How Water Works

ILLUSTRATED PROCESSES, EQUIPMENT, AND TECHNOLOGY

A Typical Water System: From Source to Tap and Back

How Water Works looks at the processes, equipment, and appurtenances of a water supply system. This month's image provides an overview of the basic parts of a water system: source, treatment, distribution, collection, sewage treatment, and reuse. In subsequent issues we'll explore the inner workings of the drinking water system components, beginning with the source and flowing through to the tap. Next month: surface water sources

1a and 1b. Water is taken from its source, which may be a reservoir (1a), river, or well (1b). Water is pumped or flows by gravity to the treatment plant.

2. At the treatment plant, impurities in the water are removed or inactivated, and fluoride may be added.
3. Clean drinking water is stored in an elevated tank.
4. Distribution mains carry water from the treatment plant or tank to service lines. Mains also provide water to hydrants for fire protection.
5. Service lines connect distribution mains to building plumbing systems.
6. Used water from sanitary sewers is piped to the sewage treatment plant.
7. At the sewage treatment plant, used water goes through a multiple-step cleansing process.
8. Cleaned water is returned to the river where it re-enters the water cycle or is additionally cleaned and reused for irrigation purposes, such as golf course watering.

Illustration elements exaggerated for emphasis.

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Highlighting Surface Water Contamination Sources

Surface water is the term used to describe water on the land surface. It may be running, such as in streams and rivers, or quiescent, such as in lakes, reservoirs, and ponds. Surface water is produced by runoff of precipitation and natural groundwater seepage. For regulatory purposes, surface water is defined as all water open to the atmosphere and subject to surface runoff. Surface water is vulnerable to numerous chemical and microbiological contamination sources and, in most cases, requires filtration and disinfection before it is safe to drink. Next month, How Water Works reveals groundwater contamination sources.

1. Lakes and reservoirs are vulnerable to natural and human contamination. For example, silt washed into lakes can smother organisms on the lake floor, upsetting or destroying aquatic ecosystems. Animal and human wastes within a watershed often find their way into surface water.
2. Rivers and streams are at the mercy of all upstream users of the water and land within the drainage basin. Some streams also have occasional periods when water quality is especially poor as a result of natural causes, such as heavy spring runoff.
3. Oil pollution from commercial vessels is a common occurrence.
4. Pesticides and fertilizers used in agriculture (4a) and on golf courses and suburban lawns (4b) account for a major portion of nonpoint source pollution.
5. Runoff containing manure from livestock and poultry producers has been a major source of surface water pollution. More than 150 pathogens found in livestock manure pose risks to humans.
6. Runoff from farmlands in the drainage basin can raise nitrate levels that can exceed state and federal standards. High sediment loads carrying phosphorus, a common nutrient, are also a problem in agricultural basins and those undergoing urbanization.
7. Runoff from parking lots and roads flushes spilled oil and gasoline and road salt into lakes and streams.
8. Hazardous and many "nonhazardous" industrial wastes contaminate surface water. Toxic chemicals, although now regulated, can still be discharged directly into surface water. Thermal pollution, such as an influx of warm water from cooling towers, also has a detrimental effect on aquatic ecosystems.
9. Air pollutants such as dioxin and mercury, along with sulfur and nitrogen oxides, precipitate into lakes and rivers by rainfall in the form of acid rain.
10. Municipal wastewater treatment plants can contaminate river and lake water.

Some illustration elements exaggerated for emphasis.

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Conventional Water Treatment Processes: Traditional Methods Stand the Test of Time

For many years, the combined processes of mixing, flocculation, sedimentation, filtration, and chlorine disinfection shown here have formed traditional water treatment plant design. This approach, known as conventional treatment, effectively removes practically any range of raw water turbidity, along with harmful bacteria, including *E. coli*, viruses, and protozoans, such as *Giardia lamblia* and amoebas. Next month, How Water Works will begin looking at these conventional treatment processes in detail.

1. **Raw water basins slow the water's velocity after it passes through the intake structure, allowing heavy sediment and grit to settle to the bottom of the basins before the water enters the treatment plant.**
2. **Chemical coagulants are added to react with the remaining small particles in the water to form particles large enough to settle out. Rapid mixing distributes the coagulant evenly throughout the water.**
3. **Flocculation basins gently mix the water with large submerged paddles so smaller particles collide to form large particles called "floc."**
4. **Floc settles by gravity to the bottom of a sedimentation basin. Clean water spills over to the filters.**
5. **Filtration removes any remaining particles. The force of gravity moves the water through filter media—primarily sand, anthracite coal, granular activated carbon, garnet sand, or some combination of these materials.**
6. **Chlorine is added for disinfection. A chlorinator meters chlorine gas from a chlorine cylinder or other container and then delivers the set dosage.**
7. **Finished water basins ensure contact time is allotted for adequate disinfection.**
8. **A clearwell stores water before the water enters the distribution system.**
9. **Pumps send clean, safe water throughout the community.**

Some illustration elements exaggerated for emphasis.

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Conventional Water Treatment Processes
Part 2: Filtration and Disinfection

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Filtration of suspended solids occurs when water passes through a bed of granular material called filter media. The suspended material removed from surface water can include floc from the coagulation, flocculation, and sedimentation processes; microorganisms; and precipitates. As water passes through the filter bed, the suspended particles are captured by the media and prevented from passing in the effluent. The water is disinfected to destroy or inactivate disease-causing organisms, such as viruses, bacteria, fungi, and protozoa. Chlorination is the most common disinfection method, but other methods are also used. Next month, How Water Works will begin looking at the distribution process.

1. Filter tanks are generally rectangular and constructed of concrete. Several filter tanks are usually constructed side by side on either side of a central pipe gallery to minimize piping.

2. Dual-media filters usually have a bed of sand covered by a layer of crushed anthracite coal or garnet. Often, a layer of granular activated carbon provides taste and odor control. The coarse layer on top removes most of the suspended particles. The particles that do pass through this layer are removed by finer media below.

3. A filter underdrain system collects the filtered water uniformly across the bottom of the filter and distributes backwash water evenly when a filter must be cleaned.

4. A trough is placed over the filter media to collect the backwash water during washing and carry it to waste.

5. Chlorine is added for disinfection. The chlorination feed equipment is usually housed in a separate room.

6. Finished water basins ensure contact time is allotted for adequate disinfection. Snake-like flow through the basin maximizes contact between chlorine and the effluent.

7. A covered clearwell stores water before it enters the distribution system.

8. Pumps send clean, safe water throughout the community.

ILLUSTRATION: RON KNOWLTON
ENGINEERING DRAWINGS: CAROLLO ENGINEERS

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Effective Filtration Relies on the Right Media Mix

Filtration plays an important role in removing naturally occurring and treatment-induced particles in water treatment plants. It usually isn't necessary to filter groundwater, because most suspended material is removed as water percolates through the soil. However, because surface water is subject to runoff and other sources of contamination, filtration is necessary to remove the suspended material for aesthetic and public health reasons.

High-rate filters—dual-media and multimedia filters—can operate at rates up to four times higher than rapid sand filters. As illustrated here, high-rate filters use a combination of filter media, not just sand. In operation, the top, coarse layer removes most of the suspended particles. Particles that pass through this layer are removed by finer media below. As a result, most of the filter bed is used, allowing for longer filter runs and higher filtration rates than a conventional sand filter.

