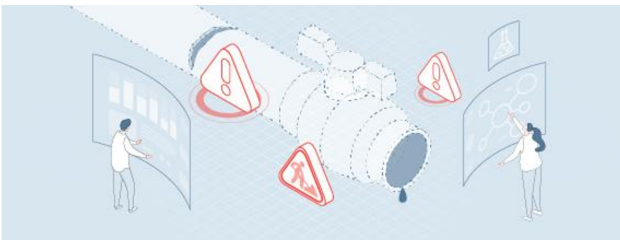
DIGITAL TWIN: YOUR ESSENTIAL PARTNER IN WATER MANAGEMENT

Virtual replicas equip utilities to proactively manage and improve water systems.

Today, digital technologies are advancing the development of sustainable water systems. Data-driven solutions facilitate efficient management of operations, prevention of problems and quick response to issues. These capabilities are especially important at this point in time, as the world's water supply is under great pressure from overexploitation of groundwater, rising demand from industries and growing populations, polluted sources, and climate change. Government policy, investment in less water-intensive industrial processes, and reduced domestic water use are among the key factors that can help safeguard water resources. Water management is another.

To help manage their water-supply operations and improve system performance, water utilities are making use of digital twins. These virtual replicas of physical assets build on effective data management, utilizing real-time data to create a shared holistic perspective of assets and enable optimization of processes through informed and timely decision making.



In the following Q&A and related case studies, WSP hydraulic modelling experts provide insight into how digital twin technologies help water-system professionals make the best decisions—to run water systems efficiently, minimizing waste and maximizing supply of water for communities. Jean-Luc Daviau explores a "faster" digital twin for the water supply system from Toronto to York Region in Canada, and Thomas Johansson discusses real-time modelling in the Linköping water supply network in Sweden.

What is a digital twin?

A digital twin is a virtual replica of an asset that incorporates associated real-time data during operation of that asset. It provides an immersive and integrated visualization of previously siloed information and enables use of modern digital analysis techniques, such as condition-based monitoring and predictive analysis, to plan for the continued functioning of infrastructure.

What value do digital twins bring to water system planning and operations?

Thomas Johansson: Real-time understanding gained through a digital twin makes for the right decisions in a timely way. Having an accurate and a completely detailed digital twin of a water network, linked to SCADA [Supervisory Control And Data Acquisition], enables operators and engineers to consider the entire water supply system when they plan upgrades, assess the best way to repair or improve the system, and respond to unusual situations.

Using a digital twin over a water supply network also offers the opportunity to train people to work with the system in the most effective way, testing measures and solutions in the model before committing them to reality. Because the digital twin can display real-world measurements with corresponding simulation results, utility staff can develop a high degree of confidence in the tool. A digital twin can help optimize pump schedules and material and energy use related to pipe repair or upgrades. In turn, these enhanced choices reduce costs as well as the utility's carbon footprint.

Digital twins help water utility operators:

- Test new equipment or control sequences virtually, without risk to real-world operations.
- Quickly determine possible solutions before going to the site physically: a safer response.
- Collaborate across engineering, planning and operations for better and faster decisions (leveraged by outside consulting, contracting and test services).
- Train to work with the system in the most effective and safe way possible: compile and display the valuable data they collect for optimal system performance; and visualize and animate time-dependent operations, such as reservoir cycling or transient pressure travel.
- Predict the future using data analytics and computer model simulations for planning (what-if scenarios), to respond intelligently to pipe breaks and to handle crises (resilience).

How would you compare the digital twins for the Swedish and Canadian water systems?

Jean-Luc Daviau: Digital twins are all about supporting utilities and their operators. The digital twin achieved in Linköping, Sweden provides real-time, detailed decision support to engineers and operators as they tackle real-world water supply challenges. It's inspiring to know it was done and is now in use. For the Toronto and York Region systems in Canada, we aspire to predict long-term, cumulative wear-and-tear using the systems' digital twins. Both day-to-day operations and emergency management have a role to play in water management.

Thomas Johansson: The digital twins for the Swedish and Canadian systems use different sensors and solution algorithms. The Linköping model can self-generate and solves flows and pressures every 10 minutes to predict gradual changes in the water network; the data in the Toronto and York Region models change monthly or yearly, but the "faster" digital twin can predict changes in the network from gradual to nearly instantaneous. For example, valve closure simulations support an operator's most frequent emergency response, which is to isolate an area with a break. Right now, in the Linkoping model, we can gauge how pressures and storage levels respond to valve closures but without the transient pressure waves.

