2. CE 3305 Lesson 2

This lesson presents the concept of design guidelines, manuals, and specific criteria.

Design is the management of constraints. Non-negotiable constraints are dictated by laws of physics, chemistry (and to some extent mankind); examples of these are: water flows downhill unless power (lift station) and money (capital cost to build, operation cost to pay for electricity to run pumps) are applied; Chemical disinfection residual will decay over time unless replenished – this constraint encourages using the treated water relatively quickly.

Negotiable constraints are the design variables that can be adjusted to satisfy the non-negotiable constraints and the desired system performance; the main components of this category are money to pay for things, time to build (and operate), aesthetics (pipe alignment/channel geometry); system performance under various anticipated conditions.

The water system designer's goal is to satisfy a need (some level of performance) by manipulating negotiable constraints. The analytical tools herein are used to test the design before committing to an actual build (presumable the full-scale experiment that fails is to be avoided).

Design guidelines encapsulated in regulatory documents, design manuals, professional, and manufacturer's literature represent guidance based upon centuries of observation and experimentation (and a lot of failures); the value is that they generally work, and reduce commercial risk for routine water system components.

2.1. Water Distribution Design Elements

The three basic elements to water distribution design are:

1. How much water will be used?
2. Where are the water consumption locations?
3. What is the water use as a function of time?

When designing new systems, calculating demands is not a straightforward process. The designer needs to know the expected demands, possible fire demands, and future expansions. There are some publications that provide average demands for residential, commercial facilities, and production/industrial facilities. Different demands need to be accounted for:

1. Customer demand Average use needed to meet non-emergency needs.

2. Fire flow demand   The computed system capacity required for ensuring minimum fire protection while maintaining a minimum working pressure in the system.

3. Ultimate expansion to the system

Many of the guidance documents spend a considerable effort in explaining how to estimate demand, others don't. Most design documents require some kind of hydraulic modeling to demonstrate that the system meets various hydraulic and water quality requirements, so demand estimation is vital for these models.

There are several time related demands that should be considered in design such as seasonal demands, weekly demands, population growth and industrial demands, etc. Seasonal demands such as hot dry summers cause increase lawn watering. Small agricultural operations or nurseries may rely on municipal water supplies to irrigate. Some of these demands can be estimated from a community?s comprehensive plan, zoning maps, regional expectations for industrial use, Another critical event to check is the peak hour demand. During steady state model runs the designer (modeler) can assign specific peak factors to different nodes.

The typical municipal system is very unsteady due to varying demands. A 24 hour simulation period should be analyzed in order to provide reasonable results. Designing a system requires a minimum system pressure during peak hour demands and a reasonable working pressures during average demand periods. The design minimum and working average pressure depends on the level of service required by the community. The minimum peak demand pressure varies by jurisdiction, but is typically around 35 psi anywhere in the system. A good average daily pressure is 50 psi or a range between 45 psi and 55 psi.

2.2. Water Distribution Systems

Water distribution systems convey water from a source to a customer.

Sources of water

- Ground water: Series of municipal wells usually requiring chemical treatment, at least to the extent of chlorinating.
- Surface water: Drawn from lakes or rivers just below the surface. Ocean-desalination plants on or near coastal regions.
- Precipitation: Large municipal reservoirs collecting rain run off and snowmelt (rainwater harvesting).

2.2.1. Transmission and Distribution Mains

Transmission lines are categorized as mains that carry large volumes of water, great distances, such as between a treatment plant and local storage facilities. Distribution lines are smaller pipes including valves, hydrants, fittings, and appurtenances, that deliver treated potable water to the customers.

2.2.2. System Types

The two types of distribution systems are looped and branched. Looped systems have pipes that are interconnected throughout such that water can move through the entire system back and forth, depending on the points of largest demand. Branched systems or dendritic systems have only one path to follow from the source to the customer. Think of the system as one-way flow.