1–3. In dual-media and multimedia filters, the coarsest material has the lowest specific gravity (material weight relative to water weight), so it tends to stay at the top. The heaviest material is the finest, and it stays near the bottom. A common combination is coarse anthracite (coal) at the top (1), fine silica sand in the center (2), and gravel at the bottom (3) to prevent sand from entering the underdrains. Garnet sand is used as an additional layer in multimedia filters. Some mixing of the layers occurs, but the media maintain their approximate respective positions in the filter bed after backwashing. The types of filter media used depend on many factors, including general raw-water quality, water quality variations, and chemical treatment used.

4. Filter tanks are generally rectangular and constructed of concrete. To minimize piping and ease access, several filter tanks are usually constructed side-by-side on each side of a pipe gallery.
5. Influent water is introduced over the filter surface.
6. Filters typically require a trough placed over the filter media to collect backwash water and carry it to waste.
7. Porous plates, perforated bricks, and other systems can be used for the filter bottom.
8. A system of underdrain piping collects the filtered water.
9. A clearwell stores filter effluent water under the filter or elsewhere.

Editor's Note: Additional How Water Works images and related products are available at www.awwa.org/howwaterworks.

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Inside a Well-Equipped Water Treatment Lab

Reliable and standardized laboratory analyses form the basis for water quality control and public health protection. Water treatment plant and distribution system operators will find the equipment pictured here in many water quality laboratories.

1. Jar-testing equipment for conducting miniature experiments in water treatment plants guides chemical selection and dosage.
2. Water taps continuously run in a long sink to bring in water from different processes of the plant for testing.
3. Bunsen-type burners perform ordinary heating procedures, such as sterilization.
4. An ammonia probe determines ammonia concentration and is used by utilities that apply ammonia during treatment to form chloramine.
5. A turbidimeter measures the loss in intensity of a light beam through a solution that correlates to suspended particulate matter in water.
6. A fluoride probe measures fluoride content in water, either naturally occurring or added during treatment.
7. A pH meter measures the hydrogen-ion activity in water to determine if the water is acidic or basic.
8. Microscopes yield information from samples on plant and animal life presence in source water, such as algae, protozoa, and crustaceans.
9. A fume hood minimizes exposure to laboratory employees by containing and removing hazardous fumes and chemicals as procedures are performed.
10. Eyewash and shower stations are accessible for personal safety in case corrosive chemicals spill on a laboratory analyst.
11. A dishwasher keeps glassware clean.
12. A refrigerator keeps samples cold and preserved until they can be analyzed and is used to store quality-assurance standards.
13. Reagent-grade water is prepared by distillation, deionization, or reverse osmosis.
14. Beam and electronic balancing equipment are certified for measuring chemicals and solids in making standards used for quality assurance.
15. Ovens prepare glassware to be clean and free of organic contamination.
16. First-aid equipment is readily available if minor medical attention is required.
17. A spectrophotometer measures a water sample's absorption of light to determine the level of certain types of organic matter in the water.
18. A chlorine analyzer determines residual chlorine levels in water samples.
19. A total organic carbon analyzer measures disinfection by-product precursors to track their removal during treatment.
20. A colorimeter measures the intensity of a water sample's color caused by organic or inorganic constituents.
21. Personal protective equipment and supplies provide for personal safety and include safety glasses, gloves, lab coats, a face shield, and a fire extinguisher.
22. A phone is needed for contact with treatment and distribution system operators and customer service.
23. Glassware used in the laboratory should be heat-resistant, borosilicate, class A glassware.

Editor's Note: For more information on laboratory procedures for water supply practices, see *M12, Simplified Procedures for Water Examination*, and *Safety First: Laboratory Safety for Water Professionals* (DVD), available from the AWWA Bookstore (www.awwa.org/bookstore).

Some illustration elements exaggerated for emphasis.

ILLUSTRATION: RON KNOWLTON

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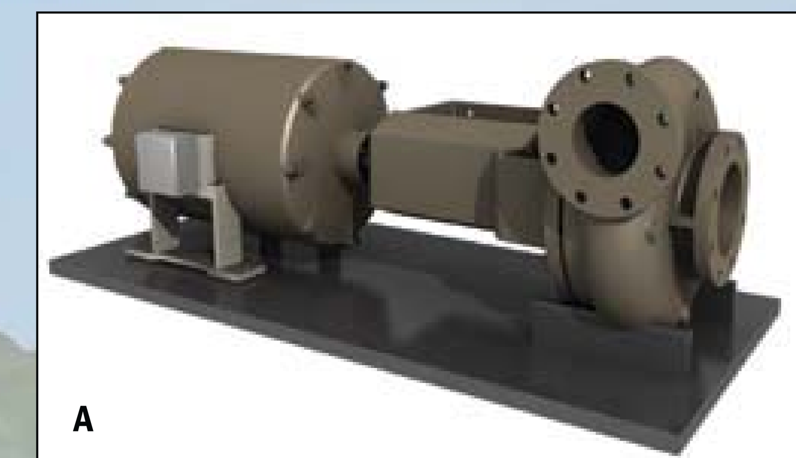
Pumps Support Widespread Applications in Water Systems

Pumping facilities are required wherever gravity can't be used to supply water to the distribution system under sufficient pressure to meet all service demands. When used, pumping accounts for most of the energy consumed in water supply operations. Pumping equipment also represents a major part of a utility's investment in equipment and machinery. Typical uses of pumps in a water system are detailed below.

1. Low-Service: Centrifugal pumps lift water from the source to treatment processes or from storage to a filter-backwashing system.
2. Well: Centrifugal or vertical turbine pumps lift water from shallow or deep wells and discharge it to the treatment plant, storage facility, or distribution system.
3. Chemical Feed: Positive displacement pumps add chemical solutions at desired dosages for treatment processes.
4. Sampling: Positive displacement or centrifugal pumps pump water from sampling points to the laboratory or automatic analyzers.
5. High-Service: Centrifugal pumps discharge water under pressure to the distribution system.
6. Booster: Centrifugal pumps increase pressure in the distribution system or supply water to elevated storage tanks.
7. Sludge: Positive displacement or centrifugal pumps pump sludge from sedimentation facilities to further treatment or disposal.

