination.

Ground Water That May Be Directly Affected By Surface Water

Under new federal requirements, each state must review the depth and type of construction of all ground water systems and determine if they should be considered "ground water under the direct influence of surface water." If a state determines that a well is vulnerable to contamination by surface water disease organisms, the well water must be treated under the same requirements as a surface water system. The requirements include mandatory disinfection and filtration in some cases.

Well Drawdown

The operation of gravity wells tends to create a cone-shaped depression in the ground-water table surrounding the well. This is called the "cone of depression," and the distance that the water level is lowered in the well after a period of operation is called the "drawdown."

The diameter of the cone of depression and the draw-down varies with the size of the well and the water flow rate through the aquifer. In porous sand and gravel the depression may be small. In denser soils it will be very significant. Wells are normally placed far enough apart so that their zones of depression do not overlap. It is also common practice to pump wells that have a significant draw down for only a few hours each day to allow the aquifer to recover.

The long-term capacity of an aquifer can be determined by tests and study of the geology of the area. Water systems managers who are unsure of the amount of water available may consult state geological experts or professional firms.

Well Construction And Operation

Siting Considerations

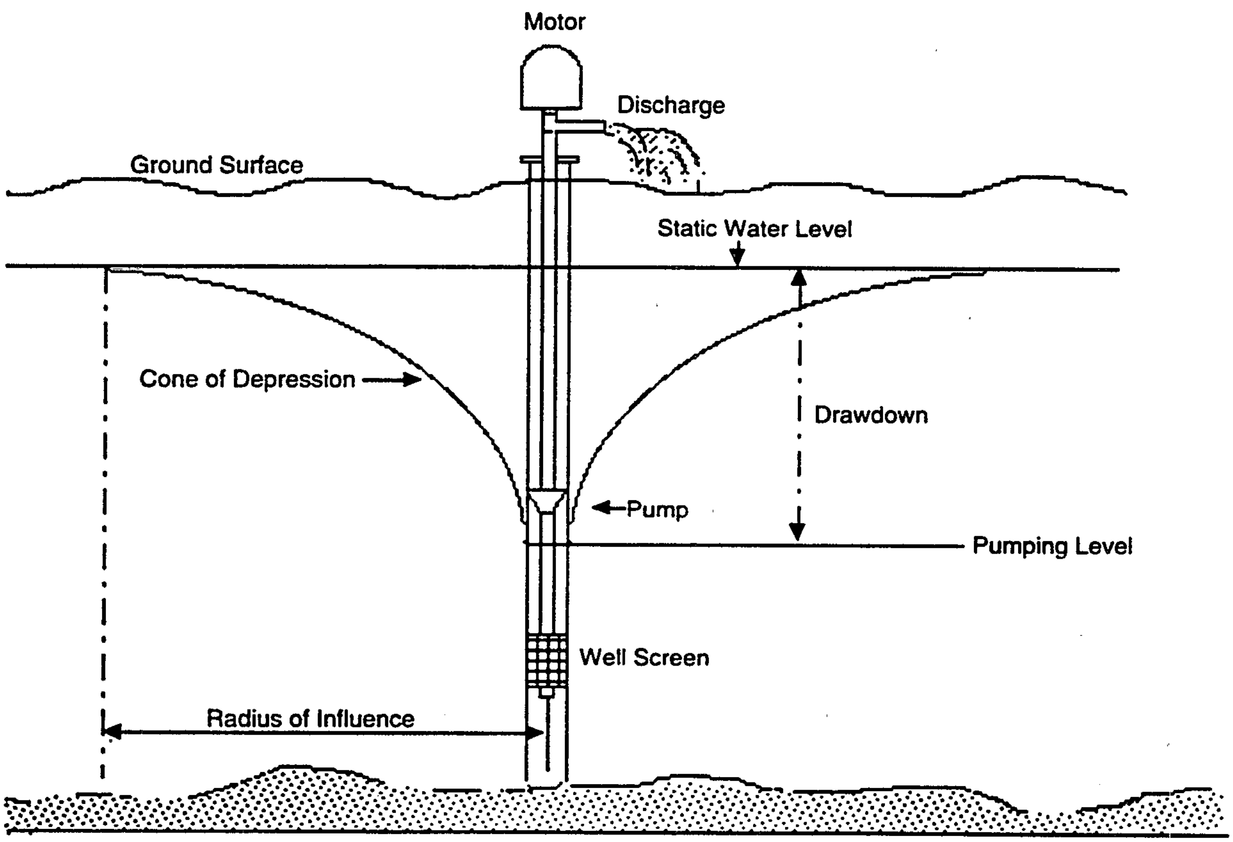
Wellhead Protection. In the past, the prime considerations in selecting sites for public water supply wells were the availability of water and cost of the land. As a result, it is not unusual to find old water system wells next to the village hall or fire station.

New chemical tests have shown that many wells have been contaminated by industrial and agricultural chemicals. As a result, Congress has required states to develop *Wellhead Protection Programs.* Wells must now be located where they will not be contaminated by activities in the well recharge area. The requirements vary with state policies, but the prime considerations are well depth, geology of the area, and the types of chemicals that might be applied, spilled, or dumped on the surface over the well. State wellhead protection policies will have a very significant bearing on the allowable locations for siting new wells.

Widely Spaced Wells. If water of good quality is generally available at any point under a community and special treatment is not necessary, public water systems often spread wells out around the distribution system. This has the advantage of keeping the zone of influence of the wells separated and reducing the need for large-diameter transmission water mains. The disadvantage is that if it is ever necessary to provide special treatment of the water, a separate treatment system must be installed at each well.

Well Fields. When an aquifer is very productive and wells have a small zone of influence, wells may be located close together in a well field. Having the wells in a group has the advantage of simplified monitoring and

Water Well Terms



maintenance, and allows water from all of them to be treated at a single plant before it is pumped to the distribution system.

Flood Protection. The potential of flooding is a prime consideration in selecting a well location. This is to prevent possible contamination by surface water during a flood and to guard against water damage to the mechanical and electrical equipment. State laws generally prohibit construction of wells in a flood zone.

Finding Productive Aquifers. The best way to determine locations for establishing productive wells is from knowledge of the geology of the region and the experience of existing wells. Most states have an agency that keeps geological records and can furnish information on likely aquifers. Good information on the experience with wells in an area is usually available from local well-drilling firms.

Locating aquifers that will supply deep, high-capacity wells can sometimes be assisted by *geophysical prospecting*. Firms specializing in this type of work use scientific instruments to determine potential water-bearing strata.

If the quality or quantity of water available in a deep strata is not known, it is usually advisable not to drill a full-size well until more information is obtained. Small-diameter test holes may be drilled first and tested over a period of time. Several test wells may be used to determine the direction of ground water flow and extent of the field of underground water.

Water Rights. Water rights laws vary from state to state and may restrict the amount or locations where a public water system can withdraw water. These policies may have considerable bearing on the siting of new wells and should be carefully reviewed before contracting for new well construction.

Well Construction

Principal well construction methods include *dug, jetted, bored, driven*, and *drilled*. Most wells serving community public water supplies are either bored or drilled.

Dug wells are excavated by hand or machines, and the walls lined with rocks, bricks, wood, or concrete to prevent caving and entry of surface water. Dug wells are usually shallow, and because of the type of construction, may be subject to surface contamination.

Jetted wells are constructed using a drill bit and drill rod that are hollow so that water can be forced down to wash the cuttings to the surface as the drill progresses. This method can only be used in soft, unconsolidated soil. When soil conditions are suitable, it is the fastest method of sinking a well and can be used for wells up to 400 to 500 feet deep.

Driven wells consist of a pipe fitted with a "well point" having a screen-covered body for drawing in the water. In porous soil with no rocks, a two- or three-inch diameter pipe can be pounded into the aquifer as far as 50 or 60 feet.

Bored wells are constructed where the earth is soft and the aquifer is not over about 40 feet deep. The hole is bored by hand or with power-driven auger bits and then lined with brick, concrete, metal, tile, plastic, or concrete pipe.

Drilled wells are used where a larger diameter pipe is needed, where hard ground or rock may be encountered, or where the well must be deep. Drilling requires the use of a derrick or crane to hold the drilling tools. The drilling bit is forced through the earth and rock by being repeatedly lifted and dropped on the end of a cable or by being rotated on the end of a shaft.

Drilled wells are most commonly installed for public water systems because it is often necessary to tap deeper aquifers to obtain adequate quantity or obtain the best water quality. Drilled wells can also be constructed with a large diameter for installation of large capacity pumps.

Casing And Screens

If a well is to withdraw water from sand or gravel aquifers, it must be constructed with a casing down to the desired area of withdrawal, and fitted with a screen at or near the bottom. The openings in the well screen must be carefully sized to allow water to enter freely, but prevent sand from entering.

A well developed to use water from a sandstone or limestone aquifer is usually cased down to the top of the aquifer, and the intake portion of the well is an open hole drilled into the rock.

When there are several waterbearing aquifers, some usually have better water quality than others. In this case, the well casing is carried through the poor quality aquifers, and open or screened only to those with the best quality.

In construction, it is important to seal around the casing pipe to prevent contamination of the well by chemicals and organisms near the well at the ground surface. Grout is usually forced into the earth around the casing to form the seal.

Well Pumps

Several different types of pumping equipment are available for lifting water out of wells. The selection of the method and equipment is primarily dictated by the water depth and the quantity of water to be pumped.

Piston pumps are used for hand-pumped wells. In general, piston pumps do not have adequate capacity or efficiency to meet the needs of public water systems.

Suction pumps work on the principle of creating a vacuum and allowing atmospheric pressure to push the water up to the pump level. This type of pump can only be used with relatively shallow wells.

Ejector pumps are operated by a centrifugal pump at the ground surface that forces water at high pressure down a drop pipe into the well. At a point below water level, the water is directed through a venturi tube, and into a riser pipe back to the surface. The jet action of the venturi carries additional water with it to the surface. A portion of the water is drawn off for use, and the remainder is pumped back down the drop pipe. Although jet pumps are widely used for private home wells, they do not have sufficient capacity to meet the needs of most public water systems.

Turbine well pumps have a vertical shaft motor located at the ground surface, and use a long drive shaft extending down the well to operate the pump suspended below the water level. The pump unit must be relatively small in diameter to fit down the well casing, and usually has several pump "stages" in order to develop adequate pressure to lift the water to the surface.

Turbine pumps are widely used by public water systems because they are available in a wide variety of capacities and can be designed to produce almost any desired pressure. The motor is easily accessible at the surface for maintenance and repair as well. Turbine pumps though, are expensive to install and maintain at greater depths. The deeper a pump must be placed, the larger it must be to pump water to the surface, and the heavier the drop pipe and drive shaft connection to it must be.

Submersible pumps combine a turbine pump with a waterproof motor that can be dropped into a well as a single unit. The unit only needs to be connected to the surface by the discharge pipe, power wires, and a lifting cable. Submersible pumps are made in sizes ranging from small pumps used for private home wells to very large units that pump hundreds of gallons per minute for public water systems.

Well System Operation

Monitoring

Water Level And Pumping Rate. Good operating practice requires that well water levels be measured periodically, both while the pump is idle (static level), and while the pump is operating (drawdown level). Changes in static and drawdown levels should be periodically reviewed for trends. If the capacity of the aquifer is exceeded with a sand or gravel well, the water system will probably soon be out of water. If the water table is dropping in a bedrock well, the pump will eventually have to be lowered in the well or may have to be replaced.

Monitoring of well levels and pump discharge can also provide information about problems within the well. Decreased productivity of a well may be due to a plugged screen or aquifer, or worn pump parts. Repairs to correct these problems should be scheduled before they become serious.

Water Quality. State regulations require periodic monitoring of microbiological and chemical quality. If laboratory analyses identify contamination in a well, the water system operator will be notified to take additional samples to confirm the initial results. If *microbiological contamination* is confirmed, state staff will advise on steps that must be immediately taken to identify the source of contamination, disinfect the well, and provide required public notification.

If *chemical contamination* is found to be present, but it does not exceed the maximum contaminant level (MCL), the state will usually require increased monitoring to determine whether the concentration is increasing. If further testing confirms chemical contamination at levels exceeding the MCL, use of the well must be discontinued or treatment installed to reduce the level of contamination.

Owners and operators of wells which have been identified as having increasing levels of contamination should immediately begin assessing their alternatives for correcting the problem. The major choices that may be considered are to:

- Attempt to locate the source of contamination and see if stopping it will allow the aquifer to return to normal.
- Determine if the plume of contamination flowing toward the well can be blocked or intercepted.
- Determine if it is economically feasible to treat the water to remove the contamination.

- Investigate whether altering the well to draw water from a different aquifer is feasible.

- Investigate the feasibility of drilling a replacement well at another location where there is no contamination.

- Investigate whether water from the contaminated well can be blended with water from an uncontaminated source to maintain the finished water level below the MCL.

- Investigate changing to a surface water source.

- Investigate purchasing water from another water system.

Although ground water quality is normally constant, it is possible for certain quality features to gradually change. It is therefore advisable to periodically review all analysis records for changes. Variations in parameters such as hardness, pH, salinity and nitrate or other chemical concentrations may indicate quality changes that will eventually require treatment or abandonment of the well.

Maintenance

Most wells require periodic maintenance. One of the most common well problems is incrustation of the well screen or of the gravel pack around the screen. This may be due to release of dissolved minerals from solution, chemical reactions, or biological activity. The principal problem material is calcium carbonate which forms a scale on the screen and cements together particles of sand and gravel. This can usually be removed by a chemical process. In some cases, maintenance of a well must be done as often as yearly.

Clogging of the screen may also result from sand lodging in the openings. Cleaning must be done by a special process, so as not to damage the screen.

Water samples from wells developed in sand aquifers should also be periodically inspected for the presence of sand. Sand is harmful in the distribution system and will also quickly wear pump parts. The sand removed from around the screen could also eventually cause collapse of the well or surface structures. A broken well screen usually causes the pumping of sand and may be repairable, but more likely, the well will have to be replaced.

Ground Water Treatment

It is becoming increasingly common for public water systems using ground water to perform one or more types of treatment before the water is furnished to the public. Often the treatment is required by federal or state regulations for public health reasons, but many water systems also install special treatment to meet public demand for better water quality.

Common Problems

Hardness is the most common well-water problem. The hardness of water is expressed in parts per million (ppm) or grains per gallon (gr/gal). Hardness in the range of 75 to 150 ppm is considered moderately hard. It is not unusual for the hardness of some well water to be 300 to 400 ppm, or even higher.

Hardness in ground water is caused by carbonates and sulfates of calcium and magnesium which are dissolved as the water flows through the ground. Very hard water inhibits lathering by soap and causes a soap "curd" that precipitates in clothes and on plumbing fixtures. Hard water can also form a buildup of scale in hot water piping and boilers, which must be removed to avoid plugging.

Where water is naturally very hard and softening is not provided by the water system, customers often install softening units on their water service. Some water systems estimate that 75% or more of their customers have softeners installed.

Iron and manganese in high concentrations are objectionable in a public water supply because they cause stains in plumbing fixtures and laundry. They may also cause objectionable taste and odor and cause difficulties in some manufacturing processes.

The presence of iron is common in ground water due to the wide distribution of iron minerals in nature. The iron is dissolved by slightly acidic ground water, and when pumped from a well, is still in the dissolved state. When exposed to oxygen, the iron is quickly converted to the oxidized form, similar to iron rust. Oxidized iron in water has a yellow-brown color. Manganese causes a similar brown color when oxidized unless sulfur is present, in which case it will be black.

The presence of iron and manganese in water also makes a water system vulnerable to growth of iron bacteria. Various types of bacteria can infest a distribution system and feed on the iron and manganese. Although these bacteria are not a health danger, they can cause taste and odor problems and result in red or black water. An infested system can be rid of iron bacteria, or the infestation controlled, with relatively high doses of disinfectant and a good flushing program.

Fluoride is present to some extent in most ground water.

Although a low level of fluoride is considered beneficial to protect teeth from cavities, levels in excess of two parts per million (ppm) may cause discoloring or deformities in teeth. Water systems with over two ppm in finished water must periodically notify the public of the potential problems.

Fluoride concentrations in excess of four ppm are considered dangerous to public health. This limit must not be exceeded. Public water systems having excessive fluoride levels may reduce the concentration to an acceptable level by blending water from high and low fluoride sources, by removal treatment, or by changing to another low-fluoride water source.

Radioactivity in the form of *radium* and *uranium* is naturally occurring in ground water in some parts of the United States. Federal MCLs have been established on the allowable concentration in drinking water for protection of public health.

A water system having wells with excessive levels of radium or uranium should investigate changing water sources or blending water with high and low radioactivity to maintain the level in water served to the public below the MCL. If no other source is available, radium and uranium removal treatment methods are available.

The radioactive gas **radon** is present in water from many wells. Ingestion of the gas at low concentrations is not considered harmful to health. But the gas can be liberated by the spray action of showers and other appliances. This gas can build up in closed buildings and create a potentially serious health danger if inhaled. Radon can be easily removed by passing water through an air stripping tower or through a bed of granular activated carbon.

Nitrates are occasionally present at excessive levels in shallow wells. The prime adverse health effect of high levels of nitrate is that it can cause methemoglobinemia, or "blue baby" syndrome if fed to young babies. High nitrate levels usually come from sewage or fertilizers that have contaminated the ground water. If a well is found to have a high level of nitrate, removal is possible, but it is usually best to seek another water source.

Sulfur (as sulfides) is also present in ground water in some areas. The sulfides give the water a "rotten egg" odor that is distasteful to most people. If another water source cannot be found, the sulfur can be removed by aeration or treatment with an oxidizing agent.

Methane can occur in ground water and is dangerous because an accumulation of the gas can, under some conditions, cause an explosion. Water with methane in it can be used by a public water system as long as the gas is carefully vented and adequate precautions are taken to prevent explosions.

Salinity (saltiness), of various degrees, is a common ground water problem in some parts of the country. An over-pumped fresh water aquifer can gradually turn saline due to intrusion of water from the ocean or an adjacent saline aquifer. Saline or brackish water can be converted to fresh water by using distillation or reverse osmosis. Both systems are relatively expensive to install and operate, but are commonly used where no source of fresh water is available.

Trihalomethanes are a group of chemicals that are formed in the water treatment process by the reaction of chlorine with certain precursors in the water. Trihalomethanes are considered cancer-causing chemicals, so the allowable concentration in drinking water is limited. The formation of trihalomethanes in ground water in excess of the limit is relatively rare, but most systems are required to periodically have samples analyzed for the total trihalomehthane concentration.

