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MANUAL FOR SAFETY REST AREA WATER SUPPLY SYSTEMS

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Final Report

Prepared for

FEDERAL HIGHWAY ADMINISTRATION
Offices of Research & Development
Washington, D.C. 20590

FOREWORD

This manual presents design and operational guidelines for rest area water supply systems that should assist State highway agencies in complying with the requirements of PL 93-523, Safe Drinking Water Act of 1974. The manual will be of interest to engineers involved in the design and operation of rest areas.

Research in highway rest areas is included in the Federally Coordinated Program of Highway Research and Development as Task 1 of Project 3E, "Reduction of Environmental Hazards to Water Resources due to Highway Systems." Mr. Byron N. Lord is the Project and Task Manager.

Acknowledgment is given to numerous State highway and health department representatives as well as individual experts listed separately in the front of this report who provided assistance during the development of this manual. Metric equivalents are not provided within the text of this report as this research was initiated before this requirement became operational.

Sufficient copies are being distributed by FHWA Bulletin to provide a minimum of one copy to each FHWA Regional and Division office and each State highway agency. Direct distribution is being made to the Division offices.

Charles F. Scheffey
Director, Office of Research
Federal Highway Administration

NOTICE

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16. Abstract

This manual was developed to assist State Highway Agencies in the planning, design operation, surveillance, and maintenance of small, on-site water systems for Safety Rest Areas. The manual presents recommendations for good water supply practice. The manual is organized into the following eight major chapters to provide a ready reference of basic information and guidelines for those involved with water supply systems at Safety Rest Areas:

I. Planning & Design Considerations
II. Source Development
III. Storage Systems
IV. Treatment
V. Hardware & Equipment Selection
VI. Distribution Systems
VII. Operation & Maintenance
VIII. Surveillance

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INTRODUCTION

In response to the Safe Drinking Water Act (PL 93-523) passed in 1974, the Federal Highway Administration initiated a research study entitled Safety Rest Area Water Supply Systems, FHWA-RD-76-103. The purpose and objectives of this study included:

- Identification of existing Federal, State, and local codes and regulations governing safety rest area water supply systems.
- Identification of current practices and existing technology of treatment systems used in safety rest areas.
- Definition of the requirements of PL 93-523 as they pertain to safety rest areas.
- Review the capabilities of existing equipment and procedures to meet the new requirements of PL 93-523.
- Provide recommendations for improvement to current rest area water supply practices.

With the completion of this study in June 1976, came the realization that many state highway departments were in need of guidelines to aid in rest area compliance with the Federal regulations, and to assist highway departments in the development and operation of safe, dependable water supply systems.

Design, operation and maintenance standards and requirements have long been readily available for conventional municipal (community) water systems, and for small water systems used by the individual homeowner and farmer. However, there is limited information available for the intermediate size systems similar to those at rest areas.

This manual is intended to assist highway agencies in the planning, design, operation, surveillance, and maintenance of small on-site water systems defined in the National Primary Drinking Water Regulations (NPDWR) as non-community water supplies. Regardless of the source, drinking water at Safety Rest Areas must conform to state, local or National Primary Drinking Water Regulations — whichever is most stringent.

More often than not, rest areas utilize on-site wells, pressure pneumatic systems and comparatively small distribution systems without conventional fire flow protection. Occasionally, springs and relatively "clean" surface water supplies are utilized. This manual is directed to the design and operation of these types of small, remote water systems.

It is emphasized that this manual is not a requirement or standard guaranteeing compliance with the NPDWR or state and local regulations, but rather the manual contains recommendations of good water supply practice. Under the NPDWR, rest area water supply systems must meet certain standards to assure a safe, adequate, reliable, and attractive supply of water. In order to assure compliance with state and local regulations, state highway departments are urged to consult with local enforcement agencies for specific "standards" which may apply within a particular state or locality, in addition to those required under the Safe Drinking Water Act. State highway departments also should contact local or state authorities for design standards, plan approval, operating permits and other requirements for the installation of new rest areas. Close cooperation with these agencies also is recommended for evaluation and renovation of existing rest area water supplies, as well as for water sampling and testing requirements.

No attempt is made to provide a completely detailed coverage of all aspects of a water supply system. Instead, this manual has been organized into eight major chapters, to provide a ready reference of basic information and guidelines for those involved in any phase of planning, operating, or maintaining water supply systems at rest areas:

I. PLANNING & DESIGN CONSIDERATIONS
II. SOURCE DEVELOPMENT
III. STORAGE SYSTEMS
IV. TREATMENT
V. HARDWARE & EQUIPMENT SELECTION
VI. DISTRIBUTION SYSTEMS
VII. OPERATION & MAINTENANCE
VIII. SURVEILLANCE

Each chapter is followed by a list of selected references to supplement the basic information described in the chapter. These references should be consulted by the reader in cases where more detailed information is required.

In addition to the information provided in this manual, the user will find many of the water supply equipment industry publications useful for details on pumps and controls, and for equipment operation and maintenance. In addition, it is strongly recommended that state highway departments obtain the following publications for use with this manual:

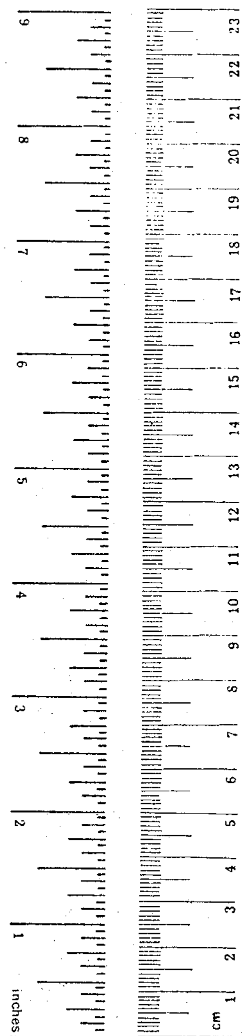
1. Environmental Protection Agency, Manual of Water Well Construction Practices, EPA-570/9-75-001. 401 M. Street S.W., Washington, D.C., 20460
2. Environmental Protection Agency, Cross-Connection Control Manual, EPA-430/9-73-002. Office of Water Supply, Washington, D.C.
3. Environmental Protection Agency, Considerations for Preparation of Operation and Maintenance Manuals, EPA-430/9-74-001. 401 M. Street S.W., Washington, D.C., 20460
4. Chlorine Institute, Chlorine Manual, 1969. Chlorine Institute, Inc., 342 Madison Ave., New York, N.Y., 10017
5. American Water Works Association, Occupational Safety and Health Standards for Water Utilities, 1974. AWWA, 6666 W. Quincy Ave., Denver, Colorado, 80235
6. AWWA, WPCF, APHA, Standard Methods for the Examination of Water and Wastewater, 14th Edition, 1975. AWWA, 6666 W. Quincy Ave., Denver, Colorado, 80235
7. Environmental Protection Agency, Methods for Chemical Analysis of Water and Wastes, EPA-625/6-74-003, Office of Technology Transfer, Washington, D.C., 20460

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

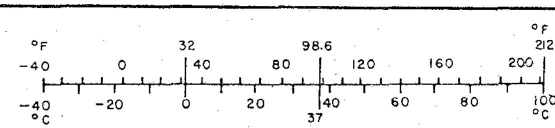
Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



I. Planning and Design Considerations

GENERAL

Before a rest area site selection is finalized, it should be determined that a bacteriologically and chemically safe and adequate water supply is available, or can be developed on the site. Careful preparatory work to locate and assure such a supply is time consuming, but may eliminate expensive changes and revisions in the final design stage, during construction and after completion of the project.

Because laws and regulations pertaining to design and construction of water supply systems vary considerably from one state to another, early consultation with appropriate governmental agencies is extremely important. It is recommended that highway departments develop a close working relationship with such governmental agencies as state and local health departments, planning departments and other agencies associated with water supplies in the state. This chapter was prepared in order to assist engineers in planning and designing rest area water supply systems, particularly in those states where guidelines are not provided.

PRELIMINARY PLANNING AND DESIGN CONSIDERATIONS

The first step in planning a rest area water supply should be to determine whether it is practically and economically feasible to connect the site with an approved, existing public water supply system. Should this option not be feasible, a study should be initiated to determine the quality and quantity of water needed to satisfy the requirements at the proposed rest area. The next step would be to determine whether it may be possible to develop an approved ground water supply of adequate quantity and reliability, on the site. If it becomes necessary to utilize a surface water supply as the source, a check should be made with responsible authorities to be sure such a supply would be approved. However, since surface sources are least dependable (quantitatively and qualitatively), their use should be considered only as a final choice.

Since wells are the most common source of water supply, much of this section will be devoted to the work necessary to determine whether well water of adequate quantity, quality and reliability is available.

As a first step in the investigation for a ground water supply, the topographic, geological and hydrological conditions of the proposed site should be examined in detail. Investigation of these conditions also are necessary for planning on-site wastewater management systems, building foundations, paving and other elements of the site. In some cases the engineer will utilize the services of a geologist or hydrogeologist in this phase of the study.

To obtain information concerning the quantity of water needed and the type system to be installed, it is recommended that the engineer consult with the traffic engineer in order to obtain an early forecast of the traffic patterns and loads to be expected at the rest facilities.

These preliminary investigations will provide the basis for the tentative design of the water supply system. Prior to the development of detailed plans and specifications, the following items should be studied:

1. A general location map of the area (a printed topographic quadrangle map, i.e., United States Geological Survey) with the location of the rest area shown.
2. Existing water supply and sewage disposal facilities, if any, now being used in or serving the area.
3. A report on the ground and surface water resources of the specific project area, including data on the quantity and quality of the water available, the average life expectancy, safe yield, and reliability of existing wells in the area (if available).
4. Any sources of water pollution, such as sewage, agricultural, and industrial waste discharges within, or affecting the general area of the proposed water system.

On the basis of this initial investigation, and any other information which will assist in the decision making process, the design engineer should be able to begin more detailed planning of the water supply system. Planning consideration should be given not only to the quantity of water needed at the site, but also to the quality. The interrelationship of storage, pumping and distribution system requirements should be studied, and early consideration should be given to operation and maintenance, and standby and emergency systems. If it is likely that the water will be filtered or softened, provisions also must be made for handling or disposing of backwashing or other waste waters.

QUANTITY OF WATER

One of the first steps in the selection of a suitable water supply source is determining the demand which will be placed on it. The essential elements of water demand include the average daily water consumption and the peak rate of demand. The average daily water consumption must be estimated:

1. To determine the ability of the water source to meet continuing demands over critical periods when surface flows are low and ground water tables are at minimum elevations, and
2. For purposes of estimating quantities of stored water that would sustain demands during these critical periods.

The peak demand rates must be estimated in order to determine plumbing and pipe sizing, pressure losses, and storage requirements necessary to supply sufficient water during periods of peak water demand.[1*]

Comfort Facility Water Needs

Table I-1 summarizes the rate of flow and flow pressure which could be expected for certain fixtures in a rest area. Per capita consumption rates can also be used as a guide in determining water

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*Raised numbers indicate footnotes, located at the end of the report.

TABLE I-1. RATES OF FLOW FOR CERTAIN PLUMBING AND REST AREA FIXTURES

Location	Flow pressure[a] —pounds per square inch (psi)	Flow rate—gallons per minute (gpm)
Ordinary basin faucet.	8	2.0
Self-closing basin faucet.	8	2.5
Sink faucet, 3/8 inch.	8	4.5
Sink faucet, 1/2 inch.	8	4.5
Ball-cock for closet	8	3.0
Flush valve for closet	15	15-40[b]
Flushometer valve for urinal	15	15.0
Garden hose (50 ft.,3/4-inch sill cock). . . .	30	5.0
Garden hose (50 ft.,5/8-inch outlet)	15	3.33
Drinking fountains	15	.75
Fire hose 1-1/2 inches, 1/2-inch nozzle. . . .	30	40.0

[a] Flow pressure is the pressure in the supply near the faucet or water outlet while the faucet or water outlet is wide open and flowing.

[b] Wide range due to variation in design and type of closet flush valves.

SOURCE: EPA, Manual of Individual Water Supply Systems, 430/9-74-007, 1974.

requirements. In general, water requirements at rest areas can be estimated using average daily traffic volumes of the six peak weekends. Previous field studies show that approximately 9 percent of the traffic will stop at the rest area, with 6.7 gallons of water being used per vehicle.[2] (This is based on 2.3 people per vehicle.)[2]

The following will serve as an example problem on how to estimate water consumption based on estimated traffic volume for an average day of six peak weekends:

Traffic Volume for Average Peak Weekend Day:	120,000* vehicles/day
Traffic Volume Stopping at Rest Area:	9% x vehicles/day (peak) .09 x 120,000 = 10,800 vehicles/day
Maximum Daily Water Need:	6.7 gal/vehicle x vehicles stopping 6.7 x 10,800 = 72,360 gallons per day

Water for Irrigation[3]

The irrigation of rest area lawns, shrubs, green areas, and ground cover should be considered and designed into the distribution system. Flows for landscaping irrigation should be added to peak rest area rates, but not to fire flows.

The rate of application on lawn and ground cover varies from 1 inch (2.5cm) per week in areas of high relative humidity to 2 or 3 inches (5 or 7.5cm) per week in arid regions.

Where the size of lawn does not justify a more extensive study, the approximate application rate required may be computed by assuming 30 gallons per hour for each 100 square feet (9.3sq.m) to be sprinkled.

Other Water Considerations

Water for fire protection at rest areas generally is not provided unless sufficient quantity and pressure is available. For example, fire hydrants would be likely only where the rest area is connected to a municipal water system. Where fire protection is required

* The actual number of vehicles per day used in this calculation should be based on the 20 yr. projected traffic design.

by law, an emergency sprinkler system may be considered as a possible solution. Fire protection demands must be considered separately from all other uses and varies on a site-by-site basis.

If fire protection is required, the system must be capable of delivering the required fire flows. A minimum of two fire hydrants should be provided in each rest area, and the water system should be capable of delivering 500 gpm to the most remote hydrant at a residual pressure of 20 psi. Hydraulic computations should be made to ensure that the system can deliver the required fire flow. Further information can be obtained by consulting the references listed at the end of this chapter.

Water for aesthetic purposes (i.e., artificial streams and fountains) is not recommended unless an abundance of water is readily available.

Additional water needs which should be considered include drinking and wash water for camper and recreational vehicle wastewater storage tanks at dumping facilities. The water demand for these recreational vehicle uses may be estimated as follows:*

Water Storage Tank	
Large Motor Homes and 5th. Wheel Vehicles	60-70 gal/vehicle
Vans and Small Slide-On Campers	10 gal/vehicle
Average (for all types of vehicles)	25 gal/vehicle
Hot Water Heater Tank (if provided)	6-7 gal/vehicle
Water for flushing holding tank	4-5 gal/vehicle

Water Conservation Measures

LOW FLOW (WATER SAVING) DEVICES. Substantial water conservation can be realized in new rest areas or in replacement construction, by the installation of low-flow or water-saving devices.

*John Alexander (Dave's Campers & Trailers, Traveland USA, Irvine, Cal.) Personal communications, Jun 1977.

Toilets. Conventional toilets use from 5-7 gallons to remove material from the bowl, wash down the sides of the bowl, and provide a 3-inch deep water seal in the trap to prevent sewer gas from entering the bowl. Most conventional toilets use more water than is needed to perform the three essential functions.

Most toilet tanks have excess volume, and the flush volume can be reduced by placing plastic bottles or "water dams," in the tank. This type of device maintains the static head and the velocity of the water while reducing the volume.

New or modified rest areas should install water saving toilets which use 3.5 gallons per flush. The International Association of Plumbing and Mechanical Officials (IAPMO)*publishes and maintains a list of approved fixtures for new installations. All water saving toilets on the IAPMO's list have been tested and will perform satisfactorily.

Faucets. Most faucets deliver more water than is actually needed for most situations. The flow can be controlled by low-flow fixtures, an attachment to the existing fixture, or flow restrictor in the water line. There are lavatory spray taps available today which use as little as 0.5 gallons of water per minute. These devices operate like an aerator to break up a small-diameter solid stream of water into a larger diameter spray flow.

Pressure Reducing Valves. Water is also wasted by excessive pressure, often exceeding the Universal Plumbing Code (UPC) recommended maximum of 80 psi in interior and exterior waterlines. In actual practice, a maximum line pressure of 50 psi would enable simultaneous effective operation of several fixtures. To maintain a maximum allowable pressure (i.e., 50 psi) pressure-reducing valves can be installed.

EXTERIOR WATER CONSERVATION. Significant amounts of water can be saved by reducing the amount of water used outside the rest area comfort facility by eliminating overwatering.

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* IAPMO, 5032 Alhambra Avenue, Los Angeles, California 90032.

Overwatering. Some of the water applied to plants and shrubs evaporates; some is used for growth; and the remainder either runs off or percolates through the ground.

Automatic sprinklers and sprinklers equipped with soil moisture override systems generally are effective in reducing or eliminating the problem of overwatering. Automatic sprinklers need periodic adjustment to take into consideration seasonal climatic variations and changes in infiltration rates. In soil moisture override systems, the sprinklers are activated at predetermined soil moisture conditions.

OTHER WATER CONSERVATION METHODS. Leak Repair. The principal causes of leaks include age, improper installation, construction materials, physical and chemical soil properties, water properties, water pressure, and improper maintenance. Types of leaks for which actual leak detection and repair programs should be established include:

- Broken water mains and joints
- Active service leaks (between the main and the rest area — if municipal water is used)
- Leakage from hydrants
- Leaks from inactive service lines
- Sewer flusher leaks
- Leakage from water storage facilities
- Leakage from faucets
- Leakage from toilets

Metering. Metering at rest areas should be encouraged from the standpoint of creating an awareness of the quantity of water used at the rest area. Installing meters will not only allow the highway departments to keep an accurate record of seasonal variations in water usage at the rest area, but also alert the rest area maintenance personnel of possible leaks. If meters are to provide accurate and useful information at the rest area, provisions must be made for adequate record keeping and review of meter readings on a regular and frequent schedule.

Grey Water Reuse Systems. A grey water reuse system collects, disinfects, filters and stores water from sinks, showers, tubs, etc. which is separate from sewage water. In grey water systems, the water is collected, treated, and recycled for use to flush the toilets and provide water for irrigation and other non-potable uses. NOTE: Grey water systems may be subject to special requirements in some states.

Waterless Toilets. Chemical, oil-carriage, composter and incinerator toilets are all examples of waterless toilets which may be of practical use in some rest area facilities. These systems are not generally acceptable for widespread use in populated areas, because of the high maintenance usually associated with them. However, they are well suited for many remote, or rural areas, such as those at rest areas. Further information regarding waterless toilets is available by consulting the Waterways Experiment Station reference listed at the end of the chapter.

Methodology to Determine Storage Needs (Demand Hydrograph)[4]

It may be necessary to provide water storage at the rest area to meet peak demands. A "supply-demand hydrograph" should be developed for the water supply at each perspective site. This curve enables the designer to evaluate various assumed inflow rates and storage volumes required to meet peak demand flow rates. By providing storage, the peak demands at the rest area can be met with lower rates of inflow. Even in systems that can meet peak demands, storage will attenuate these inflow demands and reduce pumping and pipe costs. Good engineering practice requires that an economic comparison be made between the cost of providing a system with and without storage to meet peak demands.

The use of a "supply-demand hydrograph" is best illustrated by the following example for an existing rest area. Figure I-1 shows a peak demand of 80 gpm. Since this peak demand is only a few hours in duration, a constant inflow rate of 28.4 gpm plus storage is adequate to meet peak demand flow rates. During periods of lesser demand, the supply pumps will not have to operate continuously.

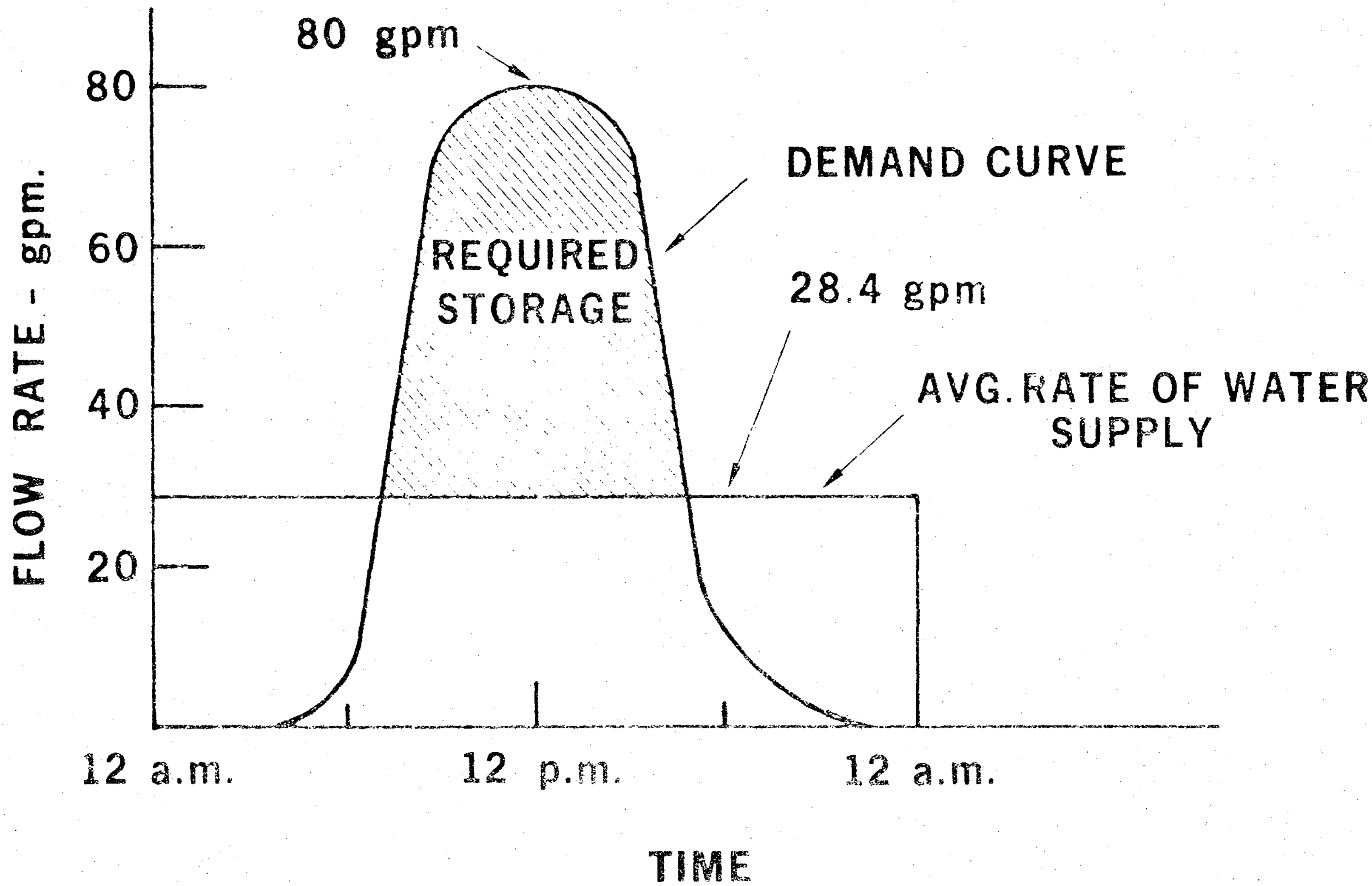

FIGURE I-1. SUPPLY - DEMAND HYDROGRAPH

For a proposed rest area, the design supply-demand usage curve must be developed. Figure I-2 shows the usage pattern as determined from the Waterway Experiment Station (WES) Research.[2] The total flow for the day can be determined using the methodology previously described on page I-5. The flow rate for any given hour can be determined by multiplying the total daily flow by the appropriate usage percentage shown in Figure I-2. The required average rate of water supply can be determined by dividing the total flow by 1,440 minutes. The required storage is the area between the two curves as shown in Figure I-2. To meet the daily demand, therefore, the corresponding storage must be added to the required average rate of supply. The designer should then evaluate greater rates of supply with correspondingly lesser storage to arrive at the optimum economic balance. In all cases, the minimum required storage is the area under the demand curve and above the rate of water supply curve.

In rest area design, several peak days may occur together as in a holiday weekend. To design for this condition, a "demand mass diagram" should be constructed as shown in Figure I-3. The design time period must be a whole number of 24 hour design periods. A design "supply-demand hydrograph" must be constructed for each 24 hour period. Then the cumulative demand curve is obtained by the summation of flows from each of the hydrographs. The average rate of water supply for the design period is obtained by drawing a line through the beginning and end of the cumulative demand curve as shown by the dashed line in Figure I-3. Parallel lines are then drawn through the highest summit and lowest sag of the cumulative demand curve. The resulting ordinate between these parallel lines is the minimum amount of required storage. It is pointed out that the average rate of water supply is also the minimum rate of water supply required over the design period.

QUALITY OF WATER

Good quality water is as essential as an adequate quantity of water. Quality includes bacterial, chemical and radiochemical considerations. An effort should be made to obtain water of moderate hardness,

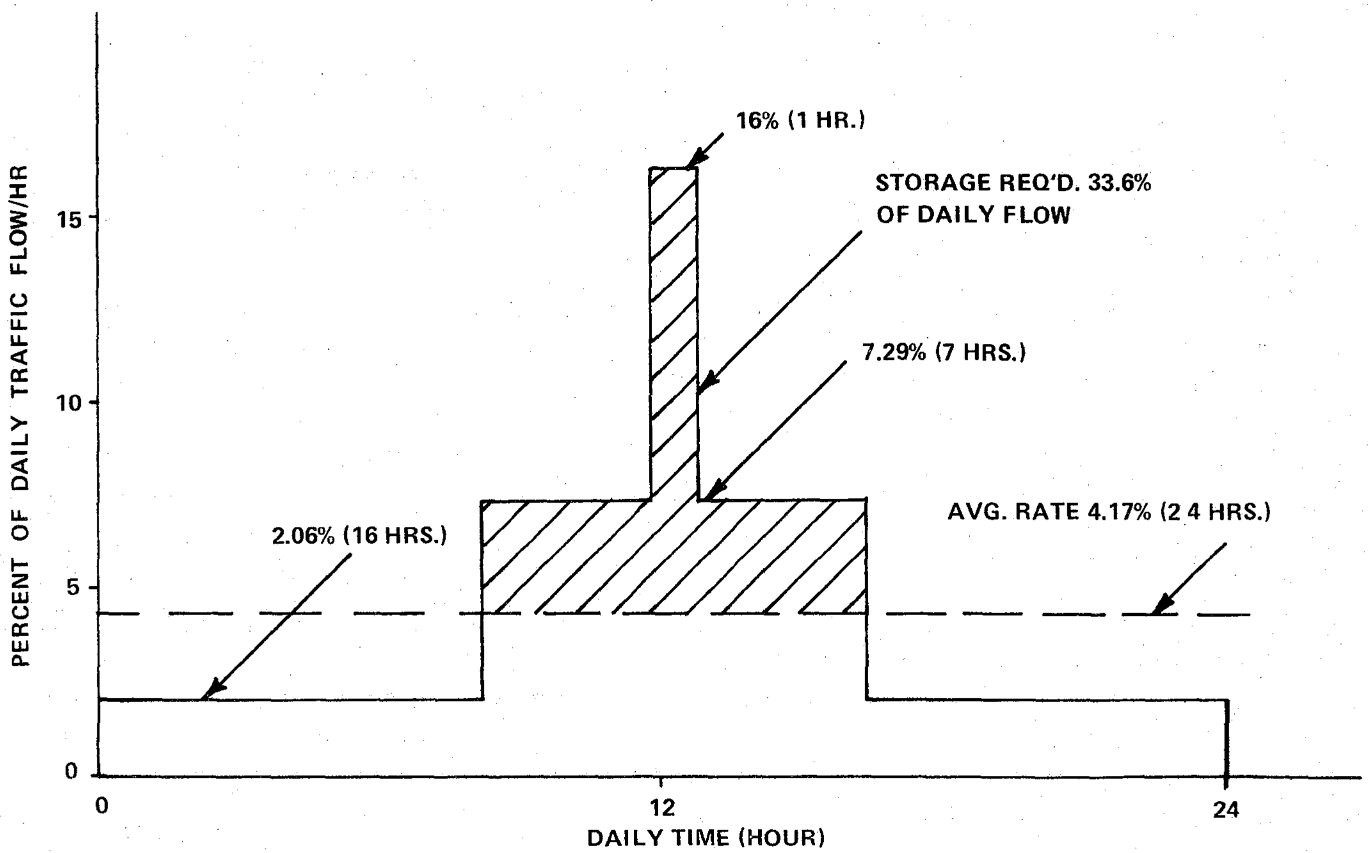

FIGURE I-2. WATER USAGE PERCENTAGE AS DETERMINED BY WES

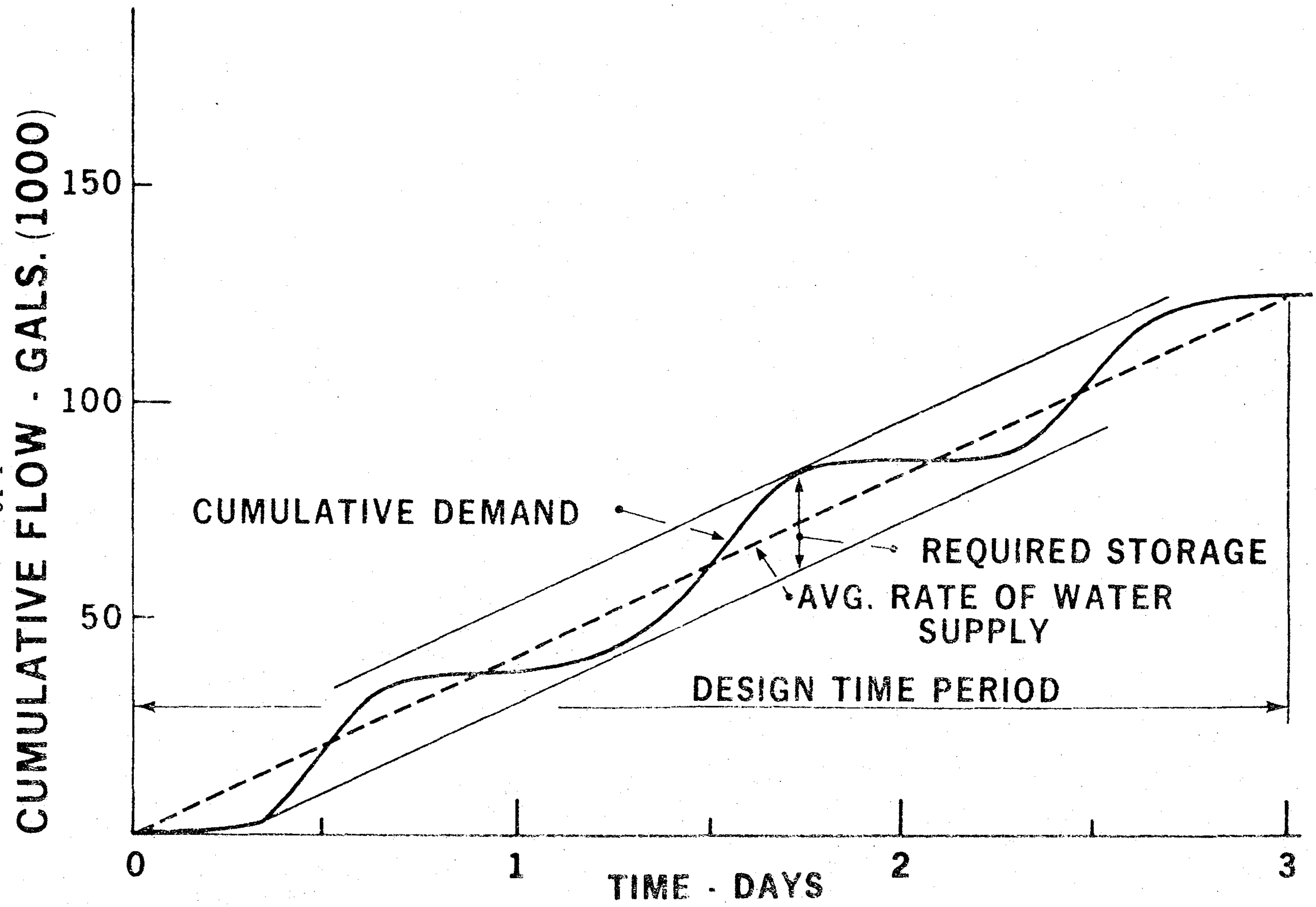

FIGURE I-3. DEMAND MASS DIAGRAM

comparatively free of objectional minerals such as sulfur, iron, and manganese. In general, water from municipal supply systems is most desirable from a water quality standpoint. Groundwater, when available in sufficient quantity and quality also is generally a desirable source. Such water is usually clear, cool, colorless, and quite uniform in quality. Underground supplies are generally of better bacterial quality and contain much less organic material than surface water, but may be more highly mineralized and could have an odor problem. Surface supplies are least desirable due to the extensive treatment usually required to render them safe. Such supplies are subject to intermittant pollution, runoff contamination, turbidity, color, freezing, and seasonal variation in flow.

Groundwater Supplies - Test Well Data

If groundwater is to be used, and the nature and extent of the groundwater aquifer is not well defined, a test well should be drilled to determine the quantity and quality of water available. As stated in EPA's Manual of Water Well Construction Practice, the purpose of drilling a test well is to obtain information on ground water quality and formation materials, and to help establish the depth and extent of the water-bearing formation at a specified site. Frequently the test hole will be enlarged and cased, becoming the finished well. This is true of nearly every well constructed by the rotary method wherein the "pilot hole" is, in effect, a test hole. Instead of drilling the test well, the permanent well could be drilled, tested, and capped during the preliminary design stage. Either method would provide definite data on water quality, quantity and depth to the water-bearing strata.

The water must be tested to determine if its physical, chemical, biological, and radiological characteristics meet State requirements. Soils information obtained from the test well should be used to aid in the design of the well screen installation, and to provide the data needed for the usually required complete log of the well.

Drinking Water Quality Requirements

All drinking water supplied at rest areas, must meet the appropriate National Primary Drinking Water Regulations (NPDWR). The water should be clear, pleasant to taste, of reasonable temperature, neither corrosive nor scale-forming and free from odor.

In many cases, raw water not conforming to the NPDWR can be treated to reduce the concentration of the objectionable substances to allowable limits. In other cases, the water quality may be improved by dilution with water from a source of better quality.

There may be a few cases where it is practical to have a dual system with the best water piped to faucets and drinking fountains and the inferior water to other fixtures for non-potable uses. Also, there may be cases where a more complex treatment system is used for the drinking water, and the untreated water is used for toilets, etc. In other cases it may be necessary to haul in water by truck, or to "attempt to" locate a different source. For instance, if there are more than one water bearing strata, undesirable water from one strata may be sealed off and only the acceptable water from other stratas would be utilized.

The specific physical, bacteriological, chemical, or radiochemical parameters of water quality which are required or recommended for health reasons or from an aesthetic standpoint as delineated in the NPDWR or National Secondary Regulations are listed and discussed in Chapter 4. Although water supplies must conform with the Primary Regulations, the Safe Drinking Water Act does not require compliance with the secondary regulations. The secondary regulations, therefore, are not Federally enforceable, but are intended as guidelines for the states.

SANITARY SURVEY OF AVAILABLE SOURCES

A sanitary survey must be made for each proposed water supply system. Those individuals conducting the survey should have a technical background in basic sanitary sciences and engineering; and a broad knowledge of sanitary facilities and features of potable water supplies and their sources. The survey considers effects of land use, land condition, development of the source, its capacity to meet existing and future needs, and the detection of all existing and potential hazards and evaluation of their importance.* Following are some items that may be pertinent to the water source and should be included in the sanitary survey conducted at a prospective rest area site.

Groundwater Supplies[3]

1. Character of local geology; slope of ground surface.
2. Size of catchment area and probable recharge rate of water-bearing formations.
3. Nature of soil and underlying porous strata; whether clay, sand, gravel, rock (especially porous limestone); coarseness of sand or gravel; thickness and area of water-bearing stratum, depth to water table; location, log, construction details, yield, and water analysis of local wells in use and abandoned.
4. Slope of water table, preferably determined from observation wells or as indicated, presumptively but not certainly, by slope of ground surface.
5. Extent of drainage area likely to contribute water to the supply.
6. Nature, distance, and direction of local sources of pollution.
7. Possibility of surface-drainage water entering the supply and of wells being flooded; methods of protection.
8. Character and quality of raw water, including physical, chemical, bacteriological and radiological analyses. Type of treatment required.

Surface Water Supplies[3]

1. Nature of surface geology; character of soils and rocks.

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* Procedures for regularly scheduled sanitary surveys conducted at existing facilities are presented in Chapter 8, Surveillance.

2. Character of vegetation, forests, cultivated and irrigated lands, including salinity and effect on irrigation water.
3. Population and sewered population per square mile of catchment area. Projected future land use of catchment area.
4. Methods of sewage disposal, whether by diversion from watershed or by treatment.
5. Character and efficiency of sewage-treatment works on watershed.
6. Proximity of sources of fecal pollution to intake of water supply.
7. Proximity, sources, and character of industrial wastes, oilfield brines, acid mine waters, etc.
8. Adequacy of supply as to quantity, including seasonal flow variations.
9. For lake or reservoir supplies: wind direction and velocity data, drift of pollution, sunshine data (algae).
10. Character and quality of raw water: physical, chemical, radiological, pesticide and bacteriological analyses.
11. Nominal period of detention in reservoir or storage basin.
12. Probable minimum time required for water to flow from sources of pollution to reservoir and through reservoir intake.
13. Shape of reservoir, with reference to possible currents of water induced by wind or reservoir discharge, from inlet to water-supply intake.
14. Protective measures in connection with the use of watershed to control fishing, boating, landing of airplanes, swimming, wading, ice cutting, permitting animals on marginal shore areas and in or upon the water, changing land use, etc.
15. Efficiency and constancy of policing.

STORAGE, PUMPING AND DISTRIBUTION SYSTEM RELATIONSHIPS

Storage, pumping and distribution systems are components of a water supply system which are interrelated and must be considered collectively in the early planning stages of a water system. The overall objective is to provide a sufficient and continuous water supply at an adequate pressure that will satisfy all needs under various conditions of demand.

An adequate supply of water is essential to maintain the water line pressure in the distribution system. Low pressures in the mains produce conditions favorable to contamination of the water by sewage or other polluting substances through back-siphonage, and cross-connections. Excessive pressures may cause leaks and waste of water and may increase the possibility of damage from water hammer.* Normal operating pressure at the service connection should not be less than 20 psig or greater than 100 psig. In most cases, however, the system should be designed for a working pressure of at least 35 psig at the rest area site.[4]

OPERATION AND MAINTENANCE CONSIDERATIONS

One of the most important features for the designer to consider is simplicity of operation and maintenance. He should plan or select equipment which once installed will not be difficult to operate or maintain, and will require a minimum of attention. He should select facilities and equipment suited to the anticipated skills and experience of the operator, and arrange the facilities to promote safety and ease of operation.

It should be cautioned that, although automated systems may appear to require a minimum of attention, such systems may in fact require specialized training of the operator, in addition to being more expensive to purchase, repair, and maintain than a simple manual system.

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* Water hammer is the ramming action that develops when a column of water is suddenly set into motion. It sometimes occurs when a pump starts, or when the water column is suddently stopped, as when a valve is closed quickly.

DESIGN LIFE OF SYSTEM

Providing capacity in all parts of a water system for all possible future uses may not be practical or economical. A rest area water system should be designed and constructed to meet estimated needs for all purposes for a reasonable period (usually 20 years),[4] and should be designed to facilitate phased expansion economically, if expansion is required. This flexibility can be provided, for example, by developing the source and sizing the mains in the distribution system for capacity greater than the 20-year estimate. Adding additional storage and a higher capacity pump would then allow the system to meet increased demands. Providing the required capacity in the distribution system and fully developing the source in the initial construction may increase cost only slightly. As a result, it may be economically advantageous to oversize water mains and certain other system components at the time of initial design and construction, in order to provide for expansion of other facilities as usage increases.

DUPLICATE/STANDBY SYSTEMS

Rest area water supply systems should be designed and operated so as to provide a safe and adequate supply of water at all times. Failures which can be reasonably anticipated, such as power failure and mechanical breakdown, should be taken into account in the design of facilities.

The degree of standby provided should be an index of the importance of the item under consideration. It is not necessary to provide a spare chemical feeder for corrosion control, but it would be advisable to provide a spare coagulant feeder when turbid water is expected. When disinfection is practiced, a spare chlorinator or other disinfection feeder should be provided. An additional factor to be taken into account is the degree of risk involved. When the plant is treating a water that is highly contaminated, more positive provisions for standby units should be made. It may also be desirable to provide for automatic shut-down and alert in situations where a critical part of the water supply system fails.

In general, to reduce the delays in restoring various units to service, it is recommended that designers try to standardize water treatment equipment at rest areas within their state, whenever possible. By standardizing certain components, spare parts may be shared among several rest areas, thus relieving each rest area of the burden of purchasing its own standby units. However, certain items of a standardized system will not be needed at every rest area, and it is not good practice to provide for treatment when it is unnecessary. The designer should maintain flexibility when considering standby and duplicate systems.

If hauled-in water is being considered as an emergency source, special provisions for truck hook-ups, pumping, and storage of such water must be a part of the overall water supply system plan at the rest area.

OCCUPATIONAL SAFETY AND HEALTH ACT (OSHA) REQUIREMENTS

During the early planning and design stages of a rest area water supply system, the design engineer should be conscious of OSHA standards. These standards are designed to help create a safer industrial environment, during both construction and non-construction type activities. Some 23 states have already adopted OSHA requirements and would necessitate state highway department compliance regarding rest areas. Most other states use the OSHA standards as recommendations of "good practice".

Further information regarding OSHA requirements applicable to water supply systems is available by consulting the reference on safety located at the end of this chapter.

ENGINEERING REPORT

The engineering report assembles basic information; presents design criteria and assumptions; analyzes alternative developments; compares costs of alternative developments; and offers conclusions and recommendations for a proposed project. It is the result of an in-depth study and evaluation, and is used as a basis for selecting the alternative for a particular installation, and should form the continuing technical basis for detailed design and preparation of construction drawings and specifications.

The information in the report should be presented briefly and concisely, but in sufficient detail to provide a reliable planning aid. The format of the report is flexible and should be adjusted to accommodate the needs of the specific project. The following provides a list of the factors which should be covered in the engineering report, where such factors are applicable:

1. Geographic Location. Describe the location of the rest area by county, latitude and longitude, basin and watershed. Include the highway on which it is located, and on which side of the highway it lies. Appropriate maps showing the rest area location also should be included.
2. Site Description. Describe the size and general shape of the site, including its capacity and condition. A description of existing potable waterworks, if any, as well as other utilities at or near the site.
3. Water Rights. Legal status of all potential sources, including rights and ownership of land which would influence development or use should be presented.
4. Soil and Groundwater Conditions. Briefly describe the character of the soil through which water mains are to be laid, and foundation conditions prevailing at sites of proposed structures. Also, describe the approximate elevation of groundwater in relation to subsurface structures.
5. Water Consumption. Describe the traffic predictions or trends as indicated by available records, and the estimated population which will be served by the proposed water supply system or expanded system. Give the present and future water consumption values used as the basis of the design, the present and estimated future yield of the sources of supply, and any emergency plans for providing water when insufficient quantities are available.

6. Possible Sources of Pollution. Describe the location and potential for contamination by such sources as: existing or proposed sewers, sewage treatment plants or sewage discharges, industrial waste disposal systems, discharge from individual sewage disposal systems, oil and gas production wells, abandoned oil and gas exploration wells, and abandoned water wells. The potential for spills of toxic materials, and contamination of surface supplies due to agricultural activities, and leaching from sanitary landfills, etc., also should be evaluated.
7. Sources of Water Supply. Describe briefly the proposed source or sources of water supply to be developed, and give the reasons for their selections. Include the local history of any existing wells in the area.
8. Quality of Water Source. Analytical data as to the character and quality of the raw water supply being developed should be summarized with special reference to fluctuations in quality, effects of changing meteorological conditions, and other pertinent factors which establish the character and quality of raw water. Complete physical, chemical, bacteriological and radiological analyses of water samples taken from the source of supply, must be submitted.
9. Proposed Treatment Processes. Summarize the proposed treatment processes, and establish the adequacy of these processes for the treatment of the specific raw water under consideration. (Consideration also should be given to the operation and maintenance of the proposed water treatment system, and the provision of standby equipment such as pumps and disinfectant feeders).
10. Pumping, Storage and Distribution Systems. Describe the physical and operational characteristics of the pumps and

drive units, pump-housing, and related appurtenances. Discuss storage facilities and their type of construction and capacities. Include the criteria for determining the amount of storage provided, and the portions which will serve flow and pressure-equalizing purposes and/or as contingency reserves. Describe the distribution system and the design criteria used in determining average and peak flow variations and related pressures; the size and kinds of pipe to be used throughout the system as related to the site conditions, depth of installation, and protection from freezing. Briefly indicate what provisions will be made to protect against cross-connections and plumbing hazards. Also, describe the valving arrangement which will allow portions of the system to be isolated for repairs or emergencies.

11. Alternate Plans. Where two or more solutions exist for providing water at the rest area, each of which is feasible and practicable, discuss the alternate plans and give reasons for selecting the one recommended, including financial considerations. For example, it may be advisable to study the feasibility of extending a municipal water line to the rest area versus installing a new, on-site well system. In areas where water quantity may be limited, the report also should consider water conservation measures such as substituting other landscaping surfaces for lawns, water-saving fixtures and flow restrictors, low-water or water-less toilets, and grey water reuse systems.

12. Financing. Give estimated cost of integral parts of water works system and the detailed estimated annual cost of operation, and explain the proposed methods of financing both the capital charges and operating expenses.

GENERAL LAYOUT

The composition of layout sheets will vary from one rest area site to another, but in general, should show the final plans for the waterworks system. Where applicable, the layout should show the following:

1. General - Rest area title and appropriate map showing location of the rest area in relation to nearby towns. Appropriate scales, contours, foliage, legends, and north arrow should be shown.
2. Existing Structures - The location and size of existing water mains, the location and nature of existing waterworks structures and appurtenances, and the location and nature of existing sewerage works structures and appurtenances affecting the proposed improvements should be noted on a key map. Sources of power in the vicinity of the site also should be identified.
3. Proposed Structures - Indicate proposed water mains and waterworks structures, with size, length, and identity. Other utilities such as power also should be identified.
4. Topography and Elevations - Existing or proposed streets, and all watercourses, ponds, or lakes, should be shown clearly. The elevation of water mains and other waterworks structures should be indicated, where pertinent. Contour lines at suitable intervals should be included on final plans.

SECURING PERMITS AND APPROVAL OF PRELIMINARY PLANS

Rules, regulations and guidelines concerning permits and approval of plans differ considerably from state to state. It is strongly recommended that planners and designers of rest area water systems contact appropriate state and local agencies regarding submission of plans. Very often all reports, plans and specifications should be submitted 30 to 60 days prior to the date on which comments or recommendations are desired, in order to permit sufficient opportunity for review. It is suggested that preliminary plans and the engineer's report be submitted for review before preparation of detailed plans and specifications.

Another consideration in obtaining approval of plans is the Environmental Impact Statement (EIS). The National Environmental Policy Act (NEPA), Public Law 91-190, requires preparation and submittal for review of an EIS for all major or controversial projects that may have significant adverse effects on the environment. It is prepared in a formal format and submitted for public review to the Council on Environmental Quality (CEQ).

The EIS is part of the planning process and is completed prior to implementation of the project. Because interrelated factors between the EIS and the engineering report may affect decisions on courses of action in both documents, the EIS and engineering report should be prepared concurrently.

DETAILED PLANS AND SPECIFICATIONS

The plans for the water supply system will be incorporated into plans for the whole facility. While state and federal agencies may be exempt from certain permit fees and procedures, policy often does provide for official submission of plans to the authorized state and local agencies.

Building agencies commonly enforce laws dealing with:

- Zoning
- Grading of properties
- Building codes, as for the pump house, building housing treatment facilities, etc.
- Plumbing, electrical and heating and ventilating code enforcement.

Health, environmental, or resource agencies usually enforce laws which include issuance of permits for well drilling and installation of water supply systems. Those codes may contain detailed requirements and instructions for such items as filing of well drilling logs, determining minimum capacity of water production or treatment system, pumping capacity, storage capacity, flow rates and friction losses, back-flow preventor standards and requirements. They also specify minimum distances between wells and sewers, streams and other potential sources of pollution.

To assure all required data are shown on plans and specifications, it is desirable to obtain copies of instructions and to discuss the requirements of approving and regulatory agencies as an early step in the planning process.

The regulatory agency should also be consulted to be sure the water analysis done in connection with the project planning and development will be done by an approved laboratory using acceptable methods.

No approval for construction usually is issued until final detailed plans and specifications have been submitted and approved by the state regulating agencies. Detailed plans for waterworks systems generally should show the following items:

1. All stream crossings, on suitable profiles with elevations of the stream bed, and the normal and extreme high and low water levels.
2. All appurtenances, specific structures, or equipment, having any connection with plans for water mains and waterworks structures.
3. Sources of water supply.
4. Conduits and supply mains.
5. Pumping station.
6. Treatment works

7. Sources of power.
8. The hydraulic profile of the water flowing through treatment works, in sufficient detail to supplement other detail plans.
9. Schematic designs should be provided of all structures and equipment not otherwise clearly indicated on the plans.
10. Disposal of wastewater.

Construction drawings and specifications should contain all information necessary for the contractor to perform his work. Construction drawings should show form of construction or what is to be done. Specifications should establish quality of componants used in the system.

Upon completion of the project, a final construction report is prepared. This should be kept in mind when preparing the detailed plans and specifications. The final report is a summary of the significant activities which took place during the construction of a project. Its primary value to engineers is to provide feedback from construction personnel to designers and estimators. A well-prepared final construction report can facilitate improved designs for future projects and increased efficiency in construction. The final report should contain, as a minimum, the following items:

1. Location and description of the project.
2. Description of the work performed.
3. Actual costs compared to initial bid costs.
4. A set of "As-Built" specifications and drawings.

In preparing the detailed plans and specifications, it should be remembered that a set of "As-Built" specifications and drawings will be filed in state highway department records for future maintenance and repair of the rest area water system.

PLANNING AND DESIGN CHECKLIST

	Yes	No
1. Does programming and budgeting provide adequate time allowances and funds to complete each phase of the project in an orderly and professional manner?		
2. Is the water supply system selected, the best and most economical for the specific rest area site, considering environmental compatibility, public health, safety, quantity, service required, reliability, cost, operation and maintenance?		
3. Where applicable, have the following items been prepared, submitted and reviewed by the proper agencies? • EIS • Engineer's Report • Sanitary Survey • Preliminary Plans • General Layout • Detailed Plans and Specifications • Other Items		
4. Are all phases of the project in compliance with required Federal, State, and local codes and regulations? If compliance with these codes and regulations is not required, they should be considered as planning guidelines.		
5. Are the facility construction drawings, specifications, and construction supervision and inspection adequate to describe and control its construction?		

References

Rating Schedules for Municipal Fire Protection, Insurance Services Office, 160 Water Street, New York, N.Y. 10038

Guide for Determination of Required Fire Flow, Insurance Services Office, 160 Water Street, New York, N.Y. 10038

AWWA, Occupational Safety and Health Standards for Water Utilities, 6666 West Quincy Avenue, Denver, Colorado 80235

Hughs, Gregory, et. al., Wastewater Treatment Systems for Safety Rest Areas, FHWA-RD-77-107, Waterways Experiment Station, Sept 1977.

II. Source Development

GENERAL COMMENTS CONCERNING SOURCE SELECTION

Rain water normally contains very few impurities except for trace amounts of minerals, gases, and other substances as it forms and falls to the ground. Precipitation is virtually free of bacterial contamination.

Once the precipitation reaches the earth's surface, there are many opportunities for organic substances, micro-organisms and other forms of contamination to be introduced. As the water flows over and through the ground surface it picks up soil particles which gives the water a cloudy or turbid appearance. It also picks up organic matter and bacteria, which are partially filtered out as the surface water seeps downward through the soil to the groundwater table.

Substances which alter the quality of water as it moves over and below the earth's surface may be classified under four major headings:[1]

1. Physical. Physical characteristics relate to the quality of water for domestic use and are usually associated with the appearance of water, its color or turbidity, temperature, taste, and odor in particular.
2. Chemical. Chemical differences between waters are sometimes evidenced by their observed reactions, such as the comparative performance of hard and soft waters in laundering.
3. Biological. Biological agents are very important in their relation to public health and may also be significant in modifying the physical and chemical characteristics of water.
4. Radiological. Radiological factors must be considered in areas where there is a possibility that the water may have come in contact with radioactive substances.

Consequently, in the development of a rest area water supply system, it is necessary to examine carefully all the factors that might adversely affect the intended use of a water supply source.

When possible, the feasibility of connecting to municipal water supply systems should be considered. Among the primary benefits to be realized in utilizing a municipal supply are:

- More efficient and simple operation and maintenance of the rest area water supply is possible.
- Better supervision can be obtained; a full-time staff of top level personnel is usually in control at the larger systems.
- Automated equipment and advanced technologies that are beyond the means of small systems become feasible and advantageous.
- More adequate and reliable service would be possible.