Looped System Advantages

- Fluid velocities are lower, reducing head losses, resulting in greater capacity.
- Main breaks can be isolated to minimize loss of service to customers.
- Fire protection is greater due to greater capacity and ability to isolate breaks.
- Looped systems usually provide better residual chlorine content due to inline mixing and fewer dead ends.

Looped System Disadvantages

- Looped systems generally cost more because there are pipes that become inadvertently redundant in order to create the loops.

Branched System Advantages

- Lower costs – Avoiding construction of pipes and appurtenances just to create a looped system reduces the cost.
- In smaller rural communities, branched systems may be the only type that is feasible, logistically and monetarily.

Branched System Disadvantages

- Main breaks take all downstream customers out of service.

- Branched systems cause poor chlorine residuals in low demand areas and may require periodic flushing of hydrants in order to pull chlorinated water into the system.
- Velocities are faster, head losses greater and capacity reduced especially during high demand.
- Fire protection is at risk due to inability to isolate a break.

2.3. Regulatory Guidance Documents

Regulatory guidance documents are a principal tool in system design, along with the designers creativity, and the owners access to right-of-way.

The EPA (Environmental Protection Agency) writes federal regulations for construction, maintenance, treatment and operation of potable water facilities. State?s EPAs (or equivalents) are charged with regulating the standards and permitting. States may write more stringent regulations if they do not violate the intent of the federal code. The various documents are precise, but teduous.

For example the federal regulation for water main separation and protection is:

Section 653.119 (Code of Federal Regulations) Protection of Water Main and Water Service Lines

a) Water Mains:

  1) Horizontal Separation:

    A) Water mains shall be laid at least ten feet horizontally from any existing or proposed drain, storm sewer, sanitary, combined sewer or sewer service connection.

    B) Water mains may be laid closer than ten feet to a sewer line
    When:

      i) local conditions prevent a lateral separation of ten feet.

      ii) the water main invert is at least 18 inches above the crown of the sewer; and

      iii) the water main is either in a separate trench or in the same trench on an undisturbed earth shelf located to one side of the sewer.

    C) Both the water main and sewer shall be constructed of slip on or mechanical joint cast or ductile iron pipe, prestressed concrete pipe, or PVC pipe meeting the requirements of Section 653.111 when it is impossible to meet (A) or (B) above. The drain or sewer shall be pressure tested to the maximum expected surcharge head before back filling.

  2) Vertical Separation:

A) A water main shall be laid so that its invert is 18 inches above the crown of the drain or sewer whenever water mains cross storm sewers, sanitary sewers or sewer service connections. The vertical separation shall be maintained for that portion of the water main located within ten feet horizontally of any sewer or drain crossed. A length of water main pipe shall be centered over the sewer to be crossed with joints equidistant from the sewer or drain.

B) Both water main and sewer shall be constructed of slip on or mechanical joint cast or ductile iron pipe, prestressed concrete pipe, or PVC pipe when meeting requirements of Section 653.111 when:

   i) it is impossible to obtain the proper vertical separation as described in (A) above; or

   ii) the water main passes under a sewer or drain line.

C) A vertical separation of 18 inches between the invert of the sewer or drain and the crown of the water main shall be maintained where a water main crosses under a sewer. Support the sewer or drain lines to prevent settling and breaking the water main.

D) Construction shall extend on each side of the crossing until the normal distance from the water main to the sewer or drain line is at least ten feet.

b) Water Service Lines:

1) The horizontal and vertical separation between water service lines, and all storm sewers, sanitary sewers, combined sewers or any drain or service connection shall be the same as water main separation described in (a) above.

2) Water pipe described in (a) above shall be used for sewer service lines when minimum horizontal and vertical separation cannot be maintained.

c) Special Conditions — Alternative solutions shall be presented to the Agency when extreme topographical, geological or existing structural conditions make strict compliance with (a) and (b) above technically and economically impractical. Alternative solutions will be approved provided watertight construction structurally equivalent to approved water main material is proposed.

d) Water mains shall be separated from septic tanks, disposal fields and seepage beds by a minimum of 25 feet.

e) Water mains and service lines shall be protected against entrance of hydrocarbons through diffusion through any material used in the construction of the line.

