# Water Distribution System Design: Part 1 - System Components

An Online Continuing Education Course for Engineers

**Course Number: EN-3037**

**Credit: 3 Hours / 3 PDH / 3 CPD**

# Water Distribution System Design: System Components

**INTRODUCTION**

Public drinking water systems provide drinking water to 90 percent of the population of the United States. A public water system has at least 15 connections or serves at least 25 people for at least 60 days a year. There are over 150,000 public drinking water systems in the US. A public water system can be publicly or privately owned. Providing safe drinking water is a partnership that includes the US EPA, state agencies, tribal agencies and water system owners.

With the large number of existing public drinking water systems, most water system projects involve improvements or extensions of existing systems. New public water systems tend to be small systems that serve relatively small developments, or rural water systems that serve a small number of users across a very large area.

The major components of a water system include pumps, pipes and storage facilities. Each of these major components will be discussed in detail. In addition to these major components, there are a large number of appurtenances that may be necessary for proper design and operation of a water system.

The design requirements for water distribution systems vary, depending on the jurisdiction. In many cases, a state agency establishes minimum requirements. These minimum requirements are often based on adoption of "Recommended Standards for Water Works," published by the Great Lakes – Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers. These standards are often referenced as "Ten State Standards" because they were developed by agencies in ten neighboring states (and one Canadian province).

Many jurisdictions have specific preferences or requirements regarding the material used for their particular water system. In order to design a system that will be readily accepted by a particular system, it is necessary for the design engineer to ask the system owner, and possibly the system operator, what materials are acceptable and what materials are unacceptable. Just because a particular material meets appropriate standards does not mean it will be allowed in all systems. However, oftentimes the standards for the utility are holdovers from many years ago and have not been updated with newer options. Designing for these systems requires both attention to detail and the need to create an open dialogue with the utility to determine their receptiveness to newer materials.

## DEMANDS ON THE SYSTEM

One of the first design requirements for a water distribution system is to establish the existing and/or proposed demands on the system. For existing systems, there are a number of ways to estimate the overall demands on the system. The precision of the estimate is a function of the extent of the data available and the time devoted to processing the data. The design of any water distribution system should allow the system to meet all the anticipated demands, while maintaining acceptable pressures.

### Normal System Demands

Several different flow scenarios are often evaluated during analysis of a distribution system. The most common flow scenario analyzed is the peak day flow. This flow will result in the highest velocities in the system and thus is the flow that will most commonly show areas where normal operating pressures are inadequate.

There are several possible approaches to determining the peak day flow for an existing system. By far the most reliable approach is to use actual records from the existing system. Most systems maintain records of meter readings at the water treatment plant on a daily basis. These records can be reviewed to estimate the maximum water use in any day. The day when the water treatment plant produced the maximum volume of water may not represent the day of maximum water use, however. In addition to records showing the maximum water use, records of water levels in the storage tanks are required. After several days of high water use in the system, it is possible that the volume of water in the storage tanks is low, so the water treatment plant may produce the maximum volume when much of this water is being used to replenish the levels in the storage tanks. In order to estimate the total volume used in the system in any time period, it is necessary to add the water produced at the water treatment plant and then adjust for the change in storage volume in the storage tanks. For example, if the water plant produced 1.5 million gallons (MG) in a day, and the storage volume in the water tanks increased by 0.2 MG, then the total water use for the day was 1.3 MG.

If hourly data is available, it is possible to develop a diurnal distribution of flow. A diurnal distribution of flow shows the variation of flow in the system throughout the course of a 24-hour period. Using the same volume approach described above, only for every hour instead of once per day, the diurnal curve for a distribution system can be established. An example diurnal curve is shown in Figure 1.

