

HYDRAULIC MODELS

Helping You Make Better Decisions

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Why hydraulic models?

Water utility managers, engineers and operators are regularly required to make decisions regarding the design and operation of their distribution systems. Some questions that frequently face decision makers:

- How big should this new pipe be?
- Which pump should we buy?
- Where should we put the new tank?

Decision-makers need to provide justifiable answers to these hydraulic questions on how to manage the utility's distribution assets.

Water distribution networks are highly-connected, complex systems. You change a pump at station A and pressures change many miles away. While intuition and experience are helpful, you also need quantitative and detailed information. Network models can help you answer more detailed questions:

- What exactly will pressure be during a peak hour if I use a 6-inch pipe instead of an 8-inch pipe?
- When the new subdivision comes on-line, what will happen to pressures



Figure 1: Elevation contours and pressure/elevation profiles in a water network



Figure 2: Finding critical pipes and valves to prioritize rehabilitation investment

in the older part of the system on the hill?

- Do I have sufficient pressure and availability at the fire hydrant at Hilltop Elementary School?

The calculations necessary to support these answers are generally too large and complicated to perform by hand. Over the years, more and more utilities have turned to hydraulic computer models to support their asset management decision making. Once, these models were so complex and difficult to use that they were mainly used by large utilities and their consultants. Now, competition and technology advances have driven costs down and the models are so easy to learn and use that even the smallest water utilities can afford them (or can't afford not to have them!). More and more regulators are insisting on seeing the results of model runs before they approve system improvements.

What is a computer model?

At the heart of any model is a numerical computer program that solves equations. There are basically two types of equations that must be solved in any hydraulic calculations:

1. Mass continuity (conservation of mass) equation
 - a. Flow rate of water into any junction of pipes equals flow out; and,
 - b. For any tank, flow in minus flow out equals change of volume in storage.

2. Energy equation – water gains or loses energy as it moves through a distribution system

- a. Losing energy due to friction/roughness as it moves through pipes;
- b. Gains energy as it passes through pumps; and,
- c. Loses energy as it passes through valves.

These equations are not terribly difficult to solve except that there is not a single energy equation or a single continuity equation. Instead, there is one continuity equation for every pipe junction or tank and one energy equation for every pipe. This means that to solve the network hydraulics, the computer must solve hundreds or thousands of equations simultaneously – not something you want to do by hand.

Solving all those equations gives the model user a good idea of what is happening in their system at a point in time (much like a snapshot). It is usually referred to as a steady model and in many cases, that is all one needs. However, water systems are dynamic, with pumps turning on and off through the day as demands vary. Models can track these gradual changes over time in what are usually called extended period simulation (EPS) runs. These are especially helpful in understanding system operation.

In addition to gradual changes in conditions, sudden changes in pump operation or valve status can trigger transient (water hammer) events that can damage

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Figure 3: Water pipe network from WaterGEMS software exported to Google Earth™

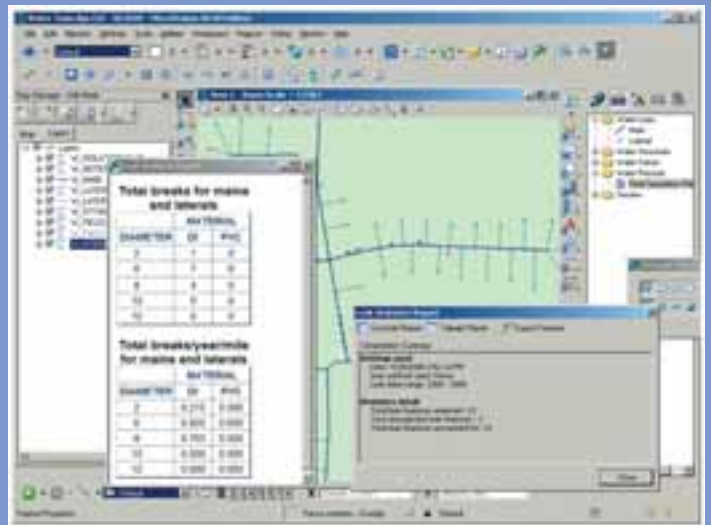


Figure 4: Water asset management for day-to-day operations

HOW WELL DO YOU UNDERSTAND HYDRAULIC MODELS? TAKE OUR QUIZ TO FIND OUT.

