The 3 A's of Hydraulic Modeling

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Hydraulic modeling is the backbone of water system engineering. Understanding "the 3 A's of hydraulic modeling" – **ACCURACY, APPLICABILITY, and ACCESSIBILITY** – will help you get the most out this important tool.

INTRODUCTION

A drinking water hydraulic model is three tools rolled into one: a map, database, and virtual water lab. **Figure 1** shows the physical locations of sources, pipes, and tanks. The database defines their geometry, connectivity, and other attributes but the map and database constitute a mere inventory; the model's real value is its simulation capability. It's a virtual lab to experiment with hydraulic performance, water quality, and energy efficiency.[1] As a 'digital twin' of the real water system, the model is a safe place to try out new scenarios before executing them in reality.

I've seen dozens of models so far in my career – from the one-well, one-tank water system of Dietrich, Idaho to the 2,000-mile pipe labyrinth serving 1,700,000 people in Phoenix, Arizona. Some models are up to date, well utilized, and in excellent condition; others lack current data, are underutilized, and provide little to no insight into the water system. So what makes a great hydraulic model?

The desirable features of a hydraulic model can be grouped under three broad categories I call the 3 A's: Accuracy, Applicability, and Accessibility. A great model will score high on all three. Let's discuss each one.

ACCURACY

It's obvious that a hydraulic model should be accurate, but it's harder to define *what* makes it accurate – or *why*. I suggest the following.

GIS basis for facilities. All water system facilities should be represented in a geographic information system (GIS) that describes their locations, sizes, and other attributes. A complete GIS inventory is a critical first step for hydraulic modeling.

Hydraulic properties. Besides the fundamental geometry provided by the GIS, the model also needs hydraulic properties. Pipe roughness (friction) is usually derived from pipe material and age. Pump curves, which define the trade-off between head and flow, can be looked up online according to the pump's name plate or determined in the field with a few measurements of flow and head. Settings for pressure-reducing valves and similar facilities should be determined in the field and recorded for input into the model.

Water demand – spatial. In the past, the practice was to spread demand uniformly throughout the model, assigning the same demand to each model node. Today, we have the technology to accurately represent actual demand locations by geocoding water bills (turning the billing address into an x, y point) or, even better, harnessing location data from advanced metering infrastructure (AMI). Doing so enhances the spatial accuracy of the water demand.

Water demand – temporal. Besides an accurate spatial pattern, you also want an accurate temporal pattern. A 24-hour diurnal curve describes the water system's unique daily demand variations and is necessary for extended-period simulation (EPS) with multiple time steps. Diurnal curves are developed from a mass balance on water sources and storage fluctuations from SCADA or from AMI data, each using hourly (or finer) data. The model may employ a single diurnal curve or several diurnal curves for distinct pressure zones, district metered areas (DMAs), or customer types.

Calibration. An important ingredient of model accuracy is calibration, the process of matching the model results to actual observations. Fire flow tests, pressure readings, flow measurements, and even chlorine residual data can inform adjustments to the hydraulic model that bring it into harmony with the observed system behavior. Calibration leads to confidence in the model and its ability to act as a digital twin.

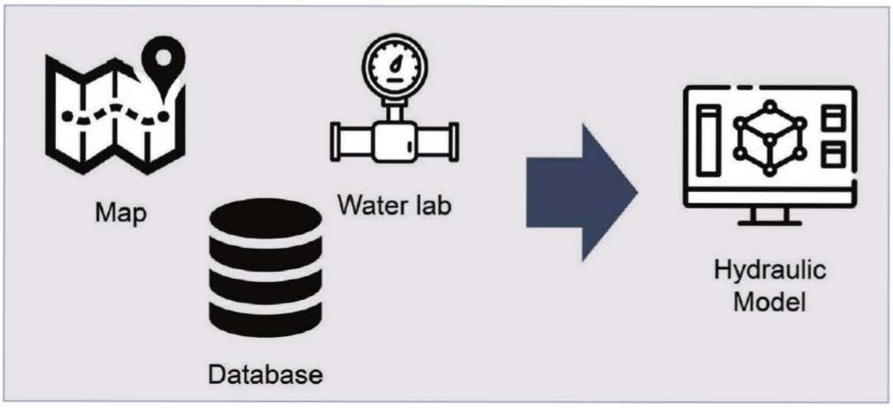

Figure 1

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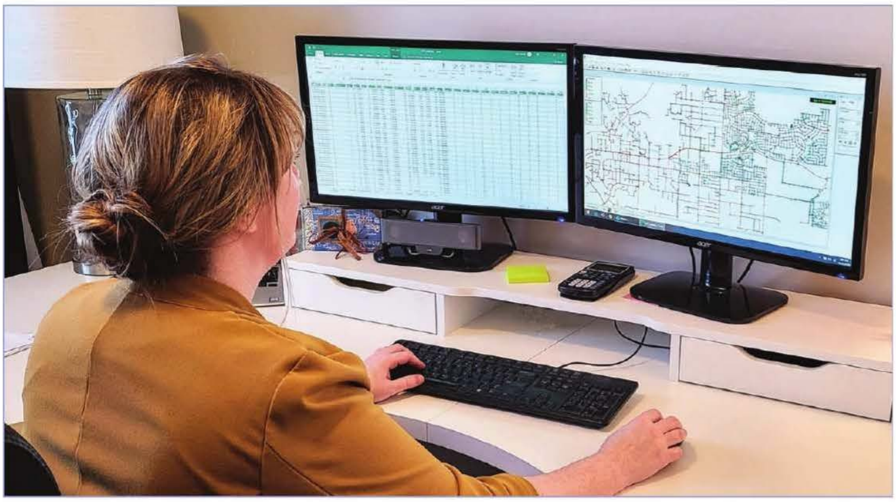

APPLICABILITY

A great hydraulic model can handle the various modeling applications that a water system needs. Here are a few examples to consider for applicability.