Common Types of Pumps

Two basic categories of pumps are used in water supply operations: velocity pumps and positive-displacement pumps. Velocity pumps, which include centrifugal (A) and vertical turbine pumps (B), are used for most distribution system applications (see complete list below left). Positive-displacement pumps, such as lobe-type rotary pumps (C), are most commonly used in water treatment plants for chemical metering.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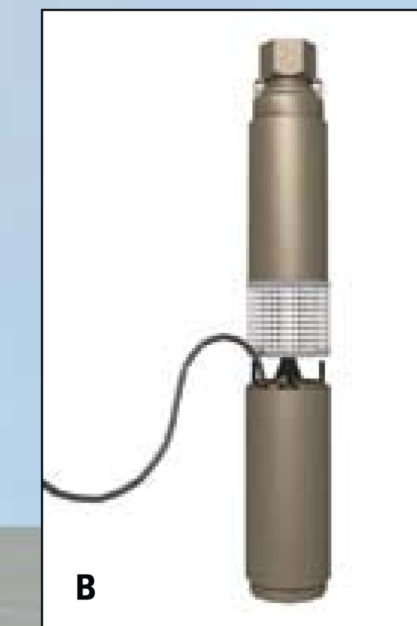
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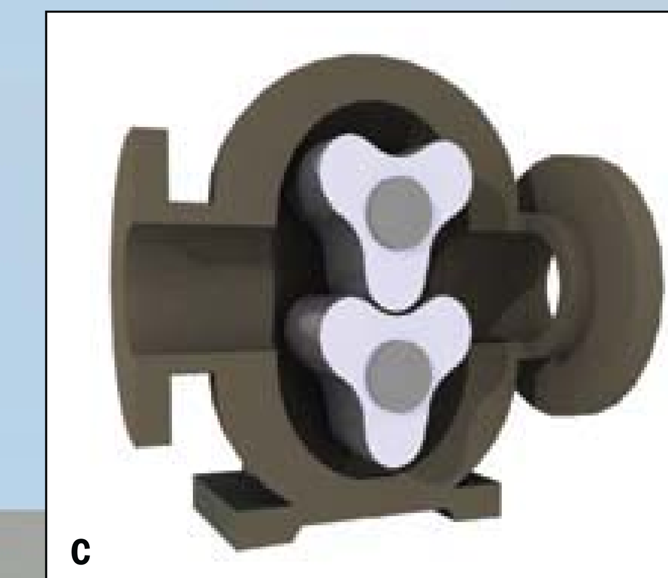
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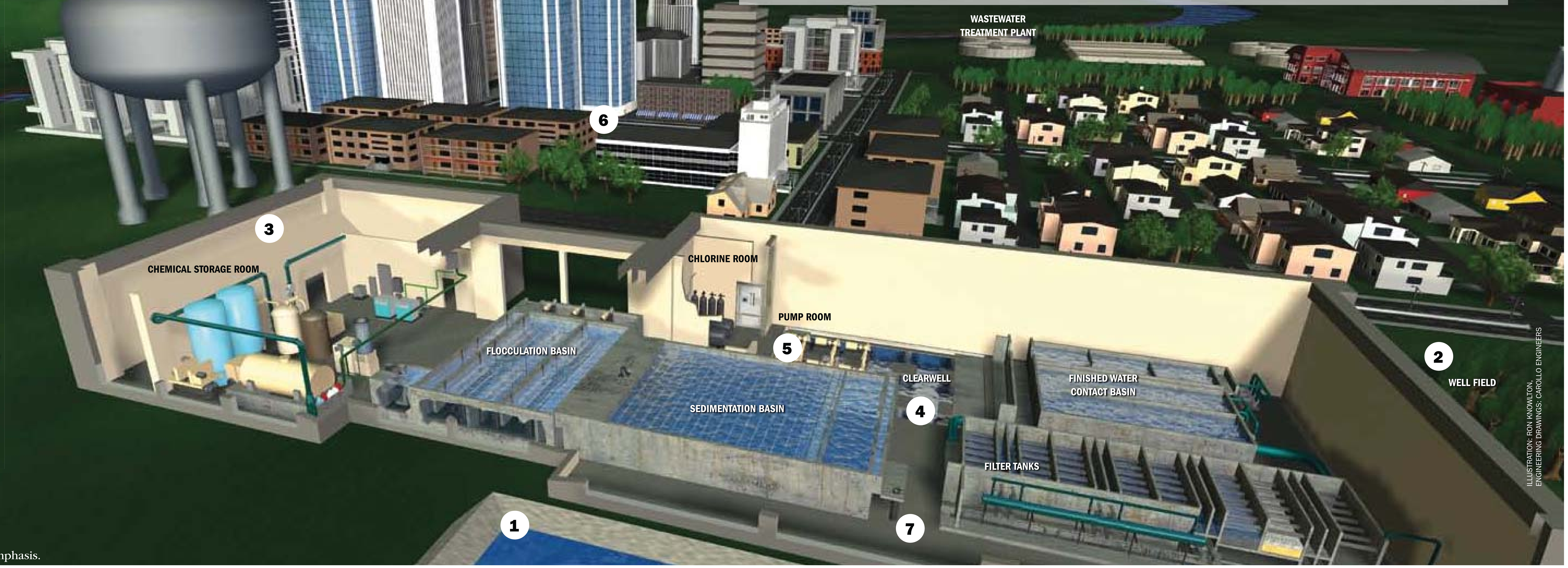

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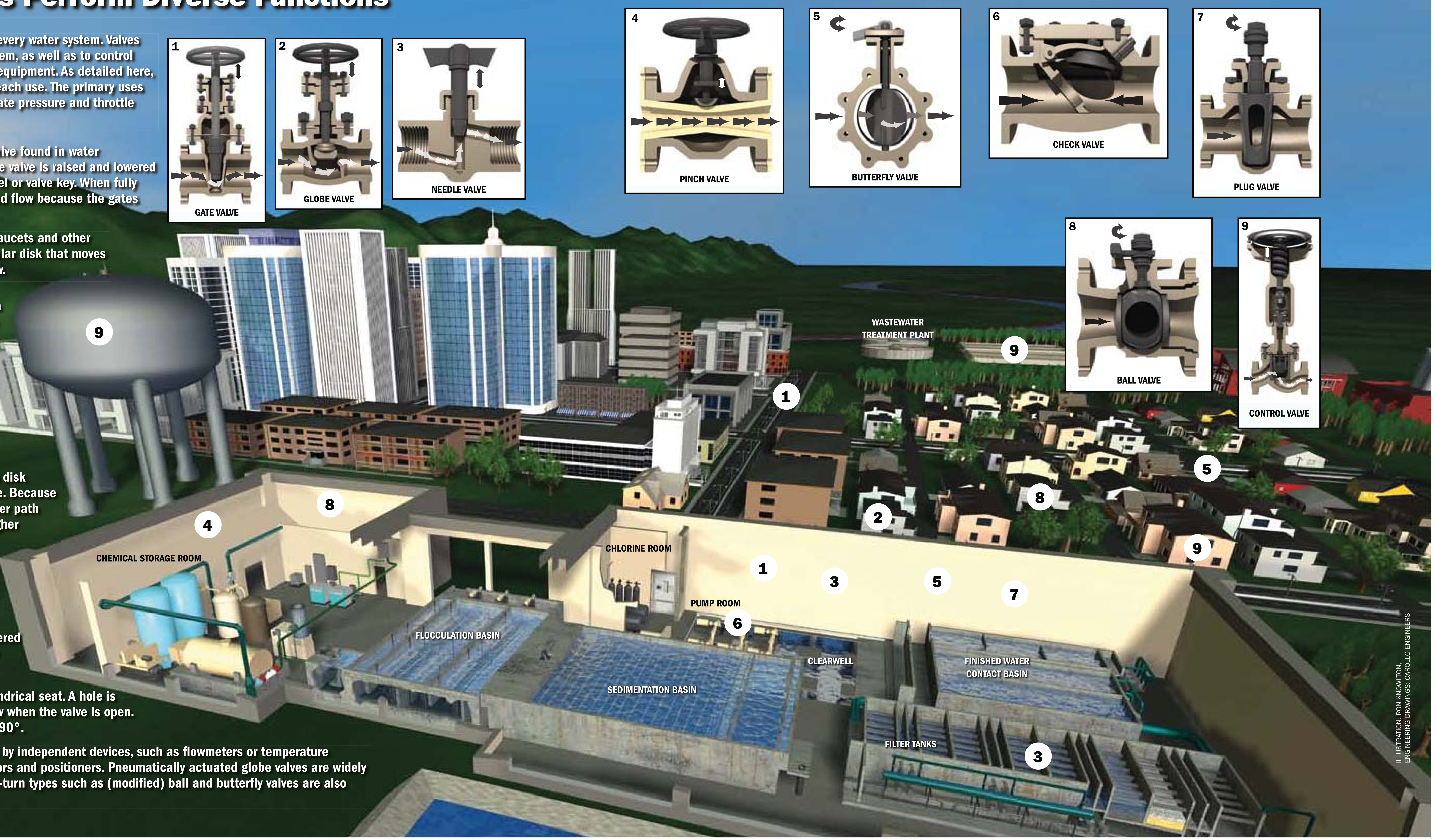
Water Utility Valves Perform Diverse Functions

Numerous types of valves are required in every water system. Valves are used to operate the distribution system, as well as to control treatment processes, pumps, and other equipment. As detailed here, the correct type of valve must be selected for each use. The primary uses are to start and stop flow, isolate piping, regulate pressure and throttle flow, prevent backflow, and relieve pressure.