EPA drinking water standards exhibit similar tedious precision and the designer will need to read entire documents to understand the intent and expectation of the regulations.

2.3.1. Texas RG-195

Examine RG-195 as representative of a state document.

2.3.2. Washington State Manuals

2.3.3. City of Houston Design Manual

Larger cities usually have their own design manuals – examine Houston's manual for information on system pressure, layout, disinfection residual, and pipe sizes.

2.3.4. City of Lubbock Design Manual

Larger cities usually have their own design manuals – examine Lubbock's manual for information on system pressure, layout, disinfection residual, and pipe sizes.

2.3.5. City of San Marcos Design Manual

Larger cities usually have their own design manuals – examine San Marcos manual for information on system pressure, layout, disinfection residual, and pipe sizes.

2.3.6. Professional Literature

For unusual situations the designer will have to visit the professional literature for guidance; usual order of preference for a designer will be a manual of practice, vendor literature, and finally the academic literature. Figure **??** is an example of a manual of practice. A manual of practice or even vendor literature is preferred over the academic

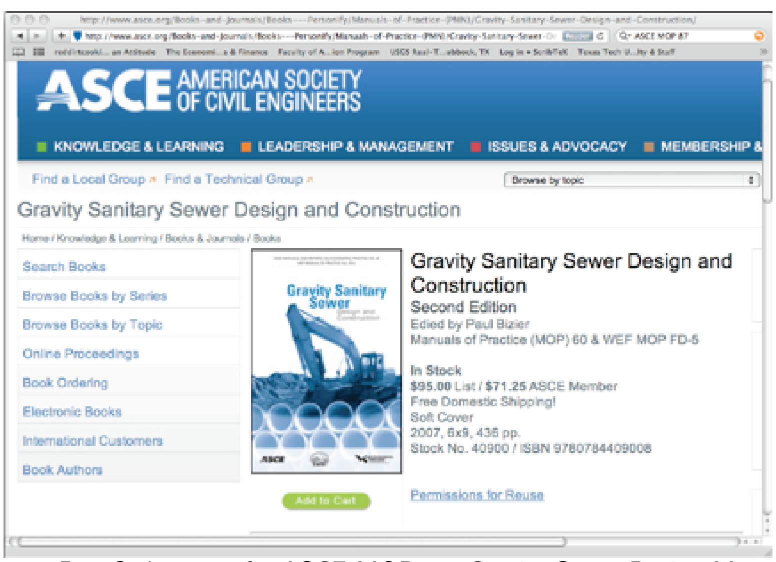

Figure 5. Order page for ASCE MOP 60, Gravity Sewer Design Manual.

literature simply because of a perception that the technologies are proven in these documents (proven in the litigation sense).

2.4. Laying Out a Project

Notice that most of the manuals spend considerable space explaining how drawings are to be submitted for approval. The actual layout is flexible (within right-of-way) and up to the hydraulic engineer to some extent.

A designer would typically use some version of the following to design a new water distribution system:

1. Set up the system grid on the area plan. Aerial photo plots to scale are excellent tools;
2. Allocate average daily demands at nodes;
3. Determine the peak factors;
4. Estimate fire demands;
5. Project demands for future expansion of the service areas.

A node is considered a junction point in a system where a demand can be attributed/assigned. Models use the nodes to calculate the system demands, pressures, water quality, and velocity. These items are usually prescribed in guidance documents with minimum/maximum acceptable values.

The practical design of a water system without the use of water distribution modeling software is possible, but requires a logical, economical approach of laying out the system; professional quality software is inexpensive (free) so there is really no reason to design a system without using a hydraulic model – hence the guidance documents nearly demand a model. Commercial software is usually far easier for a designer to use and integrated into other design tools, but is computationally about the same as free software – by all means a designer should use commercial software when it is available.

