Forest Service Handbook
National Headquarters -Washington Office
Washington, DC

Forest Service Handbook 7409.11 – Sanitary Engineering and Public Health Handbook

Chapter 40 - Drinking Water System Design and Construction

Amendment: 7409.11-2004-5

Effective date: October 01, 2004

Duration: This amendment is effective until superseded or removed.

Superseded Directive: 40--1 thru 43.83--2; 7409.11_10, Amendment 7409.11-2004-4

Approved by: Frederick L. Norbury, Associate Deputy Chief, NFS

Date approved: September 17, 2004

Responsible Staff:

Explanation of changes: Following is an explanation of the changes throughout the directive by section.

Posting Instructions: Amendments are numbered consecutively by Handbook number and calendar year. Post by document; remove the entire document and replace it with this amendment. Retain this transmittal as the first page(s) of this document. The last amendment to this Handbook was 7409.11-2004-4 to 7409.11_10.

40: Changes the chapter title from “Water Sources, Treatment and Distribution” to “Drinking Water System Design and Construction.” Incorporates requirements of current regulations and engineering standards, makes additional style, nomenclature and format changes throughout. Specific changes are as follows:

40.8: Updates references to current industry standards.

41: Revises this section to include contamination factors in development of water sources. Adds requirement to consider Federal/State Assessment procedures in determining Ground Water Under Direct Influence of Surface Water (GWUDI).

41.2: Removes reference to the hydrologic cycle and associated direction on determining sources of water. Recodes direction on the relationship of source to water quality and quantity to this section (formerly coded to 41.3).

41.3: Recodes direction on groundwater to this section (formerly coded to 41.4). Adds requirement to consider wells without well logs as GWUDI until Microscopic Particulate Analysis (MPA) or other means of classification are completed (para. 3).

41.31: Recodes direction on distance from source contamination to this section (formerly coded to 41.41).

41.32: Recodes direction on hydrogeologic investigation to this section (formerly coded to 41.42). Adds the use well surveys and/or aerial photo evaluations to list of appropriate tools of hydrogeologic investigations.

41.4: Recodes direction on surface water to this section (formerly coded to 41.5). Adds direction on GWUDI and Cryptosporidium. Provides general guidelines for considering a surface water supply.

41.42: Recodes direction on springs and seeps to this section (formerly coded to 41.52). Updates precautionary measures to help ensure quality of water from springs.

41.5: Recodes direction on wells to this section (formerly coded to 41.6). Updates exhibit 01 with current information regarding characteristics of wells. Changes phrase from "Drilled Horizontal Wells" to "Horizontal Wells" in paragraph 1.

41.51: Establishes this code to provide a separate section for updated direction on drilled wells (formerly coded to 41.6).

41.52: Recodes direction on sanitary aspects of wells to meet industry standards (formerly coded to 41.61). Updates direction regarding treatment of wastewater generated from a well (para. 1); increases minimum seal size from 10' to 20' or in accordance with state requirements (para. 5a); removes the guide on well casing selection, and updates casing materials to include Polyvinylchloride (PVC) in paragraph 6 and adds requirement to consider potential depth of standing water allowing submergence of well head (para. 8a).

41.53: Recodes and updates direction on well abandonment to include requirements on coordinating with State Primacy Agency (formerly coded to 41.62).

42: Removes the former Table 1 "Effectiveness of Various Modes of Treatment Against Certain Undesirable Constituents." Adds direction to require services of an experienced engineering specialist (para. 2).

42.1: Changes the caption from "Design of Water Treatment Facilities" to "Standards." Adds exhibit 01, "Description of Amendments to EPA Regulations," which summarizes the recent amendments to the Safe Drinking Water Act (SDWA). Adds statement regarding State Primacy and Standards of Quality.

42.2: Changes the caption from "Description of Treatment Processes" to "Disinfection" and removes detailed discussion of the types "generally most suited to Forest Service Installations." This decision and associated information should be collected and determined by the engineering staff and be based on the most current available technologies. Adds

direction on effective disinfection levels and “CT” Values. Changes the caption from “Disinfection” to “Chlorination”.

42.21: Updates direction on chlorination to include latest measurement technologies and industry standards. Removes specific direction on safety and handling of chlorine, and adds references to the industry standard, Material Data Safety Sheets (MSDS), for safety procedures.

42.22: Removes code and obsolete direction on plain sedimentation.

42.23: Removes code and obsolete direction on coagulation, flocculation, and settling.

42.24: Removes code and relocates direction on filtration to the new section 42.3.

42.25: Removes code and relocates direction on slow sand filters to the new section 42.33.

42.26: Removes code and relocates direction on aeration to the new section 42.4.

42.27: Removes code and relocates direction on softening to new section 42.51.

42.28: Removes code and relocates direction on iron and manganese removal to section 42.52.

42.29: Removes code and relocates direction on corrosion control to section 42.6.

42.3: Establishes this code and adds a reference to “EPA’s Manual of Small Public Water Supply Systems.”

42.31: Establishes this code and adds direction on conventional filtration.

42.32: Establishes this code and adds direction on direct filtration.

42.33: Establishes this code for direction on sand filtration.

42.34: Establishes this code and adds direction on bag and cartridge filtration.

42.35: Establishes this code and adds direction on other filtration technologies.

42.4: Establishes this code and adds direction on organic chemical removal, including direction on Granular Activated Carbon (GAC), and aeration.

42.5 - 42.53: Establishes these codes and adds direction on inorganic chemical removal, including updated direction on ion exchange, iron/manganese, and dissolved solids.

42.6: Establishes this code and relocates and updates direction on corrosion control to this section, incorporating the latest industry standards.

43.1: Adds design and layout parameters that are to be considered during the development of storage and distribution systems. Adds survey requirements into the design process.

43.11: Revises direction for fire demand storage to incorporate industry standards and State and local requirements. Adds an exhibit that illustrates typical hourly demand variations.

43.2 - 43.22: Removes direction on types of systems. The specifics of these system types should be reviewed in industry manuals and professional engineering references for the most up-to-date information, as well as how each system type will operate in the site specific conditions. Recodes to this section the direction on hydraulic analysis (formerly coded to 43.3).

43.3: Establishes this code and recodes to this section the direction on water tanks (formerly coded to 43.4).

43.31: Establishes this code and recodes to this section the direction on design (formerly coded to 43.41). Adds requirement to incorporate overflow into the design of storage tanks. Removes the prohibition of wood constructed tanks. The design engineer will need to decide if the materials are suitable for the application, and wood is not precluded from this decision.

43.32: Establishes this code and recodes to this section, the direction on operating conditions (formerly coded to 43.42).

43.41: Recodes direction on material for pipe and fittings to this section (formerly coded to 43.51). Removes direction on cast iron pipe with ductile iron pipe. Removes references to asbestos cement pipe. Removes references to brass and copper piping and tubing. Updates direction on plastic piping to conform with industry standards.

43.42: Adds direction on corrosion control.

43.43: Recodes the direction on selection of pipe size to this section (formerly coded to 43.52). Removes the list of minimum sizes for fixture supply piping, and removes the direction on head loss in pipe fittings.

43.5- 43.52: Recodes direction on piping systems to these sections (formerly coded to 43.4 through 43.43). Removes direction on probable demand (formerly coded to 43.53). Recodes to these sections, the direction on appurtenances, disinfection, facilities, and gauges (formerly coded to 43.6 through 43.62).

43.53 - 43.55: Establishes new codes and recodes to these sections, the direction on meters, valves, and underground locations (formerly coded to 43.63 through 43.64a).

43.6: Recodes to this section, the direction on sanitation (formerly coded to 43.7 through 43.71).

43.61: Recodes and revises the direction on cross-connection requirements to meet industry standards (formerly coded to 43.73).

43.7 - 43.72: Recodes to these sections, the direction on construction, construction control, and construction features (formerly coded to 43.8 through 43.82). Removes direction on separation of water and sewer lines formerly coded to section 43.72 because the design requirements are subject to State and local regulations regarding the separation of these utilities.

43.8 - 43.83: Removes these codes and removes direction on operation and maintenance considerations (formerly coded to 43.83). This topic is covered in Chapter 70, "Operation and Maintenance of Drinking Water and Wastewater Systems."

44 - 44.2: Establishes these codes and recodes direction on water quantity (formerly coded to 28 through 28.4) to these sections. Makes grammatical and formatting changes throughout.

45 - 45.3: Establishes these codes and recodes direction on fire protection (formerly coded to 29).

Table of Contents

40.2 - Objective

The objective of this chapter is to provide a guide to Forest Service engineers for developing water sources and delivery systems that meet quality and quantity standards and requirements.

40.5 - Definitions

Refer to FSM 7420.5 for definitions of the terms used in this chapter.

40.8 - References

1. Driscoll, Fletcher G. 1986. Groundwater and Wells, Second Edition, Johnson Division.

2. U.S. Environmental Protection Agency (EPA). 1975. Manual of Water Well Construction Practices, EPA Number: 570975001.

3. Salvato, Joseph A., Nemerow, Nelson L., Agardy, Franklin J. 2003. Environmental Engineering, Fifth Edition, John Wiley & Sons.

4. American Society of Civil Engineers, American Water Works Association. 1997. Water Treatment Plant Design, Third Edition, McGraw-Hill Professional.

5. American Water Works Association (AWWA). 1973. Water Chlorination Principles and Practices, AWWA Manual M20..

6. U.S. Environmental Protection Agency (EPA). 2003. Cross-Connection Control Manual, EPA Number 816-R-03-002.

7. Merritt, Frederick S., Loftin, M. Kent, Ricketts, Jonathan (editors). 1995. Standard Handbook for Civil Engineers, Fourth Edition, McGraw-Hill Professional.

8. American Water Works Association (AWWA). 1997. A100: Water Wells.

9. U.S. Environmental Protection Agency (EPA). 1991. Technologies for Upgrading Existing or Designing New Drinking Water Treatment Facilities, CRC Press.

10. U.S. Environmental Protection Agency (EPA). 1990. Environmental Pollution Control Alternative: Drinking Water Treatment for Small Communities, EPA Number: 625590025.

11. U.S. Environmental Protection Agency (EPA). 1992. Drinking Water Handbook for Public Officials, EPA Number: 810B92016.

12. U.S. Environmental Protection Agency (EPA). 1991. Manual of Small Public Water Supply Systems, EPA Number: 570991003.

13. U.S. Environmental Protection Agency (EPA). 1997. Small System Compliance Technology List for the Surface Water Treatment Rule, EPA Number: 815R97002.

14. Hendricks, David. 1991. Manual of Design for Slow Sand Filtration, American Water Works Association.

15. U.S. Environmental Protection Agency (EPA). 2003. Revised Guidance Manual for Selecting Lead and Copper Control Strategies, EPA Number: 816R03001.

16. Osmonics, Inc. 1997. Pure Water Handbook, Second Edition.

17. National Fire Protection Association (NFPA). 2001. NFPA 1142 - Standard on Water Supplies for Suburban and Rural Fire Fighting.

41 - Water Source Exploration and Development

When a new or an increased water use is anticipated, sources are explored to ascertain that water is available to meet present and future public demand. Present and future contamination factors are critically reviewed, as well as the management direction in the watershed or development area affecting the source.

1. A sanitary survey must be conducted in accordance with the procedures outlined in FSH 7409.11, chapter 10.

2. When evaluating potential sources of water supply, the following should be considered:

    a. The hydrologic, geologic, chemical, physical, and biological nature of potential sources of supply, and how these factors affect the quantity and quality of the potential water sources.

    b. The legal right of the Forest Service to use the water, including procedures necessary to establish the right.

    c. A comparison of quantity and quality of potential sources in relation to potential uses.

    d. The requirements to satisfactorily develop each source, and the construction, maintenance, and operation costs associated with the development.

    e. Federal and State assessment procedures used to determine groundwater under the direct influence of surface water.

41.1 - Water Rights

Some individual water rights may stem from ownership of property. Others may accrue by performing certain acts required by law. In some instances, entitlement to use diverted water may be restricted in the extent of its use. In all cases, before developing a water source,

determine the requirements of a particular State and follow Regional instructions to clearly establish the right of the Forest Service to use the water. Some States have laws relating to both surface and ground water rights. Also see FSM 2540 for further guidance on water rights.

41.2 - Relationship of Source to Water Quality and Quantity

The source of water greatly affects its quantity and quality. Forest Service engineers must evaluate the characteristics of a water source to determine a minimum sustained yield and the consistency and predictability of water quality. The water must be adaptable to the constraints imposed upon it by the intended use.

The predictability of water quality is dependent upon the protection measures taken to ensure uniform quality of a water source. Protection measures vary from closed watersheds to engineered structures that minimize contamination or deep well seals. A sanitary survey should be employed to identify actual or potential sources of contamination, and then a hydrogeologic investigation and a technical judgment must be conducted to ensure that potential pollution sources will not adversely affect the water.

The Environmental Protection Agency and State regulatory agencies have overall responsibility for all public drinking water systems. Drinking water standards assume no natural purification, regardless of source, and dictate quality assurances for all water delivered from Forest Service water systems.

41.3 - Groundwater

Groundwater is water collected directly from the zone of saturation by horizontal or vertical wells, or properly developed springs. These sources are often selected because of sustained rates of flow, constant temperature and pH, low turbidity, and reduced likelihood of biological contamination. These advantages are often offset by high levels of dissolved chemicals, which may adversely affect the intended use of the water.

Groundwater is most effectively protected when the water-bearing sand or gravel formation is overlain by strata of impermeable soil, such as clay or hardpan. In the absence of overlying impermeable strata, groundwater quality is reasonably protected when overlying formations are of a sandy character and of sufficient depth to ensure good filtering action. Groundwater quality becomes vulnerable to contamination when surface water is capable of reaching 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, sinkholes, solution channels in limestone or other karst formations, coarse gravel formations, or man-made excavations.
Consider water wells without proper well logs as groundwater under the direct influence of surface water until proven to be groundwater. Microscopic Particulate Analysis (MPA) at certain periods of the year, or other means determined by Federal and State regulatory agencies, may result in official groundwater classification.

41.31 - Distance From Source of Contamination

1. In some cases, it is not possible to avoid using groundwater that is subject to some contaminated drainage as a source of water supply. In this case, decide on a minimum distance between the water source and the origin of contamination and mitigate the situation through appropriate treatment processes. A minimum distance is dependent upon many local factors, which include, among other things, an evaluation of the following:

   a. Character and location of source of contamination,

   b. Permeability and structure of the water-bearing formation,

   c. Type of well or spring and nature of construction,

   d. Natural slope of the water table,

   e. Influence of well pumpage on the cone of depression, and

   f. The Federal and State assessment procedures used to determine groundwater under the direct influence of surfacewater.

   g. Geologic Characteristics; for example, in crystalline formations, such as fissured limestone formations, there is no safe distance, since the contamination may travel many miles.