1. Gate valves are the most common type of valve found in water distribution systems. The gate, or disk, of the valve is raised and lowered by a screw, which is operated by a handwheel or valve key. When fully open, gate valves provide almost unrestricted flow because the gates are pulled fully up into the bonnet.
2. Globe valves are commonly used for water faucets and other household plumbing. The valves have a circular disk that moves downward into the valve port to shut off flow.
3. Needle valves are similar to globe valves except that a tapered metal shaft fits into a metal seat when the valve is closed. Needle valves are used most often to precisely throttle flow.
4. Pinch valves are closed by pinching shut a flexible interior liner. This type of valve is particularly useful for throttling the flow of liquids that are corrosive or might clog other types of valves.
5. Butterfly valves consist of a body in which a disk rotates on a shaft to open or close the valve. Because the disk of a butterfly valve stays in the water path in the open position, the valve creates a higher resistance to flow than a gate valve does.
6. Check valves allow flow in only one direction. They are commonly used at the discharge of a pump to prevent backflow when the power is turned off.
7. Plug valves have cylindrical or conically tapered "plugs" that can be rotated inside the valve body to control flow.
8. Ball valves consist of a ball resting in a cylindrical seat. A hole is bored through the ball to allow water to flow when the valve is open. The valve is closed when the ball is rotated 90°.
9. Control valves respond to signals generated by independent devices, such as flowmeters or temperature gauges, and are normally fitted with actuators and positioners. Pneumatically actuated globe valves are widely used for control purposes, although quarter-turn types such as (modified) ball and butterfly valves are also used for control.



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Water Storage Structures Meet Diverse Needs

This installment of How Water Works examines water storage structures. Water storage is essential for meeting all of the domestic, industrial, and fire demands of most public water systems. Water may be stored before and after treatment. The type and capacity of water storage a distribution system requires will vary with the size of the system, the topography of the area, how the water system is laid out, and various other considerations. Next month, How Water Works will explore distribution system design.

1. Many elevated tanks are constructed of steel. The thickness of the steel varies within the tank, depending on the pressure exerted on the tank walls. The upper walls may be relatively thin, but the lower walls may have a thickness of 2 in. or more.
2. A riser pipe is generally used as both the inlet and outlet pipe on an elevated tank. In cold climates, risers are typically 6 ft in diameter or larger to allow for some freezing around the edge and for expansion when water turns to ice.
3. An overflow pipe is necessary on all tanks to safeguard the tank if water-level controls fail. The pipe discharges to a splash plate or drainage inlet structure to prevent soil erosion.
4. A drain connection empties the tank for maintenance and inspection.
5. Air vents allow air to enter and leave the tank as the water level falls and rises. The water level is measured either by a pressure sensor at the tank base or a level sensor inside.
6. Hatches are installed for entry and ventilation during maintenance and inspection.
7. Multicolumn tanks generally have a ladder that runs from the ground to the balcony (7a) and another that goes up through the access tube to the top of the tank (7b).
8. Obstruction lights or strobe lights on an elevated tank may be required by the Federal Aviation Administration to warn aircraft in the tank's vicinity, depending on the tank's height and location.
9. The same general comments for elevated tanks also apply to ground-level tanks.

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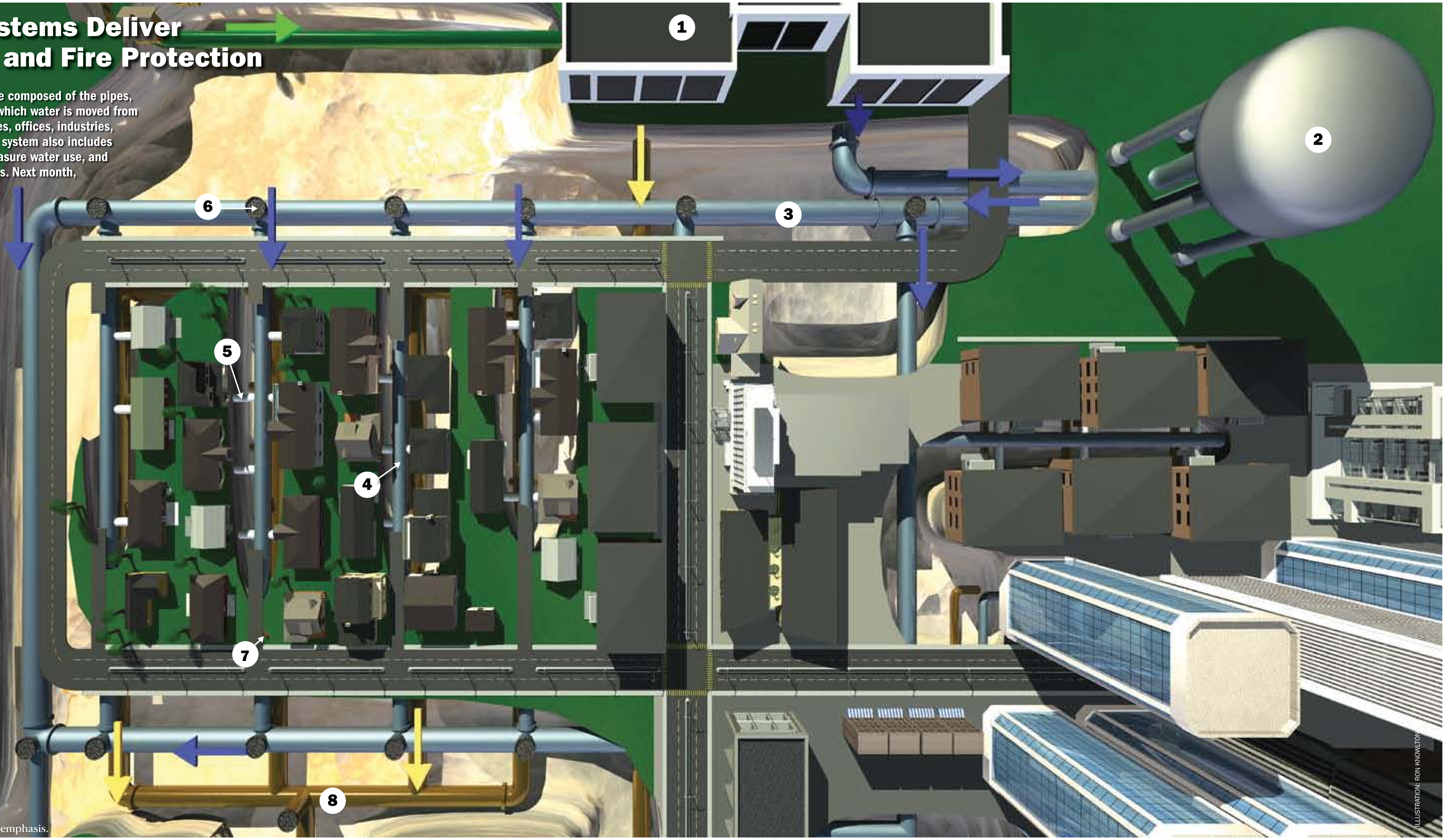
PIPELINE KEY

- UNTREATED WATER
- TREATED WATER
- WASTEWATER

Distribution Systems Deliver Drinking Water and Fire Protection

Water distribution systems are composed of the pipes, valves, and pumps through which water is moved from the treatment plant to homes, offices, industries, and other consumers. The distribution system also includes facilities to store water, meters to measure water use, and hydrants for firefighting and other uses. Next month, How Water Works will detail how water flows into a typical home.

