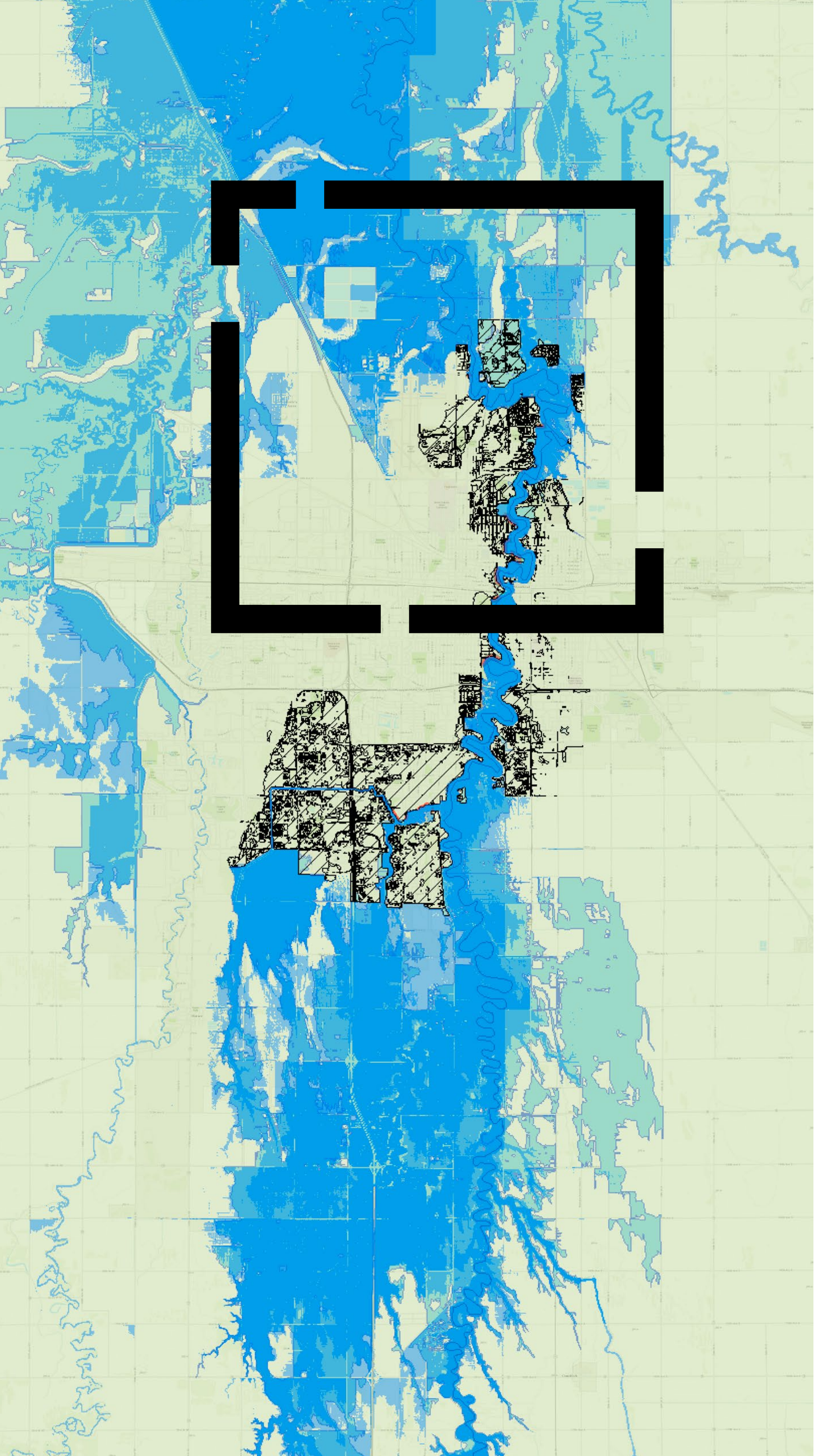
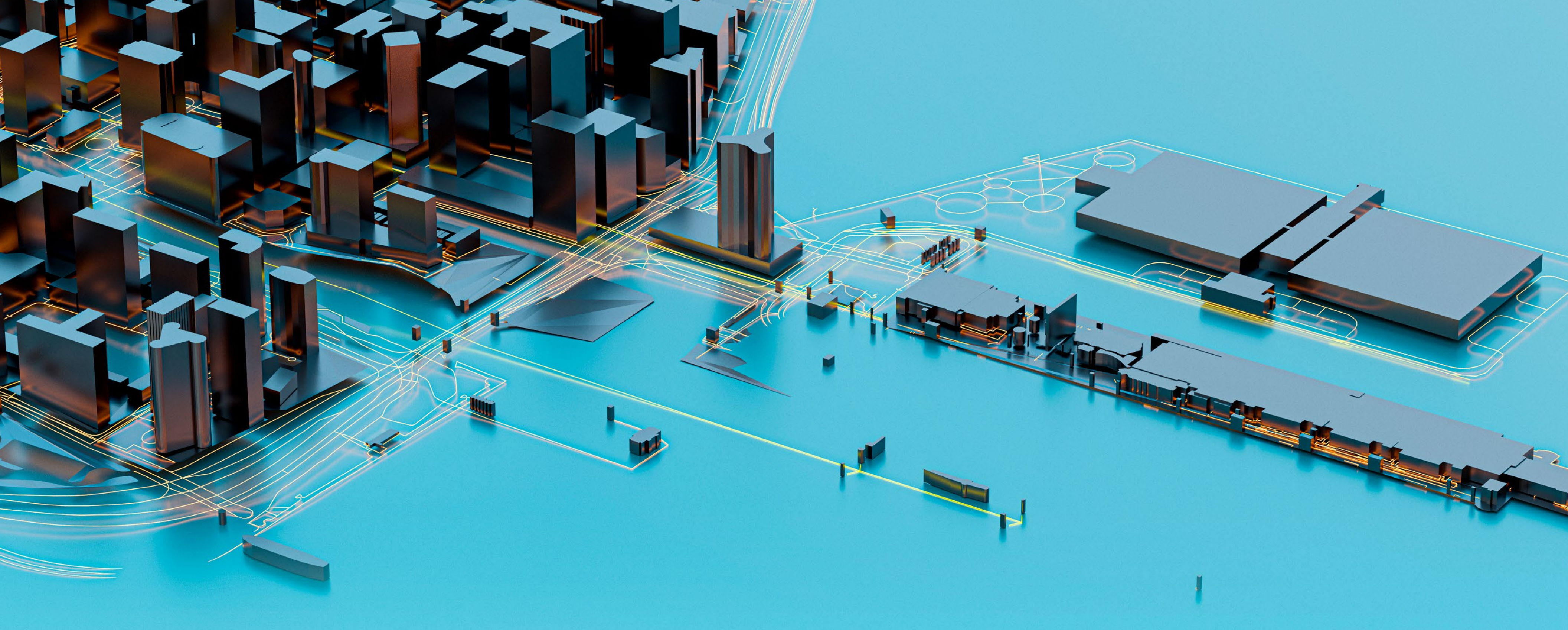
SMARTER SOLUTIONS FOR THE REAL WORLD, USING GIS—WATER