The health effects of other disinfected by-products (DBP) are currently under investigation by EPA. If the limit of a DBP is exceeded, the level can be reduced by special treatment or by changing the disinfection process.

Corrosion control treatment must occasionally be provided for ground water. Federal regulations enacted in 1991 require special monitoring for lead and copper in customers' drinking water. Where excessive levels are found, special corrosion control treatment must be provided.

Disinfection

Although properly constructed wells are generally safe from contamination by waterborne disease organisms, a system may still become contaminated. Surface contamination can get into a well through rock fissures, unnoticed defects in the well seal or pump installation, rusting out of the well casing, and from contamination during well maintenance or repair. There are also ways in which water may become contaminated while in the distribution system.

There is growing support from EPA for all ground-water systems to use disinfection. It has been found to be a relatively inexpensive way of ensuring that a system regularly meets the microbiological monitoring requirements and of reducing the possibility of a waterborne disease outbreak.

A number of disinfectants can be used by a public water system. The advantages and disadvantages of each are discussed in Chapter 3. Of all the available disinfectants, though, chlorine is the only one that provides a substantial residual that continues to be active all the way to the customer's tap. For this reason, chlorine is used as a disinfectant by most ground water systems in the United States.

Small systems sometimes feed chlorine as a solution similar to household bleach. Larger systems obtain the chlorine as a gas in cylinders and feed it into the water through a special device known as a chlorinator. Chlorination equipment can be automated to work unattended with proper safeguards to prevent freezing and vandalism.

Fluoridation

Studies over the years have shown that fluoride strengthens children's teeth and reduces tooth decay. Various methods of providing a continuing dose to children have been tried, but the only generally successful method found is to add fluoride to drinking water in the range of 0.9 to 1.2 parts per million. For this reason, most states now have requirements for public water systems to maintain the optimum level of fluoride in water furnished to the public. Many ground water sources contain some naturally occurring fluoride, so these systems only need to add the amount necessary to bring the fluoride concentration up to the state mandated level.

Federal Law does not require fluoridation but regulates naturally occrurring fluoride in source water.

Water systems may apply fluoride to the water by using a concentrated acid or by dissolving one of several types of fluoride chemicals that are available. The costs of fluoridation feed equipment and chemicals are relatively small compared to overall system operating costs.

State health department dental programs generally promote fluoridation programs in each state, and have information and technical assistance available upon request.

Softening

Public water systems occasionally provide central treatment to soften water furnished to the public. The *lime-soda ash process* is very efficient but must usually be operated as a single plant for the entire water system. This process is generally not practical where wells are widely spread. The process uses lime to remove the calcium and magnesium that cause hardness. One of the problems with the process that must be considered is how to dispose of the lime sludge that is left after treatment.

The *ion-exchange process* is also used for softening. In this process, water is passed through large tanks containing ion exchange media, about the same as home water softeners. The discharge from the softeners is blended with a percentage of hard water to produce finished water of medium hardness. Salt is used to regenerate the exchange media during a backwash cycle. One advantage of ion exchange softeners is that they can be installed at individual well locations.

Iron And Manganese Control

If iron and/or manganese levels in ground water are not too high, it is often possible to control discoloration by adding a *sequestering chemical* to the water before the disinfectant is added or the water is exposed to air. The chemical prevents the iron and manganese from oxidizing and causes them to remain in solution for a period of time. Water systems have varying degrees of success with sequestering agents. If a product is found that works, there is very little investment required for equipment, and relatively low cost for chemicals.

When sequestering chemicals will not work properly, the only other choice is to install equipment for iron and manganese removal. In this process, the iron and manganese are forced to oxidize by running the water through an aeration process, or by adding an oxidizing chemical such as chlorine or potassium permanganate to the water. The iron and manganese precipitate that is formed can then be removed by settling and passing the water through a filter.

Air Stripping

Many of the industrial chemicals found as contaminants in ground water are "volatile" chemicals. They readily escape from the water if it is aerated. Some of the taste and odor causing contaminants in water, as well as the radioactive gas radon, can also be removed from water by aeration.

The older methods of aeration included cascading the water down trays of coke and spraying the water into the air over large tanks. These methods do not generally provide sufficient aeration to remove less-volatile chemicals and do not work well in freezing weather.

More complete air stripping is now provided by *aeration towers*. The towers are tall tanks with the water to be treated flowing in at the top, and a large volume of air blown in at the bottom. The tanks are filled with plastic balls or other shapes which continually redirect the water as it flows downward through the tank. By adjusting the air-to-water ratio, very high aeration efficiency can be obtained.

An aeration tower does not take very much space, does not need to be enclosed, and has a relatively low operating cost. The prime problem in locating a tower adjacent to a well is that it may not be visually acceptable to nearby residents.

Carbon Adsorption

It has been known since ancient times that passing water through a bed of charcoal will remove tastes and odors. Granular activated carbon (GAC) is similar to charcoal in that it is a source of carbon that has been prepared to make the surface of the particles very porous. The extremely small pores have the ability to trap many harmful industrial chemicals as well as pesticides and herbicides as the water passes through a bed of GAC.

GAC treatment of ground water has been used in situations where a well has chemical contamination, and no alternate source of water is available. Large tanks containing GAC can be quickly brought in and connected to a well supply to remove the contamination while further testing is done and a permanent solution to the problem is developed.

In general, long-term use of GAC for contaminant removal is expensive. If a contaminant can be removed by aeration, the operating cost is much lower. If a contaminant can only be removed by GAC and there is no other source of water available, the process may have to be used continuously.

Chapter 3

Surface Water Sources and Treatment

Water Sources

It is relatively rare to have sufficient ground water available to serve a large community from wells. As a result, most large cities have developed at locations where fresh surface water is available from lakes or rivers. In the instances where cities grow despite not having adequate ground or surface water available, it usually becomes necessary to pipe in water from a distant lake or river.

Rivers And Lakes

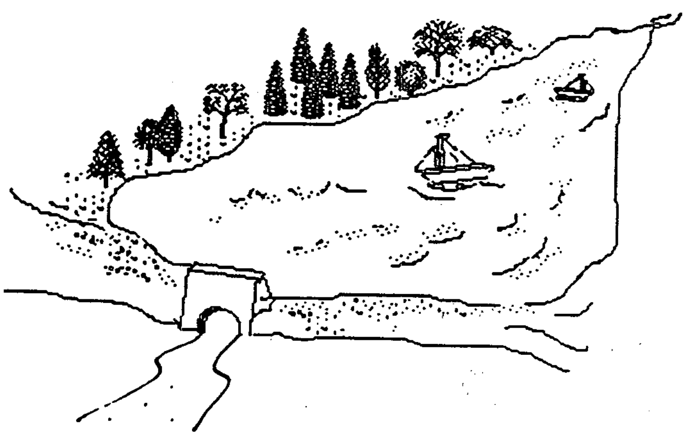
Rivers provide water of widely varying quality and quantity. Some rivers are quite clean, but most that are used as a public water supply source are relatively polluted.

As a rule, rivers used as a water source have passed through forests, cultivated fields, animal grazing areas, industrial sites, and cities. All of the exposures to water runoff from the land and sewer discharges add contaminants that can cause undesirable taste, odor, and color to the water, as well as harmful contaminants.

River water quality and quantity usually varies from day to day and with the season of the year. Water quality in some rivers is much different in spring when snow melt and rains carry silt and decaying vegetation off of forests, fields, and urban areas. Some rivers may be in flood stage in spring and flow at a very low rate in mid-summer.

The term *lake* is most often used to indicate a naturally occurring body of water, whereas an *impounding reservoir* is a facility, formed by constructing a dam across a stream, to collect and store water. The terms though, are often used interchangeably. Reservoirs are usually constructed for a combination of flood control, electric power generation, and to provide an adequate source of water for public water supply and irrigation use during periods of low stream flow.

A Fresh Water Lake



The water from lakes and reservoirs is often of better quality than water from rivers. A large amount of the suspended silt usually settles out and many of the contaminants are reduced by biological action, or their concentration reduced by dilution before the water is drawn off for public use.

Conversely, many lakes and reservoirs are subject to plant and algae growth which may cause taste and odor in the water. Lakes and reservoirs are usually popular for recreational use, so care must be taken that pollution from power boats and other human activities does not reduce the water quality for drinking water purposes.

Source Considerations

Source Selection. As a rule, public water systems cannot choose between several surface water sources. Usually only one is available, and it must be used to the best advantage. If there is a choice of sources, considerations have to be made between the water quantity and quality available, and the cost of obtaining and treating the water from each source.

Future uses that may degrade water quality or reduce the quantity available must be considered when selecting a water source. Examples would be future use by other public water systems, use for agricultural irrigation, reduced capacity of a reservoir due to silting, and use changes in the watershed.

Almost any water can be treated to acceptable drinking water quality with enough investment in treatment facilities and operating costs. The cost of treatment must be balanced against water availability. It may be more cost effective to pipe water a considerable distance from a high-quality source than to provide treatment for a poor local source.

Surface Water Contaminants. The suspended matter that causes water to appear cloudy is called turbidity. Almost all surface water has turbidity present to some degree. It is usually a combination of sand, silt, small organisms, and plant matter ranging from minute to fairly large particles. Some turbidity particles will settle out quickly. Others are so close to the density of water that they will stay in suspension almost indefinitely.

Disease-causing microorganisms can be deposited into surface water by human waste and the wastes of farm and wild animals. All surface water is therefore considered potentially contaminated with microorganisms harmful to human health.

Chemical contamination of surface water is less serious than it was a few years ago. The requirements of the federal Clean Water Act have forced industries and waste treatment systems to eliminate or greatly reduce the discharge of pollutants. The quality of most previously polluted surface water sources is now gradually improving.

Agricultural activities are still significant sources of surface water pollution. Runoff following rains often carries large amounts of animal wastes, fertilizer, and pesticides from fields to lakes and rivers. This "non-point source" of pollution, as it is termed, often causes high levels of nitrate in the water. In addition, the high levels of nutrients added to the water usually increase the growth of algae and nuisance plants in lakes and reservoirs.

Water Rights. State water rights laws vary and may at times restrict or limit the withdrawal of water by a water system. These laws must be carefully reviewed as a first step in selecting a surface water source.

Surface Water Intakes

The intake structure required to withdraw water from a surface source must be located so that it will collect the best possible water quality. At the same time it must be protected from damage by vandalism, ice, boats, and floods. In some instances, water of acceptable quality can be drawn from the shore of a lake or river. In general though, an intake at the surface will draw water of variable temperature and quality, and may become clogged by floating debris.

The best quality water can usually be obtained near the bottom, or at a relatively deep point in a lake or river. The pipe leading from the intake to the shore is usually trenched into the bottom to protect it, and the intake structure is raised to avoid drawing in silt from the bottom.

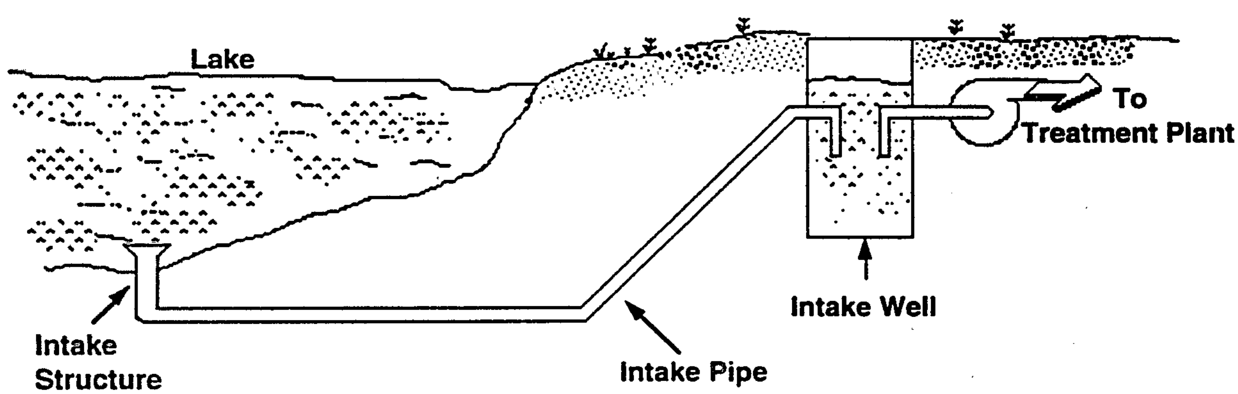
Intakes on lakes and rivers that fluctuate in depth often have structures with several valved openings at different elevations so that the depth at which water is drawn can be changed.

Under certain conditions, it is possible to use a buried intake constructed with perforated pipe buried in the bottom of the lake or stream. Where it is necessary to draw water from a particular location or depth in a lake or river to obtain optimum water quality, the intake may be up to several miles long.

Ice blocking of intakes can be a problem in colder climates. The possibility of icing must be considered in selecting the location and design of an intake structure. Some water systems have provisions for pumping treated water or steam back into an intake to blow off accumulated ice from the intake.

The water drawn through an intake is usually deposited by gravity into an intake well located on shore. This structure helps equalize flow and provides a place for stones and debris to settle out so they won't damage pumps and treatment equipment.

Typical Surface Water Intake System



In recent years, Zebra Mussels and other types of fresh water mollusks have invaded the Great Lakes and other surface water in the United States. The forecast is that they could eventually be present in most lakes and streams. These shellfish attach to underwater structures, including water intakes and pipe lines, and when the animal dies, the shell is left attached.

The potential problems to water systems include blocking of the intake inlet, reduction of intake pipe flow and taste and odor which accompany die-off of the mollusks. The design of all new water intakes should include consideration of methods of controlling the growth of mollusks in the event that they should eventually invade the water source.

Need for Treatment

It is necessary for public water systems using surface water sources to provide treatment of the water for the following reasons:

- To ensure that the water is safe from disease contamination.
- To make the water aesthetically acceptable for use.
- To minimize danger to public health from harmful chemicals.

Disease Contamination

All surface waters, as well as ground water that is under the direct influence of surface water, are at risk of contamination by bacteria and other microorganisms. Pathogenic organisms is the term generally used to cover all organisms that may cause human sickness or death. Although most disease organisms die quickly after being released to the environment in human or animal waste, there are some that can remain viable for a considerable period of time.

Disease agents of particular concern that may be transmitted in drinking water are viruses, *Legionella*, heterotrophic plate count (HPC) bacteria, *Cryptosporidium*, and *Giardia lamblia* cysts.

Relatively simple, inexpensive tests are available to detect the presence of coliform bacteria. These organisms provide an indication of the presence of wastes from humans and warm-blooded animals. All public water systems are required to periodically perform coliform tests to provide assurance that the water has been adequately treated and the system has not become contaminated.

Unfortunately, there are no simple, inexpensive tests to detect the presence of specific microorganisms such as viruses and *Giardia* cysts. Federal regulations require all surface water systems to use a treatment technique that will ensure adequate removal or inactivation of harmful organisms, without the need for specific testing. Each surface water system must employ treatment consisting of disinfection or disinfection plus filtration in a manner known to safely remove and/or inactivate the most resistant disease organisms.

Turbidity

Most surface water sources have some turbidity, and many have very high levels. Most customers would find visible turbidity in their water unacceptable, even if they are assured that it is safe to drink.

The presence of turbidity in surface water also has public health significance. Turbidity can interfere with the disinfection process and can protect some microorganisms from the effects of the disinfectant. For this reason, federal and state regulations require surface water systems to meet specific limits on effluent turbidity. The allowable level is less than the amount visible to the naked eye.

Taste And Odor

Relatively common problems with surface water sources are taste, odor, and occasionally, unacceptable color. These are usually due to natural causes such as decaying vegetation or plant and algae growth. The problems are usually seasonal and short-term, and generally not harmful to human health. They may be offensive enough to cause customer complaints if the problem is not corrected.

Taste and odor can also be caused by industrial chemicals. Although industries are now required to limit or eliminate unwanted discharges to waterways, it is possible to have contamination of a lake or river from a leak or spill, a broken pipe line, overturned tank truck, or chemicals dumped into a sewage system and not removed by treatment. Some industrial chemicals, such as phenol, are accentuated by chlorine and are offensive to consumers.

If surface water aesthetic problems occur regularly, it is best to try and eliminate the problem at the source. For instance, lakes can usually be treated with chemicals to inhibit algae growth, and stratification in small reservoirs can be reduced by mechanical mixing. Systems using river water often construct enough water storage so that they can stop drawing raw water for the period when poor quality water is passing the intake.

Taste, odor, and color can often be reduced by conventional filtration treatment. If this fails, special treatment using carbon or other chemicals can usually make water quality acceptable.

Chemical Contaminants

Chemical contaminants considered harmful to human health are occasionally present in surface water sources. One of the most common is nitrate. Nitrate levels occasionally exceed federal and state standards at times of the year when there is heavy runoff from agricultural lands. Chemical leaks and spills can occur in almost any surface water source. Systems located on a river with a large number of up-stream industries and waste treatment plants are particularly vulnerable.

Specific tests to detect the presence of all chemicals that could contaminate a surface water source are not readily available. States generally direct vulnerable surface water systems to routinely monitor for certain organic and inorganic contaminants.

Some chemicals are fully or partially removed by conventional filtration treatment, but many are not. When states determine that chemical contamination levels are dangerous to public health and the water must be used, they will require special water treatment for contaminant reduction. Water systems that experience chronic contamination of their water source by harmful chemicals may have to install continuous carbon treatment to ensure removal of contaminants.

Disinfection And Filtration

Surface Water Treatment Regulations

The *Surface Water Treatment Rule* enacted by EPA in 1989 applies to all public water systems using surface water. It also applies to all well water supplies that are designated as "ground water under the direct influence of surface water."

The two basic requirements of the regulation are:

- All surface water systems must meet standards for continuous disinfectant treatment.
- Systems that have clean water sources and meet specific operating requirements may be allowed to operate without filtration. All other systems must use filtration treatment.

All systems must operate to meet designated *CT values.* CT is the multiplication of the concentration (C) of disinfectant added to the water and the time (T) that the disinfectant is in the water before it reaches the first customer. A system may meet the required CT by feeding a low dose of disinfectant and providing a long contact time, or by applying a heavy dose with a short contact time. CT tables are available in state and federal regulations for each type of disinfectant under various conditions.

The regulation also places maximum limits on the allowable turbidity level that may be present in water furnished to customers, specifies minimum levels of chlorine residual in finished water, requires specific monitoring and reporting, and places many other operating requirements on surface water systems.

Disinfection Treatment

The disinfectants most commonly used for drinking water treatment are *free chlorine, chloramine, chlorine dioxide, ozone, ultraviolet light,* and *potassium permanganate.*

Each has advantages and disadvantages such as the cost of feed equipment, operating costs, ease of use, disinfection potency, effects on taste or odor in water, and tendency to create disinfection by-product chemicals in the finished water.