1. At the treatment plant, impurities in the water are removed or inactivated.
2. Water storage facilities are sized and operated to provide reserves for firefighting and to meet consumer demands.
3. Transmission lines are large pipes that carry large quantities of water from the treatment plant and storage tanks into the distribution system. Transmission pipes generally run in straight lines, have few side connections, and aren't tapped for customer services.
4. Distribution mains carry water from transmission lines and distribute it throughout a community. These pipes have many side connections and are frequently tapped for customer connections.
5. Service lines are small-diameter pipes that run from the distribution mains to customers' premises.
6. Shutoff valves are located at regular intervals so areas within the system can be isolated for repair or maintenance.
7. Hydrants should be located near street intersections so hoses can be used to fight a fire in any of several directions.
8. Sewage pipes carry used water away from consumers to the wastewater treatment plant.



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Fire Flow Requirements Protect Service Areas

The determining factor in sizing mains, storage facilities, and pumping facilities is often the need for fire protection. Fire flow requirements for each community are set by the Insurance Services Office, an organization that represents property and casualty fire insurance underwriters. This group determines the minimum flow that a system must be able to maintain for a specified duration. The result of this analysis contributes to a community's Public Protection Classification, one element used by insurance companies and their agents to price business and residential property insurance premiums to achieve a specified fire rating. Fire insurance rates are then based, in part, on this classification.

1. The water treatment plant maintains water quality from the point of entry into the distribution system to the point of use and delivers adequate flow to satisfy customer demands and protect from fire losses.
2. Water storage facilities are sized and operated to provide reserves for firefighting and to meet consumer demands. Fire demand can account for as much as 50 percent of the total capacity of a storage system.
3. Transmission mains are large pipes that carry large amounts of water from the treatment plant and storage facilities into the distribution system. High-value districts (such as high-rise buildings, sports stadiums, and shopping centers) may have minimum pipe sizes of 8–12 in.
4. Distribution mains are the pipelines that carry water from the transmission mains and distribute it to the customers and fire hydrants throughout the water system. Mains in residential areas should have minimum sizes of 6–8 in.
5. Service lines carry water from the utility's water mains to the consumer's home, building, or other point of use. Average single-family homes are usually served with a ¾-in. service.
6. Fire hydrants should generally have a minimum static pressure of 35 psi or higher to ensure high fire flow capacity. Pressure during fire flow conditions shouldn't drop below 20 psi.

Editor's Note: Additional information on fire flow requirements can be found in AWWA Manual M31, *Distribution System Requirements for Fire Protection*.

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Ensure Proper Fire Hydrant Installation

A fire hydrant is one of the most important parts of a water distribution system, but it's often one of the most ignored. To ensure hydrants work correctly when they're needed, proper installation procedures must be followed. The following recommendations are in accordance with ANSI/AWWA C600, *Standard for Installation of Ductile Iron Water Mains and Their Appurtenances*.

1. Connect fire hydrants only to water mains adequately sized to handle fire flows.
2. Install fire hydrants as plumb as possible.
3. Ensure hydrants are installed far enough away from the curb to avoid damage from or to turning vehicles. The recommended setback is 2-ft minimum from the face of the curb to the point on the hydrant nearest the curb.
4. The pumper outlet nozzle should face the street to enable a quick connection to the fire pumper.
5. Be sure the outlet nozzles are high enough (at least 18 in.) above the ground line to allow for attaching hoses and operating the hydrant wrench.
6. Always install an auxiliary valve between the hydrant and the supply main to isolate the hydrant for maintenance.
7. Provide thrust restraint for the auxiliary valve so the hydrant may be removed without shutting down the main.
8. Remove foreign matter from the hydrant lead before installing the auxiliary valve and hydrant.
9. In setting a hydrant, use a firm footing, such as stone slabs or a concrete base on firm ground, to prevent settling and strain on the hydrant lead joints.
10. Provide for thrust restraint of the hydrant by strapping, blocking, or using a restraining-type joint.

Editor's Note: Additional information on hydrant installation can be found in M17, *Installation, Field Testing, and Maintenance of Fire Hydrants*, which is available in the AWWA Bookstore (www.awwa.org/bookstore).

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Take Effective Steps to Emergency Repairs

The degree of urgency in making distribution repairs varies by how serious the problem is, where the problem is, and the weather conditions. A large main break must obviously be taken care of as quickly as possible. A small service leak can often be guarded and repair deferred a day or two if necessary in summer, but in winter it may have to be repaired immediately to prevent dangerous icing conditions. The bottom line is that a distribution crew must be prepared and organized to quickly, efficiently, and safely perform a repair by following a few critical steps.

1. Locate the valves that must be closed to isolate the section, notify customers that their water service will be off for a period of time, and call the local "dig safe" system to have other utilities locate their pipes and cables at the location to be excavated.

2. Mark the excavation site with barricades, flashing lights, and warning or detour signs, and station a flagger at the site if necessary to protect the work crew and the public.

3. Excavate the water main or service leak parallel to the pipeline and to one side to allow a worker to stand next to the pipe while making the repair. Put excavation and trenching controls into place for safety. Expose the break and thoroughly scrape and clean the area. Determine the type of leak/break, split, blowout, joint, or corrosion.