Geospatial Technology Connects the Dots between Real-World Problems and Big-Idea Solutions



WHAT'S INSIDE



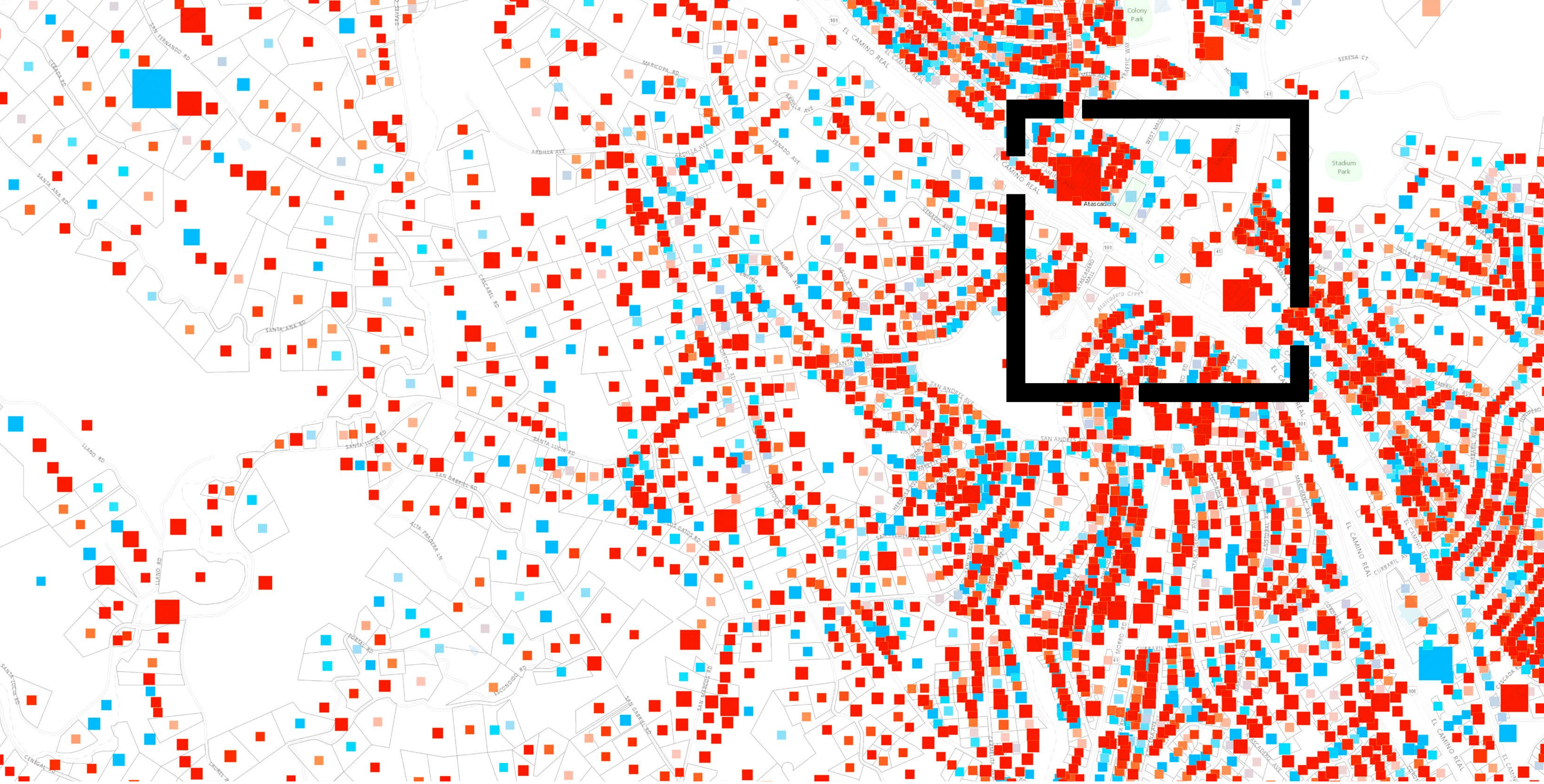
Executive Summary: **Smart Water Solutions Start with *Where***