Although there may be some problems (such as long dead-end lines) associated with connecting rest areas to municipal water supplies, the advantages and reliability of such a connection generally outweigh the problems and disadvantages. In most cases, the decision whether or not to connect to a municipal supply is a question of economics.

Groundwater, the next most desirable and dependable source, is also the source most commonly used at rest areas. Most groundwater is clear, cool, colorless and quite uniform in quality. The water quality from these underground supplies, however, can be less than desirable, depending on the construction and location of the well or spring. The geology of the area also can be an important consideration, as well as the quality of the acquifer from which the well draws. Important factors to recognize in considering underground water supplies include possible contamination from nearby sources of pollution and proper well or spring box construction. An adequate sanitary survey is essential for all well water and other groundwater sources. The details of such a survey are described in Chapter 1 of this manual.

Springs may be satisfactory sources, but since spring water is obtained from a source close to the ground surface, source of water and the location of springs must be considered and the spring properly protected against surface drainage or other sources of contamination. Regularly scheduled inspections are essential to providing an adequately protected spring water supply.

Surface waters from lakes, rivers, streams, ponds and creeks are less desirable than groundwater sources since they can be subject to intermittent pollution, runoff contamination, turbidity, accidental spills, freezing, and more seasonal variation in flow. As such, surface supplies generally require more treatment and present more operational and maintenance problems than do well supplies.

MUNICIPAL WATER SUPPLIES

When a municipal water supply system is available within a reasonable distance from the site, rest area water should be obtained from this system. This should provide a more dependable water supply and would not subject the highway departments to the provisions of the National Primary Drinking Water Regulations (NPDWR) promulgated under the Safe Drinking Water Act (PL 93-523), provided that highway departments only store and distribute water from the municipal system, use only the municipal system, and do not sell water to any person. However, regular inspections and monitoring at rest areas is recommended as good practice.

Provisions must be made to assure an adequate pressure (usually at least 35 psi) is maintained throughout the distribution system. Backflow preventers and other devices to protect against contamination from cross-connections, and the necessary valves and fittings for periodic flushing of water mains also should be considered.

If additional treatment of water from a municipal source is provided at rest areas, or other sources are developed to supplement the municipal supply, the highway department is responsible for full compliance with the provisions of the NPDWR. This situation could occur when rest areas are located at the end of municipal water lines, where some health departments recommend or require users to chlorinate water to ensure that an adequate chlorine residual is maintained. A rest area water supply, however, would generally be considered a "non-community water system," and is not subject to as extensive monitoring requirements as a "community water system." Chapter 8, Surveillance, more fully describes these monitoring requirements under the NPDWR.

GROUNDWATER SUPPLIES

Groundwater is water collected directly from the zone of saturation by horizontal or vertical wells. The pores, joints, and crevices of the rocks in the zone of saturation are generally filled with water. Although the openings in these rocks are usually small, the total amount of water that can be stored in the subsurface reservoirs of the rock formations is large. The most productive acquifers are deposits of clean, coarse sand and gravel; coarse, porous sandstones; cavernous limestones; and broken lava rock. Some limestones, however, are very dense and unproductive. Most of the igneous and metamorphic rocks are hard, dense, and of low permeability. They generally yield small quantities of water. Among the most unproductive formations are the silts and clays. The openings in these materials are too small to yield water, and the formations are structurally too incoherent to maintain large openings under pressure. Compact materials near the surface, with open joints similar to crevices in rock, may yield small amounts of water.[1]

The proper development of a ground water source requires careful consideration of the hydrological and geological conditions of the area. If the highway department wishes to take full advantage of a water source for domestic use, it should obtain the assistance of a qualified groundwater engineer, groundwater geologist, hydrologist, or contractor familiar with the construction of wells in the area. He should rely on facts and experience, not on instinct or intuition. Facts on the geology and hydrology of an area may be available in publications of the U. S. Geological Survey or from other Federal and State agencies. The National Water Well Association also offers assistance.[1]

LOCATION AND PROTECTION OF GROUNDWATER

The most effective protection of groundwater is provided by impermeable strata of clay, hardpan, etc., which may separate portions of the topsoil and water-bearing sand and gravel through which the well penetrates. In the absence of overlying impermeable strata, maximum protection is afforded the quality of groundwater when overlying formations are of a sandy character and of sufficient depth to ensure good filtering action. Minimum protection is afforded when surface water may reach the water table through relatively large openings formed in the soil and subsoil by animal burrows, tree and plant roots, cracks in soil or rock, solution channels in limestone rock, coarse gravel formations, or man-made excavations.[3]

All groundwater sources must be located at safe distances from sources of contamination. A safe distance is dependent upon numerous local factors and its determination involves, among other things, the evaluation of the following: character and location of the source of contamination, type of well construction, natural hydraulic gradient of the water table, permeability of the water-bearing formation, extent of the cone of depression formed in the water table due to pumping the well, and the type of underground formation. For example, in crystalline formation, such as fissured limestone, there is no safe distance since the contamination may travel many miles.[3]

Because the determination of a safe distance between a groundwater source and a source of contamination is dependent on many factors, it is impractical to establish arbitrary distances which will be adequate under all conditions. However, Table II-1 may be used as a general

TABLE II-1. MINIMUM RECOMMENDED DISTANCES BETWEEN WATER SUPPLIES AND VARIOUS CONTAMINATION SOURCES

Source of Contamination	Distance (Feet)	Distance (Meters)
Pit privies and vault toilets	100	30.5
Sewers	50	15.2
Septic tanks and distribution boxes	50	15.2
Subsurface sewage disposal fields (receiving effluent from septic tanks or aeration units)	100	30.5
Seepage pits (receiving effluent from septic tanks or aeration units)	100	30.5
Barnyards	100	30.5
Cesspools	150	45.7

Source: U.S. Forest Service, Sanitary Engineering and Public Health Handbook, (Draft), May 1976.

guideline in determining minimum safe distances to various sources of pollution, providing the water supply is located in a suitable geologic area. The Regulatory Agency also may have required minimum separation distances which must be observed.

In addition to the minimum distances, where the area adjacent to the water source is accessible to livestock, the site should be enclosed by a fence located in all directions not less than 100 feet (30.5 meters) from the water source. Where drainage from barnyards or other areas used by livestock may reach the water source because of local topography or soil formation, it should be diverted. All of the above are minimum distances and may be inadequate under conditions conducive to contamination, as in the case of creviced earth formations or very permeable soil. In any case, requirements of the State or local health department concerned should always be ascertained and compliance should be mandatory.[3]

WELLS

Location

As previously discussed, well sites should be located at a safe distance from any source of contamination as determined by a sanitary survey which takes into account such factors as geology, topography, soil composition, drainage patterns, and the nature and location of potential sources of pollution. Sources of pollution from insanitary surroundings include subsurface sewage disposal systems, sewer lines, livestock and animal pens, refuse disposal sites, abandoned and improperly sealed wells, industrial waste discharges, and roadway drainage.

In addition, wells should be located on the highest ground practicable in order to minimize the danger of pollution resulting from flooding, and contamination of the aquifer by infiltration through the well hole.

Test Wells

Where the general geology of a region is unknown, a test well should be drilled to determine the quality and quantity of water available.* Test wells differ from permanent wells in that the holes are usually smaller, the casings may be lighter, and no grouting is provided. Test wells also provide valuable design information for determining the proper depth of the permanent well, the best location and design of the well screens or perforations, as well as other factors.

In some cases, test wells can be converted to permanent wells by reaming to a larger diameter, and otherwise installing approved casing and performing other works to produce a well which meets all requirements for a permanent water well. Another alternative which may be considered is to drill and test a permanent well instead of a test well. If tests indicate the source to be unsatisfactory, the permanent well can be capped during the preliminary planning stages. (Procedures for proper well abandonment are described on page II-47 of this manual. On the other hand, if the source does prove to be acceptable, time and effort is spared since construction may continue on the same well.

Selection and Protection of Well Types

Once a well site has been determined satisfactory by geologic and sanitary investigation, it is necessary to choose an appropriate method of developing the aquifer. Table II-2 gives general information on the practicality of penetrating various types of geologic formations by the methods indicated.

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* Details of well construction, drillers logs, and water sample testing are described in a later section of this Chapter. Details related specifically to test well design and construction are available by consulting the Manual of Water Well Construction Practices by EPA (see references at the end of this chapter).

TABLE II-2. SUITABILITY OF WELL CONSTRUCTION METHODS TO DIFFERENT GEOLOGICAL CONDITIONS

Characteristics	Dug	Bored	Driven	Drilled			Jetted
				Percussion	Rotary		
					Hydraulic	Air	
Range of practical depths (general order of magnitude)	0-50 feet	0-100 feet	0-50 feet	0-1,000 feet	0-1,000 feet	0-750 feet	0-100 feet
Diameter	3-20 feet	2-30 inches	1¼-2 inches	4-18 inches	4-24 inches	4-10 inches	2-12 inches
Type of geologic formation:							
Clay	Yes	Yes	Yes	Yes	Yes	No	Yes
Silt	Yes	Yes	Yes	Yes	Yes	No	Yes
Sand	Yes	Yes	Yes	Yes	Yes	No	Yes
Gravel	Yes	Yes	Fine	Yes	Yes	No	¼-inch pea gravel
Cemented gravel	Yes	No	No	Yes	Yes	No	No
Boulders	Yes	Yes, if less than well diameter	No	Yes, when in firm bedding	(Difficult)	No	No
Sandstone	Yes, if soft and/or fractured	Yes, if soft and/or fractured	Thin layers only	Yes	Yes	Yes	No
Limestone			No	Yes	Yes	Yes	No
Dense igneous rock	No	No	No	Yes	Yes	Yes	No

Note: The ranges of values in this table are based upon general conditions. They may be exceeded for specific areas or conditions.

Source: EPA, Manual of Individual Water Supply Systems, EPA/430-9-74-007, 1974.

DUG WELLS. Dug wells are constructed by excavating a shaft and installing a wall, curb or casing. Because of the cost and difficulty in achieving adequate depth and sanitary construction, dug wells are seldom constructed today. Because of the difficulties in excavating below the water table, these wells usually can be sunk only a few feet below the water table. This seriously limits the drawdown that can be imposed during pumping, which in turn limits the yield of the well. Also, such wells may go dry with relatively minor drops in the groundwater level. A dug well of normal size, that taps a highly permeable formation such as gravel, may yield 10 to 30 gpm or even more in some situations with only 2 or 3 feet (0.6-0.9m) of drawdown. If the formation is primarily fine sand, the yield may be on the order of 2 to 10 gpm.

Dug wells are generally quite shallow and fairly large in diameter, 3-6 feet (0.9-1.8m) or more. They are frequently curbed at the bottom with stone, brick, tile or concrete blocks, laid up dry which permits subsurface water to seep into the well through the open crevices. The large opening at the top of the well increases hazards of contamination. As a result, the use of dug wells is not recommended, except in areas where the water-bering formation is comparatively limited in depth and permeability.* If a dug well is used, the top 10 feet (3.0m) of the curbing or casing should be watertight. Figures II-1 and II-2 show the recommended method of constructing a dug well, so as to prevent shallow subsurface contamination from entering the well. Figure II-3 illustrates the details of protecting the well from surface contamination. Because of the difficulty of extending dug wells below the zone of saturation, they frequently fail (go dry) during periods of drought. Deepening a dug well by drilling a hole in the bottom of the dug well is not recommended. (The old dug well frequently becomes a source of contamination for the drilled well.) A better procedure would be to drill a new well on a new site, abandon the dug well, and fill it with clean earth.

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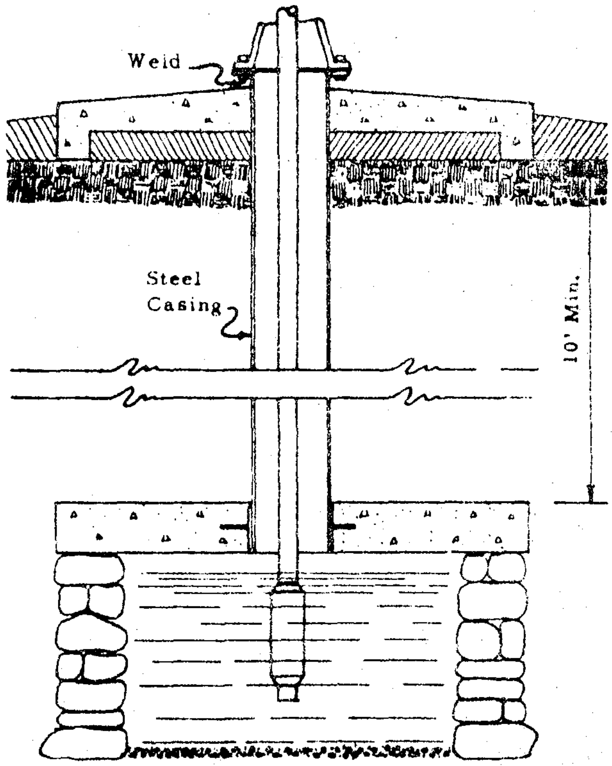
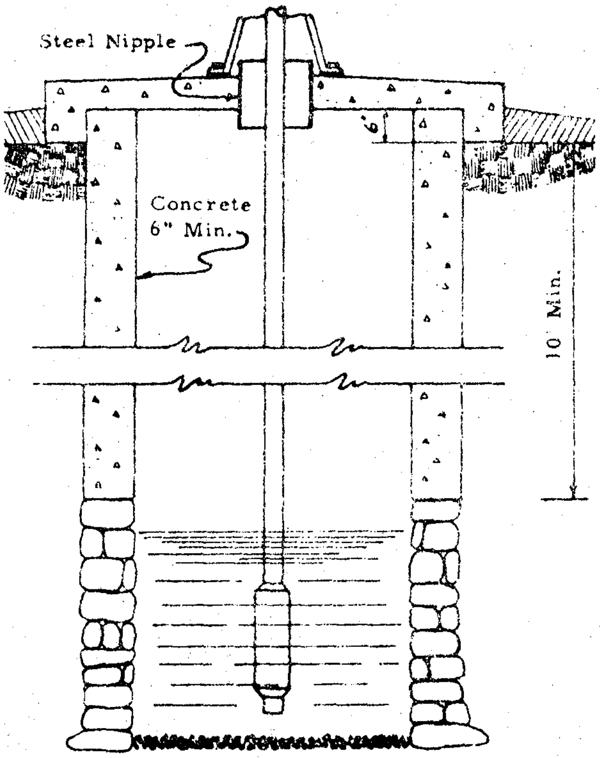
*Dug and bored wells generally are used in shallow formations where the cost of drilling to an equivalent depth would be comparatively high. In most cases however, a drilled well can be constructed where dug wells are being considered.



The concrete slab is poured on the surface with center opening to fit the casing. The slab is lowered to a point at least 10' below surface supported by the existing wall. The steel casing is placed and the exacavation void is backfilled with surface soil.

Source: Oklahoma State Department of Health, Small Water System Manual, Bulletin No. 0591, Oct. 1961.

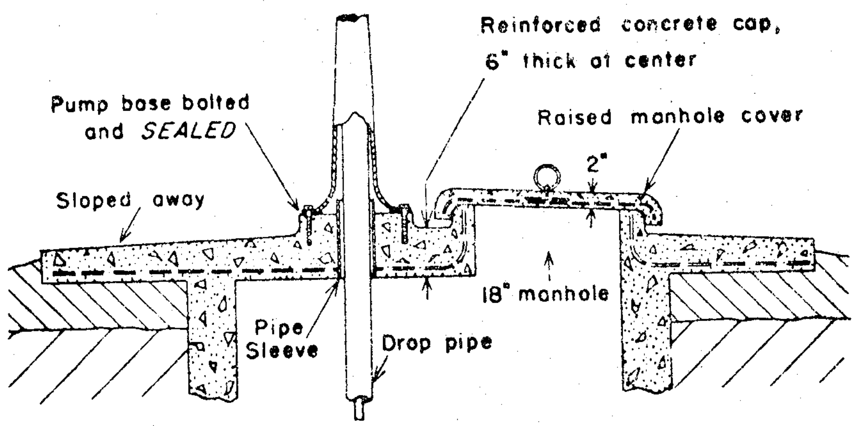
FIGURE II-1. BURIED SLAB CONSTRUCTION FOR A DUG WELL



Properly constructed new dug well with 6" concrete casing to a depth of 10 feet using rock or other masonry for support below that level.

Source: Oklahoma State Department of Health, Small Water System Manual, Bulletin No. 0591, Oct. 1961.

FIGURE II-2. DUG WELL USING ROCK FOR SUPPORT



Source: Oregon State Board of Health, Protection and Purification of Rural Water Supplies, 1971.

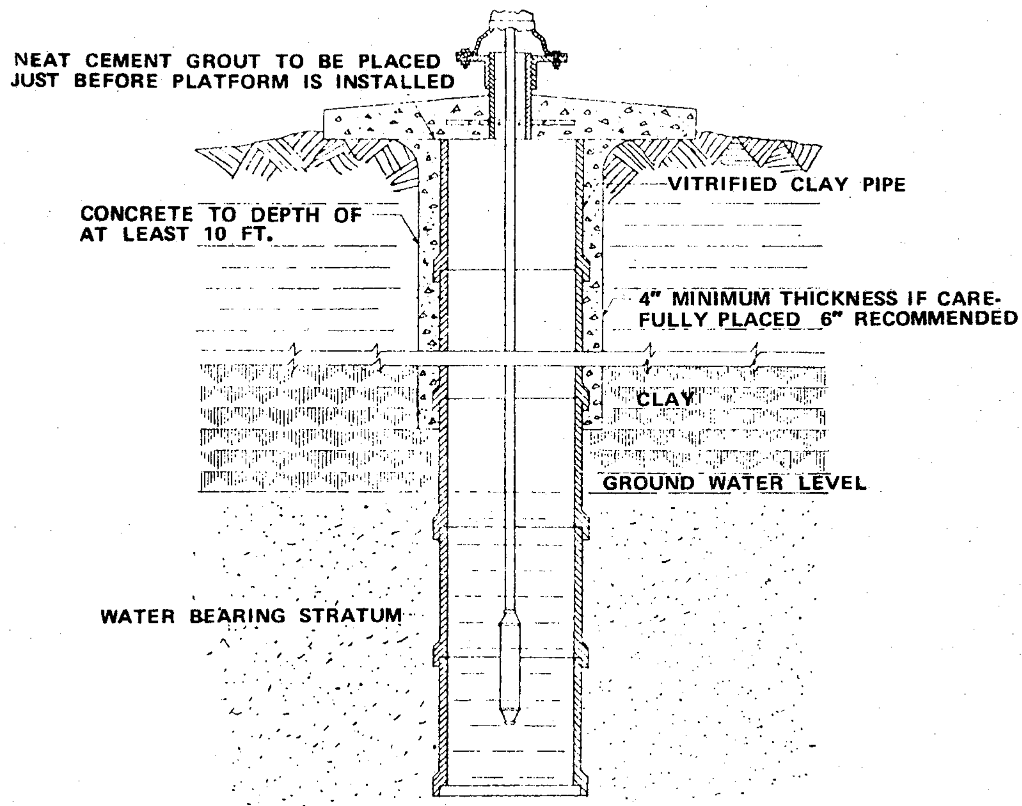
FIGURE II-3. DETAILS OF PROTECTING DUG WELL FROM SURFACE WATER CONTAMINATION

BORED WELLS. Bored wells are commonly constructed with earth augers turned either by hand or by power equipment. Such wells are usually regarded as practical at depths of less than 100 feet (30.5m) when the water requirement is low and the material overlying the water-bearing formation has noncaving properties and contains few large boulders. In suitable material, holes from 2 to 30 inches (5.1-76.2cm) in diameter can be bored to about 100 feet (30.5m) without the sides caving. A bored well tapping a highly permeable aquifer and providing several feet of available drawdown may yield 20 gpm or more. If the aquifer has a low permeability or the depth of water in the well is small, the yield may be much lower.[1]

Bored wells may be cased with vitrified tile, concrete pipe, standard wrought iron, steel casing, or other suitable material capable of sustaining imposed loads. The well may be completed by installing well screens or perforated casing in the water-bearing sand and gravel. Proper protection from surface drainage should be provided by sealing the casing with cement grout to the depth necessary to protect the well from contamination. Figure II-4 and II-5 show the recommended method of constructing and protecting a bored well.[1]

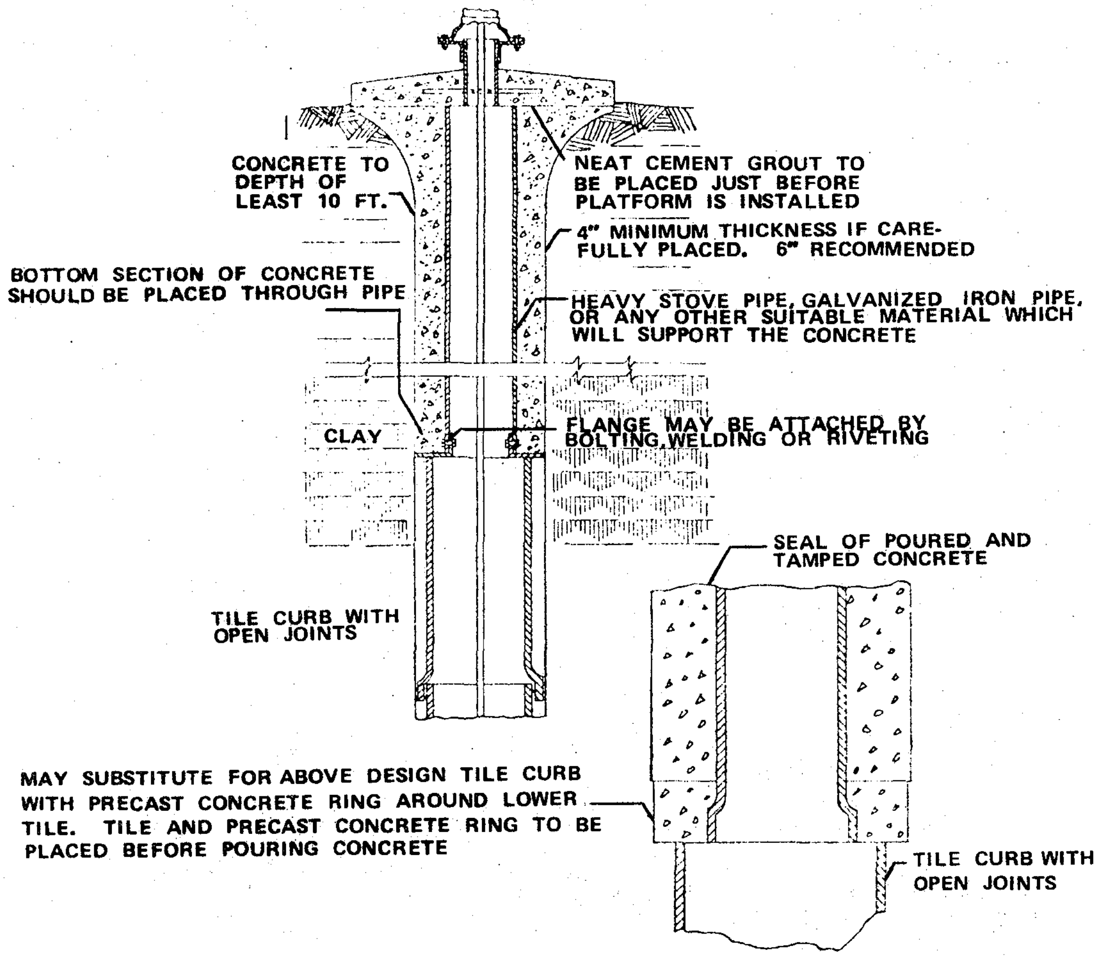
DRIVEN WELLS. Driven wells are constructed by driving a pipe that is fitted with a drive point and a screen into the ground until the water-bearing formation is reached. The use of driven well construction is limited to areas where the water-bearing strata lie at comparatively shallow depths and where there are no intervening formations of hard rocks or boulders that would interfere with the driving of the pipe. Under these conditions driven wells can be constructed rapidly and at small cost. Driven wells are seldom more than two inches (5.1cm) in diameter and are generally equipped with jet pumps.[5]

Driven wells can be sunk to as much as 30 feet (9.1m) or more below the static water level. A well at this depth can provide 20 feet (6.1m) or more of drawdown when being pumped. The small diameter of the well, however, limits the type of pumps that can be employed, so that the



Source: Iowa State Department of Health, Sanitary Standards for Water Wells, 1971.

FIGURE II-4. BORED WELL CONSTRUCTION



Source: Iowa State Department of Health, <u>Sanitary Standards for Water Wells</u>, 1971.

FIGURE II-5. BORED WELL CONSTRUCTION

yield under favorable conditions is limited to about 30 gpm. In fine sand or sandy clay formations of limited thickness, the yield may be less than 5 gpm.[1]

Figure II-6 illustrates three different types of drive-well points. In general, the serviceability and efficiency of each is related to its basic design. The continuous-slot, wire-bound type is more resistant to corrosion and usually can be treated with chemicals to correct problems of incrustation. It is more efficient because of its greater open area, and is easier to develop because its design permits easy access to the formation for cleanup.[1]

Another type has metal gauze wrapped around a perforated steel pipe base and covered by a perforated jacket; if it contains dissimilar metals, electrolytic corrosion is likely to shorten its life especially in corrosive waters.

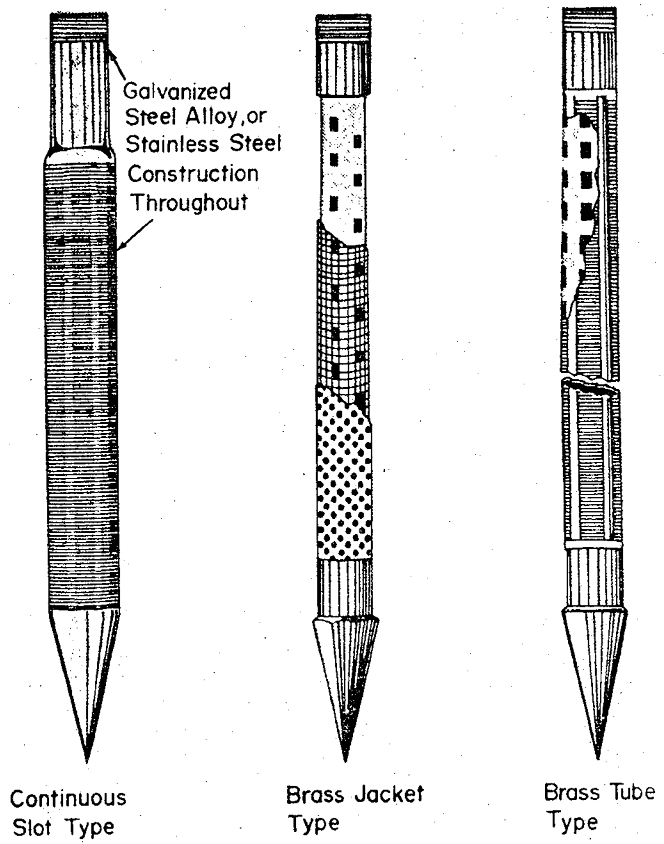
Wherever maximum capacity is required, well-drive points of good design are a worthwhile investment. The manufacturer should be consulted for his recommendation of the metal alloy best suited to the particular situation.

Figures II-7 through II-11 shows details of recommended construction for driven wells.

DRILLED WELLS. Drilled wells are constructed with drilling machines using rotary or percussion tools. The excavated material is brought to the surface by means of a bailer, sand pump, suction bucket, hollow drill tool, or hydraulic pressure.

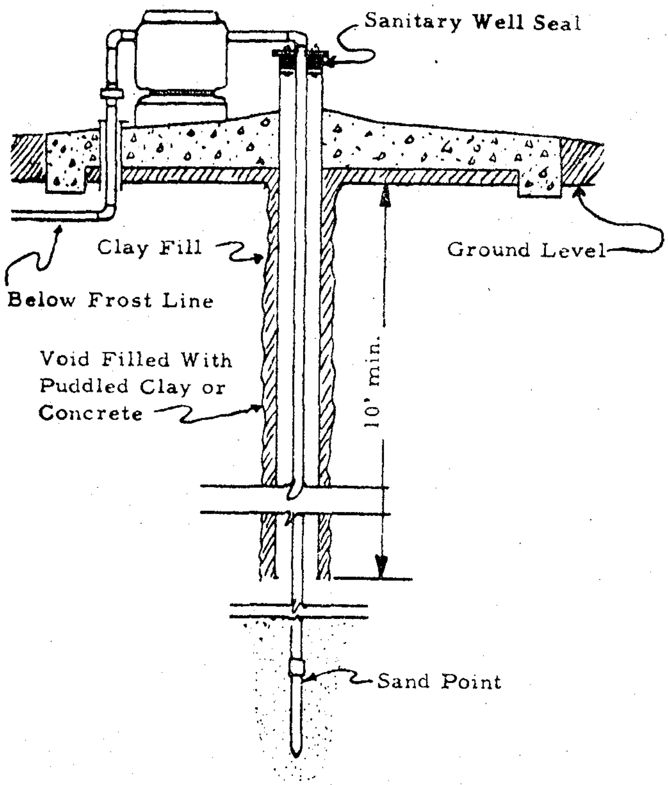
Drilled wells are the preferred method of aquifer development because they can be constructed to penetrate an aquifer located far below the water table, the yield is not influenced so much by fluctuating water tables, and the pollution hazard from surface water is reduced.[3]

Drilled wells can be constructed in all instances where driven wells are used and in many areas where dug and bored wells are



Source: EPA, Manual of Individual Water Supply Systems, EPA 430/9-74-007, 1974.

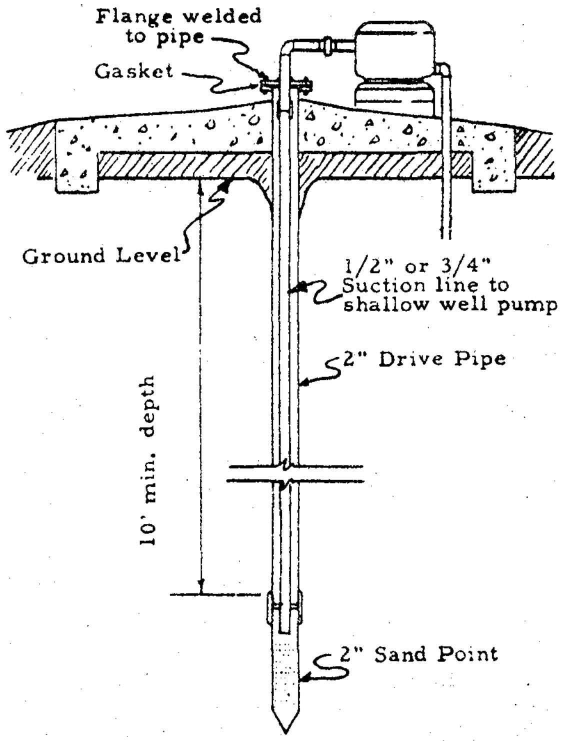
FIGURE II-6. DIFFERENT KINDS OF DRIVE-WELL POINTS



Proper method of installing a sand point well where drive pipe is used as return line and is under negative pressure. Wrought iron or steel casing 6' in diameter extends to a depth of 10' below surface.

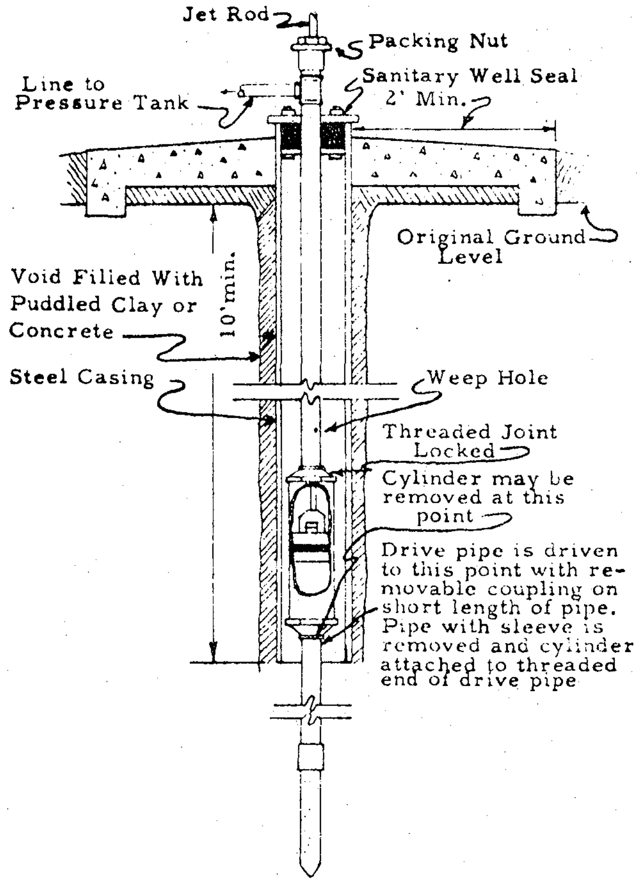
Source: Oklahoma State Department of Health, Small Water System Manual, Bulletin No. 0591, Oct. 1961.

FIGURE II-7. SAND POINT WELL USING DRIVE PIPE AS RETURN LINE



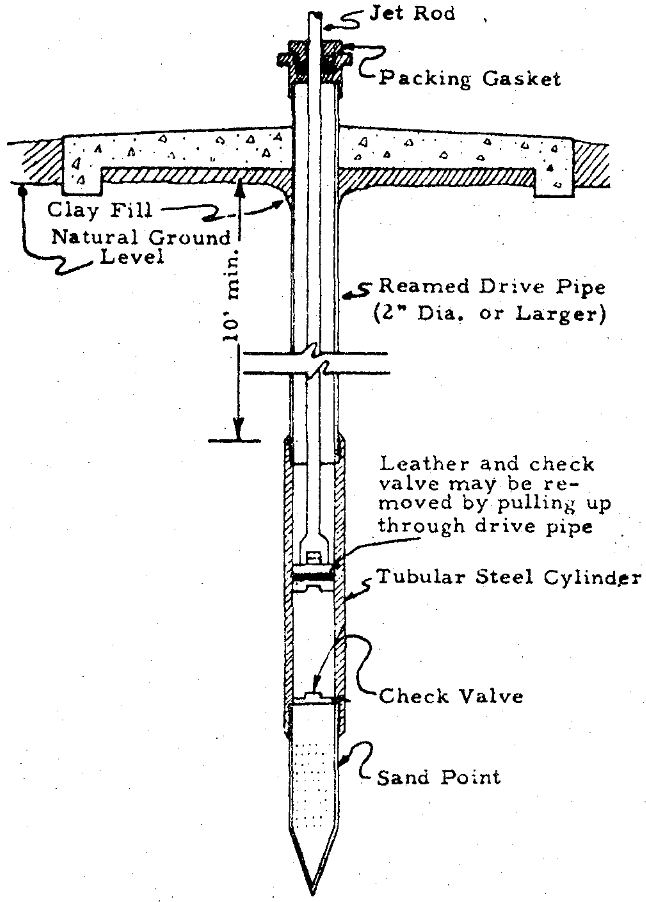
Source: Oklahoma State Department of Health, Small Water System Manual, Bulletin No. 0591, Oct. 1961.

FIGURE II-8. SAND POINT WELL WITH SUCTION RETURN LINE INSIDE DRIVE PIPE



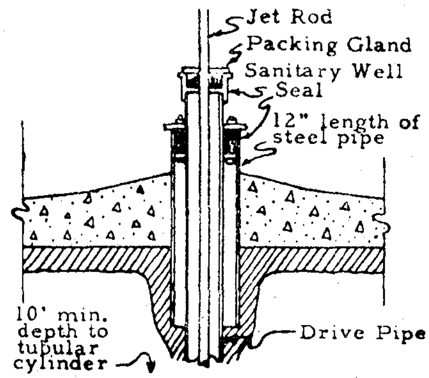
Source: Oklahoma State Department of Health, Small Water System Manual, Bulletin No. 0591, Oct. 1961.

FIGURE II-9. SAND POINT WELL USING CAST IRON CYLINDER



Source: Oklahoma State Department of Health, Small Water System Manual, Bulletin No. 0591, Oct. 1961.

FIGURE II-10. SAND POINT WELL USING STEEL TUBULAR CYLINDER ATTACHED TO SAND POINT.



A 12" length of 6" diameter steel pipe in slab permits removal of drive pipe and sand point.

Source: Oklahoma State Department of Health, Small Water System Manual, Bulletin No. 0591, Oct. 1961.

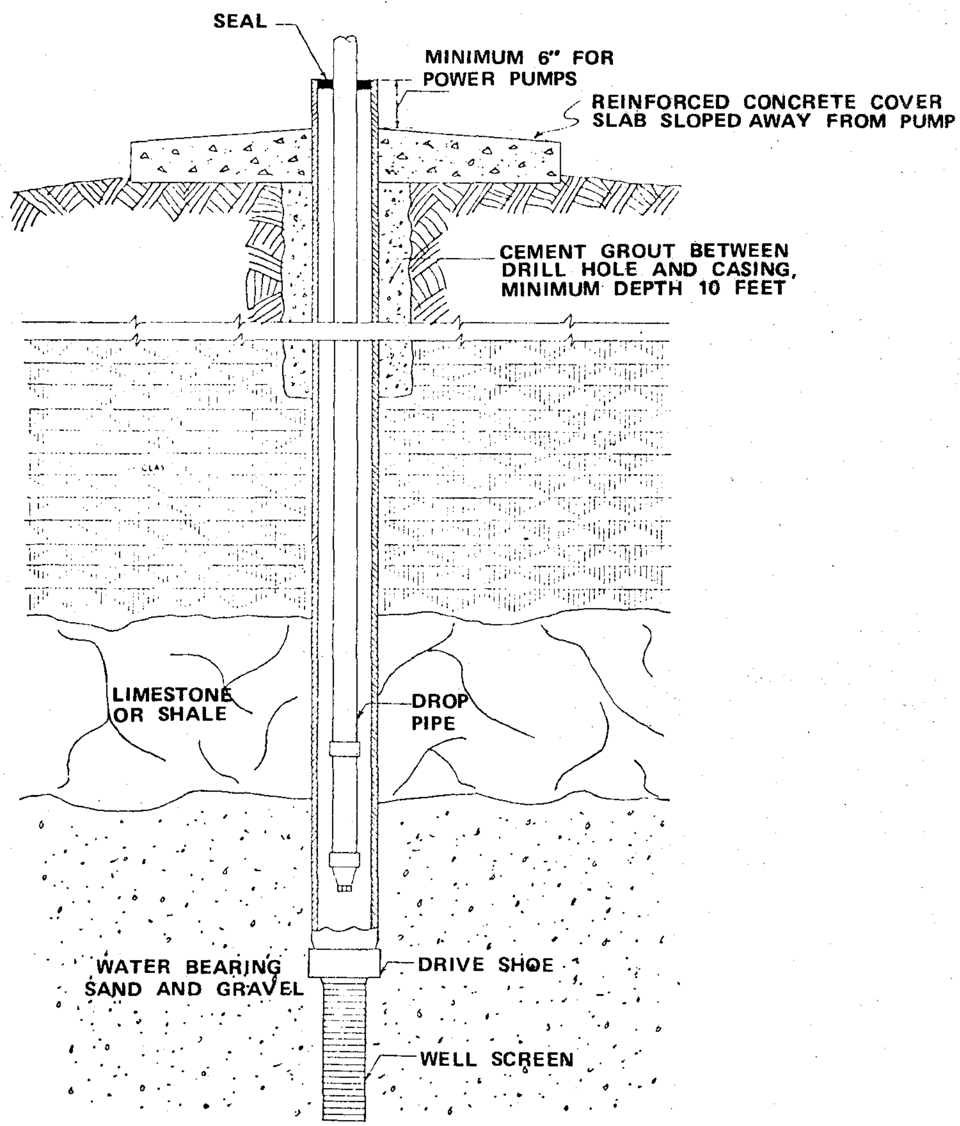
FIGURE II-11. ALTERNATE METHOD OF INSTALLING POSITIVE PRESSURE DRIVE PIPE constructed. The larger diameter of a drilled well as opposed to that of a driven well permits use of larger pumping equipment that can develop the full capacity of the aquifer. The capacity or yield of a well varies greatly, depending upon the permeability and thickness of the formation, the construction of the well, and the available drawdown. In productive formations of considerable thickness, yields of 300 gpm and more are readily attained.[1]

Figures II-12 and II-13 show a properly designed drilled well which can be constructed by the hydraulic rotary, air rotary, or percussion-tool method. No single method is superior under all conditions, but there are situations where one is definitely superior to the other, as described in the following paragraphs.

- <u>Percussion Tool Method</u>[3] - In the cable-tool percussion method of drilling, the hole is formed by the percussive and cutting action of a drilling bit that is alternately raised and dropped. This operation is known as spudding. The drill bit is a club-like, chisel-type tool. It breaks the formation into small fragments. A reciprocating motion is imparted to the drilling tools which mixes the loosened material into a sludge that is removed from the hole at intervals by a bailer or sand pump.

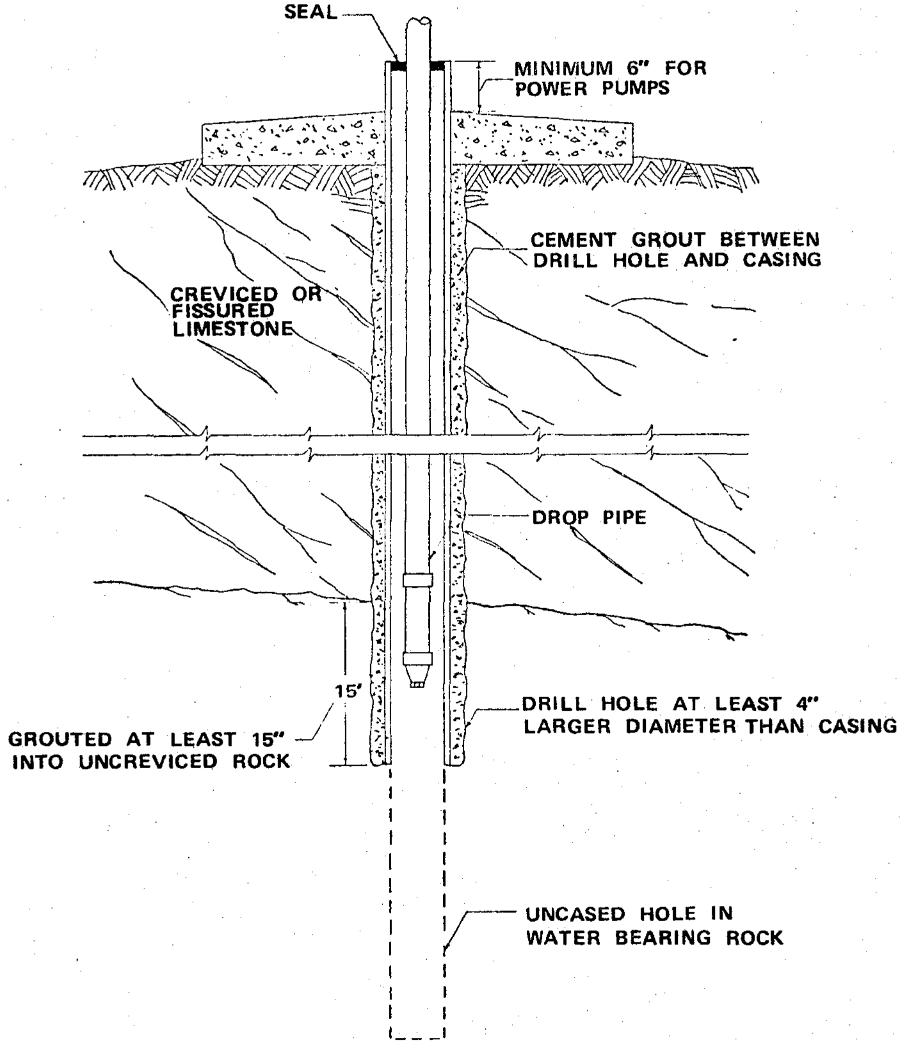
  To prevent caving of unstable formations, a casing is usually placed as drilling progresses. The percussion bit ordinarily drills a hole which is one-half inch (1.3cm) greater in diameter than the bit, leaving clearance for movement of the casing and drilling tools.

  The percussion-tool method is usually preferred when drilling through cavernous rock or other highly permeable material. Most or all of the fluid used in the rotary method may disappear in this type formation resulting in loss of return flow or loss of circulation. Where the troublesome zone is thin, there are expedients that may



Source: Iowa State Department of Health,
<u>Sanitary Standards for Water Wells</u>, 1971.

FIGURE II-12. PROPER CONSTRUCTION OF A DRILLED WELL OBTAINING WATER FROM SAND OR GRAVEL



Source: Iowa State Department of Health,
Sanitary Standards for Water Wells, 1971.

FIGURE II-13. PROPER CONSTRUCTION OF A DRILLED WELL OBTAINING WATER FROM ROCK be used to overcome loss of fluid. Commercial clay or fibrous material, such as hay or sawdust, can be mixed with the drilling fluid to seal porous formations. The percussion-tool method is also recommended where it is expected that the water supply will be secured from a rather thin, low volume aquifer with low head; otherwise the drilling mud may seal the aquifer and the supply will not be detected.

- Hydraulic Rotary Method[3]- The hydraulic-rotary method of drilling is accomplished by rotating suitable tools that cut, chip, and abrade the rock formation into small particles. The equipment consists of a derrick, a hoist to handle the tools and lower the casing into the hole, a rotary table to rotate the drill pipe and the bit, pumps to handle mud-laden fluid, and a suitable source of power. As the drill pipe and bit are rotated, drilling mud is pumped through the drill pipe, through openings in the bit, and up to the surface in the space between the drill pipe and the wall of the hole. The mud-laden fluid removes the drill cuttings from the hole and prevents caving by the pressure it exerts on the formations that have been penetrated. For soft and moderately hard materials, a drilling tool shaped like the tail of a fish, the "fishtail" bit, is used. In hard rock, a rock bit or roller bit is substituted. This bit has a series of toothed cutting wheels that revolve as the drill pipe is rotated. Water wells drilled by the hydraulic-rotary method generally are cased after reaching the required depth. If the water-bearing formation lies so deep that it probably cannot be reached by a hole of uniform diameter, the hole is started one or more sizes larger than the size desired at the bottom. Separate strings of casings of graduated sizes are used through the successive sections of the hole. An important consideration in using rotary methods is that aquifers may be sealed off by drilling mud, especially when aquifers under low head are encountered. Experience of local drillers may be of value in selection of the best drilling method.

The hydraulic-rotary method is usually preferred where the depth to water is uncertain, where solid rock will be encountered, where a well in a caving formation requiring casing during drilling by the percussion-tool method can be held open by the drilling mud, or where the extremely deep well is expected. The ability to drill an exploratory pilot bore without casing during drilling in some formations provides a means of securing information which will be useful in design of the final well.

- Air Rotary Method[3]- The air rotary method is similar to the hydraulic-rotary method in that the same type of drilling machine and tools may be used. The principal difference is that air is the fluid used instead of mud or water. In place of the conventional mud pump to circulate the fluids, air compressors are used. This method is adapted to rapid penetration of consolidated formations. It is not generally suited to unconsolidated formations where air escape into the formation can occur or when careful sampling of rock materials is required for a well screen installation. One definite advantage of this method is that small quantities of water can readily be detected during drilling operations.

Well Drilling Contracts

Preceeding sections of this chapter discuss procedures and methods of getting data which are requisite to learning of the occurrance of groundwater, its depth, quantity, quality and the type of formations in which it is found. Those data are helpful in planning and developing well drilling contracts and specifications. Even with all available information it is sometimes necessary to construct exploratory or test wells to obtain the data requisite for planning and constructing the permanent well. In some cases a consulting engineering geologist or hydrogeologist who is familiar with the particular location, may be engaged. Where hydrological conditions are similar throughout a considerable geographical area, the larger and most active well drilling contractors of the region can provide valuable advice on the subject. Where local, state or federal water resource agencies maintain well logs and records on groundwater levels, hydrogeological formation and quality, such information is useful in decision making.

LEGAL REQUIREMENTS

- Right to use groundwater - While property owners are usually authorized to develop and use groundwater on their own properties, there are some locations where the rights to groundwaters from certain aquifers are restricted. Consequently, this subject first should be checked with the appropriate water resource authority or agency.
- Credentials of well drilling contractor - Some states require that well drilling contractors be licensed or registered and meet rather specific requirements.* Obviously, a contract for well drilling should specify that the contractor does have the required accreditation plus a valid contractor's and business license or permit, where required. The contract also should provide that the contractor meet all legal requirements, as to notification of the enforcement agency, obtaining required permits, making prescribed tests, using approved materials and methods, filing a log of the well with the appropriate agency, and providing sufficient information to complete the drilling report.

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* In this case, highway department personnel without the proper credentials would not be permitted to drill the well. Regardless of state laws, however, highway personnel should not be allowed to dig, bore or drill wells unless they are properly trained and experienced in such work.

PLANS FOR WELL, WELL HOUSE, PUMP AND APPURTENANCES. A qualified, registered engineer should prepare plans and specifications for the well. A premise diagram should indicate surface topography and show all potential sources of contamination or pollution. Such items as possibility of flooding and provisions for surface drainage also should be shown.

Plans for the well cannot be completed until the well is drilled or a test well is constructed. However, plans and specifications can be made to assure an adequate internal diameter to accommodate the type and size of pump which is necessary, establish specifications for the casing type and material, and for the screen or perforations, pump installation, grouting, and sealing of the annular space surrounding the casing, openings for measuring water depth, design pump platform, arrangements for access to the well and pump for future possible removal or repairs and maintenance, and such other features as may be necessary.

The plans should be submitted to the state agency responsible for plan review and approval, the water resources agency, and the local authority responsible for building inspection and plan approval.

WELL DRILLING CONTRACTS AND DRILLING SPECIFICATIONS. It is highly recommended that design engineers consult EPA Publication 570/9-75-001, Manual of Water Well Construction Practices (1976),* prior to developing drilling contracts and specifications. The manual includes a procedure for using a comprehensive matrix to decide upon steps to be taken, procedures to follow, types of contracts to develop and the many other elements of the rather complex job of planning and contracting for the drilling of a water well.

The major elements shown horizontally on the matrix are:

Well Purpose
Design Capacity
Character of Interval Penetrated

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* Available from: Environmental Protection Agency, 401 M. Street S.W., Washington, D.C., 20460.

Character of Producing Zone
Construction Methods
Method of Payment

The major elements shown vertically are:

Test Holes, Logs and Samples
Well Construction Procedure
Well Casing Selection and Installation
Well Grouting
Well Filter Construction (Artificial)
Well Plumbness and Alignment
Well Development
Testing for Performance
Well Disinfection
Water Samples and Analysis
Well Abandonment

All of the above usually must be considered.

The method of payment varies, in part, according to the risk which must be taken by the well contractor. For certain formations the contractor will charge a given amount per foot of depth, the charge covering labor and materials, including the casing. Some contractors take the risk when they "guarantee" a given quantity of water for a stated price. The agency desiring to have a well constructed takes most of the risk when it develops a contract on the basis of paying for "time and materials".

The contract commonly will provide for drilling a test hole which may then, in some cases, be enlarged and permanently cased as the finished well. In this, as in all drilling, the contractor should fill out records including depths at which various formations are penetrated, water encountered and all information required for a well log.

Special contract elements may provide conditions under which grouting will be applied and a method of payment for such application and materials, by the sack or otherwise.

Another variable item is the installation of well screens or casing perforations, and for gravel packing or other well filter construction (artificial).

Specifications usually call for a given degree of plumbness and alignment and prescribe methods of its measurement.

Development of the well is another element to be covered, including, as applicable, work to produce a stated yield, measurement of draw-down and sand content, and establishing the method of payment for this element.

Other items include pumping tests, disinfection, and tests of the water.

A final item is to provide for sealing of unused wells in an approved manner, and cleaning up the premises, and specify the method of payment for this work.

OSHA AND OTHER PROTECTIVE PROVISIONS. The contract should contain provisions which would allow limiting the hours and days of work to reasonably satisfy nearby residents, where necessary. It should prescribe noise level limitations to protect workers, as required by OSHA rules, and also to meet community noise standards. Provisions also could regulate air pollutant emissions from internal combustion engines used on the site and require screening of light flashes from welding or other sources. The contract also should require environmentally sound disposal of drilling muds and other drilling wastes.

Barricade provisions, avoidance of dangerous or hazardous site conditions, maintenance of light, at night, and other requirements usually would be written into this type contract, as would be the case with other public construction projects. Insurance of the contractor usually would be described and specified.

Items in the safety and health category included in the Construction Industries Occupational Safety and Health Standard, 29 CFR 1926, Department of Labor, include:

Safety Training (of employees).
General Housekeeping of Construction Site.
Personal Protective Equipment, Both Individual and Site.
Availability of Medical Supplies, Personnel and Facilities.

Sanitation (including toilets and drinking water for employees).

Occupational Noise Exposure.

Exposure to Dangerous Gases, Vapors, Fumes, Dust and Mists (including exhaust gases, fumes from fuels, fumes from welding and solvents, etc.).

Illumination (both for safety and for work performance).