Free chlorine is the most widely used drinking water disinfectant in the United States. The principal advantages of chlorine are that it is a very strong disinfectant and a persisting residual of chlorine continues disinfecting as the water passes into the distribution system. Chlorine is also moderately priced and relatively easy to use.

Chloramine is a somewhat different form of chlorine that is formed when chlorine added to water reacts with ammonia. In some cases ammonia is present in the raw water, so some or all of the applied chlorine is converted to chloramine. Some water systems purposely form chloramine by adding ammonia to the water before or after the chlorine feed.

Chloramine has a long-lasting residual like free chlorine and is most often used where it has been found to work better than free chlorine in controlling tastes and odors. Care must be taken in using chloramine though, because it is a much weaker disinfectant than chlorine and is considered particularly weak in inactivating certain viruses.

Chlorine dioxide may be manufactured as needed in the treatment plant by reacting chlorine with other chemicals. It is a strong disinfectant and is used by some water systems because it is less likely to accentuate tastes and odors than free chlorine and reduces the formation of trihalomethanes.

Ozone is extremely reactive and can effectively eliminate tastes and odors in water when used as an initial disinfectant. It quickly dissipates though, so there is no disinfectant residual. Ozone must be generated as needed, and the cost of equipment and operation is considerably higher than for chlorine.

While widely used in some foreign countries for many years, ozone has not been used by many water systems in the United States. Use may increase in the future if it is found to present advantages in meeting new water quality standards.

Ultraviolet light (UV) is occasionally used for disinfecting drinking water for very small applications. UV can be used for inactivation of bacteria and viruses but is not considered effective for inactivation of *Giardia* cysts.

Potassium permanganate is used as an oxidant by many surface water systems. It has the advantages of being easy to feed and handle, reducing the formation of trihalomethanes, and acting to oxidize tastes and odors in the source water. It does not form usable residual, so systems using permanganate must also feed chlorine to provide the required disinfectant residual in the distribution system.

Disinfectant Application

Initial application of a disinfectant to surface water is usually made at or near the intake well in order to give the disinfectant as much contact time with the water as possible. The initial dose must be quite large if there is high turbidity because the suspended matter creates a disinfectant "demand." The initial application of chlorine is usually called pre-chlorine.

Some water systems also feed disinfectants at other points in the treatment process. A final dose of chlorine (post-chlorine) is then usually applied at the end of treatment to provide the desired chlorine residual in the distribution system.

Filtration Treatment

Slow sand filters were the first type of filter used by public water systems for treating water. The raw water is directed to large beds of sand where most of the suspended matter is removed as the water seeps through to perforated piping below. When the bed becomes clogged, the top inch or two of sand is removed by hand or with mechanical equipment and disposed of. After a portion of the original bed has been removed, the sand is replaced.

Slow sand filters are still used by many water systems. Two of the prime restrictions on their use are that the raw water quality must be relatively good, and a large amount of space must be available for the treatment system because of the large size of the filters.

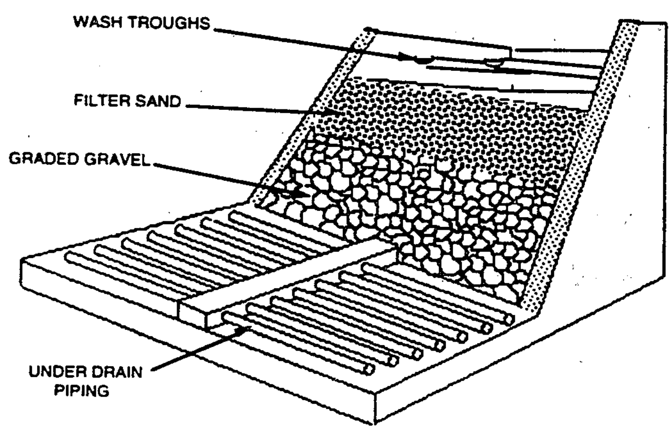
Rapid sand filters are constructed using sand of special grading and grain size so that the water will pass through rapidly. The sand is supported on layers of stone or porous plates in a steel tank or concrete box, and the filtered water is collected by a piping system at the bottom.

When a rapid sand filter becomes plugged, the sand is cleaned by backwashing. In this process, clean water is passed up from the bottom of the filter to wash the sediment to collection troughs at the top.

Some newer designs of rapid sand filters use two or more layers of sand and other media of varying specific gravity to form filters that can be operated at higher flow rates, and have increased capacity to hold dirt before plugging. Treatment plants are usually furnished with two or more filters so that water continues to be processed through the plant while a filter is backwashed.

The quantity of silt and turbidity in most surface water sources is so great that it would plug a rapid sand filter in a very short time. A sedimentation process is therefore usually used to settle out as much of the suspended matter as possible before the water is filtered.

Typical Open Box Rapid Sand Filter

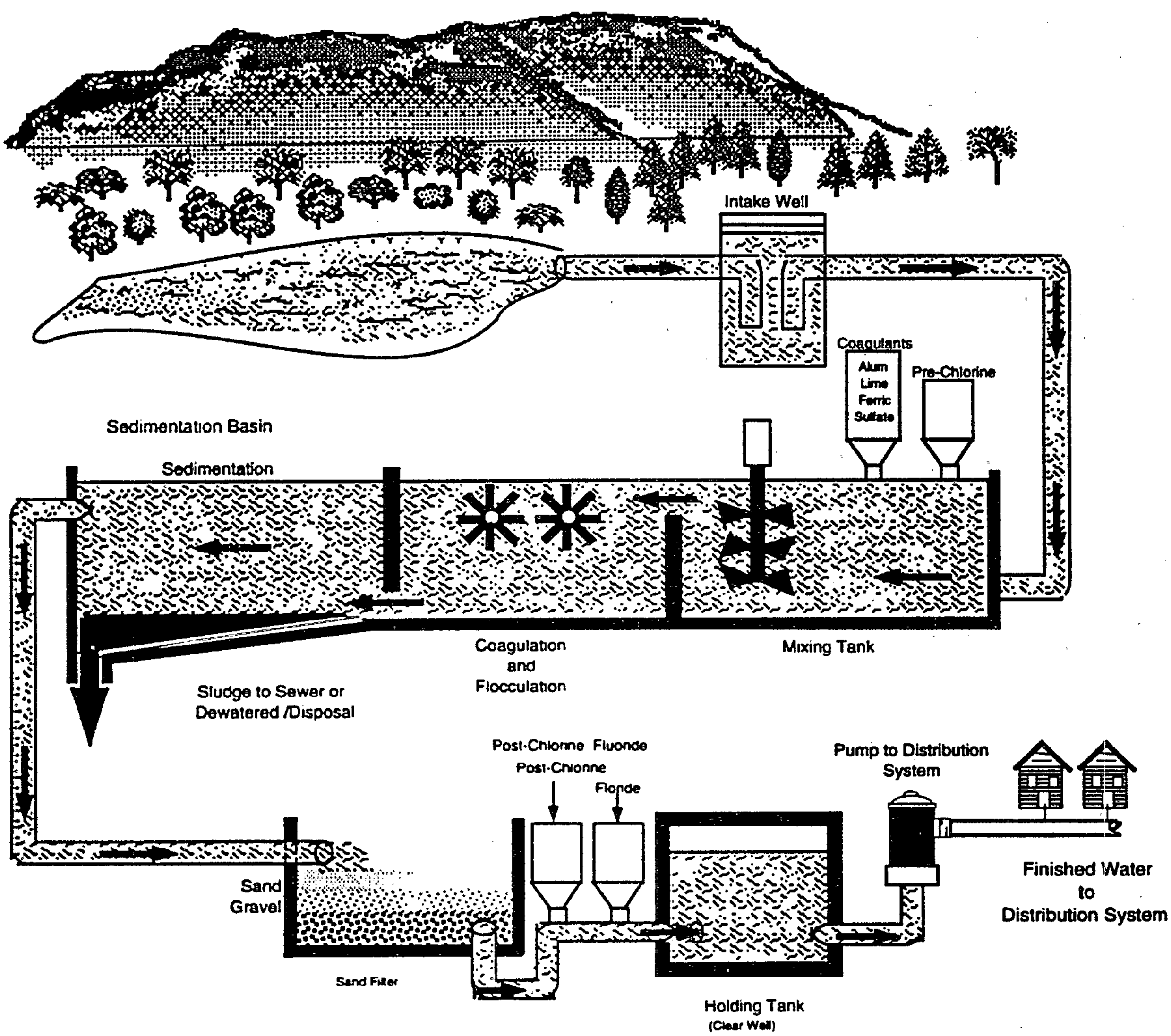


Conventional treatment is the term generally used for the combination of *chemical addition, flocculation, sedimentation,* and *rapid sand filtration* used by the vast majority of surface water treatment plants in the United States. In this process, a "coagulant chemical" is mixed with the water using mechanical mixers to bring the suspended particles into contact with each other. This has the effect of forming larger particles of "floc" made up of fine particles that have adhered to each other. The water is then directed to large *sedimentation basins* where the water is held for a period of time, allowing most of the suspended matter to fall to the bottom. Water from near the top of the basin is then directed to the rapid sand filters. The sludge that has accumulated at the bottom of the basin must be periodically removed and disposed of.

Direct filtration in its simplest form, consists only of addition of a coagulant chemical, mixing and passing the water through rapid sand filters, with no sedimentation step. In other versions, a flocculation step is used. This process can only be used where there is relatively little suspended matter in the source water because all of the turbidity is trapped by the filters and requires frequent backwashing.

Diatomaceous earth (DE) filtration is a technology that uses a relatively small filter container having a porous membrane or "septum" through which the water must pass. Diatomaceous earth, a mined product consisting of the crushed shells of microscopic sea animals, is first deposited on the septum and acts as the filter media. It is

Flow Diagram of a Typical "Conventional" Treatment Plant



usually necessary to also add a continuous body feed of diatomite during filtration in order to maintain porosity of the filter cake and extend the filter run. DE filters are widely used for swimming pool filtration. For drinking water treatment, DE filters are considered appropriate only for direct filtration of surface water with low turbidity and low bacterial levels.

Other technologies for removing suspended matter from water are occasionally used under certain circumstances, and new methods are under development that may find wide use in the future. States may approve the use of other methods as long as the water system demonstrates that the method, combined with disinfection, provides adequate inactivation, and removal of disease organisms.

Avoiding Filtration

Federal regulations allow some public water systems that use surface water sources to avoid using filtration treatment if they have source water that is consistently very clean. The principal requirements for avoiding filtration are that:

- The watershed for the water source must be protected from contamination caused by human activities.
- The turbidity and bacterial level of the raw water must be consistently low.
- Disinfection treatment of the water must be continuously carried out to meet exacting requirements.
- The water system must meet detailed monitoring and reporting requirements.

A water system that has been granted permission to operate without filtration, but later fails any of the mandatory requirements, may be directed by the state to install filtration within 18 months. Some states have a general requirement that all public water systems using surface water must use filtration.

Other Treatment Of Surface Water

Carbon Treatment

When taste, odor, or color in surface water cannot be adequately controlled by conventional treatment or by proper selection of disinfectants, water quality can usually be improved by using carbon. Harmful industrial and agricultural chemicals as well as trihalomethanes that can not be reduced to acceptable levels by other treatment methods can also usually be removed using carbon treatment.

Powdered activated carbon (PAC) is available as a very fine powder that will adsorb most taste- and odor-forming substances in raw water. The carbon is usually fed near the beginning of the treatment process, and most of it settles out with the floc in the sedimentation basin.

Surface water systems with continuing taste and odor or chemical contamination sometimes find it more advantageous to use **granular activated carbon** (GAC). Some systems use it as a coarse media in the filters where it serves a dual function of both filtration and contaminant removal. Other systems pass the water through complete conventional treatment, and then direct it through tanks filled with GAC before the water enters the distribution system. When GAC has become so plugged that it no longer functions, it must either be reactivated by a special heating process, or disposed of and replaced with new material.

Fluoridation

Most states have requirements that water systems provide an optimum level of fluoride in water delivered to the public to reduce tooth decay. Most surface water sources have little or no naturally occurring fluoride, so it is necessary to add the desired amount during the treatment process.

Fluoride may be fed to the water as a concentrated acid, or by dissolving one of several types of fluoride chemicals. The cost of chemicals and chemical feed equipment is relatively small compared to overall system operating costs and the public health benefits.

Corrosion Control

Another type of treatment that often has to be made when using a surface water source is reduction of the corrosivity of the water. Some surface water is relatively acidic and may cause iron and steel pipe and tanks to disintegrate, and lead in old plumbing and water service pipes to dissolve. In most cases, the tendency of the water to cause corrosion can be corrected by the addition of chemicals to adjust the pH and alkalinity of the water. Chemicals are also available that reduce corrosion by forming a protective coating on distribution system piping.

Chapter 4
Water Plant Operation

Plant Operators

The responsibilities of a water treatment plant operator can be grouped into the following general categories:

- Check, adjust, and operate equipment such as pumps, meters, analyzers, and electrical systems.
- Determine chemical dosages and keep chemical feed equipment charged with chemicals, adjusted, and operating properly.
- Perform routine maintenance and condition checks of equipment, and make minor repairs.
- Order and maintain a stock of parts, chemicals, and supplies.
- Maintain operating records and submit operating reports to the system owner or responsible person, and to the state.
- Perform tests and special analyses required for proper operational control.
- Collect and submit samples required by the state at the proper time.
- Keep informed of federal and state regulations affecting the water system.
- Recommend to superiors any major repairs, replacements or improvements to the plant that should be made.

The plant operator of a small water system does not usually spend full time operating the water production equipment. In addition to performing or directing water production, operation, and maintenance, the operator may also direct operation of the water distribution system, operate the sewage treatment plant and sanitary sewer system, or work at other municipal functions.

In larger and more complex treatment systems, it is necessary for the operator to spend more time performing the duties of operating and maintaining the production facilities. Surface water treatment plants usually require closer monitoring and have more operations that must be performed manually. States generally require that an operator be on duty while a surface water plant is in operation unless special monitoring and alarm equipment is installed.

Plant Maintenance

It is particularly important that water treatment equipment be properly maintained to minimize failure. A well, pump, or piece of treatment equipment that fails because of improper maintenance can be very costly and disruptive to customers. For this reason, maintenance of important pieces of equipment should be regularly performed as recommended by the manufacturer. This should be accompanied by frequent inspection and testing to anticipate failure or degenerating performance. As an example, periodic review of well records can help to anticipate repairs and schedule maintenance work.

Major maintenance on equipment, whether done by the water system or by contract, is best done at a time of year when water use is low. This enables the system to meet normal operating demands while the equipment under repair is out of service.

Water Quality Monitoring And Reporting

Bacteriological Sampling

Federal and state regulations require all public water systems to periodically collect water samples for analysis for the presence of *coliform bacteria*. The number of samples that must be collected varies with the population served and individual state policies. Most states require that samples be submitted regularly on specific days of the week or month.

Bacteriological samples must be collected at locations selected by the water system operator with the concurrence of state field staff. Samples must be collected carefully to avoid contamination and promptly transported or shipped to the laboratory for analysis. The laboratory used may be state-operated, a commercial laboratory, or a water system laboratory that has been certified by the state to perform the analyses.

The report returned by the laboratory will report the analysis of each sample as "negative" or "absence" if coliform bacteria were not found. A report of "positive" or "presence" indicates that there was some sign of contamination in the sample. If contamination is indicated in any of the samples, the operator must collect repeat samples according to state requirements. State staff may also require that other steps be taken to determine if contamination is actually present, or what may have caused the positive sample.

Organic, Inorganic, And Radiological Sampling

Water samples from community and nontransient-noncommunity water systems must be periodically collected and analyzed to detect the presence of various *organic* and *inorganic chemicals*, and *radionuclides*. The required frequency of sampling may be as often as monthly, or quarterly if low levels of a chemical have been detected. If the history of past sampling indicates no harmful contaminants, the repeat sampling frequency required may be up to several years apart.

For surface water systems, samples may be required of both the raw water before treatment and samples typical of water furnished to customers. Ground-water systems must periodically furnish water samples from each individual well, in addition to samples from typical sites on the distribution system.

Some states may have state field staff collect chemical samples in conjunction with a sanitary survey or a special visit to the system. Other states furnish the operator with sample containers and instructions indicating where and when samples must be collected and shipped. Still other states furnish the operator with only instructions on the samples that must be collected, and a list of certified laboratories where samples can be sent for analysis.

Instructions must be carefully followed to ensure that samples are collected at the proper location and time, and that containers are properly filled and shipped. In cold weather, precautions must be taken to prevent samples from freezing.

For most analyses, the laboratory must analyze a sample within a set number of hours or days following collection. If a sample arrives at the laboratory past the required holding time, new samples must be collected. In some areas of the country, it may be necessary to hand deliver or ship samples by special parcel service, to ensure that they arrive safely and on time.

When the laboratory has completed the analyses, they will send a report to the operator. If the laboratory has not furnished a copy directly to the state, the operator must send a copy to the state within a required number of days. The report will usually provide a comparison between the analysis results and established MCLs for each parameter. The system's consultant or state staff can provide further explanation of laboratory results.

Under state and federal requirements, *failure to perform required monitoring* is usually cause for the system to be directed to *perform public notification*. This is usually both costly and embarrassing to the operator and public officials. To avoid having to perform public notification, care should be taken to strictly follow state-directed requirements.

Water systems that provide treatment must also provide on-site analyses for various parameters, both to satisfy state requirements, and to provide proper operation and control of the process. Surface water systems must make periodic analyses for turbidity level, and all systems that add disinfectant must analyze disinfectant residual concentrations as required by the state. Systems that provide fluoridation must also periodically analyze for the fluoride level in water supplied to customers.

Many larger water systems operate their own laboratory to provide some or all of the required analyses. The system's laboratory must be operated by a qualified technician and certified by the state for performing each of the types of analyses.

Reporting To State Agencies

Each state has special report forms to be used by community public water systems to record operating and monitoring information. Different forms are available for various types of systems or treatment. The system operator is usually required to report operating data on every day that the system is in operation and submit reports to the state monthly. A copy of all reports should be kept for the water system files.

Water Treatment Waste Disposal

Until the 1960s, it was common practice for water systems to discharge their treatment wastes back into the lake or river being used as a water source, or any other available watercourse. Plants employing conventional treatment almost always discharged their filter backwash water and sedimentation basin sludge without treatment.