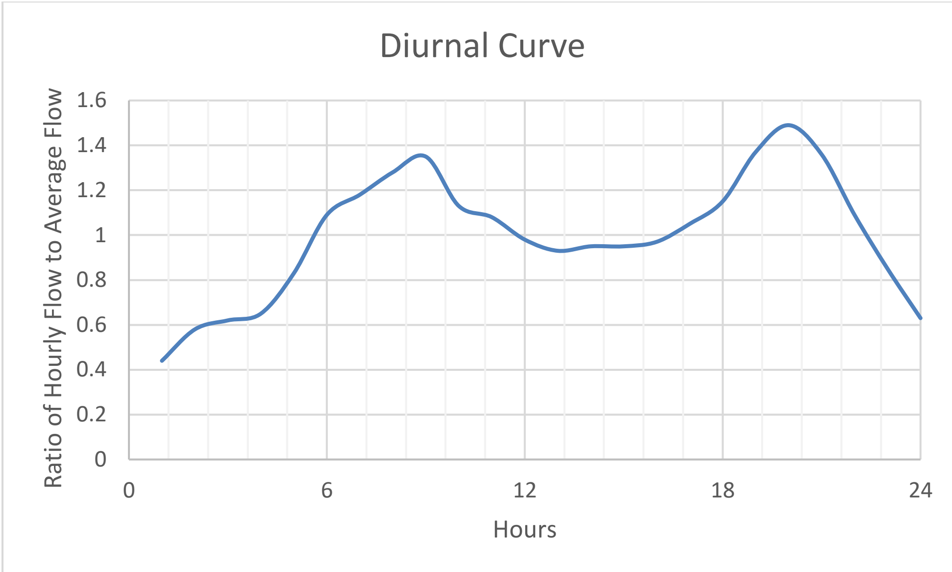



***Figure 1 – Sample Diurnal Curve***

Figure 1 represents a typical curve from a community with residential and commercial use, but not significant industrial use. In this figure, there are two noticeable peaks. The first peak will be in the morning, as people get up and prepare for work and school. The second peak will be in the evening, as people return home and prepare meals, run dishwashers and clothes washers, and irrigate grassed areas. The diurnal curve for every community will be different but should have this general characteristic shape. In some locations, the peak flow will occur in the morning rather than the evening.

**Fire Flow Demands**

Another flow scenario that is commonly analyzed is a fire flow condition. In this scenario, a large flow at a single hydrant (or sometimes multiple hydrants) is superimposed on a normal operating condition, such as the peak day flow. Fire flow demands vary depending on the size of the building and construction materials and methods. Typical single family residential buildings will have a recommended fire flow in the range of 1000 gallons per minute (gpm) to 1500 gpm, and a duration of one hour. Small to medium size commercial buildings could have a recommended fire flow in the range of 2000 gpm to 3500 gpm and duration of two or three hours. Larger buildings could have much higher fire flows, but most water distribution systems are not typically designed to deliver flows much larger than 3500 gpm. For buildings with higher fire flow demands, a dedicated fire sprinkler system in the building is required. Design of building fire sprinkler systems is a separate topic and not covered in this course, which focuses on public distribution systems.

## ACCEPTABLE OPERATING PRESSURES

The range of acceptable operating pressures varies depending on the system and the demands on the system. Ten State Standards defines the minimum system pressure under peak day conditions as 35 psi and recommends a normal operating pressure range of 60 to 80 psi. The minimum pressure is measured at the location in the system with the lowest pressure, which could be the highest elevation, but could also be a location that is hydraulically remote from the treatment plant and storage tanks. These standards also require a minimum residual pressure of 20 psi under fire flow conditions. The residual pressure under fire flow conditions is typically measured at a hydrant adjacent to the hydrant supplying the fire flows. These values represent a reasonable starting point, but there are a number of other considerations that could make them difficult to achieve.

In areas with significant elevation changes across the water system, maintaining a range of pressures that vary only 20 psi (between 60 psi and 80 psi) is very difficult. In these areas, multiple pressure zones are common, but these multiple zones often require multiple storage tanks. In smaller communities, a single tank is easier to construct and maintain. Even in larger communities where multiple pressure zones are required, it is desirable to limit the number of pressure zones. In order to accomplish this, it is often necessary to provide a much larger range of operating pressures. Where a number of pressure zones will be required, a common design practice is to have the difference in normal operating pressures in the range of 100 feet (about 40 psi). This limits the number of pressure zones required, while still maintaining suitable pressures. However, the pressures in this type of system could vary from 40 psi to 100 psi in some zones.

In areas where the topography is quite flat, construction of elevated tanks to provide an operating pressure of 80 psi can be very expensive. With a good distribution system, the pressure range throughout the system can be limited, and normal pressures in the range of 45 psi to 60 psi are often deemed acceptable.