Protective Barriers and Signs.

Fire Protection and Prevention.

Storage of Flamable and Combustible Liquids (and gases).

Use and Storage of Explosives.

Use and Care of Hand and Power Tools.

Use and Care of Welding and Cutting Equipment.

Electrical Hazards (including those from drilling rigs encountering electrical lines).

Construction and Use of Ladders and Scaffolding.

Use of Mechanical, Hoisting, Lifting and Carrying Devices.

Excavations, Trenching and Shoring.

The contract should provide that the contractor be responsible for compliance with applicable provisions of the Federal Occupational Health and Safety Standards, Part 1910 of Title 29 of the Code of Federal Regulations and the additional OSHA regulations governing construction sites, as enforced by either the Federal Department of Labor or the designated and authorized state agency.

General Well Construction Requirements

It is recommended that well construction requirements follow those described in the American Water Works Association Standard for deep wells, Publication AWWA A-100-66.*

WELL CASING. Well casings and liners have the dual purpose of sealing out contaminated and other undesirable water and of maintaining a uniform opening from the surface to the aquifer.

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* Available from: AWWA, 6666 W. Quincy Avenue, Denver, Colorado, 80235.

The casing is an integral part of the effective sizing of the well for maximum hydraulic efficiency, and it must be large enough to accommodate the most efficient pump.

The following is a guide to well casing selection:[3]

Anticipated Well Yield (gpm)	Nominal Size of Pump Bowls (inches)	Optimum Size of Well Casing (inches)	Smallest Size of Well Casing (inches)
Less than 100	4	6 ID	5 ID
75 to 175	5	8 ID	6 ID
150 to 400	6	10 ID	8 ID
350 to 650	8	12 ID	10 ID
600 to 900	10	14 OD	12 ID
850 to 1300	12	16 OD	14 OD
1200 to 1800	14	20 OD	16 OD
1600 to 3000	16	24 OD	20 OD

The selection of the type and thickness of pipe must consider the stresses to which the pipe will be subjected during installation and when it is in service, as well as the corrosiveness of the water and soil with which it will come in contact.

Steel pipe, either threaded or welded, capable of being driven, is the preferred casing material. Special pipe coatings or plastic well casing may be necessary in areas of corrosive groundwaters.

SCREENS AND SLOTTED CASINGS. Screens should be installed in wells deriving water from unconsolidated formations. The well screen allows water from the aquifer to enter the well while supporting the water-bearing formation and preventing the drill hole from collapsing. The well screen also performs the important function of preventing sand and soil particles from entering the well and causing damage to pumps.

The length of active screen must be determined in relation to the thickness of water-bearing strata, type of screen, size and spacing of openings, required well capacity and similar factors. Manufacturers of well screens provide tables of capacities and other information to facilitate selection of the most economical screen dimensions. More detailed information on well screen selection and screen placement methods are contained in the two EPA references listed at the end of this chapter.

GROUTING AND SEALING. Grouting and sealing of water wells is practiced to protect the supply against pollution, to increase the life of the well by protecting the casing pipe against exterior corrosion, to seal out water of an unsatisfactory quality, and to stabilize soil or rock formations which are of a caving nature.

The depth of the seal required for protection from surface contamination depends upon the character of the formation and the depth and proximity of sources of pollution. As a general rule, at least 10 feet (3.0m) of seal is necessary in most cases, but more may be required depending on the conditions and local regulations.

In creviced rock formations, it is extremely important to extend the well casing and grout the annular space outside the casing. Considerable protection for the supply will be attained by casing and sealing the annular space to a depth of at least 20 feet (6.1m) below the lowest level of the water table surface, during maximum drawdown.[3]

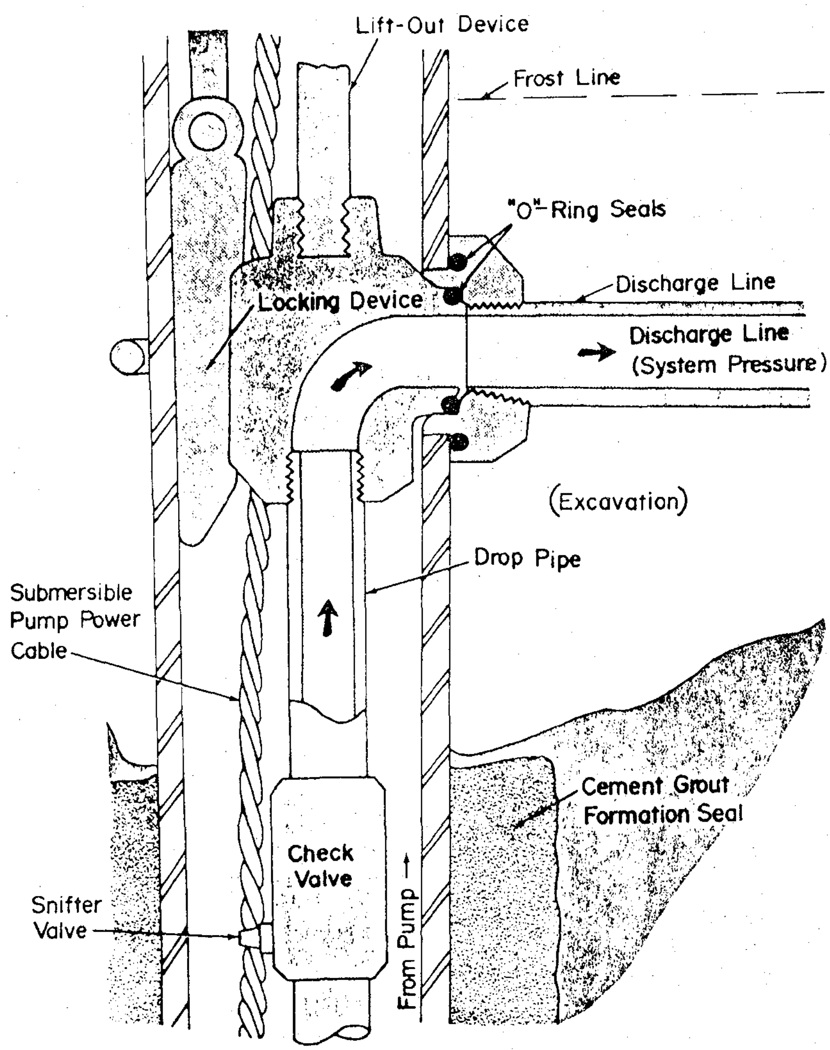
WELL COVERS AND SANITARY SEALS. Every well should be provided with an overlapping, tight-fitting sanitary cover at the top of the casing or pipe sleeve to prevent contaminated water or other material from entering the well.

The sanitary well seal in a well exposed to possible flooding should be elevated at least 2 feet (0.6m) above the highest known flood level. When it is anticipated that even with the above precautions, the well seal may become flooded, it should be watertight and equipped with a vent line whose opening to the atmosphere is several feet higher. Vents should always terminate in a downward direction, and be screened to exclude insects and vermin.

In any case, sealing of the annular space and all openings to the well should conform with applicable regulations. In addition to sealing the annular space between the casing and the delivery tube, precautions are necessary to prevent water from entering the space surrounding the outside of the casing. A well slab alone is not entirely effective since it can be undermined by burrowing animals and insects, cracked by settlement or frost heave, or broken by vehicles and vibrating machinery. The cement grout formation seal is far more effective. It is recognized, however, that there are situations that call for a concrete slab or floor around the well casing to facilitate cleaning and improve appearance. When such a floor is necessary, it should be placed only after the seal installation and the pitless installation have been inspected, and the opening between the concrete and the casing sealed with a suitable, resiliant material.

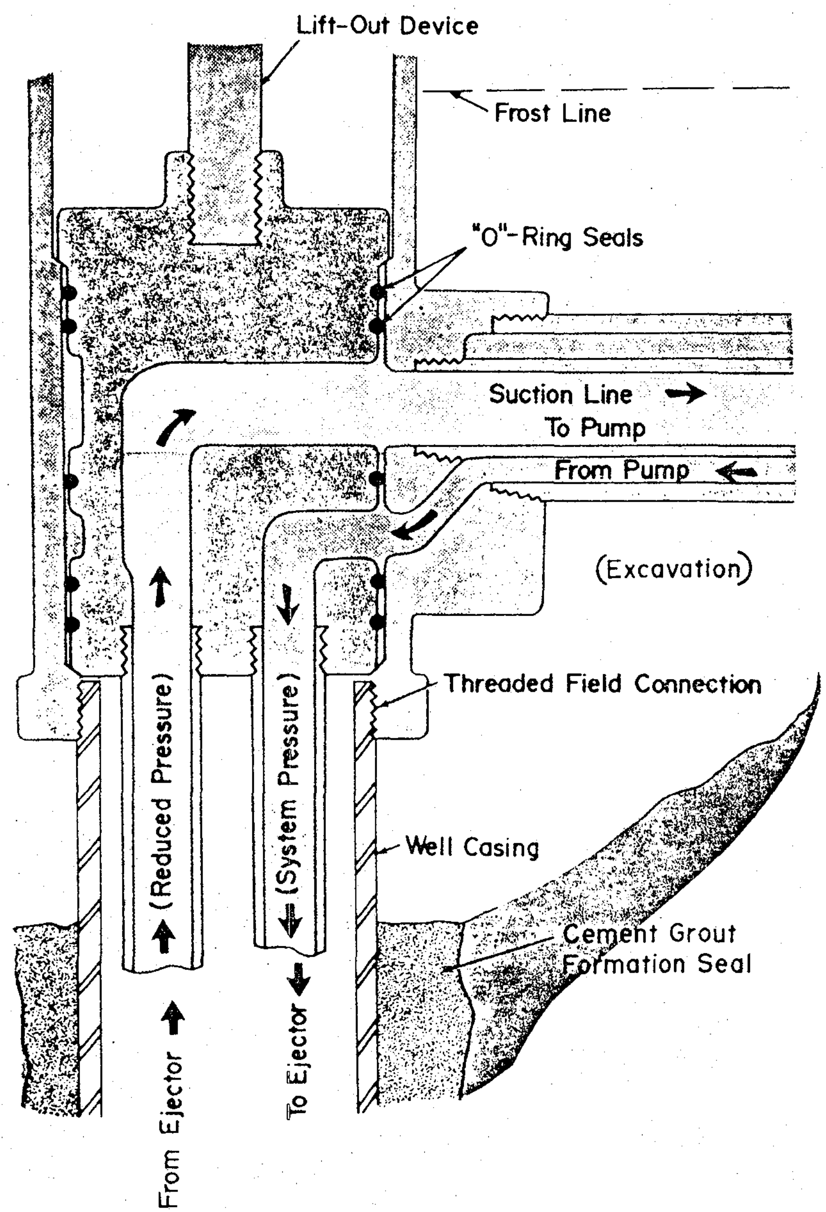
PITLESS ADAPTERS. Because of the pollution hazards involved, <u>a sub-surface well pit to house the pumping equipment or to permit accessibility to the top of the well is strongly discouraged</u>. Instead, where freezing protection must be provided, a pitless well adapter is suggested in order to eliminate well pit construction. The adapter is a specially designed connection between the underground horizontal discharge pipe and the vertical casing pipe making it possible to terminate the watertight casing of the well at a safe height, 12 or more inches (30.5cm) above final grade. The underground section of the discharge pipe is permanently installed, and it is not necessary to disturb it when repairing the pump or cleaning the well. Figures II-14 through II-17 show various types of pitless adapters which can be used for a given pump installation.

There are numerous makes and models of pitless adapters and units available. Not all are of good design, and a few are not acceptable to some states. The state or local health department should be consulted first to learn what is acceptable.



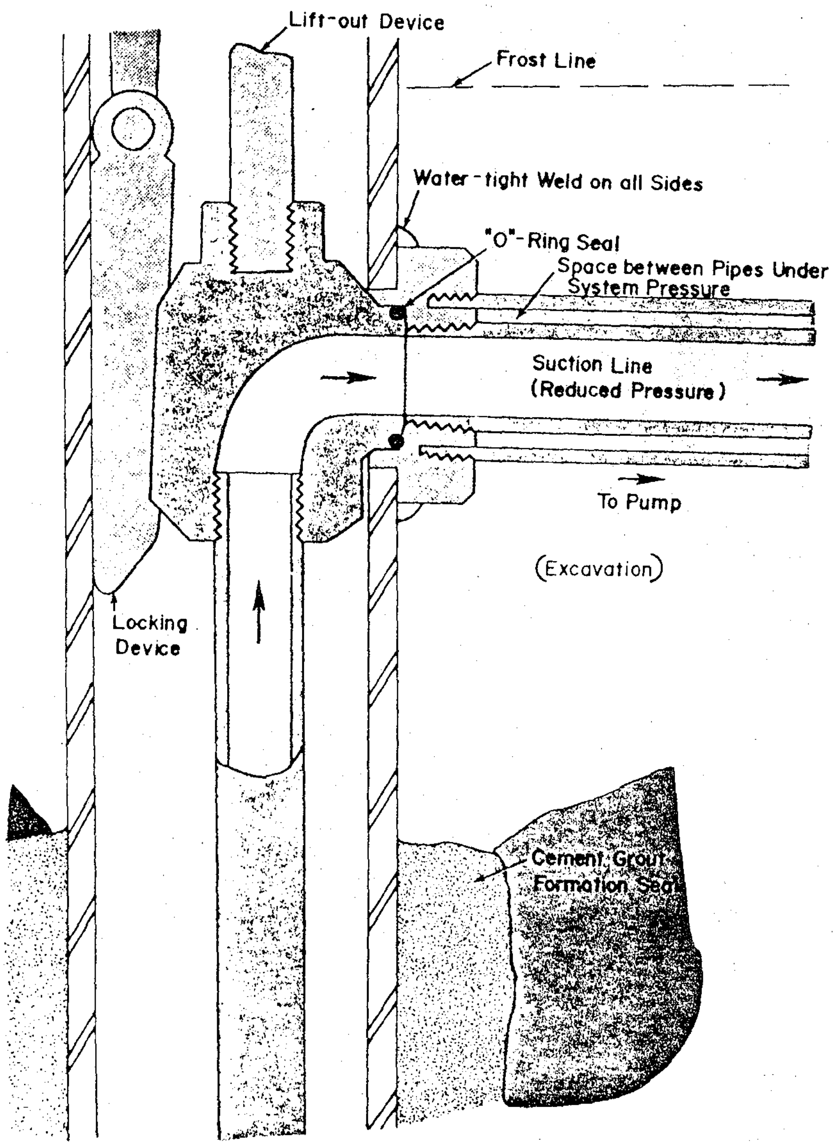
Source: EPA, Manual of Individual Water Supply Systems, EPA 430/9-74-007, 1974.

FIGURE II-14. CLAMP-ON PITLESS ADAPTER FOR SUBMERSIBLE PUMP INSTALLATION



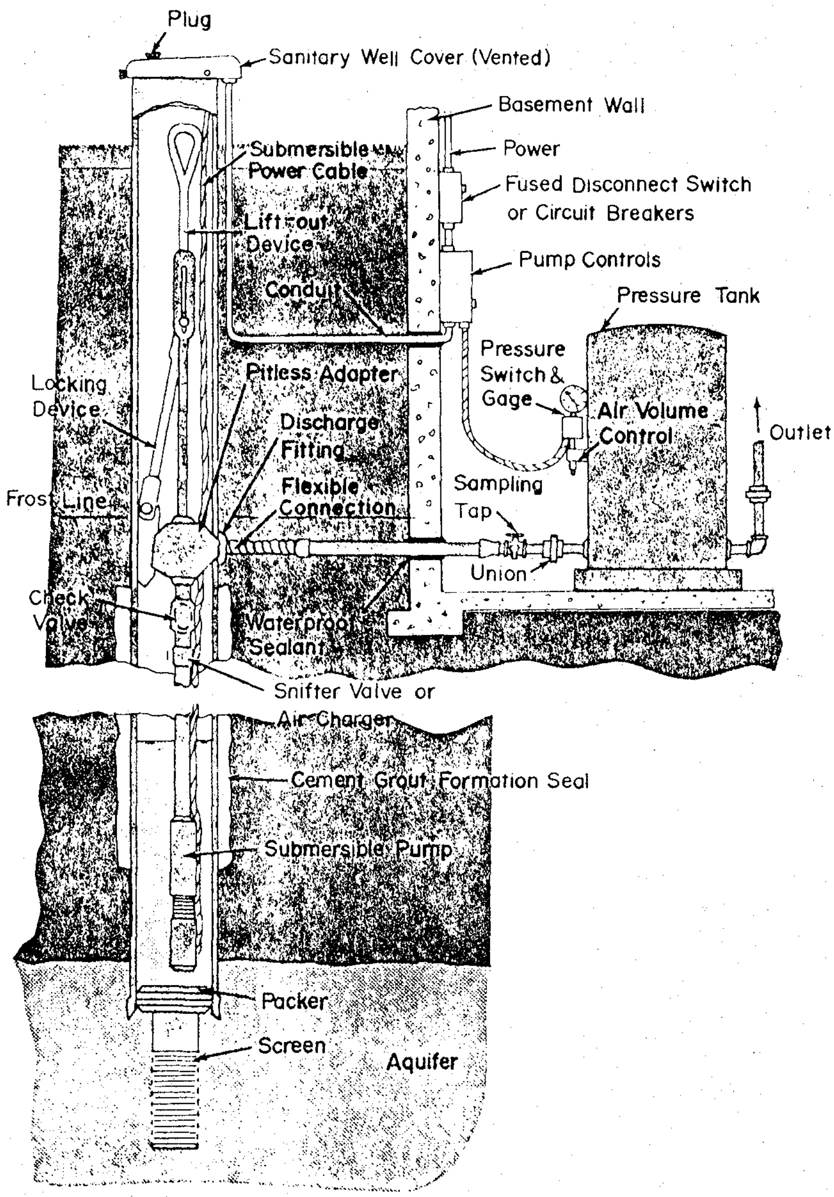
Source: EPA, Manual of Individual Water Supply Systems, EPA 430/9-74-007, 1974.

FIGURE II-15. PITLESS UNIT WITH CONCENTRIC EXTERNAL PIPING FOR JET PUMP INSTALLATION



Source: EPA, Manual of Individual Water Supply Systems, EPA 430/9-74-007, 1974.

FIGURE II-16. WELD-ON PITLESS ADAPTER WITH CONCENTRIC EXTERNAL PIPING FOR "SHALLOW WELL" PUMP INSTALLATION



Source: EPA, Manual of Individual Water Supply Systems, EPA 430/9-74-007, 1974.

FIGURE II-17. PITLESS ADAPTER WITH SUBMERSIBLE PUMP INSTALLATION FOR BASEMENT STORAGE

Both the National Sanitation Foundation* and the Water Systems Council** have adopted criteria intended to assure that quality materials and workmanship are employed in the manufacture and installation of these devices. Further information concerning these devices can be obtained by contacting either of these institutions or consulting the Manual of Individual Water Supply Systems by EPA (see reference list at the end of this chapter).

Recommendations During Drilling Operations

During the drilling and grouting operations, the premises, construction materials, tools and equipment should be maintained in a sanitary manner to prevent contamination of the well. During the periods of stoppage of the well drilling operation, the well opening should be securely covered to prevent tampering, vandalism, and accidents.

Water used in the drilling operation should be of an acceptable chemical and bacteriological quality, and the slush pit should be constructed and maintained so as to minimize contamination of the drilling mud.

Temporary toilet facilities should not be maintained within 150 feet (45.7m) of the well being constructed unless they are of a sealed, leakproof type.

DEVELOPMENT OF WELLS.[1] Before a well in unconsolidated material is put into use, it is usually necessary to completely remove silt and fine sand from the formation adjacent to the well screen by one of several processes known as "development". The development procedure unplugs the formation and produces a natural filter of coarser and more uniform particles of high permeability surrounding the well screen. After the development is completed, there will be a well-graded,

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* National Sanitation Foundation, Post Office Box 1468, Ann Arbor, Michigan, 48106.

** Water Systems Council, 221 North LaSalle Street, Chicago, Illinois, 60601.

stabilized layer of coarse material which will entirely surround the well screen and facilitate the flow of water in the formation into the well.

Wells in unconsolidated formations are frequently developed by the use of any one or a combination of several methods, including bailing, overpumping, intermittent pumping, surging with a plunger, surging with compressed air, and backwashing with water. Wells in consolidated formations (soil and rock) may also require developing. Generally, pumping or surging will remove any fines that may have plugged fractures and crevices.

Methods of development and their application must be suited to the aquifer and type of well construction. The engineer should specify the exact method of development or review and approve a detailed plan for developing the well from the well driller.

YIELD AND DRAWDOWN TESTING. In order that the most suitable pumping equipment can be selected, a pumping test should be made after the well has been developed to determine its yield and drawdown. A test pump is recommended with capacity equal to the maximum quantity of water that it is anticipated the well will produce or at least 50 percent greater than the capacity of the pump planned for permanent installation. The test pump setup also should be equipped for variable discharge so that the drawdown at various pumping rates, including the rate of the planned permanent pump, can be determined.

In making a yield test, the following should be observed:[3]

1. Record the water level in the well before pumping starts. This is called the static water level.
2. Pump the well at a constant rate taking drawdown readings periodically until the water level is stabilized. If the water level does not stabilize, reduce the rate of pumping to a lower constant rate at which the water level will stabilize.

3. Continue pumping for several hours at the same rate to be sure the water level does not change. The length of time required cannot be arbitrarily defined. Usually 24 hours should be a minimum. For contract work, it is recommended that test pumping be on an hourly basis so that the length of testing can be varied as needed.
4. Observe and record returning water levels after pumping has ceased.
5. Change pumping rate to discharge planned for permanent pump installation, and record drawdown when water levels stabilize.
6. Repeat item 4 above.

Additional information regarding the testing of wells for drawdown or yield may be obtained from the U.S. Geological Survey, the state or local health department, and the manufacturers of well screens or pumping equipment. The references by Gibson and Henderson listed at the end of this chapter also will provide useful information on this subject.

WELL DATA. The person drilling, boring, or driving a well should maintain accurate driller's logs, material setting data, and complete results of the pumping test for wells, including static and pumping water levels, and should send copies of the data to the state highway department and appropriate regulatory agencies. It should be noted that some states have strict regulations which require keeping this type of data.

The driller's log is prepared during well construction and provides a record of the various strata through which the well was constructed. The common well log is the driller's description of the geologic character of each stratum, the depth at which changes in character were observed, the thickness of the strata, and the depths at which water is encountered. Ideally, the driller should collect representative samples at measured depths and at such intervals as will show the complete lithologic character of the formations penetrated.

Well Completion

Upon completion, the well should be disinfected, and water samples collected for bacteriological, physical and chemical analysis.

DISINFECTION. Every well should be disinfected promptly after construction or repair. Disinfection is often economically and effectively accomplished by using either calcium hypochlorite (70% available chlorine) or sodium hypochlorite (12-15% available chlorine). The process is accomplished by adding the disinfectant to the well in order to disinfect the formation surrounding the well screen or perforation, and to fill the entire well, storage facility, and piping system with the disinfecting solution. It is common to allow the disinfectant to remain in the whole system for 24 hours before flushing and resampling.

When using calcium hypochlorite, a dosage of approximately 100 mg/l in the well water is desirable. This concentration is roughly equivalent to a mixture of 2 ounces of dry chemical per 100 gallons of water to be disinfected. Practical disinfection requires the use of a stock solution. The stock solution may be prepared by mixing 2 ounces of high-test hypochlorite with 2 quarts of water. The 2 quart stock solution can then be added to the remaining water to provide a concentration of approximately 100 mg/l when added to 100 gallons of water.

When calcium hypochlorite is not available, sodium hypochlorite can be used. Sodium hypochlorite is commonly available as liquid household bleach with 5.25 percent available chlorine, and can be diluted with one part of water to produce the stock solution. Two quarts of this solution can be used for disinfecting 100 gallons of water.

Table II-3 shows quantities of disinfectants to be used in treating wells of different diameters and water depths. For sizes or depths not shown, the next larger figure should be used.

Caution should be exercised in the preparation and handling of chlorine solutions as later described in Chapter 4 of this manual. Chlorine solutions are highly corrosive to metals, in addition to being subject to rapid deterioration when improperly stored.

TABLE II-3. QUANTITIES[a] OF CALCIUM HYPOCHLORITE, 70 PERCENT (ROWS A) AND LIQUID HOUSEHOLD BLEACH, 5.25 PERCENT (ROWS B) REQUIRED FOR WATER WELL DISINFECTION.

Depth of water in well (ft.)		Well diameter (in.)															
		2	3	4	5	6	8	10	12	16	20	24	28	32	36	42	48
5	A	1T	1T	1T	1T	1T	1T	2T	3T	5T	6T	3 oz.	4 oz.	5 oz.	7 oz.	9 oz.	12 oz.
	B	1C	1C	1C	1C	1C	1C	1C	1C	2C	4C	1Q	2Q	3Q	3Q	4Q	5Q
10	A	1T	1T	1T	1T	1T	2T	3T	5T	8T	4 oz.	6 oz.	8 oz.	10 oz.	13 oz.	1½ lb.	1½ lb.
	B	1C	1C	1C	1C	1C	1C	2C	2C	1Q	2Q	3Q	4Q	4Q	6Q	8Q	2½G
15	A	1T	1T	1T	1T	2T	3T	5T	8T	4 oz.	6 oz.	9 oz.	12 oz.	1 lb.	1½ lb.	1½ lb.	2 lb.
	B	1C	1C	1C	1C	1C	2C	3C	4C	2Q	2½Q	4Q	5Q	6Q	2G	3G	4G
20	A	1T	1T	1T	2T	3T	4T	6T	3 oz.	5 oz.	8 oz.						
	B	1C	1C	1C	1C	1C	2C	4C	1Q	2½Q	3½Q						
30	A	1T	1T	2T	3T	4T	6T	3 oz.	4 oz.	8 oz.	12 oz.						
	B	1C	1C	1C	1C	2C	4C	1½Q	2Q	4Q	5Q						
40	A	1T	1T	2T	4T	6T	8T	4 oz.	6 oz.	10 oz.	1 lb.						
	B	1C	1C	1C	2C	2C	1Q	2Q	2½Q	4½Q	7Q						
60	A	1T	2T	3T	5T	8T	4 oz.	6 oz.	9 oz.								
	B	1C	1C	2C	3C	4C	2Q	3Q	4Q								
80	A	1T	3T	4T	7T	9T	5 oz.	8 oz.	12 oz.								
	B	1C	1C	2C	4C	1Q	2Q	3½Q	5Q								
100	A	2T	3T	5T	8T	4 oz.	7 oz.	10 oz.	1 lb.								
	B	1C	2C	3C	1Q	1½Q	2½Q	4Q	6Q								
150	A	3T	5T	8T	4 oz.	6 oz.	10 oz.	1 lb.	1½ lb.								
	B	2C	2C	4C	2Q	2½Q	4Q	6Q	2½G								

[a]Quantities are indicated as: T = tablespoons; oz. = ounces (by weight); C = cups; lb. = pounds; Q = quarts; G = gallons.

Note: Figures corresponding to rows A are amounts of solid calcium hypochlorite required; those corresponding to rows B are amounts of liquid household bleach. For cases lying in shaded area, add 5 gallons of chlorinated water, as final step, to force solution into formation. For those in unshaded area, add 10 gallons of chlorinated water. (See "Disinfection of Wells," pp. 50 ff.)

Source: EPA, Manual of Individual Water Supply Systems, EPA 430/9-74-007, 1974.

BACTERIOLOGICAL QUALITY. Bacteriological sampling and testing after completion of the well, installation of the pumps and discharge piping, and disinfection is necessary in order to be sure that any contamination entering the well system has been removed or rendered harmless by the disinfection procedure. All sampling and analysis should be done in accordance with Standard Methods for the Examination of Water and Wastewater, 14th. Edition, 1975 (pp. 129-132).*

PHYSICAL AND CHEMICAL QUALITY. It is good practice to sample and test the water from the test well (if such a well is used) in order to assure that the water is of the best available chemical and physical quality. This will aid in determining whether to seek a better water bearing strata, or whether special treatment is necessary. In any case, regardless of whether or not a test well is used, sampling and testing of water from the completed well is necessary to be sure that the water is of suitable quality for human consumption. Poor chemical or physical quality may indicate the need for water treatment, dilution with water of better quality, or seeking an alternate source. It is necessary to make pH measurements in the field, otherwise CO_2 or other gases may escape and change the true pH reading. Iron samples must be acidified to prevent oxidation and precipitation of iron by aeration in transit, which gives a false low reading. Tests for H_2S and methane must be made in the field since these gases may escape in sample transit to the laboratory.

Water Level Management[6]

Provisions should be made for periodic measurement of static and pumping water levels in the completed well. The difference between static and pumping levels or the drawdown, makes it possible to determine the specific capacity of the well and to judge whether the well pump capacity is proper. Also, annual variations in static water level provides a means of estimating recharge characteristics and changes in well capacity.

* Available from: AWWA, 6666 W. Quincy Ave., Denver, Colorado 80235.

Well Abandonment

Test wells and groundwater sources which are not in use should be sealed by such methods as to restore the controlling geological conditions which existed before the wells were constructed. Proper sealing of abandoned wells is necessary to prevent possible pollution of aquifers and protect the quality of water in existing and future wells.[6]

When a well is to be permanently abandoned, the lower portion of it is best protected when filled with concrete, cement grout, neat cement, or clays with sealing properties similar to those of cement. When dug or bored wells are filled, as much of the lining should be removed as possible so that surface water will not reach the water-bearing strata through a porous lining or one containing cracks or fissures. Abandoned wells should never be used for the disposal of sewage or other wastes. In this, as in all other procedures, conformance with applicable State and local regulations is a basic requirement. Further information concerning basic well abandonment procedures is available in the Manual of Water Well Construction Practices, available from the EPA.

Repair and Maintenance of Wells

Whenever repair or maintenance of a well is required, measures should be taken to replace parts properly and disinfect the well before putting it back into service. Procedures for well disinfection were previously discussed on Page II-44. However, these procedures and the time the disinfectant remains in the system may need to be modified, and other precautions taken to assure that the public is not exposed to the high chlorine concentrations. Following the disinfection, a water sample should be withdrawn and submitted for bacteriological analysis to assure that it is safe for consumption, prior to returning the system to service. (This sample is considered to be in addition to routine bacteriological sampling required under State and Federal regulations.)

SPRINGS

Contrary to popular belief, spring water is not always of good bacteriological quality. In many instances, springs are derived from water supplies originating only a few feet below the ground surface.

Since it is not always practicable to determine accurately the depth from which spring water comes and whether or not the water stratum is protected from surface contamination by impervious strata, <u>extreme care should be exercised in developing springs for use as rest area water supplies</u>.

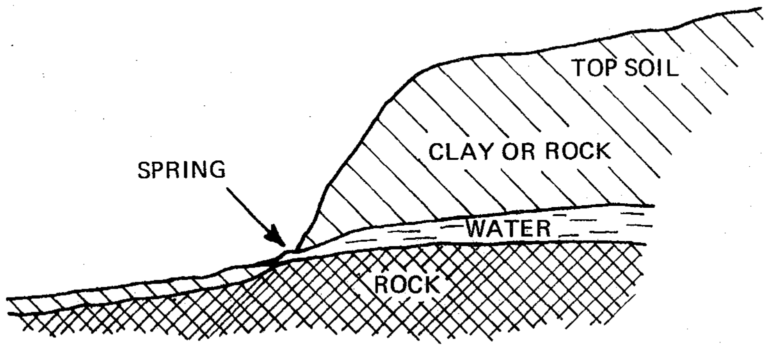
<u>Types of Springs</u>

Water appears at the ground surface from two types of springs, gravity and artesian. As shown in Figure II-18, gravity springs occur when the aquifer in which water is percolating laterally comes to the surface because of a sharp drop in surface elevation below the normal groundwater table or when obstructions to flow result in an overflow at the surface. Artesian springs are formed when faults in impermeable strata permit artesian water to escape from confinement as illustrated in Figure II-19. Artesian springs discharge from artesian aquifers at pressure higher than the discharge elevation and usually are freer from environmental hazards than are gravity springs, although the qualify of artesian springs still is not assured without proper testing and treatment.

<u>Factors to be Considered in Developing Springs</u>

In all cases where a spring is being considered as a source of potable water supply, it should be observed for turbidity after rainfall. This should be done even when rains occur in a radius of several miles from the spring. Turbidity would be one indication as to whether or not surface water contributes to the spring flow as well as the dependability of the spring. Another method of establishing the dependability of the source is to measure the spring flow after rainfall during wet seasons, as well as during dry seasons of the year. In making such measurements, an entrapment should be provided so that all flow will pass through one area. Other considerations which should be studied before developing a spring water supply include knowing the nature of the strata underlying the porous strata as well as the slope of the water table.

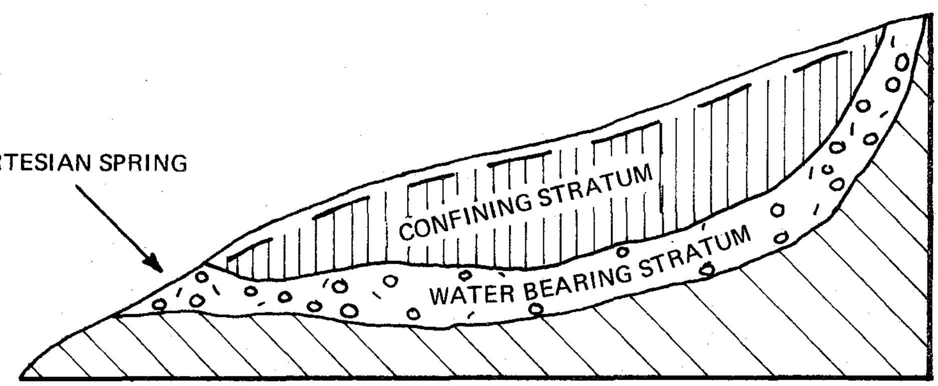
LOCATION. The source of supply must be a water bearing formation located at a point free from flooding and at the minimum distances to existing or proposed sources of pollution as previously specified in Table II-1.



TYPICAL SPRING, BEFORE DEVELOPMENT

Source: Oregon State Board of Health, Protection and Purification of Rural Water, 1971.

FIGURE II-18. GRAVITY SPRING



Source: Montana Department of Health, Circular No. 11

FIGURE II-19. ARTESIAN SPRING

PROTECTION. For proper protection of the spring, the following recommendations are suggested: All springs should be housed in casings with watertight walls and tops; direct surface drainage should be diverted away from the spring; the entire area within 100 feet (30.5m) of the spring should be fenced to prevent trespass of livestock and unauthorized persons; and any portion of surface drainage diversion ditches lying above the spring should be within the fenced area. Figure II-20 shows a method of protecting the spring from surface influences. The illustration shows a concrete structure over and around the spring. This has an arched opening on the side from which the water is flowing so as to allow the water to flow into the structure. Just above this opening is a concrete ledge which is intended to prevent surface water from washing into the spring. The manhole entrance has a "pill-box" type of lid. This lid, constructed of metal or concrete, is so designed that no surface wash can get into the spring water.

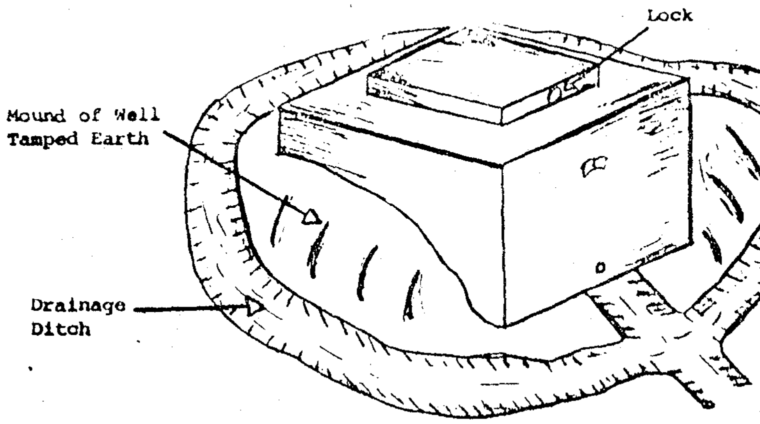
<u>Construction and Installation Guidelines</u>

The features of a properly constructed spring system are the following: (1) an open-bottom, watertight basin intercepting the source which extends to bedrock or a system of collection pipes and a storage tank, (2) a cover that prevents the entrance of surface drainage or debris into the storage tank, (3) provision for the cleanout and emptying of the tank contents, (4) provision for overflow, and (5) a connection to the distribution system or auxiliary supply. These features are illustrated in Figure II-21.

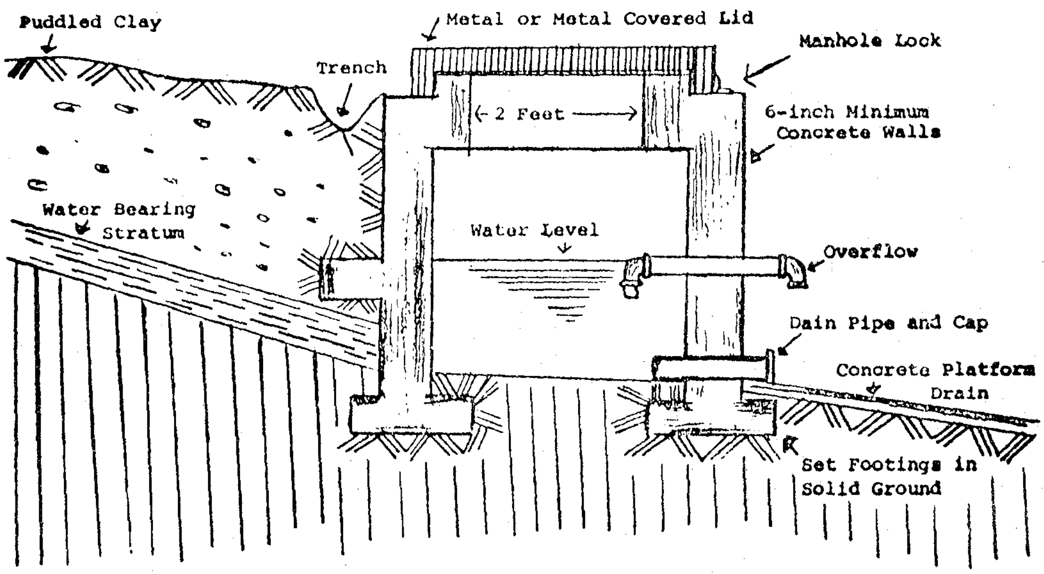
Springs should have substantial and watertight walls of concrete, vitrified tile or other suitable material extending to the water bearing strata which extends to bedrock or other impervious formation.

The spring should have an overlapping watertight cover which extends over the top edge of the spring at at least 2 inches (5.1cm). The cover should be heavy enough so that it cannot be dislodged by children and should be equipped for locking.

A drain pipe with an exterior valve should be placed close to



SPRING BOX

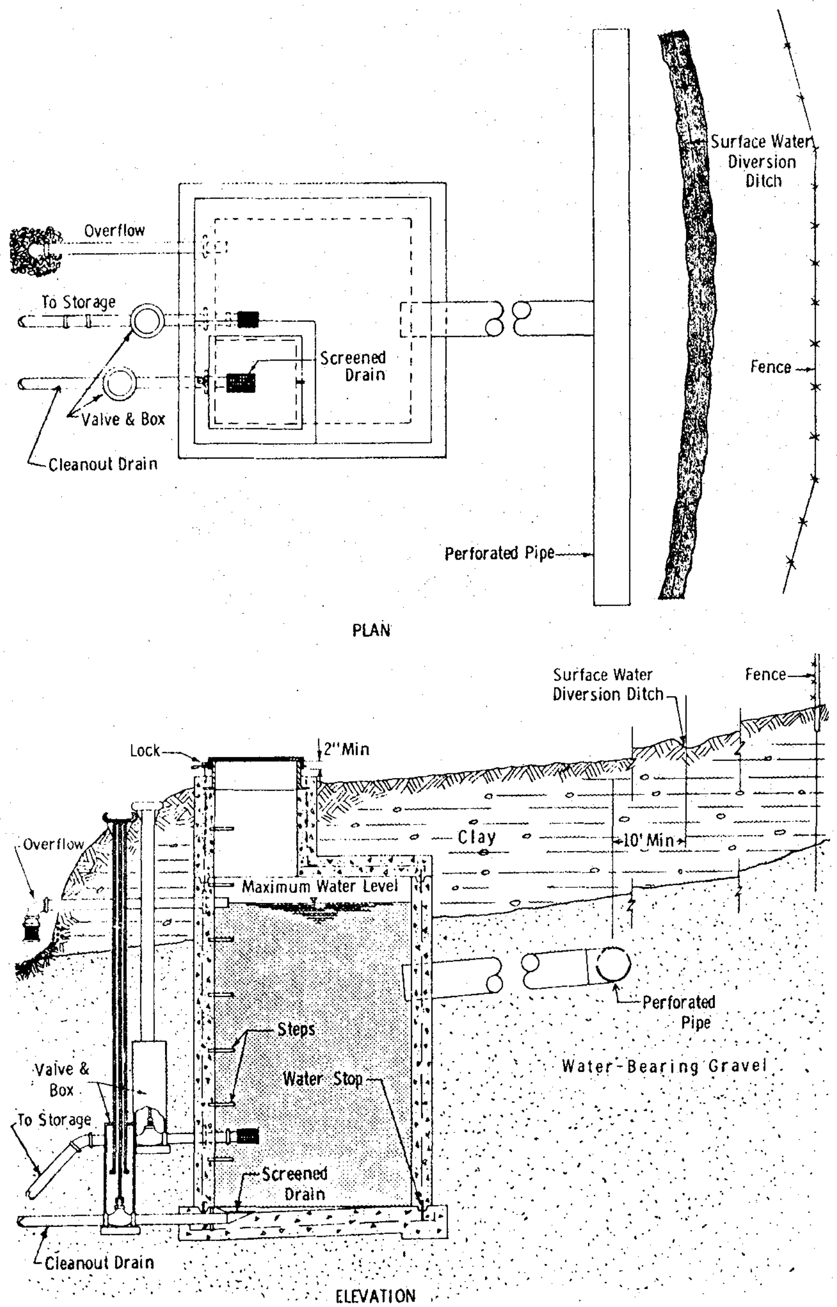


SECTION THROUGH CENTER OF SPRING BOX

If water enters spring at side, leave an opening in the wall on that side.
If water enters at bottom, have all walls solid and bottom open.

Source: Montana Department of Health,
Circular No. 11.

FIGURE II-20. GOOD SPRING CONSTRUCTION



Source: EPA, Manual of Individual Water Supply Systems, EPA 430/9-74-007, 1974.

FIGURE II-21. SPRING PROTECTION

the wall of the tank near the bottom. The pipe should extend horizontally so as to clear the normal ground level at the point of discharge by at least 6 inches (15.2cm). The discharge end of the pipe should be screened to prevent the entrance of rodents and insects.

The overflow is usually placed slightly below the maximum water-level elevation and screened. A drain apron of rock should be provided to prevent soil erosion at the point of overflow discharge.

The supply outlet from the developed spring should be located about 6 inches (15.2cm) above the drain outlet and properly screened. Care should be taken in casting pipes into the walls of the tank to insure good bond with the concrete and freedom from honeycomb around the pipes. Springs and "horizontal wells" can also be developed by suitably placing perforated pipe, or pipe with open joints, in a formation from which water can be obtained.

Treatment

Upon completion of spring construction, the spring encasements should be disinfected by a procedure similar to that used for dug wells. If the water pressure is not sufficient to raise the water to the top of the encasement, it may be possible to shut off the flow and thus keep the disinfectant in the encasement for 24 hours. If the flow cannot be shut off entirely, arrangements should be made to supply disinfectant continuously for as long a period as practicable.

Spring water should not be used for drinking or domestic purposes until it has been shown to be safe for these purposes. Provision should be made for effective and continuous disinfection as minimum treatment. As with other sources of water, samples of raw spring water should be submitted for physical and chemical analysis prior to use, in order to determine whether additional treatment is required to produce a safe supply which meets the National Primary Drinking Water Regulations.

INFILTRATION GALLERIES

An infiltration gallery is essentially a horizontal well that collects water along its entire length. Such galleries are usually laid in the alluvium near a body of surface water, and below the level of the surface water.

General Considerations

Infiltration galleries may be used in streambeds, or a short distance back from the bank of a stream or lake to pick up water. A properly constructed infiltration gallery removes suspended matter from the water but cannot be relied upon to produce bacteriologically safe water even though the water quality may be substantially improved. The water is still essentially surface water and should be considered as such in determining treatment needs. Native sand and gravel should be used in such installations only if suitable or if it is impractical to haul in special aggregates. Care must be taken to eliminate all wood, leaves, and foreign matter from the sand and gravel, which might decay and cause odors or taste in the water.[3]

Infiltration galleries are frequently used to collect water from wet meadows. In such cases, the gallery becomes in effect a shallow dug well, and should be treated as such.

The feasibility of using infiltration galleries should be investigated before intakes are constructed in streams, lakes, ponds, etc. This is especially desirable where considerable pollution of surface supplies is present, or where the water is colored, highly turbid, or supports a growth of algae.

Protection

Infiltration galleries are subject to the same sanitary hazards as shallow wells but have greater exposure to pollution because of their horizontal position. The following precautions should be taken to protect against contamination:[7]

1. Soil Filtration. To ensure adequate removal of suspended matter and bacteria, each infiltration gallery should be constructed and located to provide the collected water the maximum filtration through soil and sand.

2. Protection from Contamination. With the exception of service facilities, the surface area above and within a minimum of 100 feet (30.5m) or a "safe" distance of each gallery should be void of buildings and dwellings and should be protected by a fence to prevent trespass of livestock and unauthorized persons.
3. Surface drainage should be diverted away from the gallery.

Construction and Installation[1]

A typical installation generally involves the construction of an underdrained, sand-filter trench located parallel to the stream bed and about 10 feet (3.0m) from the high-water mark. The sand filter is usually located in a trench with a minimum width of 30 inches (76.2cm) and a depth of about 10 feet (3.0m). At the bottom of the trench, perforated or open joint tile is laid in a bed of gravel about 12 inches (30.5cm) in thickness with about 4 inches (10.2cm) of graded gravel located over the top of the tile to support the filtering material. The embedded tile is then covered with clean, coarse sand to a minimum depth of 24 inches (61cm), and the remainder of the trench backfilled with fairly impervious material. The collection tile is terminated in a watertight, concrete basin from where it is diverted or pumped to the distribution system following chlorination.

Where soil formations adjoining a stream are unfavorable for the location of an infiltration gallery, the debris and turbidity which are occasionally encountered in a mountain stream can be removed by constructing a modified infiltration gallery-slow sand filter combination in the stream bed. A typical installation involves the construction of a dam across the stream to form a natural pool or the excavation of a pool behind the dam. The filter is installed in the pool behind the dam by laying perforated pipe in a bed of graded gravel which is covered by at least 24 inches (61cm) of clean, coarse sand. About 24 inches (61cm) of free board should be allowed between the surface of the sand and the dam spillway. The collection lines usually terminate in a watertight, concrete basin located adjacent to the upstream face of the dam from where the water is diverted to chlorination facilities. Experience with these units indicates that they provide satisfactory service with limited maintenance.

Treatment[6]

The quality of water secured from infiltration galleries depends on the rate of percolation of the water and the filtering ability of the soil. The natural filtration of the surface water tributary to an infiltration gallery materially improves the physical character of the water and thus purification may be restricted to disinfection rather than artificial filtration and disinfection. In any case, infiltration galleries must be disinfected by a procedure similar to that for dug wells. Because of natural filtration, infiltration galleries may provide economical means of securing clear water when available surface water is turbid and when adequate quantities of groundwater are not available.

SURFACE WATER

Although rivers, creeks, ponds and irrigation canals may offer fairly dependable sources of raw water in some cases, these waters generally are exposed constantly to contamination. As a rule, surface water should be used only when groundwater sources are not available or are inadequate in quantity or quality. The possibility of physical and bacteriological contamination of surface water makes it necessary to regard such sources of supply as unsafe for domestic use unless reliable treatment, including filtration and disinfection, is provided.

Other major disadvantages of using surface supplies include susceptability to freezing and inadequate quantities of water available during certain seasons of the year.

Among the items to be considered in selecting a surface source are: quality, distance from distribution system, elevation, rainfall, area of watershed, type of soil or use made of watershed, control over watershed, sources, types and amount of pollutional material entering the stream.

The design of water systems using surface water sources varies greatly depending on the actual source of supply. Because of the extensive design and construction details involved in developing surface supplies, these will not be discussed here. Assistance in designing and planning surface water facilities is available from Federal, State and sometimes local health agencies. The U.S. Soil Conservation Service and publications from the state or county agricultural or geological departments also provide information and advice regarding surface water supplies.

TYPES OF SURFACE SOURCES[1]

Principal sources of surface water which may be developed include controlled catchments, ponds or lakes, surface streams, rivers, creeks, and irrigation canals. Except for irrigation canals, where discharges are dependent on irrigation activity, these sources derive water from direct precipitation over the drainage area.

A controlled catchment is a defined surface area from which rainfall runoff is collected. It may be a roof or a paved ground surface. The collected water is stored in a constructed covered tank called a cistern or reservoir.

A pond or lake should be considered as a source of water supply only after groundwater sources and controlled catchment systems are found to be inadequate or unacceptable. The development of a pond as a supply source depends not only on the selection of a watershed that permits only water of the highest quality to enter the pond, but also usage of the best water collected in the pond.

Streams and irrigation canals represent other sources of surface waters which may be used, if properly protected and treated.

CONSIDERATIONS IN ESTIMATING YIELD OF SOURCE

For controlled catchments, simple guidelines to determine water yield from rainfall totals can be established. When the controlled catchment area has a smooth surface or is paved and the runoff is collected in a cistern, water loss due to evaporation, replacement of soil moisture deficit, and infiltration is small. As a general rule, losses from smooth concrete or asphalt-covered ground catchments average less than 10 percent; for shingled roofs or tar and gravel surfaces losses should not exceed 15 percent, and for sheet metal roofs the loss is negligible.

A conservative design can be based on the assumption that the amount of water that can be recovered for use from an impervious catchment area is three-fourths of the total annual rainfall. (See Figure II-22.)

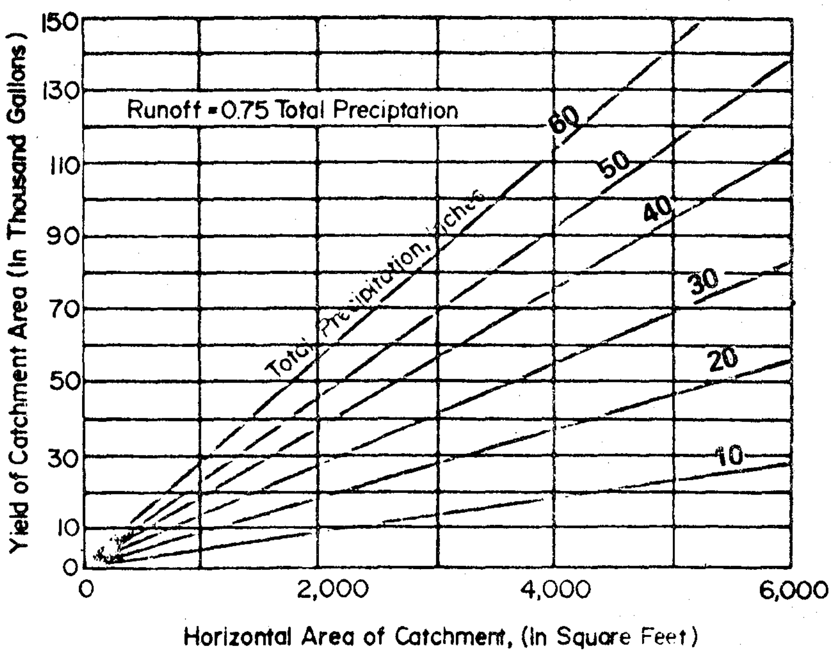
In determining the safe yield for rivers and streams the minimum streamflow of record must exceed the estimated future water demand on the peak day, particularly if no storage is provided. The reader is referred to Chapter 1 for details regarding storage requirements. The best hydrologic data on minimum stream flows is that recorded on the specific watershed in question. In the absence of such data or with a short period of record, it may be necessary to use estimating methods. Stream flow and weather records of contributing or adjacent watersheds can be used in estimating the safe yield of the source. Consultation with the USGS or Soil Conservation Service is recommended in determining the safe yield of surface supplies.

A careful study should be made of all factors which affect and determine the safe yield of a proposed surface water source, including such data as geographical location, storm paths, prevailing winds, temperature, humidity, type and intensity of precipitation, topography and size of recharge basin, orientation of basin, kind of soil, kind of vegetation, condition of ground surface, type and extent of artificial drainage, extent of surface storage in lakes, ponds, and swamps, condition and slope of stream channel, average slope of basin, character of drainage net, evaporation, infiltration and other losses.

SOURCE CONTAMINATION AND PROTECTION

Catchments

Ground-surface catchments should be fenced to prevent unauthorized entrance by either man or animals. There should be no possibility



Source: EPA, Manual of Individual Water Supply Systems, EPA 430/9-74-007, 1974.