Although water treatment wastes are generally not toxic, they cause discoloration of the water, may be detrimental to wildlife, and might have an effect on biological life in a lake or river. Under requirements of the Clean Water Act, water treatment plants and industries are required to meet effluent standards for waste discharges. It is usually expensive to treat water plant waste to acceptable effluent standards for discharge directly into a waterway.

Most filtering systems now direct **backwash water** from the rapid sand filters back to the intake and blend it with incoming water. It has been found that this has little effect on the treatment process and the suspended matter in the backwash water is eventually removed by the sedimentation process.

Sedimentation basin sludge is relatively difficult to dewater and dry due to the presence of alum. Land application or burial of the sludge is sometimes used for disposal where there is no other practical alternative available. The most practical method of disposal is to discharge the sludge to the local sanitary sewer system. When the alum sludge mixes with the other sludge at the waste treatment plant, it is usually easily handled and disposed of. Most waste treatment authorities agree to accept the sludge but may charge a fee to cover their handling costs. The authorities may also place limitations on the amount and times of sludge discharged.

Lime sludge created by a softening plant cannot usually be discharged to a sanitary sewer system. The lime could be disruptive to the waste treatment process, and there is concern that the lime will build up and block the sewers. Lime sludge is usually dried and buried, or spread on farm land where farmers accept it as an alternative to agricultural lime to condition their soil.

Ion-exchange softening backwash water is generally clear, but objectionable because it is salty. Under some circumstances, states may allow softener backwash to be discharged to a lake or stream if there is enough dilution.

Backwash water may also be discharged to a sanitary sewer system if approved by the proper wastewater disposal authority. It may not be allowable to discharge the backwash water to a land surface because the salt will eventually build up to make the soil unusable. Discharge to a buried seepage bed may also be prohibited because of the potential contamination of ground water.

The disposal of water treatment plant wastes by almost any means other than discharge to the sanitary sewer system will usually *require a permit* under environmental protection laws. State authorities should be consulted on allowable methods of disposal, permits required, and monitoring requirements before a new disposal method is used. Environmental laws are strict, and violators may be subject to heavy fines and possible liability for an environmental problem that they have created.

Chapter 5

Water Distribution System Operation And Maintenance

Distribution System Facilities

The water *distribution system* is the collection of pipes, valves, fire hydrants, storage tanks, and reservoirs that carry water from the water source(s) or treatment plant, and deliver it to customers.

Water Mains

The piping in the distribution system should be large enough to meet maximum domestic and industrial use by customers, provide ample flow for fire protection, and allow for expansion.

Since fire flow is almost always the largest demand, it usually determines the pipe sizes required in the system. Occasionally, fire flow capacity cannot be provided for economic reasons. This exists in some rural areas where homes are far apart and can only be practically served by small-diameter pipes that furnish only domestic needs.

The water *mains* are the large-diameter pipes that are normally buried in the public street right-of-way. Six-inch diameter mains installed in most residential areas are generally considered the minimum size that will provide adequate fire flow.

The term *transmission main* usually designates a larger size pipe line installed to move large quantities of water from one point to another. For instance, a water system with a central treatment plant usually requires several transmission mains to supply principal use areas. Transmission mains for a small system may be only eight or ten inches in diameter, while large system pipes can be two or three feet in diameter. Most water main pipe is made of cast iron, asbestos-cement, or plastic.

Cast iron (CI) pipe has been used for water mains for many years. Many systems have cast iron mains that are over 100 years old and still functioning. Older cast iron pipe had no lining and under some water conditions, moderate to severe *tuberculation* occurs in the pipe. This is an action where rust builds up in mounds on the pipe interior.

Tuberculation reduces the capacity of the pipe both because of constriction of the opening and the added roughness of the walls. When tuberculation gets to the point of seriously restricting flow, the main must be mechanically cleaned or replaced. The interior of most cast iron pipe produced in recent years has been coated with a thin layer of cement to protect the pipe interior.

Ductile iron (DE) is the newer version of cast iron that is now in general use. The material appears about the same as cast iron, but it has been treated so that the metal is somewhat flexible and less subject to breaking or cracking.

Asbestos-cement (A-C) pipe is made of cement mixed with asbestos fibers for reinforcement. It has been widely used in many water systems because of its light weight, ease of handling, competitive price, and relative resistance to corrosion.

Polyvinyl chloride (PVC) water main pipe is a relatively new plastic material that is produced in the same general sizes as cast iron pipe. PVC pipe is lightweight, easy to cut , competitively priced, resistant to corrosion, and somewhat flexible. On the negative side, PVC is more easily crushed than metal pipe and is difficult to find if location records are not kept.

Larger size water mains are also constructed of reinforced concrete, steel, or fiberglass depending on their intended use, type of installation, and soil conditions.

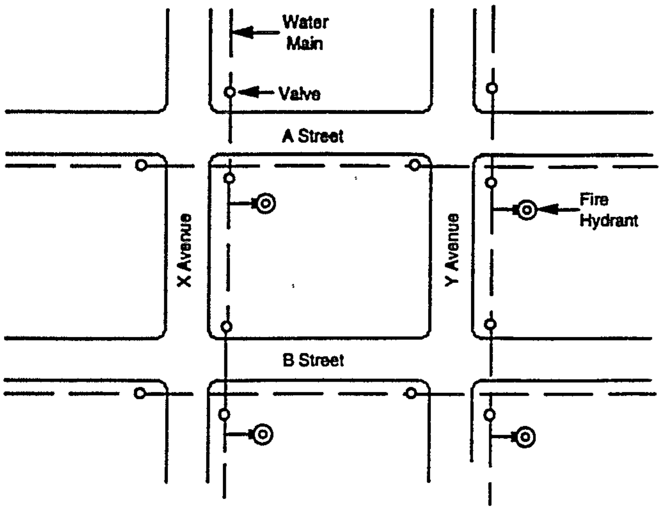
The depth at which water mains are buried varies greatly throughout the United States. Mains can be buried quite shallow in southern states because the only concern is physical damage. Mains are buried deeper where there is moderate ground frost and may be buried up to eight feet deep in northern states.

Valves and Hydrants

Valves are installed at intervals in water main piping so that segments of the distribution system can be shut off for maintenance or repair. Valves should be located close enough so that only a few homes or businesses will be without water while a main is being repaired. When mains are installed in normal grid systems with mains in all streets in both directions, it is recommended that three valves be installed at each intersection.

Each valve is installed with a *valve box* that extends to the ground surface and has a cap that can be removed so that a *valve key* can be used to operate the valve. Valves should, if possible, be located where the box is easily

Water Mains and Valves Installed in a Grid Pattern



located and where damage by snow plows and other equipment is least likely.

Fire hydrants are of two general types. A **wet barrel** hydrant is full of water at all times and can only be used in parts of the country where there is no danger of freezing. **Dry barrel** hydrants have the valve located at the bottom of the barrel and are operated by a long shaft extending down from the operating nut on the cap. Dry barrel hydrants also have a small valve connected to a weep hole at the bottom that allows water to drain from the barrel when the hydrant valve is shut off.

Hydrant locations should be selected carefully. They should be readily visible and located near a paved surface where they will be accessible to fire-fighting equipment. They should also be placed where they are protected from damage by vehicles and are least liable to be covered by plowed snow.

Public officials should always insist that police enforce parking restrictions adjacent to fire hydrants so they won't be blocked if needed. Police should also be reminded to watch for vandalism and unauthorized use of hydrants, and report incidents to the water system manager.

Bright paint protects hydrants from rusting and makes them easy for the fire department to find. Well-maintained hydrants also project a positive public image of the water system.

Water Services

The small-diameter pipe used to carry water from the water main connection to an individual building is referred to as a *water service*. A water service pipe may range from three-quarters-inch in diameter for a small home to two-inch for an apartment building. Large buildings and industries often have services that are even larger.

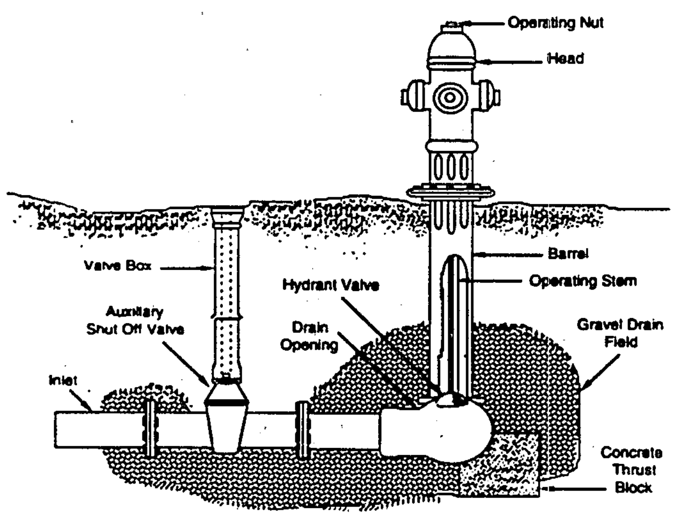
Each water service usually has a buried valve called a *curb stop* inserted in the line at a point in the public street or alley right-of-way. Water system policies generally standardize the curb stop location at a set distance between the curb and sidewalk, or on the lot line. The buried valve is fitted with an adjustable *service box* (curb box) that extends to the surface and has a removable cap so a valve key may be inserted to operate the valve. The curb stop is primarily used to shut off the service if the building being served is vacant or repairs are needed. It is also a way of discontinuing service for non-payment of the water bill.

Water system policy varies on responsibility for maintenance and replacement of water services. Some systems require that all of the service, beginning at the main, be maintained by the property owner. Other systems require property owners to maintain only the portion beyond the curb stop, lot line, or meter pit.

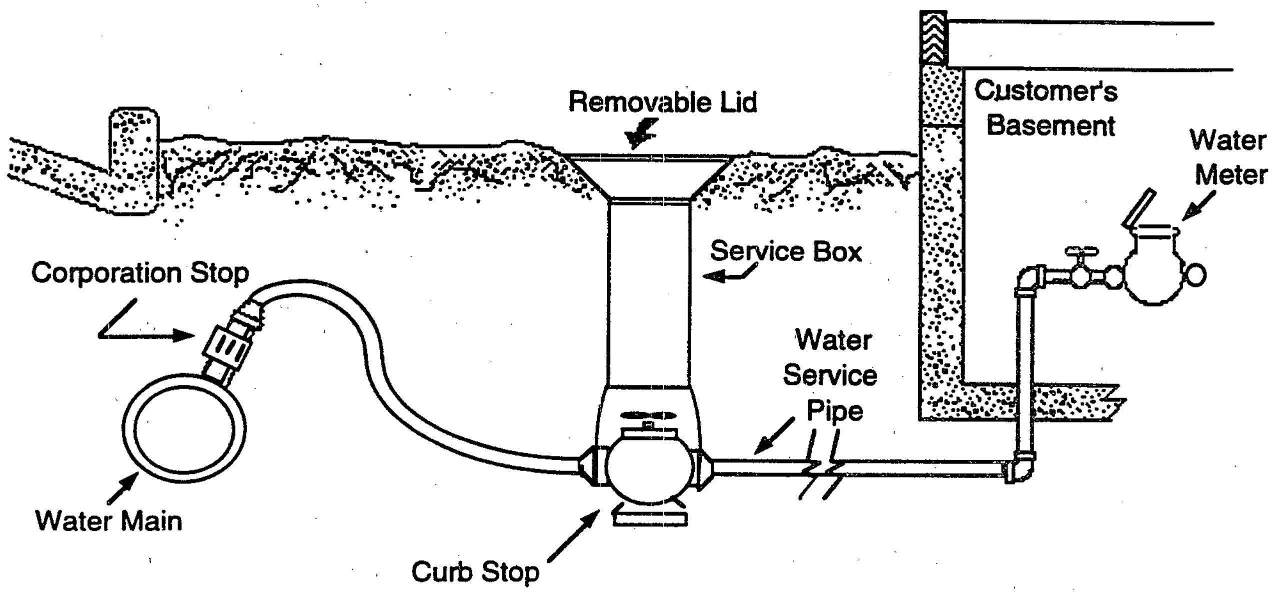
Water service pipes are generally made of lead, galvanized iron, copper, or plastic. **Lead** was the best material available for small pipes when the first water systems were developed, and lead water services are still in use in many older systems. Lead is relatively flexible and resists corrosion, but gradually becomes more likely to leak or break as it gets older.

New federal regulations designed to protect the public from the danger of lead in drinking water, require systems

Typical Fire Hydrant Installation



Typcial Water Service Installation



to ensure that leaching of lead from water services is minimized. Systems with "aggressive" water that tends to dissolve lead may have to install additional chemical treatment to meet the requirements. Systems that cannot adequately control the leaching of lead, may be required to remove existing lead service pipes and replace them with other material.

Galvanized iron pipe was used for water services for many years, but corrodes very quickly in some types of soil.

Copper pipe came into use in the early 1900s and gradually became the preferred material in many areas of the country. Copper is flexible, fairly easy to install, resistant to corrosion, and projected to last almost indefinitely under most water and soil conditions.

Plastic pipe has been used for water services since shortly after World War II. It is lightweight and easy to install, flexible, moderately priced, and resistant to corrosion. In some areas, plastic pipe has been used almost exclusively for years. There are many types of plastic, but only certain types and grades are approved for potable water use. Plastic pipe must be tested for durability and freedom from constituents that may cause taste, odor, or release toxic chemicals. Only pipe that has the seal of an accredited testing agency printed on the exterior should be used for water services or other potable water purposes.

Water Storage Facilities

The primary reason for providing storage of treated water is to have a reserve supply readily available during an emergency or periods of heavy water use. For instance, the stored water can be used to maintain pressure for a period of time if a well or pressure pump should fail or lose power. It will also provide added capacity during a fire and help to temporarily maintain pressure in the distribution system during a water main break.

Another function of storage is to allow a treatment plant to operate at a relatively constant rate. When customers are using water at a low rate, excess water can be stored. When use is high, stored water is used to meet the demand without having to alter the operation of the treatment plant.

The quantity of water storage that should be provided on a system is usually based on the amount of water required to meet domestic and fire flow needs. Many systems find it advisable to furnish more than the minimum storage capacity. For instance, storage of enough water to last one or two days may be provided by systems that depend on a single long transmission main for source water. Systems that have periodic episodes of temporary poor quality in their source water also frequently provide enough storage to allow them to avoid taking water until water quality improves.

Water storage facilities fall into the categories of elevated tanks, standpipes, hydropneumatic systems, and ground reservoirs. Elevated tanks are the most familiar because they are visible in prominent locations in most communities. Elevated tanks are generally constructed of steel, with the tank portion supported on legs or a pedestal. Tanks are generally located on the highest ground that is available and acceptable to the residents. The public is not generally bothered by an existing tank located in a residential neighborhood, but usually will not want a new tank erected near their homes.

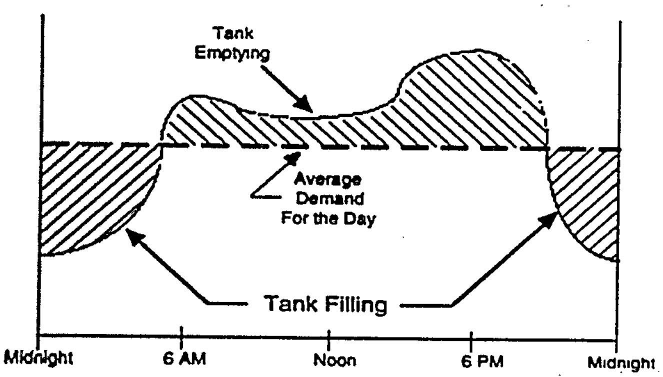
An elevated tank normally "rides" on the water system, and the elevation of the water in the tank determines the water pressure on the system. A signal indicating the water level in the elevated tank is commonly used to vary the operation of the pressure pumps supplying the system. When the water level is near the top of the tank, the supply of water is reduced or stopped before the tank overflows. When the water level falls to a predetermined point in the tank, flow to the system is increased.

Occasionally, a water system must operate at a pressure that would overflow the elevated tank. In this case, water is admitted to the tank by an automatic valve that shuts off flow before the tank overflows.

In water systems, a *standpipe* generally refers to an above-ground tank that is the same size from the ground to the top. Standpipes are primarily used where they can be located on a high point of land so that all or most of the stored water will furnish usable pressure to the water system.

Hydropneumatic systems have been developed primarily to serve small systems where an elevated tank is not practical. A large pressure tank is buried or located above ground and kept partially filled with water and partly

Typical Filling and Emptying Cycles of a Tank and Reservoir



with compressed air. The balance of compressed air against the water maintains the desired pressure in the system and forces water out of the tank when needed. An air compressor is required to maintain the proper air-to-water ratio.

A *water reservoir* is generally a large tank in which treated water is stored under no pressure. The water must be pumped out of the reservoir and into the system when needed. Reservoirs are constructed of concrete or steel and may be above ground, partially underground, or completely buried. Water is usually admitted to a reservoir by a remotely operated valve during times when excess water is available, such as in the middle of the night. Pumps are then operated to add water from the reservoir to the system as needed during the day or in an emergency. Occasionally, a water system has a high point of ground available where a reservoir can be constructed so that it will supply adequate pressure to the system without re-pumping.

The prime advantages of a reservoir are that it can be constructed to store relatively large quantities of water and can be completely buried where an above ground structure would be objectionable to residents. When a reservoir is completely buried, the land above it is sometimes used for a park or recreational area. The prime disadvantage is the cost of power to operate the pumping equipment.

Water Metering

Types Of Meters

The principal uses of water meters on a water system are to record the amount of water treated and delivered to the water system, and to measure water used by customers. The two general types of meters used are *velocity* and *displacement* meters.

Velocity meters are used where large quantities of water must be measured. They work on the principle of converting a measurement of the velocity of water passing the measuring point into quantity of flow. These meters are commonly used at each well or water intake, at intermediate points in the treatment system, and at the points where water enters the distribution system. Velocity meters are also used to measure the amount of water admitted to and/or pumped from reservoirs and may also be used for customers that use large quantities of water.

Velocity meters commonly measure water flow by means of propellers, turbines, pressure measurement, and electronic sensing. The flow rate is then automatically translated into gallons or cubic feet registration by the meter register.

Displacement type meters measure the number of times a container of known volume is filled and emptied. This method is more accurate than a velocity meter, but is only practical for measuring relatively low flow rates.

The nutating disk meter is a type of displacement meter commonly used for water services because it is durable, relatively trouble-free, moderately priced, and quite accurate over the normal flow range of most water customers.