2. Because determination of a minimum distance between a groundwater source and a source of contamination is dependent on many factors, such as topography, geology, economics, and landownership, it is impracticable to establish arbitrary distances, which may not be adequate under all conditions. Each installation should be inspected by a person with sufficient training and experience to evaluate all the factors involved. Required setbacks are generally set by local codes. Available information on travel of pollutants in underground formations suggests minimum distances from ground-water supplies to various contamination sources in accordance with the following tabulation:

3. In addition to observing minimum setback distances, where the area adjacent to the water source is accessible to livestock, the groundwater source should be enclosed by a fence located in all directions not less than 100 feet 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. In any case, the State or local regulatory agency should be consulted and applicable permits should be obtained. The permit should define physical requirements that must be designed into the development.

41.31 - Exhibit 01

Minimum Recommended Distances Between Water Supplies and Various Contamination Sources

Source of contamination	Distance (feet)
Pit privies and valut toilets	100
Sewers	50
Septic tanks and distribution boxes	50
Subsurface sewage-disposal fields (Receiving effluent from septic tanks or aeration units)	100
Seepage pits (Receiving effluent from septic tanks or aeration units)	100
Barnyards	100
Cesspools	150

41.32 - Hydrogeologic Investigation

When developing groundwater sources, the development costs may exceed economic feasibility. Qualified personnel should conduct a geologic investigation to provide subsurface information that will be used to estimate costs associated with the development of the source, and to lessen the risk of developing a source that produces insufficient quantity or poor quality. This investigation may include:

1. Exploratory drilling,
2. Electric logging,
3. Electric resistively surveying,
4. Seismic refraction surveying,
5. Well survey of the area, or
6. Aerial photo evaluation.

Additional assistance on geology and hydrology may be obtained from State specialists and consultants, the Water Resources Division of the U.S. Department of the Interior, U.S. Geological Survey, and local well drillers.

41.4 - Surface Water

Surface water includes water from streams, lakes, ponds, or other sources where the water is at the surface of the ground. Most water developed by shallow wells, springs, or other catchments close to the surface should also be considered surface water or groundwater under the direct influence of surface water. This should be determined during the sanitary survey. Surface water supplies are often subject to rapid and extreme changes in character. Surface water supplies are also subject to pollution from many sources, and are particularly susceptible to microbiological contamination by organisms such as *Giardia lamblia* and *Cryptosporidium parvum*. Surface water supplies are the least protected sources of water for domestic purposes, because of the potential for widely variable water quality. They are subject to temperature stratification, inversions, and mixing. Aquatic plants, ranging from algae to higher forms, create taste and odor problems. Human activities can introduce contamination by bacteria and possibly petroleum products. Mineral content can vary widely due to seasonal changes in runoff conditions. Seasonal variations causing turbidity and organic growth can be vexing operational problems.

When considering a surface water supply, perform the following:

1. Evaluate the proposed water source for vulnerability to contamination from sources such as wastewater discharges, industrial operations, mining and use of pesticides in the watershed.

2. Use watershed stability and control measure to improve the quality and reliability of a surface water source.

3. Conduct a thorough sanitary survey of the watershed area and a bacteriological, chemical, and physical examination to help determine the probable characteristics of the surface water and the type of treatment required.

4. Design and construct surface water collection facilities to ensure consistent quantity and quality of the water in compliance with Federal, State, and local regulations.

5. Consider direct intake structures only after careful analysis of water-quality variations and the intended use of the water.

6. Consider water wells without proper well logs as groundwater under the direct influence of surface water until proven to be groundwater as determined by Federal and State regulatory agencies.

41.41 - Infiltration Galleries

Infiltration galleries may be used either in streambeds or a short distance back from the bank of a stream or lake to collect water. Infiltration galleries may also be used to collect water from wet meadows. A properly constructed infiltration gallery removes suspended matter from the water, but cannot be relied upon to produce bacteriologically safe water. The water is still essentially surface water and must meet surface water treatment requirements. 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 remove all wood, leaves, and foreign matter from the sand and gravel which might decay and cause odors or tastes in the water.

41.42 - Springs and Seeps

Springs, if properly developed, can be defined as groundwater sources upon evaluation and approval by Federal or State regulatory agency. Springs that demonstrate wide seasonal fluctuations in flow are suspected of being under the direct influence of surface water. Caution should be used in excavating and exploring the spring source so as not to disturb the flow and perhaps lose the spring. In seep areas, it may be necessary to lay perforated pipe in a gravel bed to collect sufficient water. In such cases, construction similar to infiltration galleries may be required.

Use the following precautionary measures to help ensure continuing high water quality of developed springs:

1. <u>Spring Location</u>.

   a. Ensure that the spring exits competent rock in a clearly defined flow or exists as a subsurface point source at least 5 feet deep (7 to10 feet is preferred). If possible, avoid horizontal seep lines as they have a higher degree of risk from surface water contamination.

b. Keep the area above the spring (such as the uphill edge of the saturated area) dry.

c. Choose steeper slopes over shallower slopes, because depth of cover is attained more quickly.

d. Collect water where it flows from the formation, before any potential of surface water influence.

e. Do not develop springs in depressed areas, or downgradient from surface water features or pollution sources, such as pit toilets and sewage disposal fields.

f. If possible, avoid areas that have heavy growth of trees or brush since deep roots can interfere with the spring and require increased maintenance, and burrowing animals or decaying roots can channel contamination to the spring.

2. Spring Construction.

a. Excavate carefully. Imprudent excavation may alter the water flow. If possible, excavate to a depth where the point source of the spring is isolated.

b. Seal the spring box from surface water influences. It is very important to protect the collected groundwater from outside moisture or other sources of contamination.

c. Include spring box plumbing components, such as collection pipe, discharge pipe, overflow pipe, sampling tap and vent. In cold climates, a winter overflow will also be required.

d. Do not allow growth of large shrubs or any trees over the spring area. Roots can damage the spring box and breach the seal.

e. Provide for conveying surface drainage away from the site. A 12-inch deep surface-diversion ditch located uphill of the spring should prevent uphill contamination from moving across the source. The diversion ditch should preferably be located at least 25 feet uphill of the spring.

f. Construct a sturdy fence around the spring area to prevent entry of livestock. The fence should be at least 50 feet, and preferably 100 feet, from the source. The drainage ditch should be inside the fence at all points uphill from the source.

3. Spring Water Quality. Monitor the quality of the spring with periodic checks. A marked increase in turbidity after storms may indicate that surface runoff is reaching the spring. Follow State regulations for assessment and testing to determine whether the spring is under the direct influence of surface water. The required procedures may extend through several seasons of operation. If the spring is classified as groundwater under the direct influence of surface water (GWUDI), the water must meet Federal and State surface water treatment requirements.

41.5 - Wells

Groundwater occurs in consolidated rock materials and in loose unconsolidated materials. Any type of rock, sedimentary, igneous, or metamorphic, whether consolidated or unconsolidated, may be an aquifer if it is sufficiently porous and permeable.

An aquifer performs two important functions, storage and transmission. The openings or pores in a water-bearing formation serve both as storage spaces and as a network of conduits. The groundwater is constantly moving from areas of recharge to areas of discharge. Movement is usually very slow, with velocities measured in feet per day or even feet per year. As a consequence of this and of the great volume that can be represented by its porosity, an aquifer may retain enormous quantities of water in transient storage.

Openings in subsurface geologic formation may be:

1. Openings between individual particles, as in formations of sand and gravel;

2. Crevices, joints, or fractures in consolidated material which have developed from breaking of the rock; or

3. Solution channels and caverns in limestone, and

4. Openings resulting from shrinkage and from the evolution of gas in lava.

Conduct a geologic investigation of the well site and make recommendations for the appropriate construction method to use for developing the aquifer (percussion, jetting, or rotary). Exhibit 01 provides general information on the suitability of different well construction methods for various conditions.

1. <u>Horizontal Wells</u>. Jointed or fractured aquifers, occurring in igneous rock, are often tapped with horizontal drains. This method of water development consists of drilling one or more horizontal holes into an area where water may be developed. A pipe with perforations is then inserted in the hole, the area around the pipe is grouted, and the groundwater flows through the pipe for use as needed.

2. <u>Vertical Wells</u>. Vertical wells are generally classified as dug, bored, jetted, driven, and drilled.

   a. <u>Dug Wells</u>. Dug wells are open excavations from which the earth was removed by hand or machine-powered shovels. Dug wells are presently used, but the development of new ones should be discouraged because they are generally shallow and subject to surface sources of contamination.

   Infiltration galleries are in essence dug wells. All dug wells should be considered collection facilities for surface waters by virtue of their susceptibility to surface contamination.

   b. <u>Bored Wells</u>. A bored well is one in which the excavation is made by the use of hand or power augers.

c. Jetted Wells. A jetted well is one in which the excavation is made by use of a high-velocity jet of water.

d. Driven Wells. A driven well is one which is constructed by driving a pointed screen, referred to as a drive point, into the ground. Casings or lengths of pipe are attached to the drive point as it is being driven.

Driven wells are prohibited for potable water supplies in many States, because of the inability to provide a seal around the casing.

e. Drilled Wells. A drilled well is one in which the excavation is made by either percussion or rotary drills. The excavated material is brought to the surface by means of a bailer, sand pump, suction bucket, hollow drill tool, or hydraulic or air pressure.

Drilled wells are the preferred method of groundwater development because;

(1) they can be constructed to draw water far below the water table,

(2) the groundwater is less subject to surface contamination, and

(3) the yield is less influenced by fluctuating water tables.

41.5 - Exhibit 01

Characteristics Of Various Well Construction Methods

Characteristic	**Type of Well Construction Tool**				
	Bored Rotary	Driven Percussion	Drilled Percussion	Drilled Rotary	Drilled Jetted
Range of practical depth	0 - 100 ft	0 - 50 ft	0 - 5,000 ft	Indefinite	0 - 100 ft
Diameter	2 - 30 in	1¼ - 2 in	4 - 18 in	4 - 24 in	4 - 12 in
Suitable in geologic formations:					
Clay	Yes	Yes	Yes	Yes	Yes
Silt	Yes	Yes	Yes	Yes	Yes
Sand	Yes	Yes	Yes	Yes	Yes
Gravel	Yes	Fine	Yes	Yes	¼" pea gravel
Cemented Gravel	No	No	Yes	Yes	No
Boulders	Less than well diameter	No	In firm bedding	Difficult	No
Sandstone	Soft	Thin layers	Yes	Yes	No
Limestone	Soft, Fractured	No	Yes	Yes	No
Dense Igneous Rock	No	No	Yes	Yes	No

Note: The values in this exhibit are based upon general conditions; values may differ under site-specific conditions.

41.51 Drilled Wells

1. Drilled Vertical Wells. Vertical wells shall meet the requirements specified by the Regulatory Agency for a commercial well. The depth and diameter of the casing are determined by the well seal length and yield requirements. The drilling method must be approved by the Regulatory Agency and produce an acceptable sanitary facility.

2. Drilled Horizontal Wells. Horizontal wells are difficult to drill in alluvial material because the drill is often diverted by round rocks and boulders, such that either the drill binds or a zigzag hole results. Horizontal drains are more successful when the native material is solid rock, impermeable clay, or material cemented together by leaching clays or limestone.

Depth of the well seal is of critical importance. The intent is to develop a true groundwater source by sealing off potential surface water contamination. Some jurisdictions require 50 vertical feet of cover above the well seal location. To achieve this, the annular seal would have to be properly installed 100 feet into the hillside on a 2:1 slope.

3. Drilling Methods. Drilled wells are constructed by the hydraulic rotary, air rotary, or percussion-tool method. Experience of local drillers can be invaluable in selecting the best drilling method.

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-head chisel tool. It breaks the formation into small fragments. A reciprocating motion is imparted to the drilling tools, which mix the loosened material into a sludge that is removed from the hole by a bailer or sand pump. Above the water table, water is added to form a slurry to facilitate removal of the cuttings. If the water-bearing formation lies at a depth that cannot be reached by a hole of uniform diameter, the hole must be started one or more sizes larger than the size desired at the bottom.

The well casing is usually not installed as drilling progresses; it is preferable to delay casing installation until the drilling is completed. Ordinarily a hole is drilled slightly greater in diameter than the bit, leaving clearance for movement of the casing and string of tools. If the casing is placed while drilling and cannot be advanced for some reason, such as skin friction on the casing, a smaller casing is inserted inside the original casing and the well is continued at a smaller diameter. The smaller casing is cut off near the bottom of the larger casing and the space between the casings sealed.

The hydraulic-rotary method of drilling is accomplished by rotating suitable tools that cut, chip, and abrade the rock formations into small particles. The equipment consists of:

a. A derrick,

b. A hoist to handle the tools and lower the casing into the hole,

c. A rotary table to rotate the drill pipe and the bit,

d. Pumps to handle mud-laden fluid, and

e. 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 "drag" 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.

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 advantage of this method is that small quantities of water can readily be detected during drilling operations.

4. Drilling Method Selection.

a. Cavernous Rock and Highly Permeable Material. 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, rotary drilling may be employed using expedients to overcome loss of fluid. For example, commercial clay or fibrous material, such as hay or sawdust, can be mixed with the drilling fluid to seal porous formations.

b. Thin, Tight Aquifers. 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.

c. Uncertain-Depth Aquifers. The air rotary method is usually preferred where the depth to water is uncertain, where solid rock will be encountered, or where an 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.

41.52 - Sanitary Aspects of Well Structures

The goal in the drilling of all wells on National Forest System land is to produce safe water and to protect the aquifer from which the water is taken. Drilling standards for nonpotable water wells cannot be less than standards for potable water wells. This includes those wells drilled for irrigation and stock water purposes.

Care must be exercised during the construction phase to prevent the injection of contaminants into the substrata. The well structure must incorporate features to minimize sand and turbidity intrusion and safely seal the well from surface contamination.

1. Developing. This is the process by which the maximum quantity of sands and fines is extracted from the aquifer, that might otherwise be drawn into the well bore or impede the yield. This process also establishes a natural gravel pack around the well screen by developing a formation of native materials in which the coarse-grained particles are brought to the surface of the perforated casing or screen to act as a filter in removing fines from the well water. 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 or rock) may also require developing. Generally, pumping or surging removes any fines that may have plugged fractures and crevices. The following direction relates to unconsolidated formations only. The yield of the well may be lost or greatly reduced by over-development. Conversely, many wells may be "sand pumpers" or may yield only a fraction of their potential if they are not adequately developed. Methods of development and their application differ with the water-bearing formations, with the companies drilling the well, and with individual drillers. Running a bailer up and down in the well a few times can provide some agitation, but cannot be considered developing. The engineer should specify the exact method of development or receive a detailed plan for developing the well from the well driller. Wastewater from the well developing operation may require special treatment to prevent surface water features from becoming turbid.

2. Gravel Packing. Gravel-packed wells are also known as gravel filter or gravel wall wells. Gravel packing is the process by which selected gravel is placed between the outside of the well screen and the face of the undisturbed water-bearing formation. It is especially useful in the development of water from formations composed of fine material of uniform grain size which cannot be adequately developed to form a natural gravel pack. Either during or after the gravel packing of the well, the usual development processes are employed to remove fine material that may be unstable and to stabilize the inserted gravel.