The water issues we increasingly face—disparity between water availability and demand, water pollution, and competition for limited water resources—are global problems that require big-picture, macro solutions.

The United Nations Development Programme cites poor resource management as the main cause of water scarcity, which will affect nearly half of the world's population by 2025. In addition to aging infrastructure, climate change and population growth are creating water-related crises around the world, centering around issues of extreme scarcity and lack of access.

As water issues intensify, so does awareness of the effects of water management decisions. Many aging large water engineering projects need to be replaced with designs in tune with natural systems.

According to a study by Deloitte, the majority of water and sewerage companies across the world face challenges similar to those of businesses in other sectors: revenue growth, optimal operating margins, asset performance, and resilience. In these key areas, stakeholders need constant reassurance. ▶



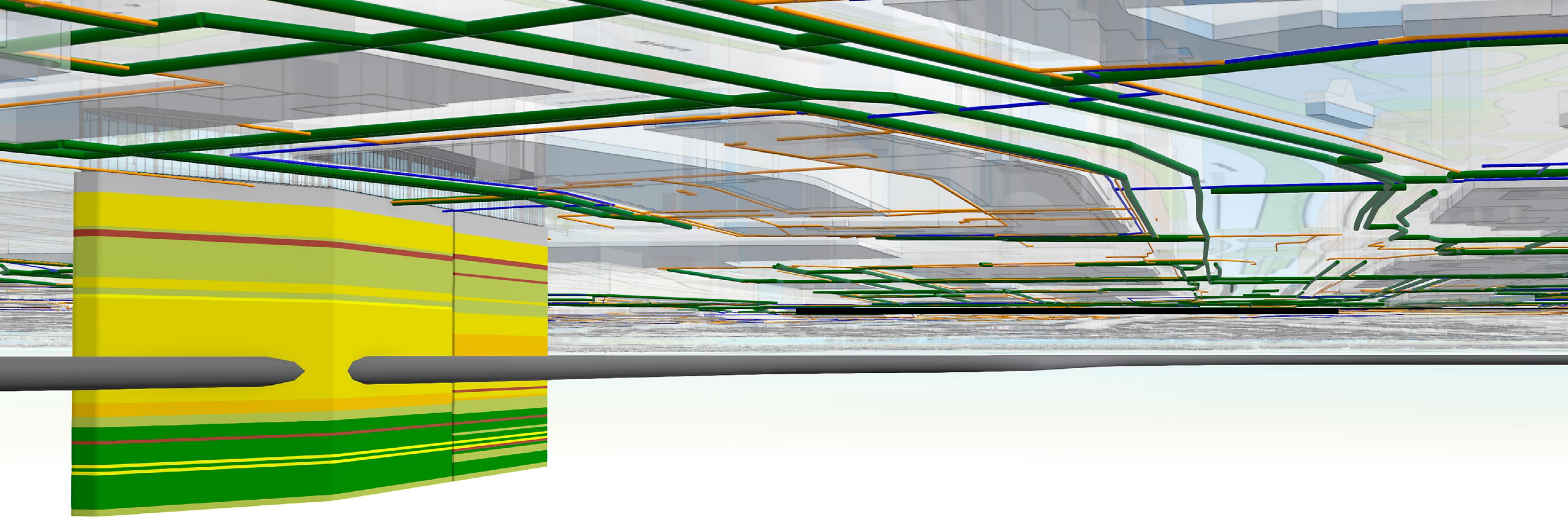
The same Deloitte research found that while utility companies are collecting more data than ever, they still face challenges in organizing, accessing, and leveraging it. Top issues include data siloes, duplication, quality, and volume, leading companies to use a small proportion of their data to perform tasks or solve problems. The vast majority of data goes unexploited.