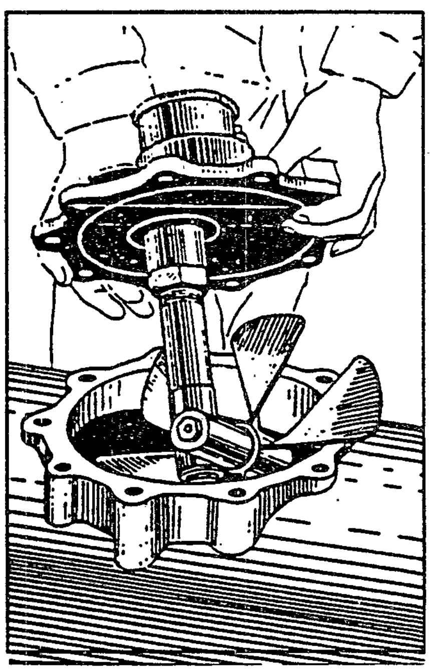
Water Production Metering

The rate of water flow from pumps, wells, and treatment facilities in the U.S. is usually expressed in *gallons per minute* (gpm). A well pump, for instance, may be rated to produce 500 gallons per minute. The total output of a water plant or system is usually expressed as *million gallons per day* (mgd).

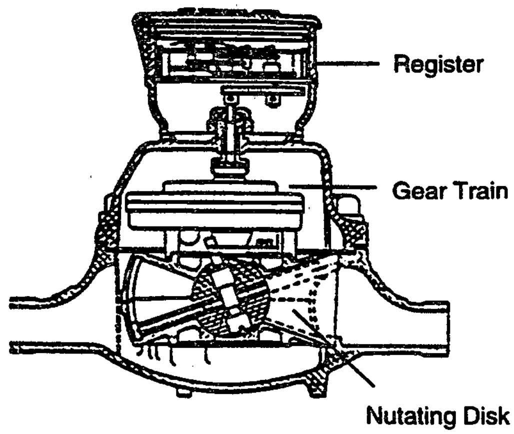
The total quantity of water pumped to the distribution system should be accurately measured and recorded.

One of the important uses of pumpage records is for comparison with the amount of water metered to customers. The long-term difference between the two

A Propeller Meter Mounted Directly In A Pipeline



Cut-Away of a Nutating Disk Meter



records is generally the amount of water not paid for, or "lost" from the distribution system. Analysis of production meter records should also be made to check such things as well productivity, trends in customer use, and the need for system expansion.

Customer Metering

Some water systems do not install water meters on part or all of their customer's water services. They instead charge the customers at a flat rate based on the water service size or number of plumbing fixtures. Systems that charge on a flat rate save on the cost of meter installation and maintenance, meter reading, and simplified billing. It has been demonstrated, though, that customers generally use and waste much more water if the water is not metered. Un-metered customers commonly leave water running, do not promptly repair leaks, and do excessive watering of lawns and gardens. There are many water systems that have avoided having to expand their water production facilities by instead installing meters on customer services.

Customers with larger-than-normal water bills often complain that their meter must be running fast. Investigation often finds that they actually have an un-noticed water leak. On the other hand, as a meter wears, it usually begins to *under*-record use, which, of course, means that revenue is being lost.

All water systems should have some type of water meter repair or replacement program. Meters should be periodically removed for testing and repair in a meter shop maintained by the water system, or sent to the factory or an outside firm to be reconditioned. The economics of disposing of worn meters and replacing them with new meters should also be considered.

In warm climates, domestic water meters may be located in a garage, buried in a shallow pit, or exposed near a building. In areas where there is danger of freezing, the meter is most commonly placed in customer basements. Where there is no basement, some systems will allow the meter to be installed in a ground floor utility room or closet. Meters are also frequently installed in pits in the parkway where there is not a suitable location in the building. Some municipal systems and most rural water systems install meters in pits as a means of avoiding having to enter customer buildings, and facilitating meter reading and repair.

Several different schemes and types of remote meter reading devices have been developed to speed meter reading and reduce customer inconvenience by allowing an inside meter to be read from outside the building. Some systems mount basement meters next to a glass block set in the basement wall. Various types of remote reading devices that are now available have a special transmitter mounted in the meter that sends a signal through a wire to a register mounted on the exterior of the building. Some units have a reproduction of the meter register on the exterior. Others are designed to allow the meter reader to plug in a portable unit that electronically records the meter reading for later interpretation by a computer.

Meters used for measuring water use by residential, business, and industrial customers in the U.S. are usually made to register in either gallons or cubic feet. Whichever type of registration a water system used when their first meters were purchased is usually the way it must continue. Water rates for the system are then expressed in the same units using either dollars per 1000 gallons or dollars per 100 cubic feet. For conversion, 1 cubic foot equals 7.48 gallons.

Distribution System Operation And Maintenance

Distribution System Records

In smaller water systems, the operator who has been in his position for a long time often keeps a mental map of the system and few written records. Public officials should recognize this problem and arrange for another employee or a consultant to record the system information on to permanent maps and records.

Every water system must maintain an up-to-date *water distribution system map.* It should include information such as measurements from each valve to above ground features such as trees, curbs, and extended lot lines. Fire hydrants should also be shown on the map with measurements for both the hydrant and the hydrant control valve. Water main information should be as detailed as possible with indications of size, type of material, depth, periodic location measurements, and date of installation.

Many water systems maintain the official distribution system map in a single plat book kept in the water system or village office. A better way is to have the information drawn on a tracing so that blueprint copies can be made for field work, and for use by fire and building departments.

The newest method of system record-keeping is to put plans and other records on a computer. This method will be used by increasing numbers of systems as computers become less expensive and more employees are acquainted with computer operation. Some water systems have changed to computer record-keeping by having all existing records transferred by a professional firm. The system staff is then trained to operate and maintain the records in the future.

Records should also be maintained of distribution system repairs and the condition of both the interior and exterior of water mains and valves. Whenever a piece of pipe is removed, a small piece should be kept and tagged with the date and location. Also, if a water main pressure tap is made, the piece of pipe wall that is removed should be identified and retained. These samples can be important in assessing any corrosion or tuberculation taking place on the system.

Water service information must also be recorded as installations or repairs are made. A metallic water service pipe with an inadequate location record can usually be located using an electronic pipe locator, but the process takes longer than using good record information. A pipe locator will not generally work on plastic pipe, so finding a pipe with no record can be difficult and expensive.

Water service information is often maintained on file cards indexed by street address. Important information that should be obtained and recorded before the pipe is covered in the trench are measurements locating the water main tap, the type and size of pipe, burial depth, measurements to the curb stop or meter pit, location of the pipe at various points, and the location where the pipe enters the building. In some cases this information is obtained by the building inspectors if it is their duty to approve the installation of the water service.

When a water service is repaired or replaced, the file should be updated with details of new material and any changes in size or location. One of the prime reasons for maintaining good records of water service locations is to be able to quickly and accurately locate them so that they may be avoided during adjacent construction. Excavation for sewer installation or repair, installation of utility poles, burial of cables, and gas main work are all likely to strike a water service if the location is not identified.

Fire hydrants should each be assigned an identifying number and have an individual record sheet or card. Basic information that should be obtained at the time of installation includes the make and model, installation date, depth and location measurements, as well as the initial capacity determined by flow tests. Continuing records should then be kept of all maintenance and repair performed and the results of subsequent flow tests.

Maintenance Needs

Water distribution system equipment is often neglected, since most of the valves and other equipment are buried and seldom used. Some of the problems that are caused by poor system maintenance include customer complaints of poor water quality or lack of pressure, difficulties in repairing water main leaks, and inadequate or unreliable water availability for fighting fires.

Broken water mains and water services must usually be shut off and repaired as soon as possible after they are identified. A serious leak from a broken main can drop pressure in the whole system, creating a potential for system contamination.

Although leaks cannot be anticipated, there are steps that can be taken to make sure the repair is accomplished as quickly and smoothly as possible. The first task in repairing a leak is to shut down the smallest possible section of main so as to inconvenience the least number of customers. In some circumstances, there may be six or more valves that must be operated to isolate one section of main. If valves cannot be located, or are found to be inoperable, the repair crew must continue searching until an appropriate combination of valves is found. During this delay, time and water are being wasted, plus a larger-than-necessary number of customers may have to be without water while the repair is made. Conversely, the water system with good records and a valve check and operation program should be able to quickly locate and operate the correct valves to shut down the minimum section of main and progress with the repair.

Similarly, many small systems can go for years without having to use a fire hydrant for fighting a fire. The importance of the hydrants is therefore sometimes overlooked. Three of the more common reasons for a hydrant not functioning properly are: (1) unnoticed damage, (2) improperly drained and frozen barrel, and (3) closed valves in the distribution system. All of these problems can be readily identified and corrected by a water system that has a regular program of hydrant inspection and testing. Failure of hydrants to operate properly during a fire could leave water system personnel and managers liable to a suit for damages, in addition to causing needless risk to life and property.

Maintenance Of Equipment

Water mains that are properly installed perform well over a long period of time in most water systems. The most frequent problems are breaks and leaks. Most breaks are simple cracks at right angles to the length of pipe and can be repaired by exposing the pipe and slipping a repair sleeve over the break.

Another common problem in water distribution is the buildup of rusty sediment in the bottom of mains. The sediment is generally not harmful to health and usually causes few customer complaints as long as it is not disturbed. But if water flow is suddenly increased, such as from use of a fire hydrant, the sediment will be disturbed and can turn customer's water anywhere from slightly rust-colored to dark brown. Not only are customers reluctant to drink and use the water, but it may badly stain laundry items.

Sediment in water mains can be caused by iron or manganese that was in the source water and has precipitated out, or from the presence of iron bacteria in the system. It can also be from rusting of old cast iron pipe. If the problem is not too severe, some systems have found that a thorough flushing of the system once or twice a year is sufficient. Other systems have found that certain mains, such as dead-end sections, must be flushed as often as weekly to maintain acceptable water quality. If the problem is severe, professional advice should be obtained on the best method of correcting it.

Old water mains that become encrusted to the point of seriously restricting flow can be cleaned using a power rodding machine or by pushing a flexible "pig" through the line using water pressure. In most cases, the incrustation will quickly re-form on the interior of a cleaned pipe, so consideration should be given to applying a cement lining on the pipe interior. Although this process is expensive, it is usually less expensive than replacing the pipe.

Water distribution system valves should be periodically operated for several reasons: this provides an opportunity to ensure that valve boxes are exposed and have not been filled or damaged, it assures that the valves are open and work properly, and it loosens up the valves so that they will operate more easily. Systems with a large number of valves often purchase power valve-turning equipment to speed the job of "exercising" their valves. When valves are operated, the number of turns should be counted to make sure they are fully operated in both directions. Valves that do not operate properly should be dug up and repaired as soon as possible.

Fire hydrants should be operated and tested at regular intervals. Many systems have a yearly program that is a combination of flushing water mains and testing hydrants. Records should be kept of the static pressure, flow test results, and any repair work performed on each hydrant. In freezing climates, whenever a hydrant is used, an inspection should be made to make sure that the barrel has fully drained.

Water Main Extensions

Water mains must be periodically extended to accommodate new customers. If the extension is relatively short, the work can often be done by water system employees. For larger extensions, a contractor is usually employed. Land development firms usually pay for preparing plans and installation of the water mains and hydrants to serve the new properties.

It is important that the manufacturer's recommendations be followed for proper bedding, blocking and installation of the pipe, valves, and hydrants. A poor installation job can create extra work for years, repairing re-occurring leaks and broken mains.

Most states require submission of the plans and specifications for water main extensions for approval before the work is begun.

Chapter 6

Water System Management

Organization

Types Of Water System Ownership And Management

Privately owned water systems may be operated as an individual enterprise, a partnership, or a corporation. In order to survive under the review and control of the state Public Service Commission, systems must be properly organized and managed to operate efficiently. Ownership of large systems is usually vested in a relatively large group of stockholders whose control over operations is exercised through an elected board of directors. The directors, in turn, place direct control of operations in the hands of an executive, normally titled president.

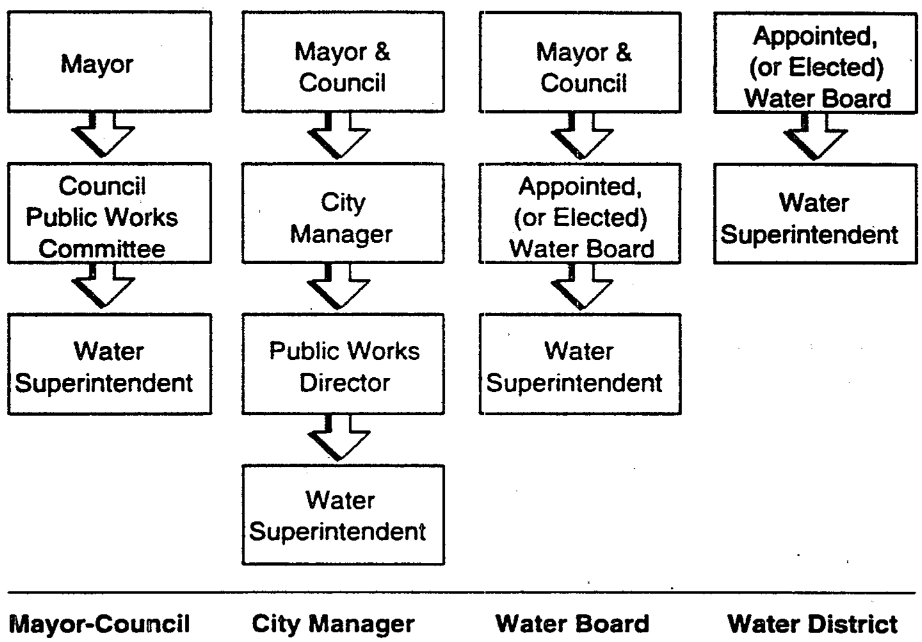
Under *public ownership*, the property owners, voters, or customers are actually the "owners" of the system. Elected or appointed officials are ultimately responsible for employing staff to direct and operate the water system.

The organization of publicly owned water systems generally follows one of the following patterns.

- In a *mayor-council* type of government, where the water system is incorporated with other municipal departments, the mayor is ultimately the system's chief executive. The mayor normally participates in making policy and oversees the implementation of the policy. He is usually assisted in this management function by a water or public works committee of the council that monitors the water system operation. In some instances, the water system operator reports directly to the mayor and council. Under other organization plans, the operator reports to a director of public works who has other management duties, including the street and sewer departments.

- Under the *council-manager* plan, the city or village manager is usually considered the executive in charge of the water system. But the manager is employed and retains his position at the pleasure of the town council. The manager is usually a professional administrator who makes day-to-day management decisions. The council is usually called on only to approve or decide on major expenditures and policy. In this type of organization, the water

General Types of Management Organization of a Publicly Owned Water System



system operator usually reports either directly to the city manager, or through a director of public works.

- In some instances, the operation of the water system is separated from other municipal departments. Control is placed under a separate trusteeship-level committee called the *Water Board* or *Water Commission*. This elected or appointed body acts and operates somewhat independently of the town mayor and council. This often has the advantage of allowing the water system to be insulated from political pressures.

- Some water systems are organized as separate *water districts* or *associations*. In the case of some rural water districts, they exist where there are no municipal governments. The top management of these systems rests with an elected or appointed water system board of directors.

- Public water systems are often also operated by a *township, county*, or other unit of government. In these cases, the elected board members are usually the officials responsible for the water system.

There are many variations and mixtures of these systems, depending on the size of the water system, how the system originated, and local politics.

In most municipalities, water production, distribution, and meter reading are under the direction of a *water superintendent*. The superintendent, in turn, directs foremen, operators, and maintenance workers. In some cases, water billing is done as a separate water system function, but in most cases this is incorporated with other municipal accounting and billing.

In larger systems, the management duties are often separated, with a *plant manager* having responsibilities for operating the production facilities, and a separate *distribution manager*. In other instances, the distribution system is operated and maintained as a part of the streets and sanitation department.

New small water systems are often created by land development firms. A water system is installed by the developer to serve the new properties, but after all lots have been sold, the developer usually wants to be relieved of the responsibility. In some cases, the small system will not be accepted for incorporation with an adjoining system because the facilities do not meet the construction standards of the larger system. Some of these systems are taken over and operated by a homeowners association. Others are operated by firms that specialize in operating small systems.

Public officials should be aware that water systems created in this way can result in substandard service to customers unless they are properly planned, constructed, and supervised.

Water System Organization

The organization of small public water systems often becomes obscure because there are relatively few employees with multiple responsibilities. But, it should be kept in mind that the same organizational principals should apply as in any other business. There are many texts devoted to proper business organization principles, but a few of the prime points that should particularly be observed by public water systems are:

- Each individual should have only one "boss," and all direction and guidance should normally be through that person. The formal chain of command should be clearly designated by the organization chart.

- Specific delegation of authority should be made to employees at each level.

- The tasks, duties, and responsibilities of each person should be defined as precisely as possible.

The result of poor organization is indecision by employees in performing their work, lack of coordination between employees, and poor relations between employees and their superiors. This will usually cause water quality and/or customer service to suffer.

Personnel

Personnel Requirements

Technological changes are rapidly making the operation of public water systems more complicated. Operators and workers must have the knowledge and abilities to deal with complicated electronics, more powerful machinery, new treatment methods, and compliance with regulations. Increased ability requirements also extend to office work where the operation of computers is becoming essential even in relatively small systems.

Public officials should bear in mind that the safest, most efficient operation of the water system will be achieved by following the principles of employment management.

- Salaries and fringe benefits should be adequate to attract competent persons.

- Selection of new employees should be based on experience, aptitude, and character.
- There should be a viable promotion and compensation policy to keep employees interested in their work.

Employee Training

Both the employees and managers of public water systems should realize the need for proper employee training. Most water system employees are trained by their supervisor and/or co-workers. A new worker is often assigned to work with an experienced worker to learn the duties he is to perform. Unfortunately, many people are not good teachers, and many workers resist sharing their knowledge for fear it will jeopardize their position. This type of training may perpetuate errors and misinformation if the trainer is not himself performing the tasks properly.

The principal benefits of good employee training are:

- Improved morale and interest of employees in their work.
- Increased employee productivity, loyalty, and dedication.
- Decreased chance of employee errors that cause problems such as damage to equipment or contamination of the water supply.
- Improved opportunity for employees to develop into future supervisors.

On-the-job training of employees should be a deliberate, conscious effort. Supervisors or experienced employees who are willing to share their knowledge should be designated as trainers and allowed the time necessary to do this work. The following sources of outside training opportunities are also available to water system employees:

- Training seminars conducted by the state public water supply agency, the state Rural Water Association, the AWWA Section, and other water works organizations.
- Correspondence courses.
- Meetings of local water operator groups.
- Water works courses provided by colleges.