FIGURE II-22. YIELD OF IMPERVIOUS CATCHMENT AREA of the mixture of undesirable surface drainage and controlled runoff. An intercepting drainage ditch around the upper edge of the area and a raised curb around the surface will prevent the entry of any undesirable surface drainage.

Ponds and Lakes

Where ponds furnish the water supply, it is extremely important that measures be taken to provide drainage areas large enough to afford sufficient water for maximum water needs. Drainage areas should preferably not include cultivated land. Grass and woodland areas are considered the most satisfactory terrain since less silt is present in the pond water collected from these areas. This allows more efficient filter operation with less frequent cleaning, and the decrease in pond capacity as a result of silt deposits is minimized.

Careful consideration of the location of the watershed and pond site reduces the possibility of chance contamination.

The watershed should:

1. Be clean, preferably grassed.
2. Be free from barns, septic tanks, privies, and soil-absorption field.
3. Be effectively protected against erosion and drainage from livestock areas.
4. Be fenced to exclude livestock.

The pond should:

1. Be not less than 8 feet (2.4m) deep at deepest point.
2. Be designed to have the maximum possible water storage area over 3 feet (0.9m) in depth.
3. Be large enough to store at least 1 year's supply.
4. Be fenced to keep out livestock.
5. Be kept free of weeds, algae, and floating debris.

Rivers and Streams

Stream intakes should be located upstream from sewer outlets or other sources of contamination. Whenever possible, the water should be pumped or diverted for use when the silt load is low. A low-water stage usually means that the temperature of the water is higher than normal and the water is of poor chemical quality. Maximum silt loads, however, occur during maximum runoff. High-water stages shortly after storms are usually the most favorable for diverting or pumping water to storage. These conditions vary and should be determined for the particular stream.

TREATMENT CONSIDERATIONS

Most surface waters require chemical coagulation, sedimentation, filtration, and disinfection to make them suitable for use as public water supplies. A combination of treatment methods will, if properly carried out, convert a moderately polluted water into a safe drinking water. It is increasingly difficult, because of easier access and greater recreational use of streams, lakes, and watersheds, and urban and industrial development, for unfiltered surface water from even protected watersheds to meet the requirements of the National Primary Drinking Water Regulations.[6]

Most unfiltered surface supplies are unable to produce consistently a suitably clear and colorless water, even though they can sometimes meet bacteriological requirements with suitable catchment areas, prolonged storage in impounding reservoirs, strict control of pollution sources on the catchment and storage areas, and effective disinfection.[6]

Local circumstances and the characteristics of each water supply govern the treatment required, as well as the design and construction of the plant needed to assure that a safe drinking water supply is provided.[6]

Before considering the extensive treatment generally required to render a surface water supply safe for human consumption, it may be beneficial to consider the use of a "dual system." In a "dual system" two separate water supply systems would be designed and operated - one for drinking water, and one for sanitation, irrigation and aesthetic purposes. Ideally, the limited groundwater resource would be developed in order to provide a relatively safe drinking water supply with a minimum of treatment. The remaining water requirements for sanitation and irrigation could then be satisfied by utilizing the surface water source without special treatment.

PUMPING FACILITIES

TYPES OF PUMPS

The four most commonly used types of pumps for small water supply systems include positive displacement, centrifugal, jet and hand pumps. The use of hand pumps, however, is limited to areas where no power supply is available, or to sites in areas subject to freezing, where a piped water system would necessitate heating of buildings or pumphouse. Selection of the proper type of pump for a given situation is described on Page II-64 of this manual.

Positive Displacement Pumps

There are several types of positive displacement pumps available but the operating principal of each type is basically the same. Reciprocating, helical, and regenerative turbine pumps are all considered positive displacement pumps since they force or displace the water through a pumping mechanism.

RECIPROCATING PUMPS. This pump consists of a mechanical device which moves a plunger back and forth in a closely fitted cylinder. The plunger is driven by the power source, and the power motion is converted from a rotating action to a reciprocating motion by the combined work of a speed reducer, crank, and a connecting rod. The cylinder, composed of a cylinder wall, plunger, and check value, should be located near or below the static water level to eliminate the need for priming.

The reciprocating pump is theoretically suitable for pumping wells of any depth, such depth being limited practically by strength of material, power source, and economics. Maximum suction lift is limited to 15-25 feet (4.5-7.6 meters) or less. One objectionable feature of reciprocating pumps is the uneven flow produced. However, this factor would be considered unimportant when pumping to a storage system.

HELICAL OR SPIRAL ROTOR PUMPS. The helical rotor consists of a shaft with a helical (spiral) surface which rotates in a rubber sleeve. As the shaft turns, it pockets or traps the water between the shaft and the sleeve and forces it to the upper end of the sleeve. These pumps are self-priming and will operate under difficult suction conditions, but wear rapidly in water containing sand. Consequently, when helical pumps are to be used, special consideration should be given to providing proper well screens to exclude sand from being pumped. These pumps have a maximum suction between 15-18 feet (4.6-5.5m).

REGENERATIVE TURBINE PUMP. This type of pump incorporates a rotating wheel or impeller which has a series of blades on its outer edge and a stationary enclosure called a raceway or casting. Pressures several times that of pumps relying solely on centrifugal force can be developed.

Centrifugal Pumps

Centrifugal pumps contain a rotating impeller mounted on a shaft turned by the power source. The rotating impeller increases the velocity of the water and discharges it into a surrounding casing shaped to slow down the flow of the water and convert the velocity to pressure.

Turbine and submersible pumps are multistage centrifugal pumps that are commonly used in small water supply systems. Since these pumps force water directly into the distribution system, the pump assembly must be located below the maximum drawdown level. This type of pump can deliver water across a wide range of pressures with the major limiting factor being the size of the unit and the horsepower applied. When sand is present or anticipated in the water source, special precautions should be taken before this type of pump is used since the abrasion action of the sand during pumping will shorten the life of the pump.

It is recommended that all turbine and submersible pumps conform to the design and specifications prescribed by the American Water Works Association (AWWA Standard for Deep Well Vertical Turbine Pumps - Line Shaft and Submersible Types, AWWA E101-71).*

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*Available from: AWWA, 6666 W. Quincy Ave., Denver Colorado, 80235.

TURBINE PUMPS. The vertical-drive turbine pump consists of one or more stages with the pumping unit located below the drawdown level of the water source. A vertical shaft connects the pumping assembly to a drive mechanism located above the pumping assembly.

SUBMERSIBLE PUMPS. When a centrifugal pump is driven by a closely coupled electric motor constructed for submerged operation as a single unit, it is called a submersible pump. (See Figures II-23 and II-24.) The electrical wiring to the submersible motor must be waterproof and the electrical control properly grounded to minimize the possibility of shorting and thus damaging the entire unit. Submersible pumps offer several advantages: (1) they are suited for installation in poorly aligned wells; (2) wells subject to flooding can be completely sealed; (3) a minimum amount of surface equipment is needed, and (4) operation is silent.

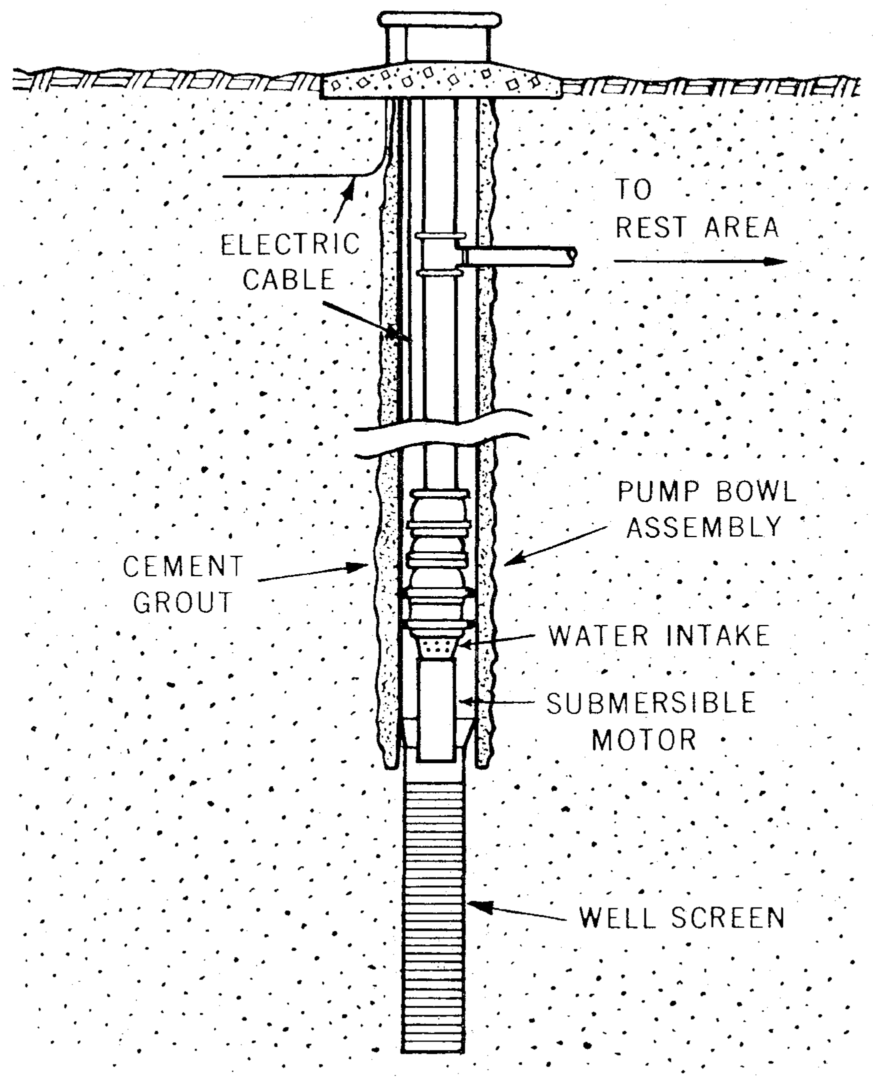
Jet Pumps

This type of pump is a combination of a centrifugal pump and an ejector and has application in shallow wells and for small capacities.

PUMP SELECTION

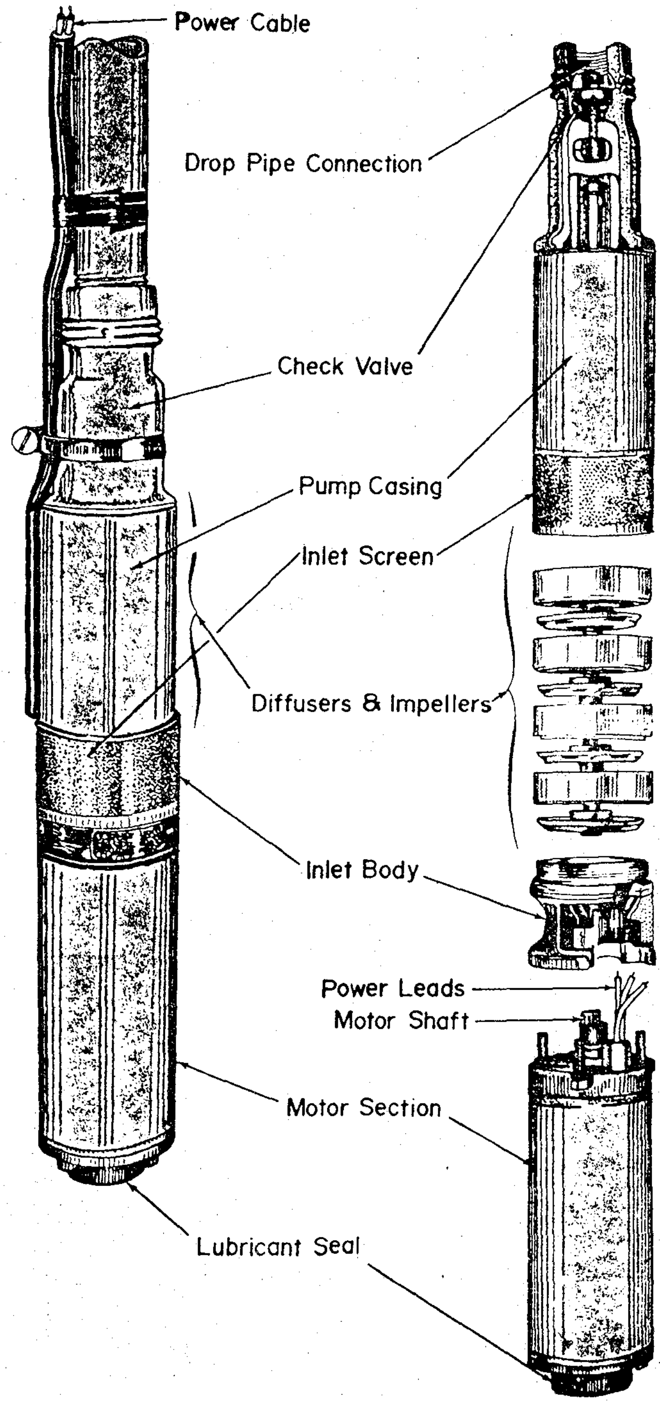
Perhaps one of the most difficult problems facing the engineer designing a rest area water supply system is the choice of type and capacity of the pump to be used in the system. There are such a variety of pumps available and so many applications, that it is often difficult to narrow the choice to one specific unit. Factors to be considered in selecting a pump for a particular well installation include the following:

1. Pump capacity.
2. Depth of well and pumping level.
3. Yield of well.
4. Inside diameter of well.
5. Condition of bore, (straight or crooked).
6. Daily needs and instantaneous demands.
7. Pressure requirements and storage tank.



Source: FHWA

FIGURE II-23. PLACEMENT DETAILS OF A SUBMERSIBLE PUMP



Source: EPA, Manual of Individual Water Supply Systems, EPA 430/9-74-007, 1974.

FIGURE II-24. EXPLODED VIEW OF SUBMERSIBLE PUMP

8. Total operating head pressure of pump at normal delivery rates, including lift and all friction losses.
9. Power requirements and availability of power at the site.
10. Characteristics of water to be pumped, particularly abrasive properties (sand), and corrosive properties.
11. Ease of maintenance and availability of dealer.
12. First cost and economy of operation.
13. Reliability and durability of pumping equipment.
14. Position of pump placement, (horizontal or vertical).

Table II-4 can be used as a guide in selecting the proper type of pump for a given situation. The table also shows advantages and disadvantages which should be considered in the pump selection process. The rate of water delivery required depends on the time of effective pump operation as related to the total water consumption between periods of pumping. Total water use should have been determined during early planning stages as discussed in Chapter 1. The period of pump operation depends upon the quantity of water on hand to meet peak demands and the storage available. When the well yield is low in comparison to peak demand requirements, an appropriate increase in the storage capacity is required.

The life of an electric drive motor will be reduced when there is excessive starting and stopping. The water system, therefore, should be designed so that the interval between starting and stopping is more than 1 minute.

One method of determining the pump capacity required to satisfy the needs of a rest area would be to count the number of fixtures planned for the site, and refer to Figure II-25. For example, a rest area with five toilets, four washbasins and three outside hose bibs has twelve fixtures. Referring to Figure II-25, twelve fixtures would require a pump capacity between 9 and 11 gallons per minute. This simple calculation does not take into account the possibility that low well capacity may limit the size of pump that should be installed. In this case, the system can be reinforced by providing additional storage to help cover

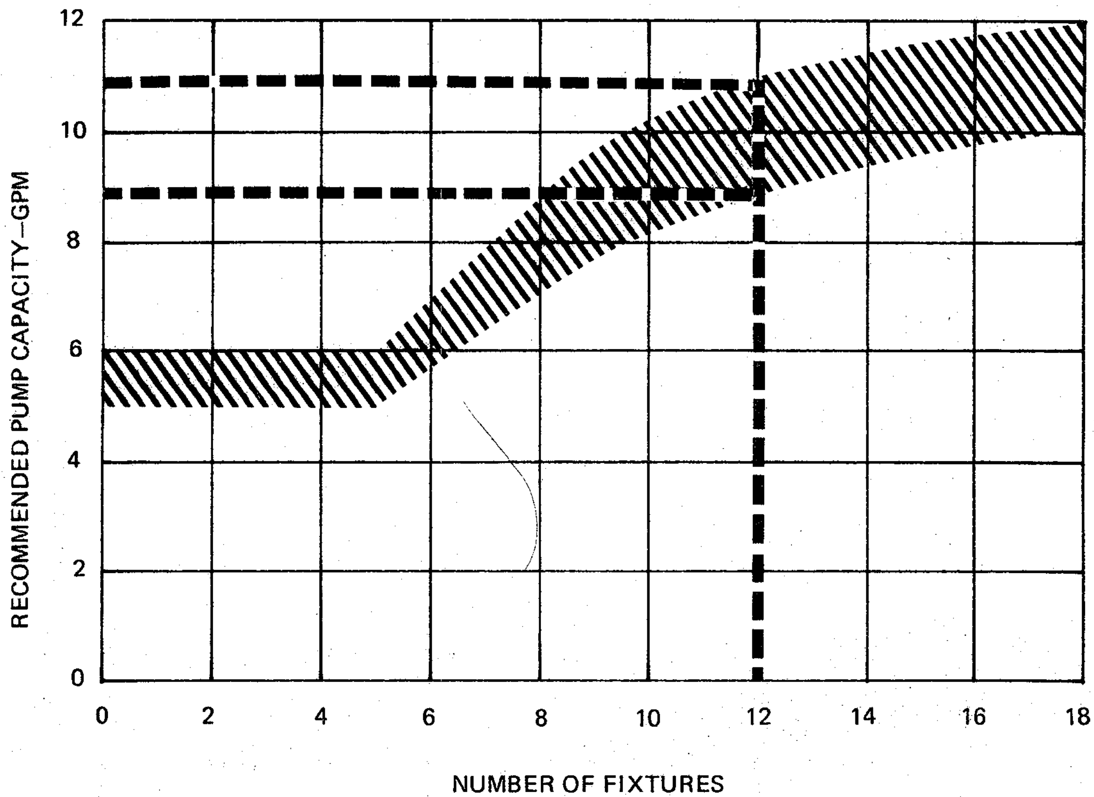
TABLE II-4. INFORMATION ON PUMPS

Type of Pump	Practical suction lift[1]	Usual well-pumping depth	Usual pressure heads	Advantages	Disadvantages	Remarks
Reciprocating:						
1. Shallow well 2. Deep well	22-25 ft. 22-25 ft.	22-25 ft. Up to 600 ft.	100-200 ft. Up to 600 ft. above cylinder.	1. Positive action. 2. Discharge against variable heads. 3. Pumps water containing sand and silt. 4. Especially adapted to low capacity and high lifts.	1. Pulsating discharge. 2. Subject to vibration and noise. 3. Maintenance cost may be high. 4. May cause destructive pressure if operated against closed valve.	1. Best suited for capacities of 5-25 gpm against moderate to high heads. 2. Adaptable to hand operation. 3. Can be installed in very small diameter wells (2" casing). 4. Pump must be set directly over well (deep well only).
Centrifugal: 1. Shallow well						
a. Straight centrifugal (single stage)	20 ft. max.	10-20 ft.	100-150 ft.	1. Smooth, even flow. 2. Pumps water containing sand and silt. 3. Pressure on system is even and free from shock. 4. Low-starting torque. 5. Usually reliable and good service life.	1. Loses prime easily. 2. Efficiency depends on operating under design heads and speed.	1. Very efficient pump for capacities above 60 gpm and heads up to about 150 ft.
b. Regenerative vane turbine type (single impeller)	28 ft. max.	28 ft.	100-200 ft.	1. Same as straight centrifugal except not suitable for pumping water containing sand or silt. 2. They are self-priming.	1. Same as straight centrifugal except maintains priming easily.	1. Reduction in pressure with increased capacity not as severe as straight centrifugal.
2. Deep well						
a. Vertical line shaft turbine (multi-stage)	Impellers submerged.	50-300 ft.	100-800 ft.	1. Same as shallow well turbine. 2. All electrical components are accessible, above ground.	1. Efficiency depends on operating under design head and speed. 2. Requires straight well large enough for turbine bowls and housing. 3. Lubrication and alignment of shaft critical. 4. Abrasion from sand.	

TABLE II-4. (Continued)

Type of Pump	Practical suction lift[1]	Usual well-pumping depth	Usual pressure heads	Advantages	Disadvantages	Remarks
b. Submersible turbine (multistage)	Pump and motor submerged.	50-400 ft.	50-400 ft.	1. Same as shallow well turbine. 2. Easy to frost-proof installation. 3. Short pump shaft to motor. 4. Quiet operation. 5. Well straightness not critical.	1. Repair to motor or pump requires pulling from well. 2. Sealing of electrical equipment from water vapor critical. 3. Abrasion from sand.	1. 3500 RPM models, while popular because of smaller diameters or greater capacities, are more vulnerable to wear and failure from sand and other causes.
Jet:						
1. Shallow well	15-20 ft. below ejector.	Up to 15-20 ft. below ejector.	80-150 ft.	1. High capacity at low heads. 2. Simple in operation. 3. Does not have to be installed over the well. 4. No moving parts in the well.	1. Capacity reduces as lift increases. 2. Air in suction or return line will stop pumping.	
2. Deep well	15-20 ft. below. ejector.	25-120 ft. 200 ft. max.	80-150 ft.	1. Same as shallow well jet. 2. Well straightness not critical.	1. Same as shallow well jet. 2. Lower efficiency, especially at greater lifts.	1. The amount of water returned to ejector increases with increased lift - 50% of total water pumped at 50-ft. lift and 75% at 100-ft. lift.
Rotary:						
1. Shallow well (gear type)	22 ft.	22 ft.	50-250 ft.	1. Positive action. 2. Discharge constant under variable heads. 3. Efficient operation.	1. Subject to rapid wear if water contains sand or silt. 2. Wear of gears reduces efficiency.	
2. Deep well (helical rotary type)	Usually submerged.	50-500 ft.	100-500 ft.	1. Same as shallow well rotary. 2. Only one moving pump device in well.	1. Same as shallow well rotary except no gear wear.	1. A cutless rubber stator increases life of pump. Flexible drive coupling has been weak point in pump. Best adapted for low capacity and high heads.

[1]Practical suction lift at sea level. Reduce lift 1 foot for each 1,000 ft. above sea level.



Source: EPA, Manual of Individual Water Supply Systems, EPA 430/9-74-007, 1974.

FIGURE II-25. DETERMINING RECOMMENDED PUMP CAPACITY periods of peak demand. (See "Storage," Chapter 3.)

After all system characteristics have been determined, the type of pump that offers suitable capacity to perform the work efficiently should be selected. Before a final choice is made, the pump specifications comparison curve for various types of pumps offered by different manufacturers should be studied.

Selection should not be determined on efficiency or price alone. All of the preceding factors should be considered, with installation and maintenance costs based on the term of anticipated use. The most economical installation is not necessarily the one with the lowest initial pump cost.

The selection of a pump for any rest area installation should be based on competent advice. Authorized factory representatives of pump manufacturers are among those best qualified to provide this service. Further information regarding pump selection, installation, etc., can be obtained by consulting the reference on pumps at the end of this chapter.

LOCATION AND PROTECTION OF PUMPING FACILITIES

The following factors should be considered in pump location and protection planning:

1. The pump head or enclosure should be designed to prevent pollution of the water by lubricants or other maintenance materials used during operation of the equipment. Pollution from hand contact, dust, rain, birds, flies, rodents or animals, and similar sources should be prevented from reaching the water chamber of the pump or the source of supply.
2. Pump base or enclosure should be designed to facilitate the installation of a sanitary well seal within the well cover or casing.
3. Pump bowl should be installed below the pumping water level in the well so that priming will not be necessary.
4. The design should provide for frost protection including pump drainage within the well.

5. The installation should be designed to facilitate necessary maintenance and repair, including overhead clearance for removing the drop pipe and other accessories.

In general, these same sanitation specifications apply to both hand and power pump installation. Specific types of installations which should be considered for various pump systems include the use of check valves, well vents, and projection from lightening.

Check Valves[1]

The only check valve between the pump and storage should be located within the well or upstream from any portion of a buried discharge line. This will assure that the discharge line will remain under positive system pressure at any point where it is in contact with soil or a potentially contaminated medium, whether or not the pump is operating. There should be no check valve at the inlet to the pressure tank or elevated storage tank. There are no special check valve location requirements which apply to a concentric piping system, with the external pipe constantly under system pressure.

Submersible and jet pumps normally have check valves installed within the well.

Well Vents

A well vent is recommended on all wells not having a packer-type jet pump. The vent prevents a partial vacuum inside the well casing as the pump lowers the water level in the well. (The packer-type jet installation cannot have a well vent, since the casing is subjected to positive pressure.) The well vent – whether built into the sanitary well cover or conducted to a point remote from the well – should be protected from mechanical damage, have watertight connections, and be resistent to corrosion.

The opening of the well vent should be located not less than 24 inches (61cm) above the highest known flood level. It should be screened with durable and corrosion-resistant materials (bronze or stainless steel no. 24 mesh) or otherwise constructed so that openings exclude insects and vermin, and should terminate in a downward direction.

Lightening Protection[1]

Voltage and current surges produced in powerlines by nearby lightening discharges constitute a serious threat to electric motors. The high voltage can easily perforate and burn the insulation between motor windings and motor frame. The submersible pump motor is somewhat more vulnerable to this kind of damage because it is submerged in ground water - the natural "ground" sought by the lightening discharge. Actual failure of the motor may be immediate, or it may be delayed for weeks or months.

There are simple lightening arresters available to protect motors and appliances from "near miss" lightening strikes. (They are seldom effective against direct hits.) The two types available are the valve type and the expulsion type. The valve type should be preferred because its "sparkover" voltage remains constant with repeated operation.

Just as important as selecting a good arrester is installing it properly. The device must be installed according to instructions from the manufacturer and connected to a good ground. In the case of submersible pumps, this good ground can be achieved by connecting the ground terminal of the arrester to the submersible pump motor frame by means of a no. 12 stranded bare cooper wire. The low resistance (1 ohm or less) reduces the voltage surge reaching the motor windings to levels that it can resist.

If steel well casing extends into the groundwater, the ground can be improved still further by also connecting the bare copper wire to the well casing. IMPORTANT NOTE. Connecting the ground terminal of the arrester to a copper rod driven into the ground does not satisfy grounding requirements. Similarly, if a steel casing that does not reach the groundwater is relied upon, the arrester may be rendered ineffective.

Additional advice on the location and installation of lightening arresters can be obtained from the power company serving the area.

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III. Storage Systems

TYPES OF STORAGE AND SELECTION CONSIDERATIONS

Storage is an essential element of a water supply system, particularly where a water source of limited yield is being used. The principal function of distribution storage is to make it possible to process the water or pump from wells at times when facilities would otherwise be idle and to distribute and store it in advance of its actual need at a single rest area or at a pair of rest areas located on opposite sides of the highway. Storage makes it possible to more nearly equalize the demands on the source of supply, stabilize system flows and pressure, and provide reserve supplies in the distribution system for emergencies.

The selection of type of storage (gravity, reservoir or hydropneumatic) depends on the amount of water to be stored, topography, economics, freezing problems and vandalism potential.

PRESSURE TANK STORAGE SYSTEMS

One of the most common types of storage used for small water supply systems is a hydropneumatic pressure tank. This system depends on air compressed in the tank to supply pressure, and as a result, has very limited water storage capacity in comparison to tank size.

For water supply systems where the peak demand may be several times the average demand, a pump-pressure tank system has the following operational disadvantages:[3]

1. The pump must be sized to meet the peak demand (including fire, if appropriate) because no significant storage is provided by the pressure tank. This increases the size and cost of the pump and motor.
2. A single pump system sized to meet the peak demand will be required to start and stop frequently during normal operations.

3. High-volume, short-duration pumping of a water source may occur and may be undesirable, particularly for wells or springs.

However, where peak water demands are close to the average demand and storage requirements are relatively small, hydropneumatic tanks are a suitable and economical system.

Figure III-1 shows the major components of a pressure storage system below ground level. The water enters the closed tank from the pump compressing air in the tank. The compressed air produces a head to force water from the tank to opened faucets until the pressure drops to 20* pounds or some other predetermined pressure at which point the pressure switch starts the pump. The pump operates until the pressure switch stops the motor at 40* pounds pressure. The air volume control is a device designed to force air into the tank on each pumping cycle to replenish the air lost by absorption through the water.

A larger volume of water can be delivered per cycle, by a pressure tank by precharging the tank with air prior to filling with water. This is accomplished with a hand-operated or motor-driven air pump. Precharging reduces the number of pumping cycles on the pump, lowering the cost of operation. A tank precharged with 20 pounds pressure will deliver 36.6 percent of the total tank capacity as compared to only 15.5 percent when the tank is filled at atmospheric pressure.

NON-PRESSURIZED STORAGE SYSTEMS

In areas where hydropneumatic systems are unable to furnish an adequate quantity of water, non-pressurized storage systems must be considered. Non-pressurized storage systems include gravity and non-elevated reservoir systems.

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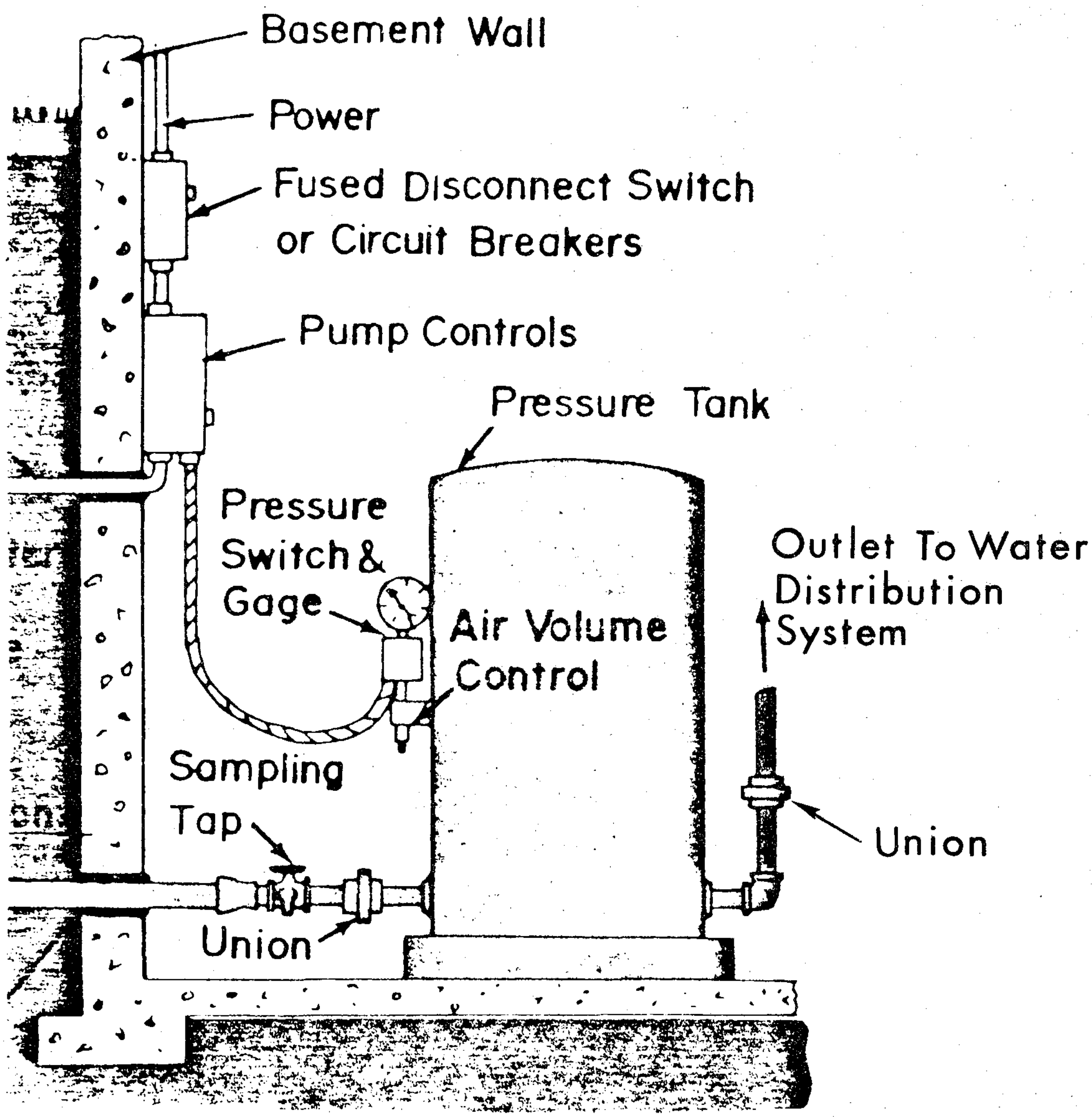
* Pressure controls may be set at different levels to accommodate systems where various facilities are at different levels, valves operating at different pressures, etc.



Source: EPA, Manual of Individual Water Supply Systems, EPA 430/9-74-007, 1974.

FIGURE III-1. PRESSURE STORAGE SYSTEM

Gravity Tanks

The most common design of a system utilizing a gravity type storage facility is one in which the storage facility "floats on the line." In other words, the pump and the storage facility are directly and separately connected to the distribution system. The pump starts and stops at pre-determined levels in the storage facility. During prolonged periods of high demand the distribution system is fed by both the pump and the storage facility. When the water level in the storage facility is above the level at which the pump automatically starts, the system is supplied from storage. By proper location of the storage facility and the pump, maximum water flow can be achieved with a minimum of friction loss. In addition it is possible to locate the storage facility on a location at higher level than the source or pump, and to thereby reduce the height of the tower or standpipe.

In hilly terrain, the tank is usually placed on a nearby hill to obtain the needed elevation naturally. In level areas, the tank must be located on a tower built especially for tank support, as shown in Figure 111-2.

Non-Elevated Reservoir Storage

Non-elevated reservoir storage tanks are either poured-concrete or large steel tanks, constructed above or below ground (Figure 31). In either case, this type of storage configuration supplies little or no pressure head.

Non-elevated storage reservoirs primarily are used when the water source provides a constant but limited flow of water, insufficient to satisfy peak demands when they occur and where it is not economical to provide elevated storage to satisfy all needs. By selecting a well pump with somewhat less capacity than the well yield, it is possible to pump over long periods of time and store the water in the reservoir system to meet peak demands.

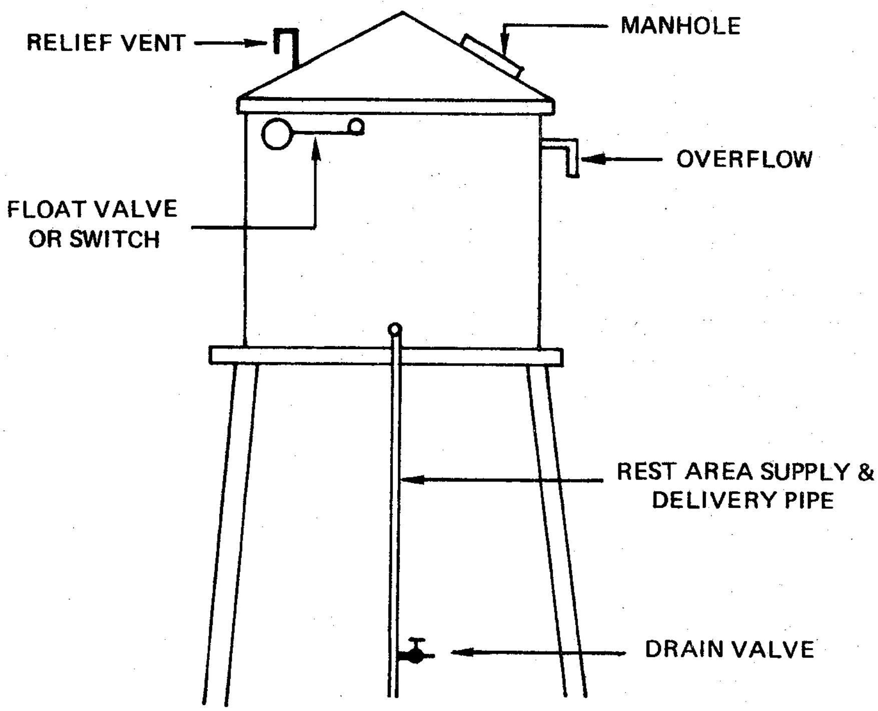


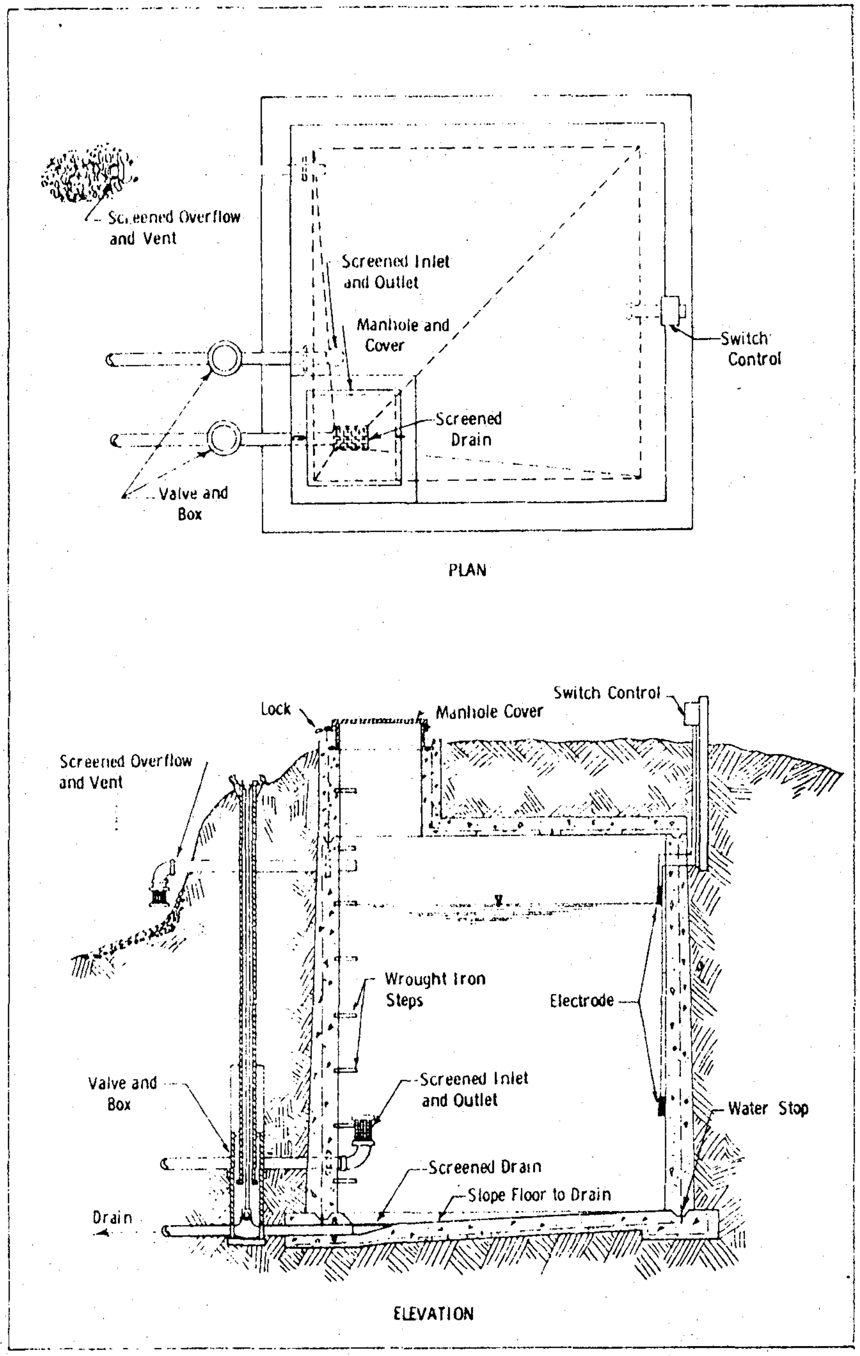
FIGURE III-2. GRAVITY STORAGE SYSTEM

With this type of arrangement, a second pump is required in order to pump water from the storage reservoir and put it under pressure. Both pumps work automatically. The well or supply pump is controlled by water-level sensors located in the storage tank and the pressure pump is controlled by a standard pressure switch.

WATER STORAGE REQUIREMENTS

HYDROPNEUMATIC TANKS

For installations such as rest areas, some knowledge of the maximum water demand and available pumping rate must be known in order to determine the size of the tank required for adequate storage. The tank plus the pump must be capable of supplying the required quantity of water during peak water demands. This can be accomplished by basing the design on pump cycles, as described below:



Source: U.S. Department of HEW, Public Health Service, <u>Environmental Health Practices in Recreation Area</u>, 1968.

FIGURE III-3. TYPICAL CONCRETE RESERVOIR

Time to Fill + Time to Empty = Cycle Time

$$\frac{V}{P-Q} + \frac{V}{Q} = \text{Cycle}$$

where:

V = Useable volume of tank (gals)
P = Pumping rate (gpm)
Q = Water demand (gpm)

Minimum cycle time will occur when:

$$Q = 1/2P$$

$$\frac{V}{P-1/2P} + \frac{V}{1/2P} = \text{Cycle Time}$$

$$\frac{2V}{P} + \frac{2V}{P} = \text{Cycle Time}$$

$$\frac{4V}{P} = \text{Cycle Time}$$

$$V = \frac{P \times \text{Cycle Time}}{4}$$

If cycle time equals 16 minutes:

$$V = \frac{P \times 16}{4}$$

$$V = 4P$$

and if useable volume of the tank is 25%.

$$\text{Gross } V = \frac{4P}{0.25}$$

$$\text{Gross } V = 16P$$

NOTE: The pumping rate must always be greater than the demand. If it is not, the mass diagram approach must be used, as previously described in Chapter 1.

NON-PRESSURIZED STORAGE SYSTEMS

Ground level or underground storage tanks should have adequate capacity based on supply-demand hydrograph design, as described in Chapter 1.

PROTECTION AND LOCATION OF STORAGE FACILITIES

LOCATION FOR PUBLIC HEALTH SAFETY

The bottom of a ground-level reservoir should be established above the groundwater table and preferably above any possible flooding. Where the bottom of the reservoir is below the normal ground surface, sewers, drains, privies, standing surface water, and similar sources of contamination should be no closer than 100 feet (30.5 m). The top of a ground-level reservoir should be not less than 2 feet (0.6 m) above the normal ground surface or any possible flood level.

PROTECTION PRINCIPALS

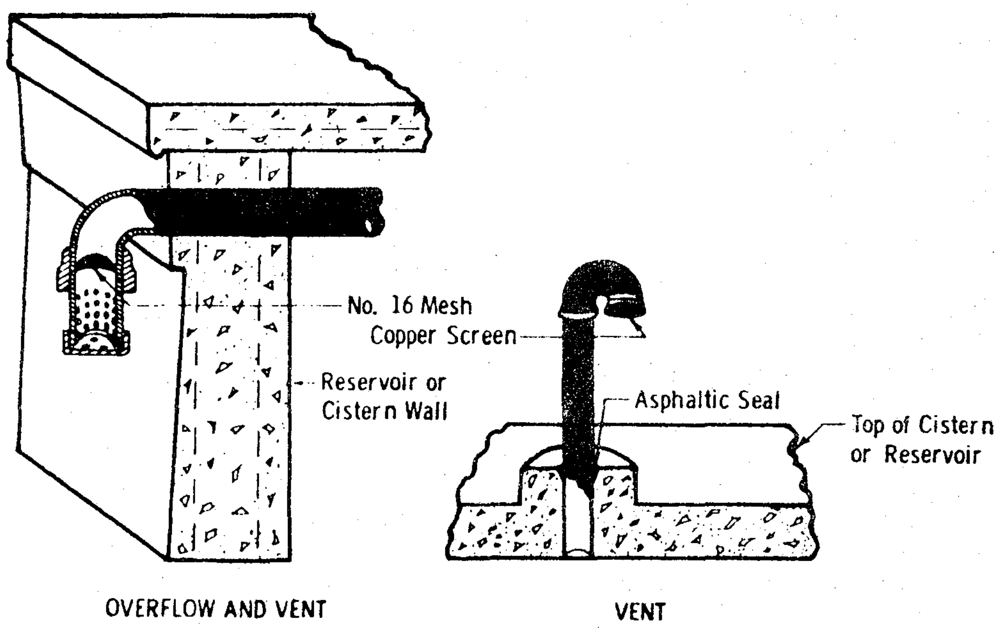
Covers and Roofs

A suitable and substantial locked cover should be provided for any reservoir, elevated tank, or other structure used for finished water storage. Covers should be watertight, made of permanent material, and constructed to drain freely and to prevent contamination from entering the stored water. The surface of a storage reservoir cover should not be used for any purpose that may result in contamination of the stored water.[1]

The roof of the structure should be well drained, but downspout pipes may not enter the reservoir or connect to the overflow. Parapets, or similar construction which would tend to hold water or snow on the roof, generally are not approved.

Vents

Any vents or openings for water-level control gauges or other purposes that project through covers on storage reservoirs and elevated tanks should be screened and constructed to prevent the entrance of dust, rain, snow, birds, insects, or other contaminants. A ground-level vent must terminate in an inverted-U construction, the opening of which is at least 24 inches (0.6 m) above the ground (Figure III-4).



Source: EPA, Manual of Individual Water Supply Systems,
EPA 430/9-74-007, 1974.

FIGURE III-4. VENT AND OVERFLOW CONFIGURATIONS

Manholes

Manholes and manhole frames (Figure III-5) used on covered storage reservoirs and elevated tanks should be fitted with raised, watertight walls projecting at least 6 inches (15.2 cm) above the level of the surrounding surface. Manholes used for ground level reservoirs in heavy snowfall areas should be elevated 24 to 36 inches (0.6 - 0.9 m). Each manhole frame should be closed with a solid watertight cover, with edges projecting downward at least 2 inches (5.1 cm) around the outside of the frame.

The manhole covers should be provided with a sturdy locking device and should be kept locked when not in use.

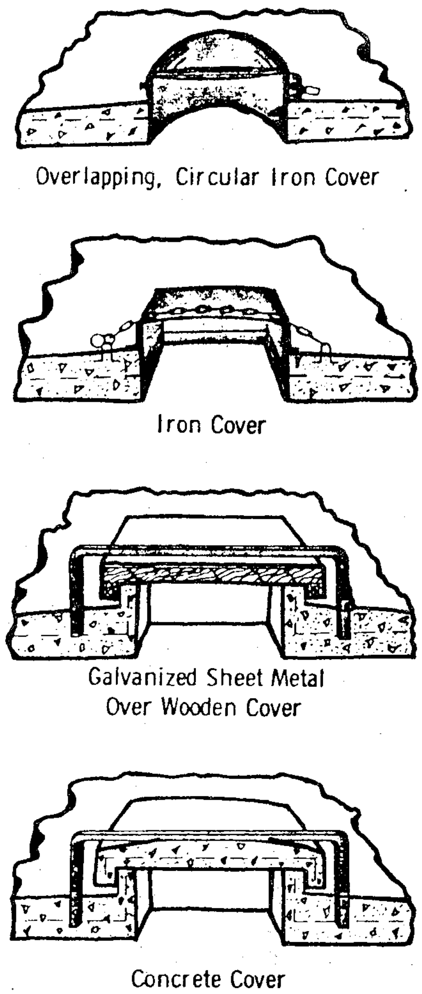
Finished water storage structures should be designed with reasonably convenient access to the interior for cleaning, maintenance and sampling.

Freezing

All finished water storage structures and their appurtenances, especially the riser pipes, overflows, and vents should be designed to prevent freezing or ice formation which will interfere with proper functioning. Consideration should be given to heating and/or insulation of exposed pipes and valves.

Pipes To and From the Storage Reservoir[7]

Any overflow, blow-off, or clean-out pipe from a storage reservoir should discharge freely into an open basin from a point not less than three diameters of the discharge pipe above the top or spill line of the open basin. All overflow, blow-off or clean-out pipes should be turned downward to prevent entrance of rain and should be screened with removable 24-mesh screen to prevent the entrance of birds, insects, rodents, and contaminating materials. If the discharge pipes are likely to be submerged by surface or flood water, a watertight blind flange should be provided to attach to the pipe opening to prevent contaminated water backflowing into the reservoir. If the reser-



Source: EPA, Manual of Individual Water Supply Systems,
EPA 430/9-74-007, 1974.

FIGURE III-5. TYPICAL MANHOLE COVERS FOR WATER STORAGE TANKS voir must be emptied when the normal outlet is submerged by surface or flood waters, pumps with outlets above the flood water should be used for emptying.

All inlet and outlet pipes of storage reservoirs should be properly supported and constructed to minimize the effects of settling, and wall castings should be provided with suitable collars to ensure watertight connections.

Drainage From Structures

The reservoir or tank should be designed so that it will drain to the ground surface in such a manner as to preclude contamination by surface water and access by animals. No direct connection normally should be made to a stormwater drain or sewer. In lieu of drains, the construction of a small sump in the bottom of the reservoir is recommended. The sump should be located directly under the manhole to enable suction line from a portable pump to be placed in sump. When emptying of the reservoir is necessary, it may be dewatered to a relatively low elevation with the regular service pumps and the remaining water discharged through the portable pump.

Pressure Tanks

Special consideration must be given to local laws relating to structural design and safety devices for pressure tanks. ASME "Code" tanks and relief valves for non-fired pressure tanks will be required by most state and local health and building codes. A tank located above the normal ground surface and completely housed to prevent freezing, or earth-mounded with one end projecting into an operating house, is deemed most satisfactory. If housed wholly or partially in a pit, the pit should be drained to the ground surface with no direct connection to a sewer. The tank itself should have a piping bypass to permit operation of the system during tank repairs, an access manhole, and a drain. Control equipment required for effective use of a hydropneumatic tank includes pressure gauge, water sight glass, automatic or manual blow-off for excess air, mechanical means for adding air, and pressure operated start-stop controls for the pumps.

Protection From Trespassers

Fencing, locks on access manholes, and other necessary precautions should be taken to prevent trespassing, vandalism, or sabotage.

PAINTING/CATHODIC PROTECTION

Proper protection from corrosion should be given to metal tanks by paints or other protective coatings, and cathodic protection provided. (American Water Works Association Tentative Standard AWWA D102, latest edition, Painting and Repainting Steel Tanks, Standpipes, Reservoirs, and Elevated Tanks, for Water Storage, contains pertinent information on painting and repainting storage reservoirs.) This standard lists several types of paint and coatings which have in general given good service. Newer coatings, not included in the above standard, should be tried only on a tentative basis and with the approval of the reviewing authority.

Cathodic Protection

Cathodic protection is one of several methods used to protect metal surfaces from corrosion. Cathodic protection can be provided either by (1) attaching a metal of higher oxidation potential to the pipe (such as aluminum or zinc) which will corrode and be sacrificed to provide desired protection, or (2) by using direct-current electricity to feed electrons into the metal to produce a negative charge so that electric currents will flow from the surrounding soil to the metal instead of the reserve. The relative behavior of different metals may be gaged by use of the Galvanic Series shown in Table III-1. As an example, lead would be anodic (corroded) if used in the presence of cooper. That is, the copper would be protected by the presence of the sacrificial lead. Cathodic protection systems should be designed by engineers familiar with such systems.

DISINFECTION

It is always necessary to disinfect a water storage system before placing it in use under the following conditions:[1]

TABLE III-1. GALVANIC SERIES OF METALS AND ALLOYS

Corroded (anodic or least noble)
Magnesium
Zinc
Aluminum (commercially pure)
Steel or Iron
Cast Iron
Lead
Tin
Brasses
Copper
Bronzes
Protected (cathodic or most noble)
Chromium-Iron (passive)

1. Disinfection of a system that has been in service with raw or polluted water, preparatory to transferring the service to treated water.
2. Disinfection of a new system upon completion and preparatory to placing in operation with treated water or water of satisfactory quality.
3. Disinfection of a system after completion of maintenance and repair operations.

The entire system, including tank or standpipe, should be thoroughly flushed with water to remove any sediment that may have collected during operation with raw water or during repairs. Following flushing, the system should be filled with a disinfecting solution containing at least 100 mg/l of available chlorine, as used in disinfecting a well. This solution is prepared by adding 1.2 pounds of high-test 70 percent calcium hypochlorite to each 1,000 gallons of water, or by adding 2 gallons of ordinary 5% strength liquid bleach to each 1,000 gallons of water. A mixture of this kind provides a solution having not less than 100 mg/l of available chlorine.

The disinfectant should be retained in the system, tank, or standpipe, if included, for not less than 24 hours, then tested for residual chlorine and drained out. If no residual chlorine is found, the process should be repeated. The system is next flushed with treated water and put into operation.

IV. TREATMENT

GENERAL

The need, methods, and procedures for treatment of well, spring or surface supplies depends upon the physical, chemical, radiological, and bacteriological characteristics of the raw water. The water should contain no chemical or physical impurities which make it unsafe for human consumption or render it offensive to the senses of sight, taste, or smell. Water which is not appealing to the consumer may prompt him to turn to some other, unsafe source of water. Water should not be excessively corrosive to water mains or rest area plumbing, nor should it have hardness characteristics that would result in scale formation in pipes and hot water heaters.

As discussed in an earlier chapter, most groundwater is clear, cool, colorless and quite uniform in character. Although underground supplies are generally of better bacterial quality than surface sources, groundwater may be more highly mineralized and may require some treatment. Most surface sources, on the other hand, require chemical coagulation, sedimentation, filtration and disinfection to make them suitable for drinking water supplies.