How then can a "faster" digital twin change the way water utilities carry out their operations?

Jean-Luc Daviau: While many emergency scenarios such as power failures can be predicted ahead of time, the same is not true of the best way to respond to a pipe break or fire that can occur anywhere.

Networks are a heterogeneous fabric of pipes that have "folds" due to topography, "cuts" due to rail or highway corridors, and "strings" that link distant parts via tunnels or transmission mains. Disturbing any point of this surface affects the entire system in ways that are hard to predict.

A digital twin allows operators to isolate the area by closing water valves, and the model can also generate a list of the impacted customers. This can be done today using a geographic information system [GIS] framework and reasonably detailed hydraulic models. A "faster" digital twin can do the same while also indicating the fastest safe speeds or sequence to close these valves or fire hydrants, to avoid causing wear-and-tear—or another break elsewhere. Gaining such insight requires consideration of every pipe and the dynamic equipment parameters that represent a system's response to fast events, both of which are available through a hydraulic transient ("faster") model.

Digital twins require GIS and SCADA links but benefit most from large-scale IoT sensors and cloud-based data to store, process and serve-up, hundreds of times, the pressure and flow measurement data. Of course, faster pressure sensors are also needed for a "faster" twin. The faster computers and high-speed sensors we have today enable us to use a "faster" digital twin to tackle transient event simulation with a high level of detail, just like we do for everyday events across entire water systems.

There are two key concepts to get across to engineers and system operators as they look toward the future: Number one, a system's response time increases with size, making it more vulnerable to changes in flow or pressure; the same pump stop can be tolerable one year and problematic 10 years later. Number two, transient mishaps can wreak havoc within systems. Picture a dam break; it's fast and destructive, but it is visible. Liberating that kind of energy underground would present immense challenges in terms of response, containment and resolution. With the right tools, utilities and their operators can prevent major issues and more effectively manage problems when they arise.

Case Studies
Linköping Water Supply Network, Real-time Modelling – Sweden

Client: Tekniska Verken AB

Tekniska Verken AB is the municipality-owned company in the municipality of Linköping, Sweden that serves the Linköping area: 1,568 km² with a population of 163, 000.
Tekniska Verken contacted WSP some years ago and asked for help to update an old hydraulic model over the water supply network. The aim was also to start the work toward establishing an online model for the network, continually fed with data from the SCADA system (Supervisory Control And Data Acquisition) system. WSP's part in the project was to build the model and connect it to the SCADA system, help Tekniska Verken to carry out capacity studies, and train those working in the system so that they now run the system themselves.

Tekniska Verken had a growing need for an updated hydraulic model due to extensive growth in the municipality with a lot of new housing and industry areas. A growing population calls for the ability to carry out accurate capacity studies and to optimize all assets as well as system performance in an aging water supply network. Optimization includes identifying problems—such as those related to pressure, leaking pipes and water quality—and underperforming areas.

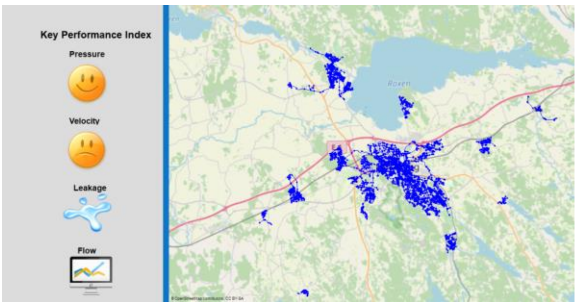


Figure 1 – Simplified overview of the real-time model of the Linköping area

The digital twin model has been instrumental in managing and operating the layers of water-related infrastructure—including booster stations and associated pipe networks, storage tanks and treatment facilities—thereby providing ongoing support for the proper functioning of the network. In addition to capacity studies, the digital twin has facilitated general studies of the network, hydraulic design of new areas, identification of operational issues, and support when redimensioning/relining the existing network.

The model is built directly from the geographic information system and the customer consumption system. When the data regarding flow, pipe pressure and reservoir levels is collected from the SCADA system, via the database, a simulation of the entire network is performed automatically. In that way, Tekniska Verken gets a new overview with actual data every 10 minutes 24/7.[1] The data provides a base to identify, examine and correct current problems before they become major issues. All the used SCADA data is stored, so it can also be applied to perform historical simulations; studying occurrences in the past supports proactive maintenance in the water supply system, to prevent reoccurrence.