3. Formation Stabilization. Formation stabilization is the practice of introducing a clean, non-uniform, sand-gravel mixture into the annular space around a well screen installed in a well. This process aids in the natural development of the well and prevents caving zones above the aquifer from contaminating the water supply. The size of well casing or screen openings is selected to permit natural development of the well just as if the formation stabilizer was not used. This technique requires limited knowledge of the aquifer and adequate grading of the gravel pack and the size of casing or screen openings.

4. Well Screens and Perforations. Wells deriving water from unconsolidated formations can be equipped with perforated casing or well screens, depending on the entry velocity desired. Perforated casing or well screen allows water from the aquifer to enter the well while it supports the water-bearing formation and prevents the drill hole from collapsing. A properly designed well screen also performs the important function of preventing sand from entering the well.

The length of active screen must be determined based on factors such as thickness of water-bearing strata, type of screen, size and spacing of openings, and required well capacity. For best results, the screen should be designed to produce a minimum loss of head or drawdown between the water-bearing strata and the well. It is desirable not to specify the length in advance but to wait until adequate information is available regarding the thickness and character of the water-bearing strata. If water is to be obtained from a well tapping more than one aquifer, the screens required for the various water-bearing strata may require different lengths and opening sizes.

Casing perforations are used in lieu of well screens in formations where a natural screen can be formed by the perforations and native granular materials in the aquifer. If sufficient information is available, the casing may be perforated in advance of installation.

5. 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 chemical quality, and to stabilize soil or rock formations. Material used for the annular well seal must be placed by methods that prevent freefall, bridging or segregation of sand or aggregates from cement-based sealants.

a. Depth of Seal. The depth required for protection from surface contamination depends upon the character of the formation (whether porous or impervious, fine- or course- grained) and upon the depth and proximity of such sources of pollution as sinkholes, sewage disposal units, abandoned or poorly constructed wells, mine workings, and outcrops. At least 20 feet of seal is necessary increasing to 50 feet for most commercial application or in accordance with State codes or requirements. The actual volume of sealant installed should be verified by calculating expected quantities.

b. Corrosion Protection. The casing is particularly sensitive to corrosion in the zone of aeration. Properly placed grout extends the life of the casing by protecting it from oxidation or extremely chemically aggressive ground waters. For protection, the grout must be at least ½- inch thick.

c. Creviced Rock and Unwanted Aquifers. Extension of well casing and sealing of the annular space are particularly important in creviced rock formations, which have connection with the ground surface. Unless the annular space is sealed, a direct channel can develop between crevices in the upper part of the formation, which may contain contaminated water, and the point of intake at the lower terminal of the casing pipe. In creviced rock formations, considerable protection

for the supply may be attained by casing and sealing the annular space to a depth of at least 20 feet below the lowest pumping level.

6. Casing. Well casings and liners have the dual purpose of sealing out contaminated and other desirable water and of maintaining a uniform opening from the surface to the aquifer.

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

Selection criteria for the type and thickness of pipe must include 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.

The preferred casings are steel pipe (either threaded or welded) and polyvinylcholride (PVC) well casing. Strength requirements are critical when specifying PVC well casing. Special pipe coatings may be necessary in areas of corrosive ground waters. All materials must be certified by NSF International for NSF/ANSI Standard 61: Drinking Water System Components - Health Effects.

Consideration should be made during casing installation for hand pump installations so that proper strength and extension above the ground is achieved.

7. Disinfection. Bacterial protection is an ongoing process during well construction, especially immediately after construction, and after well modifications are made, such as the pulling and replacement of a pump.

The well driller should exercise care during construction to ensure the use of clean tools, free of soil, grease, and oil; uncontaminated drilling mud; and other uncontaminated materials. Material ejected during the drilling operation should be conducted away from the well head. It is desirable to maintain a chlorine residual in the drilling mud, especially in low-yield wells.

Disinfection is often economically and effectively accomplished by using calcium hypochlorite (70 percent available chlorine). A dosage of approximately 100 mg/l in the well water is a desired concentration, but this figure should be considered as only a guide.

8. Ground-Level Development.

a. Slab. A well slab alone is not an effective seal because 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. Care should be taken to ensure that standing water cannot get deep enough in an enclosure to submerge the well head. Install drains of sufficient size to accommodate discharge from pressure relief valves or broken pipes.

b. Pitless Adapters. Because of the pollution hazards, a well pit to house the pumping equipment or to permit accessibility to the top of the well is not allowed.

The pitless adaptor is available to eliminate well-pit construction. It 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) 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.

Pitless-adapter-equipped wells should be located outside of associated structures or buildings, to facilitate maintenance.

c. Sanitary Seals. Every well must be provided with a tight-fitting sanitary cover at the top of the casing or pipe sleeve to prevent contaminated water or other material from entering the well. When it is anticipated that a well seal may become flooded, it should be watertight and equipped with a vent line with an opening to the atmosphere that is at least 2 feet above the highest known flood level.

The seal in a well not exposed to possible flooding should be either watertight, with an approved vent line, or self-draining, with an overlapping and downward flange. If the seal is of the self-draining (nonwatertight) type, all openings in the cover should be either watertight or flanged upward and provided with overlapping, downward flanged covers.

41.53 - Well Abandonment

Unsealed, abandoned wells constitute a potential hazard to the aquifer and public health. Abandoned wells should be properly sealed, with the intent of restoring, as much as feasible, the controlling geological conditions that existed before the well was drilled or constructed. Abandoned wells should never be used for the disposal of sewage or other wastes.

The proper sealing of an abandoned well involves consideration of the construction of the well and the geological and hydrological conditions of the area. The main factors to be considered are the elimination of any physical hazard, the prevention of any possible contamination of the groundwater, the conservation and maintenance of the yield and hydrostatic pressure of the aquifer, and the prevention of any possible contact between desirable and undesirable waters.

When a well is to be permanently abandoned, the lower part 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 as possible should be removed in order to prevent surface water from reaching the water-bearing strata through a porous lining or one containing cracks or fissures.

The State regulatory agency has jurisdiction over well abandonment. Proper permits should be secured and applicable standards followed during the well abandonment process.

41.54 - Wells Constructed But Not in Service

Wells are often constructed at sites in anticipation of developing the site at a later date. The well may remain unused for a few months to a few years. In this case, the well casing should extend at least 2 feet above the highest known flood level or the existing ground and be provided with an overlapping, tightfitting sanitary seal at the top of the casing. Prior to connecting such a well to a distribution system, it should be measured for depth, plumbed for alignment, checked for soundness, tested for yield and drawdown, and disinfected.

41.55 - Artesian Wells

When a well is projected into an artesian water formation, the construction of the well should be such that it conserves the supply and head by preventing loss of water into overlying lower-head formations, and by preventing leakage to the surface around the casing pipe. Construction should also be such that the developed flow can be controlled.

Artesian wells may be developed in either consolidated or unconsolidated formations. In the construction of artesian wells, the initial drilling operations should extend into, but not through, the impervious formation confining the water under artesian head. The protective casing should be installed, then the cement grout seal for the annular space should be installed and given ample time to cure. The drilling operations into the artesian strata are then continued with or without casing protection. Where the nature of the impervious confining bed is such that erosion by the flowing water may occur, a casing extending into the artesian aquifer is essential.

Flow-control devices may consist of valved pipe connections, water-tight pump connections, or receiving reservoirs set at an elevation corresponding to that of the artesian head. Valving arrangements should be automatic, if manual control to prevent wasting water is not practical. The life of an artesian well, particularly if the water is corrosive, may be prolonged substantially by the installation of a replaceable eductor, or flow pipe, properly sealed with packers at the top and bottom of the casing.

If it is necessary to disinfect the well after construction, a supply of concentrated hypochlorite should be placed in the artesian aquifer below the casing. The chlorine residual can be measured at the well head.

41.56 - Well Record

A well record, or log, recording the various strata through which the well was constructed, must be prepared during the well construction. A copy of the log should be included in the Operation and Maintenance manual, and a copy should be retained in the project file for future reference. Copies of the log should be filed with appropriate authorities (FSM 2540).

Any of several types of well logs may be produced, including electrical-resistivity and gamma-ray logs. 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 each stratum, and the depth to water.

Samples of subsurface materials obtained during the progress of the drilling operation, are, in most cases, the best source of geologic and hydrologic information. The principal object in drilling test holes is to obtain samples that reveal the character, depth, and thickness of the various strata.

Ideally, the driller should collect representative samples at measured depths and at such intervals to show the complete lithologic character of the formation penetrated. The coring method that can be used when drilling consolidated rocks is the nearest thing to this ideal situation. Drive-core sampling methods that are applicable when drilling unconsolidated or soft materials are next best.

The samples usually obtained by other methods are cuttings resulting from the action of the drill bit. While not entirely representative of the formations penetrated, they are commonly relied upon for future groundwater exploration.

Interpretation of these samples should be completed by a qualified ground-water geologist.

41.67 - Yield and Drawdown

1. Yield Test. Preliminary yield tests are needed as construction of well progresses to determine whether the well should be drilled deeper, whether development should be undertaken, or whether the required capacity has been obtained.

A final yield test is necessary to determine the capacity of the well and to plan the permanent pump installation. Final yield tests are performed on all new wells. Existing wells should be tested for yield when a higher capacity pump is planned and when reliable test results are not already available.

Final yield tests should be performed by pumping. Bailing tests are not considered reliable and should not be used for determining the final yield. The test pump capacity should be equal to the maximum anticipated well production, or at least 50 percent greater than the capacity of the pump planned for permanent installation. The test pump setup should be equipped for variable discharge so that the drawdown at various rates, including the rate of the planned permanent pump, can be determined.

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

a. Record the water level in the well before pumping starts. This is referred to as the static water level.

b. 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 where the water level will stabilize.

c. 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.

d. Observe and record returning water levels after pumping has ceased.

e. Change pumping rate to discharge planned for permanent pump installation, and record drawdown when water levels stabilize.

f. Repeat paragraph d.

2. Determination of Water Level and Drawdown in Deep Wells. The most satisfactory method of determining the water level in a deep well involves the use of a ¼-inch air line of known vertical length, a pressure gauge, and an ordinary automobile tire pump, or a source of compressed air or other gas. If possible, the air line pipe should:

a. Reach at least 20 feet beyond the lowest anticipated water level in the well to ensure more reliable gauge readings and

b. Not be attached to the pump column or bowls, because being so would hinder the removal of the pipe should any leaks develop.

Use an air pressure gauge to determine the pressure in the air line. Some manufacturers provide pumps with the air line and pressure gauge already installed.

The ¼-inch air line pipe is lowered into the well, a tee is placed in the line above ground, a pressure gauge is screwed into one tee opening and the other tee opening is fitted with an ordinary tire air valve to which the air source is attached. All joints must be made carefully and must be airtight to obtain correct information. When air is forced into the line by means of the pump, the gauge pressure increases until all the water in the line has been expelled.

When this point is reached, the gauge reading becomes constant. The maximum maintained air pressure recorded by the gauge should be equivalent to the pressure necessary to support a column of water of the same height as that forced out of the air line.

The length of the water column should be equal to the amount of air line submerged. Deducting this pressure, converted to feet of water, from the known length of the ¼-inch air-line pipe determines the water level. If the well pumping continues, additional measurements can be taken to determine rate of drawdown, point at which drawdown remains constant for the particular pumping rate, and so on.

Electrical sounding devices may also be used to determine water levels. The space between the well casing and the pipe column should be used to lower the sounding device to avoid entangling the sounder.

42 - Water Treatment

All surface water sources and some groundwater sources require treatment of some form. The purposes of water treatment are to produce safe and aesthetically pleasing water for the

customer. Producing biologically and chemically safe water in accordance with Federal and State regulations and standards is the primary goal. Aesthetically pleasing water can be characterized as odorless, colorless, pleasant tasting, cool, clear, non-staining, and neither corrosive nor scale forming. Some properties may not be fully achievable at some Forest Service sites given the source water conditions and economic constraints.

The selection and design of water treatments should be performed by a qualified engineer experienced in this field of work. Various alternatives should be evaluated to measure the quality of water produced and to determine life cycle cost-effectiveness. The alternatives should be based on sound engineering principles and consider the following factors:

1. Regulations and standards.
2. Raw water characteristics.
3. Treatment process compatibility and effectiveness.
4. Operating considerations.
5. Operator skills needed.
6. Initial and annual costs.
7. Existing system configuration.
8. Future needs and changing conditions.
9. Emergency situations; reliability needed.
10. Alternatives to providing treatment - find new water source, connect to public system, and eliminate water at site, and so on.
11. Management of wastes generated by treatment processes.

Sections 42.1 through 42.6 contain brief descriptions of technologies the Forest Service typically uses. Additional information can be obtained from other drinking water references, such as those listed in section 40.8.

42.1 - Standards

The regulations, standards and options for water treatment have become increasingly enlarged in scope and complexity in recent years. Drinking water projects generally require the services of engineering specialists who regularly practice in the field of water supply engineering.

Water quality and design standards are defined from several sources. Environmental Protection Agency (EPA) regulations (40 CFR part 141) were developed as a result of the Safe Drinking Water Act (SDWA) (42 U.S.C. 300f) and subsequent amendments, and are the principal driver of water quality standards. The National Primary Drinking Water Regulations

(36 CFR part 142) are concerned with contaminants that affect human health. The National Secondary Drinking Water Regulations (40 CFR part 143) are guidelines for contaminants or parameters that affect the aesthetic qualities of water. See FSM 7420 for a brief description of these regulations and direction applicable to Forest Service public and nonpublic drinking water systems. State agencies responsible for enforcement of the SDWA may adopt regulations and design standards that are no less stringent than the National regulations. Forest Service public systems must comply with the State requirements as well as the applicable fire, safety, building, electrical, plumbing codes and ordinances and Occupational Safety and Health Administration (OSHA) safety standards.

Exhibit 01 describes several aspects of the amendments to the EPA's regulations from 1986 and 1996.

42.1 - Exhibit 01

Description of Amendments to EPA Regulations

1. The EPA regulations were significantly changed by the 1986 and 1996 Amendments to the SDWA (42 USC 300f).

a. Some of the major aspects of the 1986 Amendments, which affect many Forest Service systems are as follows:

(1) The Surface Water Treatment Rule (SWTR) (40 CFR part 141) established requirements for filtration and disinfection of surface water and groundwater under the direct influence of surface water (GWUDI). The rule established treatment technique requirements for turbidity and disinfection to achieve 99.9 percent removal or inactivation of *Giardia lamblia* cysts and 99.99 percent removal or inactivation of viruses. Additional regulations have since been published, which impose additional treatment and monitoring requirements to ensure protection against microbial pathogens such as *Cryptosporidium parvum*.

(2) The Total Coliform Rule (TCR) (40 CFR part 141) established maximum contaminant levels (MCLs) for coliforms, as well as requirements for coliform monitoring frequency and regular sanitary surveys. The Phase I, II and V rules set MCLs for 83 organic and inorganic contaminants.

(3) The Lead and Copper Rule (40 CFR part 141, subpart I) established lead and copper action levels and treatment technique requirements.

b. The 1996 Amendments to the SDWA (Pub. L. 104-182) initiated several regulations and programs affecting Forest Service systems, such as:

(1) Source water assessments to assess pollution threats.