Regardless of source, drinking water should conform to the state, local, or National Primary Drinking Water Regulations (NPDWR) - whichever is most stringent and should be disinfected before use. Water not conforming to these standards can, in many cases, be treated to reduce the concentration of objectionable substances to within allowable limits. Table IV-1 lists contaminants for which maximum concentration limits have been set under the NPDWR, and the various treatment processes available to remove each contaminant. Treatment techniques applicable to rest areas are discussed in subsequent sections of this chapter. Further information on other treatment methods may be found by consulting the reference list at the end of the chapter.

Local circumstances and the characteristics fo each water supply govern the treatment required and the design of the plant needed

TABLE IV-1

DRINKING WATER CONTAMINANTS FOR WHICH MAXIMUM CONCENTRATIONS HAVE BEEN SET* AND AVAILABLE TREATMENTS

INORGANIC	
Contaminant	Treatment Methods
Arsenic:	
As^{+3}	Ferric sulfate coagulation, pH 6-8 Alum coagulation, pH 6-7 Excess lime softening Oxidation before treatment required
As^{+5}	Ferric sulfate coagulation, pH 6-8 Alum coagulation, pH 6-7 Excess lime softening
Barium	Lime softening, pH 10-11 Ion exchange
Cd^{+3}	Ferric sulfate coagulation, above, pH 8 Lime softening Excess lime softening
Chromium:	
Cr^{+3}	Ferric sulfate coagulation, pH 6-9 Alum coagulation, pH 7-9 Excess lime softening
Cr^{+6}	Ferrous sulfate coagulation, pH 7-9.5
Fluoride	Ion exchange with activated alumina or bone char media
Lead	Ferric sulfate coagulation, pH 6-9 Alum coagulation, pH 6-9 Lime softening Excess lime softening
Mercury:	
Inorganic	Ferric sulfate coagulation, pH 7-8
Organic	Granular activated carbon
Nitrate	Ion exchange
Selenium:	
Se^{+4}	Ferric sulfate coagulation, pH 6-7 Ion exchange Reverse osmosis
Se^{+6}	Ion exchange Reverse osmosis
Silver	Ferric sulfate coagulation, pH 7-9 Alum coagulation, pH 6-8 Lime softening Excess lime softening

* National Primary Drinking Water Regulations (NPDWR).

TABLE IV-1

DRINKING WATER CONTAMINANTS FOR WHICH MAXIMUM CONCENTRATIONS HAVE BEEN SET* AND AVAILABLE TREATMENTS (Continued)

Contaminant	Treatment Methods
ORGANIC	
Endrin	Coagulation and Filtration followed by Activated Carbon Adsorption
Lindane	Coagulation and Filtration followed by Activated Carbon Adsorption
Toxaphene	Coagulation and Filtration followed by Activated Carbon Adsorption
2, 4-D	Coagulation and Filtration followed by Activated Carbon Adsorption
2, 4, 5-TP	Coagulation and Filtration followed by Activated Carbon Adsorption
Methoxychlor	Coagulation and Filtration followed by Activated Carbon Adsorption
OTHER	
Turbidity	Granular media filtration Diatomaceous earth filtration
Microbiological	Chlorination Ozonation Chlorine dioxide Ultraviolet irradiation Iodination
RADIOACTIVE	
Alpha Emitters (Radium-226, 228, and Gross α - Activity)	Lime or Lime-soda softening Ion exchange softening Reverse osmosis
Beta and Photon Emitters**	Reverse osmosis Lime softening Ion exchange

** Treatment for each Radioisotope must be considered separately.

to assure that the water will consistently meet drinking water standards for bacteriological, physical, chemical, and radiological qualities.

It is highly recommended that appropriate state agencies are kept informed of plans for treatment systems at rest areas, since some processes and equipment may be unacceptable in certain states. In addition, some agencies may be able to provide useful information regarding treatment of unique or local water quality problems.

NATIONAL PRIMARY DRINKING WATER REGULATIONS

National Primary Drinking Water Regulations established maximum contaminant levels (MCL's) for 10 inorganic contaminants, turbidity, coliform organisms, 6 pesticides, and radionuclides. However, not all of these MCL's are required for safety rest areas under federal law, but may be required under some state and local regulations.

Tables IV-2 and IV-3 show the established MCL's for the inorganic chemicals limited by the NPDWR, and Table IV-4 lists the MCL's for organic chemicals. Maximum contaminant levels and corresponding treatment for coliform organisms, nitrate, and turbidity are discussed in a later section of this chapter (pages IV-7 through IV-14), since these contaminants must be observed at rest areas.

The NPDWR established MCL's for two categories of radioactive contaminants - alpha emitters, and beta and photon emitters. The MCL's for alpha emitters are 5pCi/l for combined radium -226 and radium -228, and 15pCi/l for gross alpha activity including radium -226, but excluding radon and uranium.

For beta and photon radioactivity from man-made radionuclides, the average annual concentration in drinking water must not produce an annual dose equivalent to the total body or any internal organ greater than 4 millirem/year.

Except for the radionuclides listed in Table IV-5, the concentration of man-made radionuclides causing 4 millirem total body or organ dose equivalents must be calculated on the basis of a 2 liter per day

TABLE IV-2. MAXIMUM CONTAMINANT LEVELS (MCL's) FOR INORGANIC CONTAMINANTS EXCEPT FLUORIDE

Contaminant	MCL, (mg/l)
Arsenic	0.05
Barium	1.
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10
Selenium	0.01
Silver	0.05

Source: Federal Register, Vol. 40, No. 248, Dec 24, 1975, pp 59570

TABLE IV-3. MAXIMUM CONTAMINANT LEVEL (MCL)[a] FOR FLUORIDE

Temperature		MCL, (mg/l)
°F	°C	
53.7 and below	12.0 and below	2.4
53.8 to 58.3	12.1 to 14.6	2.2
58.4 to 63.8	14.7 to 17.6	2.0
63.9 to 70.6	17.7 to 21.4	1.8
70.7 to 79.2	21.5 to 26.2	1.6
79.3 to 90.5	26.3 to 32.5	1.4

[a]Determined by the annual average of the maximum daily air temperature for the location in which the community water system is situated.

Source: Federal Register, Vol. 40, No. 248, Dec 24, 1975, pp 59570.

TABLE IV-4
MAXIMUM CONTAMINANT LEVELS (MCL'S)
FOR ORGANIC CHEMICALS

Contaminant	MCL, (mg/l)
Chlorinated hydrocarbons:	
Endrin (1,2,3,4,10, 10-hexachloro-6,7-epoxy-1,4 4a,5,6,7,8,8a-octa-hydro-1,4-endo, endo-5,8 - di-methane naphthalene).	0.0002
Lindane (1,2,3,4,5,6-hexachloro-cyclohexane, gamma isomer).	0.004
Methoxychlor (1,1,1-Trichloro-2,2 - bis [p-methoxphenyl] ethane).	0.1
Toxaphene ($C_{10}H_{10}Cl_8$-Technical chlorinated camphene, 67-69 percent chlorine).	0.005
Chlorophenoxys:	
2,4-D, (2,4-Dichlorophenoxyacetic acid).	0.1
2,4,5-TP Silvex (2,4,5-Trichloropheno-oxypropionic acid).	0.01

Source: Federal Register, Vol. 40, No. 248, Dec 24, 1975, pp 59570-1.

TABLE IV-5
AVERAGE ANNUAL CONCENTRATIONS ASSUMED TO PRODUCE
A TOTAL BODY OR ORGAN DOSE OF 4 MREM/YR

Radionnclide	Critical Organ	pCi Per Liter
Tritium	Total body	20,000
Strontium-90	Bone marrow	8

Source: Federal Register, Vol. 41, No. 133, Jul 9, 1976, pp 28404.

drinking water intake, using the 168 hour data listed in "Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure," NBS Handbook 69 as amended August 1963, U.S. Department of Commerce.* If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ should not exceed 4 millirem/year.

PROPOSED NATIONAL SECONDARY DRINKING WATER REGULATIONS

While primary regulations are devoted to constituents and regulations affecting the health of consumers, secondary regulations are those which deal with the aesthetic qualities of drinking water. Secondary contaminant levels may not have a significant direct impact on the health of consumers, but the presence of these contaminants in excessive quantities may discourage the utilization of a drinking water supply by the public.

Primary drinking water regulations are applicable to all public water systems and are enforceable by EPA or the states which have accepted primacy**; secondary regulations are not federally enforceable and are intended as guidelines for the states.

Table IV-6 presents the proposed secondary MCL's which are recommended for compliance by all public water systems.

DRINKING WATER REGULATIONS APPLICABLE TO SAFETY REST AREAS

Under the Safe Drinking Water Act, safety rest areas which regularly provide their own water supply to an average of at least 25 individuals per day for at least 60 days a year, or which have at least 15 service connections are considered "public water systems." Furthermore, the new regulations have created two categories of public water supply systems: those serving year-round residents (community water systems), and those serving intermittent or transient users (non-community water systems).

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* Available from: NTIS Superintendent of Documents.

** States with "primacy" are those which have applied to EPA and subsequently received approval for primary enforcement responsibility under the Safe Drinking Water Act.

TABLE IV-6. MAXIMUM CONTAMINANT LEVELS (MCL'S) UNDER PROPOSED SECONDARY REGULATIONS

CONTAMINANT	LEVEL
Chloride	250 mg/l
Color	15 Color Units
Copper	1 mg/l
Corrosivity	Non-corrosive
Foaming Agents	0.5 mg/l
Hydrogen Sulfide	0.05 mg/l
Iron	0.3 mg/l
Manganese	0.05 mg/l
Odor	3 Threshold Odor Number
pH	6.5 - 8.5
Sulfate	250 mg/l
TDS	500 mg/l
Zinc	5 mg/l

Source: Federal Register, March 31, 1977, pp 17146.

As now stated, the regulations define a community system as "a public system which serves at least 15 service connection or regularly serves at least 25 residents throughout the year." Non-community systems are basically those systems serving transients-that is, all public systems which are not considered community water systems.

Because most safety rest areas are used principally by transients, they generally are considered non-community water systems. The NPDWR require only the observation of maximum contaminant levels for nitrates, turbidity, and microorganisms. The observation of maximum contaminant levels for all other organic and inorganic chemicals and radionuclides is not required, since these contaminant levels are based on the potential health effects for long-term exposure. However, it should be recognized that the NPDWR require all states to have regulations and standards equally stringent as the NPDWR. As such, the National Regulations are considered to be minimum requirements for acceptable water quality. In some states, highway departments will be required to observe National Secondary Drinking Water Regulations and/or maximum contaminant levels for more substances than required by the National Primary regulations.

The following sections are a discussion of contaminants which must be observed at rest area water supplies, as designated by the NPDWR.

Microbiological Contamination

The allowable coliform count depends on the analytical technique used and the sample size, as follows:

- Membrane filter technique - Coliforms not to exceed 1/100 ml as the arithmetic mean of all samples examined per month, and not to exceed either:
  - 4 coliforms/100 ml in more than one sample (when less than 20 samples per month) or
  - 4 coliforms/100 ml in more than 5 percent of the samples (when 20 or more samples taken per month)

- Fermentation tube method - (10-ml portions or 100-ml portions)

  10-ml portions - coliforms not to be present in more than 10 percent of portions in any month, in either:

  . 3 or more portions in one sample (when less than 20 samples are taken per month)

  . 3 or more portions in more than 5 percent of the samples (when 20 or more samples/month are taken)

  100-ml portions - coliforms not to be present in more than 60 percent of portions in any month, and in either:

  . 5 or more portions in more than one sample (when less than 5 samples are taken)

  . 5 or more portions in more than 20 percent of the samples (when 5 or more samples taken)

Analyses must be conducted in accordance with the analytical recommendations set forth in Standard Methods for the Examination of Water and Wastewater, American Public Health Association, 14th Edition, 1975, (or the current edition) except that a standard sample size must be employed.

Bacteria are present in all surface waters, even in uninhabited areas. In addition, the number of bacteria increases immediately following a heavy rain, the result of contaminated surface runoff. On the other hand, groundwaters from properly located, constructed, and maintained wells generally contain few bacteria, and rarely are contaminated with coliform organisms.

The presence of coliform organisms in wells receiving water from geologic formations that afford good filtration can indicate:

- Entrance of contamination through a faulty pump seal, improperly sealed annular space around the well, or similar deficiencies

- Contamination introduced by repair or maintenance operations
- Contamination through cross-connections
- Contamination during sampling
- Improper disinfection of well following drilling operations

Wells which penetrate stratified, widely jointed, cracked or cavernous rock formations usually are sealed through these strata to prevent the entrance of any potentially contaminated water. Where such rock formations are used as a source of water, disinfection may be necessary. Also, lower bacterial counts should be evident in deep wells which are relatively isolated from surface contaminants.

Disinfection systems which are effective in destroying coliforms bacteria include chlorination, iodination, ultraviolet irradiation, and reverse osmosis.* All of these treatment processes are discussed in later sections of this manual.

Nitrates

Because of the known adverse health effect of nitrates, the EPA set maximum contaminant levels for all water supplies at 10 mg/l as nitrogen (or the equivalent of 45 mg/l as NO_3^-). Ingestion by infants of nitrates in concentrations greater than this may subject them to methemoglobinemia (or "blue baby" disease) which is most likely to occur in infants less than three months old. The disease reduces the blood's capacity to transport oxygen from the lungs to the tissues and literally results in suffocation. Breast-fed infants of mothers drinking such waters may also be affected in the same way. If the nitrate concentration is high enough, even adults can be poisoned, although this condition is rare.

*Although reverse osmosis is not principally a method of disinfection, the process does remove a significant quantity of bacteria, where used under proper operating conditions.

The existance of a nitrate problem at rest areas can be determined only on an individual basis by a nitrate analysis of the water supply. The pattern of occurrence and concentrations of nitrates and other nitrogen compounds in groundwater is one of the least understood problems encountered in water sanitation. High nitrate concentrations have been found in ground waters which may be affected by waste discharges and agricultural practices, and in deep aquifers far removed from any known source of pollution.[8]

The removal of nitrates from a drinking water supply is sometimes not only a difficult problem but also an economic problem for small scale water supplies. Among the known methods of nitrate reduction are ion exchange, microbial denitrification, ammonia stripping and demineralization (distillation, reverse osmosis or electrodiasis) all of which are rather expensive processes.

When high nitrates are encountered in a safety rest area well water supply, a study should be made to determine whether the well can be sealed off from the nitrate-bearing strata, and the well deepened to an equifer where nitrate levels are acceptable. It is commonly known that nitrates are most prevalent in shallow groundwaters. At the same time, a survey to locate the source of the nitrates may be justified. This may reveal manure piles, other organic, or subsurface sewage disposal systems which are contributing the nitrates to the well.

<u>Turbidity</u>

The Maximum Allowable Contaminant Level

1 Nephelometric Turbidity Unit (NTU)* as determined by a monthly average or 5 NTU based on an average for 2 consecutive days. Five or fewer turbidity units may be allowed (with state approval) if the higher turbidity does not:

- Interfere with disinfection

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* Analysis using the Nephelometric Method is described in <u>Standard Methods for the Examination of Water and Wastewater</u>, APHA, 14th Edition, 1975.

- Interfere with microbiological determinations, and
- Prevent maintenance of an effective disinfection agent throughout the distribution system (as determined by testing for residual in the system).

Turbidity can be caused by a wide variety of inorganic as well as organic substances, ranging in size from colloidal to coarse dispersions. In a well or spring, turbidity often indicates inadequate protection from surface runoff and possible bacterial contamination. Turbidity in drilled wells may be caused by improper construction, the presence of iron, microscopic cell growth, or as a result of failure to cement-grout the space between drill hole and casing. Turbidity in rivers often can be traced to runoff from agricultural operations, heavy rains that disturb the soil, and domestic and industrial wastes. Organic materials that reach rivers and impoundments serve as nutrients for algae and other plant and microbial organism growth that subsequently produces additional turbidity.

Turbidity limits have not been set for groundwater supplies, since turbidity is not usually a problem in properly developed wells. In some cases, fine sand may be included in pumped groundwater, or iron may preciptate, resulting in turbidity. But these situations are not considered to be health hazards. On the other hand, in some fractured or jointed geologic formations (particularly cavernous limestone) turbidity may be a problem due to the water's short retention time in an aquifer. In these cases the EPA suggests that states either require treatment of groundwaters or set maximum turbidity limits. Hence, the possibility that some states will require turbidity limits for certain groundwater supplies cannot be ruled out.

Aside from the possible effect of turbidity on disinfection effectiveness, turbidity is also an important aesthetic consideration at rest areas. Although up to 5 turbidity units may be allowed in some water supplies, the general public associates turbidity with possible pollution and health hazards. Consequently, people often will not accept turbid water. In cases where water supplies (ground or surface) are not aesthetically acceptable, consumers may ignore safe domestic supplies and use waters from uncontrolled sources which may be contaminated.

Turbidity can readily be controlled by proper coagulation and filtration. There are several types of filtration systems which could suffice - For example, rapid-sand or diatomaceous earth filtration. Because of the wide variation in substances causing turbidity, each problem area must be analyzed individually to select the most appropriate equipment.

DISINFECTION

GENERAL

All rest area water supplies, whether they be groundwater or surface water should receive treatment by disinfection regardless of the quality of the water. The benefits from the added protection provided by disinfection far outweigh the increased cost and the added maintenance incurred by the state highway department.

Water disinfection processes involve specialized treatment for the destruction of harmful and otherwise objectionable organisms. Disinfection processes are employed for the purpose of destroying or inactivating disease-producing (pathogenic) organisms. The survival of such organisms depends upon such factors as temperature, environmental, physiological, and morphological factors, including pH, oxygen, and nutrient supply dilution; competition with other organisms; resistance to toxic influences; ability to form spores; and others.

In addition to destroying pathogenic organisms, many nuisance organisms of aesthetic and economic significance, both plant and animal, are sometimes vulnerable to disinfection and can be partially or completely controlled by suitable treatment. Insofar as disinfection is concerned, the factors affecting the survival of these organisms in water include the organisms' natural resistance or imposed resistance (e.g., encasement in algae, suspended material, tubercules, etc.) to the disinfectants.

The major factors influencing the efficiency of disinfection and, consequently, the kind of process employed in water treatment, include:

1) Kind and concentration of organisms to be destroyed
2) Kind and concentration of disinfectant
3) Contact time provided
4) Chemical character and temperature of the water to be treated.

The process of disinfection can be accomplished using various chemical and nonchemical methods. The mechanism of destruction and rate of disinfection of the various methods will not be discussed in detail in the following sections since this material is beyond the scope of this manual. Details of this nature can be found by consulting the reference list at the end of this chapter.

Principal methods of chemical disinfection which have application to rest areas include chlorination and iodination. Nonchemical methods for disinfection include the direct application of thermal energy, ultraviolet-, gamma-, X-, and microwave irradiation. Except for ultraviolet irradiation, nonchemical techniques have limited application in the field of water treatment (particularly for small systems, such as rest areas), and therefore will not be covered in this manual.

DISINFECTION BY CHLORINE AND ITS DERIVATIVES

Chlorination is the oldest and most common method of disinfection used for drinking water in the United States. Depending upon pH and chemical characteristics of the water, the following substances may be formed when chlorine is added to the water supply:

- Free available chlorine, which in its most active state is hypochlorous acid (HOCl).
- Combined available chlorine, consisting of monochloramine (NH_2Cl), dichloramine ($NHCl_2$), and (rarely) nitrogen trichloride (NCl_3).

Each of these chlorine compounds exists in the water supply under different conditions. But more significantly, the species differ in their relative disinfecting powers as well as their ability to provide lasting residual protection. A thorough understanding of chlorine chemistry is important in designing even a small-scale chlorination systems for drinking water supplies. It is important to recognize the concept of 'free residual chlorine' and the test procedures for distinguishing between chloramines and other 'combined chlorine residuals' and 'free residual chlorine.'

Advantages and Disadvantages of Chlorination

Three of the most obvious advantages to chlorine as a disinfectant are (1) chlorine residual provides continuous protection of the water supply as long as it remains in the water, (2) chlorine residual can be readily measured using a simple test kit, and (3) chlorine is a relatively inexpensive disinfection method for small water supply systems. Another advantage is that chlorine can be used to oxidize sulfur, iron, manganese, and cyanide as well as remove certain tastes and odors. From the standpoint of equipment, hypochlorinators are generally easy to operate and fairly reliable as well. Gas chlorinators are more complicated than hypochlorinators and are not always suitable for rest areas.

The more important disadvantages to using chlorine as a disinfectant are:

- Excessive residual chlorine in the water supply often results in a noticeable taste and odor.
- If the water has not been adequately pretreated before chlorination, some organic substances may result in health hazards, as well as produce objectionable tastes and odors. (The reference by Symons, and EPA publication 570/9-76-003 listed at the end of this chapter should be consulted with regard to the occurance and control of chlorinated organics).
- When chlorine gas is used, a number of precautions and safety devices are required for safe storage and handling of chlorine. See pages IV-27 and 28 of this manual or consult the AWWA and Chlorine Institute references for details on safety measures and OSHA requirements.

Forms of Chlorine

Sources of chlorine used in water treatment include liquified chlorine gas*, sodium hypochlorite, calcium hypochlorite, and chlorine dioxide. Table IV-7 shows various commerically available chlorine products and their corresponding percent available chlorine. Although chlorine dioxide has some advantages over other forms of chlorine, it is not suitable for rest areas, principally due to its high cost.

LIQUIFIED CHLORINE GAS. Liquified chlorine gas is shipped in steel cylinders having capacities ranging from 150 to 500 lbs. It is also available in one ton cylinders. Chlorine as a liquid is usually better than 99.5 percent pure, a fact that makes the liquid form particularly desirable. Liquified chlorine gas is fed into a water supply using gas chlorinator equipment, as later discussed in this chapter.

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* The term "liquified chlorine gas" should not be confused with liquid hypochlorite, laundry bleach. Liquified chlorine gas pertains to the compressed chlorine gas stored in a steel cylinder.

TABLE IV-7
PREPARATION OF 1% CHLORINE SOLUTION
FROM VARIOUS CHLORINE PRODUCTS

Product	Form	% Available Chlorine	Amount required to make 1% chlorine solution when diluted to 1 gallon*
Purex Clorox Hypro White Magic Nubora SaniClor White Rose Master X	Solution	3% and 5%	5 cups + 6 tablespoons 3 cups + 4 tablespoons
Clor	Solution	15%	1 cup + 4 teaspoons
Diversol	Powder	3%	3 pounds
HTH-15	Powder	15%	10 ounces
Chlorinated lime	Powder	25%	6 ounces (fresh powder)
B-K	Powder	50%	3 ounces
HTH-70	Powder	70%	2 ounces
Perchloron	Powder	70%	2 ounces

*Note: As the available chlorine in any of these products is subject to change by the manufacturer, the strength given on the label should always be checked before using. If it has been changed from the strength given here, adjust the dilution accordingly.

Source: Oregon State Board of Health, Planning and Protection of Rural Water, 1971.

CALCIUM HYPOCHLORITE. Calcium hypochlorite may contain 65 to 70 percent available chlorine. It is in the form of a stable, free flowing white powder readily soluable in water, forming solutions that are quite stable. Calcium hypochlorite solutions should be dissolved or mixed with water and allowed to settle. After a satisfactory settling time the clear liquid should be syphoned or drawn off into the solution container from which the feeder (hypochlorinator or metering pump) takes suction. This method of handling prevents the calcium deposits from clogging the feeder.

One of the advantages of calcium hypochlorite is its shelf life. Under cool and dry storage conditions, calcium hypochlorite will lose only 3 to 5 percent of its available chlorine in a year-long period. However, calcium hypochlorite is not used quite as commonly for water disinfection as sodium hypochlorite because of its high price, the necessity for on-site mixing equipment, and residual sediment from the powder.

SODIUM HYPOCHLORITE. Largely beause it is much easier to handle, sodium hypochlorite (household bleach, swimming pool chlorine) has gained favor over calcium hypochlorite as a source of chlorine in small treatment plants. Sodium hypochlorite is a liquid generally containing between 12 and 15 percent available chlorine. It is usually shipped in gallon plastic containers, however, larger carboys are available and less expensive. Considering the amount of chlorine available this compound may be slightly more expensive than the calcium hypochlorites. However, since the material is already a solution and there are no solids to clog the feeder, sodium hypochlorite is quite commonly preferred.

On-site generation of sodium hypochlorite using salt is possible, but generally not economical for small water supply systems such as those found in rest areas.

Types of Chlorination Equipment

Although the most commonly used form of chlorine for larger water supply systems is the gaseous form, it is not generally used in small water supply systems. Hypochlorinators not only are less expensive, but also are more simple to operate. In addition, gas chlorinator installations require special enclosures separate from other rest area facilities, ventilating systems, gas masks, and other facilities not required with hypochlorinators. In smaller plants, chlorine if fed into the system through noncorrosive piping in the form of a solution, either as sodium or calcium hypochlorite, by means of chemical proportioning pumps.

HYPOCHLORINATORS. Hypochlorinators pump or inject hypochlorite solutions into the water. Types of hypochlorinators include positive displacement feeders, aspirator feeders, suction feeders, and tablet hypochlorinators. Figure IV-1 shows a typical hypochlorinator installation connected to a well pump.

POSITIVE DISPLACEMENT FEEDERS. A common type of positive displacement hypochlorinator is one that uses a piston or diaphragm pump to inject the solution. This type of equipment, which is adjustable during operation, can be designed to give reliable and accurate feed rates. The stopping and starting of the hypochlorinator can be synchronized with the pumping unit. A positive displacement feeder can be used with any water system; however, it is especially desirable in systems where water pressure is low and fluctuating.

It is advisable to precede the hypochlorinator with a Y-strainer or similar type in-line filter to trap small particles which easily enter the chlorinator working mechanisms and cause operational failures. It is also desirable to arrange the hypochlorite solution container so as to provide a positive head on the feeder, to thereby avoid any possibility of air-locks or "loosing prime."

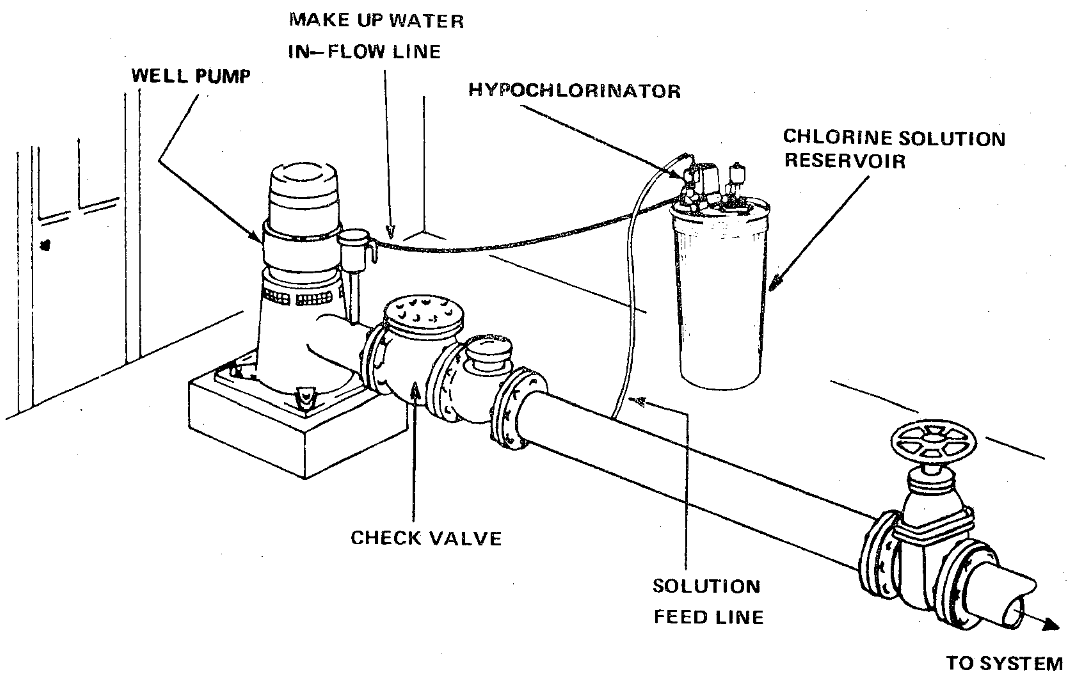

FIGURE IV-1. CHLORINATED WATER SUPPLY SYSTEM

In addition, the outlet from the hypochlorite reservoir should be an inch or two above the bottom to permit an accumulation of sediment below the outlet. Where the hypochlorinator feeds directly into the water supply pump discharge line, of course, the positive displacement pump must have the ability to operate against the maximum head anticipated in the system.

The positive displacement feeder is a precision instrument requiring regular operator checks and periodic maintenance as described in Chapter 7 of this manual.

ASPIRATOR FEEDERS.[1] The aspirator feeder operates on a simple hydraulic principle that employs the use of the vacuum created when water flows either through a venturi tube or perpendicular to a nozzle. The vacuum created draws the chlorine solution from a container into the chlorinator unit where it is mixed with water passing through the unit, and the solution is then injected into the water system. In most cases, the water inlet line to the chlorinator is connected to receive water from the discharge side of the water pump, with the chlorine solution being injected back into the suction side of the same pump. The chlorinator operates only when the pump is operating. Solution flow rate is regulated by means of a control valve, though pressure variations may cause changes in the feed rate.

SUCTION FEEDERS.[1] One type of suction feeder consists of a single line that runs from the chlorine solution container through the chlorinator unit and connects to the suction side of the pump. The chlorine solution is pulled from the container by suction created by the operating water pump.

Another type of suction feeder operates on the siphon principle, with the chlorine solution being introduced directly into the well. This type also consists of a single line, but the line terminates in the well below the water surface instead of the influent side of the water pump. When the pump is operating, the chlorinator is activated so that a valve is opened and the chlorine solution is passed into the well.

In each of these units, the solution flow rate is regulated by means of a control valve and the chlorinators operate only when the pump is operating. The pump circuit should be connected to a liquid level control so that the water supply pump operation is interrupted when the chlorine solution is exhausted. When the disinfectant is introduced at the suction side of the pump, a device or method should be provided to prevent air lock of the pump.

TABLET HYPOCHLORINATORS.[1] The tablet hypochlorinating unit consists of a special pot feeder containing calcium hypochlorite tablets. Accurately controlled by means of a flowmeter, small jets of feed water are injected into the lower portion of the tablet bed. The slow dissolution of the tablets provides a continuous source of fresh hypochlorite solution. This unit controls the chlorine solution. This type of chlorinator is used when electircity is not available, but requires adequate maintenance for efficient operation. It can operate where the water pressure is low.

GASEOUS FEED CHLORINATORS. In installations where large quantities of water are treated, chlorine gas in pressure cylinders may be used as the disinfectant.[1]

In the safest gas chlorinator systems, the chlorine gas is ejected into the water supply line through a diffuser that causes a partial vacuum to act on the chlorine regulator device on the chlorine cylinder. If that vacuum is interrupted, the chlorinator shuts down.

Figure IV-2 shows a gas chlorinator with such a diffuser system. The high cost of this type of chlorination equipment and the safety precautions necessary to guard against accidents, justifies its use only at rest areas where water demands are too great to use hypochlorinators economically, or where no power source is available to operate hypochlorinator feeders.

Chlorine Dosage

As with many other disinfection methods, chlorination is restricted in its effectiveness if the water is not relatively clear,

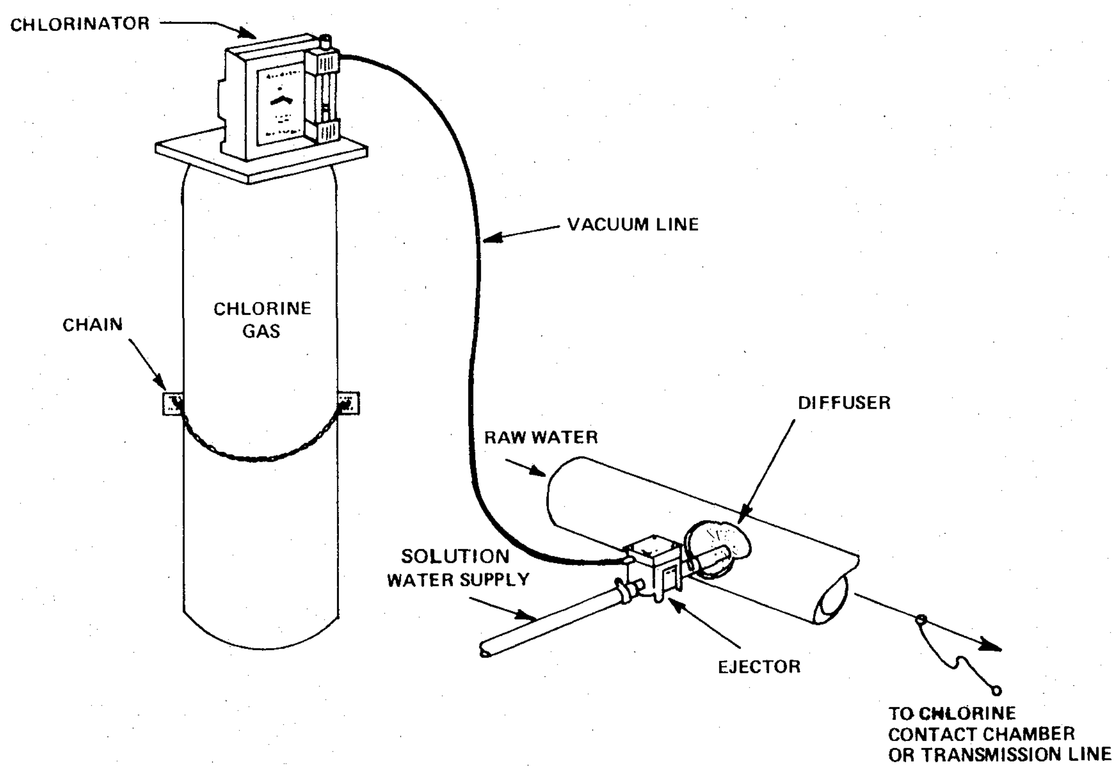

FIGURE IV-2. GAS CHLORINATOR SYSTEM

if it contains large amounts of substances which exert a chlorine demand or the pH of the water is very alkaline. Therefore, when these conditions exist, pretreatment is recommended. The dosage of chlorine required to effectively kill bacteria in a water supply depends upon such factors as:

- General quality of water - suspended solids, organic matter, ammonia, and compounds which may result in "combined" chlorine
- Temperature of water
- pH of water

  } Effectiveness of chlorine decreases as water temperature decreases and as the pH (alkalinity) increases
- Type of chlorine residual - free chlorine (HOCl) is much more effective than combined chlorine
- Contact time - the time required for the chlorine to contact and kill microorganisms.

Contact time can be reduced if a high residual chlorine concentration is used. Similarly, if a low residual (0.2 to 0.5 mg/l) is desirable, a longer contact time is necessary for effective disinfection.

In discussing the effectiveness of chlorination it is important to note that simple chlorination may kill certain bacteria, but not provide sufficient disinfection to kill viruses or protozoa. In general, however, treated water with a turbidity of less than 5 NTU, a pH less than 8, and an HOCl residual of 1 mg/l (0.3 to 0.4 mg/l in practice) provides adequate protection after 30 minutes contact time.*[9]

A method known as superchlorination-dechlorination may be used in overcoming and simplifying the problem of insufficient contact time in such water systems. With this method, chlorine is added to the water in increased amounts (superchlorination) to provide a minimum chlorine residual of 3.0 mg/l for a minimum contact period of 5 minutes. Removal of the excess chlorine (dechlorination) follows to eliminate

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*Recall that chlorine residual is that part of the total dosage which remains after the chlorine demand is satisfied.

objectionable chlorine tastes. Dechlorination equipment is commercially available. Although this method is a recognized effective method of chlorination, it may be too expensive for general usage in all but isolated cases.

Chlorine Residual Testing

Whenever chlorination is used as a method of disinfection, residual chlorine testing is essential to control chlorination and determine whether or not sufficient chlorine exists in the water at any time.

A chlorine residual can exist in water as combined or free available chlorine residual. Because of their difference in disinfection efficiency, it is important to know whether the residual in the water supply exists as free or combined chlorine. While it is common to simply measure chlorine residual by the orthotolidine, colorometric method, the only approved method under the NPDWR is the N, N-diethyl-p-phenylenediamine (DPD) method. The DPD method is considered to be superior to, and equally simple as the orthotolidine (OTA) test. The DPD procedure may be simplified to give only free and combined available chlorine or total residual available chlorine. Complete details of the DPD procedure are described in Standard Methods for the Examination of Water and Wastewater, listed in the references at the end of this chapter.

Because of its many advantages, including ease of control, the practice of free residual chlorination is recommended for rest area water supply systems. If ammonia is present in the water, a free chlorine residual can be obtained by adding sufficient chlorine to combine with all of the ammonia nitrogen and form a compound known as nitrogen trichloride. Once this is done, the addition of any further chlorine will produce a free chlorine residual.

Commercially available residual chlorine test kits should be used whenever chlorine disinfection is practiced. As required by the NPDWR, the test kit must employ the DPD method of residual testing.

Manufacturers of such kits include:

- Hach Chemical Company, Ames, Iowa
- Bausch and Lomb.

Complete, detailed instructions are given with each test kit. However, for those who wish to obtain further information concerning the test and laboratory procedures for determining chlorine residual by this method, a complete description is included in Standard Methods.

Safety Measures and OSHA Requirements

The characteristics of many water chlorination chemicals, particularly compressed liquified gas, require special care in handling and are subject to strict governmental controls. The following paragraphs very briefly describe the principle elements of concern and OSHA requirements which should be observed when using any form of chlorine. The chlorine references listed at the end of this chapter should be obtained and carefully reviewed before chlorinating any rest area water supply.

Chlorine gas is primarily a respiratory irritant, which can cause difficulty in breathing and ultimately death by suffocation. Liquid chlorine causes severe burns when coming in contact with skin, eyes, and mucus membranes.

In addition to its health hazards, precautions must be taken to keep chlorine and chlorine equipment free from moisture since it will become highly corrosive.

There are a number of handling and storage procedures which should be followed in order to minimize or eliminate the hazards associated with chlorine. The major points to be considered include:

- Store and handle cylinders in such a way as to prevent colliding with one another and secure so vertical cylinders cannot be tipped over to rupture the connection with the chlorinator.
- Do not store cylinders in the chlorine feeding room,

but rather in a room separate from the comfort station and operations quarters. The room should be fireproof, properly ventilated, and equipped with outward opening doors and exhaust fans on the floor.

- Approved respiratory equipment (gas masks) should be stored in a handy location outside the chlorination room.
- Store cylinders in a cool, dry place, and never allow the temperature to exceed 140° F (60°C).
- Provisions should be made for a complete "leak control" program which includes prevention, detection (using ammonia) and correction.

In addition, operators of chlorine facilities at rest areas should be properly trained in the following:

- Protective wearing apparel, particularly respiratory equipment such as gas masks
- Handling and storage of containers
- Leak detection and repair
- Hazards and appropriate precautions (including fire and corrosion protection)
- First aid and emergency procedures
- Posting warning signs if a leak should occur and cannot be stopped immediately.

Cost of Chlorination

Factors to be considered in the cost of chlorination systems relate to equipment and operating costs as well as maintenance requirements. In general, the major cost factors will depend on:

- Quantity of water to be disinfected
- Type of chlorinator unit (gas chlorinator, hypochlorite pump, or injector)
- Chlorine source (sodium hypochlorite, calcium hypochlorite, or liquified chlorine gas)
- Safety equipment (if chlorine gas is used).

The amount of chlorine dosage depends on a number of factors, the most important being the basic chlorine demand of the water, which depends upon organic constituents, etc. Other factors are the amount of chlorine required to produce free residual chlorine and the residual desired. The latter may be somewhat higher, for instance, for a treated surface water supply than for a properly protected well or spring which is disinfected only as a precaution.

For small-scale disinfection systems, with pump capacities below 30 gal/min, gas feed equipment is usually too expensive compared to equipment needed for hypochlorites. For this reason, calcium hypochlorite (powder or tablets) and sodium hypochlorite (water-chlorine solution) are often more economical. For larger treatment facilities, with pump capacities of 60 gal/min or more, equipment costs are more than offset, making gas more economical.

Some of the larger manufacturers of chlorinators for small water supplies include:

- BIF Industries
  West Warwick, Rhode Island
- Fischer and Porter
  Warminster, Pennsylvania
- Wallace and Tiernan
  Belleville, New Jersey.

Another important consideration is the relative cost per unit available chlorine for the various types of chlorine. Table IV-8 shows comparative chlorine costs for chlorine gas, calcium hypochlorite, and sodium hypochlorite.

TABLE IV-8
COMPARATIVE CHLORINE COSTS

Description	Approximate Cost
Chlorine in tank cars	\$0.05 per pound Cl_2
Chlorine in one-ton cylinders	0.11 per pound Cl_2
Chlorine in 150-Lb. bottles	0.24 per pound Cl_2
Sodium hypochlorite in 55 gal. drums (14% available Cl_2).	0.58 per pound Cl_2
Calcium hypochlorite (65% available Cl_2)in 50 Lb. drums.	1.55 per pound Cl_2
Chlorine dioxide (1.34# sodium chlorite @ \$1.20/Lb. and 0.5 Lb. chlorine @ \$0.11/Lb.)	1.67 per pound ClO_2

Source: Clean Water Consultants, 1976.

DISINFECTION USING IODINE

Among the promising methods of disinfection that may become more popular in future years is the use of Iodine (I_2). Iodine is an effective disinfectant which does not usually produce harmful effects in man.[10] At the present time, however, the use of iodine has largely been restricted to disinfection of swimming pools and small quantities of drinking water. For the latter, rather complex iodine liberating compounds are common. Tincture of iodine has long been used for emergency disinfection of small quantitites of water. Before planning an iodination system at a rest area, the process should be approved by the appropriate regulating state agency. Although iodination can be an effective disinfectant, not all states consider it to be safe and dependable under all circumstances.

Advantages and Disadvantages of Iodination

ADVANTAGES. Because iodine is relatively stable in aqueous solutions it does not readily react with organic matter to form undesirable compounds, as chlorine does. Another advantage is that it is a good disinfectant over a pH range of 3 to 8. Other advantages include:

- Its action depends less on contact time and temperature than chlorine.
- Due to its stability, iodine provides longer protection against pathogenic organisms than chlorine residual.
- It does not impart offensive tastes and odors to the water.
- As it hydrolyzes it forms HOI, which is almost as good a disinfectant as HOCl.
- Disinfection of remote spring-fed or hand-pump water supplies is possible using commercially available iodinators.
- It is effective against more pathogenic organisms (cysts, viruses, etc.) within short time periods than chlorine.

The results of an evaluation of iodination systems at Forest Service facilities were published in January 1976.[11] Conclusions of the study indicated that iodinators operate quite successfully under a veriety of flow and pressure conditions. Systems in operation have provided excellent disinfection of water supplies with very little equipment maintenance requirements to date.

DISADVANTAGES. Besides being about 20 times more costly than chlorine, the major drawback to the use of iodine as a disinfectant is that higher concentrations of iodine (on a ppm basis) are necessary to produce the same bacterial kills as chlorine. Another disadvantage of iodine is that it is not recommended for continued use as a disinfectant, since thyroid disorders could occur in certain susceptible individuals, although this has not yet been documented. However, this is not likely to be a problem at most rest areas, since water supplies at rest areas are normally not continuously used by individuals. The exception would be when the rest area operator lives at the site.

Special Considerations

Results of the U.S. Forest Service study[11] show iodination to be a safe and effective method of disinfection for potable water supplies serving transient users for three weeks or less, using a free residual iodine concentration of not more than 1.0 mg/l. This limit is based on past studies and recommendations by the EPA in response to questions concerning possible physiological effects.

The following condensation of a letter from the Environmental Protection Agency, dated February 20, 1973, more clearly describes the potential health hazards associated with exposures to iodinated waters:

> The evidence indicates that small amounts of iodine (3 to 10 mg) per day can be expected to impair to some degree the production of thyroid hormones. However, it appears that it would take more than a week of exposure to an iodinated water supply to induce symptoms of reduced thyroid function in the few succeptible individuals probably present in every community.

There is also reported evidence of the occasional occurrence of thyroid goiter or thyroid hormone insufficiency in unborn infants of mothers who have ingested excessive amounts of iodine. The smallest reported amount of iodine inducing such an adverse effect is 12 mg daily. The 2 or 3 mg of iodine per day acquired from drinking water would in itself probably not be harmful but it is additive to the total iodine obtained by the mother from other sources.

Short-term exposure to an iodinated water supply containing 0.5 to 1.0 mg/l iodine should not be harmful. Long-term exposure, such as in municipal water systems supplying permanent residents, may in rare instances have an adverse effect on individuals with impaired thyroid function or on the unborn child. Therefore, the use of iodine for treating such supplies bears this risk.

In summary, the opinion of experts in the field indicates that little if any hazard to consumers whould exist if disinfection with iodine were practiced on those water supplies where the consumers are transient and use the water for drinking purposes for periods of three weeks or less.

Effectiveness

Studies sited by Weber[10](1968) indicated that 1.3 mg/l iodine are required to effectively kill E. coli in a 30-second time period. However, for best protection, a higher dosage of iodine may be used to be effective against not only E. coli, but also cysts and viruses. Table IV-9 illustrates the differences in relative cysticidal and vircidal efficiencies of iodine at 77°F (25°C), and at various contact periods.

In the higher pH ranges, iodine is more effective than chlorine residual as a disinfectant. For example, at a pH of 8 at 77°F (25°C), chlorine exists as relatively ineffective OCl ion, while iodine exists as HOI and I_2, with both forms being effective disinfectants. Table IV-10 more clearly illustrates the effects of pH on hydrolysis of iodine and chlorine.

Safety Measures

Commercial iodine is a volatile, crystalline solid which is corrosive to most metals. When heated, iodine forms a violet, toxic

TABLE IV-9
RELATIVE CYSTICIDAL & VIRICIDAL
EFFENCIES OF IODINE @ 25°C

Contact Time (Min)	I_2 Residual (mg/l) Cysticidal	Viricidal
10	3.7	6.3
5	6.0	13.6
2	12.5	34.0

Source: AWWA, Water Quality and Treatment, 3rd Edition, 1971.

TABLE IV-10
EFFECTS OF pH ON HYDROLYSIS
OF IODINE AND CHLORINE

Content of Residual (percent)				Content of Residual (percent)			
pH	I_2	HOI	IO	pH	Cl_2	HOCl	OCl
				4	0.5	99.5	0
5	99	1	0	5	0	99.5	0.5
6	90	10	0	6	0	96.5	3.5
7	52	48	0	7	0	72.5	27.5
8	12	88	0.005	8	0	21.5	78.5
				9	0	1.0	99.0

Source: Briar Cook, Iodine Dispenser for Water Supply Disinfection, U.S. Department of Agriculture - Forest Service, Equipment Development and Test Report 7400-1, Equipment Development Center, San Dimas, Calif., January 1976.

vapor; but this vapor is less hazardous than other halogens commonly used in water treatment.

Cost of Iodination*

Costs for iodination equipment are moderate and dependent on the size of unit desired; 5-lb and 8-lb units are available for $198 and $267, respectively, including one filling of iodine crystals.[11] Based on 1-lb units capable of treating 241,000 gallons of water at 0.5 mg/l, the 5-lb unit would produce water at 16¢/1000 gal and the 8-lb unit would cost 14¢/1000 gal. Iodine crystals for replenishment cost approximately $12/lb.

Several models of Iodinamics Iodinators are available and currently in use at safety rest areas and U.S. Forest Service facilities (including Models 124-8 and 123-5). A typical iodination system is illustrated in Figure IV-3.

DISINFECTION BY ULTRAVIOLET IRRADIATION

Disinfection by ultraviolet light is best accomplished in the wavelengths between 2500-2650 angstroms (Å). Systems employing this treatment method generally use low-pressure mercury vapor lamps, which radiate energy at 2527Å. Depending upon dosage and type of organism cell receiving the radiation, disinfection occurs by killing the cell, retarding its growth, or changing its heredity by gene mutation.[10]

Advantages and Disadvantages

ADVANTAGES. Some of the major advantages to using UV for disinfection include:

- No tastes or odors result from this treatment, since no chemicals are added to the water.
- Overdosing produces no detrimental effect.
- Short contact periods provide effective disinfection.

* Based on data available during 1975.

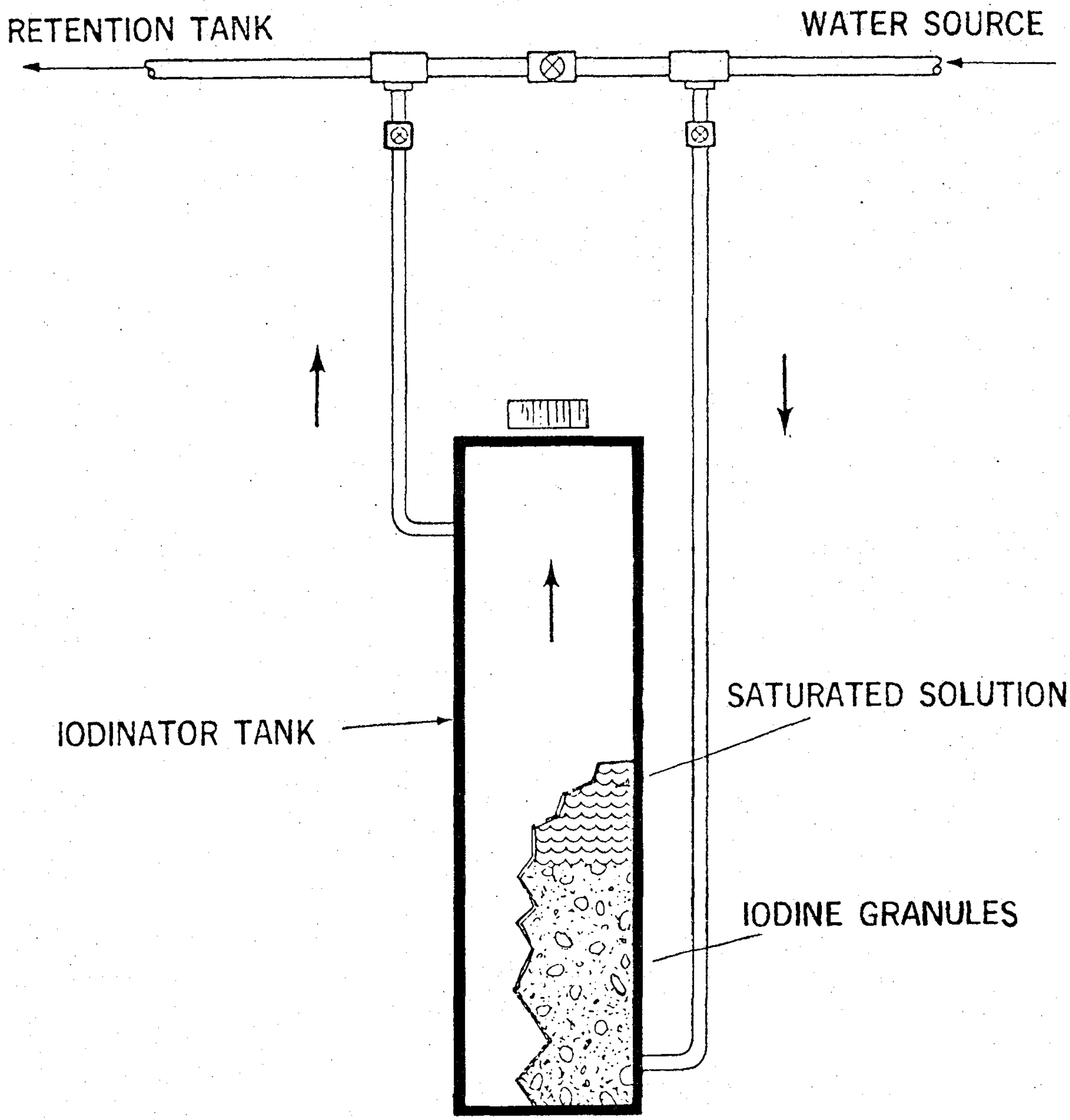

FIGURE IV-3. TYPICAL IODINATION SYSTEM

- It is considered to be quite a "safe" method of disinfection as compared with some of the safety hazards associated with liquified chlorine gas and ozone.

DISADVANTAGES. The primary disadvantage of ultraviolet irradiation treatment is that it provides no residual protection against recontamination. Except for utilizing equipment as mentioned below for indicating the intensity of ultraviolet irradiation penetrating the water, the only way to check its continuing effectiveness is by time-consuming microbiological tests. Other disadvantages include:

- Thorough water pretreatment is required because turbidity, color, salts and many other constituents interfere with disinfection.
- The process requires expensive equipment and high electrical energy levels, usually too costly for use in rest areas.
- Frequent and expensive equipment maintenance is necessary to ensure system reliablity.