Operator Certification

Most states now require that community public water systems must be under the direction of a *certified operator*. Increasing emphasis is expected to be placed on mandatory certification as a means of ensuring that the complex responsibilities of water system operation are under the direction of competent persons.

Certification programs vary from state to state, but in general, water system operations are divided into several degrees of complexity, ranging from a simple well supply to a full surface water treatment system. The operation of a distribution system is also usually assigned a separate class. An operator must usually achieve certification for each lower class before proceeding to the next class.

Award of certification in each class is usually based on passing a state-administered examination, in addition to having required education credits, and meeting an experience requirement of months of service actively working in a water system organization. Most states allow reciprocity with other states that they consider to have an equally stringent certification program.

A person can prepare for a certification examination by self-study or using a correspondence course. State examinations generally emphasize specific points and processes. The best way to prepare for these exams is through a certification preparation course. These courses are held periodically around the state, and may be sponsored by the state, a water works organization, or a local college.

Water operators usually must renew their certification every few years. A growing number of states are requiring operators to have a specified number of *continuing education units* (CEUs) in order to renew certification. The CEUs are awarded for attending seminars and training courses. The continuing education requirement helps ensure that certified operators are keeping abreast of changing rules and technology.

Public Relations

Managers of municipal and other publicly owned water systems generally devote little time and effort to public relations (PR). There are always so many other things to do that this is usually at the bottom of the priority list. Besides, the public has no choice other than to use water from the system, so why waste time on public relations?

When a water system keeps a low profile, the public rarely realizes the complexity of the operation, the problems that must be coped with, and the product and service the system is providing. Many customers do not even know where the water comes from. As long as service is reliable, water quality is acceptable, and there are no drastic changes in rates or policy, the public generally has little interest in the operation of the water system.

Maintaining good public relations does not have to be a big effort. Many things can be done to inform the public and maintain a good image, that do not require a lot of work or cost:

- Public relations should start *at the top*, with managers maintaining an open and tolerant attitude toward customers and promoting that attitude with subordinates.

- *Meter readers and billing office personnel* have by far the greatest exposure to the public of all water system employees. These employees must maintain a good appearance, positive attitude, cheerfulness, and tact in dealing with the public.

- *Keeping the public informed* of water system work takes extra effort but is appreciated by customers. The person who has the water unexpectedly turned off in the middle of a shower or the housewife who has clothes in the washer when the water turns brown due to main flushing has good reason to be irate. Personal visits to customers are best if work that will disrupt service or property must be done immediately. Doorknob cards or post cards work well if the work is scheduled for a day or so in the future.

- The use of *postcard billing* has rather reduced the ability of water systems to add information notes to customers along with water bills. Some systems have been able to design their postcard with enough room to add a short public information message. Others send the postcard bill in an envelope once a year so that public information material can be enclosed.

- *Pamphlets* on water are available from federal and state agencies and various associations. These can be purchased in quantity or copied for distribution to customers.

- Another opportunity to inform the public that is often available to a municipally operated water systems is to include articles in the *town newsletter* used by many communities to inform the public on local matters. Information that can be provided include details of upcoming work to be done on the water system, advanced warning and details of rate increases, and homeowner suggestions, such as how to look for plumbing leaks.

- *Informing children* about the local water system can be both gratifying and pay good dividends. This includes providing information and literature for teachers to use in their classes, arranging for a water system employee to speak before classes, or taking classes on a tour of the water plant. Not only will the children be better-informed, but they will take the information presented to them home and project a positive image of the water system to their parents.

- Trucks, tractors, fire hydrants, elevated tanks, and other *water system equipment* that is seen by the public should be kept clean, well-painted, and in good repair. Besides projecting a good image, there is usually a side benefit that employees take better care of equipment that is well-maintained.

- Attention should be given to the *appearance of employees* as well. Many systems now provide uniforms for employees. This is a relatively inexpensive fringe benefit that encourages workers to maintain a neat appearance in spite of having to perform relatively dirty work.

When major work or policy changes will affect customers, a special public information effort is usually advisable. Examples are major construction projects that will cause inconvenience to the public, a change in water quality, or a significant rate increase. It is often best to inform all affected customers with a letter that fully explains what is to be done and why.

New state and federal requirements for water quality and system operation often require systems to make expensive improvements. It is important that these systems begin to get public support for funding as soon as it is known that they are affected by the requirements. It should be emphasized that the requirements are considered necessary to protect the public from dangerous diseases or chemical contamination.

Financial Considerations

Accounting

All public water systems should be operated as a business with careful accounting of expenditures, revenues and property. Proper accounting maintains records of the assets of the operation, the outstanding financial obligations, revenues, and the costs of operation. An interpretation of the accounting records and data is normally presented in periodic reports. These reports may be monthly or quarterly, but the most important one is the year-end report that shows financial standing at the end of the calendar year or fiscal year.

Private and investor-owned water systems must follow good accounting practices in order to determine taxes to be paid and account to the controlling board and stockholders on dividends to be paid. They must also show that the business is being efficiently operated in order to justify the need for adjustment of water rates to the state Public Service Commission.

The need for *publicly owned* water systems to follow good accounting practices is less obvious. There is often the tendency in small municipalities to group water revenues and expenditures with all other municipal operations.

One important reason for maintaining special, separate accounting for the water system is that most systems have one or more outstanding loans or bond issues. These obligations are usually based on water revenue and must be paid off over a specific period of time. Careful control of finances must therefore be maintained to ensure that adequate funds are available to meet obligations in addition to operating expenses.

There is also a chance that a water system will want to borrow funds again in the future. The system that can show good accounting practices and a good record of meeting past obligations will usually be able to obtain future funding at more favorable interest rates.

Some states require that publicly owned water systems receive state Public Service Commission approval for rate increases. In this case, good accounting practices are essential to justifying the request for Commission approval.

Meter Reading And Billing

With few exceptions, it is standard practice for public water systems to install meters on all water services, including those serving municipal and charitable organizations.

Customer meters are read at regular intervals by a meter reader who travels from house to house. Readings are entered on a meter card or in a meter book for each address. Readings are then submitted to the billing office to begin the billing process. Some systems place multiple meter readers in the field at the same time to get all meters read within a few days, which allows for all billing on a set date. In larger systems, meter reading is usually on a continual basis.

Where all or most meters are located inside buildings, there is usually a problem of getting the meter reading from homes where the residents are not home on weekdays. Some systems partially solve this problem by having meter readers work on Saturdays.

Many systems have the meter reader leave a doorknob card if nobody is at home. The card requests the occupant to read their own meter and return the attached postcard by a specified date. Not all occupants, though will take the time to do this.

Where a meter reading cannot be obtained, the bill is estimated, based on use in preceding periods, and given the time of year. It is generally not good policy to estimate a bill more than two or three times in succession in order to prevent the difference between estimated and actual use from becoming too large.

Meter readers will usually receive a better reception for entering residences if they are provided with neat distinctive uniforms and proper identification. It also helps if readers always work the same area so that customers recognize them.

One of the newer meter reading improvements requires the installation of a connection from an inside meter to an outside terminal. The meter reader can then obtain water-use information from the terminal without entering the building. As a matter of practice, though, the meter reader should enter the building and inspect the meter installation every year or two.

It is relatively common for municipally owned water systems to include sewage, garbage collection, or other charges along with the water bill. Sewage charges are structured in various ways but are often proportional to water use. It is not good practice to have hidden costs included in water bills. If a municipality uses the water bill to collect for other services, they should be positively identified as separate items on the bill.

Most water systems have gradually changed from sending bills in an envelope to use of a postcard bill. This saves the cost of an envelope, the labor of stuffing envelopes, and requires less postage. Most municipalities and water systems prefer to do their own billing, but commercial firms are available to provide billing in an efficient manner.

Water Rates

In the United States, water rates are usually either expressed in dollars per 1000 gallons or dollars per 100 cubic feet, depending on which type of meter registration is used.

A minimum charge for each billing period is usually set up based on service or meter size. This is the water system cost for maintaining staff and equipment, meter reading and billing and other fixed costs, even if no water is used by the customer. The rate schedule used by water systems generally falls into one of the following methods of bill computation.

- *Flat rate*: all customers pay the same rate per unit of water used, regardless of the amount of water use.

- *Two-tiered, flat rate*: customers are charged a minimum, plus a flat rate for water used.

- *Pure declining block*: the charge per unit of water declines in steps or "blocks" with increased water use.

- *Two-tiered, declining block*: an initial minimum charge covers a specified amount of water, and all use in excess is charged at progressively lower rates.

- *Pure increasing block*: the charge per unit of water *increases* with increasing use.

- *Two-tiered, increasing block*: an initial minimum charge covers a specified quantity, and use in excess of this amount is charged at increasing rates.

Generally, if an adequate supply of water is available and water system facilities are adequate, a declining rate structure is used. If there is a limited amount of water available or system facilities are limited, no incentive for increased use may be offered. In some areas with severe shortages, a disincentive is actually created by increasing the rates for increased use.

Customers with similar water use patterns are often grouped into rate classes such as residential, commercial, and industrial. There may be a different rate structure for each class based on when and how water is taken from the system. For instance, industrial customers who use the same amount of water year-round present some advantage in water system operation in comparison with residential customers who have wide swings in use at certain times of the year. Industries may at times also be given a preferential water rate to encourage them to settle or stay in a community.

A *rate analysis* is a study that considers all factors to establish water rates as equitably as possible for all customers. One of the prime factors considered in the analysis is the value of all of the property and equipment owned by the water system. Records of expenditures and income, and a bill analysis of water used by various classes of customers are also required. Much of the information required for a study can be gathered by water system staff, but the actual analysis of the information is usually best done by a professional firm.

Publicly owned water systems frequently do not maintain good property and operating expense records. When such a system wishes to perform a rate study, it is usually necessary to employ a professional firm to make property appraisals and the expense estimates necessary to complete the rate analysis calculations.

Funding Improvements

A water system owned by a *municipality or incorporated community* has three basic sources of financing: taxes, revenue from water sales, and other charges and contributions. The existence of these revenue sources allows a system to establish credit so it can borrow money by issuing bonds or notes. The borrowed funds must then be repaid over a period of time, using money from one or more of the sources.

Taxes may be used as a source of funding for a new water system where it is necessary to borrow against the credit of the community and subsidize the operation until it can become self-sustaining. Once the water system has sufficient revenue, the tax funds are no longer needed.

Revenue from water sales and other charges should, at a minimum, pay for operation and maintenance of the system, as well as interest on, and redemption of borrowed funds. A portion of the cost of system replacement and additions is also paid for from revenue. However, when improvements are made from current revenue, the current customers are paying for facilities that will primarily benefit future customers. This is why major improvements are usually funded by bonds, so that the costs will be paid for by the customers who enjoy the benefits.

Contributions to the water system are commonly required from new customers to assist in financing the cost of establishing their new service. Included is usually the cost of water main extensions, valves and hydrants, service connection, and meter installation.

Grants or other awards of funds that do not have to be repaid are sometimes made to water systems by various government agencies. The availability of these funds for water system use varies, depending on the economy, the interests of legislators, and other factors.

Bonds are frequently issued by water systems to acquire land, replace outdated or failing equipment and facilities, and expand the system. The bonds provide large sums of money when needed and permit repayment at a relatively uniform level over a period of years. There are many types of bonds which may be issued, but the two that are most common are general obligation and revenue bonds.

General obligation (GO) bonds pledge the taxing power of the municipality against the bonds, but are paid off mostly or entirely from water revenue. The advantage of a GO bond issue is that the added security of having both revenue and potential tax income to meet the obligation may secure a more favorable interest rate.

The disadvantage of GO bonds is that the bond issue becomes part of the municipal debt, and will be included in determining the remaining bonding capacity of the municipality. This obligation can seriously restrict the ability of a small municipality to issue GO bonds for other community improvements such as sewers, road construction, or buildings. A GO bond issue is usually approved by residents of the municipality in a referendum vote.

Revenue bond issues pledge the revenues of the water system to pay the interest and redeem the bonds when due. Some municipalities have the authority to issue bonds without a referendum vote. Revenue bonds can usually be issued much more quickly than GO bonds, but must be set up under good legal guidance. Among the requirements for good acceptance of the bonds is that the water system set up reserve funds to ensure that adequate funding is available to retire the bonds on schedule even if revenue should drop or unexpected operating expenses occur.

Low-interest loans are sometimes available to a publicly owned water system from state or federal agencies, under varying circumstances. This special funding is often available for construction of a new water system or specific improvements to an existing system.

The principal federal funding sources that may be available to public water systems are the Rural Development Administration (RDA) and the Department of Housing and Urban Development (HUD). Many states also have special funds that on occasion may be available for water system use. The availability of these funds is usually tied to special conditions regarding where they may be applied, such as community size, economic conditions, or actual need.

Private- or investor-owned water systems, unlike publicly owned systems, cannot be financed entirely by bonds or securities. As in any other form of private business, the owners must provide a substantial part of the equity. The larger systems are organized much the same as an electric or gas utility, with a relatively large number of stock-holders. These systems are generally operated efficiently and have very good stock ratings.

Smaller investor-owned systems must be operated efficiently and continuously show a good rate of return on investment in order to sustain operation. Private- and investor-owned systems are not generally eligible to receive the grants or low-interest loans available to publicly owned systems.

Adapting to Change

Restructuring

Some small water systems may have difficulty complying with changing state and federal drinking water regulations without causing their customers' water bills to be excessive. For these systems, the solution may be *restructuring*. Restructuring means changing a water system's management, operation, or type of ownership in order to be more efficient or to take advantage of new sources of funding. Some examples of restructuring are:

- Public officials responsible for very small municipal systems should consider the alternative of contracting with a private firm to provide operation services. A firm specializing in this type of work often has the knowledge and equipment to operate the system more efficiently as well as provide more reliable water service to customers.

- Small, privately owned systems are not generally eligible for state or federal grants or low-interest loans. Consideration should be given to becoming part of an area water service district so that new sources of funds for operation and improvements will be available.

- A number of small systems may join together in an association to take advantage of quantity purchasing, use of a shared certified operator, joint use of specialized eqiupment and other cost-saving procedures.

Additional details on restructuring are provided in the reprinted EPA pamphlet that appears in Appendix D of this handbook. Additional information is available in the EPA publication *Restructuring Manual* (EPA 570/9-91-0350). A copy of this guidebook may be obtained by calling the Safe Drinking Water Hotline at 1-800-426-4791, or by writing the Office of Ground Water and Drinking Water Resource Center, USEPA, 401 M Street, SW, Washington, DC 20460.

Chapter 7

Water System Operation Programs

Planning

Maintenance Planning

Proper maintenance of both production and distribution equipment is essential to the efficient operation of a water system. The sudden breakdown of equipment can cause serious problems, such as loss of system pressure or inadequate treatment.

Management attitude toward maintenance is important. There should be a clear policy directing a maintenance program, including specifying work to be done, when it is to be done, and who is to do it. Maintenance is often a rather thankless job, so managers should make extra effort to reaffirm the need and commend employee efforts.

Personnel performing maintenance work should be specifically designated by supervisors. Problems develop when a directive is left open for "somebody" to do the work at an unspecified time. Not everyone is qualified, experienced, or likes to do maintenance work. To assign responsibility to someone who does not like the work or does not have the aptitude may mean that it will not be done properly.

Instructions on each piece of equipment should be maintained in a file, and workers should be allowed time to study the information in the file before beginning a maintenance job. If the manuals are not clear or sufficient, many manufacturers are willing to have a representative visit the water system and provide further instruction. Where this is not possible, manufacturers will usually provide consultation by phone.

Tools, spare parts, test instruments, and shop facilities must be made available for workers to properly perform maintenance work. Required parts and materials should be anticipated to the extent possible before work is started. The materials and tools should be available so that, once work has started, it can continuously progress. Having a proper place to do maintenance work, such as a clean, heated workshop can also speed the job and insure that it is performed properly.

Maintenance work should be *planned and scheduled* in advance. The frequency should generally be in accordance with the manufacturer's recommendation, in addition to local experience. Some maintenance jobs may be required weekly to ensure proper equipment operation and prolong its life. Other frequencies commonly used are monthly, quarterly, and yearly. Frequencies of longer than a year are difficult to remember, so special effort must be made to keep records and reminders of when the work should be done.

It is often desirable to schedule maintenance jobs by season of the year. Well maintenance is usually scheduled for spring and fall, and treatment plant maintenance is often done when the weather is not suitable for outside work.

Records and reports of repair and maintenance work must be kept to achieve an effective program. It is common practice to keep a record card or notebook sheet for each piece of equipment. The record should include information such as the make, model, serial number, installation date, manufacturer's representative address, and recommended maintenance schedule. Space should also be provided on the sheet for recording the date and details of work performed.

Emergency Planning

All public water systems can be the victim of various kinds of disasters. In general, the problems that can disrupt a water system operation fall into two categories.

- *Natural disasters*, such as earthquakes, floods, hurricanes, tornados, forest fires, landslides, snow and ice storms, and failure of the water source.

- *Manmade disasters*, such as vandalism, explosions, strikes, riots, terrorism, and warfare.

Some potential emergencies can be averted or minimized by advance preparations. For instance, good security at water facilities can help reduce vandalism. Beyond the problems that can be prevented, water system managers must be prepared to act swiftly and efficiently in the event of an emergency.

The first step in developing an emergency plan is to analyze which types of emergencies the water system is most likely to experience, and the effect of each. An emergency response plan is then developed to include a list of preparations that can be made in advance, and projections of the steps that would be taken in the event of each emergency. Some of the primary steps suggested for a water system to prepare for major emergencies are:

- Maintaining water system records in good order and readily available for use.
- Maintaining a contact list of state and local water supply and disaster agencies, equipment suppliers, contractors, key personnel in nearby water systems, and any other person or organization that might be able to provide assistance during an emergency.
- Maintaining a good stock of repair parts that might be required in an emergency and a list of where additional parts may be obtained quickly.
- Considering the need for standby generators or auxiliary power drives for equipment for use during failure of commercial electric power.
- Obtaining tools and equipment that will facilitate emergency repairs, and maintain them in a state of readiness for quick response during an emergency.

Replacement And Expansion Planning

Water system equipment is usually replaced for one of the following reasons: it has failed or is failing; it has become obsolete and should be replaced with a newer model; or it must be replaced with a unit that is larger or has more capacity.

Planning for the replacement of equipment should be a continuous process. An indication that equipment should be replaced will often come from the observations of plant operators, maintenance workers, supervisors, equipment company representatives, or from the state drinking water program staff. These people all have a genuine interest in seeing that the water system has proper and reliable equipment, so their suggestions should be honestly considered and evaluated.