Capital planning. Perhaps the most common application of hydraulic modeling is capital planning. Water master plans and similar studies rely on hydraulic models to simulate existing and future conditions. Engineers can then identify existing or future system deficiencies and develop capital projects to address them.

Development review. Proposed land developments undergo engineering review to ensure that new water connections will have sufficient service from the existing water system. A hydraulic model of the new development can evaluate peak day demand, fire flow capacity, and pressure to confirm pipe sizing and other design issues. In Utah, hydraulic modeling of new developments is not just a good idea, it's the law.[2]

Water quality analysis. One of the most underutilized capabilities of hydraulic modeling is water quality simulation. Beyond the treated water source, a number of chemical, biological, and physical processes affect water quality in the distribution system, and hydraulic modeling is well suited to study them. A couple local examples stand out. Modeling helped Riverton City, Utah, improve low chlorine residuals after a new surface water source was introduced in 2015.[3] In the 2019 fluoride overfeed that occurred in Sandy City, Utah, water quality modeling played a prominent role in both the immediate response, where trace simulations helped determine the extent of the fluoride release, and the subsequent investigation, where forensic modeling recreated the hydraulic and chemical conditions at the time of the incident.[4]

Energy management. A hydraulic model is an excellent tool for identifying energy inefficiencies (like pumping in circles) and testing alternative operations (like adjusting pressure-reducing valves). Dozens of Utah and Idaho water utilities have participated in energy management programs recently, many relying on their hydraulic models to inform their actions. North Salt Lake, Logan, and Jordan Valley Water Conservancy District are just a few such examples.[5]

Unidirectional flushing (UDF). UDF is becoming the preferred method for pipeline flushing. The technique produces high velocities and better scouring with less water, but requires specific valve sequences and timing. A hydraulic model helps with both. SUEZ Water Idaho (serving the Boise area) has used hydraulic modeling to plan UDF for 373 miles of its 1,421-mile system since 2018.

Customer relations. More than a tool for water system staff, hydraulic models and the associated maps and graphs can also help customers.[6] One water operator recently told me about a customer, who had complained about low pressure for years and failed to grasp the reasons why – even after several explanations. After learning to use the hydraulic model, the operator was ready when the customer called again. Equipped with a web-based model on his tablet, he visited the customer and showed a map to place the customer's home in the context of the water system, and then showed a graph of the typical pressure to help the customer understand what fluctuations to expect.

ACCESSIBILITY

An accurate and applicable model is of little use when it's not accessible. Too often, the model is housed on a single computer and used by only one person. While guarding your master copy is wise, you should make copies accessible to others within your organization or project team. The more people who use the model, the better it becomes over time. Consider the following features of accessibility.

Multiple users and sites. A hydraulic model should not be limited to a single wizard behind a curtain. It should be available to multiple engineers, operators, managers, office staff, and consultants, who can review and discuss it often and address any limitations.

Open source and shareable. Even if you rely on commercial software for serious modeling, you should export open-source copies (i.e., in EPANET .inp format) that others can use without a license.

Web-based. Historically, hydraulic models have been limited to software installed on local computers. Today, however, options are expanding for cloud-based models that are accessible from anywhere, including from tablets and smartphones, using an Internet browser.[7] Such options open new possibilities for model use in the field, team meetings, and customer interactions.

Training. Hydraulic modeling is rarely required coursework, even for graduate-level engineers. I encourage training your staff, particularly operators,[8] to use your hydraulic model, with topics and exercises customized to address the specific situations they encounter.

CONCLUSION

A hydraulic model is essential for drinking water planning, design, and operation. No matter what condition your model is in now, I invite you evaluate it against the 3 A's of Accuracy, Applicability, and Accessibility and consider how you can improve it.

Do you need to make GIS updates a priority? Does you model have pump curves? Should you develop a chlorine residual simulation? Does your staff know how to use the model (or even where to find it)? Consult with your team, make modeling a priority, and put it to good use for the benefit of your staff and your customers.

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Dedicated to advancing sustainable water supply, **Dr. Rob Sowby** is a water resources engineer at Hansen, Allen & Luce, where his practice focuses on the planning, modeling, and energy management of public water systems. He is also Co-chair of the forthcoming AWWA manual M83, Energy Management of Pumping and Treatment Processes. This article is based on his presentation at the 2020 Virtual AWWA Intermountain Section Water Summit.

[1] Steven C. Jones and Robert B. Sowby, "Water System Optimization: Aligning Energy Efficiency, System Performance, and Water Quality" (*Journal AWWA*, June 2014), *https://doi.org/10.5942/jawwa.2014.106.0087*; Matt Huang, "Consider the Value of Hydraulic Modeling for Operators" (*Opflow*, July 2019), *https://doi.org/10.1002/opfl.1216*.

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[3] Kayson M. Shurtz, Steven C. Jones, Robert B. Sowby, D. Scott Hill, and Daniel 'K' Woodbury, "Hydraulic Modeling Finds, Fixes Chlorine Residual Gaps" (*Opflow*, June 2017), *https://doi.org/10.5991/OPF.2017.43.0038*.

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