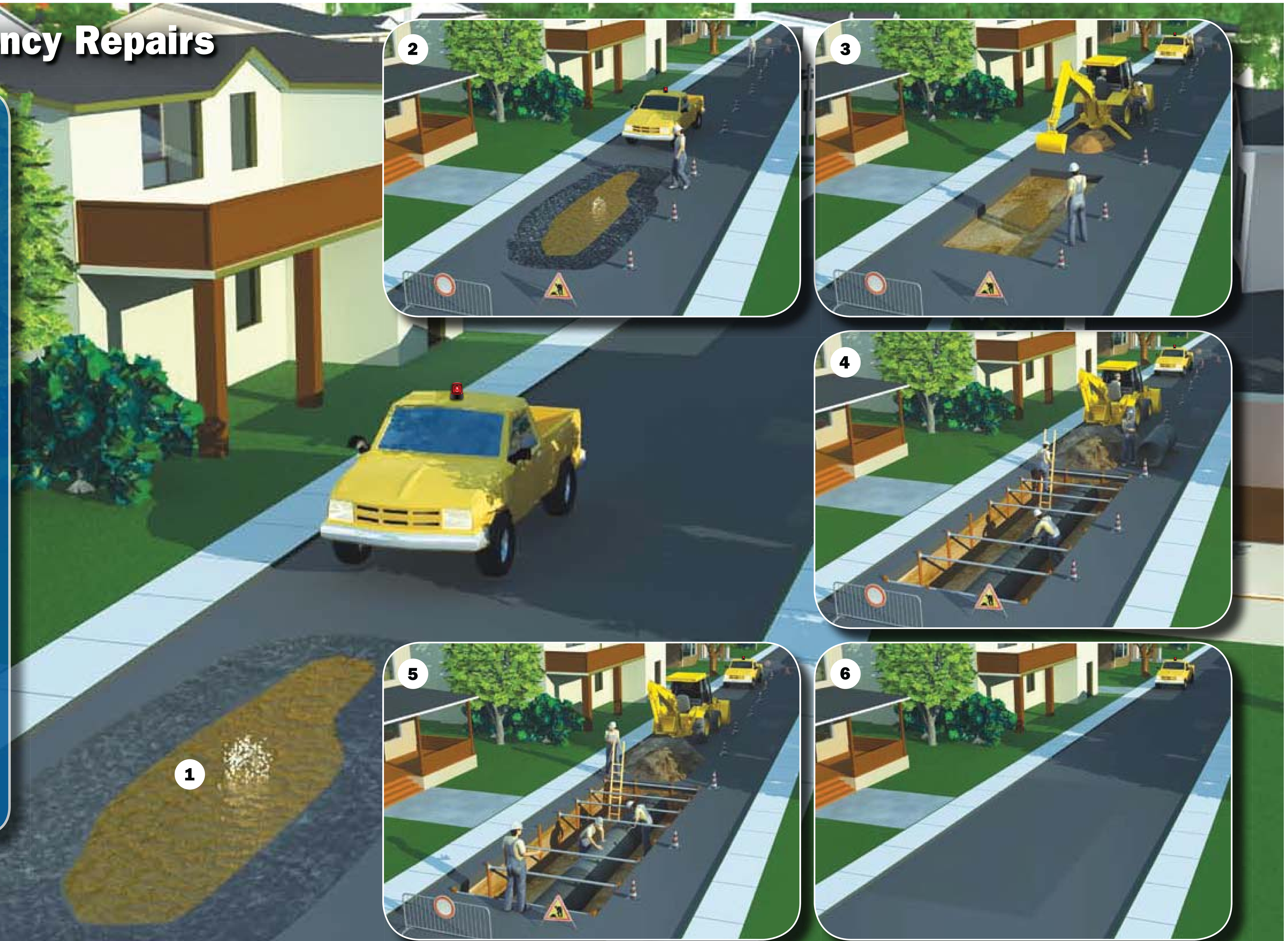
4. Determine and obtain pipe material, outside diameter, and repair equipment and parts/clamps needed. Secure materials onsite. Disinfect hand tools, saws, and tapping machines used in the repair. Clean and disinfect parts and materials before installing them in the system. Make repairs.

5. Flush, clean, and disinfect new pipe repair. Depending on the magnitude of the repair, ANSI/AWWA Standard C651-05 can be used as a guideline for disinfection. Apply any corrosion protection materials. Follow applicable ANSI/AWWA standard or manual for hydrostatic test of the line, depending on pipe material. Test for coliform using ANSI/AWWA C651-05 standards. Ensure proper disposal of chlorinated water using dechlorinating or neutralizing agent.

6. Backfill and repair ground and surfaces to original condition or better. Document new components, field conditions, potential causes of break or leak, location of project, and estimated cost.

Editor's Note: For more information on pipeline installation and disinfection, these resources are available from the AWWA Bookstore (www.awwa.org/bookstore):

- *Water Transmission and Distribution*
- *Water Distribution Operator Training Handbook*
- *AWWA Water Operator Field Guide*
- *Pipe Profile Series—Five-DVD Set*
- *Risk Management of Large-Diameter Water Transmission Mains*
- *Drinking Water Distribution Systems: Assessing and Reducing Risks*



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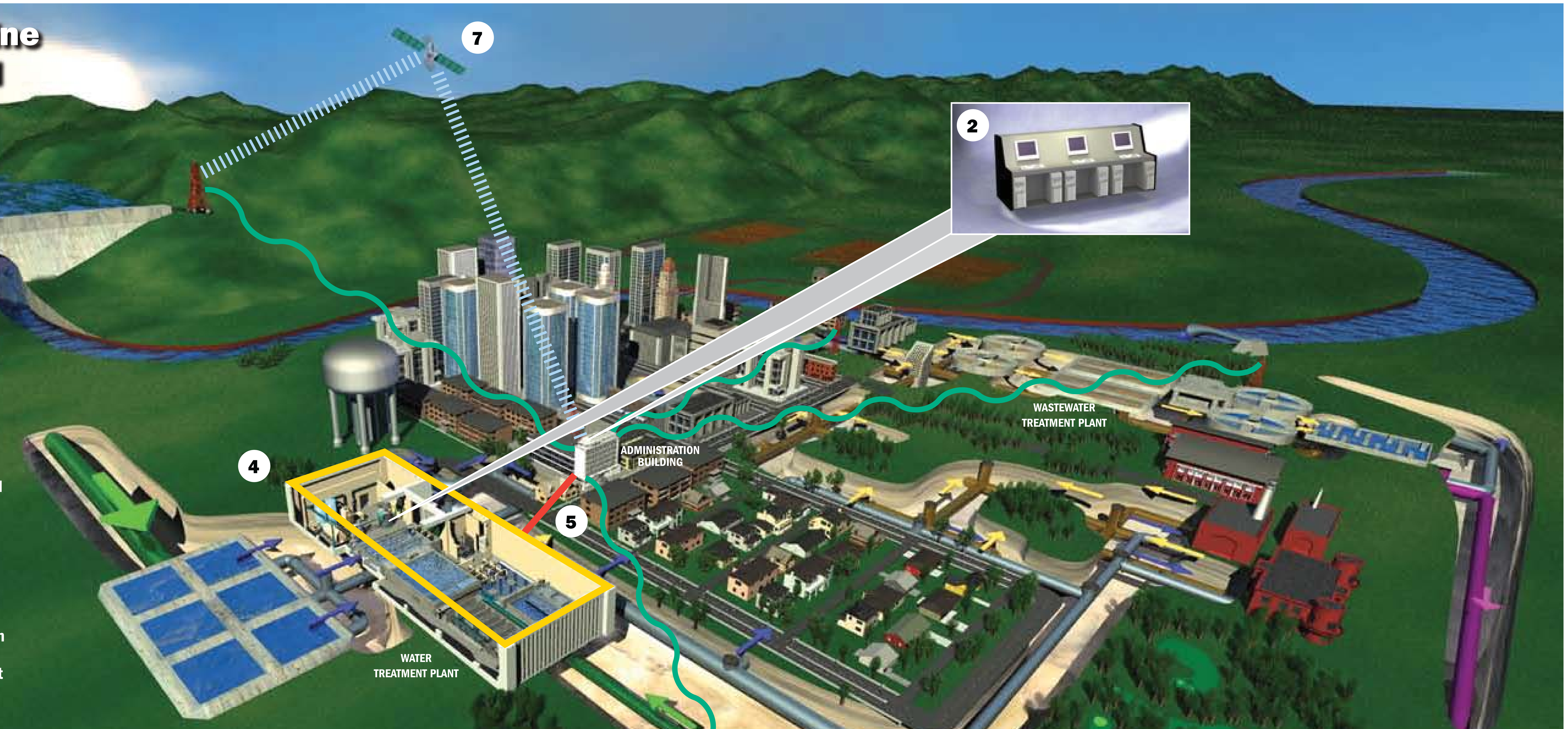
Telemetry Systems Streamline Instrumentation and Control

As water facilities became more widely distributed, data and control signals had to be transmitted over longer distances. Telemetry systems were developed to provide long-distance communication with pumping stations and distribution and supply systems, including valves, storage tanks, and booster pumps.

Telemetry systems typically consist of three main components: a telemetry transmitter, a receiving unit, and the telemetry channel or communication channel that connects the transmitting and receiving devices. In most systems, these three components are known as the remote terminal unit (RTU), the supervisory control and data acquisition (SCADA) system, and the communication protocol and physical communication network.