2.4.1. Existing Data

The designer will need reliable sources to determine demands. Obviously a discussion with the owners is critical but the actual quantities will have to be calculated for a design situation. A land use plan or zoning map will help to determine the future demands. Use standards developed by the American Water Works Association for typical demands for a particular land use, such as industry, residential density, etc. These need to be compiled and situated on the area map. Once complete this method can help you determine node locations and assume pipe diameters. Fire flows that can spike demand can be assumed. Local fire departments can provide specifications on nozzle flow.

2.4.2. Schematics

When an existing system is modeled the process is known as analysis. Modeling during the course of designing a project is much more difficult. While modeling an existing system requires input of available of existing data. The level of accuracy and detail of data depends on the available data and map accuracy. When a system is being designed and modeled there is a trial and error process involved. Topographic maps, general routes, and pipe sizes are assumed. The process of developing a schematic for modeling is very dynamic. A schematic of a proposed system for an existing community may be changed several times based on public input, political divisions, and cost comparisons. Much like an electrical schematic or roadway system layout, a pipe network will have nodes (junctions). Small systems can be greatly affected by small changes in demand and design. Large metropolitan systems are less affected by local demand changes at nodes.

2.4.3. Pipe Diameter

The selected pipe diameters can affect the model significantly. There are economic considerations in choosing the pipe diameters, many jurisdictions specify minimum pipe sizes – sometimes these are still too small and the designer needs to acknowledge this fact. The trench is the biggest cost, and the hydraulics should be used to set adequate pipe sizes. Designers need to determine the proper pipe size in order to meet peak demands and fire protection while maintaining an adequate dynamic pressure in the system. During design, once a model is built using good reasoning or assumptions, model runs will give results and demonstrate pipes that are too small either by hydraulic grade line or by low pressure. If you review the model output and see a significant drop in pressure, increase the pipe diameter and try another run. Finding which pipe to increase may not be an easy task.

2.4.4. Pressure Zones

Pressure zones are set up to regulate pressure in locations where large grade changes will create too much pressure at the lower end of the system and not enough pressure in the higher ends. A differential of less than 60 feet (25.4 psi) does not require a new pressure zone. More than an 80 feet differential generally will require a pressure zone. In areas of even larger grade differentials, such as hill country or mountain communities, several consecutive pressure zones may be needed. The following equations can assist you in determining the HGLs for the pressure zones. HGL_{MIN} = Highest Elevation + (2.31x Minimum Working Pressure) HGL_{MAX} = Lowest Elevation + (2.31x Maximum Working Pressure)

It is important to converting pressures to the HGL because most models are based on the HGL. In the case of multiple pressure zones, it is important to use the service connection datum instead of the pipe elevation or valve elevation, in these equations. Use of accurate topographic maps is very important in setting up pressure zones. As the designer you must layout the zones in order to determine the corridors so that survey field crews can be sent out to collect accurate data for the design phase.

2.4.5. Junction Location and Elevation

Location of junctions will depend more upon the planned layout of the project site than the affect they will have upon the model. In general grid distribution node locations have little affect upon the overall model since there are customer demands along the system between nodes. Node locations and their elevations are more relative in large transmission mains. Nodes generally should be placed at the lowest elevation of a looped system where the grades fluctuate significantly. This is not always possible. When junctions are put at lower elevations, the distribution and capacity are improved. In systems where pressures are expected to fluctuate or are generally low, it would be good practice to relate system node elevations to the highest point of service. Other choices of datum could be relative to the ground, or to the center of the pipe. Be consistent in order to accurately represent the model once a relative datum is chosen.

2.4.6. Materials

The pipe materials will effect system performance. In general water distribution systems are built from ductile iron pipe, ABS, PVC, and HDPE. All are good materials for specific applications and various fittings to join different materials are available. Different jurisdictions may specify specific materials – hence the designer needs to read the guidance document for the specific locale.