The water supply systems of today are very complex with multiple points of operation and interconnectivity; the original systems were not designed for subsequent additions. Having a digital twin model over the water supply network is a natural step for Tekniska Verken in their task to run the system efficiently and continue to support community water needs.

A "Faster" Digital Twin for the Water Supply from the City of Toronto to York Region - Canada

Clients: Toronto Water and the Regional Municipality of York (York Region)

Toronto Water is a division of the City of Toronto that operates a water supply system from Lake Ontario northward to supply York Region in Ontario, Canada. The dozens of pump stations and large transmission networks in both systems serve 4 million residents across 2,400 km^2.

Toronto and York Region both recognized that utilities must pay close attention to hydraulic transients[2] due to the higher frequency of leaks and breaks in aging infrastructure. At scale, "water hammer," a type of hydraulic shock, either causes catastrophic failures or continuous and significant deterioration of infrastructure, reducing its life expectancy and driving-up staff and repair costs.

Figure 2 - South Toronto and South York Region Hydraulic Transient Models

To manage water supply risks, the WSP team[3] updated these water systems' hydraulic models and related pressure measurements to match

[1] The time interval is influenced by the complexity of the model.

[2] Digital twins use sensors and 3D models to mirror system performance in real-time (or nearly so). A "faster" digital twin does the same for transient events that occur up to 1000 times faster and risk damaging systems. Hydraulic transient states typically occur upon power failure, resulting in pumps kicking-off and eventually re-starting, ultimately to return the system to its "normal" operation. Transient model software simulates such events and is able to account for the compressibility of water, special valves and surge control equipment.

[3] WSP was the lead consultant, with HydraTek as sub-consultant.

24/7 performance. The tests used existing SCADA (Supervisory Control And Data Acquisition) system sensors, supplemented with transient pressure sensors that recorded data at 1/100s intervals to collect real-world dynamic responses to power failures. These IoT (internet of things) sensors and web interfaces help calibrate the models in an operational sense—with the goal of supporting preventative maintenance and reducing the frequency of pipe breaks and the extent of emergency road closures for repairs.

When WSP created the original technology inside HAMMER software 20 years ago, the software's core code allowed for massive increases in computer power that would eventually enable simulations of systems with hundreds of pipes. The Toronto and York Region system models have tens of thousands of pipes that are solved for transient flow and pressure equations using 3/1000s time increments; however, it takes several hours or days to simulate a transient event that lasts just minutes in the real world. These simulations are useful now to manage risks and control pumps. As computing and sensors evolve, there will come a day when even such large systems can be simulated in real time for transient events—a capability currently available only for simpler pipelines or high-risk nuclear systems.

The "faster" digital twin (transient) models and sensors now enable risks to be managed effectively across large, complex networks because the interactions caused by pressure waves travelling at the speed of sound can be accurately measured, simulated and therefore controlled. For the Toronto and York Region systems, over 300 transient scenarios were simulated to quantify and reduce risks arising from emergency conditions, such as power failures, control valve mishaps, or hydrant flow starts/stops during fires. The resulting extremely high and low transient pressures simulated across the system were correlated to pipe-break data and mapped to highlight areas with the highest risk.

Without such tools, simpler and conservative predictions drive up capital and operating costs because engineers cannot quantify the extent to which the network is its own protection, as loops can split and dissipate transient energy.

The updated and improved models are now information assets that will be maintained by the in-house hydraulic engineers at Toronto Water and York Region and used to answer operational questions such as how to respond to pipe breaks, special events or changes in demand (such as during COVID-19) and how to grow the system. Over the next few years, the models will also "grow" and connect, forming a single model, so that the large-scale system can be truly represented at the highest accuracy to pinpoint problem areas.

Contacts

Jean-Luc Daviau
Manager, Infrastructure
Hydraulics
Canada

Jean.Luc.Daviau@wsp.com

Thomas Johansson
Project Manager, Infrastructure
Hydraulics
Sweden

Thomas.Johansson@wsp.com

About WSP

WSP is one of the world's leading professional services consulting firms. We are dedicated to our local communities and propelled by international brainpower. We are technical experts and strategic advisors including engineers, technicians, scientists, architects, planners, surveyors and environmental specialists, as well as other design, program and construction management professionals. We design lasting solutions in the Transportation & Infrastructure, Property & Buildings, Environment, Power & Energy, Resources and Industry sectors, as well as offering strategic advisory services. Our talented people around the globe engineer projects that will help societies grow for lifetimes to come. wsp.com