(2) Affordable treatment technologies for small systems.

(3) Contaminant monitoring relief or reduced frequency based on source water assessments and site testing.

(4) Guidance for operator certification standards.

(5) Consumer confidence reports on water quality served.

42.1 - Exhibit 01--Continued

2. Other sources of design and water quality standards include:

   a. American Water Works Association Standards (listings of available AWWA Standards can be found on the World Wide Web/Internet at *www.awwa.org*).

   b. "Recommended Standards for Water Works" 2003 Edition by the Great Lakes - Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers (available from Health Educations Services on the World Wide Web/Internet at *www.hes.org*), local, State, and county agencies.

   c. World Health Organization (guidelines and references can be found through the World Wide Web/Internet at *www.who.int*).

42.2 - Disinfection

Disinfection kills or inactivates pathogenic microorganisms found in drinking water supplies. Effective disinfection is measured by compliance with regulations in terms of the following:

1. Percentage removal or inactivation of *Giardia lamblia* cysts and enteric viruses;

2. Control of other harmful microorganisms;

3. Minimal formation of harmful byproducts; and

4. Meeting the maximum contaminant levels (MCLs) for the disinfectants being used.

Disinfection treatment can be effective on water supplies with very low and stable turbidity, such as most groundwater supplies. Use disinfection treatment in combination with filtration, per Surface Water Treatment Rule requirements (sec. 42, ex. 01) for surface water and groundwater under the direct influence of surface water (GWUDI),

Measure disinfection effectiveness in terms of CT values. ACT value at any given point in the water system is calculated by multiplying the residual disinfectant concentration (C, in mg/l) by the disinfectant contact time (T, in minutes). Calculated CT values are compared to tabular CT values established by EPA for various disinfectants, water conditions (temperature, pH, residual concentration) and percent of required pathogen deactivation. The calculated CT value for the system must equal or exceed the tabular CT or the treatment is not considered adequate.

Chlorine is the most widely used disinfectant, although other disinfectants such as chloramines, ozone, ultraviolet (UV) radiation, chlorine dioxide, and mixed oxidants are becoming more prevalent. Ozone and UV are very effective disinfectants; however they do not provide a stable residual. Therefore, addition of a second disinfectant (usually chlorine) is typically required to maintain a disinfectant residual in order to prevent microbial growth in the storage and distribution system.

Disinfection systems must be designed in all cases to protect the integrity of the water supply. Designs must incorporate system shutdown or other backup measures in the event of disruptions in treatment due to power outage, equipment failure, and so forth.

42.21 - Chlorination

1. Chlorination is used primarily as a disinfecting agent, but can also serve the following purposes:

    a. Pretreatment for filtration,

    b. Bleaching for color control,

    c. Iron and manganese removal, and

d. Taste and odor removal.

2. Most States require measurement of free chlorine residual using the N,N-diethyl-p-phenylenediamine (DPD) method in the "Standard Methods for the Examination of Water and Waste Water" (20th edition, published by the American Public Health Association, the American Water Works Association, and the Water Environment Federation). The standard methods should be consulted for other residual tests, which may be applicable when the DPD method produces erroneous results due to color-causing chemical constituents in the water.

3. Chlorine is available in gas, solid, and liquid (bleach) forms. Chlorine gas is highly toxic, and while a gas chlorination system may pose the greatest risk of chlorine gas exposure, the solid and bleach forms also emit chlorine gas, and therefore, require safety precautions, such as storage in separate, well-ventilated rooms. Although chlorine is nonflammable, it is a highly reactive oxidant that can result in fire or explosion when combined with other substances. Strictly follow all manufacturers' safety precautions. The following briefly describes the most common forms of chlorine supplied:

a. Chlorine gas is supplied in 150-lb. bottles, 1-ton cylinders, and railcars, and provides 100% available chlorine. Gaseous chlorine is typically used only at larger water systems where skilled personnel are available to maintain the rigorous safety precautions required.

b. Solid chlorine is available in calcium hypochlorite powder, granules, and tablets, and provides 65% - 75% available chlorine (typically 65%). All three forms can be used to make a hypochlorite solution, which is typically injected into the water system using a hypochlorinator.

4. Hypochlorinators are electric- or water-powered chemical feed pumps used to inject chlorine solutions into water systems. Both types require regular operator checks and maintenance.

5. Electric motor-driven hypochlorinators dispense chlorine at a preset rate, requiring the operator to determine the average flow rates throughout the water system. A power outage may allow untreated water to enter the distribution system.

6. Hydraulically operated hypochlorinators are usually cam-driven off a rotating-disc water meter. The hypochlorinator dispenses the chlorine solution proportionally to demand over a range of flow rates. External power is not required, but the hydraulically operated hypochlorinator must have the required operating head. During periods of low or no flow, chlorine does not enter the distribution system. Where the rate of flow is variable, and particularly if low flows are common, care must be exercised to ensure that the water meter operates and controls the unit accurately throughout the range of expected flow. Use of a non-modulating float valve at the storage tank inlet may ensure that flow through the chlorinator will be constant when operating.

7. Low-concentration solutions (2-5 percent) can be prepared on site according to the following formula:

Pounds of calcium hypochlorite required	=	% strength of solution desired	x	gallons of solution required	x	8.34 lb solution per gallon	÷	% available chlorine in bulk compound

8. The tablet form of chlorine can also be directly applied to water by an erosion chlorinator, which uses the water system flow to erode the tablet. Erosion chlorinators are sometimes used in very small systems or where power is not available. They are easily maintained; however, consistent dosing may be difficult to achieve.

9. Chlorine is available as a liquid in the form of sodium hypochlorite (bleach) and provides 3% - 15% available chlorine (typical 5.25%). Liquid chlorine is typically injected into the water system using a hypochlorinator pump. When using chlorine and chlorine compounds, follow these general safety considerations:

a. Wear neoprene chemical gloves, safety glasses, protective outerwear, and a dust mask when handling the dry form. Do not allow contact with skin, mucous membranes, eyes, or clothing. Chlorine is harmful if swallowed.

b. Always add chlorine chemical, liquid, or powder to water. Do not add water to the chemical.

c. Contamination with any foreign material may result in a fire. Do not store hypochlorite powder with any other material.

d. Keep chlorine protected from heat. When heated above 350˚F, chlorine compounds decompose rapidly with the evolution heat and oxygen accompanied by chemical fuming. If the drum or container is closed, sufficient pressure can be generated to blow off the lid or rupture the container.

e. Chlorine is a strong oxiding agent, incompatible with soap, paint products, solvents, acids, pool products, vinegar, beverages, and so on. Keep away from combustible materials.

f. Use only clean, dry containers to store or measure calcium hypochlorite. Always keep the storage container covered.

g. Do not drop, roll, or skid a container of calcium hypochlorite.

h. Rinse empty calcium hypochlorite containers thoroughly with water.

i. In case of a leak or spill, there should be no smoking or exposed flame. Flush with large quantities of water and dispose of waste in accordance with local, State, and Federal regulations.

j. Have Material Safety Data Sheets (MSDS) readily available in all areas where chlorine compounds are used. In case of accidental exposure, follow emergency procedures on the MSDS and call a physician immediately.

42.3 - Filtration

Filtration is the process of removing suspended matter from water as it passes through beds of porous material. The degree of removal depends on the character and size of the filter media, the thickness of the porous media, and the size and quantity of the suspended solids. Filtration alone should not be relied upon to produce bacteriologically safe water; it should be followed by disinfection. Pilot testing is usually required to verify filtration design effectiveness.

There are several filtration technologies that can be used for small Forest Service water systems including conventional, slow sand, direct, diatomaceous earth, and bag and cartridge filtration, and various membrane processes (see EPA's Manual of Small Public Water Supply Systems, EPA 570/9-91-003, May 1991). Filtration of surface water and groundwater under the direct influence of surface water must meet the most recent SDWA Surface Water Treatment Rule (sec. 42.1) requirements. Filtration designs must include provisions for monitoring turbidity and disinfectant residual, and for system shutdown or bypass when raw or finished water exceeds design parameters. Conservative judgments should be made regarding operational time and costs.

Due to the high concentration of bacteria and other microbial organisms, as well as chemical constituents (iron, alum, and so on), all backwash material must be conveyed to a wastewater treatment facility or otherwise be properly disposed.

42.31 - Conventional Filtration

Conventional filtration refers to a series of processes including chemical coagulation and flocculation, sedimentation, and filtration. There are several types of commonly used filter media, including sand, anthracite, garnet, and others, which are utilized in single-, dual- or tri-media designs. There are a variety of package plant systems that utilize variations of conventional treatment involving dual-stage filtration, roughing filters, and dissolved air flotation, among others.

42.32 - Direct Filtration

Direct filtration involves chemical coagulation followed by filtration (the sedimentation process is excluded). This treatment scheme is most effective when raw water turbidity is less than 10 nephelometric turbidity units (NTU); raw water color and algae must also be considered. Performance is particularly sensitive to proper coagulation chemistry.

42.33 - Slow-Sand Filtration

Slow sand filtration involves percolating untreated water through a bed of sand at low velocity (generally less than 0.4 m/hour). Over time, a sticky mat of biological matter forms on the sand surface, where particles are trapped and organic matter is biologically degraded. As this

surface cake develops during the filtration cycle, the cake (rather than the sand) assumes the dominant role in filtration. When the sand becomes clogged, the filter must be cleaned by scraping off the top layer of the filter bed.

Advantages of slow sand filtration include design and operational simplicity. Disadvantages include limited operational flexibility and the need for manual cleaning.

42.34 - Bag and Cartridge Filtration

Bag filters and cartridge filters, which remove particles by physical straining, have been successfully used on several Forest Service installations where the source water is low in turbidity, algae, and other particulate matter. Sizing of bag or cartridge filtration systems is based on the quality of the source water and volume to be delivered. Bag filters consist of one or more layers of fabric and are available in various materials, with pore sizes ranging from 1 - 40 microns. Cartridge filters typically have pleated fabrics, membranes, or strings wrapped around a filter element with varying surface areas for filtration. Both bag and cartridge filters are housed in pressure vessels. Bags or cartridges of 1 - 5 micron absolute pore size can economically filter water with turbidity of 1 Nephelometric Turbidity Unit (NTU) or less. Where turbidity consistently exceeds 1 NTU, filter life may be shortened to a matter of hours. In this case, prefiltration may be used. Prefiltration can be accomplished by sand or multi-media filtration followed by bag or cartridge filters of 10 micron or larger pore size.

42.35 - Other Filtration Technologies

In some circumstances, other filtration technologies may be considered, including diatomaceous earth filtration, and membrane filtration (such as microfiltration, ultrafiltration, nanofiltration and reverse osmosis). When selecting a process, consider the extent of pre- and post-treatment required, degree of operator skills required, initial and operational costs, and extent of membrane integrity monitoring required.

42.4 - Organic Chemical Removal

For the removal of natural or synthetic chemicals, the technologies most suitable to use are granular activated carbon (GAC) and aeration.

GAC removes chemicals by absorption onto the porous surfaces of the carbon particles. Various kinds of GAC are available; the most frequently used carbon is coal based.

Aeration is the process of mixing a liquid (such as water) with air. This allows volatile chemicals to escape in gaseous form. Aeration can be effective in removing taste- and odor-causing compounds, such as hydrogen sulfide, and can also add oxygen to eliminate the “flat” taste from stored water. Many methods are available for obtaining effective aeration, including spraying water into the air, packed column or tower aeration, Higee aeration, diffused aeration, mechanical aeration, and multiple tray aeration. Although the aeration of water may be accomplished in an open system, adequate precautions should be exercised to eliminate possible external contamination of the water. An open system may be classified as under the influence of surface water, and thereby require treatment as such. Whenever possible, a totally

enclosed system should be provided. Open systems such as tray aerators should be properly screened and encased to provide protection from windblown debris and insects that may lay eggs in the stagnant portion of aerator trays.

42.5 - Inorganic Chemical Removal

42.51 - Softening

Water softening is a process for the removal of minerals, primarily calcium and magnesium that cause hardness. Excessive hardness is problematic because the minerals can be deposited on the surfaces they touch, leaving a hard scale. Hard water reacts with soaps and detergents, leaving a dingy film and reducing cleaning effectiveness. Over time, scale buildup can cause an appreciable reduction in pipe capacities and pressures. Experience has shown that hardness values greatly in excess of 200 mg/1 (12 grains per gallon) may cause some problems to the users.

Water may be softened by either the ion-exchange or the lime-soda ash process, but both processes increase the sodium content of the water and may make it unsuitable for people on a low-sodium diet. The lime-soda ash process is not generally recommended for small water systems.

Ion exchange devices consist of a bed of plastic (polymer) beads which are supersaturated with sodium. As the hard water passes through the ion exchange unit, the calcium and magnesium attach themselves to the resin beads, and the sodium ions (which do not cause hardness) are simultaneously released into the water. When the softening capacity becomes exhausted, the ion exchange resin is regenerated by washing it with a brine solution. This replenishes the sodium and enables the ion exchange process to continue. The backwash water from the recharging cycle must be disposed of properly, possibly by connections into a wastewater system. However, it should be noted that the waste load may have a harmful effect on small biological treatment processes.

The ion-exchange method of softening water is relatively simple and can be easily adapted to the small or individual water supply system. Only a portion of the hard water needs to be passed through the softening process because the exchange process produces water of zero hardness. The processed water can then be mixed with the hard water in proportions to produce a final water with a hardness between 50 - 80 mg/1 (3 to 5 grains per gallon). Waters with a turbidity of more than 10 Jackson units should be properly treated for removal to increase the effectiveness and the efficiency of the softening process.

42.52 - Iron and Manganese Removal

Iron in excess of 0.3 to 0.5 mg/1 stains laundry and plumbing fixtures and causes water to appear rusty. When manganese is predominant, the stains are black. Iron may be present as soluble ferrous bicarbonate in alkaline well or spring waters; as soluble ferrous sulphate in acid drainage waters or waters containing sulfur; as soluble organic iron in colored swamp waters; as suspended insoluble ferric hydroxide formed from iron-bearing well waters which are subsequently exposed to air; and as a product of pipe corrosion producing red water.

The presence of as little as 0.1 mg/1 iron in a water encourages the growth of such bacteria as *Leptothrix* and *Crenothrix*. Carbon dioxide also encourages their growth. These organisms grow in distribution systems resulting in small gray or brownish flakes, masses of stringy or fluffy growths which can plug mains, service lines, meters, and pumps. The control of iron bacteria can be accomplished by:

1. Removal of iron from systems.

2. Increased concentration of dissolved oxygen in the water (above 2 mg/1).

3. Continuous addition of copper sulfate to a dosage of 0.3 to 0.5 mg/l.

4. A free chlorine residual concentration of at least 0.3 mg/l.

The removal of both iron and manganese can be achieved by various treatment technologies including aeration, filtration, oxidation by chlorination or ozonation, and softening. Environmental Engineering Specialists should be consulted for recommendations on the treatment process best suited to the volume and operational complexity of the particular water development.