Special Considerations

To ensure disinfection, it is essential that the ultraviolet light be applied to every drop of water. In order to permit the passage of ultraviolet rays, a mercury vapor lamp must be constructed of quartz or other special glass. The rays are stopped or reduced in intensity by any film on the tube and by the light absorbing substances such as phenols and other aromatics. Dissolved and suspended solids, turbidity, algae, and color of the water also interfere with the effectiveness of ultraviolet irradiation and should be removed in pretreatment. In addition, the time/intensity ratio of exposure must be adequate, and the water must be well mixed and spread thinly during exposure to ensure adequate exposure to the total flow. Regular maintenance and inspection are essential.

Effectiveness

It has been shown that 99.9 percent kill can be achieved using a single 30-watt germicidal lamp (properly installed and maintained) for disinfecting water flows from 650 to 4500 gal/hr.[10]

In another study, research for the Army Medical Research and Development Command [12] indicated that 0.5 to 1.5 mg/l of ozone generated in the presence of ultraviolet light was an effective disinfectant for drinking water.

Testing of Lamps

Equipment has been developed to indicate the concentration of ultraviolet rays penetrating the water. This equipment provides added assurance of the effectiveness of the process. The unit incorporates the principle of a built-in meter which actually measures and records the intensity of irradiation to which the film of water was being subjected. In addition, these units can easily be connected with alarm systems, to notify the operator when insufficient rays have penetrated the water supply.

Cost of Ultraviolet Irradiation

A number of ultraviolet disinfection systems are available from various manufacturers, including:

- Atlantic Ultraviolet Corporation
  Bay Shore, New York
- Triton Water Systems
  Gardena, California
- U.V. Purification Systems, Incorporated
  Scarsdale, New York
- Ultradynamics, Incorporated
  Santa Monica, California

Large systems, with capacities ranging from 75 to 20,000 gal/hr cost $300 to $6,400. Smaller units capable of handling peak flows of 60 gal/hr are available for about $275.

Energy demands for ultraviolet irradiation are approximately 80 kw-hr/1000 gallon.

Before making U.V. installations, all proposed equipment should be approved by the offical regulating agency of the safety rest area where installation is being considered. For most efficient use, U.V. units should be considered only for waters with relatively low levels of contamination at the time of disinfection.

SOFTENING

GENERAL

Water softening is a process for the removal of minerals, primarily calcium and magnesium, which cause hardness. These elements usually are present in compound form as bicarbonates, sulfates or chlorides. The hardness in water can form scale deposits in the water lines, which can result in an appreciable reduction in pipe capacities and pressures. The appearance of excessive scale from hard waters will also be aesthetically objectionable.

In the rest area application, the economic benefits of water softening are not evident unless the total hardness of the water exceeds 200 mg/l expressed as $CaCO_3$ (calcium carbonate). However, when the total hardness exceeds 300 mg/l, softening is virtually mandatory for the protection of plumbing and equipment. It is generally recommended to provide a residual hardness of 75-100 mg/l in the water supply system.[4] This can be accomplished by softening a portion of the water supply and then blending it with the remaining raw water to acheive the desired hardness range.

METHODS OF SOFTENING

The two most commonly used methods of softening are lime-soda ash and zeolite softening. However, because of the complexities involved in lime-sode ash treatment, it is not recommended for use in safety rest areas, and consequently will not be further discussed in this manual.

Zeolite Process

The zeolite process causes a replacement of the calcium or magnesium ions by sodium ions. The process takes place when the hard water containing calcium or magnesium compounds comes in contact with an exchange medium. The materials used in the zeolite process are insoluble, granular materials that possess a unique property of ion exchange. Ion-exchange material may be classed as follows: glauconite (or greensand); precipitated synthetic, organic (carbonaceous), and synthetic resins; or gel zeolites. The last two are the most commonly used for domestic purposes.

The type of ion-exchange material used is determined by the type of water treatment required. For example, when a sodium zeolite is used to soften water by exchanging the sodium ion for calcium and magnesium ions in the hard water, the sodium zeolite eventually becomes of insufficient quantity to effect the exchange. After a certain period of time determined by the exchange rate, the exchange material must be regenerated. The sodium ion is restored to the zeolite by passing a salt ($NaCl$) or brine solution through the bed. The salt solution used must contain the same type of ions which were displaced by the calcium and magnesium. The solution causes a reversal of the ion-exchange process, restoring the exchange material to its original condition.

The type of regenerating material or solution which must be used depends upon the type of exchange material in the exchange column.

The sodium zeolite method of softening water is relatively simple and can be easily adapted to small water supply systems such as rest areas. Only a portion of the hard water needs to be passed through the softening process because the exchange process produces water of near-zero hardness. The processed water can then be mixed with the hard water in proportions to produce a final water with the recommended hardness between 75 and 100 mg/l.

Zeolite softener capacities range from about 85,000 to 550,000 milligrams of hardness that can be removed for each cubic foot of the ion-exchange material. Water softeners are designed for automatic, semi-automatic, or manual regeneration. Fully automatic units regenerate on a predetermined schedule (controlled by a time clock or other device) and return to service automatically. Semi-automatic units are started manually, but otherwise are automatic. With manual units, all steps in the operation -- backwashing, brining, and rinsing -- are manually controlled.

Before installing a water softener which must be regenerated on the site, a special check should be made to determine whether water quality control regulations will permit disposal of the waste brine and back-wash water into the soil or surface streams. Some agencies consider such discharge to constitute an excessive burden of total dissolved solids (T.D.S.) on the aquifer or stream. In such case, the alternative is utilization of a service company which regenerates their units at a location where the brine is not a pollution problem.

Water softeners should be installed only by responsible persons in strict accordance with the instructions from the manufacturer and applicable codes. The materials and workmanship should be guaranteed for a specified period of time. First consideration in securing ion-exchange water-softening equipment should be given to those companies providing responsible servicing dealers permanently located within a reasonable distance from the rest area.

Major manufacturers of ion exchange equipment include:

- The Bizco Company
  New Haven, Connecticut
- Cochran Environmental Systems
  Pennsylvania
- General Filter Company
  Ames, Iowa
- Permutit
  Paramus, New Jersey

Provision For Waste Brine Disposal

Zeolite softeners produce appreciable quantities of brine waste. Provisions must be made for proper disposal of these wastes since they cause an undesirable increase in the T.D.S. concentrations of waste-receiving waters and groundwater. The backwash material from the recharging cycle of a softener may be plumbed into the wastewater system; however, it should be noted that the treatment load resulting from the exchanged chemicals may have a deleterious effect on small biological treatment processes. Other disposal methods which should be considered include using evaporation ponds, controlled dilution, uncontrolled dilution, and brine disposal wells.

Treatment Limitations

Ion exchange resins remove limited amounts of dissolved iron and manganese by the exchange method previously described. These impurities are disposed of during regeneration. However, some types of iron compounds, turbidity, slime, and fine sediment will not be removed. Such materials cling to the resin and insulate it from the water to be treated, thus inhibiting efficient exchange. Therefore, when interfering subtances are present in concentrations sufficient to cause problems, it is recommended that an iron removal filter be installed in the system prior to softening. Water with a turbidity of more than 10 NTU also warrants pretreatment to increase effectiveness and efficiency of the softening process.

IRON AND MANGANESE CONTROL

GENERAL

Neither iron nor manganese are harmful to health in the concentrations generally found in water. However, there are a number of aesthetic and operational objections to these contaminants in water supplies. The maximum allowable concentration for iron and manganese should not exceed 0.3 mg/l and 0.05 mg/l respectively, to maintain an acceptable water quality. When both are present beyond this concentration, special attention should be given.

Most water supplies contain some iron. The iron may be picked up or dissolved by the water as it passes through underground iron deposits or from contact with the metal parts of the water system - the well casing, pump, and piping. The more corrosive the water, the more iron it will dissolve from contact with the metal parts.

Iron and manganese may also be present in surface water, particularly in water drawn from the bottom of deep lakes where iron and manganese may be dissolved under anaerobic conditions from bottom deposits or rocks and minerals on the lake bottom. Mixing or aeration of lakes to prevent oxygen and thermal stratification often will correct this condition. Iron and manganese may also be found in surface waters which receive acid industrial wastes or mine drainage.

Well water is usually clear and colorless when drawn from the faucet or tap. When water containing colorless, dissolved iron (usually ferrous bicarbonate) is allowed to come in contact with a sink or flush tank, the iron combines with oxygen from the air to form a reddish-brown precipitate commonly called rust. Manganese acts in a similar manner, but forms a brownish-black precipitate. These impurities can impart a metallic taste to the water or to any food in whose preparation such a supply is used. Deposits of iron and manganese produce rusty or brown stains on plumbing fixtures. The use of soaps or detergents will not remove these stains, and bleaches and alkaline builders can intensify the staining process. After a prolonged period, iron deposits can build up in pressure tanks, water heaters, and pipelines. This build-up reduces the available quantity and pressure of the water supply.

METHODS OF IRON AND MANGANESE CONTROL

A number of processes may be used, alone or in combination, for the removal of iron and manganese. Their selection will depend upon the character and quality of the raw water, and upon the chemical state of the iron and manganese compounds. Therefore, the selection of one or more processes should meet specific local conditions, based upon engineering investigations (including analysis of representative samples of water to be treated). It may be necessary, in certain cases, to conduct treatability studies to gather pertinent information to be used as the basis of design.

Specific treatment processes applicable to rest areas for the control of iron and manganese deposition include: (1) oxidation and filtration, (2) ion exchange, and (3) sequestering with polyphosphates.

Oxidation and Filtration

Oxidation followed by filtration is probably the most common method of treating iron and manganese bearing waters. The oxidation can be accomplished by aeration or by chemical oxidation using chlorine, potassium permanganate, or ozone. In some cases, contact time or a detention period of 20-45 minutes is required following oxidation in order to allow time for completion of the oxidation reactions. (The retention time may be determined by pilot plant studies). Aeration followed by filtration will normally reduce the iron to an acceptable level if the original concentration was not too high (less than 0.6 mg/l). In order to be treated using this method, the pH of the water must be raised above 7.0.

Chlorination followed by filtration through a sand or carbon filter can remove iron. This combination method is the most commonly used since it provides complete correction of iron and manganese problems and assures disinfection as well. However, similar to the aeration-filtration system, the water must be non-corrosive, otherwise additional pre-treatment is necessary.

Ion Exchange

Some water conditioning systems contain a resinous material that will remove soluble iron on an ion-exchange basis (the same way as calcium and magnesium are removed in water softening). This process is limited to water with low concentrations of iron and manganese, generally less than 0.5 mg/l. Higher concentrations and the slime produced by iron bacteria can clog the resin and reduce its effectiveness.

This process is not acceptable where the raw water contains dissolved oxygen which could cause the iron to precipitate. It is a specialized process of removing iron and manganese and, if used, the recommendations of equipment manufacturers must be followed. In addition, ion exchange is a rather expensive process and the finished water may also be corrosive.

Sequestering With Polyphosphates

This process is generally suitable for low concentrations of iron and manganese, 3 mg/l or less. Sequestering agents contain a phosphate compound which "coat" the soluble iron and prevent its oxidation when the water is exposed to air. The compound is not effective against iron which is already oxidized. The process is also not suited for water which is heated, since the polyphosphate will lose its dispersion properties and become ineffective. In addition, the application of the polyphosphate must take place prior to aeration or chlorination in order to prevent the precipitation of ferric hydroxide.

Where this process is used, phosphate dosages should not exceed 10 mg/l since higher concentrations may stimulate bacterial growth in the distribution system. Dosage rates of 5 mg/mg Fe + Mn are commonly used.

SPECIAL CONSIDERATIONS

Safety Measures and OSHA Requirements

Certain treatment methods for the removal of iron and manganese warrant special attention with respect to safety. When oxidation is provided by using chlorine, this can be accomplished by hypochlorites which necessitate less stringent safety controls. If liquified gas is used, there are extensive safety procedures which should be adopted as previously described in this manual (pages IV-27 and 28).

Treatment Limitations

Under certain conditions, the presence of iron compounds in the water leads to the growth of iron organisms (crenothix) which may cause slimy or solid growths on iron pipe such as well casings and delivery pipes, iron water mains and pipes, and on certain fixtures. The organism can be controlled by constant or periodic chlorination or by removing iron to levels beneath that required for growth of the organism. Iron bacteria may impart unpleasant taste and odor to the water, discolor plumbing fixtures, and clog pumps. They may be concentrated in a specific location and may periodically break loose and appear at the faucet in detectable amounts of rust.

Iron-removal filters or water softeners can remove iron bacteria; however, they often become clogged and fouled because of the slime buildup. A disinfecting solution such as chlorine bleach should be injected into the water to control the growth of iron bacteria. Such a solution causes a chemical reaction which allows an iron precipitate to form. This precipitate can be removed with a suitable fine filter.[1]

TASTE AND ODOR CONTROL

The need for taste and odor control is primarily associated with aesthetic requirements rather than health requirements. However, there are several health-related considerations which should be noted. If water at a rest area has an unpleasant taste or odor, some users will turn to other, possibly less-safe, sources of drinking water. If the tastes or odors are attributable to the presence of chloro-organic compounds, there is a health-related need to remove the organics by activated carbon adsorption or other means prior to chlorination.

A fairly common source of unpleasant tastes and odors, especially in certain well water supplies, is hydrogen sulfide. As with other undesirable impurities in well water, the first control step is to determine whether the undesirable water is derived from a stratum which can be sealed-off so water is derived from a stratum which is free of the impurity. Removal of hydrogen sulfide necessitates special pilot tests to determine which method or methods are most effective. In some cases, aeration plus sedimentation will suffice. In other cases lime and chlorination may be of value.

Proposed secondary standards promulgated under the authority of the Safe Drinking Water Act recommend a maximum contaminant level (MCL) for odor at 3 Threshold Odor Number (TON)*. No MCL has been established for taste.

IDENTIFYING CAUSES OF TASTE AND ODOR PROBLEMS

In planning facilities for taste and odor control it is helpful to know what the potential sources of the problem may be. Tastes and odors present in individual or small water supply systems fall into two general categories -- natural and man-made. Some natural causes may be traced to the presence or contact of water with algae, leaves, grass, or decaying vegetation and other organic materials. This situation is most commonly experienced with surface water supplies originating from ponds or lakes.

Extreme conditions of hardness, iron, or acidity can also create naturally poor-tasting water. A "rotten egg" odor and flavor generally indicates water containing sulfur bacteria, hydrogen-sulfide gas, or sulfate-reducing bacteria, while a metallic flavor usually indicates excessive concentrations of iron.

Some of the man-made causes of taste and odor may be attributed to the presence of chemicals or sewage. Water which has a salty taste may be attributable to runoff containing high concentrations of deicing salt which may have been improperly stored or placed on the highway in excess amounts to control icing during the winter months. Also, if the water supply is located near an industrial center, the taste may be the result of phenols and other chemical wastes, while an oily flavor may indicate the

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* Threshold Odor Number of water is the dilution factor required before the odor is minimally perceptible. A TON of 1 indicates that the water is essentially odor-free.

presence of a leaky fuel tank or oil storage tank. Phenols produce especially strong tastes when water containing that chemical is chlorinated. The solution may be in phenol removal by eliminating its source or through use of activated carbon. Sometimes special disinfecting processes are used to prevent the formation of the chloro-phenols which cause the problem. For instance, in some cases chlorine dioxide is substituted for ordinary chlorine.

METHODS OF CONTROLLING OR REMOVING TASTE AND ODOR

Depending upon the cause, taste and odor can be removed or reduced by aeration, use of an oxidizing agent such as chlorine, or by treatment with activated carbon. When taste and odor are due to algae in open impoundment reservoirs, the problem may be reduced by adding copper sulfate, chlorine or an approved algicide to the reservoir.

Another method of taste and odor control would be control or prevention of the problem at the source, rather than employing an expensive and perhaps unnecessary treatment technique.

Chlorination

Chlorine is an effective agent in reducing tastes and odors present in water. The process requires the presence of free chlorine in sufficient amount to cause oxidation of the taste and odor producing compounds. In addition, adequate contact time must be provided to complete the chemical reactions involved. Frequently this process requires dechlorination to bring the residual chlorine to an acceptable level.

When chlorine or chlorine compounds are used to oxidize organic matter in water, consideration must be given to preventing potentially harmful chloro-organic compounds from reaching consumers. This can be accomplished by adsorption on activated carbon, or removal by coagulation and filtration as previously mentioned. Safety measures associated with the use of chlorine must be observed, as previously described on pages IV-27 and 28 in this manual.

Activated Carbon

The activated carbon treatment consists of passing the water through granular activated carbon or mixing powdered activated carbon with the supply to attract dissolved gases, liquids, and finely divided solids. It is therefore extremely effective in controlling organic tastes and odors. Activated cabon is the active ingredient in carbon filters available commercially from the manufacturers or producers of water-conditioning or treatment equipment. The recommendations included with the filter should be followed.

POWDERED ACTIVATED CARBON. Powdered activated carbon is usually added as a pre-mixed slurry or by means of a dry-feed machine. Agitation is necessary to keep the carbon from depositing in the mixing chamber. The required dosage of carbon in a water treatment plant depends upon the tastes and/or odors involved, but provisions should be made for adding up to 40 mg/l, with contact times generally ranging from 10 to 15 minutes, prior to removing the carbon by filtration.

GRANULAR ACTIVATED CARBON. When granular carbon is used, the carbon is placed inside a pressure-type filter. In this system, the carbon beds are normally placed after the conventional filtration systems, but in some cases where the water is relatively clean, the carbon may be used without pretreatment. One of the principle reasons for the use of granular carbon is its ability to be regenerated after its adsorptive capacity has been exhausted.

Copper Sulfate

The most frequent source of taste and odor problems in small water supplies obtained from surface sources is algae.

When algae are present in a water supply, their growth can often be controlled by copper sulfate treatment or by chlorination.

Continuous or periodic treatment of water with copper compounds to kill algae or other growths should be controlled to prevent copper in excess of 1.0 mg/l as copper in the distribution system. Care should be taken to obtain a uniform distribution and to avoid local high concentrations.[6] In alkaline waters with appreciable bicarbonates, the soluble copper sulfate is converted to relatively insoluble copper carbonate and is thereby removed. In waters with a pH below 7.0 and with little alkalinity, the copper sulfate tends to remain in solution.

The amount of the copper sulfate dosage varies with the particular species of organism involved as well as the temperature, pH, and alkalinity of the water. A dose of 0.3 mg/l*, however, will generally control all but a few of the growths likely to cause trouble in drinking water. For certain species of fish, particularly those of the trout family, this dosage may be poisonous. The approximate doses of copper sulfate in mg/l which should not be exceeded to avoid killing various kinds of fish are given in Table IV-11. If applied in the recommended quantities, copper sulfate is safe for both human and marine life.

The span of time over which a treatment will be effective will vary, depending upon sunshine, reseeding, and local conditions. Several treatments per season are generally required. Control will be easier and more effective if the treatment is done before the algae bloom, or reach their maximum growth and development. In waters with a pH below 8.0 the addition of at least 1.0 mg/l free chlorine will usually control algae and some use this method in place of copper sulphate.

Because algae and other chlorophyl-containing plants need sunlight to grow, it is also recommended that water be stored in covered reservoirs with adequate chlorine residual in order to further inhibit the growth of algae.

FILTRATION

GENERAL

Filtration is a water treatment process which separates suspended and colloidal impurities from water by passing the water through

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* 0.3 mg/l is equivalent to about 2.5 pounds of copper sulfate per million gallons or 1 ounce in 25,000 gallons.

TABLE IV-11. APPROXIMATE MAXIMUM TOLERANCE LIMITS OF VARIOUS FISH TO COPPER SULFATE

Kind of Fish	Copper sulfate (milligrams per liter)	Pounds per million gallons
Trout	0.15	1.2
Carp	0.30	2.5
Suckers	0.30	2.5
Catfish	0.40	3.5
Pickerel	0.40	3.5
Goldfish	0.50	4.0
Perch	0.70	6.0
Sunfish	1.20	10.0
Black Bass	2.00	17.0

Source: Wyoming Department of Health and Socal Services, Minimum Standards for Private or Semi-Public Water Supplies, 1973.

a porous medium. Water filtration is primarily a physical process, although some biological activity may occur when bacteria, protozoa, and algae are present in the unfiltered water. The degree of removal depends on the character and size of the filter media, the thickness of the porous media, loading rates, flow rates, headloss, and the size and quantity of the suspended solids. Since bacteria can travel long distances through granular meterials, filters should not be relied upon to produce bacteriologically safe water even though they greatly improve the quality. When a water source contains a large amount of turbidity, a large portion of it can first be removed by sedimentation.

TYPES OF FILTERS

Filters can be categorized into slow sand filters, rapid sand filters, pressure sand filters, and diatomaceous earth filters. These various types of filters can be reasonably efficient in removing such undesirable constituents as turbidity and bacteria. They are less efficient in removing color, taste, and odor, and iron and manganese.

Due to cost considerations and complicated operation and maintenance requirements, slow sand and rapid sand filtration systems generally are not used for small water supplies such as those found at rest areas. Consequently, these systems will not be discussed in this manual. Further information is available by consulting the reference by Culp or the AWWA reference on treatment, listed at the end of this chapter.

Pressure Sand Filters

Pressure sand filters are similar in principle to rapid gravity filters except that they are completely enclosed in an upright, steel, cylindrical shell through which water is filtered under pressure. Pressure filters are used where the raw water is supplied under pressure and where it is desired to filter and deliver the water to the distribution system without further pumping. Figure IV-4 illustrates a typical pressure sand filter system. Pressure filters generally operate at rates of 2 to 3 gpm/ft^2 of filter area, commonly require a filter aid, and require backwashing.

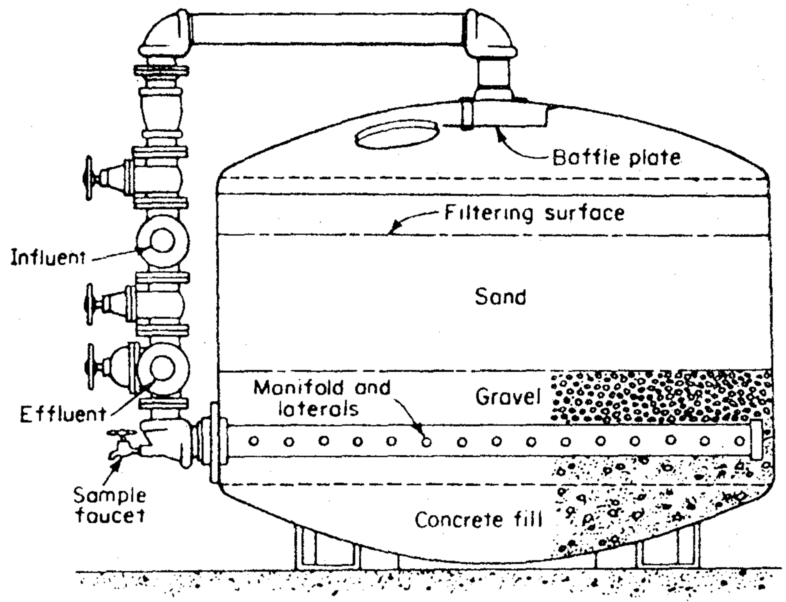

FIGURE IV-4. PRESSURE SAND FILTRATION SYSTEM

Diatomaceous Earth Filters

The diatomite filter is a pressure or vacuum process which uses a porous support (septum) precoated with diatomaceous earth as the filter medium. The system can all be arranged to constantly feed diatomaceous earth at a regulated rate (body feed) to prolong the time between backwashing. This is especially desirable with water with appreciable turbidity. Other filter aids also may be used. Figure IV-5 shows a typical diatomite filtration system, with all of the major components identified. Normal filtration rates are 1 to 2 gpm/ft^2 of filter surface area, although higher rates are sometimes recommended.

SPECIAL CONSIDERATIONS

Pressure Sand Filters

Pressure filters are usually suited for iron and manganese removal (where concentrations do not exceed 2 mg/l of Fe and Mn), and slight reductions in turbidity. The main advantage to pressure filtration is that only one pump is required to take water from the source, and force it directly into the filter.

Pressure filters are subject to the same types of operating difficulties as those encountered in rapid sand filters. There are added difficulties in introducing chemicals under pressure (coagulants must usually be well mixed into the water and allowed to settle in a basin before being pumped into the filter). Pressure sand filters have limited application in removing turbidity and treating contaminated water for drinking purposes. These filters generally are unsuitable for treating surface water supplies.

Diatomaceous Earth Filters

Although diatomaceous earth filters have a relatively low initial cost, require little space, and require low maintenance, the system does have limitations. Perhaps the most important limitation

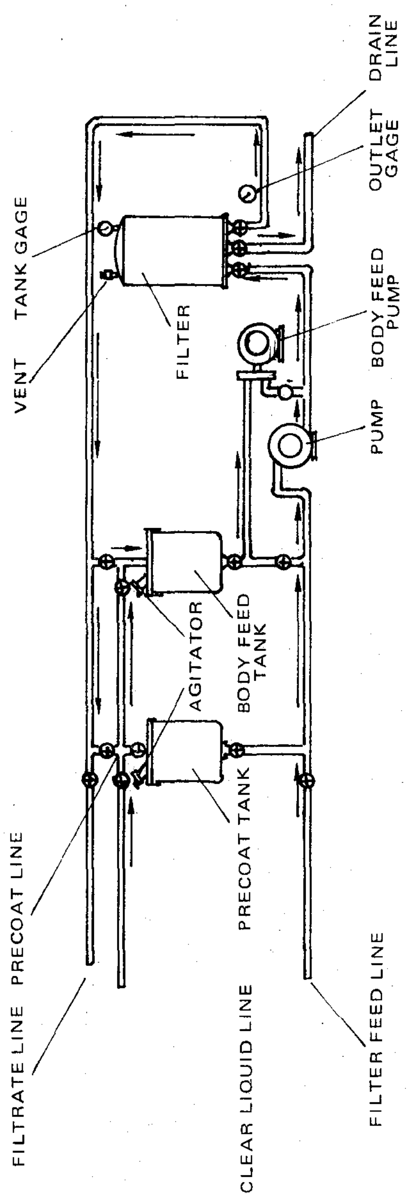

FIGURE IV-5. DIATOMITE FILTRATION SYSTEM COMPONANTS is that the turbidity of the water must be low, otherwise excessive clogging of the septum occurs; this results in short runs and requires excessive backwashing. There is also the hazard that improper coating will permit by-passing of the filter medium.

It must also be understood that although diatomite filters are capable of removing 85 to 90 percent of the bacteria present in the raw water, disinfection is still necessary.

Regardless of the contaminants to be removed by diatomite filtration, careful preliminary testing of the feedwater must be conducted in conjunction with cost comparisons with conventional filtration prior to process selection.

Activated Carbon Filter Media

Activated carbon is commonly used to control the organic materials causing the unpleasant taste and odor found in certain water supplies. It also has been highly effective in removing color, foaming agents (measured by MBAS-methylene blue active substances), and mercury. Very recently, activated carbon has also demonstrated its potential for removing organic pesticides, organophosphate insecticides, and carcinogenic compounds formed by the reaction between chlorine and various organic chemicals (trihalomethanes).

Where both activated carbon and chlorine disinfection are practiced, it must be recognized that activated carbon is an effective dechlorinating agent. Normally, the chlorination follows the use of activated carbon; the exception is in those cases where the process is intended to result in a chlorine-free, disinfected water.

Use of activated carbon requires adequate ventilation and respiratory protection for the rest area water supply operator. In addition, proper storage of the carbon is essential in order to prevent fire hazards. Operators of rest areas using activated carbon treatment should be properly trained in fire control, and first aid, as well as in the hazards associated with activated carbon and the precautions which should be taken. Complete details regarding these elements of OSHA are more fully described in the Occupational Safety and Health Standards for Water Utilities, by AWWA listed at the end of this chapter.

TOTAL DISOLVED SOLIDS (TDS) REMOVAL

Certain groundwater aquifers are very highly mineralized, containing excessive salts, or dissolved solids, mainly sodium, calcium, magnesium, sulfate, chloride, and bicarbonate. These highly mineralized supplies with TDS concentration as high as 3,000 mg/l occur in arid and semi-arid states including Texas, Oklahoma, Kansas, Nebraska, North and South Dakota, parts of Arizona, New Mexico, Colorado, California, Utah, Wyoming, Montana and Nevada.[13] For these waters to be used as potable supplies, TDS concentrations should be reduced to levels acceptable to the concerned state health department or the agency responsible for enforcing the NPDWR in the particular location. Among the methods of TDS removal which can be used at rest ares, are ion exchange and membrane processes including reverse osmosis and electrodialysis.

REVERSE OSMOSIS (RO)

To understand reverse osmosis it is necessary to know what is meant by "osmosis". Figure IV-6 is an aid to describing both osmosis and reverse osmosis. As shown in the figure, osmosis involves the movement of fresh water through a semipermeable membrane to the side of the membrane containing a salt solution. This flow will continue until the system reaches equilibrium. Reverse osmosis involves applying a mechanical pressure to the saline solution, so that water will be forced through the membrane, leaving the salts behind in a concentrated form.

Reverse osmosis is effective in removing or reducing numerous contaminants which may be present in a potable water supply. Table IV-12

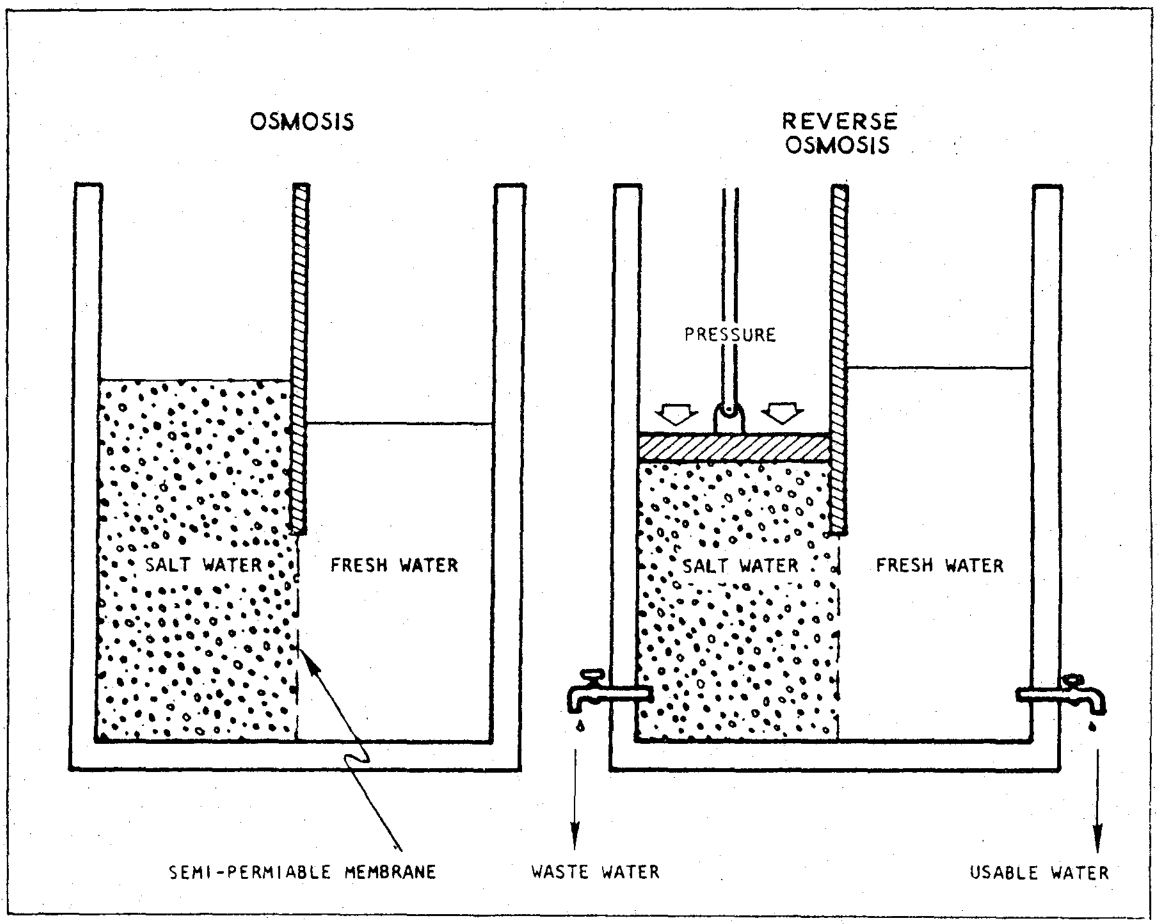

FIGURE IV-6. DIAGRAM OF OSMOSIS AND REVERSE OSMOSIS PROCESSES

TABLE IV-12

CONTAMINANTS WHICH CAN BE REDUCED OR REMOVED BY REVERSE OSMOSIS*

Arsenic	Lead
Bacteria	Manganese
Barium	Mercury
Cadmium	Nitrates
Chlorides	Organic Pesticides
Chromium	Selenium
Color	Silver
Copper	Sodium
Cyanide	Sulfates
Iron	Zinc

* Removal efficiency depends on contaminant concentrations in the raw water, pH, temperature and other water chemistry considerations. Exact removal efficiency should be determined by pilot tests for a particular water supply.

lists the contaminants which can be treated using reverse osmosis.

Special Considerations For RO

There are several types and configurations of RO equipment which are suitable for use in demineralizing rest area water supplies. To select a suitable system for a particular installation it is necessary to know the quality of the water to be treated, including variations in composition, temperature and other factors, Pilot plant tests may be desirable to check the suitability of equipment for the particular water to be treated. Applicability of the process should be demonstrated to the satisfaction of the state before such systems are installed.

Cost of RO

Operating costs for reverse osmosis can be divided into the following:

- Membrane replacement.
- Operating costs covering power, labor, pretreatment, and cleaning.

Costs will vary considerably depending on plant size and design and raw water characteristics. For example, high raw water temperatures will result in high maintenance costs due to frequent membrane replacement.

ELECTRODIALYSIS (ED)

Similar to reverse osmosis, electrodialysis is a method of reducing dissolved solids in a water supply by passage through semi-permeable membranes. ED units are made up of "cell-pairs", a cell-pair being anion and cation selective membranes sandwiched between spacers. Several of these cells are assembled in a stack between a pair of electrodes. Water introduced into alternate cells is demineralized by passage of a direct current through the cells. The degree to which desalting can be achieved depends only on the residence time of the solution and the current density employed. The process becomes correspondingly slower at low salinity levels and, for water supplies, is usually stopped at a TDS of about 500 mg/l. Thus, like reverse osmosis, the energy requirement depends on the concentration of dissolved solids in the feedwater and is proportional to the electrical equivalents of the salts removed from the feedwater.

Electrodialysis is capable of desalinating waters with up to 10,000 mg/l of salt, as well as removing turbidity, microorganisms, and certain undesirable toxic elements and compounds. Table IV-13 shows typical demineralization of water which has undergone treatment by electrodialysis. The data show TDS reduced by a factor of five, and hardness reduced by a factor of 15.

Special Considerations For ED

Electrodialytic efficiency is severely impaired by the presence of particulate matter, soluble and insoluble organics, iron and manganese, and hydrogen sulfide. If these contaminants are present, they must be removed by a suitable pretreatment process. Electrodialysis membranes can also suffer from mild bacterial attacks, although this is rare. The addition of chlorine to the feedwater is usually sufficient to prevent this occurrence. As with all desalinization processes, there may also be problems associated with disposal of the salt which must be flushed from the membrane surfaces.

Like reverse osmosis, laboratory or pilot tests should be conducted prior to design of an ED system to obtain data on the acceptable range of feedwater concentrations to produce water of a desirable quality.

Cost of ED

As a first approximation to determination of the cost of electrodialysis, one may assume costs to be directly proportional to the salinity of the feedwater. The cost breakdown for parts and supplies for a 12,000 gpd plant in current use at one safety rest area is shown in Table IV-14. For this particular ED system, the cost of producing water

TABLE IV-13. WATER DEMINERALIZATION BY ELECTRODIALYSIS

Species	Concentration (ppm)		Percent Remaining
	Feed	Product	
Sodium, Na^{+}	670	145	21.7
Calcium, Ca^{2+}	128	9	7.7
Magnesium, Mg^{2+}	16	1	6.0
Total hardness, $CaCO_3$	385	24	6.2
Chloride, Cl^{-}	1120	207	18.5
Sulfate, SO_4^{2-}	161	12	7.5
Bicarbonate, HCO_3^{-}	66	22	33.0
Nitrate, NO_3^{-}	4	1	--
Fluoride, F^{-}	1.84	0.88	47.8
Total dissolved solids (by summation)	2163	398	18.3

Source: Walter J. Weber, Physicochemical Processes for Water Quality Control, Wiley and Sons, Inc., N.Y., 1972

TABLE IV-14

PARTS & SUPPLIES COST FOR 12,000 GPD
ELECTRODIALYSIS PLANT*

Parts & Supplies	Cost
Electrode Spacer	$ 51.20
Muriatic Acid	88.90
Replatinize Elctrode, Grommet & Tape Gasket	110.55
Electrode & Cement	424.90
Bottom PVC End Block	124.45
Silica Sand	22.72
Filters	242.48
Connector Assembly & Mylar Tape	99.26
Cation & Anion Membranes	578.80
Total	$1,743.26

*Actual costs over a 1-year period from 1973-1974 was only $0.54/1000 gallons during the fiscal year 1973-74.

ION EXCHANGE (IE)

Ion exchange processes have been used successfully for demineralizing water. Many combinations of various cation and anion exchange resins have the ability also to demineralize water. Unlike zeolite softening, the principle of ion exchange and demineralization is that one resin will remove all "positive" ions and the other will remove all "negative" ions. Since salts are made up entirely of cations ("+") and anions ("-"), the process can remove all dissolved salts. The units are regenerated by soaking the resin in an acid to remove positive ions, and in an alkaline material to remove negative ions. This regeneration process is very similar to soaking zeolite resin in sodium chloride to restore the resin for softening.

There are a number of demineralizing ion exchange systems which can provide varying degrees of purity. Units are available using automatic or manual regeneration. Pilot studies using the water to be treated may be necessary to check the effectiveness of the proposed ion exchange system. As with other TDS removal methods, ion exchange systems should not be purchased or installed prior to consultation and approval from the regulating state agency.

Special Considerations For IE

Although cation exchange resins are quite stable and require infrequent replacement, anion exchange resins deteriorate more rapidly and must be changed more often. The most common contaminants which can foul resins include turbidity; sodium hydroxide; metal complexes such as copper, nickel, and cobalt cyanides; oxidizing agents; industrial organic contaminants; dissolved organic compounds; and micro-organisms. When these contaminants are present in the water supply, pretreatment may be necessary prior to treatment by ion exchange.

Another consideration which must be given attention is the provision of suitable disposal for regenerate wastes and rinse water.

Cost of IE

Although ion exchange may be quite suitable for small water supply systems, no actual cost data are available for rest area installations.

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V. HARDWARE AND EQUIPMENT SELECTION

Various pieces of hardware and equipment needed for different treatment processes were discussed in Chapter 4. Consequently, this chapter will deal solely with general guidelines for selection of such equipment.

In general, equipment should be selected based on special state and local requirements, reliability, availability, the experience and skill of operating personnel, comparative purchase cost, and the costs associated with operating and maintaining such equipment.

Local and state health authorities should be consulted for approval prior to the purchase of treatment equipment. Any new processes or materials should have been thoroughly tested and the results compared with those obtained with available, proven, commercially available equipment or material. The testing should have been performed by a nationally recognized testing laboratory or facility, or should have been performed under a qualified engineer with tests performed by qualified personnel associated with a recognized testing laboratory. Those supervising and making the tests should not normally be directly associated with the manufacturer or developer, or the results of tests by the manufacturer or developer should have been confirmed by qualified, independent authorities.

HARDWARE AND EQUIPMENT SPECIFICATIONS

Specifications should cover the quality, kind, and grade of all materials, equipment, construction workmanship, methods of assembly, and installation. Materials and appurtenances should be of a quality free from defects and suitable to accomplish the objectives for safety rest area water supply systems. As appropriate, suitable guarantees or warrantees should be required.

When specifications for hardware and equipment are being developed, the engineer should keep in mind national standards or "seals of approval"* applicable to equipment.

Some of the more common standards, specifications, and certifications which the engineer should consider and which may be required by some states are outlined below:

- Underwriter's Laboratory - UL (for all electrical equipment)
- American Society for Testing Materials - ASTM (for materials quality, kind and grade; for asbestos-cement pipes; and for plastic pipes and fittings)
- American Water Works Association - AWWA (for cast iron pressure fittings; for concrete, plastic, steel, and asbestos - cement pipes; for valves and hydrants; for water meters; and for pumping equipment
- National Sanitation Foundation - NSF (for plastic pipes, fittings, valves and tanks; cartridge type filters; and pitless well adapters)
- American National Standards Institute - ANSI (for cast iron pipes and fittings)
- Uniform Plumbing Code (International Association of Plumbing and Mechanical Officials, IAPMO, and National Plumbing Code (American National Standards Institute, ANSI) for acceptable pipe sizes, fittings, vacuum breakers or other equipment, unless covered by applicable state or local code.

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* For example, some hardware and equipment have no actual standards, but rather a 'seal of approval' by a recognized organization is given. (i.e., NSF issues a seal of approval on certain plastic water containers which can be adequately disinfected for reuse.)

EQUIPMENT "GUARANTEES"

The purchase of water treatment equipment should be only from reputable water equipment manufacturers and distributers. All equipment purchased should have a performance guarantee which conforms to specifications written prior to the purchase of the equipment. This is particularly important where the health of the public could be critically affected. For example, the accuracy and reliability of certain chemical feed equipment and chlorinators used in water treatment would be considerably important.

RELIABILITY OF EQUIPMENT, STANDBY EQUIPMENT, AND SPARE PARTS

Only with considerable attention to many design details of a water treatment plant can overall system reliability be obtained. The potential for equipment damage resulting from lightening, power loss and other adverse conditions also should be considered.

The degree of standby provided should be dependent upon the importance of the item under consideration. It is not necessary to provide a spare chemical feeder for corrosion control or for fluoridation, but it is recommended to provide a spare coagulant feeder when turbid water is expected, and always a spare chlorinator, disinfectant feeder, or disinfecting device. When continuity of pumping is essential, a spare pump unit also should be considered.

In many instances, the units under consideration may not be absolutely essential, and the plant will function moderately well without them for a limited period of time. For example, if a pump breaks down, a rest area having two wells* may function reasonably well with only one for a limited time so that no spare well pumps may be necessary.

An additional factor to be taken into account is the degree of risk involved. When the plant is treating a water that is highly

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* This is not to suggest that all rest areas be provided with two wells. However, there are cases where two wells have been provided at certain rest areas in order to provide a sufficient quantity of water under peak demand conditions.

contaminated, a more positive allowance for standby units should be made than might be required for a treatment such as iron removal alone. Provisions for automatic shut down also might be considered as an alternative.

EASE OF OPERATION AND MAINTENANCE

The efficiency of a water system's operation is heavily dependent upon maintenance. Responsibility for proper operation rests mainly with rest area operators, but the treatment system designer also has a vital role in this area. Selection of facilities and equipment suited to the anticipated skills and experience of operators, and the arrangement of facilities to promote safety and ease of operation enhance successful plant performance.

As a result, every effort should be made to utilize equipment which is reliable and which requires a minimum frequency of maintenance. Systems which call for constant manual handling of chemicals, and repeated maintenance or repair of equipment are not only inconvenient for the operator, but also increases labor costs and may contribute to equipment malfunctioning. Lack of maintenance and improper maintenance procedures will shorten the useful life of the equipment, create hardships, property damage, and sometimes can result in adverse health effects and even loss of life.

EQUIPMENT SERVICING BY MANUFACTURER

It is necessary to assure both the dependability and availability of manufacturer servicing of equipment, prior to the purchase of water supply equipment for rest areas. It is equally important that the availability of replacement parts for equipment be assured. This is particularly important when unique or new treatment processes are being considered. Past studies of rest area water supply systems indicate that many problems could have been avoided by more careful attention to the selection of equipment with respect to manufacturer servicing.

For all equipment, and certainly for very complex systems -- such as electrodialysis and reverse osmosis -- it is recommended that a special service agreement with the manufacturer be considered.

STANDARDIZATION OF EQUIPMENT

When conditions permit, standardization of water supply and treatment equipment at rest areas throughout a state, is recommended. Equipment standardization generally results in savings in purchasing costs, ease of repair, replacement, and operation. One spare standby system (pump, chlorinator, etc.) can be kept on hand in a centralized location to replace systems which break down or need repair.

Where state regulations are not designed to permit standardization of equipment*, engineers may be able to obtain permission from the state to purchase certain equipment from the same manufacturer, when such standardization could be proven to result in reduced health risks to the general public.

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* It is uneconomical or impossible for most highway departments to purchase water supply equipment in quantity for several planned rest areas far in advance of their anticipated use. As a result, separate specifications for equipment bids normally must be prepared for each rest area and the highway department in some states may be unable to routinely purchase equipment from the same manufacturer.

VI. Distribution System

Delivery of a safe water supply depends upon the protection of the water in the distribution system. Among the most important features of the distribution system are:

- Mains and pipes of adequate size to enable maintaining sufficient pressure throughout the system, during periods of maximum use.
- Valving arrangements to enable readily isolating various sections and fixtures from the system, for repair and during emergencies.
- Pressure and flow guages to aid in proper operation and to enable keeping records.
- Materials which are safe and which will withstand the conditions to which they may be exposed.
- Controls, devices and practices which prevent hazards from cross-connections.
- In sub-freezing climates, design and facilities to prevent freezing.
- Policies, procedures, equipment, materials and trained personnel to adequately disinfect and test the system or portions thereof. After repairs or replacements.
- Avoidance of laying water and sewer lines in same trench or in close proximity to each other, underground.
- Devices and valving to minimize water hammer, as needed.
- Fixtures which include self-stopping faucets and as indicated, flow restricters, to conserve water.
- Air relief and pressure reducing valves, as required.
- Meters and recording systems for quantity and quality of water.

Many failures to meet the bacteriological requirements of the National Primary Drinking Water Regulations are directly related to poor operating and maintenance procedures for distribution systems, or to the presence of sanitary defects in the system. Some causes that contribute to poor bacteriological quality are: cross-connections; inadequate main disinfection; close proximity of underground water to sewer mains; improperly constructed, maintained, or located blow-off, vacuum, and air relief valves; and negative pressures in the distribution system.

DESIGN, INSTALLATION, AND OPERATIONAL CONSIDERATIONS

The distribution system of a water supply presents many opportunities to impair water quality. A most common problem is contamination introduced during repair, replacement or laying and installation of new mains, repair of wells and pumps, and similar activities. Of special concern is contamination from water accumulations in trenches during pipe laying or replacement. This would be especially serious if sewer and water lines were in the same trench. Such installations would also present a hazard when negative pressures occurred in water mains. Because of these concerns, many codes prohibit laying water and sewer mains in the same trenches or in close proximity.

Policies and procedures should be adopted and personnel should be trained, provided with materials, equipment and test kits to assure effective disinfection and flushing of new and repaired portions of the system. Special consideration should be given to locating air relief valves, pressure regulators and back-flow preventing devices so they are not subject to flooding.

Water lines and hose bibs in proximity to the sewage treatment or disposal system should be protected with appropriate back-flow preventers. Special consideration should be given to the design of lawn irrigation systems to assure adequate protection from back-flow. Similar protection may be needed for connections to various water treatment units.

Plumbing codes, either local, state or national, should be followed to assure protection from back-siphonage from toilets, wash basins, and other potential sources of contamination.

PIPES

Types of Pipe Material

Materials used in water distribution systems should conform to applicable AWWA, ASTM, ANSI, NSF, or other applicable standards, including standards acceptable to the State. A number of factors must be weighed in selecting the best type of pipe for installation in different parts of a water system including: costs, availability, sanitation aspects of the material, durability, corrosion resistance, initial and sustained carrying capacity, and ease of installation and maintenance. In pipeline design, maximum internal pressures and external trench loading must both be considered.

CAST IRON PIPE. There are two types of cast iron pipe available for water systems: gray cast iron pipe (CIP) and ductile iron pipe (DIP). The characteristics of long life, toughness, imperviousness, and ease of tapping are provided in gray cast iron, whereas ductile iron pipe is stronger, tougher, and more dictile.

Although cast iron has a certain resistance to corrosion, some soft waters low in alkalinity and high in oxygen content can cause the pipe to lose an appreciable part of its carrying capacity as a result of excessive corrosion. Most cast iron pipe has a 1/8-inch thick lining of cement or enamel to help eliminate this deterioration problem. Cast iron pipe lengths may be joined together using several types of joints. The most commonly used joint is the "slip-on" joint which greatly speeds installation time and reduces costs. It has been reported that there is less problem with leakage using this type joint than with the use of older methods.

STEEL PIPE.[3] As described by AWWA standards, there are two types of steel water pipe: fabricated, electrically-welded steel pipe; and mill-type steel pipe. Steel pipe has four characteristics that make it useful in water systems: strength, an ability to resist load but yield to it, an ability to bend without breaking, and resistance to shock.

Like cast iron pipe, steel pipe is subject to corrosion by waters high in acidity, conductivity, carbon dioxide, and oxygen content. Corrosion protection can be provided by galvanizing the pipe, or by lining large diameter pipe with cement.

Steel pipe commonly is jointed by thread and coupling or by the use of companion flanges.

ASBESTOS-CEMENT PIPE. The ingredients used to make asbestos-cement pipe include: asbestos fibers, silica sand, and cement. Although asbestos fibers make up the smallest percentage of the total volume of pipe material ingredients, their tensile properties add significantly to the overall pipe strength.

Because of the concern for the carcinogenic properties of asbestos fibers, there has been some question of the suitability of asbestos-cement pipe for a potable water system. However, tests and studies have indicated very little migration of the fibers from the pipe to the water. Asbestos-cement pipe is currently considered fully acceptable for water supply installations.

By virtue of its method of manufacture, asbestos-cement pipe is smooth on the outside, and has a very smooth interior bore. Therefore, no coatings of any kind are used.

Because of its chemical composition, the pipe is relatively unaffected by corrosive water or soils. It has lower tensile and flexural strength than iron or steel pipe and requires good installation practices to prevent pipe damage. Special care should be taken when cutting the pipe so that no rough edges are left, resulting in erosion of asbestos fibers.

Asbestos-cement pipe lengths are joined by special couplings also made of asbestos-cement. Two flexible rubber o-rings are placed within the coupling and make a water tight seal. These joints also provide some degree of flexibility in laying the pipe.

Due to its initial cost, asbestos-cement pipes are becoming very popular, particularly in remote water systems.

COPPER TUBING. Although it is a little more expensive, copper tubing has many advantages over galvanized steel piping, including the fact that it is available in rigid as well as flexible forms. It is easier to transport and install, is generally more resistant to corrosion, and has a smoother inside surface which results in better pressure at service outlets. Copper tubing is classified by its wall thickness and hardness, and is available in types K, L, and M. Type K has the thickest wall, and is used for heavy duty purposes such as pump-suction lines and underground piping. Type L has a slightly thinner wall, is standard-weight, and generally used inside buildings. The thinnest and most light-weight copper tubing is type M, which should be used only for light-duty applications and should not be buried in the ground.

Hard copper tubing cannot be bent without kinking, and when a change in direction is required, a fitting such as an ell must be used. Soft copper tubing may be bent readily, using a bending tool.

Copper tubing should not be joined directly to galvanized pipe, without special non-electrical conducting fittings, since electrolysis could result under certain conditions, and cause the joint to corrode.

PLASTIC PIPE. Plastic, the most recent pipe material added to the market, offers several advantages over other piping materials. It is economical to purchase, light-weight, easily worked, and can stand a limited amount of freezing. In addition, plastic is practically immune to attack by natural waters, making it particularly valuable in areas where much incrustation of pipes is expected.

The primary disadvantages of plastic pipe are its loss of shape and strength when subjected to higher temperatures. However, plastic pipe specifically formulated and approved for elevated temperatures is available. Also, under certain conditions, plastic pipe may be susceptible to damage by gnawing rodents.

Manufacturers have adopted standards and a uniform system of labeling plastic pipe. The label should indicate the type of plastic used, size, pressure rating, manufacturers name, the commercial standard it meets, and the National Sanitation Foundation Seal (NSF). All plastic pipe used in water supply systems should be manufactured in accordance with ASTM and Department of Commerce Products Standards and should bear the NSF seal. This seal assures that non-toxic virgin materials were used and that the pipe is safe for drinking water systems.

Table VI-1 contains an alphabetical listing of various plastic materials that are, have been, or may be used in water systems. Only three are in common use today, PVC, PE, and ABS; with ABS now being used primarily for drainage, waste, and vent (DWV) fittings and pipe for interior application. ABS was popular a few years ago for water systems, but inasmuch as it has only half the available hoop stress compared to PVC, when subjected to internal pressure, the latter product is considered to be a better material for water lines.

Joints and fittings for plastic pipe are made from plastic, nylon, brass, galvanized iron and possibly other materials. Joints with plastic pipe and fittings are most commonly made with 'solvent welds' or by threading. Stainless steel clamps are also used.

Pipe Size

Water systems, regardless of size, cannot supply adequate capacity or pressure to all water-using outlets unless the distribution system is tailored to the water use requirements. If the pump and storage system pressures are adequate, but the piping is too small, it will not be possible to supply water outlets with the necessary flow rate or pressure during heavy use periods.