1. RTUs are the remote devices that collect data, typically from field devices, and transmit the data. RTUs may also perform local control functions. An RTU acquires data through electrical signals connected to it or from other devices via a serial data connection.
2. A SCADA system consists of one or more computers, often in a network. The system provides an interface to the RTUs through the communication network and an interface between the operators and the system.
3. The communication system may be classified into two broad categories: analog and digital. In analog telemetry, the signal is continuously transmitted. In digital telemetry, the signal doesn't have to be transmitted continuously but is transmitted as digital data representing a particular instantaneous value of the process variable. Most telemetry systems installed today have both. Telemetry data and control signals travel through communication media, such as wire, or through wireless channels, such as radio waves. Choosing the right media depends on the signal type, conditions, and use.
4. Copper wire has been used for many years to convey data and status information. Twisted-pair and coaxial cable are common copper wires in digital communication.
5. Leased or dedicated telephone lines are provided by the local telephone service and continuously connect a remote site with the main computer. The advent of fiber-optic technology has opened new network services and possibilities.
6. Radio telemetry systems offer an alternative to finer lines, wire lines, or telephone lines to communicate with remote sites. A typical radio system consists of a master station, main antenna, remote antennas, remote radio/modems, RTUs, and repeaters, if needed. Repeaters are used where distance or the terrain doesn't allow the master station proper communication with the remote site.
7. Satellite telemetry provides a radio link at a high cost in some isolated applications, but these systems aren't limited by terrain or distance.



1 TRANSMISSION PROCESS
SENSOR ➔ RTU ➔
COMMUNICATION SYSTEM ➔
RTU ➔ PC

3 COMMUNICATION MEDIA
COPPER LINE
PHONE LINE
RADIO SIGNAL
SATELLITE SIGNAL

PIPELINE KEY
UNTREATED WATER
TREATED WATER
WASTEWATER
RECYCLED WATER

ILLUSTRATION: RON KNOWLTON,
ENGINEERING DRAWINGS: CAROLLO ENGINEERS

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How Water Works

ILLUSTRATED PROCESSES, EQUIPMENT, AND TECHNOLOGY

An Inside Look at Residential Water Use

North American households use approximately 146,000 gal of water annually, according to the Awwa Research Foundation. Of this amount, 42 percent is used indoors, and the remaining 58 percent is used outdoors. By far the largest percentage of indoor water use occurs in the bathroom for toilet flushing (20.1 gal/person/day) and showering (13.3 gal/person/day). Clothes washers were the second largest water users (15 gal/person/day). For information on residential water efficiency, visit the Water Saver Home website (www.h2ouse.org), a virtual encyclopedia of water-saving tips, and AWWA's drinktap.org consumer website. Next month, How Water Works details fire-flow requirements and backflow prevention considerations for commercial facilities.

1. Distribution mains are the pipelines that carry water from the transmission mains and distribute it to the customers and fire hydrants throughout the water system. Mains in residential areas should be at least 6–8 in. in diameter.
2. Service lines carry water from the utility's water mains to the consumer's home, building, or other point of use. Average single-family homes are adequately served with a ¾-in. service.
3. A shutoff valve, or curb stop, is used to easily turn off the service line for repairs or nonpayment of the water bill.
4. Water meters calculate how much water is used. In cold climates, indoor meters should be located as close as possible to where the pipe enters the home. Meters in warmer climates are often located on an outside wall or in a lawn pit.
5. Backflow-prevention devices may be installed to create an isolated or closed plumbing system, preventing water from flowing back into the public water pipes.
6. In the building, fresh water fills the hot water heater (6a), and piping is split to supply cold (blue) and hot (red) water to taps and fixtures, including outdoor irrigation systems.
7. Drain/waste/vent piping (brown) disposes of used water and waste, exhausts sewer gases, and provides proper pressure for drainpipes.

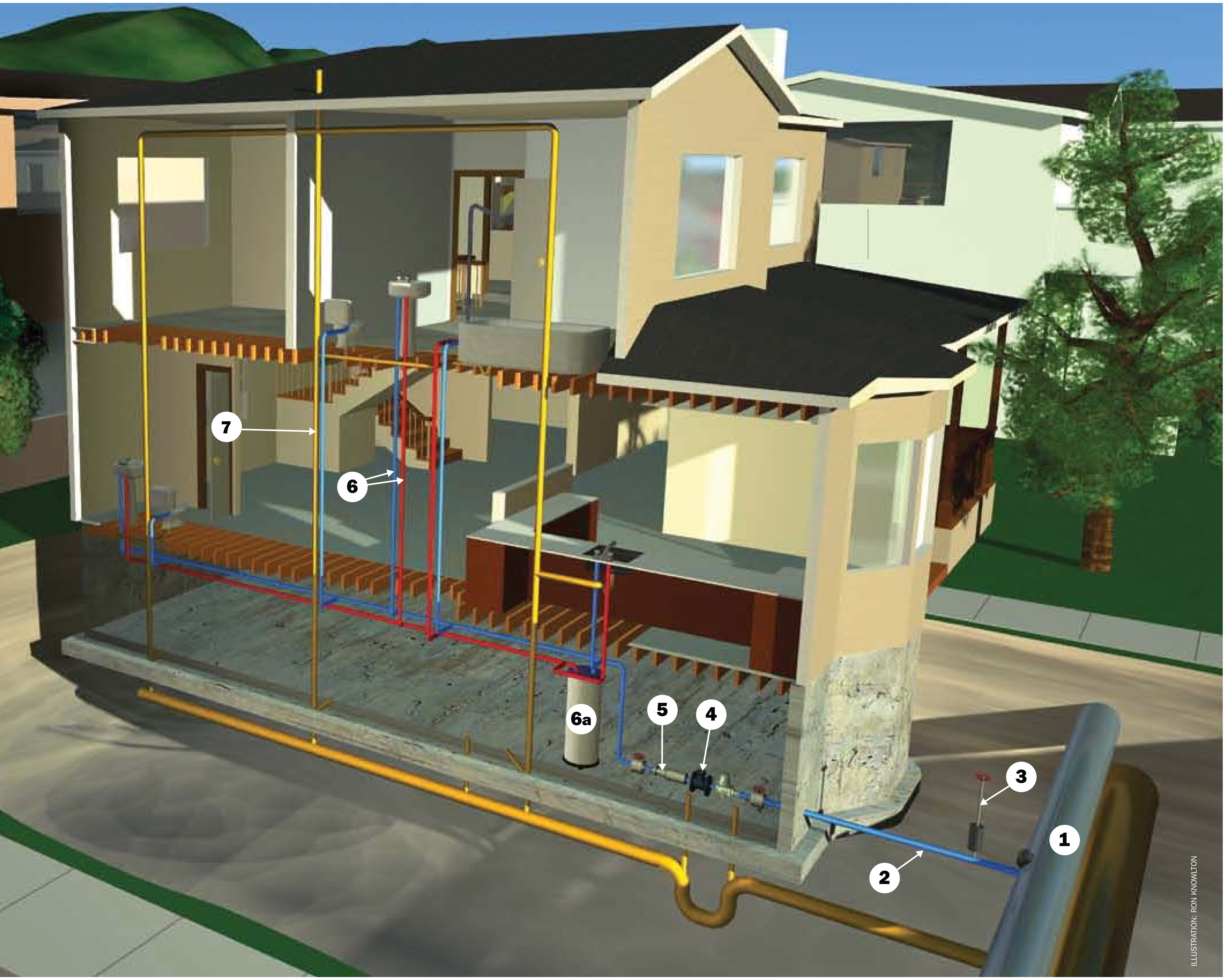

ILLUSTRATION: RON KNOWLTON

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ILLUSTRATED PROCESSES, EQUIPMENT, AND TECHNOLOGY

Water Conservation Reaps Big Benefits

Water conservation is a key component of overall water resources planning. Carefully designed and implemented conservation programs can bring many benefits, including the efficient use of available sources of supply, public recognition and participation, and improved support for water pricing adjustments.