When a piece of equipment needs to be replaced, investigation should be made of improved models that might be more reliable or efficient, or have other advantages. Consideration should also be given to up-sizing equipment when it is replaced, to allow for future needs. One of the primary advantages of replacing equipment before it completely breaks down is that more time can be taken to evaluate the alternatives before making a selection.

If there is a question of how or whether a piece of equipment should be replaced, it is usually best to get the opinion of a professional engineer who is experienced in water system design. The engineer will analyze the overall effects of equipment replacement, consider alternatives available, and suggest the best approach.

The steps required in preparing and executing a major project for water system *expansion and improvements* are usually as follows.

- Preparation of a study and cost estimate to suggest what should be done.
- Specific decisions by management on work to be done, and method of funding.
- Preparation of plans and specifications, and arrangements made for funding.
- Approval of plans and specifications by the state.
- Acceptance of bids and letting contracts.
- Overview of construction to ensure conformity with plans.
- Equipment start-up, and training of employees.

Each of these steps may take up to several months, so it is not unusual for the time between inception and completion of a major project to take several years. Planning, therefore, must be extended as far into the future as possible.

Expansion of the water source, increased storage capacity, treatment improvements, and water distribution improvements are some of the needs that must be considered to stay abreast of customer demands.

In addition, due to new federal and state requirements, planning must also consider changes in operation or treatment that may be mandated by new regulations.

Water system managers should try to maintain five- and ten-year projections of improvements and changes that should be made in the system. Long-range plans must be continually reevaluated and updated to keep abreast of changing demands, requirements, and technology.

Programs For Proper Water System Operation

Water Accountability

The un-metered water that is used or wasted on the system generally produces no revenue. Water system managers should therefore strive to account for as much of the water produced as possible.

The principal requirements for accountability are to have accurate metering of all water being pumped to the distribution system and to have 100% metering of all water services.

The difference between the water pumped and the total of water metered to customers is then either used for an un-metered purpose, or wasted. The principal un-metered uses that are normally necessary, at least to some extent, and *authorized* are:

- Fire fighting.
- Water main flushing.
- Fire hydrant testing.
- Sewer flushing.
- Street cleaning.
- Filling tank trucks.
- Construction use.

Some water systems obtain revenue from some of these uses by making charges, such as tank truck filling fees, or installation of temporary meters for construction use. It is also possible to estimate these uses in order to maintain better water accountability.

The unmetered water that cannot be accounted for as authorized, is wasted due to broken mains, water leaks, and unauthorized use. Unauthorized uses can usually be controlled by public education and alerting system employees, police, and public works employees to report any use that they suspect is not authorized.

Except in areas of very porous soil, water leaks tend to either come to the surface or find their way into a crack in a sewer. The public, police, and other public workers should be encouraged to report leaks so that prompt repairs can be made. Hidden leaks can often be detected by sewer maintenance crews when they notice excessive flow in a sewer line. Suspected leaks can often be located by using a listening device that amplifies the noise made by escaping water.

Water systems having source water with a high value, or where there is a shortage of water, must make a special effort at water accountability. Unmetered use must be held to a minimum and the search for hidden leaks intensified. Many water systems have found that employing the services of a professional leak-survey firm will identify leaks that have a lost-water value over a period of time in excess of the cost of having the survey performed.

Water Conservation

On the whole, the United States has plenty of fresh water, but it is not always distributed so that we have the desired amount at all locations. In areas with plentiful water there is generally little interest in conservation. Where short-term shortages exist, the conservation measures usually consist of restrictions on lawn sprinkling. Otherwise, it is general practice to attempt to supply the public with as much water as they wish to use.

In situations where water rates will be greatly increased as a result of water system improvements, some systems recommend water conservation measures to customers as a means of minimizing their bill increases.

There are some areas of the country, though, where the amount of water readily available is much less than required for unrestricted use. When expansion of water sources cannot keep up with the demand, water conservation measures become essential.

Substantially raising the cost of water usually serves to make most customers more aware of the need to conserve water, but there are usually some who are not concerned by the cost. Systems with long-term water shortage problems usually start with customer conservation education programs. The program tries to instill a customer awareness on reducing use and waste.

Recommendations are also made on changes in plumbing fixtures or methods of water use to conserve water. Examples are installing flow restrictors on shower heads, taking showers instead of baths, and providing instruction on landscaping methods that do not require watering.

When voluntary conservation is not sufficient to meet the water use reduction needs, it becomes necessary to exert additional control with local laws. Requirements usually include mandatory installation of low-water-use plumbing fixtures in all new construction and fines for not adhering to sprinkling restrictions.

Fire Protection Requirements

The variation in property fire insurance rates between different communities is due primarily to the rating that has been assigned to the community. The ratings are provided in most states by ISO Commercial Risk Services, Inc., which is a nonprofit corporation serving the insurance industry.

Most communities in the United States have been classified by the grading schedule on a scale of 1 through 10. Class 1 is a system with a highly rated fire department and water supply facilities and procedures. Class 10 communities have no fire protection within five miles.

In the grading process, a 40% weight is placed on the water system. As a result, a community with a good fire department, but an inadequate water system, will probably be assigned a poor rating. Water system rating considerations include ability of the supply works to meet maximum demands, capacity of mains to deliver fire flow, and details of hydrant distribution, size and maintenance. Details of the water system rating procedures are provided in *American Water Works Association Manual M-31.*

Cross-Connection Control

A *cross-connection* is a piping connection or condition which will allow a foreign substance to flow into a water system. Over the years, thousands of cases have been recorded of contamination of a public water system as a result of back-flow of contamination through a cross-connection. The conditions under which contamination occurs from a cross-connection are often unusual. Nevertheless, the recorded cases of waterborne disease serve as proof that these violations do occur.

Back-pressure is the situation where contamination is forced into a potable water system through a connection that has a higher pressure than the water system. An example is a heating boiler. Normally, water is automatically filled into a boiler, but if the boiler gets too hot and the excessive pressure is not otherwise released, the pressure may force boiler water back into the water system.

Back-siphonage can occur when there is reduced pressure or a vacuum formed in the water system. This might be caused by a water main break, the shut-down of a portion of the system for repairs or heavy water use during a fire. If a vacuum is formed in the system for even a short time, any directly connected container of liquid might be siphoned back into the piping system.

There are many places in homes, businesses, and industries where cross-connections can unknowingly be present. Early plumbing fixtures possessed a number of potential cross-connections that are now avoided by newer designs. For example, early bath tubs had the fill spout located inside the tub. It is now required that the spout be located above the tub rim to eliminate any possibility of back-siphonage of tub water into the plumbing system.

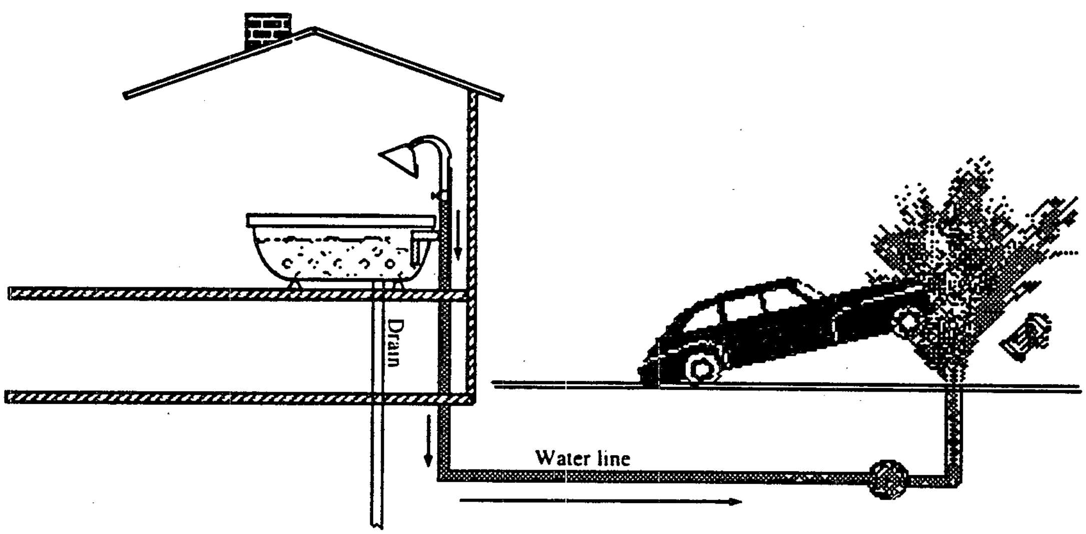
State public water supply agencies generally require or urge all public water systems to have an active cross-connection control program. Model plans are available to assist water system managers in enacting appropriate control ordinances, making inspections, and educating customers on cross-connection prevention.

Safety

All public water systems should have a safety program to minimize the pain, costs, and disruption of the organization that can occur when someone is injured in an accident. In the water works industry, three general areas of safety are of concern:

- Prevention of work-related injury to employees.

Illustration of the Potential of Back-siphonage from a Submerged Bathtub Inlet



- Prevention of automobile and other vehicle accidents.

- Prevention of injury to the general public.

To minimize *job-related* injuries, supervisors should be knowledgeable about recommended safety practices and make a practice of regularly reviewing them with employees. Employees who are constantly reminded of safety and safe practices, eventually get into the habit of "thinking safe." Safety should especially be emphasized during emergencies when workers are tempted to take short-cuts or work under dangerous conditions to hurry the job.

Safe conditions and practices that management should insist on are:

- Good housekeeping.

- Use of personal protective equipment whenever required.

- Prompt attention to even slight injuries.

- Proper operation of tools and equipment.

Management has an obligation to furnish employees with proper protective gear. Safety glasses, hardhats, and dust masks are usually provided for employees who are exposed to dangerous conditions. It is the duty of the supervisor to set an example by wearing his protective equipment, and insisting that workers make use of and take care of the equipment that is issued to them.

The water system should also furnish workers with proper tools to do their work in a safe manner. Many accidents are caused from trying to do a job with the wrong tool. It is again the duty of the supervisor to see that proper tools are available and taken care of, and that the workers use them correctly.

Although the operation of vehicles seems somewhat incidental to the operation of a water system, it often accounts for the largest number of water system accidents. Supervisors must remember to stress safe vehicle operation as a safety item.

The safety of the public must also be constantly considered when performing water system work. For instance, if a person is injured falling into an improperly guarded excavation, it not only causes ill will, but also places system management and individual employees at risk to a suit for damages.

Protecting the public includes providing traffic control when working in streets, protecting excavations, and providing security at buildings, storage areas, and water towers.

There are a number of federal and state agencies involved in ensuring safe working conditions. The Occupational Safety and Health Act (OSHA) regulations intend to create work places free from hazards that could cause physical harm or death. The Act also allows for civil and criminal penalties for violations of the requirements.

Lead And Copper Contamination Control

A regulation enacted by USEPA in June 1991 requires all community water systems, as well as nontransient-noncommunity systems to set up special programs to monitor for lead and copper in drinking water.

The ingestion of excessive amounts of lead and copper is associated with a number of adverse health effects. In particular, children who have had excessive exposure to lead are likely to experience a delay in mental and physical development, impaired mental abilities, and behavioral problems.

Major sources of human exposure to lead include lead-based paint, lead-contaminated soil and dust, some food and utensils, and as a contaminant in drinking water. Lead contamination of soil and dust is caused primarily from past use of leaded gasoline.

It is rare for there to be an appreciable amount of lead or copper in either ground or surface water. The principal cause of lead and copper in drinking water is from corrosion of materials in the distribution system and building plumbing. When water is in contact with lead or copper for a period of time, some of the metal is dissolved. The principal sources of lead contamination are from lead pipe, lead-tin solder used for joining copper pipe, and brass plumbing fixtures. Copper contamination can be cause by corrosion of copper pipe. The concentration of lead or copper that may be present in drinking water is affected by a number of factors, such as the contact time, the corrosiveness of the water, and the age of the piping.

Monitoring required for each system includes selection of customers who have plumbing systems vulnerable to lead and copper contamination, and collecting samples of water that has set in the piping for at least six hours.

If lead or copper levels are found to be excessive, the system may have to begin special treatment of the water to reduce its corrosivity and a public education program to warn customers of the health dangers. If lead contamination cannot be adequately controlled by reducing water corrosivity, the system may be required to begin a program of replacing old lead water service lines with new material.

Appendix A

Sources of Additional Information and Assistance

• The *U.S. Environmental Protection Agency* (EPA) is responsible for protection of drinking water supplies under the Safe Drinking Water Act. The agency establishes national drinking water standards and monitors state enforcement of drinking water standards, system management, and operations. The EPA's principal office is located in Washington, DC. The agency maintains a Safe Drinking Water Hotline to provide information on drinking water regulations, policies, and documents. The Hotline hours are 8:30 a.m. to 5:00 p.m. Eastern Standard Time, Monday through Friday excluding holidays. The Hotline number is:

1-800-426-4791

There are also ten regional offices of the U.S. Environmental Protection Agency in the United States. These offices may be contacted for information on drinking water regulations and policies regarding water systems located within their region. The address and phone numbers of the regional offices are listed in *Appendix B*.

• *State drinking water agencies* have been designated by the governor of each state to accept primary enforcement responsibility for the operation of the program within their state. Each agency also has several field offices that can be contacted for specific information on state requirements for the operation of public water systems. The principal offices of each state agency is listed in *Appendix C*.

• The *American Water Works Association* (AWWA) is a scientific and educational association that conducts research and provides technical publications, information, training, and technical assistance to the public water supply industry. The central office is in Denver, Colorado. Each state is also represented by an AWWA Section that is generally quite active in holding meetings and presenting training classes. For further information contact:

American Water Works Association
6666 W. Quincy Avenue
Denver, CO 80235
1-303-794-7711

• The *National Rural Water Association* (NRWA) provides technical publications, training, and technical assistance to small water systems and rural water districts. Many states also have a state organization and staff who provide technical assistance and training. For further information contact:

National Rural Water Association
P.O. Box 1428
Duncan, OK 73534
1-405-252-0629

• The *Rural Community Assistance Program* (RCAP) consists of six regional agencies formed to develop the capacity of rural community officials to solve local water problems. The program provides on-site technical assistance, training, and publications to rural communities. The addresses of RCAP agency offices are listed in *Appendix C*.

• The *National Ground Water Association* is a not-for-profit professional society and trade association representing the groundwater industry. The Association provides expositions, education, and research on wells and ground water, and has many publications available on ground water subjects. For information contact:

National Ground Water Association
6375 Riverside Drive
Dublin, OH 43017
1-614-761-1711

• The *New England Water Works Association* (NEWWA) is a membership organization representing consultants, water supply operations and management professionals, and technical experts. NEWWA sponsors workshops, offers publications, and provides its members with an opportunity to exchange ideas and information on water works operations and management.

New England Water Works Association
42A Dilla Street
Medford, MA 01757
1-508-478-6996

• The *Rural Development Administration* (RDA) provides grants and loans for rural water systems and communities with populations less than 25,000. For additional information contact:

Rural Development Administration
14th and Independence Ave., SW
Washington, DC 20250
1-202-720-9619

• The *National Drinking Water CLearinghouse* (NDWC) was established in 1991 at West Virginia University to develop and maintain services and information related to small community drinking water systems. Intended for communities of less than 10,000 people and those who work with them, the NDWC provides publications, databases, referrals, and educational products.

National DrinkingWater Clearinghouse
West Virginia University
P.O. Box 6064
Morgantown, WV 26506-6064
1-800-624-8301

Appendix B

U.S. Environmental Protection Agency Drinking Water Programs

EPA Headquarters
401 M. Street, S.W.
Washington, DC 20460
800-426-4791

EPA Region 1
JFK Federal Building
Boston, MA 02203
617-565-3610
Connecticut, Massachusetts, Maine, New Hampshire, Rhode Island, Vermont

EPA Region 2
26 Federal Plaza
New York, NY 10278
212-264-1800
New Jersey, New York, Puerto Rico, Virgin Islands

EPA Region 3
841 Chestnut Street
Philadelphia, PA 19107
215-597-8227
Delaware, Maryland, Pennsylvania, Virginia, West Virginia, District of Columbia

EPA Region 4
345 Courtland Street, NE
Atlanta, GA 30365
404-347-2913
Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee

EPA Region 5
230 South Dearborn Street
Chicago, IL 60604
312-886-6197
Illinois, Indiana, Ohio, Michigan, Minnesota, Wisconsin

EPA Region 6
1445 Ross Avenue
Dallas, TX 75202
214-655-7155
Arkansas, Louisiana, New Mexico, Oklahoma, Texas

EPA Region 7
726 Minnesota Avenue
Kansas City, KS 66101
913-551-7032
Iowa, Kansas, Missouri, Nebraska

EPA Region 8
One Denver Place
999 18th Street, Suite 1300
Denver, CO 80202
303-293-1413
Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming

EPA Region 9
75 Hawthorne Street
San Francisco, CA 94105
415-744-2250
Arizona, California, Hawaii, Nevada, American Samoa, Guam, Trust Territories of the Pacific

EPA Region 10
1200 Sixth Avenue
Seattle, WA 98101
206-553-6648
Alaska, Idaho, Oregon, Washington

Appendix C

State Drinking Water Agencies

Region 1
Connecticut Department of Health Services
Water Supplies Section
150 Washington Street
Hartford, CT 06106
203-566-1251

Division of Water Supply
Department of Environmental Protection
One Winter Street, 9th Floor
Boston, MA 02108
617-292-5529

Drinking Water Program
Division of Health Engineering
Maine Department of Human Services
State House (STA 10)
Augusta, ME 04333-0010
207-289-2070

State of New Hampshire
Water Supply and Pollution Control Div.
6 Hazen Drive
P.O. Box 95
Concord, NH 03302-0095
603-271-3139

Division of Drinking Water Quality
Rhode Island Department of Health
75 Davis Street, Cannon Building
Providence, RI 02908
401-277-6867

Water Supply Program
Vermont Department of Environmental Conservation
103 S. Main Street
Waterbury, VT 05671-0403
802-863-7220

Region II
Bureau of Safe Drinking Water
Division of Water Resources
New Jersey Department of Environmental Protection
P.O. Box CN-029
Trenton, NJ 08625
609-292-5550

Bureau of Public Water Supply Protection
New York State Department of Health
Room 406, University Place
Albany, NY 12203-3399
518-458-6731

Water Supply Supervision Program
Puerto Rico Department of Health
P.O. Box 70184
San Juan, PR 00936
809-763-4307

Planning and Natural Resources
Government of Virgin Islands
Nifky Center, Suite 231
St. Thomas, Virgin Islands 00802
809-774-3320

Region III
Office of Sanitary Engineering
Delaware Division of Public Health
Cooper Building
P.O. Box 637
Dover, DE 19903
302-739-5410