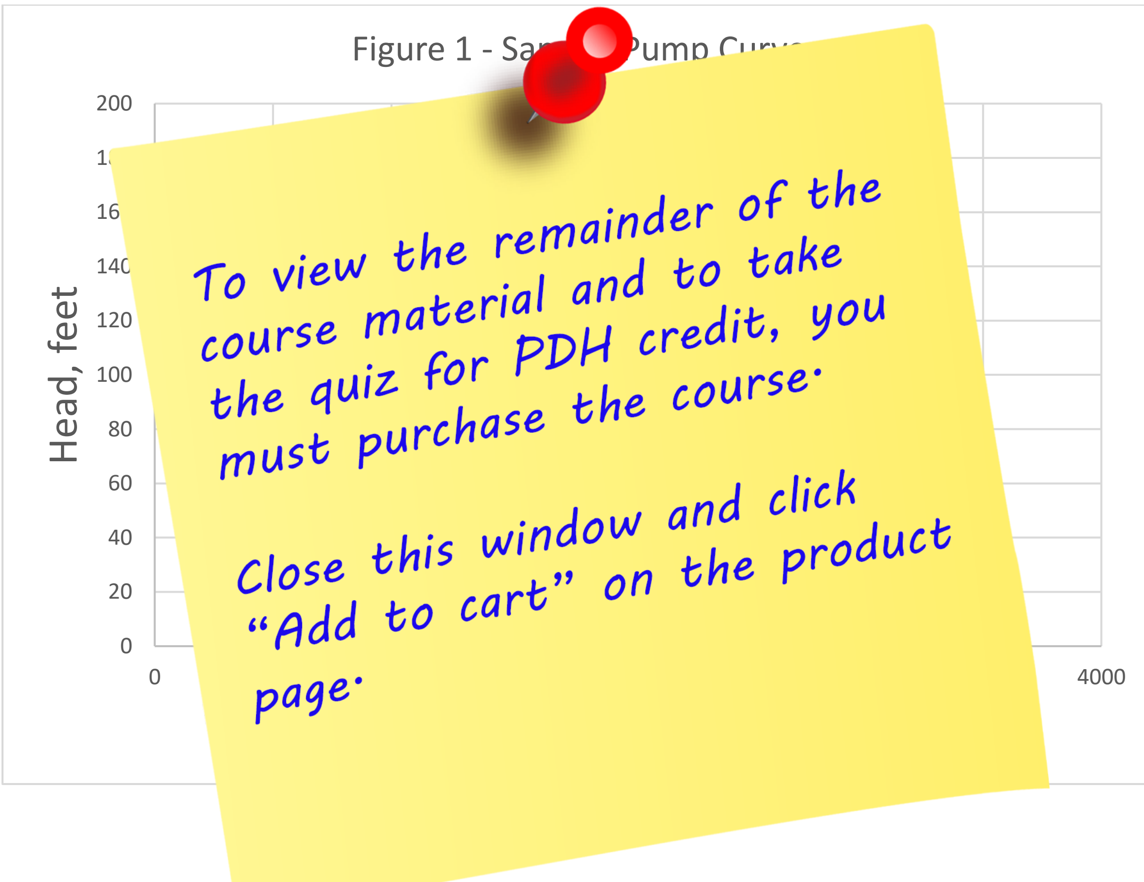
## MAJOR SYSTEM COMPONENTS AND FUNCTION

### Pumps

Most water distribution systems start with a pump system. For systems that include a water treatment facility, the pumps are often termed high service pumps and are installed at the downstream end of the treatment process. For systems that are served directly by wells (with treatment often limited to just disinfection), the well pumps provide the energy necessary to pump the water from the well into the storage tanks.

This course is not intended to be a complete course on design of pumps, but rather provide a basic discussion on the role of pumps in water distribution system and some basics on selection of appropriate pumps.

The most important part information on the pump, in relation to the water system, can be obtained from the pump curve. Each pump will have a different curve, and these curves can only be obtained from the manufacturer of the pump. Pumps are commonly specified to provide a specific flow rate (usually in gallons per minute, gpm) at a specific head (usually in feet of total dynamic head). However, this represents only one point on the pump curve, and the pump will not always operate at this specific point. For example, the head conditions will vary depending on the water level in the storage tanks. Figure 1 shows an example of a pump curve for a typical centrifugal pump.




The design point for this pump is likely in the range of 2500 gpm at 100 feet TDH. The design point is typically closer to the right side of the pump curve. There are two additional points of interest on this pump curve. The first point is farthest left point, which is the no flow condition at about 181 feet TDH. If the static head on the discharge side of the pump is greater than about 181 feet, then even when the pump is running, there will be no flow. This is often termed the shut off head for the pump. Very small pumps can sometimes be allowed to run at or close to shut off head, but larger pumps should never be allowed to run against shut off head. The second point of interest is the farthest right point, about 3400 gpm at 45 ft. TDH. This point is often termed the runout of the pump. In general, a pump should never