A common public perception is that water conservation means restricting or curtailing customer use as a temporary response to drought. Though water use restrictions are a useful short-term drought-management tool, most utility-sponsored water conservation programs emphasize lasting long-term improvements in water use efficiency while maintaining quality of life standards. Water conservation simply means doing more with less—not doing without. Examples of potential conservation measures for single-family homes include the following:

1. Work with the real estate industry to require low-consumption toilets be installed at the time of sale. Also, provide rebates or vouchers for retrofits with low-water-use toilets—typically $50 to $100 per toilet replaced.
2. Work with local energy companies to offer rebates for high-efficiency clothes washers. Rebates would be scaled to water efficiency as rated by the Consortium for Energy Efficiency (www.cee1.org). Also, educate customers on the latest clothes washer water-conserving technology.
3. Use leak-detection equipment to determine if and where leaks are occurring on home premises. For low-income households, provide a plumber to the customer to repair leaks for free.
4. Distribute free retrofit kits to older single-family homes. The kit could contain a low-flow showerhead; toilet leak-detection dye tablets, displacement device, or early closure device; a faucet aerator; faucet washers to fix leaky faucets; and a pamphlet on how to conserve water.
5. Provide incentives for outdoor-use restrictions, including irrigation system upgrades, soaker hoses, mulch and soil amendments, new plant materials, and turf reduction.

Editor's Note: For more information on water conservation, these resources are available from the AWWA Bookstore (www.awwa.org/bookstore):

- *M52: Water Conservation Programs—A Planning Manual*
- *Consumer's Guide to Water Conservation (DVD)*
- *Handbook of Water Use and Conservation*
- *Socioeconomic Impacts of Water Conservation*
- *Bill Stuffer: Water Conservation at Home*

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ILLUSTRATED PROCESSES, EQUIPMENT, AND TECHNOLOGY

Administrative Processes Set to Satisfy Customer Demands

Water utilities work for customer satisfaction to minimize complaints and associated costs, maintain goodwill, and increase support for utility improvement initiatives. A good way to improve customer satisfaction is to optimize a utility's administrative processes that directly affect customers.

1. Customer services include call center operations, billing, payment, credit, and collection. The quality of customers' service experience defines customer opinion of a utility, so good service ultimately reduces complaints and enhances the utility's image within the community. Best-performing utilities offer customers many options for billing and payment.

2. Management and administration staff provide support in the areas of finance and accounting, contract coordination, technical library maintenance, inventory, records, visual and audio services, information technology and telecommunications infrastructure, legal services, facilities and vehicle maintenance, insurance and risk management, and safety needs.

3. Finance manages financial resources and provides electronic record keeping. These responsibilities often are carried out through staff specializing in budgeting, accounting, treasury operations, rate administration, purchasing, and records and document administration.

4. Human resources directs and supervises all human resources activities, including interpreting, updating, and enforcing personnel policies; maintaining and revising classification and pay plans; and implementing policies, procedures, and programs related to recruiting, hiring, managing, and retaining employees.

5. Public affairs responds to customer concerns and manages customer relations, maintains cooperative relationships with local administration and government agencies, coordinates the administration of distributor contracts, and facilitates the utility's relations with the general public and special public groups.

6. Operations and maintenance is responsible for overall plant operations, including ongoing facility maintenance and replacement, to the satisfaction of outside regulating agencies and local customers.

7. Planning identifies and integrates current and future water and facilities needs and resources. General activities include preparing and presenting demographic projections and raw and treated water consumption forecasts, developing short- and long-range plans for facility developments, and forming, analyzing, and interpreting hydraulic studies.

8. Engineering is responsible for the design, construction, and related engineering aspects of physical additions or improvements to the water system.

9. The meter shop installs and maintains all residential and commercial water meters. Although use of automated meter reading technologies is increasing, most water utilities still manually read most of their meters.

10. Purchasing and receiving oversees deliveries to the supply yard (10a), which houses the tools, materials, and equipment used in construction and maintenance work.

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ILLUSTRATED PROCESSES, EQUIPMENT, AND TECHNOLOGY

Best Practices Support Sustainable Water Systems

Preparing water systems to operate sustainably helps utilities optimize processes in terms of the triple bottom line: environmental impact, social aspects, and economics. The tools and practices presented here can be used to enhance a utility's performance regarding these three factors. When combined, these tools and practices support overarching sustainability principles and maximize triple bottom line benefits.

1. Proper **emergency planning** and **demand forecasting** enable utilities to be less vulnerable to effects of extreme weather events and more resilient when recovering from weather events, with fewer service disruptions and minimal societal impact.
2. **Integrated water resources management** allows a utility to cultivate a diverse supply portfolio, arranging diversified water sources vital to meeting future water demands, ensuring public health, and providing economic and environmental sustainability.
3. **Asset management** is essential for water infrastructure sustainability when assets near the end of their useful life, approaching a need for replacement. Proper asset management keeps utilities informed of the functioning status of their assets, leading to fewer "surprise" replacements.
4. Third-party **rating systems** provide a sustainability-focused framework for evaluating projects from planning stages through operations and maintenance.
5. **Water loss control** represents utility accountability efforts regarding operations, employing auditing of water supplies and implementing controls to minimize system losses and optimize supply efficiency. Reducing losses results in financial gains and efficient water use.
6. **Stakeholder engagement** is critical to any project; public meetings, surveys, and other tools are most effective when there is two-way communication. Stakeholders are heard, and their feedback furthers sustainable project improvements.
7. Conducting a **cost-benefit analysis** demonstrates a utility's sustainable return on investments and can help determine appropriate rates.
8. **Water conservation** involves long-term improvements in water use efficiency and is critical to ensuring an adequate water supply today and for future generations. Water conservation efforts can have a large effect when conducted through commercial, industrial, and institutional sectors.
9. **Green infrastructure**, such as bioswales or permeable pavers, cost-effectively manages stormwater and improves water quality before the water reaches a treatment facility. City parks are a great way to incorporate this type of infrastructure while creating a community amenity.
10. **Source water protection** encompasses protecting drinking water sources from contamination and pollution, such as from agricultural runoff, and is key to sustaining safe and reliable drinking water supplies. Protecting source water results in financial savings during treatment processes and benefits the environment.
11. **Energy efficiency** is critical to high-energy-intensive functions of utility operation and maintenance. Energy efficiency benefits the environment and can help shift system operating costs away from energy bills to more sustainable solutions.
12. **Water reuse** is a viable approach to address existing and anticipated water shortages. Used water from homes and businesses is highly treated to be reused to augment and sustain a community's available water supply.
13. **Effective utility management (EUM)** is a process for water and wastewater utilities to identify and address their management needs. EUM is based on systems that promote activities for making water-sector utilities more sustainable, helping to ensure the sustainability of the communities they serve.

Editor's Note: To see more images in the *How Water Works* series, visit AWWA's *How Water Works* Resource Community (www.awwa.org/howaterworks). Also, an interactive CD, posters and related products can be purchased from the AWWA Store (www.awwa.org/store).

SOME ILLUSTRATION ELEMENTS EXAGGERATED FOR EMPHASIS.

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