42.53 - Dissolved Solids Removal

Membrane technologies, such as reverse osmosis and electrodialysis, are very effective in removing inorganic ionic contaminants and most dissolved non-ions. These processes have high capital and operating costs, and also require a high level of pretreatment.

42.6 - Corrosion Control

Corrosion is commonly defined as an electrochemical reaction in which metal is deteriorated or destroyed when in contact with elements of its environment, such as air, water, or soil. Corrosion control is important not only for continuous and efficient operation of the individual water system, but also for delivery of properly conditioned water that has not picked up trace quantities of metals which may be hazardous to health. Minimizing corrosion can lead to an appreciable reduction in the maintenance and replacement frequency of water pipes, water heaters, and other metallic appurtenances of the system. The Lead and Copper Rule (40 CFR part 141) provides renewed strategies for corrosion prevention. Consult the Environmental Protection Agency's "Revised Guidance for Selecting Lead and Copper Control Strategies", March 2003, Publication EPA-816-R-03-001, for additional information.

In the process of corrosion, there is a flow of electric current from the corroding portion of the metal toward the electrolyte or conductor of electricity, such as water or soil. Any characteristic of the water that tends to allow or increase the rate of this electrical current increases the rate of corrosion. Characteristics of water that affect its corrosiveness include the following:

1. Acidity. A measure of the water's ability to neutralize alkaline materials. Water with acidity or low alkalinity tends to be corrosive.

2. 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.

3. Oxygen Content. The amount of oxygen dissolved in the water. Amount dissolved in water promotes corrosion by destroying the thin protective hydrogen film that is present on the surface of metals immersed in water.

4. Carbon Dioxide. A colorless gas that dissolves in water and forms carbonic acid and tends to attack metallic surfaces.

5. Water Temperature. The corrosion rate increases as water temperature increases. 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 corrosion is that of feeding small amounts of commercially available film-forming materials, such as polyphosphates or silicates (the film protects the pipe from contact with corrosive water). Other methods of corrosion control include the installation of dielectric or insulating unions, reduction of velocities and pressures, removal of oxygen or acid constituents, or the use of nonmetallic piping and equipment.

It should be noted that corrosion and scale are related problems, but the causes and effects should not be confused. Corrosion essentially destroys metal. Scale, on the other hand, tends to form deposits and clog pipes. The products of corrosion often contribute to scale formation and aggravate the problem of its treatment.

43 - Storage and Distribution Systems

43.1 - Design and Layout

The design and layout of a storage and distribution system requires expertise in the theoretical and practical applications of hydraulic, sanitary, structural, and economic engineering.

1. Design and Layout Parameters.

    a. Raw water supply and quality.

    b. The current National Primary Drinking Water Regulations and the Secondary Drinking Water Regulations.

    c. Treatment technologies and their operational and maintenance parameters.

    d. Variations in demand and other uses.

    e. Distribution system equipment design, operation and maintenance.

    f. Sampling and testing.

    g. Water works standards.

2. Profile and traverse surveys. Traverse surveys should be tied into land and property corners. Monuments should be provided in sufficient number and spacing to provide adequate vertical and horizontal control of construction without the necessity of extensive resurvey.

43.11 - System Elements

Design considerations for a water facility include demand, supply, storage, head, and distribution.

1. Demand. The demand is the water required to supply the needs of the facility users during a given period of time. The demand period may be instantaneous, 5 to 10 minutes, hourly, daily, or longer. Shorter demand periods generally affect pipe size and pumping capacity. Longer demand periods affect storage. The design flow for a water distribution system is the maximum hourly or peak demand flow. More information on estimating demand rates is provided in section 44 on Water Quantity.

2. Supply. Water may be supplied into a system directly from the source or from the treatment facilities. In a system without storage, such as a hydropneumatic system, the supply rate must be equal to the demand rate. If the supply rate is not equal to the demand, and storage is needed to compensate for the deficiency.

The supply may enter the system at any convenient point. There may be more than one source which supplies the system at various locations, so careful evaluation is needed to determine the best arrangement. A single source is desirable.

3. Storage. If storage is needed, two types should be considered:

   a. Working storage, and

   b. Reserve storage. Working storage is that required to equalize the daily demand and provide more efficient use of pumps and other mechanical equipment. It prevents depletion of the supply during peak demand periods. Reserve storage is that needed to maintain the supply during periods of emergency demands, such as power outage, equipment breakdown or maintenance, and fire. The design should, if possible, prevent drawing on fire storage in any event other than fire.

The amount of storage for fire demand should be determined based on the recommendations outlined in fire protection publications; State and local regulations; and input from local fire protection providers. Storage for other emergencies should be determined after consideration of reasonable estimates of demands during probable shutdown times. Considerations include time of year, probable use, and probable duration of the interruption.

Working storage requirements are best determined by use of a mass diagram. An illustration of this method is provided in exhibit 01, figures 1-3. Figure 1 shows a typical hourly demand curve for a recreation area having day and night use. This curve is expressed in terms of the percent of the total daily volume for each hour of the day. This illustration of the mass diagram method shows a demand curve that applies to a daily demand of 6,000 gallons per day. It also shows a mass curve constructed for a uniform supply of 5 gallons per minute, but

this curve is shown only to illustrate the slope of the curve and has no correspondence to time of day in this table.

4. Head. Head is a measure of energy within a hydraulic system. It is often described in linear terms (feet, meters), but actually measures energy in foot-pounds per pound (meter-Newtons/ kilogram). Head may appear as pressure, velocity, or elevation head.

Forest Service installations do not normally require pressures in excess of 65 pounds per square inch (150-foot pressure head), but fire protection systems should provide 40-50 pounds per square inch at the hose nozzle.

In all cases, the distribution system pipe and fittings must be adequate to accommodate the maximum pressures that may occur, including water hammer. Manufacturers' recommended working pressures should be provided at all fixtures. In no case should the pressure be less than 15 p.s.i. under design conditions.

5. Distribution. The area in which the distribution system is to be developed should be examined carefully to determine the desired location of all hydrants, faucets, fountains, toilets, and other services with respect to the location of buildings, roads, trails, campsites, and other areas of concentrated use. For recreation areas, consult with the Recreation Planner on the desired layout. For administrative and other building sites, determine the number, type, and location of all water-using fixtures both inside and outside the buildings. Consider the potential for reducing piping by using a "loop" system or by centrally locating the supply or storage. A loop distribution system also eliminates dead end lines and provides redundancy to fixtures if a section of distribution line breaks or must be closed. Flow within the system will vary with the demand, and the alternatives should be evaluated.

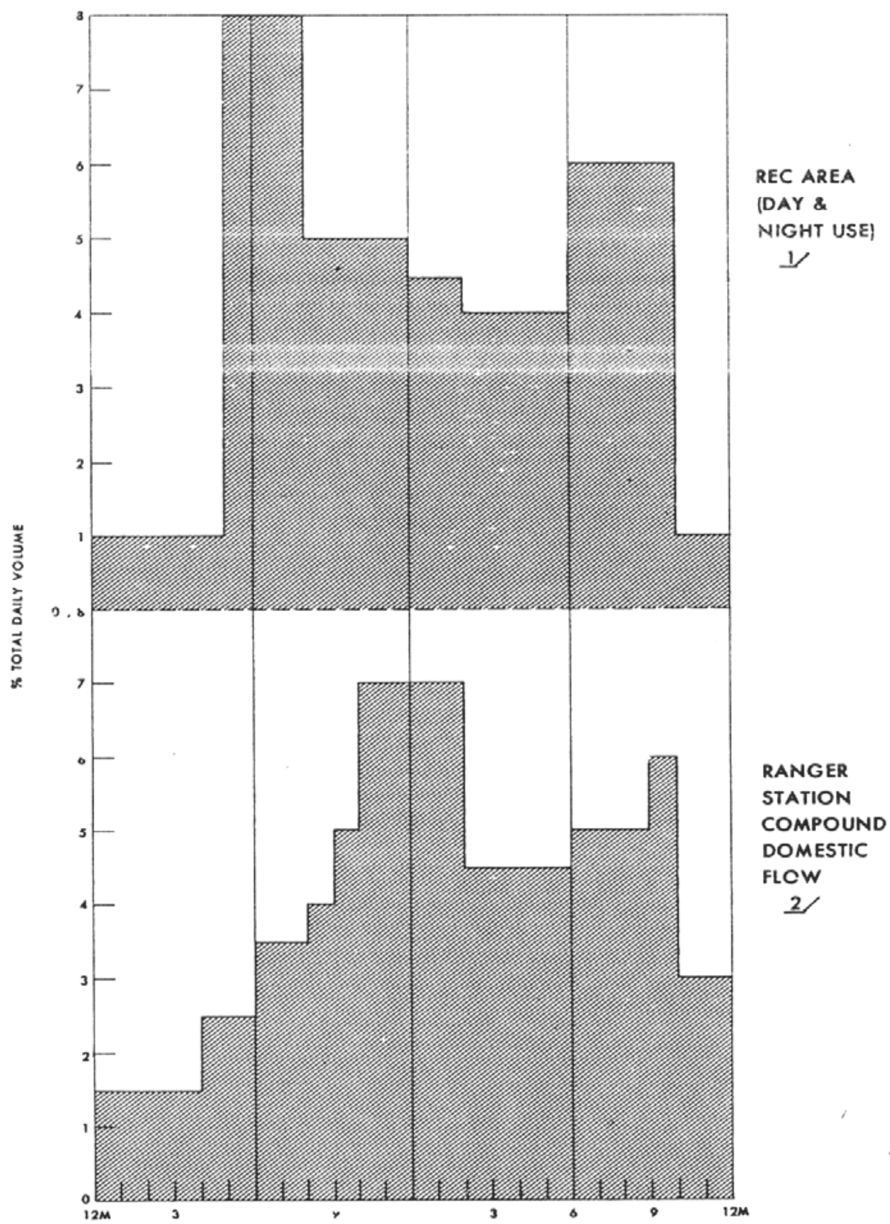
A fire hydrant should be accessible throughout the year and conveniently located to fight the potential fire. The firefighting capacity of the water system should be determined based on direction in FSH 7309.11, State and local regulations, input from local fire protection providers, publications by the National Fire Protection Association (further information can be obtained through the World Wide Web/Internet at *www.nfpa.org*), and so on. Consider operational and maintenance features, such as seasonal operations, disinfection, draining, and venting procedures.

A contour map can aid in designing and determining the approximate location of the facilities. Pipes should not be located in either intermittent or perennial stream bottoms where they can wash out. The location of necessary storage should be tentatively decided upon at this stage. This approximate layout of the distribution system should be used as the basis for the profile and traverse to follow and can be sketched on a contour map, if desired. The water system is shown on administrative site development plans.

Make profile and traverse surveys. Traverse surveys should be tied into land and property corners. Monuments should be provided in sufficient number and spacing to provide adequate vertical and horizontal control of construction without the necessity of extensive resurvey.

43.11 - Exhibit 01

Typical Hourly Demand Variations



1/ SAN DIMAS EDC WASTE CHARACTERIZATION STUDY, 1074 - 1975.
2/ SEE REFERENCE 5.

Figure 1

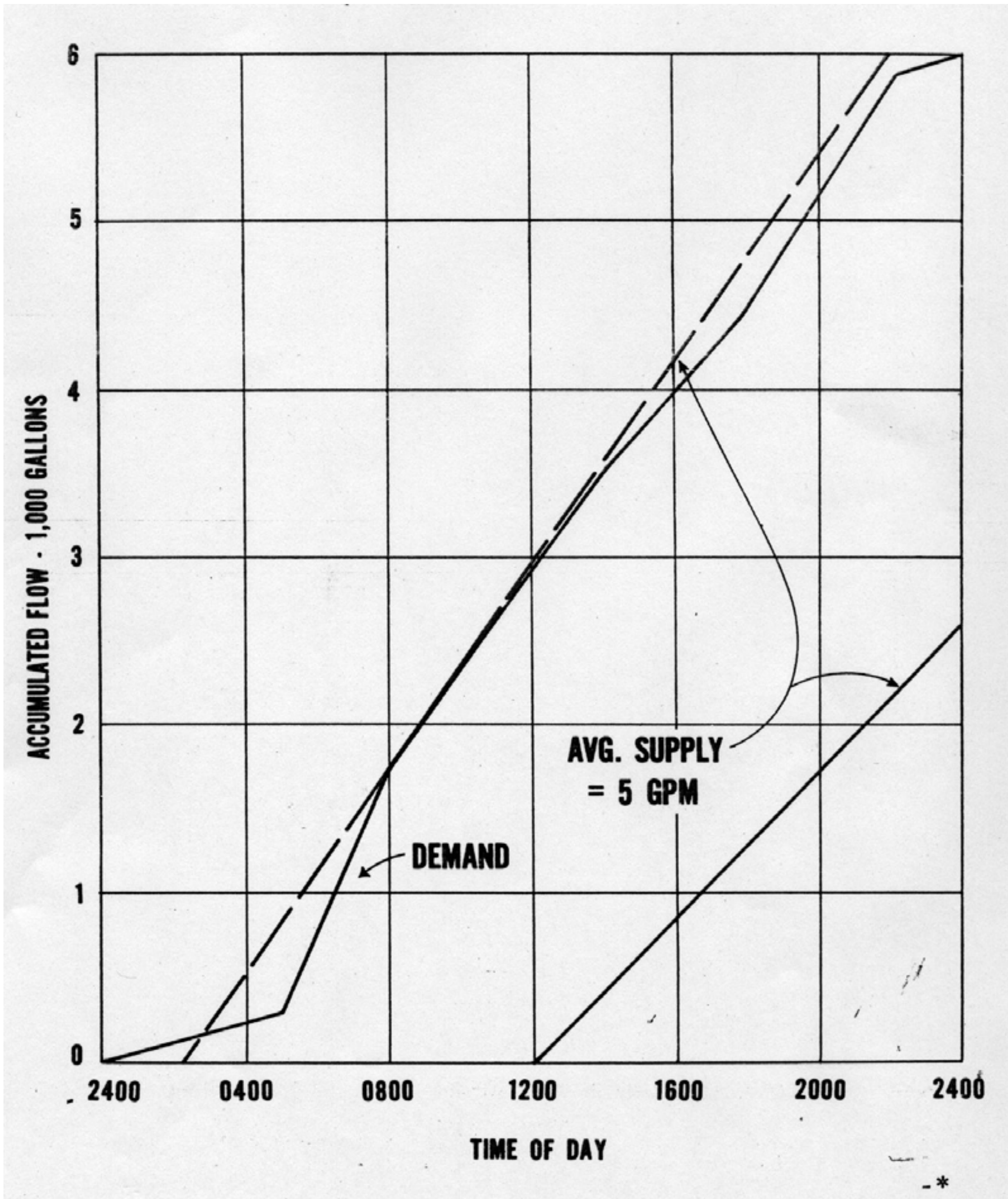
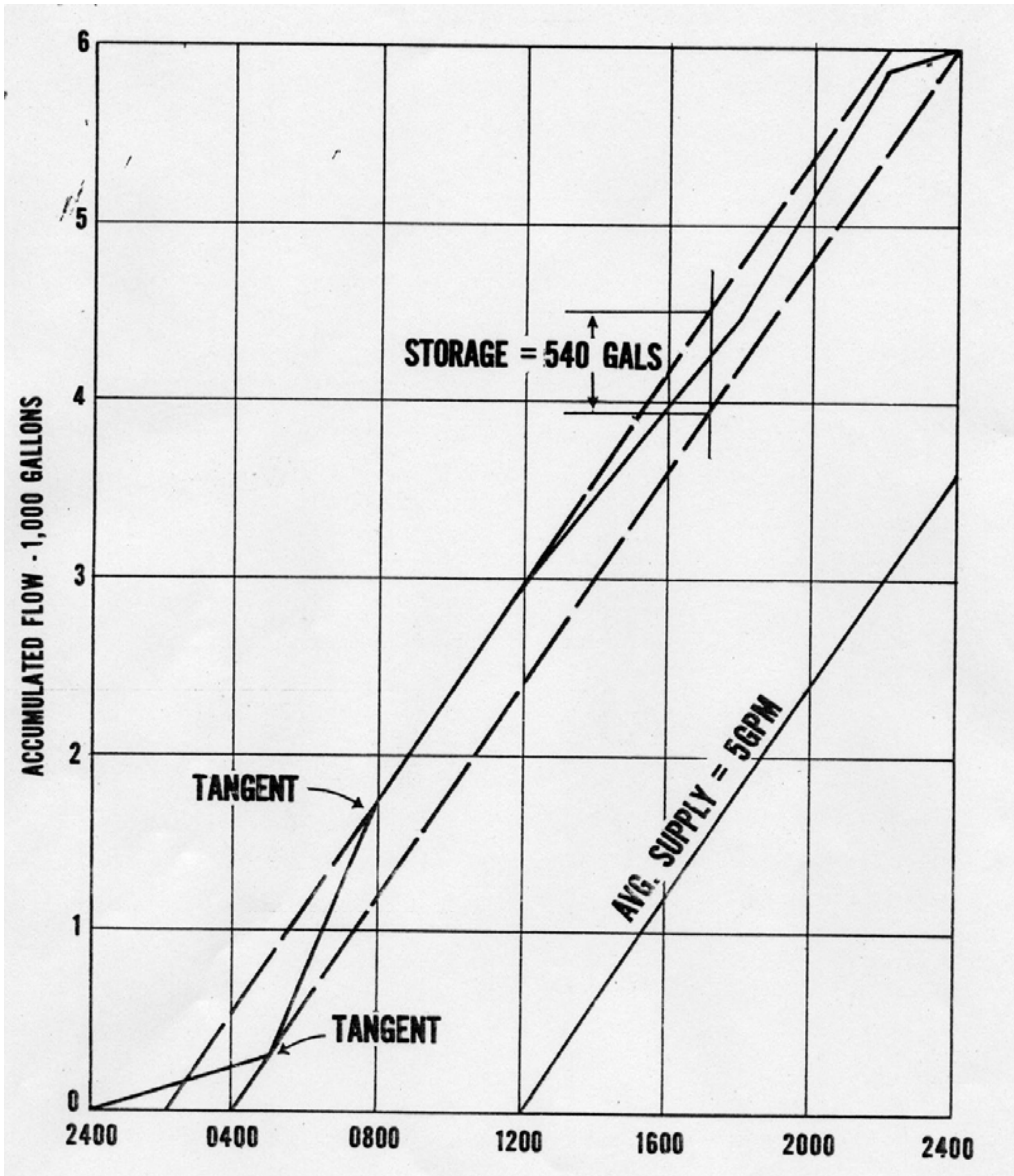