The pump, storage, and water distribution system must be considered as a unit in order to plan a water system for maximum economy and performance. This is due to the effect of discharge pressure on pump capacity. Figure VI-1 shows head pressure capacity curves for

TABLE VI-1. PLASTIC PIPING MATERIALS

Name	Composition	Application	Comment
ABS	Polymers of acrylonitrile, butadiene, styrene	Inplant chemical lines; service lines	Chemically resistant; lightweight; can be threaded, solvent welded or slip coupled; low mechanical strength
CAB	Cellulose acetate butyrate	Salt water; water lines; inplant systems	Range from flexible to rigid; can be threaded, slip sleeved, or solvent welded; low heat resistance.
CPVC	Chlorinated polyvinyl chloride	Hot water lines	Good heat resistance, dimensional stability; chemical inertness.
Delrin	Linear acetal	Water lines	Good mechanical properties; stability; low heat resistance.
Penton	Chlorinated polyether	Pipe lining	Good heat resistance; dimensional stability; chemical inertness.
PE	Polyethylene	Distribution mains; service lines; inplant systems	Resists impact at subzero temperatures; flexible, noncorrosive, soft.
PVC	Polyvinyl chloride	Distribution mains; service lines; inplant systems	Some forms resist impact; can be cut, threaded, welded, drilled, noncombustible; rigid.
PP	Polypropylene	Service lines; inplant systems	Greater high temperature resistance than PE; poor resistance to low temperatures.
Saran	Vinylidene chloride	Pipe lining	Chemically resistant; brittle at low temperature.
Teflon	Fluorocarbons	Pipe lining; inplant	Self-supporting tubing.

Source: U.S. Forest Service, Sanitary Engineering and Public Health Handbook (Draft), May 1976.

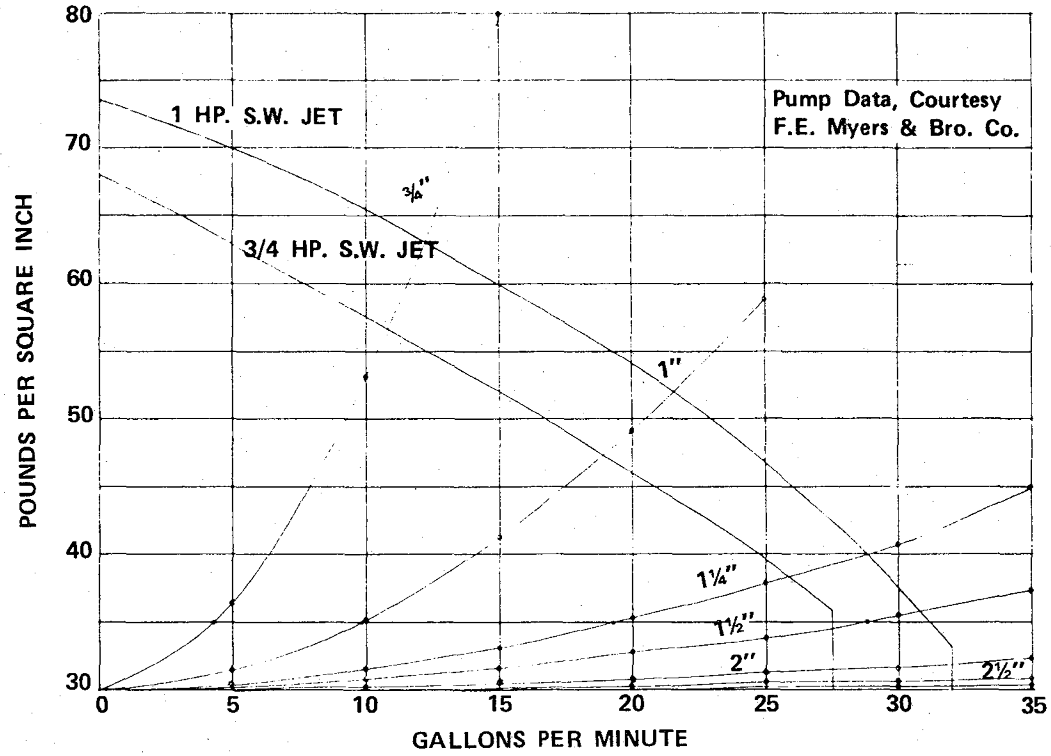

FIGURE VI-1. EFFECT OF PIPE SIZE ON SYSTEM CAPACITY various pipe sizes for a 3/4 and a 1 horsepower shallow well jet pump having flooded suction.

The proper selection of pipe size should take into consideration the following factors:

1. Head must be available to deliver adequate flow at fixtures.
2. Head variations due to friction loss at maximum flow rates should be limited. A maximum design head variation of 5-10 psi between static and design flow rates, at a fixture, is desirable.
3. Normal operating flow velocities should range from 2 to 7 feet per second.
4. Sizes of pipe to blow-off and drains should be adequate to pass material in the lines and develop a flushing velocity.
5. Water hammer, being a function of velocity, is developed when a liquid flowing in a pipe line is abruptly stopped by the closing of a valve. Dynamic energy is converted to elastic energy, and a series of positive and negative pressure waves travel back and forth in the pipe until they are dampened out by friction. Water hammer pressures can be greatly reduced by the use of slow-closing valves, automatic release valves, air chambers, and surge tanks.

In addition, adequate pipe size must be based on correct determination of peak water demands. Design work involving major hydraulic analyses and pipe sizing should be done by competent hydraulic engineers who are thoroughly familiar with both the theoretical and practical aspects of hydraulics. Interior piping, fittings, and accessories should conform to the minimum requirements for plumbing of recognized national plumbing codes, or the equivalent applicable plumbing code of the locality.

INSTALLATION OF MAINS[6]

The installation of water mains involves transporting and handling the pipe and appurtenances; ditching and excavation; laying, joining, testing, and disinfecting the pipe; backfilling the trench; and replacement of road, paving, sidewalk, lawn, or other surfaces.

Complete specifications for the installation of pipe and fittings are given in the AWWA standards.*

Excavation can be carried out in several approved ways - by hand labor, power shovel, back hoe, or trenching machine. In digging trenches, gradual curves should be made at bends in lines unless special elbows have been provided for these points. The trench should be opened only so far in advance of pipe installation as is necessary. It is best to keep the trench as narrow as possible and to shape the bottom on the trench to form a complete bed. If rock is encountered, or if the bottom material is undesirable for bedding, it should be excavated 6 inches (15cm) below the grade and refilled with sand or fine gravel tamped in place.

When the trench is suitably prepared, the pipe should be lowered and joined. All pipe connections should be made under dry conditions. Soiled piping should be thoroughly cleaned and disinfected before connections are made, and old piping should not be reused. Care should be exercised in handling all pipes, in order to prevent damage from occurring. Various pipe manufacturers give special instructions for the handling and jointing of their pipe.

Blocking or firmly positioning tees, bends, caps, plugs, hydrants, and other fittings is an important part of pipeline installation. Any unbalanced pressure in a pipeline must be counterbalanced with blocking or positive ties, inasmuch as many modern joints can easily be pulled apart.

After pipe, fittings, valves and other appurtenances are installed and inspected, a selected backfill is placed in the trench. The backfill material which is in close proximity to the pipe should

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* Available from: AWWA, 6666 West Quincy Avenue, Denver Colorado 80235

be free of rock and large stones, and should not contain cinders or other unsuitable substances which would not produce a dense, compact fill. In order to protect the pipe from future settlement and other disturbances, backfill material should be tamped in 6 inch (15 cm) layers at optimum moisture for a height of at least 12 inches (30 cm) over the piping. If possible, joints should be left exposed until pressure and leakage tests are concluded. Where trench settlement is unimportant, the trench can be filled with excavated material pushed in by bulldozers and mounded over the pipe trench, after the initial 12 inches (30 cm) of tamped material have been put in place.

CROSS-CONNECTIONS

A cross-connection is any actual or potential connection or arrangement, physical or otherwise, through which a non-potable water or other unapproved fluid could flow into a potable water system or facility.

There are two major types of cross-connections. The first is a direct connection between a potable water supply system and a system carrying unapproved water or fluids. Under such conditions the unsafe fluids can enter the potable water system whenever they are under higher pressure and the connection is open. These conditions must be eliminated, whenever possible. When it is not practical to eliminate such connections, they must be protected by an approved back-flow prevention device. The other type cross-connection is one whereby vacuums or negative pressures in the water supply system can draw contaminated or unapproved fluids into the water supply system. These conditions are avoided by providing an approved air gap between the water outlet and the overflow level of the fixture, tank or vessel to which the water discharges, or by proper installation and location of approved type vacuum breakers.

Control of cross-connections is possible only through knowledge and vigilance by the designer and operator of rest area water systems. The Cross-Connection Control Manual EPA 430/9-73-002, by EPA or some other comparable publication should be a familiar tool for both designers and operators. The reference list at the end of this chapter should be consulted for the EPA manual, as well as other appropriate cross-connection material. Regular surveillance for cross-connections should be carried out and also be part of an annual condition survey at each rest area. Plumbing and piping should be installed in accordance with recognized plumbing codes and only by persons (usually registered plumbers) who are aware of the dangers and types of cross-connections.

Identification of Potential Hazards

There are a number of plumbing hazards which could occur at rest area facilities. In some case, the health hazards could be severe, while other situations would be moderate or minor. Regardless of the severity, direct connections between potable and non-potable supplies should be eliminated completely, otherwise the connections should be properly protected using state health department approved methods and devices.

Removal of the physical link is preferred because it eliminates the possibility of failure of a mechanical device. However, the operation of some fixtures and devices requires water outlets which are submerged below the level of potentially contaminated liquids. For instance, the siphon jet and, in fact, all water inlets to the conventional water closet, terminate beneath the over-flow level. This, in the case of flushometer valve operated toilets, constitutes a potential cross-connection. However, all modern flushometer valve operated toilets are provided with approved vacuum breakers which effectively prevent back-siphonage or back-flow. Similarly, properly located, approved vacuum breakers at the hose bib prevent back-siphonage when the hose is submerged in potentially contaminating fluids.

Methods and Devices for Back-flow and Back-siphonage Prevention

Table VI-2 lists cross-connection hazards and recommended prevention devices. The list is not intended to be absolute or all-inclusive, but rather to serve as a guide in understanding cross-connections, their degree of hazard, and generally acceptable methods

TABLE VI-2.

CROSS-CONNECTIONS, HAZARDS AND RECOMMENDED TYPES OF PREVENTION DEVICES[1]

Direct or Indirect Water Connections	Degree of Hazard			Recommended Device				
					For Backflow		For Backsiphonage	
	Severe	Moderate	Minor	Air Gap*	Reduced Pressure Device	Double Check-Valve Assembly	Pressure Vacuum Breaker	Atmospheric Vacuum Breaker
I. Subject to backpressure:								
A. Pumps, tanks, and lines handling:								
1. Sewage and lethal substances	x			x	x			
2. Toxic substances	x			x	x			
3. Nontoxic substances		x			x	x		
B. Water connection to steam and steam boiler:								
1. Boiler or steam connection to toxic substances	x			x	x			
2. Boiler or steam connection to nontoxic substances (boiler blowoff through approved gap)		x		x	x	x		
II. Not subject to backpressure:								
A. Sewer-connected waste line (not subject to waste stoppages)	x			x	x		x	x
B. Low inlets to receptacles containing toxic substances	x			x	x		x	x
C. Low inlets to receptacles containing nontoxic substances		x		x	x	x	x	x
D. Low inlets into domestic water tanks			x		Each case should be treated separately			
E. Lawn sprinkler systems	x			x	x		x	x
F. Coils or jackets used as heat exchangers in compressors, degreasers, etc.:								
1. In sewer lines	x			x	x			
2. In lines carrying toxic substances	x			x	x		x	x
3. In lines carrying nontoxic substances		x			Each case should be treated separately			
G. Flush valve toilets	x			x	x			
H. Toilet and urinal tanks		x		x				x
I. Trough urinals		x						x
J. Valved outlets or fixtures with hose attachments that may constitute a cross connection to:								
1. Toxic substances	x			x	x		x	x
2. Nontoxic substances		x		x	x	x	x	x

* For backflow or backsiphonage

Source: AWWA, Cross-Connections and Backflow Prevention, Second Edition, 1974.

of protection. Each of the devices is discussed in more detail in the following paragraphs.

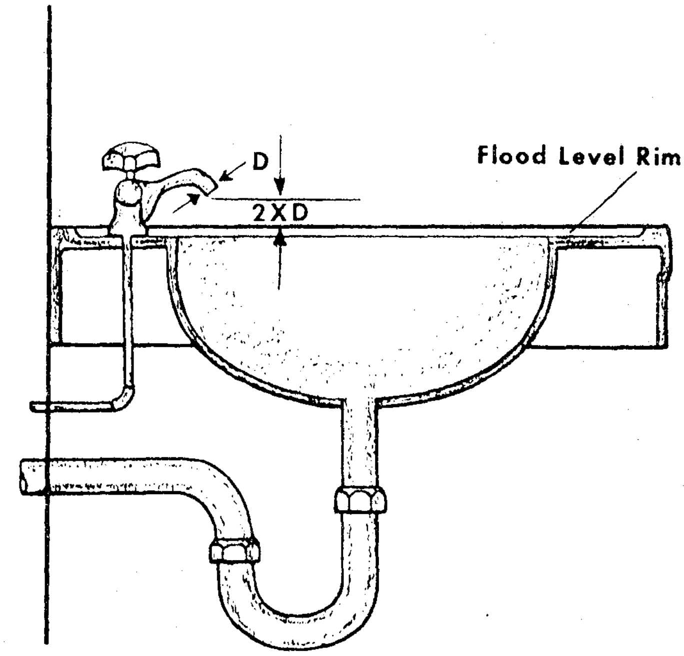
AIR GAP SEPARATION. The only absolute means of eliminating the physical link between a potable and non-potable system is through the use of an air gap, as illustrated is Figure VI-2. Air gaps should be used whenever possible and where they are used, must not be bypassed. The vertical distance between the supply pipe and the flood level rim should be at least two times the diameter of the supply pipe, but never less than 1" (2.5 cm). The air gap can be used on a direct or inlet connection and for all toxic substances. Some examples of commonly used plumbing fixtures which should be provided with air gaps are shown in Table VI-3.

Cross-connection control usually involves a combination of preventive measures. Air gap separation is usually practical for faucets over basins, sinks and hoppers. However, if faucets are threaded for a hose, a vacuum breaker is usually required downstream from the faucet. The lawn irrigation systems may be protected by simple vacuum breakers in some cases. However, where some sprinkler heads are at higher elevation than the water supply connecting valve, a more costly and effective back-flow preventer usually is needed.

Toilets and urinals which are directly connected to the water supply system in contrast to those with flushing tanks, usually must be protected by vacuum breakers.

The water line to a sewage treatment plant may have to be isolated by an air gap separation and re-pumping or by an approved back-flow preventer. However, local authorities should be contacted for regulations since back-flow preventers sometimes are not accepted as a substitute for air gap separation for water lines to sewage treatment plants or pumping stations.

ATMOSPHERIC TYPE VACUUM BREAKER. The most commonly used atmospheric type anti-siphon vacuum breakers incorporate an atmospheric vent in combination with a check valve. The unit is installed downstream from the control valve or faucet so that it is under pressure only



Source: EPA, Cross-Connection Control Manual, EPA, 430/9-73-002, 1973.

FIGURE VI-2. AIRGAP ON LAVATORY

TABLE VI-3.
Minimum Airgaps for Generally Used Plumbing Fixtures

Fixture	Minimum airgap	
	When not affected by near wall[1] (inches)	When affected by near wall[2] (inches)
Lavatories and other fixtures with effective openings not greater than 1/2 inch diameter	1.0	1.50
Sink, laundry trays, goose-neck bath faucets and other fixtures with effective openings not greater than 3/4 inch diameter	1.5	2.25
Over rim bath fillers and other fixtures with effective openings not greater than 1 inch diameter	2.0	3.0
Drinking water fountains-single orifice 7/16 (0.437) inch diameter or multiple orifices having total area of 0.150 square inch (area of circle 7/16 inch diameter)	1.0	1.50
Effective openings greater than one inch	(3)	(4)

[1] Side walls, ribs, or similar obstructions do not affect airgaps when spaced from inside edge of spout opening a distance greater than 3 times the diameter of the effective opening for a single wall, or a distance greater than 4 times the diameter of the effective opening for 2 intersecting walls.

[2] Vertical walls, ribs, or similar obstructions extending from the water surface to or above the horizontal plane of the spout opening require a greater airgap when spaced closer to the nearest inside edge of spout opening than specified in note 1 above. The effect of 3 or more such vertical walls or ribs has not been determined. In such cases, the airgap shall be measured from the top of the wall.

[3] 2 times diameter of effective opening.

[4] 3 times diameter of effective opening.

Source: EPA, Cross-Connection Control Manual, EPA 430/9-73-002, 1973.

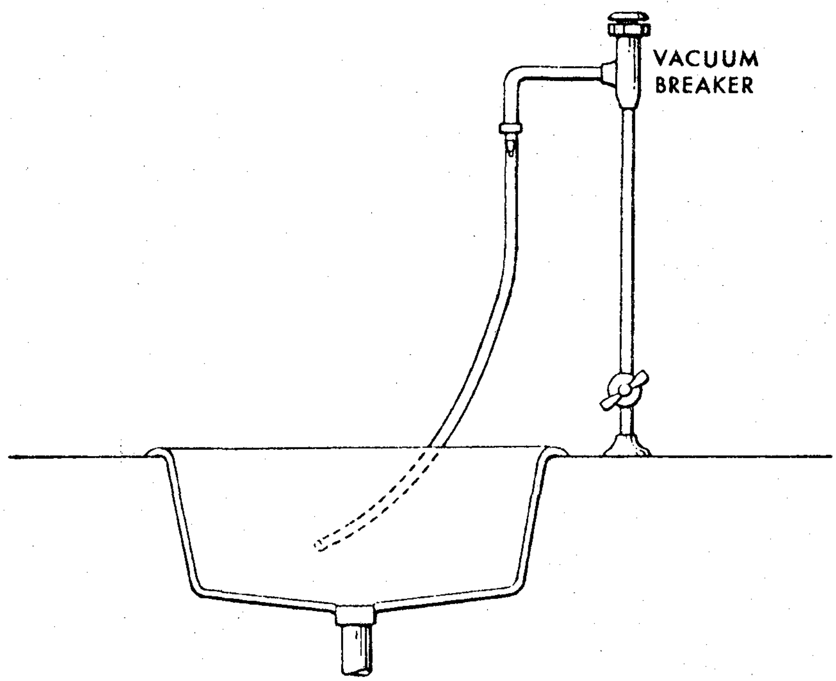
when water is flowing through. When the control valve or faucet is closed, a check valve closes the passage from downstream to the water supply line, and another valve-like arrangement provides an opening to atmosphere. If a vacuum occurs, the check valve tends to prevent back-flow and, at the same time, the opening to the atmosphere breaks the vacuum. The unit must be installed at least several inches above the overflow level of the fixture it serves. The combined action also prevents back-flow even though the valve parts may become quite deteriorated.

While air gap separation is preferred because it eliminates the possibility of failure of a mechanical device, there are many situations which necessitate vacuum breaker installation such as the flushometer valve toilet, hose bibs, and similar installations. Figure VI-3 shows a typical non-pressure type vacuum breaker installation on a faucet.

PRESSURE TYPE VACUUM BREAKERS.[3] Pressure type vacuum breakers may be used as protection for connections to all types of non-potable systems where the vacuum breakers are not subject to back-pressure. These units may be used under continuous supply pressure. They must be installed above the usage point.

A back-flow preventer with intermediate atmospheric vent is a device made for 1/2" and 3/4" lines and may be used as an alternate for pressure type vacuum breakers. In addition, they have the added advantage of providing protection against back-pressure.

REDUCED PRESSURE BACK-FLOW PREVENTERS. In situations where it would be extremely difficult to provide a physical break between two systems and where back-pressures can be expected, a reduced pressure zone back-flow preventer (RPZ) can be used, except where state or local regulations require air gap separation. As was mentioned previously, some states require air gap separation of lines serving sewage treatment plants and sewage pumping facilities. The back-flow preventer operates on the principle that there is a zone of reduced pressure



Source: EPA, Cross-Connection Control Manual,
EPA, 430/9-73-002, 1973.

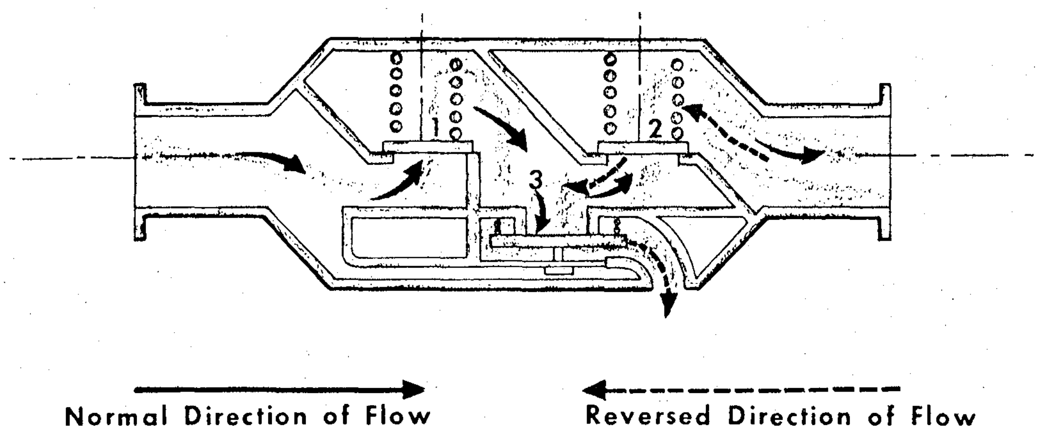
FIGURE VI-3. TYPICAL VACUUM BREAKER INSTALLATION between two check valve type devices, as illustrated in Figure VI-4. A differential pressure diaphram system opens a valve in the intermediate zone if its pressure ever approaches the pressure on the supply side. This assures that if the valves should become defective, it will not be possible for pressure in the intermediate zone to get high enough to cause a back-flow.

Reduced pressure zone devices are used on all direct connections which may be subject to back-pressure or back-siphonage, and where there is the possibility of contamination by material that does constitute a potential health hazard. This device requires testing to insure it is working properly. Some health jurisdictions require at least annual tests, with the results officially reported. Some jurisdictions require that the individual who conducts the test, in addition to having any other accreditation, such as a licensed plumber, must have passed special tests to qualify for periodic testing of back-flow preventers, double check valves and pressure vacuum breakers. Regulations usually require that such valve assemblies be equipped with appropriate test cocks to facilitate following required test procedures. If these valves are used in rest areas, regularly programmed inspections by accredited inspectors should be provided.

DOUBLE CHECK VALVE ASSEMBLY.[3] These devices are used on supply lines 1 inch (2.5 cm) and larger. The double check valve assembly costs less, but is less effective than the reduced pressure back-flow preventer. For this reason, a double check valve assembly is used as protection of direct connections through which foreign material might enter the potable system in concentration which would constitute a nuisance or be aesthetically objectionable, such as air, steam, hot water, or other material which does not constitute a serious health hazard.

APPURTENANCES

Every distribution system should be equipped with certain appurtenances in order to provide for adequate sanitation, operation, and maintenance. Those appurtenances considered to be essential to the water system include gages, meters and valves.



1 & 2 = Check Valves
3 = Zone of Reduced Pressure

Source: EPA, Cross-Connection Manual,
EPA, 430/9-73-002, 1973.

FIGURE VI-4. REDUCED PRESSURE ZONE BACKFLOW PREVENTER - PRINCIPLE OF OPERATION

Gages[3]

The operator of a water system needs to be aware of the pressures within the system. Water hammer, pressure fluctuations, and extremely low pressures are detrimental to the distribution facilities, inconvenient to the user, and may contribute to contamination. Opening fire hydrants and drains may cause low pressures and/or high velocities and may disturb sediment.

Pressure gages with maximum and minimum indicators located at appropriate points in a system can be a useful tool for rest area operators.

Water Meters

Water meters are necessary for obtaining water usage data associated with the operation and maintenance of a rest area system. Water meters provide important water usage data, including seasonal variations, which can be used in the design of future rest areas. The more complex systems may require several meters placed at more than one location. When these meters are strategically located, they can aid significantly in the detection and correction of leaks or breaks in the system.

There are a number of types of water meters which can be used at rest area facilities, the most common of which include saddle meters, flange tube meters and a simple meter which can be installed between a pair of flanges at any angle. The latter type is the simplest and most economical meter generally available. Some metering devices are capable of measuring flow rates, as well as total volumetric water usage. These devices are available in various ranges of flow rate capacities and are adaptable to several sizes and types of pipes.

The AWWA references on water meters listed at the end of this chapter will provide additional information on the selection and use of water meters.

Flow-Control Valves and Orifices

Valves serve to direct and control the flow of water. They can provide either ON-OFF or proportional control, manual or automatic adjustment, or fluid blending. Some valves such as check valves also are used in certain situations for back-flow prevention. Good piping design depends on the proper application and use of valves and fittings.

Valves are available in a number of designs: globe, ball, gate, plug, butterfly, diaphragm, and needle. All of these types can be equipped with devices to automate the application. Despite the wide range of designs, all valves have only one purpose: to slow down or stop the flow of fluid. Some designs provide accurate control characteristics, while others are only suitable for ON-OFF applications.

Valves are usually installed in pipes that supply water heaters, softeners and other equipment in order to permit shutting the water off while making repairs or alterations. These valves and devices normally are installed where piping enters the building.

GATE VALVES. This classification includes wedge, disc, double disc and plug disc. In general, these designs are all used for ON-OFF control and not for throttling of the flow. Problems that develop when these designs are used for throttling include a high pressure drop, erosion and wire drawing of the gate and seat, and the resulting failure to block the flow. Proper use of these valves includes installation as shut-off valves between pump and pressure tank or other equipment, bypass valves for equipment, or control valves and shut-off valves on supply lines. These shut-off valves allow the servicing of various parts of the system without draining the entire system. Figure VI-5 shows a typical illustration of a gate valve.

GLOBE VALVES.[3] This design includes disc globe valves, angle valves, Y valves, and needle valves. In general, the globe design, Figure VI-6, is a high pressure drop valve which enables accurate throttling of the flow. Repeatable, stable flow settings can be obtained with valves of this type.

When manual control of the rate of flow is necessary, the disc design is normally used. If accurate, automatic control is required, a needle valve is most practical since it provides sensitive adjustments proportional to flow. Seats and discs of globe type valves

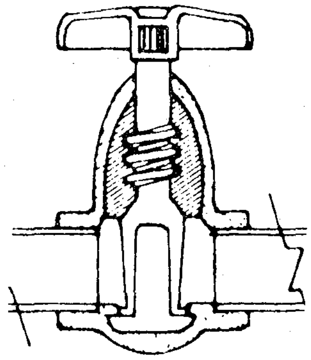


FIGURE VI-5. GATE VALVE

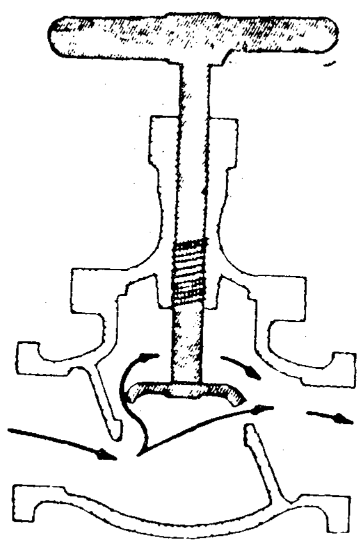


FIGURE VI-6. GLOBE VALVE

separate completely at the first turn of the hand wheel, eliminating the sliding friction that is a problem in gate valves. Globe valves are preferred where tight seating, frequent operation, and accurate control are required. Angle valves, though similar in construction and operation to globe valves, offer two added advantages. Because of the shape, two fittings can be eliminated, and the pressure drop is approximately one-half that experienced with globe valves since the fluid makes only one 90-degree turn.

BALL AND PLUG VALVES.[3] Ball and plug valves are intended for ON-OFF applications and should not be used for throttling flows. A ball or truncated cone (plug) with a hole approximately the same diameter as the pipe is used to pass or block the flow as illustrated in Figure VI-7. The restricting element rotates through 90 degrees from fully open to fully closed, providing a quick shut-off when needed. Because the valve orifice is straight-through with little change in diameter from the pipe diameter, these designs provide a very low pressure drop. In some instances, the entrance and exit pressure losses may be greater than the pressure drop across the valve.

CHECK VALVES.[3] Check valves are applied to prevent an undesired direction of flow in piping. Several designs are used, including ball, lift, and swing checks. When the flow reverses in the line, the check valve automatically closes, preventing the backward flow of the water as shown in Figure VI-8.

Check valves should always be installed between a deep-well reciprocating pump and the pressure tank to relieve pressure from the differential cylinder at the pump head. Submersible pumps may use two check valves. One valve usually is located at the top of the pump in order to prevent back-flow from causing the impellers to backspin. When a second check valve is used, it should be installed in the drop pipe, or pitless unit, in the well casing. This valve will allow a deep hole located between the two valves to drain part of the pipe. When the pump is started, it will then force the air from the drained part of the pipe into the pressure tank, thus recharging the pressure tank.

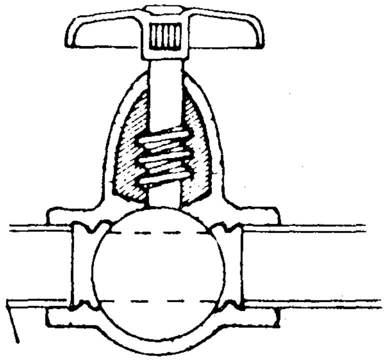


FIGURE VI-7. BALL VALVE

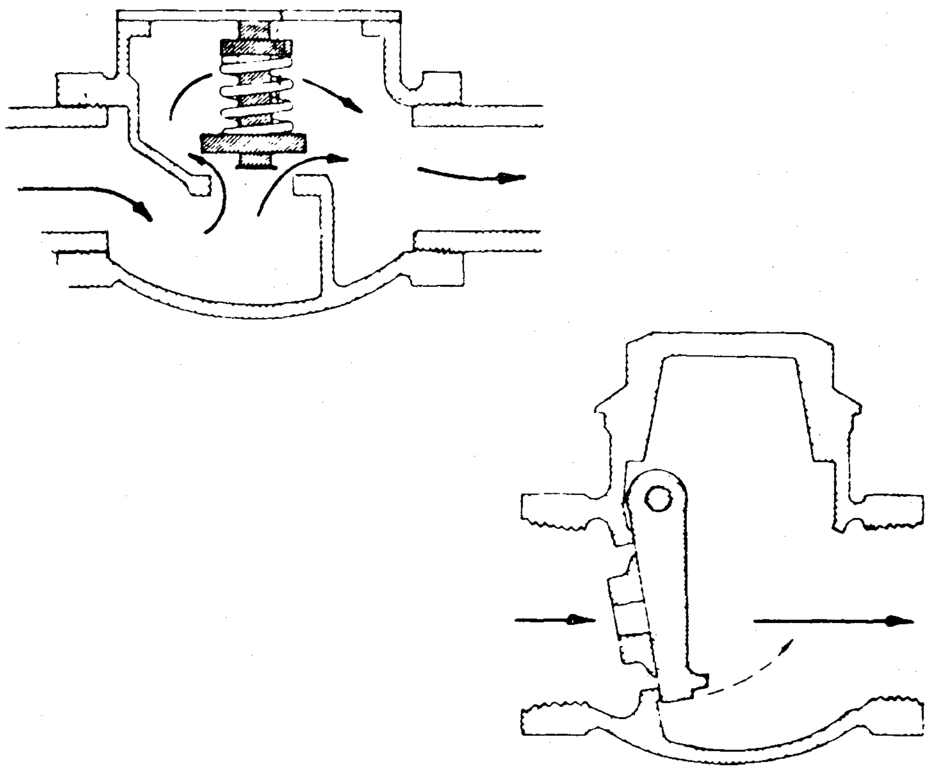


FIGURE VI-8. TWO TYPES OF CHECK VALVES

Each type of check valve design has a distinct area of application. Ball checks normally are used with small proportioning pumps or with diaphragm pumps on both the suction and discharge sides; swing checks are normally used in conjunction with gate valves; lift checks are used with globe valves for both liquid and vapor service.

Swing checks can be installed either horizontally or vertically. Horizontal lift checks are used on horizontal lines, and vertical and angle lift checks are used on vertical lines. Swing check valves provide a lower pressure drop than lift check valves, but lift checks provide tighter seating and are used where pressure drop is not critical.

Silent check valves are basically slow closing check valves. The rate of closing can be adjusted by an external weighted lever or by an enclosed spring which is part of the valve. These valves should be used in situations where the inertia of flowing water, if suddenly stopped, could damage parts of the system.

FOOT VALVES.[3] A foot valve (illustrated in Figure VI-9) is a special type of check valve installed at the end of a suction pipe or below the jet in a well to prevent back-flow and loss of prime.

The operation of most shallow well and deep well jet pumps is dependent, in part, on the proper functioning of the foot valve. The valve must have good flow characteristics to prevent excess vacuum loss which normally reduces pump capacity. Wherever it is possible, a foot valve should be used on shallow or deep type jet water systems to assure a positive prime from the water level in the well to the pump. This is an added protection for vital parts such as rotary seals, sealing rings and parts which may be damaged from heat.

RELIEF VALVES.[3] A relief valve permits water to escape from the system in order to relieve excess pressure. These valves are spring controlled and usually are adjustable to relieve at varying pressures. A typical relief valve is illustrated in Figure VI-10.

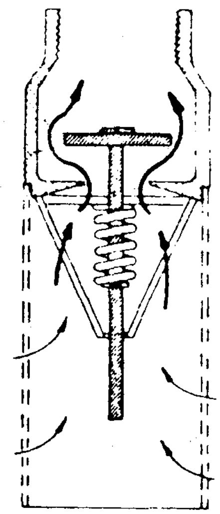


FIGURE VI-9. FOOT VALVE INSTALLED AT THE END OF A SUCTION PIPE

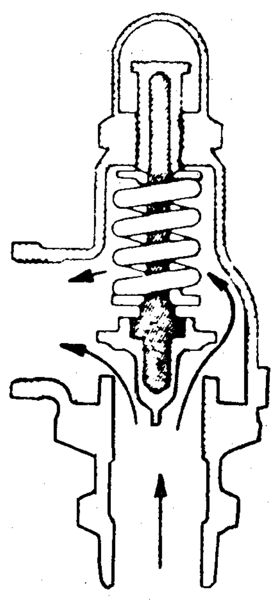


FIGURE VI-10. RELIEF VALVE

Relief valves should be installed in systems that may develop pressures exceeding the rated limits of the pressure tank or distribution system. Positive displacement reciprocating, and submersible pumps, and water heaters are such items which can develop these excessive pressures.

Whenever there is a question of safety, a relief valve should be installed. The relief valve must be capable of discharging the flow rate of the pump. The valve should be installed between the pump and the first shut-off valve.

FLOW-CONTROL VALVES.[3] Flow-control valves provide uniform flow at varying pressures. They are sometimes needed to regulate or limit the use of water because of limited water flow from low-yielding wells or an inadequate pumping system. They may also be needed with some treatment equipment.

These valves are often used to limit flow to a fixture. Orifices, mechanical valves, or diaphragm valves are used to restrict the flow to any one service line or complete system and to assure a minimum flow rate to all outlets. These valves are particularly useful at rest area installations where water conservation must be practiced.

SNIFTER VALVES.[3] A snifter valve will introduce air into the water displacement type of pressure tank air volume control. A snifter valve is similar in appearance to an automobile tire air valve, but has a weaker spring (see Figure VI-11). Snifter valves should be protected from dust, dirt and insects.

FROST-PROOF FAUCETS. Frost-proof faucets are installed on the outside of a structure, with the shut-off valve portion extending into the heated structure or below the frost level to prevent freezing. As long as the hose is disconnected, the water between the valve and the outlet will drain out after each use, so that no water is left to freeze.

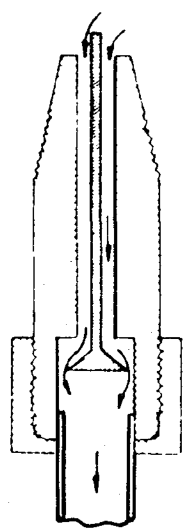


FIGURE VI-11. SNIFTER VALVE

FROST-PROOF HYDRANTS. Frost-proof hydrants make outdoor water service possible during cold weather without the danger of freezing. The shut-off valve is buried below the frost line. In porous soils, ordinary self-draining, frost-proof hydrants may be used. These hydrants employ a small weep hole in the base of the hydrant riser pipe as the means of draining the hydrant into a gravel filled sump in the porous soil, so that freezing will not occur. Properly located and designed, these hydrants do not pose a severe threat to public health; however, the installation of a check valve would provide added safety against possible contamination of the water supply.

In very tight soils where natural drainage is limited or non-existent, the hydrant should drain into a recepticle which can be pumped out after use.

In any case, frost-proof hydrants may be considered a cross-connection and may not be acceptable in all states. Such hydrants, therefore, should be used only after approval by appropriate regulating state agencies.

VALVES FOR SAMPLING AND TREATMENT. Design of the distribution system should include appropriately located sampling cocks or faucets. For instance, a sampling cock on the discharge line from the well will enable sampling the "raw water". A special arrangement may be provided to facilitate chlorinating the well, if chlorination should become necessary. Sampling cocks or faucets are required at various points in any treatment system to assure proper chemical dosages and results.

Switches

Float switches respond to a high and/or low water level as with the solenoid which controls operation of the water supply or well pump, or a basement sump pump. A pressure switch with a low pressure cut-off stops the pump motor if the line pressure drops to the cut-off point. A low-flow, cut-off switch is used with submersible pumps to stop the pump if the water discharge falls below a predetermined, minimum operating pressure. Switches which control supply and well pumps should be of a type which has high reliability and which can be rather accurately set.

PROTECTION PRINCIPLES

Water distribution systems should be designed, constructed, and operated to provide, at all times, an adequate supply of water at ample pressure, not less than 20 psi in all parts of the system. With friction and head loss taken into account, a normal operating pressure of 30 to 35 psi is recommended. Low or negative main pressure represents a definite health hazard, as contamination from trenches, cross-connections, poor quality plumbing or other system hazards can be drawn into the water supply. It has been found that most of the rather recent water-borne disease outbreaks were the result of contamination of the water after it was pumped into the distribution system. For this reason, an adequate disinfection residual, if disinfection is provided, should be maintained and in no case should the residual pressure go below 20 psi.

SEPARATION OF WATER MAINS AND SEWERS

To avoid the possibility of contamination of water supplies by sewage, it is necessary that certain precautions be taken where sewer and waterlines must be installed in the same area. Horizontal and vertical separation are necessary, but where it is impossible, special care must be taken in construction of the pipelines.

Parellel Installations

Water mains should be laid at least 10 feet (3 m) horizontally from any sanitary sewer or sewer manhole. Separation distance should be measured from edge-to-edge. No water pipe or main should pass through or come in contact with any part of a sewer or sewer manhole.

When local conditions prevent a horizontal separation of 10 feet (3 m), a water main may be laid closer to a storm or sanitary sewer if the bottom of the water main is at least 18 inches (46 cm) above the top of the sewer. Where this vertical separation is not feasible, the sewer should be constructed of materials and joints that are equivalent to water main standards of construction and be pressure tested to assure watertightness prior to backfilling.

Crossing

When conditions do not allow a vertical separation with the water line crossing 18 inches (46 cm) above the sewer line, the new water line should be encased in concrete for a length of 10 feet (3 m) normal distance on each side of the sewer crossing. Stability of the water and sewer lines at a point of crossing is critical, inasmuch as leakage of either one may damage the bedding of the other and thereby result in contamination of water.

PIPELINE PROTECTION

Pressure Testing and Leakage Testing[6]

As previously discussed, the pipe system and its appurtenances should be designed to maintain an adequate positive water pressure (normally 30 to 35 psi) throughout the system.

In laying new mains, hydrostatic-pressure tests and tests for leakage should be made prior to completion of trench backfilling. To make such tests each valved section of the main should be slowly filled with water and air should be expelled from the line through hydrants or taps made at the high points.

The pressure test is usually made by means of pump and test gage and at a test pressure at least 50 percent greater than the working pressure in the line. The test pressure should be maintained for at least one hour, and an examination should be made of the line for visible leaks or pipe movement. Any obvious defects should be fixed before the leakage test is made and the pipe is backfilled.

The leakage test should be conducted after the pressure test is completed. Leakage tests are conducted by measuring, through a calibrated meter, the amount of water which enters the test section under normal working pressures for a period of at least two hours.

Corrosion Control

The control of corrosion is important not only for continuous and efficient operation of the rest area water system, but also for delivery of properly conditioned water that has not picked up trace quantities of metals that may be hazardous to health. Whenever corrosion is minimized there is an appreciable reduction in the maintenance and the potential need for replacement of water pipes, water heaters, or other metallic appurtenances of the system.

Corrosion of metals underground is a complex process. A study of corrosion history in similar soils of the area is undoubtedly the best indicator of the exterior corrosion that can be expected. A chemical analysis of the water to be used, and determination of the pH will indicate the corrosiveness of the water. The important characteristics of a water that affect its corrosiveness include the following:[3]

- Acidity - A measure of the water's ability to neutralize alkaline materials. Water with acidity or low alkalinity tends to be corrosive.
- Conductivity - A measure of the amount of dissolved mineral salts. An increase in conductivity promotes flow of electrical current and increases the rate of corrosion.
- Oxygen content - Amount dissolved in water promotes corrosion by destroying the thin protective hydrogen film that is present on the surface of metals immersed in water.
- Carbon dioxide - Forms carbonic acid which tends to attack metallic surfaces and asbestos-cement pipe.
- Water temperatures - The corrosion rate increases with water temperature.

The materials and methods commonly employed in control of corrosion are described in the following paragraphs.[3]

- Corrosion-Resistant Metals or Alloys. These materials either possess low corrosion potentials or form protective coatings of dense oxides when corroded. Examples are: stainless steel, monel metal, tin, and copper.

- Coatings. Coatings interrupt both anodic and cathodic reactions by preventing escape of cations and denying access of water and oxygen. Metallic (zinc, tin, and chromium) or nonmetallic coatings (paints, cement, bituminous materials, epoxy and plastic) are used. Zinc coatings (galvanizing) protect pipe by oxidizing to form a protective film. In acid conditions, however, zinc galvanizing is not an effective protection.

- Nonmetallic Materials. Poor conductors of electricity such as wood, asbestos, cement, concrete, epoxy and plastic are resistant to corrosion under most conditions. These materials are, however, subject to deterioration other than corrosion. For example, sulfate compounds may cause deterioration of concrete.

- Insulation. Insulation creates a resistance to the flow of electrical currents. Examples are (1) the insertion of insulating couplings or connectors (rubber or plastic gasket) between dissimilar metals to prevent galvanic currents and (2) the use of insulation joints in water mains to oppose the flow of stray electrical currents.

- Cathodic Protection. Cathodic protection can be provided either by (1) attaching a metal of higher oxidation potential to the pipe (such as aluminum or zinc) which will corrode and be sacrificed to provide desired protection, or (2) by using direct-current electricity to feed electrons into the metal to produce a negative charge so that electric currents will flow from the surrounding soil to the metal instead of the reverse. Cathodic protection systems should be designed by engineers familiar with such systems.

- Other Prevention Methods. When corrosion is caused by the acidity of the water supply, it can be effectively controlled by installing an acid neutralizer ahead of a water softener. Another method of controlling some corrosion conditions is by feeding small amounts of commercially available film-forming materials such as polyphosphates or silicates. Other methods for controlling corrosion are the reduction of velocities and pressures (if they are excessive), removal of oxygen or acid constituents, and chemical treatment to decrease the acidity.

  Caution should be exercised in adding chemicals to the water supply for corrosion control. These chemicals should conform to applicable AWWA Standards and must be approved by the regulating state agency.

Protection from Freezing

As a result of freezing, physical damage (cracking or breaking) to water lines can create sanitary hazards to water quality in addition to interrupting service. As a precaution, the top of all water pipes should be at least 6 inches (15 cm) below the maximum recorded depth of frost penetration in the area of installation. The minimum depth of water mains should be 3 feet (0.9 m) from ground surface to top of pipe. NOTE: In some areas of the U.S., the frost line will extend below 3 feet (0.9 m). It is recommended that local soil authorities be consulted with regard to frost depth, if frost is a concern.

Disinfection[1]

New mains and repaired main sections should be adequately disinfected before being placed back in service. The procedure for disinfection of the water distribution system is as follows:

- The entire system should be thoroughly flushed with water to remove any sediment that may have collected.
- Following flushing, the system should be filled with a disinfecting solution of calcium hypochlorite and treated water. This solution is prepared by adding 1.2 pounds of high-test 70 percent calcium hypochlorite to each 1,000 gallons of water, or by adding 2 gallons of ordinary household liquid bleach to each 1,000 gallons of water. A mixture of this kind provides a solution having not less than 100 mg/l of available chlorine.
- The disinfectant should be retained in the system, tank, or standpipe, if included, for not less than 24 hours, then examined for residual chlorine and drained out. If no residual chlorine is found present, the process should be repeated.
- The system is next flushed with treated water and put into operation.

Bacteriological Sampling

Before new or repaired lines and appurtenances are placed in service, the absence of contamination should be demonstrated by bacteriological sampling and examination. This sampling should be completed after disinfection and flushing of the system as previously described. It should be noted that this sampling normally would be considered a "special" or separate sampling required in addition to routine surveillance sampling prescribed under state and federal regulations. The routine surveillance program is discussed in detail in Chapter 8 of this manual.

References

EPA, Cross-Connection Control Manual, EPA 430/9-73-002, 1973. 401 M. Street S.W., Washington, D.C. 20460.

AWWA, Backflow Prevention and Cross-Connection Control, AWWA Manual M14, 1966. AWWA, 6666 W. Quincy Ave., Denver, Colorado 80235.

AWWA, Cross-Connections and Backflow Prevention, 2nd Edition, 1974. AWWA, 6666 W. Quincy Ave., Denver, Colorado 80235.

AWWA, Water Meters - Selection, Installation, Testing and Maintenance, AWWA Manual M6, 2nd Edition, 1973. AWWA, 6666 W. Quincy Ave., Denver, Colorado 80235.

AWWA, Sizing Water Service Lines and Meters, AWWA Manual M22, 1975. AWWA, 6666 W. Quincy Ave., Denver, Colorado 80235.

VII. Operation and Maintenance

The objectives of operation and maintenance (O&M) of water systems are to achieve optimum performance and economy with proper utilization of personnel. All rest area water supply systems should be operated and maintained in an effective and efficient manner in accordance with all state and local requirements. The tool for optimum performance is the O&M Manual, and the keys for full operator effectiveness are his qualifications and training. The Safe Drinking Water Act and its primary regulations provide justification for proper water system planning, design, construction, operation and maintenance. Existing systems may need modifications, or very complex operation by highly skilled operators to meet the new water quality standards.

PERSONNEL/STAFFING

All rest area water supplies should be maintained and operated by personnel who are qualified by training, education and experience to be fully competent to effectively carry out the functions which are requisite for a safe and reliable water supply. Modern equipment and procedures alone are not enough to produce consistently high quality water service. Qualified and efficient personnel are the key to good operation and maintenance which is so essential to providing a safe and adequate water supply to the traveling public.

OPERATOR CERTIFICATION

Certification through appropriate state certification programs is satisfactory evidence of operator competency. It is recommended that operators of rest area water supply systems be properly trained under one or more of the training programs discussed later in this chapter. Whenever possible, and wherever complex water treatment systems are used, the operator also should be certified by the state, or should meet the requirements of a good state certification program for the type system he will operate or supervise. In some cases, certification of rest area operators at very small facilities may not be advisable. For example, some highway departments have found that certifying maintenance personnel makes the trained individuals a target for employment with adjacent small communities. In deciding to certify rest area operators, it must be remembered that operator certification may be a mandatory requirement of some states.

Whether or not the operators are certified, it is strongly recommended that at least one person from each highway district in each state be trained and certified or qualified for certification in order to insure that (1) acceptable sampling practices are being used, (2) maintenance of equipment is kept up to date, and (3) required notifications are correctly processed. By having certain district level engineers qualified for certification, at least one individual would be available to take care of problems at several rest areas, as well as assist in training new personnel when operator job turnovers occur.

OPERATOR TRAINING

The following paragraphs briefly describe some of the more common water treatment operator training programs which state highway departments may wish to consider.

State Regulatory Agency Sponsored Classes

As a result of the Safe Drinking Water Act, many states already sponsor, or plan to sponsor operator short course training sessions. These are often conducted in collaboration with colleges or universities, where laboratory facilities are available. The programs will vary in size and complexity from state to state, but in many cases, the program will provide at least basic training in the operation of water treatment plant processes most commonly used in the state. The state agency with primary enforcement responsibility should be contacted directly for a list and description of training courses available.

American Water Works Association (AWWA)

AWWA offers a number of publications, training course outlines, and training workshop packages. Material is available for various grades of classification. The course material is designed for use by both instructors and students in short courses, night schools, or in service training programs.

AWWA also offers a series of films and slides for use in safety training. Among the AWWA manuals which describe the basic water supply practices normally associated with water system operations are:

- Safety Practice for Utilities
- A Training Course in Water Distribution
- Simplified Procedures for Water Examination
- Recommended Practice for Backflow Prevention and Cross-connection Control
- Basic Water Treatment Operator's Manual
- Emergency Planning for Water Utility Management
- Water Chlorination Principals and Practices.

These, and other useful material can be obtained by contacting AWWA directly:

American Waterworks Association
6666 West Quincy Avenue
Denver, Colorado 80235.

Local City High School and College Courses

A number of local high schools and city colleges offer special training courses for the operation of water supply systems. In some cases these courses are taught by or sponsored by state health department staff members. The availability and usefulness of such courses should be examined when operator training programs are being planned.

On-the-Job Training by Equipment Manufacturers

When water treatment equipment is initially purchased and installed at a rest area, some provision should be made to adequately train at least one member of the state's highway department and the rest area manager to operate and maintain the equipment. This could be achieved by making sure that the manufacturer provides adequate on-the-job training when the equipment is installed.

State Highway Department Classes

Some state high department may find limited training courses available, or a lack of sources specifically tailored to the needs of rest area operators. In this case, the state highway department may need to provide its own special training courses to satisfy the sometimes unique requirements apparent at rest areas. Should this situation occur, it is recommended that AWWA be contacted for a complete listing of available teaching aids and publications. In addition, the state health department or other agency with primary enforcement responsibilities should be contacted for their support. State highway departments also may find useful information available from the EPA. For example, a "Manual for Water System Operators" currently is being developed for EPA by AWWA. An FHWA Rest Area Training course on water supply and wastewater treatment also is under development, and will be useful to state highway departments in the near future.

OPERATION AND MAINTENANCE MANUALS FOR OPERATORS

The purpose of an O&M Manual is to give water treatment operators the proper understanding, techniques, and references necessary to efficiently and effectively operate and maintain their systems during routine and emergency periods. The manual should cover the entire system and should provide answers to the questions that frequently arise during operation. Every rest area water system, regardless of size, will benefit if operated in conjunction with a well-prepared

O&M Manual. Ideally, the state highway department would prepare a single general manual reflecting state regulations, and be applicable to all rest areas in the state. This "general" information could then be supplemented with detailed manufacturer operating and maintenance procedures which normally would accompany various pieces of equipment in use at each specific rest area.

A good O&M Manual considers the complexity of the system and is tailored to the needs, comprehension, and competence level of the person who will ultimately be operating the system. It should be a flexible tool which can be modified and updated as necessary. In addition, the manual must be comprehensive and accurate, since it will be the only guide available specifically prepared to assure proper O&M for the life of the rest area facility.

CONTENTS OF MANUAL

The format and content of the O&M Manual should be tailored to the specific system. The following is a suggested list of those items considered most essential to an O&M manual. For smaller systems, several chapters may be combined or in some cases deleted. Manuals should be prepared in a hard covered loose-leaf binder so that updates and amendments can be readily accomplished.

<u>Table of Contents</u>:

1. INTRODUCTION

   Operator responsibility and how he fits into the state highway department organization, planning and budgeting requests for system O&M, job qualifications, certification and appropriate training requirements and opportunities.

2. STANDARDS AND REQUIREMENTS

   Primary and secondary drinking water standards, monitoring requirements and frequency and reporting procedures.

3. SAFETY

   Emergency telephone numbers, electrical hazards, mechanical hazards, chlorine and chemical hazards, explosion and fire hazards, safety equipment requirements (first aid kits, gas masks, fire extinguishers, etc.) accident reporting, list of pertinent safety references, warning signs and sample wording, barricades and warning lights.

4. SYSTEM DESCRIPTION, OPERATION AND CONTROL

   Overview of entire water system, simplified flow diagram, discussion of each unit process, common operating problems and possible solutions, instructions on start-up and shut-down procedures.

5. LABORATORY TESTING

   Sampling program, including complete description of sampling instructions, sampling equipment and sample preservation, analytical techniques, interpretation of test results, sample result records, list of names and addresses of state and/or certified commercial laboratories.