Water Supply Program
Maryland Department of the Environment
Point Breeze Building 40, Room 8L
2500 Broening Highway
Dundalk, MD 21224
301-631-3702

Water Hygiene Branch
Department of Consumer and Regulatory Affairs
Environmental Control Division
Suite 203, 2100 Martin Luther Kine Ave.
Washington, DC 20020
202-404-1120

Division of Water Supplies
Pennsylvania Department of Environmental Resources
P.O. Box 2357
Harrisburg, PA 17105-2357
717-787-9037

Environmental Engineering Division
Office of Environmental Health Services
State Department of Health
Room 554
East 1900 Kanawha Blvd., East
Charleston, WV 25305
304-348-2981

Division of Water Supply Engineering
Virginia Department of Health
Room 109-31
1500 East Main Street
Richmond, VA 23219
804-786-1766

Region IV
Water Supply Branch
Department of Environment Management
1751 Congressional W.L. Dickinson Drive
Montgomery, AL 36130
205-271-7773

Drinking Water Section
Department of Environmental Regulation
Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, FL 32399-2400
904-487-1762

Drinking Water Program
Georgia Environmental Protection Division
Floyd Towers East, Room 1066
205 Butler Street, S.E.
Atlanta, GA 30334
404-656-5660

Drinking Water Branch
Division of Water
Department of Environmental Protection
18 Reilly Road, Frankfort Office Park
Frankfort, KY 40601
502-564-3410 Ext. 543

Division of Water Supply
State Board of Health
P.O. Box 1700
Jackson, MS 39215-1700
601-960-7518

Public Water Supply Section
Division of Environmental Health
Department of Environment, Health and
Natural Resources
P.O. Box 27687
Raleigh, NC 27611-7687
919-733-2321

Bureau of Drinking Water Protect
Department of Health and
Environmental Control
2600 Bull Street
Columbia, SC 29201
803-734-5310

Division of Water Supply
Tennessee Department of Health
and Environment
150 Ninth Avenue, North
Terra Building, 2nd Floor
Nashville, TN 37247-3411
615-741-6636

Region V
Division of Public Water Supplies
Illinois Environmental Protection Agency
2200 Churchill Road
P.O. Box 19276
Springfield, IL 62794-9276
217-785-8653

Public Water Supply Section
Office of Water Management
Indiana Department of Environmental Management
105 South Meridian
P.O. Box 6015
Indianapolis, IN 46206
317-233-4222

Division of Water Supply
Michigan Department of Public Health
P.O. Box 30195
Lansing, MI 48909
517-335-8326

Minnesota Department of Health
Section of Water Supply and Well Management
Division of Environmental Health
925 S.E. Delaware Street
P.O. Box 59040
Minneapolis, MN 55459-0040
612-627-5133

Division of Drinking and Ground Waters
Ohio Environmental Protection Agency
1800 WaterMark Drive
P.O. Box 1049
Columbus, OH 43266-0149
614-644-2752

Bureau of Water Supply
Department of Natural Resources
P.O. Box 7921
Madison, WI 53707
608-267-7651

Region VI
Division of Engineering
Arkansas Department of Health
4815 West Markham Street - Mail Slot 37
Little Rock, AR 72205-3867
501-661-2623

Office of Public Health
Louisiana Department of Health and Hospitals
P.O. Box 60630
New Orleans, LA 70160
504-568-5105

Drinking Water Section
New Mexico Health and Environment Department
1190 St. Francis Drive
Room South 2058
Santa Fe, NM 87503
505-827-2778

Water Quality Service
Oklahoma State Department of Health
P.O. Box 53551
Oklahoma City, OK 73152
405-271-7370

Texas Water Commission
Water Utilities Division
8900 Shoal Creek
Building 300, Suite 309
Austin, TX 78756
512-458-7542

Region VII
Surface and Groundwater Protection Bureau
Environmental Protection Division
Iowa Department of Natural Resources
Wallace State Office Building
900 East Grand Street
Des Moines, IA 50319
515-281-8869

Public Water Supply Section
Bureau of Water
Kansas Department of Health and Environment
Forbes Field, Building 740
Topeka, KS 66620
913-296-5503

Public Drinking Water Program
Division of Environmental Quality
Missouri Department of Natural Resources
P.O. Box 176
Jefferson City, MO 65102
314-751-0535

Division of Drinking Water and Environmental Sanitation
Nebraska Department of Health
301 Sentenial Mall South
P.O. Box 95007, 3rd Floor
Lincoln, NE 68509
402-471-2541

Region VIII
Drinking Water Program
Colorado Department of Health
4300 Cherry Creek Drive South
Denver, CO 80220-1530
303-331-4546

Water Quality Bureau
Department of Health and Environmental Sciences
Cogswell Building, Room A206
Helena, MT 59620
406-444-2406

Division of Water Supply and Pollution Control
ND State Department of Health and Consolidated Laboratories
1200 Missouri Avenue
P.O. Box 5520
Bismark, N.D. 58502-5520
702-224-2354

Office of Drinking Water
Department of Water and Natural Resources
Joe Foss Building
523 East Capital Avenue
Pierre, SD 57501
605-773-3754

Utah Department of Environmental Quality
Division of Drinking Water
288 North 1460 West
Salt Lake City, UT 84114-4830
801-538-6159

DEQ - Water Quality
Herschler Building, 4 West
122 West 25th Street
Cheyenne, WY 82002
307-777-7781

Region IX
Compliance Section
Office of Water Quality
3033 N. Central, Room 200
Phoenix, AR 85001-600
602-392-4002

Office of Drinking Water
California Department of Health Services
714 P Street, Room 692
Sacramento, CA 95814
916-323-1382

Safe Drinking Water Branch
Environmental Management Division
P.O. Box 3378
Honolulu, HI 96801-9984
808-543-8304

Public Health Engineering
Nevada Department of Human Resources
Consumer Health Protection Services
505 East King Street, Room 103
Carson City, NV 89710
702-687-4750

Guam Environmental Protection Agency
Government of Guam
Harmon Plaza Complex Unit D-107
130 Rojas Street
Harmon, Guam 96911
671-646-8863

Division of Environmental Quality
Commonwealth of the Northern Mariana Islands
Torres Hospital
P.O. Box 1304
Saipan, CM 96950
670-322-9355

Marshall Islands Environmental Protection
Authority
P.O. Box 1322
Majuro, Marshall Islands 96960
Via Honolulu

Government of the Federated States of Micronesia
Department of Human Resources
Kolonia, Pohnpei 96941

Palau Environmental Quality Protection Board
Hospital
Koror, Palau 96940

Region X
Alaska Drinking Water Program
Wastewater and Water Treatment Section
Department of Environmental Conservation
410 Willoughby
Juneau, AK 99801
907-465-2653

Drinking Water Program
Division of Environmental Quality
Idaho Department of Health
and Welfare
1410 North Hilton
Boise, ID 83706
208-334-5860

Drinking Water Program
Department of Human Resources
Health Division
P.O. Box 14450
Portland, OR 97201
503-229-6302

Drinking Water Section
Department of Health
Airdustrial Park
P. O. Box 47822
Olympia, WA 98504
206-753-1280

Rural Community Assistance Program Agencies

Community Resources Group Inc.
2705 Chapman
Springdale, AR 72764
501-756-2900

Great Lakes Rural Network
109 South Front Street
Freemont, OH 43420
419-334-8911

Midwest Assistance Program, Inc.
P.O. Box 81
New Prague, MN 56071
612-758-4334

Rural Community Assistance Corporation
2125 19th Street, Suite 203
Sacramento, CA 95818
916-447-2854

Rural Housing Improvement, Inc.
218 Central Street, Box 429
Winchendon, MA 01475-0429
617-297-1376

Virginia Water Project, Inc.
Southeastern Rural Community
Assistance Program
702 Shenandoah Avenue, NW
P.O. Box 2868
Roanoke, VA 24001
703-345-6781

Appendix D

Helping Small Systems Comply With The Safe Drinking Water Act— The Role of Restructuring EPA/812-K-92-001

United States Environmental Protection Agency | Office of Water | EPA/812-K-92-001 September 1992

EPA

Helping Small Systems Comply With the Safe Drinking Water Act
The Role of Restructuring

Providing Safe, Affordable Drinking Water...

If you are reading this, chances are you know of small drinking water systems that are between a rock and a hard place. They are trying to figure out how to stay in compliance with increasingly complex Safe Drinking Water Act (SDWA) requirements without charging more than their customers can afford.

Requires Doing Business Differently...

Many small systems are able to provide excellent service at a reasonable cost. However, small systems facing compliance and financial difficulties over the long term may want to restructure their ownership or operations. Restructuring solutions can be as simple as several systems sharing a certified operator or as ambitious as the creation of a regional water authority.

And Making a Team Effort.

Successful restructuring takes team work. Careful planning is required to bring water systems, technical assistance providers, regulators, and consumers together in a coalition that can address everyone's needs.

This brochure answers some of the most commonly asked questions about restructuring and provides sources of additional information.

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Q: What is restructuring?

A: Restructuring is the adoption of management and/or ownership changes that help a drinking water system address new responsibilities and increased costs.

Systems can restructure in a variety of ways. For example:

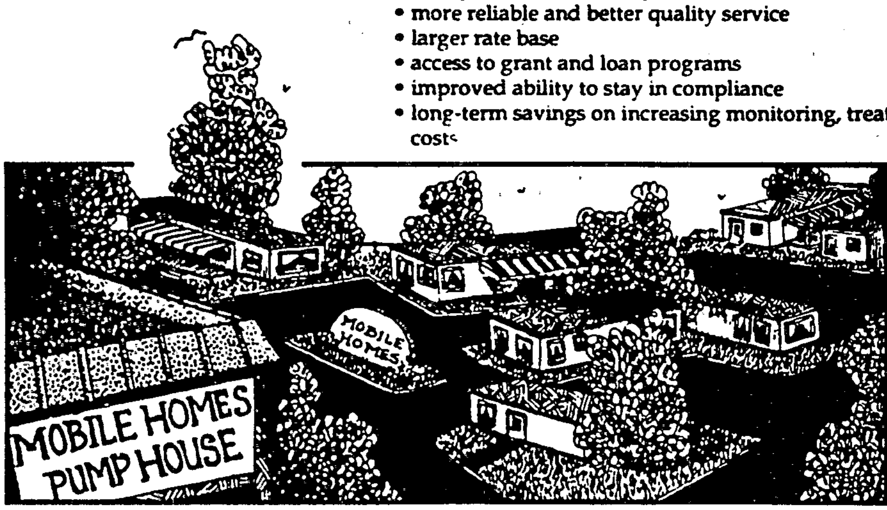
- Groups of small systems can buy and share services together.
- Systems can contract with a private company or larger water system to receive services such as operation and maintenance, meter reading and billing, and sample collection and analysis.
- A small system can merge with or be bought out by a larger one. Systems may be physically connected following this kind of restructuring, but they don't have to be.
- Small privately owned systems can restructure into a non-profit cooperative or public service district and become eligible for federal and state grants and loans.

Q: What are the benefits of restructuring?

A: The primary benefit is economic. Restructuring can give small system operators access to technical, managerial and financial resources they could not afford on their own.

Systems who make management changes through restructuring may also benefit from:

- ability to make necessary investments in facilities and personnel
- more reliable and better quality service
- larger rate base
- access to grant and loan programs
- improved ability to stay in compliance
- long-term savings on increasing monitoring, treatment and operation costs



Q: Won't water rates increase due to restructuring?

A: Water rates are increasing for everyone—small systems may be able to minimize big increases by restructuring.

Changes made to the Safe Drinking Water Act in 1986 are improving health protection. In 1986, EPA required water systems to meet standards for only 22 contaminants. Today, systems must comply with standards for more than 80 different substances including micro-organisms and chemical by-products of various industrial and agricultural practices.

These new requirements mean new testing and analysis expenses for all systems and increased water treatment costs for many. Small systems will be hardest hit because they have fewer customers to share the costs. For example, additional water testing costs of $5,000 per year would mean $200 per family served by a system with only 25 connections. However, for a larger system of 2,000 connections the same $5,000 expense would amount to only $2.50 per family.

Q: Does restructuring mean loss of local control?

A: No, not necessarily. Some restructuring options enable systems to remain independently owned and operated.

Local control is a very important issue to consider in choosing whether or not to restructure. Some restructuring options, such as contracting for operation and maintenance services or cooperative buying, allow for a great deal of local control. These options are also useful to consider when it is not possible or not desirable to physically interconnect separate systems. Other types of restructuring, such as formation of a public service district, allow for less local control but may give a system access to grants and low interest loans. The State drinking water program, technical assistance providers and others can help an individual system decide on the best option.

Satellite Management Success Story

Shortly after Congress passed the Safe Drinking Water Act Amendments of 1986, the mayor and city council of Rolesville, North Carolina knew the cost of providing water to the town's 714 residents was on its way up.

The town would need a trained operator who could devote more time to running the 256 connection system than did the current operator, who had many other duties as well. But, town officials knew, the cost of training, wages, and fringe benefits was unaffordable.

Contract operations and maintenance (O&M) was the only option the town had, felt the mayor. He presented the town council with a proposal to hire Crosby Water and Sewer Inc. in nearby Wake Forest to run the system. The council agreed in late 1987.

Crosby Water and Sewer maintains Rolesville's wells, tests water quality, installs and reads meters. The company also advises town officials on water system improvements and other water related issues, all for $8,500 to $9,500 a year. That's less than even a part-time trained operator would cost, according to the mayor.

The benefits of contract O&M were not long in coming to Rolesville, officials note. During the first year that Crosby operated the system, the company's operational expertise helped reduce by 75 percent town's use of chemicals to treat water.

Q: Is restructuring the answer for small systems?

A: No. Small systems facing compliance problems over the long term will need a mixture of solutions.

Every small system's situation is different. Its needs and the practicality of meeting those needs through restructuring will vary depending on:

- Local water quality
- Nature and cost of required improvements
- Current user costs and customer ability to pay
- Geography and distance between systems
- Availability of grants and loans
- Availability of technical assistance
- Local political considerations.

In many cases, restructuring won't solve all the problems. In addition to restructuring systems should also consider:

- Improving their mangement and operations through training and technical assistance;

- Finding out what flexibility the state drinking water program can offer...for example, some states may be willing to require less frequent monitoring in certain circumstances;

- Utilizing appropriate low-cost technology if increased treatment is necessary;

- Educating customers about new requirements, increased health protection and rising costs.

Consolidation Creates a Regional System

Consolidating numerous non-viable drinking water systems into a single, viable one can make system improvements affordable and ensure the provision of safe drinking water. That's what happened north of Lakeport, California, where 51 small water systems and 500 individual connections were formed into a single water system in December 1990.

Prior to consolidation, 80 percent of the area's small systems were having trouble meeting water quality standards. Both the ground water and Clear Lake were poor sources of supply.

Residents complained about the water, and a juvenile hall in the area was having severe water quality problems. Development of a 100-unit subdivision was threatened when the developer's well went dry after only 8 houses were completed. The county wanted to build a jail in the area, but couldn't without adequate water.

A county-sponsored feasibility study considered eight options, including creation of a regional water system. Although some residents faced water bill increases of $12 a month, voters approved the formation of a County Service Area and decided to build a new modern treatment facility

Q: Who is able to help systems with restructuring?

A: Small systems have limited resources — time, manpower, equipment, parts, inventory, and knowledge. Restructuring can sometimes help to compensate for these limitations but it does require careful upfront planning. The following organizations are interested and knowledgeable about drinking water systems restructuring and can help a system find a local source of assistance.

American Water Works Association (AWWA), Small System Department, 6666 West Quincy Avenue, Denver, CO 80235. (303) 794-7711.

National Rural Water Association (NRWA), 2915 South Thirteenth Street, P.O. Box 1428, Duncan, OK 73534. (405) 252-0629.

Rural Community Assistance Program (RCAP), 602 S. King Street, Suite 402, Leesburg, VA 22075. (703) 771-8636.

State drinking water program staff and EPA Drinking Water Mobilization Coordinators can also facilitate restructuring efforts. The SDWA Hotline (800-426-4791) can identify the appropriate contact in your area.

Q: Where can I get more information?

A: The EPA Office of Water recently published a restructuring manual.

The *Restructuring Manual* (EPA570/9-91-035) covers different types of restructuring options and discusses some of the most commonly encountered problems that can slow or stop a restructuring effort. It is available from the EPA Safe Drinking Water Hotline (1-800-426-4791) or the Office of Ground Water and Drinking Water Resource Center, USEPA, 401 M St. SW, Washington, DC 20460.

EPA

Safe Drinking Water Hotline
(800) 426-4791

U.S. Environmental Protection Agency
Drinking Water Programs

For More Information, contact the office that represents your state

EPA Region 1
GW Mngt./Water Supply Branch
John F. Kennedy Federal Building
Boston, MA 02203
(617) 565-3610
Connecticut, Maine, Massachusetts, Rhode Island, New Hampshire, Vermont

EPA Region 2
D/G Water Protection Branch
26 Federal Plaza
New York, NY 10278
(212) 264-1800
New York, New Jersey, Puerto Rico, Virgin Islands

EPA Region 3
D/G Water Protection Branch
841 Chestnut Building
Philadelphia, PA 19107
(215) 597-8227
District of Columbia, Maryland Pennsylvania, Virginia, West Virginia

EPA Region 4
Municipal Facilities Branch
345 Courtland Street, N.E
Atlanta, GA 30365
(404) 347-2913
Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, Tennessee

EPA Region 5
Safe Drinking Water Branch
77 West Jackson Blvd
Chicago, IL 60604
(312) 886-6197
Illinois Indiana Minnesota Michigan, Ohio Wisconsin

EPA Region 6
Water Supply Branch
1445 Ross Avenue
12th Floor, Suite 1200
Dallas, TX 75270
(214) 655-7155
Arkansas, Louisiana, New Mexico, Oklahoma, Texas

EPA Region 7
Drinking Water Branch
726 Minnesota Avenue
Kansas City, KS 66101
(913) 551-7032
Iowa, Kansas, Missouri, Nebraska

EPA Region 8
Drinking Water Branch
999 18th Street, Suite 500
Denver, CO 80202
(303) 293-1413
Colorado, Montana, North Dakota, South Dakota, Utah, Wyoming

EPA Region 9
D/G Water Protection Branch
75 Hawthorne Street
San Francisco, CA 94105
(415) 744-2250
Arizona, California, Hawaii, Nevada, American Samoa, Guam

EPA Region 10
Drinking Water Branch
1200 Sixth Avenue
Seattle, WA 98101
(206) 553-6648
Alaska, Idaho, Oregon, Washington

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