6
5
4
3
2
1
0
ACCUMULATED FLOW - 1,000 GALLONS
2400
0400
0800
1200
1600
2000
2400
TIME OF DAY
AVG. SUPPLY
= 5 GPM
DEMAND

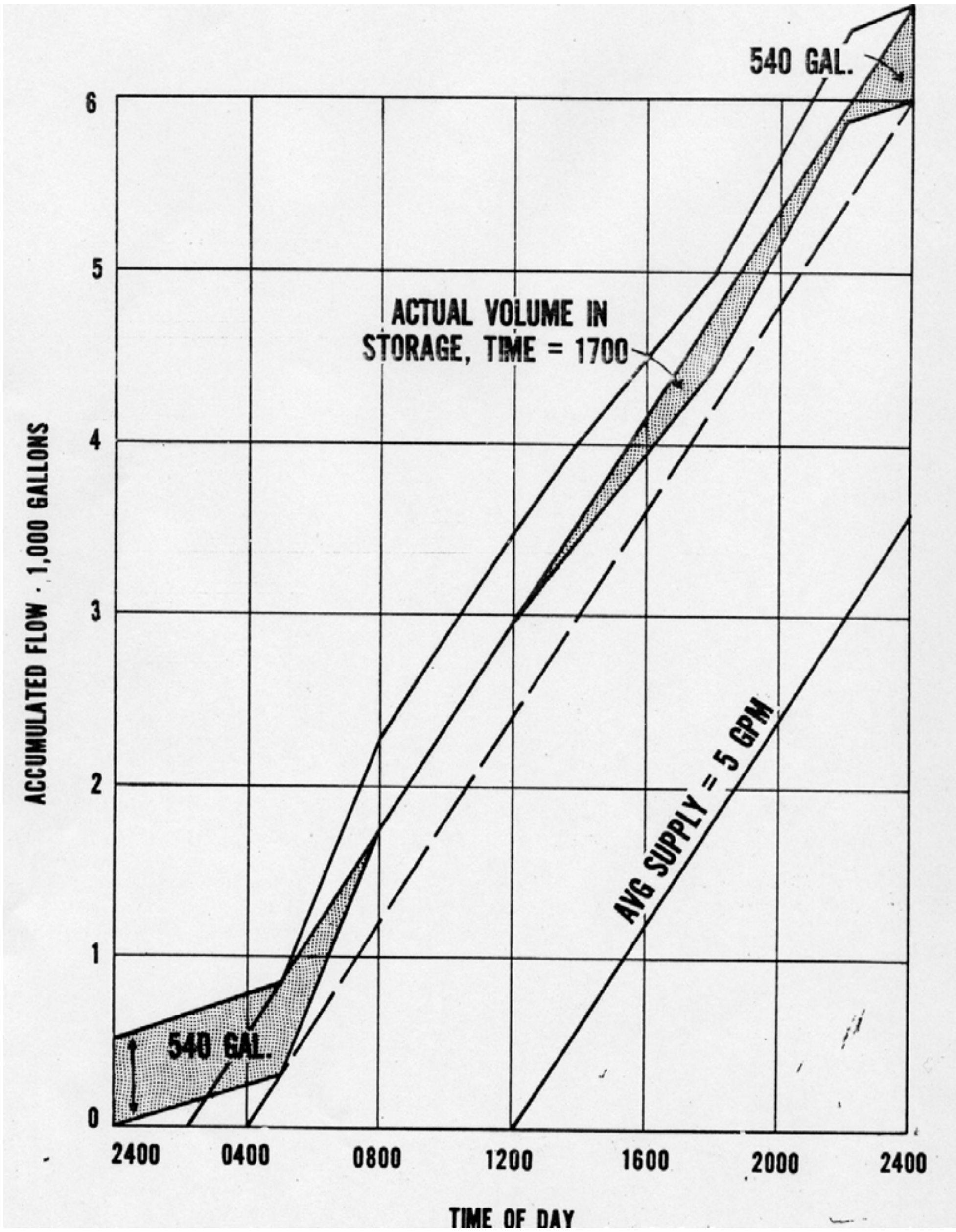
Figure 2



6
5
4
3
2
1
0
ACCUMULATED FLOW - 1,000 GALLONS
2400
0400
0800
1200
1600
2000
2400
STORAGE = 540 GALS
TANGENT
TANGENT
AVG. SUPPLY = 5GPM

43.11 - Exhibit 01--Continued

Figure 3



43.11 - Exhibit 01--Continued

Note that the construction of the mass curve for the demand is the same as that for the supply, except the procedures is reversed in order. To construct the demand mass curve, the accumulated percent of the daily flow is determined for any given hour (for this example, 0500, 0800, 1200, 1400, 1800, 2200, and 2400) and plotted as an ordinate. The slope of the line is the demand rate in volume per unit of time. To construct the supply mass curve, the flow rate in volume per unit of time is converted to accumulated volume by multiplying by the number of time units and plotting the accumulated volume for the appropriate time. In both instances, the ordinate is the accumulated volume, and the slope is the flow rate.

Move the supply curve parallel to the horizontal axis, maintaining its original slope, until it is tangent to the demand curve at the left-most point. In figure 1, the demand beginning at the origin has been disregarded because the supply rate is greater than the demand as evidenced by the steeper slope of its curve. Next, draw the supply curve tangent to the demand curve at its right-most point as shown in figure 2. The vertical distance between the two supply curves represents the needed storage. Since the total demand is always less than the total supply as indicated by the curve on the left, and greater than the supply indicated by the curve on the right, it is logical that the difference is the required storage.

To determine the volume of water in storage at any particular time, an additional curve is required. Construct another demand curve, identical to, and parallel to, the first, tangent to the left supply curve at its bottom-most point. This is the same as raising the demand curve by the amount of the storage. The ordinate between the lower demand curve and the upper supply curve, after the beginning of the supply, is the amount in storage. This is explained by the fact that, for any given time, the ordinate for the supply is greater than that for the demand; the difference is that stored.

Prior to the start of the supply curve, the ordinate between the two demand curves is the volume of water in storage. The explanation for this is that the reservoir is full at the beginning of the day, and until such time (0500) that the demand rate exceeds the supply rate, the reservoir will overflow. Therefore, the storage will not begin drawdown until 0500, and the ordinate between the two demand curves, which is the maximum storage volume, is the water volume in storage until the rate of demand exceeds the rate of supply. The shaded areas in figure 3 illustrate where these volumes may be measured. Note that the areas under the curves are not meaningful; only the ordinates measure volumes. For any time cycle repeated within the season for which the mass curve is drawn (usually, as in this illustration, it is 24 hours), the volume in storage at the beginning of the cycle equals the volume in storage at the end of the cycle.

Note that where the slope of the supply curve is greater than that of the demand, the reservoir is filling; where it is less, the storage is being depleted.

The mass curve can be drawn for a period of a week or longer, using periods of low demand to fill the storage tank. If the demand for the season is greater than the supply, it is possible to begin filling the storage tank prior to the beginning of the season, but there are precautions to be taken. Piping arrangements should be such to minimize dead water areas, and measures are necessary to prevent biological growths in the tank during the long retention time.

43.2 - Hydraulic Analysis

Analyze the hydraulic characteristics of the distribution system at static and various flow situations. This can be done graphically by plotting the profile of the lines, elevations of facilities, and the static head and pressure head for various flow situations. A tabulation of this information may be used, but may not be as illustrative, particularly in undulating terrain. The analysis should determine the following information:

1. Static pressure throughout the system.

2. Velocity of flow with the following situations:

    a. Normal operation flows.

    b. Fire flows.

    c. Flushing or filling flows.

3. Hydraulic forces at changes in direction, changes in size of lines, and at appurtenances. Determine the need for thrust blocking and anchorage.

4. Working pressure at fixtures and service points.

5. Head variations from static to various flow conditions.

6. Negative or low heads.

Operating velocities should not exceed 10 feet per second; velocities less than 4 feet per second are recommended. High velocities stress the pipe system and fixtures, may cause water hammer, reduce pressure, and develop venturi effects at fittings that may allow contaminants to enter the system.

Systems with wide variations in pressure require careful design and may require special control valves. Less than 25 percent difference between static and operating flow is recommended. Where necessary, use pressure-regulating, pressure-reducing or flow-control valves at fixtures to control flow. Do not utilize friction loss in distribution lines to reduce pressure, even if it is available.

43.3 - Water Tanks

43.31 - Design

The following structural and control features should be included in the design of water tanks:

1. Protection from freezing during cold weather operation.

2. Appurtenances including overflow, vent, ladders, access points for cleaning and inspection, and liquid level measurement.

3. Controls: Overflow, drains, valves, various discharge levels, inlet, and control of a reserve.

Potable water tanks are usually constructed of steel, concrete or other materials with a smooth nonporous surface. Interior coatings must comply with the National Sanitation Foundations (NSF) Standard 61.

Additional information on the design of water tanks is available in American Water Works Association Standard D100 and National Fire Protection Association NFPA 22: Standard for Water Tanks for Private Fire Protection, 2003 Edition. Additional information on coatings and tank protection is available from American Water Works Association and the Steel Structure Paint Council.

43.32 - Operating Conditions

The following operating conditions are required for water tanks:

1. Cleaning and disinfection procedures must be followed.

2. Valves and controls must be in place to prevent the loss of reserve storage if a line break occurs.

3. Water level records and readings must be maintained.

4. Control must be in place to isolate the tank from the system for cleaning or repair.

5. Ladders, manholes, hatches, and ventilation must be accessible to facilitate maintenance.

6. Inlet, outlet, and level controls must be accessible for maintenance and inspection without contaminating the water.

43.33 - Sanitary Features

Sanitary features must include:

1. Screens on vents and other openings to prevent access by birds, insects, and small mammals.

2. Good drainage away from the tank area, the tank top, drains, and overflows. There should be no danger of flooding or submerging. Snow or ice should not be allowed to build up around hatches or vents.

3. Raised overlapping (shoebox) type covers.

4. Controlled access.

Measuring the water level should not contaminate the water. Automatic devices may be unsanitary, if they provide a hole for access by bugs. A permanently installed scale may prevent insertion of an unsanitary stick or other device.

43.4 - Piping Systems

43.41 - Material for Pipe and Fittings

1. Design Considerations. Many design factors affect the choice of pipe materials. Factors to consider include:

   a. The corrosive characteristics of the water and soil that contact the pipe.

   b. Loads that are imposed on the pipe by the earth cover, and possibly by other loads.

   c. The hydraulic pressures, both static and working pressures.

   d. The availability and cost of manufactured sizes.

   e. The initial hydraulic carrying capacity of the pipe and its change with use.

   f. The permanence of the need to be served.

   g. Accessibility of the site and ease of transporting materials and equipment.

   h. Construction requirements, including method of joining and bedding, labor, and equipment required in construction.

   i. Maintenance and operation features, such as ease and cost of making repairs, susceptibility to damage, and salvage value if for temporary use.

   j. Sanitation aspects of the material. Relative smoothness of the interior surface can improve the ability of disinfectant introduced into the system to reach the target organism. Pipe materials may contaminate the water and degrade its quality by corrosion or loss of volatile toxic solvents from the material.