6. MAINTENANCE

   Planning and scheduling for maintenance items, equipment and parts inventory, special tools and equipment maintenance records, lubrication, warranty provisions, contract maintenance.

7. CONDITION SURVEYS*

   This is a regular on-going responsibility of the operator to inspect various parts of the water system for damage and wear, in order to allow time to purchase replacement parts. A checklist should be developed for the specific system as part of the O&M manual. Framework and scheduling for periodic in-depth survey of the entire system also should be provided.

8. UTILITIES

   Outline and description of various utilities and their interrelationship and what to do should failure occur, location of all utility lines on the site, list of names, addresses and phone numbers to contact for all utilities.

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* Not to be confused with the sanitary survey referred to in the National Primary Drinking Water Regulations.

9. EMERGENCY PLANS AND PROCEDURES

   Summarize possible situations of an emergency situation, safeguards and alarms built into the system, action to be taken in the event of an emergency, coordination and contacts to be made, emergency standby equipment (including types of equipment, their location and operation).

10. RECORDS AND REPORTS

   Daily operating logs (such as chlorination records), reports to state and Federal agencies, laboratory records and reports, maintenance records and reports, operating costs and records (such as those for chemicals, supplies, equipment replacement), sanitary survey records.

11. APPENDIX

   As-built drawings, sample forms and worksheets, schematics, manufacturer's literature and manuals, and other material too bulky to include in the main text of the manual. This material may be bound separately if necessary.

REFERENCES FOR MANUAL PREPARATION

It is strongly recommended that the manual preparer obtain a copy of Considerations for Preparation of Operation and Maintenance Manuals (listed below). This document is the basis for the guidelines listed above, modified for the smaller and less complex systems characteristic of rest area installations. Contained with the manual are detailed checklists and narratives of O&M functions, sample forms, reports, and cost-labor job estimates. State and local regulations, policies, requirements, reporting instructions and related materials also should be consulted and should be included as reference material, along with the following:

1. Considerations for Preparation of Operation and Maintenance Manuals, EPA-430/9-74-001, U. S. EPA, Office of Water Program Operations, Washington, D.C. 20460
2. Standard Methods for the Examination of Water and Wastewater, 14th Edition, AWWA, WPCF, APHA

3. Manual of Individual Water Supply Systems, EPA 430/9-73-003, U.S. EPA, Water Supply Division, Washington, D.C. 20460
4. Manual for Evaluating Public Drinking Water Supplies, U.S. EPA, Water Supply Division, Washington, D.C. 20460
5. Recommended Standards for Water Works, Report of Committee of the Great Lakes — Upper Mississippi River Board of State Sanitary Engineers. Published by Health Education Service, Box 7283, Albany, New York 12224
6. Basic Level Water Treatment Operator's Practice, AWWA, 6666 W. Quincy Avenue, Denver, Colorado 80235

It is also recommended that state regulatory agencies and equipment manufacturers be contacted for their lesson books as helpful references in the preparation of O&M manuals. Also, as previously mentioned, various relevant publications by AWWA should be consulted and made available during manual preparation.

SERVICE/MAINTENANCE OF EQUIPMENT

An effective equipment maintenance program is necessary to insure that all equipment is kept in a highly reliable operating condition. It is important to provide sufficient funds for maintenance, repairs, spare parts, and standby equipment to keep the system operating satisfactorily.

Each rest area should have adequate tools, equipment, work area, stock of spare parts, and other essentials for maintaining all parts of the system without undue or unnecessary interruption of service.

Every rest area also should have a planned program of preventive maintenance which includes regular inspection, lubrication, prompt restoration of worn parts, servicing, and other maintenance in order to minimize breakdowns and thus permit continuous functioning of the system.

It is unwise to depend upon memory or the personal notes of supervisors or operators for the scheduling of preventive maintenance. A planned maintenance program should be designed to accomplish the following objectives: (1) schedule inspections, lubrication, and necessary repairs of regular and standby equipment on a definite periodic basis; (2) time preventive maintenance work so that it is evenly distributed throughout the year; (3) standardize each inspection procedure, itemizing and illustrating all items to be covered; (4) schedule maintenance work so that similar or related work is done consecutively; (5) provide a readily accessible record of the maintenance work to be performed upon each piece of equipment at given times during the year, together with a record of when such work was actually performed.

The following sections describe general maintenance requirements normally associated with various parts of the common water supply system. It is not intended to serve as a complete preventive maintenance program, but rather as a guide to providing an effective maintenance program. More detailed information should be obtained from manufacturers specific equipment. Other references which may be useful include:

1. Water Utility Equipment Maintenance Manual, Texas A&M University, Engineering Extension Service, College Station, Texas
2. Rural Water Systems Planning and Engineering Guide, Commission on Rural Water, contains troubleshooting guide for pumps. (Available from Information Clearinghouse, 221 North LaSalle Street, Suite 2026, Chicago, Illinois 60601.)

It should be cautioned that whenever equipment and devices which come in contact with the water supply are repaired or replaced, they should be thoroughly disinfected to protect the water supply from contamination. This word of caution should be emphasized to operators both in training classes, and in O&M manuals.

PUMPS AND CONTROLS

Routine maintenance should begin with frequent inspections of the entire pumping unit. Inspections should include the following:

- Packing - to see that it is properly adjusted (and lubricated if it is a lubricated packing)
- Mechanical Seal - if used, should be checked for cooling, alignment, tension and/or lubrication
- Bearings - check for vibration, overheating, roughness, lubrication
- Motors - to be sure they are not over-heating
- Controls - to determine that pumps start and stop at planned pressures
- Air-water levels - for pneumatic tanks to assure that planned air-water level is maintained to avoid excessively frequent starting of pump
- Overload controls and safety switches - to assure these are in proper working order
- Check-valves - periodically check to determine they are not leaking
- Storage tanks - periodically observe to assure pumps are not delivering excessive amounts of sand
- Draw-down and water level - periodically check water level in well with pump operating and idle.

All belts, bolts and electrical connections should be checked and tightened when found loose. The pump and surrounding area should be kept clean, dry, and properly painted to prevent rust; and exposed metals which are subject to corrosion should be properly painted.

For reciprocating pumps, routine maintenance also should include checking valve settings, and replacing piston rings. In some cases, cylinder liners, piston rods, bearings, and gaskets also must be replaced as a result of wear.

CHEMICAL FEEDERS

In addition to the maintenance considerations described below, procedures should be developed to periodically test the accuracy of the dosage applied by all chemical feeders.

Dry Feed Units

Generally, the maintenance on dry feed units consists of keeping them operating freely and accurately. This is accomplished by keeping all moving parts lubricated, all belts or chain drives properly adjusted, and the build-up of chemicals removed from weighing and dispensing areas. This is because the accumulated weight of the build-up is being weighed each time and results in an inaccurate feed.

Solution Feeders

Solution feeders usually are diaphragm pumps or piston or plunger pumps and generally are classified as metering pumps. These pumps all have adjustments for regulating the feed, and are controlled by changing the length of the plunger stroke, variable speed drives, or using belt and step pulleys. On all units, there are check valves and section and discharge valves, all of which must be kept free and clean. Proper lubrication where required is essential to satisfactory operation.

FILTERS

Diatomite Filters

As previously discussed in Chapter 4, diatomite filters may be designed for simple periodic replacement of the entire filter coating or for continuous addition of a "body feed." The latter is especially necessary for waters with considerable turbidity and suspended material which would otherwise necessitate excessively frequent replacement of the filter coating. Constant automatic addition of diatomite (body aid) prolongs the period between back-washing.

In most cases the system is designed to deliver at the established flow rate until the pressure loss through the filter reaches an established maximum, as determined by gauges which read inlet and outlet pressures, or directly read the pressure loss through the filter system.

The thoroughness of removal of the partially clogged filter cake depends in part upon the filter design and in part upon proper operation. For instance, some systems include mechanical spinning of the filter unit to aid in cleaning. The adequacy of filter maintenance should be periodically checked by reading the rate-of-flow indicator to assure that the unit is delivering water at its design rate. Proper provision must be made for collecting and disposing of the removed filter material.

Activated Carbon

All activated carbon units must be serviced or replaced when tests or observations indicate the unit is not properly removing taste, odor, color or other elements for which it is intended. If the activated carbon unit also removes turbidity, pressure loss through the unit will build up, as in all filters, and the unit must be serviced or replaced as necessary.

When cartridge-type, pre-coat filters are used, maintenance consists of replacing the entire cartridge when the water pressure decreases noticeably, or the unit is no longer performing its intended function.

Larger type pre-coat filters, on the other hand, must be removed and cleaned by washing them of accumulated dirt particles. After several cleanings, the filter material becomes exhausted and must be replaced.

Maintenance for bed-type activated carbon filters consists of backwashing the filter bed to remove suspended dirt particles, or replacing the spent carbon. The frequency of cleaning and backwashing or carbon replacement depends upon the type of carbon filter system used and the frequency at which the filter becomes saturated with contaminants. When used in connection with sand or similar granular filters, activated carbon is added along with a coagulant, and is automatically removed when the filter is backwashed.

DISINFECTION UNITS

From a public health viewpoint, disinfection can be the single most important step in water supply operation. As previously stated, the disinfecting unit usually should be provided in duplicate. Regular, periodic and required tests for disinfectant in the water supply gives an indication of the performance of the unit. However, other maintenance precautions are essential.

Chlorinators and Iodinaters

The maintenance program, of course, depends in part on the type of feeder and the form in which the chemical is obtained.

Gas chlorinator systems necessitate a whole series of maintenance and operation precautions for safety, in addition to those practices which are necessary to assure constant and reliable dosage.

Since sodium hypochlorite already is in solution form, there are no solids to clog the feeder. It is desirable, however, to install sensing units in the solution container to sound an alarm or provide for automatic shutdown of the well pump, if the disinfection supply becomes too low.

The storage reservoir, connections, fittings and pump must be periodically checked, cleaned of deposits, and observed to be in proper condition. The chemical should be stored according to the precautions of the supplier and should be used up within the recommended maximum storage period, to assure that the solution is of the required strength.

The residual of the treated water should normally be checked after replenishing the supply and servicing the system to assure the required dosage is being applied.

Among the main service and inspection functions are to check diaphragms and plungers for wear or defects, unclog orfices and free any valves which become stuck with accumulations of deposits. If the units have strainers, these also must be checked and cleaned at regular intervals.

Ultraviolet Irradiation Units

The effectiveness of ultraviolet irradiation is seriously impaired when the light must penetrate turbid water or a film on the light emitting surface. Such surfaces should be checked frequently for light intensity and cleaned of any material which would block radiation from reaching the water.

Units with automatic controls to monitor the radiation intensity require lamp replacement every one to three years. Without automatic controls, lamp changes every six months are more common. NOTE: Water hammer may result in more frequency replacement of bulbs.

Since ultraviolet efficiency is dependent upon low turbidity, the entire water supply system must be operated to assure consistantly clear water.

WATER CONDITIONING UNITS

Zeolite Softeners

Periodic or constant, automatic testing to monitor the treated water indicates when the exchange material needs to be regenerated. Mixing salt to produce a brine is a normal operating function. The process of soaking the Zeolite material in brine may be either a manual operation involving draining the cylinder, replacing the water with brine, allowing to soak for several hours, draining the spent brine, washing the unit to remove surplus salt (including chlorides and other chemicals), and placing in service. Units are available for automatically cycling the processes.

The frequency of recharging varies with the size of the unit, the hardness of the water, and the amount of water used. Some require charging daily. Others may not need recharging for two or three weeks.

Under certain circumstances the zeolite may become coated with slime or deposits, which reduce its efficiency. Special treatment with chlorine or selected chemicals may be necessary.

If the water supply contains dissolved iron and it is exposed to oxygen, oxidized iron may accumulate in the zeolite bed. In this case, the zeolite occasionally requires backwashing to keep the iron particles from accumulating and fouling the bed. Special salt, or chemicals to add to the regular salt also are available, which will help prevent fouling of the zeolite bed. In any case, after use for a long period of time, the zeolite may need replacement.

Reverse Osmosis

Since reverse osmosis depends upon water passing through very fine pores, the membranes are severely affected by turbidity and suspended particles. Water which is not clear should be treated by a filtration system. The flow through the unit must be regulated or the unit must be designed to provide a constant flushing action to remove and waste the salts and fine materials trapped on the surface of the membrane.

With proper raw water quality and flow design, the membranes can be expected to last for 1 to 3 years. As with other treatment units, the efficiency is monitored by periodically testing the finished water to determine the percentage removal of undesirable chemicals.

STORAGE TANKS

To assure long life and to prevent the formation of deep-seated rust or corrosion, steel tanks should be given proper care. Precautionary measure include: proper protective coatings on the inside and outside of metal storage tanks, and in some cases cathodic protection. In addition, both outside and inside surfaces of tanks should be thoroughly inspected at intervals not exceeding two or three years, depending upon the operating conditions and experience factors of the rest area. The tank should be emptied so the inside can be thoroughly inspected. The surfaces should be washed and scraped or brushed to remove deposits and foreign material, and sediments should be removed from the bottom. If surface coating is necessary, AWWA specifications should be followed for coatings of inside surfaces to be sure the material is effective and will not impart undesirable or toxic effects to the water.

To assure an adequate life, the surfaces must be properly prepared for coating. Storage tank exposure produces a very severe environment for surfaces, since parts of the walls are alternately exposed to wetting and drying, and parts not submerged are exposed to air with a high relative humidity. The exterior is commonly exposed to the hot, baking sun, wind, rain, hail and snow in some localities. Every surface must be free from rust, old paint scale, blisters, dirt and other foreign material, and should be thoroughly dry before any new coating is applied.

Whenever the interior of a storage structure is emptied and entered for inspection, cleaning and painting, or for any other purpose, it should be thoroughly disinfected by some standard recognized method before being placed back in service. This is usually accomplished by cleaning the surfaces with a chlorine solution and by exposing the surfaces to a chlorine solution in a manner similar to the processes recommended for disinfecting new tanks and mains.

Other items which should be inspected and maintained include the following:

1. Trap doors, manholes, and other entrances should have tight-fitting covers and be kept closed when not in use. Any such doors which are exposed to vandalism should be kept locked.

2. There should be no leaks and no unnecessary openings.
3. Vents should be screened and in good condition; ladders, balconies, and handrails on elevated tanks also should be safe and in good condition.
4. Float controls on elevated tanks should be maintained in operating condition and good repair.
5. Pressure gauges and water level indicators of hydro-pneumatic tanks should be serviced and checked. Also the devices provided to maintain the proper air-water ratio should be checked.

DISTRIBUTION SYSTEM

The following list of considerations should be included in the normal operation and maintenance of the distribution system:

1. Regular bacteriological, physical and chemical analyses as required by state regulations (Chapter 8).
2. Measurement of water use: measure the total water usage as indicated by the meter or meters. With systems which include non-pressurized storage tanks, measure water storage level periodically with the pumps off, and calculate the water usage rate. Unexplained increased use may indicate leakage or breaks; unexplained lowered use may indicate that the meter itself is malfunctioning.
3. Clean, flush and disinfect seasonal systems prior to putting in service. Periodically flush portions of these systems which are not normally subject to regular flow.
4. Check the operation of the appurtenances, valves, hydrants, etc. Visually check the system at least annually.
5. Pressure gages with maximum and minimum indicators should be read, recorded, and reset at least weekly.
6. Continually be alert to prevent cross-connection and backflow situations. Check hose connections for vacuum breakers. Check reduced pressure backflow prevention

valves on an annual basis, or as required by the state. EPA, Cross-Connection Control Manual, EPA 430/9-73-002, 1973, should be consulted for testing procedures for preventers.

7. Observe wet areas throughout the system; they may indicate leakage.
8. At sites subject to freezing, make sure that all mains, valves, tanks and parts of the system are either properly protected from freezing, or are drained properly.

VALVES AND CROSS-CONNECTION CONTROL DEVICES

Valves and cross-connection control devices should be subject to routine inspection to determine that the device is functioning normally. Malfunctions may be indicated by excessive weeping or leakage of the device. Stains or watermarks on the outside body of the device may also indicate malfunction.

Internal inspection should also be made periodically. Rubber membranes and gaskets, valve seats, and the internal mechanism should be carefully inspected for rupture, scoring of metal, scaling, corrosion, or any accumulation of dirt or foreign matter that would prevent the safe operation of the device.

A complete record, including date of installation and information on all inspections, tests, and repairs, should be maintained on each device. Any defects found during inspection or testing should be corrected immediately before allowing the device to be placed back in service.

Test procedures for various types of valves, vacuum breakers and backflow preventers are described in detail in the EPA Cross-Connection Control Manual, EPA 430/9-73-002, 1973.

EQUIPMENT MAINTENANCE RECORDS

Adequate records for equipment maintenance, repairs and chemical dosing are an integral part of good water supply plant operation. Records used properly save time when trouble occurs, and provide proof that problems were detected and corrected.

Records also provide an excellent check on tasks which have been completed or which need to be performed, especially maintenance. All equipment in a water-treatment plant requires periodic service; some daily, some weekly, and some monthly or yearly. Adequate records show when service was last performed and when the time for service is approaching. As a result, a schedule can be maintained, with nothing overlooked or forgotten.

When accurately kept, records provide an essential basis for design of future changes or expansions of the water supply facility and also can be used to aid in the design of facilities for other locations where similar problems may be encountered.

EMERGENCY PLANS OF ACTION

The operation of rest area water supplies should be directed toward providing a continuous, uninterrupted supply of high quality water to the traveling public. Under most conditions this level of service can be maintained. However, disruptions in water supply and quality impairment can, and do occur under certain situations. Consequently, precautions should be taken to reduce the potential effects of emergency situations, whenever possible.

PREPARATION OF EMERGENCY PLANS

The potential effects of disasters on water supplies include: plant (structural) damage, reservoir damage, storage tank damage, broken mains, watershed damage, contamination, power outages, communication disruption, transportation failure, and employee shortages.

In reviewing the types of emergencies which can effect a rest area water supply system, it is apparent that their nature is such that advance preparation and planning are essential. There simply is not time under most emergency conditions to both plan and take the necessary corrective measures. The planning must be done, in a general way, prior to the emergency.

During the preparation of emergency plans for rest area water supplies, the following items should be considered:

1. Protective measures which can be taken to minimize disaster effects - this might include alternate sources of water; acquisition of special equipment and supplies (chemicals, critical spare parts, standby electric generators, etc.); availability of water distribution trucks; automatic valves to close and isolate main breaks.
2. Special training of personnel - this should be considered a part of the regular training given to rest area water supply operators. The training should include emergency operating instructions provided by treatment equipment manufacturers.
3. Step-by-step actions to be taken by the operator in the event of an emergency - including contacts to be made and specific priorities to be considered.
4. Notification requirements under the Safe Drinking Water Act - highway department staff and rest area operators should be aware of these emergency notification requirements and make plans for compliance in the event it becomes necessary. (See Chapter 8 for details.)

Regardless of the simplicity or complexity of the plan, the state should review and approve all plans for emergency action. EPA reference,* Considerations for Preparation of Operation and Maintenance Manuals can be used as a guide in assembling an emergency plan.

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*Available from EPA, 401 M. Street S.W., Washington, D.C. 20460

REFERENCES

EPA, Cross-Connection Control Manual, EPA 430/9-73-002, 1973. EPA, 401 M. Street S.W., Washington, D.C. 20460

AWWA, Basic Level Water Treatment Operator's Practices, M18, 1971. AWWA, 6666 W. Quincy Ave., Denver, Colorado, 80235

VIII. Surveillance

The key to safe water lies in the combination of quality of source, the nature of physical facilities, the operation and maintenance of the facilities, and the capability of this combination to produce and deliver water of an acceptable quality. The continuous surveillance of water quality and water facilities is a most important means of assuring delivery of high quality water at all times.

Every highway department should develop and implement surveillance plans as necessary to assure delivery of safe water to the traveling public. These surveillance plans must comply in all respects with the National Primary Drinking Water Regulations (NPDWR) and local and state laws, rules, and regulations. Under Section 1413 of Public Law 93-523, the Safe Drinking Water Act, the state has primary responsibility for enforcement if it has adopted laws, policies and an implementing program satisfactory to the EPA Administrator. If the state has not accepted or qualified for primary enforcement responsibility, the EPA Regional Administrator's Office is responsible. Upon completion of plan development, therefore, the EPA or the state (whichever has primary enforcement responsibility) should review the surveillance plans prior to implementation. Surveillance plans by highway departments generally should include:

1. Regular sanitary surveys of the source of supply and its environment, pumping and treatment facilities, storage systems, distribution system, laboratory and testing equipment, records and records systems, together with effective policies and procedures for promptly correcting defects.
2. Program approved by the state (or EPA) for the detection and elimination of cross-connections, together with a program for testing and maintaining backflow prevention devices.

3. Regular collection of water samples to meet the NPDWR, and applicable state standards.
4. Analysis of samples in accordance with the NPDWR and applicable state standards.
5. Provision for public and state notification when violations of the NPDWR occur.
6. Operational control testing (if treatment is provided at rest areas).
7. Provision for use of approved laboratory facilities.
8. Systematic and well organized program for keeping and periodically reviewing records of water-quality tests, water usage rates, pressures, planned maintenance and surveillance and all other pertinent data.

SOURCE AND FACILITY SURVEILLANCE

RELIABILITY OF EXISTING SYSTEMS

The highway department should provide and maintain the condition of rest area water supply systems in a manner which will assure reliability in meeting applicable regulations and standards. This requirement should pertain to the source of supply, treatment, transmission, storage and distribution facilities, as well as the proper operation of these facilities. In addition, this should include continuing assessment of the capability, effectiveness, and reliability of the treatment process in removing contaminants from the source of supply. System reliability assessments should include the identification and evaluation of all factors having potential for impairing the quality of the water as delivered to the consumers; the elimination of hazards; and the provisions of appropriate preventive and control measures. This assessment is particularly important for rest areas which have been in operation for a period of time, and which have not been continuously subject to close supervision by technically qualified state personnel.

SANITARY SURVEYS

The National Primary Drinking Water Regulations (NPDWR) require states to conduct sanitary surveys on a systemic basis. As defined by the NPDWR: a "Sanitary survey means an on-site review of the water source, facilities, equipment, operation and maintenance of a public water system for the purpose of evaluating adequacy of such source, facilities, equipment, operation and maintenance for producing and distributing safe drinking water." The regulations provide that monitoring frequencies for coliform bacteria can be changed by the entity with primary enforcement responsibility for an individual non-community system based on the results of a sanitary survey. Although the frequency of these sanitary surveys is not specifically stated in the regulations, an annual inspection is recommended. The person in charge of the rest area water supply should arrange to accompany the primary enforcement inspection official on both the original inspection and on follow-up inspections made to assure that defects are corrected. If such official inspections are not made at least annually, then interim sanitary inspections should be made by the person in charge of the rest area supply.

The discovery of new potential sources of contamination, or of new opportunities for the introduction of new contaminants from existing sources may require adjustments in treatment and surveillance procedures. The need is obvious for a regular systematic sanitary survey program to locate and identify health hazards of this kind and to make necessary changes in the water system. Generally, the sanitary survey is augmented by analysis of microbiological, chemical and physical tests which are made routinely in an effort to correlate unsatisfactory test results with conditions revealed by the survey.

The official regulatory/enforcement agency will utilize its own sanitary survey forms. However, the persons in charge of each rest area water supply may include additional details and descriptive items in their own sanitary survey forms. Although no precise outline can be prepared to cover all aspects of every water system to be surveyed, the following basic data should, as a minimum, be evaluated as applicable to the particular rest area installation.

I. Description

A. Site Identification

1. Rest Area Name
2. Highway on which rest area is located (including the direction of traffic flow into the rest area)
3. Nearest city or town in either direction of the rest area.
4. Mile post
5. Use period of the rest area (year-round, March-November, etc.)
6. Water demand

B. Survey Data

1. Date of survey
2. Survey participants, name and affiliation.
3. Purpose of survey (whether routine or due to tests that did not meet standards)
4. Date and summary of last survey

C. System Description

1. Source
2. Treatment
3. Storage
4. Distribution

D. History

1. When built
2. Major modifications
3. Major extensions
4. Major repairs

E. Schematics, Well Logs, etc.

II. Source Evaluation

A. Ground Water Supplies

1. Geology and topography
2. Nature of soil and strata
3. Water table, drainage area, slope, etc.
4. Proximity to pollution sources
5. Physical, chemical, bacteriological, radiological, and pesticide analyses
6. Protection from accidental spillage

B. Surface Water Supplies

1. Geology
2. Nature and topography of watershed
3. Character of vegetation, etc.
4. Upstream uses and ownership
5. Pollution potential of watershed
6. Susceptibility of watershed to change – i.e. variable runoff, seasonal use, animal use, etc.
7. Physical, chemical, bacteriological, radiological and pesticide analyses
8. Reservoir characteristics
   a. Wind direction and velocity
   b. Drift of debris and pollution
   c. Algae
   d. Protection from pollution sources such as fishing, swimming, animals, etc.
   e. Protection from accidental spillage

III. Source Protection

A. Wells

1. Evaluation of well characteristics
   a. Well log of depth, formations, etc.
   b. Casing, screen, perforations, seals, etc.
   c. Pumping rates, drawdown, etc.
2. Protection from floods and flooding
3. Protection from surface runoff
4. Protection of well head
   a. Sanitary seal
   b. Casing extended above ground

c. Protected vent
d. Protection from erosion, animals, etc.

5. Potential for cross-connection with non-potable sources
6. Proper casing, curbing, sealing and grouting
7. Watertight installation of pump and accessories
8. Sound condition of all construction

B. Springs

1. Determine if spring is in fact a spring source or intermittent surface source.
2. Evaluate spring encasement for proper watertight installation.
3. Protection from surface runoff
4. Suitable watertight cover or lid
5. Suitable and well protected overflows, drains, vents
6. Evaluation of potential sources of pollution
7. Suitably fenced to protect area from entry by livestock or other animals
8. Protection from trespass

C. Surface Source Intakes

1. Protection from runoff (i.e., by trenching, etc.) or entry of other undesirable water
2. Protection from large domestic animals, floating materials, etc.
3. Protection from bottom muds, sands, plugging, etc.
4. Proper screening and location of intake pipes
5. Protection from undesirable uses through the use of signs, fences, etc., as applicable
6. Evaluate ability of intake to withstand physical damage by ice, wind, accident, etc.
7. Capability of intake to furnish adequate quantity of water
8. Protection from trespass

IV. Treatment Evaluation

1. Review applicable water quality standards and regulations.
2. Compare treated water quality test results with applicable standards.
3. Compare design flows with actual use records.
4. Insure treatment system is being used as designed or modified for most efficient and effective treatment.
5. Insure treatment system has flexibility to meet standards during stress periods such as heavy runoff, high demand, drought.
6. Review trends in quality which may indicate a deteriorating system.
7. Review disinfection equipment, installation, detention time, and residuals.
8. Review emergency plans and standby equipment.

V. Distribution System Evaluation

A. Storage Protection

1. Protection against flood waters
2. Protection against surface runoff
3. Suitable watertight roof, locked with covers and lids designed with overlapping flanges to prevent leakage
4. Properly screened and positioned vents, drains, overflows, etc.
5. Adequately supported pipes, fittings, etc.
6. Proximity to sources of pollution
7. Adequate frost protection
8. Protection from trespass

B. Distribution System Protection

1. Adequate pressure
2. No excessive leakage
3. Acceptable pipe materials, joints, and fittings
4. Proximity to sources of pollution
5. Proximity to sewer lines

6. Proper drains
7. Properly constructed and maintained blowoff, vacuum, air release and air relief valves
8. Properly constructed and maintained stream and river crossings
9. Adequately sized pipe for all uses
10. Adequate frost protection
11. Valving to enable isolating various portions of the system for repairs and during emergencies

C. <u>Cross-Connections</u>

1. Proper selection, installation, testing and maintenance of backflow devices
2. No connection between potable and non-potable water lines unless protected by approved backflow prevention device
3. Adequate system pressure
4. Evaluation of potential for negative pressures
5. Proper air-gaps throughout system
6. Non-potable water piping identified

VI. <u>Procedural Evaluation</u>

1. Review management and operation methods.
2. Review operator skill and qualifications including training, experience, etc.
3. Review O&M Manual for update material and use.
4. Review test results, including disinfection
   a. Proper frequency
   b. Proper sampling techniques and handling
   c. Proper laboratory equipment
   d. Proper laboratory procedures
   e. Proper recording
   f. Proper evaluation
   g. Proper follow-up and corrective action
5. Evaluate hands-on operation and maintenance
   a. Is plant operation efficient?
   b. Is plant operation effective?
   c. Are recommended operational and control procedures being used?

d. Is recommended maintenance being performed at required frequencies?

6. Is plant operation being checked daily or at other required intervals?

7. Are all parts of system properly cleaned, disinfected, flushed and tested at seasonal start-up or periodic intervals?

8. Review all records and reports for adequacy and accuracy.

VII. Deficiency Summary and Corrective Action Schedule

A complete summary of all items requiring corrective action should be compiled, along with a schedule for completing each item. In some cases, immediate action may be required or the system closed.

MODIFICATION OF EXISTING FACILITIES

In order to meet the NPDWR and applicable state standards, the modification of existing rest area water system facilities may be necessary. The necessary modifications can best be identified by a thorough sanitary survey by a properly trained individual, as previously described. During the on-site investigation, particular attention should be given to the evaluation of operation and maintenance procedures and operator training. In certain cases, it will be found that costly and unnecessary facility modifications can be avoided by implementing a more careful operation and maintenance program and/or a special training program for operators.

However, if facility modification is necessary, and if the modification involves substantial change in the source, treatment, distribution or storage system, it may be required that plans and specifications for proposed changes be submitted to the primary enforcement agency for approval, before the changes are begun.

SAMPLING REQUIREMENTS FOR REST AREAS (AS NON-COMMUNITY WATER SYSTEMS)

The following are excerpted from the NPDWR. However, the primary enforcement agency is authorized to establish additional requirements which may result in programs beginning earlier, tests being performed more frequently, additional items being included in the requirements, or more stringent requirements. In addition, the management of the rest area water supplies may elect to make additional tests, for various reasons (i.e., operational control purposes).

BACTERIOLOGICAL SAMPLING REQUIREMENTS

- Non-community water systems to be sampled for coliform each calendar quarter durinq which the system provides water to the public.
- Sampling will begin within 2 years following June 1977. If, the state on the basis of a sanitary survey, determines that some other frequency is more appropriate, that frequency shall be the frequency required under these regulations.
- When a maximum contaminant level has exceeded the coliform counts described above, the supplier of water must notify the public.
- When the coliform colonies in a single membrane filter sample exceed four per 100 ml, at least two daily check samples must be collected and examined from the same sampling point. The frequency for additional check samples may be established by the state, but check sampling must continue until the results obtained from at least two consecutive check samples show less than one coliform per 100 ml.
- When coliforms occur in:
  - 3 or more 10-ml portions of a single sample, or
  - all 5 of the 100-ml mportions of a single sample taken by the fermentation tube method,

  at least two daily check samples must be collected and examined from the same sampling point. The frequency for additional check samples may be established by the state, but check sampling must continue until at least two consecutive check samples show no positive tubes.

- When the presence of coliform bacteria in water taken from a particular sampling point has been confirmed by any check samples, the supplier of water must report to the state within 48 hours.
- With the approval of the state and based upon a sanitary survey, chlorine residual monitoring may be substituted for not more than 75 percent of the samples required to be taken. Chlorine residual samples must be taken at points which are representative of the conditions within the distribution system at the frequency of at least four for each substituted microbiological sample. There must be at least daily determinations of chlorine residual.
- When the chlorine residual option is exercised, a minimum of 0.2 mg/l free chlorine must be maintained throughout the distribution system. When a sample indicates less than 0.2 mg/l free chlorine, the water at that location must be retested as soon as practicable and at least within one hour. If the original analysis is confirmed the following must be done within 48 hours:
  - Report the confirmed chlorine residual to the state
  - Sample for coliform bacteria and report analysis to the state
- Analyses for residual chlorine shall be made in accordance with Standard Methods for the Examination of Water and Wastewater, 13th ed., pp 129-132.
- Samples taken as a result of failure to maintain the required chlorine residual should be included in the calculation of normal monthly or quarterly averages.
- The state may withdraw its approval of the use of chlorine residual substitution at any time.

TURBIDITY SAMPLING REQUIREMENTS (REQUIRED FOR SURFACE WATER SUPPLIES ONLY)

- Only safety rest areas using surface water supplies must observe the maximum turbidity level.
- Samples will be taken at representative entry point(s) to the distribution system at least once per day.
- The measurement will be made according to Standard Methods for the Examination of Water and Wastewater, American Public Health Association, 13th ed. pp 350-353 (Nephelometric Method).
- If the results of a turbidity analysis indicates that the maximum allowable limit has been exceeded, the sampling and measurement must be confirmed by resampling as soon as practicable and preferably within one hour. If the repeat sample confirms that the maximum allowable limit has been exceeded, the state designated agency must be notified. If the results of the repeat sample are less than the first sample, the second value should be used in the calculation of the monthly average.
- If the monthly average of the daily samples exceeds the maximum allowable limit, or if the average of two samples taken on consecutive days exceed 5 turbidity units (TU), the public must be notified.
- Sampling for non-community water systems (including safety rest areas) will begin within two years after June 1977.

Because of the importance and required frequency of sampling and testing for chlorine residual and turbidity, these must be measured by each water supply operator. Simple, modern test equipment is commercially available to improve the accuracy and speed of making these tests. In some cases, it may prove to be advisable to consider obtaining automated, recording equipment, some of which is available with alarms to warn of failure. Chlorine measurements should include tests for free chlorine residual and total chlorine residual.

NITRATE SAMPLING REQUIREMENTS

- As non-community water systems, nitrate analyses will be required at safety rest areas within two years following June 1977. States will determine the intervals at which these analyses will be repeated.
- When a nitrate sample exceeds the maximum contaminant level of 10 mg/l as Nitrate (N), a second sample shall be analyzed within 24 hours. If the mean of the two analyses exceeds the maximum contaminant level, the state designated agency and the public must be notified.
- Nitrate analysis will be performed in accordance with either the Brucine Colorimetric Method, Standard Methods for the Examination of Water and Wastewater, 13th ed., pp 461-464, or the Cadmium Reduction Method, Methods for Chemical Analysis of Water and Wastes, pp 201-206, Environmental Protection Agency, Office of Technology Transfer, Washington, D.C. 20460, 1974.

OTHER CONTAMINANT SAMPLING REQUIREMENTS

Sampling for inorganic contaminants (other than nitrates), organic contaminants and radioactivity are not required at rest areas designated as non-community water supplies under the NPWDR. Only where a particular problem is suspect, will state agencies with primary enforcement responsibility normally require regular sampling of these contaminants. However, states may require, or highway departments may choose to include tests for other contaminants as part of their periodic testing programs, both those required of community water supplies and those included in the proposed National Secondary Drinking Water Regulations (Federal Register, Vol. 22, No. 62, March 31, 1977). The National Secondary Standards are not mandatory, unless the state elects to include them in their primary standards. The secondary standards include such items as chlorides, color, corrosivity, copper, hydrogen, sulfide and other odors, iron and manganese, sulfates (because of laxitive effect) total dissolved solids (TDS) and zinc. Table IV-6 (Page IV-8) gives a complete listing of the contaminants and their respective MCL's under the proposed National Secondary Standards.

SAMPLE ANALYSIS AND LAB FACILITIES

OPERATIONAL CONTROL TESTING

Day-to-day operation of certain water systems requires that a minimum number of water samples be collected and analysed in order to properly operate the plant and to control product quality. Such tests should present evidence that: (1) the water has been properly prepared for each major step in the treatment process; (2) that each unit process such as mixing, coagulation, sedimentation, filtration, activated carbon adsorption, softening, iron and manganese removal, disinfection, and taste and odor control has proceeded according to plan; and (3) the finished water is clean, has no objectionable taste or odor, has no excessive concentration of organic and inorganic chemicals, and is safe for human consumption.

The frequency, type, and number of analyses required depend greatly upon raw water quality and the complexity of treatment provided. In general, the complexity of treatment provided at most rest areas does not require extensive operational control testing. The following sections describe minimum operational control tests for various treatment processes which may be commonly found at rest areas. It should be emphasized that these tests are not required by the NPDWR, but rather are suggestions for "good practice."

Disinfection Only

Rest areas providing disinfection only should provide equipment for the measurement of residual disinfectant, pH, turbidity, and temperature.

Ion Exchange

Plants providing for removal of iron, manganese, or hardness by ion exchange should provide equipment for testing residual disinfectant, iron, temperature, manganese, and hardness.

Softening

Rest areas providing chemical precipitation for water softening and iron and manganese should provide an electric pH meter; equipment for determining alkalinity, hardness, temperature, residual disinfectant, iron and manganese content and turbidity.

Turbidity Removal

Since the effectiveness of disinfection is dependent upon a low turbidity, regular, periodic turbidity measurements are essential. This is especially true where the system includes facilities for turbidity removal. To be in conformance with current regulations, turbidity measuring devices must employ the nephelometric method. The turbidimeter must consist of a nephelometer with light source for illuminating the sample and one or more photoelectric detectors with a readout device to indicate intensity of light scattered at right angles to the path of the incident light. The unit is calibrated by using Formazin Turbidity Units (FTU).

SAMPLE PRESERVATION

Complete preservation of water samples is a practical impossibility. Regardless of the nature of the sample, complete stability for every constituent can never be achieved. At best, preservation techniques can only retard the chemical and biological changes that inevitably continue after the sample is removed from the source. Consequently, provisions must be made for prompt analysis of samples after collection.

Methods of preservation are relatively limited and generally are intended to (1) retard biological action, (2) retard hydrolysis of chemical compounds and complexes and (3) reduce volatility of constituents. Preservation methods are generally limited to pH control, chemical addition, refrigeration, and freezing. Most commonly, refrigeration at temperatures near freezing or below is the best preservation technique available, but it is not applicable to all types of samples.

The recommended methods of preserving samples and limitations on their holding time are given in Table VIII-1, which was obtained from Methods for Chemical Analysis of Water and Wastes, EPA, 625/6-74-003.* More specific instructions for preservation and sampling are detailed in the above mentioned EPA manual for chemical analysis.

LABORATORY FACILITIES

For the purposes of determining compliance with NPDWR, test results of laboratory analyses may be considered only if they were conducted in a laboratory approved and certified for such analyses by an official approval agency. The approval generally is contingent upon maintenance of proper laboratory methods and technical competence. The laboratory also must be available for inspection at reasonable times during which analyses are being conducted.

Certified laboratories may be either public agency or commercial, with a wide variation in the number and complexity of tests they can perform. Possible sources of qualified laboratories include:

1. State health departments
2. County health departments
3. Hospitals
4. Public utility districts
5. Water companies

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*Available from EPA, Office of Technology Transfer, Washington, D.C. 20460.

TABLE VIII-1. RECOMMENDATION FOR SAMPLING AND PRESERVATION OF SAMPLES ACCORDING TO MEASUREMENT

Measurement	Vol. Req. (ml)	Container	Preservative	Holding Time(1)
Acidity	100	P,G(2)	Cool, 4°C	24 Hrs.
Alkalinity	100	P,G	Cool, 4°C	24 Hrs.
Arsenic	100	P,G	HNO_3 to pH<2	6 mos.
Bromide	100	P,G	Cool, 4 C	24 Hrs.
Chloride	50	P,G	None Req.	7 days
Chlorine Req.	50	P,G	Cool, 4°C	24 Hrs.
Color	50	P,G	Cool, 4°C	24 Hrs.
Cyanides	500	P,G	Cool, 4°C NaOH to pH 12	24 Hrs.
Dissolved Oxygen				
Probe	300	G only	Det. on site	No Holding
Winkler	300	G only	Fix on site	No Holding
Fluoride	300	P,G	Cool, 4°C	7 Days
Hardness	100	P,G	Cool, 4°C	7 Days
Iodide	100	P,G	Cool, 4°C	24 Hrs.
Metals				
Dissolved	200	P,G	Filter on site HNO_3 to pH<2	6 Mos.
Suspended			Filter on site	6 Mos.
Total	100		HNO_3 to pH<2	6 Mos.
Mercury				
Dissolved	100	P,G	Filter HNO_3 to pH<2	38 Days (Glass) 13 Days (Hard Plastic)
Total	100	P,G	HNO_3 to pH<2	38 Days (Glass) 13 Days (Hard Plastic)
Nitrogen				
Ammonia	400	P,G	Cool, 4°C H_2SO_4 to pH<2	24 Hrs.(3)
Kjeldahl	500	P,G	Cool, 4°C H_2SO_4 to pH<2	24 Hrs.(3)
Nitrate	100	P,G	Cool, 4°C H_2SO_4 to pH<2	24 Hrs.(3)
Nitrite	50	P,G	Cool, 4°C	24 Hrs.(3)
pH	25	P,G	Cool, 4°C	6 Hrs.(4)
Phosphorus				
Orthophosphate, Dissolved	50	P,G	Filter on site Cool, 4°C	24 Hrs.(3)
Total	50	P,G	Cool, 4°C	24 Hrs.(3)
Total, Dissolved	50	P,G	Filter on site Cool, 4°C	24 Hrs.(3)
Selenium	50	P,G	HNO_3 to pH<2	6 Mos.
Silica	50	P only	Cool, 4°C	7 Days
Specific Conductance	100	P,G	Cool, 4°C	24 Hrs.(5)
Sulfate	50	P,G	Cool, 4°C	7 Days
Sulfide	50	P,G	2 ml zinc acetate	24 Hrs.
Sulfite	50	P,G	Cool, 4°C	24 Hrs.
Temperature	1000	P,G	Det. on site	No Holding
Threshold Odor	200	G only	Cool, 4°C	24 Hrs.
Turbidity	100	P,G	Cool, 4°C	7 Days

NOTE:

1. It has been shown that samples properly preserved may be held for extended periods beyond the recommended holding time.
2. Plastic or Glass
3. Mercuric chloride may be used as an alternate preservative at a concentration of 40 mg/l, especially if a longer holding time is required. However, the use of mercuric chloride is discouraged whenever possible.
4. If samples cannot be returned to the laboratory in less than 6 hours and holding time exceeds this limit, the final reported data should indicate the actual holding time.
5. If the sample is stablized by cooling, it should be warmed to 24°C for reading, or temperature correction made and results reported at 25°C.

6. Municipal treatment plants
7. Commercial laboratories
8. Military bases
9. Forest Service and National Park Laboratories

Only tests for turbidity and chlorine residual tests can be performed outside of a certified laboratory, providing the tests are performed according to approved methods, with approved equipment and reagents, and by a person who is trained and accredited to officially perform such tests (a qualified plant operator).

RECORD KEEPING

The regulations require that each safety rest area maintain records of sample analyses and of actions to correct violations of the National Primary Drinking Water Regulations. The following records must be present on or near the premises of the water supply for no less than the period described below:

Record	Number of Years Record to be Retained
Bacteriological	5
Chemical	10
Corrective Actions	3
Sanitary survey reports or summaries	10

Actual lab reports may be kept or transferred to summaries which include the following:

- The date, place, and time of sampling, and the name of the person who collected the sample.
- Identification of the sample as to whether it was a routine distribution systems sample, check sample, raw or process water sample, or other special purpose sample.
- Date of analyses.
- Laboratory and person responsible for performing analyses.

- The analytical technique/method used.
- Analytical results.

If lab summaries are to be used in place of actual lab reports at rest areas, a standard form should be constructed to ensure completeness of information to be retained at the site. Although not stated in the regulations, it is recommended that if the state highway departments make up the form, the form should be submitted to the primary enforcement agency in the state for approval.

REPORTING REQUIREMENTS

Reporting requirements of the National Primary Drinking Water Regulations provide for notification of both the state and the public concerning various aspects of compliance with the regulations.

The rest area water supply operator must report the following to the state agency with primary enforcement authority:

- All test results and measurements within 40 days following a test
- Failures to comply with any regulation or monitoring requirement within 48 hours of the failure

These state notifications are necessary whenever the analysis is performed by a commercial or private (state-certified) lab. Where a state-operated lab performs the analysis, no such notification is necessary if the state has primary enforcement responsibility. If the state does not have primary enforcement responsibility, the EPA administrator must be notified of the violation. Consequently, for rest areas using anything other than state-operated labs, reporting requirements will be in effect for all bacteria and nitrate analyses. Results of turbidity and residual chlorine tests, if they are performed will also fall under this reporting requirement. For rest areas located in very remote areas, notification of failures to comply with the regulations within the 48-hour time limit could present a problem. However, under normal circumstances, when results are within acceptable concentration limits, 40 days should be more than sufficient time to mail results to the enforcing state agency.

PUBLIC NOTIFICATION

When a rest area water supply system fails to meet any part of the regulations concerning maximum contaminant levels, test procedures, monitoring requirements, or variances or exemptions, notice must be given to the persons served by the system, probably in the form of a sign posted in a prominent place where it would be readily observed by the public or at drinking fountains and faucets where the public is apt to obtain water. The notice is likely to include such information as the significance of the situation to public health; steps taken to correct the problem; results of any additional sampling; and preventative measures that can be taken by the public. The form and manner of the notice is subject to state approval and must meet a number of criteria, including:

- No unduly technical language
- No unduly small print
- Billingual notices, where necessary
- No undue alarming of the public

It is recommended that each state highway department provide guidelines or standards for public notification which can easily be used when such notifications are necessary at rest areas. Again, the standards or guidelines should be subject to approval by the regulating agency to ensure their acceptability.

References

AWWA, WPCF, APHA, Standard Methods for the Examination of Water and Wastewater, 14th Edition, 1975. AWWA, 6666 W. Quincy Ave., Denver, Colorado 80235.

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GLOSSARY

ACTIVATED CARBON -- A highly adsorbent form of carbon, used to remove odors and toxic substances from water.

ADSORPTION -- The adhesion of a substance to the survace of a solid or liquid.

ALGAL BLOOM -- A proliferation of living algae on the surface of lakes, streams or ponds, algal blooms are stimulated by phosphate enrichment.

ALKANITY -- Water having a pH greater than 7.0.

AQUIFER -- An underground bed or stratum of earth, gravel or porous stone that contains water.

BACKFILL -- The material used to refill a ditch or other excavation, or the process of doing so.

CARCINOGENIC -- Cancer producing.

CHLORINATOR -- A device for adding a chlorine-containing gas or liquid to drinking water.

CHLORINE RESIDUAL -- That part of the chlorine dosage which remains in the water after the chlorine demand is satisfied.

CROSS CONNECTION -- Any physical connection between a potable water supply and any waste pipe, soil pipe, sewer, drain, or any unapproved source or system.

COAGULATION -- The clumping of particles in order to settle out impurities; often induced by chemicals such as lime or alum.

COLIFORM ORGANISM -- Any of a number of organisms common to the intestinal tract of man and animals whose presence in water is an indicator of pollution and of potentially dangerous bacterial contamination.

CORROSION -- The gradual deterioation of material by chemical processes.

Glossary (Continued)

DIATOMACEOUS EARTH (DIATOMITE) -- A fine siliceous material resembling chalk used as a filter media in the treatment of water.

DISINFECTION -- Effective killing by chemical or physical processes of all organisms capable of causing infectious disease.

ELECTRODIALYSIS -- A process that uses electrical current and an arrangement of permeable membranes to separate soluble minerals from water. Often used to desalinize salt or brackish water.

ENVIRONMENTAL IMPACT STATEMENT -- A document prepared by a Federal agency on the environmental impact of its proposals for legislation and other major actions significantly affecting the quality of the human environment. Environmental impact statements are used as tools for decision making and are required by the National Environmental Policy Act.

FILTRATION -- In water treatment, the mechanical process that removes particulate matter by separating water from solid materials usually by passing it through sand.

GREY WATER -- Waste water which is free from fecal contamination which is collected, treated and stored for reuse as non-potable water.

GROUNDWATER -- The supply of freshwater under the earth's surface in an aquifer or soil that forms the natural reservoir for man's use.

HARD WATER -- Water containing dissolved minerals such as calcium, iron and magnesium. The most notable characteristic of hard water is its inability to lather soap. Some pesticide chemicals will curdle or settle out when added to hard water.

IMPERVIOUS -- Nonporous.

INFILTRATION -- The flow of a fluid into a substance through pores or small openings. Commonly used in hydrology to denote the flow of water into soil material.

GLOSSARY (CONTINUED)

PATHOGENIC -- Causing or capable of causing disease.

PERMEABLE -- Open to passage or penetration; substances that allow the passage of fluids.

pH -- A measure of the acidity or alkalinity of a material, liquid or solid. pH is represented on a scale of 0 to 14 with 7 representing a neutral state, 0 representing the most acid and 14, the most alkaline.

PHENOLS -- A group of organic compounds that in very low concentrations produce a taste and odor problem in water. In higher concentrations, they are toxic to aquatic life. Phenols are byproducts of petroleum refining, tanning and textile, dye and resin manufacture.

RESERVOIR -- A pond, lake, tank or basin, natural or man-made, used for the storage, regulation and control of water.

RUNOFF -- The portion of rainfall, melted snow or irrigation water that flows across ground surface and eventually is returned to streams. Runoff can pick up pollutants from the air or the land and carry them to the receiving waters.

SUMP -- A depression or tank that serves as a drain or receptacle for liquids for salvage or disposal.

SURVEILLANCE SYSTEM -- A monitoring system to determine environmental quality. Surveillance systems should be established to monitor all aspects of progress toward attainment of environmental standards and to identify potential episodes of high pollutant concentrations in time to take preventive action.

TURBIDITY -- A cloudy condition in water caused by the suspension of silt or finely divided organic matter.

Glossary (Continued)

VECTOR -- Disease vector — a carrier, usually an arthropod, that is capable of transmitting a pathogen from one organism to another.

WATER HAMMER -- The ramming action that develops when a column of water is suddenly set into motion. It sometimes occurs when a pump starts, or when the water column is suddenly stopped, as when a valve is closed quickly.

WATER SUPPLY SYSTEM -- The system for the collection, treatment, storage and distribution of potable water from the sources of supply to the consumer.

WATER TABLE -- The upper level of ground water.

Footnotes

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3. U.S. Forest Service, Sanitary Engineering and Public Health Handbook (Draft), May 1976

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5. Kansas State Department of Health, A Manual of Recommended Standards for Locating, Constructing, and Equipping Water Wells for Rural Homes, Bulletin # 4-1, 1974

6. EPA, Technical Guidelines for Public Water Systems, June 1975

7. Environmental Protection Agency, Manual for Evaluating Public Drinking Water Supplies, EPA 430/9-75-011, 1975

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FEDERALLY COORDINATED PROGRAM OF HIGHWAY RESEARCH AND DEVELOPMENT (FCP)

The Offices of Research and Development of the Federal Highway Administration are responsible for a broad program of research with resources including its own staff, contract programs, and a Federal-Aid program which is conducted by or through the State highway departments and which also finances the National Cooperative Highway Research Program managed by the Transportation Research Board. The Federally Coordinated Program of Highway Research and Development (FCP) is a carefully selected group of projects aimed at urgent, national problems, which concentrates these resources on these problems to obtain timely solutions. Virtually all of the available funds and staff resources are a part of the FCP, together with as much of the Federal-aid research funds of the States and the NCHRP resources as the States agree to devote to these projects.*

FCP Category Descriptions

1. Improved Highway Design and Operation for Safety

Safety R&D addresses problems connected with the responsibilities of the Federal Highway Administration under the Highway Safety Act and includes investigation of appropriate design standards, roadside hardware, signing, and physical and scientific data for the formulation of improved safety regulations.

2. Reduction of Traffic Congestion and Improved Operational Efficiency

Traffic R&D is concerned with increasing the operational efficiency of existing highways by advancing technology, by improving designs for existing as well as new facilities, and by keeping the demand-capacity relationship in better balance through traffic management techniques such as bus and carpool preferential treatment, motorist information, and rerouting of traffic.

3. Environmental Considerations in Highway Design, Location, Construction, and Operation

Environmental R&D is directed toward identifying and evaluating highway elements which affect the quality of the human environment. The ultimate goals are reduction of adverse highway and traffic impacts, and protection and enhancement of the environment.

4. Improved Materials Utilization and Durability

Materials R&D is concerned with expanding the knowledge of materials properties and technology to fully utilize available naturally occurring materials, to develop extender or substitute materials for materials in short supply, and to devise procedures for converting industrial and other wastes into useful highway products. These activities are all directed toward the common goals of lowering the cost of highway construction and extending the period of maintenance-free operation.

5. Improved Design to Reduce Costs, Extend Life Expectancy, and Insure Structural Safety

Structural R&D is concerned with furthering the latest technological advances in structural designs, fabrication processes, and construction techniques, to provide safe, efficient highways at reasonable cost.

6. Prototype Development and Implementation of Research

This category is concerned with developing and transferring research and technology into practice, or, as it has been commonly identified, "technology transfer."

7. Improved Technology for Highway Maintenance

Maintenance R&D objectives include the development and application of new technology to improve management, to augment the utilization of resources, and to increase operational efficiency and safety in the maintenance of highway facilities.

* The complete 7-volume official statement of the FCP is available from the National Technical Information Service (NTIS), Springfield, Virginia 22161 (Order No. PB 242057, price $45 postpaid). Single copies of the introductory volume are obtainable without charge from Program Analysis (HRD 2), Offices of Research and Development, Federal Highway Administration, Washington, D.C. 20590.

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