1. **What two types of equations are solved in a model?**
 - a. Energy and power
 - b. Energy and continuity (conservation of mass)
 - c. Suction head and power
 - d. Energy and waterhammer
2. **In a storage tank, flow in – flow out =**
 - a. Change in storage volume
 - b. Head
 - c. Horsepower
 - d. NPSH
3. **In the energy equation, a pump:**
 - a. Adds suction head
 - b. Causes friction
 - c. Reduces flow
 - d. Adds energy
4. **In modeling, GIGO stands for:**
 - a. Great Input – Great Output
 - b. Gold In – Gold Out
 - c. Goofs In – Goofs Out
 - d. Garbage In – Garbage Out
5. **Which is NOT one of the overall types of data you need for a model?**
 - a. Demands
 - b. Weather
 - c. Physical properties
 - d. Operating conditions
6. **How many continuity equations must be solved in a single model run?**
 - a. One for every pipe
 - b. One for every pump
 - c. One for every valve
 - d. One for every junction and tank
7. **What does GIS stand for?**
 - a. Geographic Information System
 - b. Global Integrating System
 - c. Geospatial Information Science
 - d. Geodetic Integration System
8. **If a pipe is undersized, the model will show this with:**
 - a. Low velocity and flow
 - b. Low pressure and high pump suction pressure
 - c. High velocity and low pressure downstream
 - d. Low demand and high pressure
9. **An EPS model run is a**
 - a. Extra Pressure Simulation
 - b. Energy Prediction System
 - c. Extended Period Simulation
 - d. Efficiency Prediction Setup
10. **Sudden changes in flow can trigger**
 - a. Tank overflow
 - b. Waterhammer
 - c. Pump inefficiency
 - d. NPSH

8. c, 9. c, 10. b.
1. b, 2. a, 3. d, 4. d, 5. b, 6. d, 7. a,

Answer key

the distribution system. A different form of the equations must be solved to predict what will happen during these events and what can be done to prevent damage.

Other kinds of model runs include:

- Water quality, which tracks water quality or water age through source blended systems
- Criticality, which can help you identify critical pipes and valves in the system whose failure might be especially disruptive or costly

- Fire flow analysis, which evaluates available fire flow and pressures
- Energy, which projects how much energy pumps should be using during daily operation
- Maintenance flushing, which helps establish and manage a main flushing program
- Automated design, which helps size pipes and plan rehabilitation

In addition to the hydraulic equation solver, models have a graphical user interface (GUI), which enables the

user to visualize the network model as it is being built and display output in tables, on maps, with graphs, contours and profiles. Some examples of these are shown across the bottom of pages 34-35.

How do we create a model of our system?

Building a model of a particular system consists of obtaining the software, learning how to use it and providing the input data to describe the system. The input data consists of three overall types of data:

1. Description of the physical characteristics: pipe sizes and connectivity, elevations, pump characteristics
2. Assignment (rate and location) of various types of water demands
3. Selection of the operating conditions (which pumps are running, what the tank water level is) to be simulated

To create a model, the minimum requirement is an inventory and consolidation of paper maps of the system and as-built drawings. Users can directly and easily draw the network and manually input descriptive data and demands. However, it is more frequently the case these days that commercial tools are used to automate the model building process. To relieve the user from the tedium and potential for error in manual data entry, data can be imported from existing sources such as CAD (Computer Aided Design) maps, GIS (Geographical Information Systems) systems and databases. The basic law of computer modeling can be summarized by GIGO – Garbage In – Garbage Out. The quality of the results of a model analysis is directly related to the care exercised by the user in gathering and entering model data.

In building a model, it is best to “start small by thinking big.” That is, it is better to gradually layer detail into the model by incorporating the larger mains early in the process and then adding in smaller diameter mains. These large main models are referred to as *skeletonized* models, and by carefully crafting your models by layering detail, you will gain familiarity and better understanding of the system early on and nurture a growing understanding about the behavior and character of your distribution system.

How can I use a model to solve problems?

Basically, models enable you to experiment with alternative solutions to identify the superior solution. By running through many “what if” scenarios, you can eliminate bad solutions, identify good solutions and gain insight into the behavior of your system before you invest any money in solving the problem. Some of the problems include:

Pipe sizing. Once you have installed a pipe, it is too late to say “Gee, I should have laid a 12-inch.” You cannot experiment with real pipe sizes in the real system, but in a model, you can experiment with alternative sizes and load them with future demands to see not only what will work today but what will work when demands increase in 20 years. If a pipe is too small, the model will indicate this with very high velocity in the pipe and low pressures downstream of that pipe.

Pump selection. Pumps usually represent the largest operating cost for most utilities. Selecting pumps that work well with the system is essential, and energy costing modules in models can assist in performing the life-cycle

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costing need for intelligent pump selection. Sometimes, pumps that work well alone do not run efficiently with other pumps. Modeling can identify those mismatches and help you avoid them.

Emergency planning. Distribution systems need to work well even when there is a pipe break, pump failure or a power outage. You cannot afford to simulate an actual pipe failure but with a model, you can simulate how your system will respond during an outage. Sometimes, the model calibration work will identify mistakenly closed valves or pumps not running on their curves.

Pressure zone layout. In hilly terrain, it is difficult to operate a system that will provide pressures that are not too high at low points and not too low at high points. Models can be used to simulate pressures in the system for a wide range of pressure zone boundaries,

tank levels and PRV (pressure reducing valve) settings to identify the system that best serves the customers.

Water quality mixing. In systems with multiple sources, the water quality can vary throughout the system. Customers often complain when the taste and odor of their water varies. By running a water quality simulation with a model, you can see which customers are receiving water from which sources and how that changes with time of day and pump operation. There are often surprises with the results of the runs.

A water system hydraulic model can take the dirty work out of solving a wide range of water distribution hydraulic problems. With tens of thousands of dollars at risk with each decision a utility manager makes, use of a model to provide decision support more than justifies the investment in the model. ○