2. Pipe Materials. The following are choices of pipe material that can be used in Forest Service water systems:

   a. Ductile Iron Pipe. Characteristics of ductile iron pipe include long life, high strength, impact resistance, imperviousness, and ease of tapping. Although corrosion resistant, ductile iron pipe may require polyethylene encasement in highly corrosive soils.

b. Steel. There are two types of steel water pipe: (1) fabricated, electrically-welded steel pipe; and (2) 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. Steel pipe is subject to corrosion by aggressive water. Corrosion protection can be provided by cement lining in larger diameter pipe.

c. Aluminum. Aluminum pipe has the advantages of light weight, high strength, and good resistance to corrosion. Primary use to date has been for portable sprinkler systems and temporary water systems for construction projects. Quick-coupling fittings have been developed to facilitate moving the pipelines.

d. Plastic. Plastic pipe prevalently used in water systems includes polyvinyl chloride (PVC) pipe (most common) and polyethylene (PE) pipe. Acrylonitrile-butadiene-styrene (ABS) pipe has been used in the past; however, due to its low mechanical strength, its use is now typically limited to gravity drain applications. Advantages of plastic pipe include corrosion resistance and low head loss.

All plastic pipe used in Forest Service water systems must bear the National Sanitation Foundation (NSF) seal and should be pressure-rated for a minimum of 160 psi.

43.42 - Corrosion Control

Corrosion is a complex process, particularly in underground environments. The extent of corrosion can best be predicted by performing a chemical analysis of the water to be carried, and studying the past corrosion in similar soils of the area.

The materials and methods commonly employed in control of corrosion include:

1. Corrosion-Resistant Metals or Alloys. These materials either possess low corrosion potentials or form protective coatings of dense oxides when corroded. Stainless steel and Monel metal are examples.

2. 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, and plastic) are used.

3. Nonmetallic Materials. Poor conductors of electricity, such as cement, concrete, 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.

4. Insulation. Insulation creates a resistance to the flow of electrical currents. Examples are (1) the insertion of insulating couplings or connectors (rubber or plastic gaskets) 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.

5. Cathodic Protection. Cathodic protection can be provided either by:

a. Attaching a metal of higher oxidation potential to the pipe, such as aluminum or zinc to provide desired protection, or

b. Using direct-current electricity to feed electrons into the metal to produce a negative charge so that electric currents flow from the surrounding soil to the metal instead of the reverse. Cathodic protection systems should be designed by Engineers familiar with such systems.

43.43 - Selection of Pipe Size

There is a practical limit to the number of pipe sizes in a distribution system. Consider the following when selecting pipe size:

1. The available head must be able to deliver adequate flow at fixtures.

2. Head variations should be limited. The head variation at a fixture should be limited to a maximum of 25 percent difference between static and design flow.

3. Operating velocities should not exceed 10 feet per second. Velocities less than 4 feet per second are recommended.

4. Pipe for blowoff and drains should be adequate to pass material in the lines and develop a flushing velocity.

Water hammer, being a function of velocity, is developed when a liquid flowing in a pipeline is abruptly stopped by the closing of a valve. Dynamic energy is converted to elastic energy and a series of positive and negative pressure wave's 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.

43.5 - Appurtenances

Piping systems require various subordinate parts, which provide for sanitation, operation, and maintenance of the system.

43.51 - Disinfection Facilities

Permanent disinfection facilities must be provided for systems in which a disinfectant residual is mandated or necessary to provide safe water. Provisions must also be made to allow disinfection of systems when they are opened for the season or when contamination is detected

43.52 - Gauges

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 gauges with maximum and minimum indicators, located at appropriate points in a system, can be a useful tool for the system operator.

43.53 - Meters

Water-use measurements are required for the operation and maintenance of a system. More complex systems may require several meters located at more than one location. See section 63, Measuring Devices, for additional details on meters.

43.54 - Valves

Valves serve to direct and control the flow of fluids. They can provide either ON-OFF or proportional control, manual or automatic adjustment, fluid blending, and backflow prevention. Good piping design depends on the proper application and use of valves and fittings through understanding of the equipment capability and how it was intended to be used.

Valves are available in a number of designs, as described in the following paragraphs, 1 through 10. Despite the wide range of designs, all valves have only one purpose, to slow down or stop the flow of fluid. This is done by blocking the flow of the fluid with an obstruction that can be adjusted inside the pipe without leakage from the pipe to the outside. Some designs provide accurate control characteristics, while others are only suitable for ON-OFF applications. In general, the better the control characteristics, the greater the pressure drop across the valve.

1. Gate Valves. This classification includes wedge, disc, double disc, plug disc, and butterfly valves. 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 shutoff valves around equipment, bypass valves for equipment, or control valves and shutoff valves on supply lines.

2. Globe Valves. This design includes disc globe valves, angle valves, Y valves, and needle valves. In general, the globe design 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. Several factors are responsible for the performance of these valves. The high-pressure drop is caused by changing the direction of flow through the valve; typically two 90-degree turns are made by the fluid. As the fluid follows this flow pattern, it passes through an orifice which is partially restricted by the "globe" which can actually be a disc, needle, globe, or other shape, depending on the manufacturer and the desired accuracy of the flow setting.

When manual control of the rate of flow is necessary, use the disc design. If accurate, automatic, control is required, a needle valve is most applicable because it provides sensitive adjustments proportional to flow. Seats and discs of globe-type valves 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, because the fluid makes only one 90-degree turn.

3. Ball and Plug Valves; Ballcentric Valves. 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. The restricting element rotates through 90 degrees from fully open to fully closed, providing a quick shutoff 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.

Ballcentric valves may be used for flow throttling and flow balancing. An eccentric plug is rotated to achieve this, with low pressure drop across the valve.

4. Check Valves. 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 solution. Each of these designs has distinct areas of applications. 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-check valves 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 a 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 that 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.

5. Foot Valves. A foot valve 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 or prime.

6. Frostproof Faucets. Frostproof faucets are installed on the outside of a structure, with the shutoff valve portion extending into the heated structure to prevent freezing. After each use, the water between the valve and outlet drains, provided the hose is disconnected, so water is not left to freeze.

7. Sanitary Frostproof Hydrants. Sanitary frostproof hydrants make outdoor water service possible during cold weather without the danger of freezing or contamination. The shutoff valve is buried below the frostline. Sanitary frostproof hydrants usually employ one of three methods to prevent freezing and contamination:

a. A small weep hole below the frostline in the base of the hydrant riser pipe is the means of draining the hydrant after each use so freezing does not occur. Contamination from ground- or surface-water flow is prevented by special check valves in conjunction with some other type of syphonbreakers.

b. Water drains from the barrel into an internal reservoir.

c. Immersion heaters are constructed into the barrel. Alternatively, any pipe or hydrant can be made frostproof with the use of electrical heat tape. This system requires electricity, so its use is limited.

The type of hydrants in paragraphs 7b and 7c are inherently sanitary because they have no outside access Frostproof hydrants, which employ the weep-hole method, with no provisions for backflow prevention, must not be installed in potable water systems (ordinary check valves are not considered backflow prevention valves). Their use should be restricted to stock watering or irrigation facilities deriving water from other than a potable supply line.

8. Relief Valves. Relief valves permit water to escape from the system to relieve excess pressure. They are spring controlled and are usually adjustable to provide relief at varying pressures.

Install a relief valve in systems that may develop pressures exceeding the rated limits of the pressure tank or distribution system. Positive displacement and submersible pumps and water heaters 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. Install the relief valve between the pump and the first shutoff valve. A combined pressure and temperature relief valve is needed on all water heaters.

9. Flow-Control Valves. 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 ensure a minimum flow rate to all outlets.

10. Snifter Valves. A snifter valve introduces 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. The tire valve does not function properly on a water displacement type system. Shield snifter valves from dust, dirt, and insects.

43.55 - Underground Locations

Valves designed for direct burial in underground locations are built to withstand the rigorous demand of this type of service. These valves come with special features, such as nonrising

stems, extension rods with heavyweight operating stems, and valve boxes. Valves with lightweight operating wheels and stems, rising stems, or other features not designed for burial should not be used underground.

Underground locations are subject to submergence and contamination. Stop and waste (also called stop and drain) valves must not be used in underground locations because of this. Such use would be classified as a cross-connection.

43.6 - Sanitation

Sanitation of a water storage and distribution system requires careful consideration of the relationship of various contamination sources and potential access points to the water system. The major potentials for contamination are sewage and pit or vault toilets; however, soil, air, and rainwater can also carry contamination into a water system. Any opening into the water system should be considered a potential point of contamination.

Water storage and distribution systems that are used seasonally and drained are particularly susceptible to contamination. Contamination may enter the water system during periods when there is no positive pressure in the lines. Drains may become submerged while open, and the draining process may induce contamination. Drains should be carefully designed into the system. Drainage should always be downslope and away from the drain ends, which should always be above ground level (also known as daylighting).

The interior of the water storage and distribution system provides many places for contamination and bacterial growth to develop and to evade detection and disinfection. Deadend lines, sediment and rough pipe interiors, hydrants, valve bonnets, air tanks, and controls are examples. Contamination may periodically break loose and flow in slugs through the system. Periodic bacterial tests may never detect this. A disinfectant residual may protect the water if the contamination is not extreme.

Sanitary design should be included at the following features and circumstances:

1. Location of various sources of potential contamination.

2. Location and screening of vents, snifter valves, and air charge intakes.

3. Cross-connections, connections to irrigation systems, stock watering, hoses, appliances, and equipment.

4. Portions of the water storage and distribution system that cannot be flushed, such as dead ends.

5. Low or fluctuating pressure; for example, at pump intake lines, high points in a distribution system, high velocity locations, such as pump discharges, and small lines to a single fixture.

6. Drains; for example, on seasonal systems, fire hydrants, frostproof hydrants.

7. Accessibility and valving controls to facilitate disinfection.

8. Water systems that receive low or infrequent use. The ability to maintain a uniform disinfectant residual in a water system is critical. Disinfectant will dissipate from water that sets for extended periods of time. Maintaining high residuals in part of the system to ensure a minimum residual throughout may make the water unpalatable and encourage use from unsanitary sources.

9. Disinfection levels when the water system is used for fire. Disinfection residual may dissipate from reserve storage for fire. Also, use of the system for firefighting increases the contamination potential because velocity is greater, sediment is disturbed, hydrants and hose may be contaminated, backflow or low pressures can occur. Therefore, disinfection levels should be tested and adjusted as needed during fire flows.

43.61 - Cross-Connections

Plumbing that provides a connection of a potable (drinking) water supply with nonpotable water is a health hazard. Control cross-connections through knowledge and vigilence by the designer and water system operator. The Environmental Protection Agency Cross-Connection Control Manual (February 2003, EPA 816-R-03-002, also available through the World Wide Web/Internet at *www.epa.gov/safewater/crossconnection.html*) should be a familiar tool. Regular surveillance for cross-connections should be carried out and should also be part of an annual condition survey. Plumbing should be installed only by persons who are aware of the dangers and types of cross-connections.

1. Common Cross-Connection Hazards at Forest Service Facilities. The following is a list of plumbing cross-connection hazards common to Forest Service facilities, in addition to those listed in appendix "A" of the Cross-Connection Control Manual:

   a. Booster pump suction line or unpressurized lines.

   b. Fire hydrants.

   c. Drained and seasonally used systems, including the draining procedures and the vent and drain facilities.

2. Typical Cross-Connection Control Devices

   a. Air Gap. An air gap is an air space which vertically separates the potable water system from the nonpotable water system (or other source of contamination, such as flood level). The air gap should be at least two times the diameter of the supply pipe, but never less than 1 inch. The air gap can be used on a direct or inlet connection and for all toxic substances. For example, an air gap should be provided when potable water is used to make up chemical solutions or fill livestock water troughs. This simply means terminating the water pipe or hose above the tank or trough.

b. Atmospheric-Type Vacuum Breaker. The most commonly used atmospheric-type antisiphon vacuum breakers incorporate an atmospheric vent in combination with a check valve. Its operation depends on a supply of potable water to seal off the atmospheric vent, admitting the water to downstream equipment. If a negative pressure develops in the supply line, the loss of pressure permits the check valve to drop, sealing the orifice, while at the same time the vent opens, admitting air to the system to break the vacuum.

Atmospheric vacuum breakers may be used only on connections to a nonpotable water system where the vacuum breaker is never subjected to back-pressure and is installed on the discharge side of the last control valve. It must be installed above the usage point. It cannot be used under continuous pressure.

c. Hose-Bibb Vacuum Breakers. The vacuum breakers are small inexpensive devices with hose connections, which are simply attached to sill cocks and threaded faucets, or wherever there is a possibility of a hose being attached that could be introduced to a contaminant. However, like the atmospheric-type vacuum breaker, they should not be used under continuous pressure. A hose-bibb vacuum breaker should be installed on every sill cock to isolate garden hose applications.

d. Pressure-Type Vacuum Breakers. Pressure type vacuum breakers may be used as protection for connections to all types of nonpotable 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 backflow preventer with intermediate atmospheric vent is a device made for 1/2 inch and 3/4 inch lines and may be used as an alternate equal for pressure type vacuum breakers. They provide the added advantage of providing protection against back-pressure.

e. Double-Check-Valve Assembly. These devices are used on supply lines 1 inch and larger. The double-check valve assembly costs less, but is less effective than the reduced pressure backflow preventer. For this reason, a double-check-valve assembly is used as protection of direct connections through which foreign material might enter the potable water system in concentration which would constitute a nuisance or be esthetically objectionable, such as air, steam, hot water, or other material which does not constitute a health hazard. Check valves are not recommended for boiler fill lines.

f. Reduced-Pressure Backflow Preventer. 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 constitutes a potential health hazard. This device requires periodic testing to ensure it is working properly.

43.7 - Construction

43.71 - Construction Control

Traverse and elevation surveys are required to locate and control the construction of water storage and distribution systems. Survey ties and elevations should be made on all buried fittings, valves, and appurtenances. As-built drawings should show details of complex subsurface assemblies. Photos may be useful.

43.72 - Construction Features

If the water system is used during freezing weather, the pipeline must be buried below the frostline, usually 2 to 7 feet. If the pipe is laid on the surface of the ground, it may be subject to vandalism and the water may not only freeze easily, but during hot weather it may become very warm. Pipe laid on the surface of the ground should be supported throughout its entire length. Spans of 3 or 4 feet of 2-inch pipe have been known to bend due to the burden of winter snow and ice, and are frequently broken at the couplings. Care should be taken in laying pipe to hold carefully to the established gradeline. Low places without drains are apt to freeze and burst in the winter; high places in the line tend to trap air. Air and vacuum relief valves and air release valves should be provided on water supply lines if grades require it.

In digging trenches, gradual curves should be made at bends in lines, unless special elbows have been provided for these points. The pipe should be braced against the side of the trench with blocking before backfilling to reduce stress at the joints. Pipes below roadways should be buried at least 2 feet or deeper, depending upon the load bearing capacity of the pipe. The bottom of the excavated trench should be graded to provide even bearing for the pipe, with no projecting rocks. Trench width should be ample for working, and workmen must be protected if necessary by shoring the sides of the trench by an approved method. Backfill should be tamped in 6-inch layers at optimum moisture. In testing the pipe for leaks, just enough backfill should be placed to prevent pipe movement as the pressure is gradually applied.

If the pipeline is buried, carefully measure and record the distances, giving double ties and elevations, from hydrants, monuments, and other features that appear on the surface to all tees, elbows, crosses, and other buried features.

All pipe connections should be made under dry conditions. Soiled piping should be thoroughly cleaned and disinfected before connections are made. Old piping should not be reused.

Sweat fittings are the only kind available for rigid tubing. Flare-type fittings may be used only with flexible tubing and are used primarily for underground type K piping.

Special dielectric couplings are available for joining copper pipe to galvanized steel pipe. They prevent galvanic corrosion that normally occurs when the two types of pipe are joined. These fittings also interrupt grounding for electric wiring as they break the ground connection. Where copper and steel pipe are used in the same system, install dielectric couplings and provide a separate approved ground for the electrical system.

All types of pipe must be carefully laid. Plastic pipe requires some special precautions. Flexible plastic pipe should not be stretched, but rather should be laid zigzag in the trench so that approximately an additional foot per one hundred feet is provided for expansion and contraction. That procedure is called snaking the pipe.

The trench bottom must be free of sharp rocks that may damage the pipe. Install a pipe under a driveway subject to heavy traffic inside a rigid conduit to avoid crushing. Before backfilling the trench, the pipe should be covered with a thin layer of fine sand or rock-free soil.

Plastic pipe should not be laid in an area infested with gophers and other rodents, unless a continuous rodent-control program is practiced.

44 - Water Quantity

Estimates of average daily and peak hourly water demand are necessary for the proper and economical design of water treatment, storage and distribution facilities, and to select a suitable supply source.

The quantity of drinking water used for domestic purposes generally varies with many site and regional factors, including the availability of water, local use habits, number, location and type of plumbing fixtures provided, available pressure, and age of the facility.

Water consumption at recreational facilities varies by the type of site use and the type of plumbing fixtures offered. Residential water demand varies widely, primarily because of lawn and garden irrigation needs. Vehicle washing is a common water-consumption practice and must be included in the per capita use guides. Fire protection demand must be considered separately from all other uses, and varies on a site-by-site basis.

Providing capacity in all parts of a water system for all possible future uses may not be practical or economical. A water system should be designed to meet estimated needs for all purposes for a reasonable period, such as 10 to 20 years, and to facilitate economical expansion. This flexibility can be provided, for example, by developing the source and sizing the mains or trunk lines in the water distribution system for capacity greater than the 10- to 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 costs only slightly.

Water conservation can and should be considered in determining water quantity, especially where water supply is limited. Some means to achieving conservation include the use of low flow plumbing fixtures, metering and use of water efficient landscape practices, such as Xeriscaping. Several good references on water conservation can be obtained from the American Water Works Association (AWWA) and the National Drinking Water Clearinghouse.

44.1 - Average Daily Water Use

Average daily water use consists of the sum of the domestic, irrigation, and other daily water demands. This can best be estimated based on actual site water use records. Many Forest Service sites have recording devices; however, data are not always being collected and

analyzed. Early in the planning stage of water system replacement, it is useful to check for use data and, if necessary, to reactivate water use data collection.

When specific site use records are not available, data extrapolation from sites with similar types of use can be useful for estimating consumption. If no site use records are available, consumption must be estimated empirically from appropriate sources such as state guidelines, AWWA references, Ten State Standards, and so on.

44.11 - Domestic Consumption

Exhibit 01 shows some per capita consumption rates for use as guides in determining domestic use demand at Forest Service facilities. Additional rates for other uses can be found in the EPA "Manual of Small Public Water Supply Systems."

Hourly flows may vary according to use patterns of the facility. Typically, the average hourly flow rates for domestic use are highest during mealtimes, near bedtimes, and during laundry periods. At night and during intervening daytime hours, domestic flow is typically very low and may be near zero. Therefore, the hourly flow rate should not be determined by simply dividing the average daily use by 24 hours, as the result will be lower than the actual flow occurring during usage.

Domestic consumption can be reduced by emphasis on water conservation education and will be reduced as plumbing fixtures manufactured under new standards become installed. The Energy Policy Act of 1992 established maximum water usage standards for fixtures manufactured after 1994. The reduced showerhead and faucet flow rates of 2.5 gallons per minute and the 1.6 gallon per flush water closet will effectively reduce the current consumption rates shown in exhibit 01 by 20 to 50 percent.

44.11 - Exhibit 01

Average Daily Design Flow

Consumer Use	Consumption in gallons per day	Unit
Camping Facility		
Without flush toilets	5	PAOT*
With flush toilets	20-30	PAOT*
With flush toilets and showers	25-50	PAOT*
Trailer with –		
water connection	25	PAOT*
water and sewer connection	50	PAOT*
Day Use		
Without flush toilets	1	Person
With flush toilets	5	Person
With toilets and showers	20	Person
Travel trailer dump station	20-30	Trailer
Dwellings		
Single family	75-125	Person
Bunkhouse/Dormitory	50	Person
Barracks (with kitchen)	60-65	Person
House trailers	50-75	Person
Mess halls	15	Person
Office	15-25	Person
Miscellaneous		
Laundry	50	Wash
Organization camp	35-75	Person
Motel-lodge	35-75	Person

*PAOT-Persons At One Time.

The average daily demand should be computed as a summation of the products of individual system users and their respective per capita daily consumption.

44.12 - Irrigation and Other Requirements

Irrigation requirements for lawn, shrubs, green areas, ground cover, and vegetable gardens should be considered and designed into the water distribution system. Requirements for cropland irrigation are beyond the scope of this Handbook. These flow requirements should be added to peak domestic rates, but not to fire flows unless sprinkling is automatically controlled to take place during periods of low water use. The best references for specific sprinkler systems are the descriptive literature readily available from the various sprinkler manufacturers. Special consideration should be made for averaging irrigation flows, because they are often applied at a periodic rate other than daily.

The rate of application on lawn and ground cover varies from 1 inch per week in areas of high relative humidity to 2-3 inches 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 to be sprinkled. The irrigation system should be on a timer to allow sprinkling in the early morning hours, to minimize evaporative losses and to maximize available system head for uniform application. Early morning operation will also avoid peak demand periods, probably eliminating a need for an increase in the primary distribution system.

Other water requirements must also be considered. These include fleet equipment washing and other commercial uses, and livestock watering.

44.2 - Peak Demand

Peak demand flow, also known as maximum hourly and instantaneous rate of flow, is the basis for the design of the water distribution system.

For very small systems (serving less than 3 residences), the peak demand may be calculated by adding the peak flow rates of all fixtures on the system. For larger systems, other techniques must be utilized, including engineering experience with performance of similar systems. Often, State guidelines recommend or require minimum peak flow rates. The following are some methods to estimate the peak demand flow rate:

1. Exhibit 01 shows the instantaneous rates of flow ordinarily expected for certain domestic plumbing fixtures for different pressure ranges. This exhibit is useful in estimating peak demands due to simultaneous operation of a number of fixtures. Engineering judgment is needed to determine those combinations of fixtures that would contribute to an hourly peak flow within a given development.

Note that the flow rates shown in exhibit 01 are for fixtures manufactured prior to 1994, when the maximum usage standards for plumbing fixtures were established. The instantaneous rate of flow for most fixtures is generally unchanged, except for faucets and showerheads (usage to be reduced to 2.5 gpm) and water closets (usage to be reduced to 1.6 gallon per flush).

2. Another method of estimating peak demands is the fixture-unit method described in the Uniform Plumbing Code, Appendix A - Recommended Rules for Sizing the Water Supply

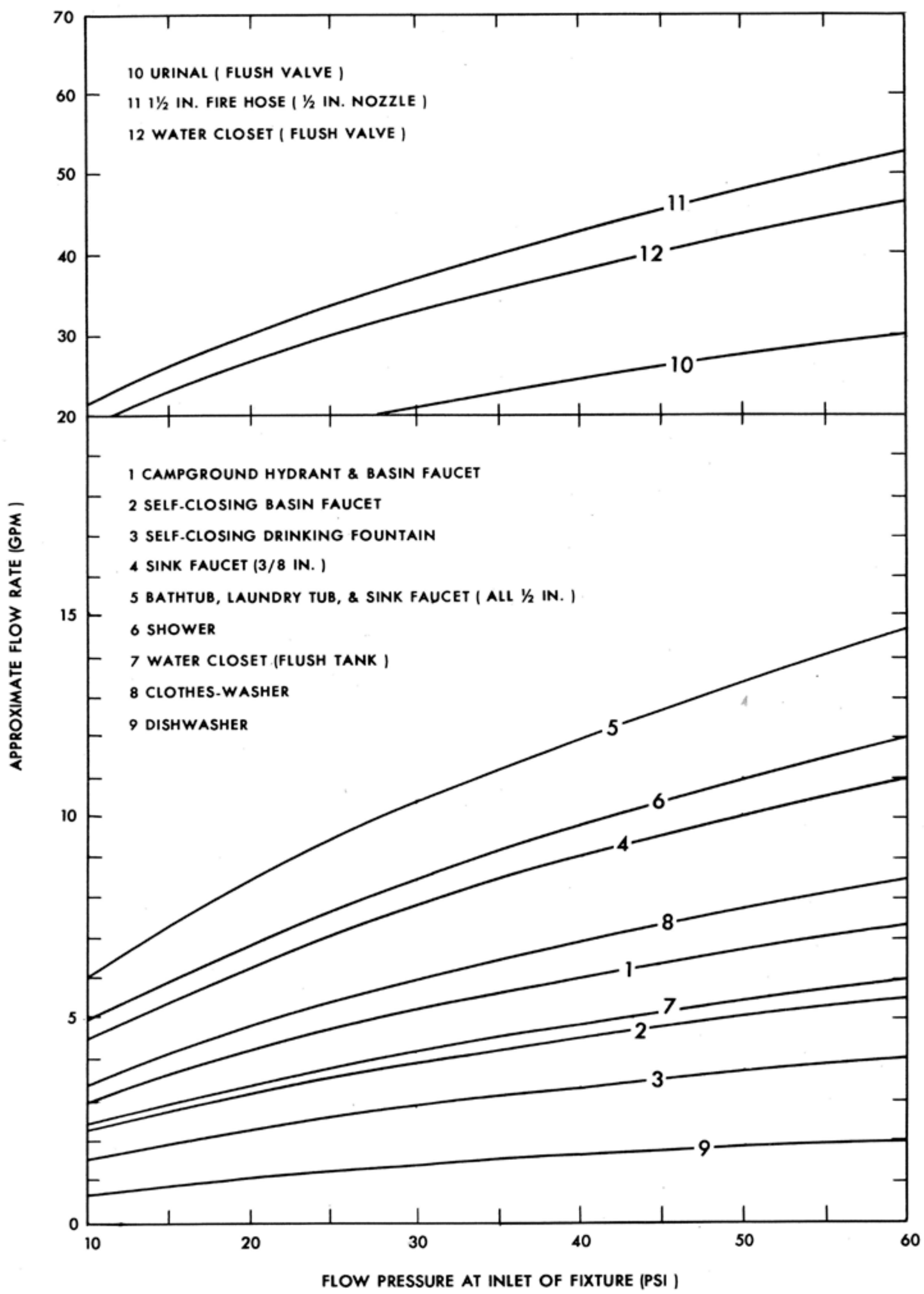
System. It was originally developed to estimate peak flows for apartment buildings. Peak hourly flows based on these instantaneous flow rates will be somewhat high for small water systems. Additions to flows determined by the fixture unit method should be made for continuous flows, such as lawn irrigation.

Several studies of water consumption in individual residences, at highway rest areas, and in camping areas indicate that peak hourly flows 8 to 9 times the average daily flow rate are not uncommon. These observations were verified by San Dimas Technology Development Center in the early 1970's.

In determining the average daily flow rate, it must be remembered that recreational flows occur over periods significantly less than 24 hours. This will increase the average hourly flow rate 30-50 percent over that of a 24-hour day.

44.2 - Exhibit 01

<u>Instantaneous Rates of Flow for Certain Plumbing Fixtures</u>



45 - Fire Protection

45.1 - Policy

Fire protection policy can be found in FSM 5137, FSH 7309.11, and FSH 6709.11. A brief description of the requirements are as follows:

1. Limit facility fire protection to prevention, use of fire extinguishers on incipient stage fires, safe evacuation of personnel to protection of exposed improvements, and containment of structural fire by exterior attack.

2. Forest Service employees shall limit structural fire suppression actions to exterior attack.

45.2 - Planning Drinking Water Systems for Fire Protection

In planning for a water system upgrade or replacement, fire protection alternatives need to be developed and analyzed for risk, consequences, and costs.

Where the site is located within range of a local structural fire department, structural fire protection can be provided via options, which may or may not require major capacity development of the domestic water system. If the water system is to supply fire protection, quantities should be provided in accordance with requirements of National Fire Protection Association (NFPA) 1131 - Standard on Water Supplies for Suburban and Rural Fire Fighting. If response time, equipment and personnel capability are suitable, and if buildings with sprinkler systems are planned for the site, then a hose and hydrant system that meets NFPA 24 - Standard for Installation of Private Fire Service Mains and Their Appurtenances, would be the appropriate fire protection system.

For sites located beyond the limits of a local structural fire department, the water system should only provide capacity to meet the objective of preventing fire spread to adjacent wildland or structures spaced at least 40 feet apart (see NFPA 224 - Standard for Homes and Camps in Forest Areas). This can be accomplished by several means, depending on the site characteristics and structures. For remote guard station or work center sites with few structures and low daytime occupancy, it may not be beneficial to provide any water system development greater than that needed for domestic consumption. For Ranger Stations and work centers with a larger number of structures and housing units, it may be advantageous to provide a smaller-sized hose and hydrant system to meet the spread prevention objective.

A cost analysis should be performed to compare the increased cost of water system fire protection capacity with the cost of remote area life insurance premiums for systems with rural fire department protection; for spread protection, display the added cost of water system improvements.

45.3 - Design Guidelines for Fire Protection

1. Hose and Hydrant System for Local Structural Fire Department Utilization. If the drinking water supply is adequate and gravity storage is possible, the storage and distribution capacity should be designed in accordance with NFPA 24 - Standard for Installation of Private Fire Service mains and Their Appurtenances.

2. Hose and Hydrant System for Fire Spread Prevention. Where the drinking water supply is adequate, a gravity storage is possible and trained structural fire fighting personnel are not available, the system should be designed to provide the following:

   a. Hose Stream: Two 1-1/2 inch hose streams simultaneously at 40 gpm each, 40 - 50 psi pressure at the hydrant, 1/2 inch nozzles, 200 feet maximum hose length. If the configuration of building and barriers provide only minimal clearances, an additional simultaneous hose stream may be warranted. Physical activities would be restricted to wetting down adjacent buildings and grounds. Dousing of a building engulfed in flames would only be performed to enhance spread prevention without depleting fire storage.

   b. Storage: Approximately 50 percent of that storage required for structural fire protection; provide one hour flow for the 2 or 3 hose streams.

3. Design criteria. The criteria for building sprinkler systems can be found in NFPA 13 - Standard for the Installation of Sprinkler Systems and NFPA 13R - Standard for the Installation of Sprinkler Systems in Residential Occupancies Up To and Including Four Stories in Height. Generally the criteria is for up to four sprinklers per compartment with demand calculated at a minimum of 18 gpm per operating sprinkler or 13 gpm per number of designed sprinklers. Storage is 30 minutes at demand rate.