Architecture, engineering, and construction (AEC) firms have a strong opportunity to support utility companies and other water-focused organizations in solving problems. By leveraging technologies, civil engineering firms can help harness and make sense of the vast amount of water and infrastructure data and become indispensable partners with their customers. One crucial technology, an enterprise geographic information system (GIS), empowers users to gather, store, and analyze data from countless internal and external sources. The outcome is a comprehensive, place-based understanding that factors in relationships between physical entities, natural systems, and human behaviors. Teams use GIS to freely and securely share data, collaborating to create a single source of truth for projects and reduce redundancies and inefficiencies. ▶

Here are some additional ways GIS enables smart water planning and positions AEC firms as value-added partners with their customers:

- **Data collection and analysis–**While a survey of the water industry shows that 33 percent of water utilities are interested in real-time control and big data system analytics, they are hindered by challenges associated with managing and analyzing big data. Using an enterprise GIS, utility operators can collect, store, analyze, map, and display all relevant data points, making GIS an ideal solution for smart water planning.
- **Smart technology enablement–**The Internet of Things (IoT) can connect a GIS with faucets, pipelines, waterways, aquifers, and wells embedded with sensors, actuators, and network connectivity. This allows a water utility to collect and report real-time information about water availability, consumption, quality, and losses.
- **Modeling for the real world–**It's now possible to create a digital twin of water infrastructure solutions by creating 3D models within a GIS environment. Users can model waterways and create whole watershed forecast models that greatly expand situational awareness about flooding. Operators can also use modeling to achieve a simultaneous view of all variables and perform impact studies. They can map the location of existing pipes, valves, pumps, meters, wells, and other facilities and layer it with real-time water usage, system maintenance, and historical data to ensure that water access isn't threatened during infrastructure updates.
- **Water resources analysis–**Water industry professionals can gain valuable insights into water resources by using GIS to display water flow rates, direction, depth, and accumulation–on the same map, at the same time. In conjunction with terrain analysis and pollution data, engineers can help identify, monitor, and protect water sources.
- **Customercentric solutions–**Sharing project deliverables securely via GIS allows clients to understand project decision-making, easily access and manipulate data, provide collaborative feedback, and integrate models with their own GIS for future maintenance needs.

With a simultaneous view of all key factors, AEC firms can support water planning decisions that serve the most people with the least environmental impact while giving customers a competitive advantage. ■



SECTION 1

ELEVATING THE QUALITY OF WATER MODELING BY USING DIGITAL TWIN TECHNOLOGY

Smart and sustainable water solutions depend on real-world planning, in many cases using a digital twin. A digital twin is a virtual representation of a physical asset, process, or system that integrates virtual engineering models with city-scale reality models and GIS data. It's now possible to contextualize a 3D building information model (BIM) within a GIS environment to create a digital twin that provides access to thousands of internal and external data points.

Additionally, digital twins are continuously updated with virtual operational data from SCADA systems, sensors, meters, and other measured sources–creating a real-time model that can be used in both planning and operations.

For example, a 3D BIM is a powerful tool for developing an urban flood management solution. But if that same model can be contextualized using information about historic flood levels, residents' usage of the area, topography, or climate to forecast the impact of future events on the proposed design, it becomes an intelligent solution. That is what differentiates digital twins from static 3D models.

The end result is a digital representation of infrastructure and its physical surroundings that supports planning, design, construction, and operations for smart water networks. Digital twins of water systems provide timely, accurate, and reliable data that planners can use to perform what-if analyses, run simulations, and make informed decisions throughout the life cycle of a water system. This includes long-term system vulnerability and capacity planning as well as immediate performance monitoring and emergency response.

Planners gain a GIS-BIM point of truth for an entire project, facilitating global collaboration from a single data center by using a digital twin. As the model is fed from various data sources, it grows in accuracy and usefulness. From an operations standpoint, more reliable and accessible data means fewer people in the field, avoiding unnecessary costs, risk, and time delays. ■

CASE STUDY

TAIWAN USES DIGITAL TWIN TO PREPARE FOR FLOODING EVENTS

Situation

Taiwan—a 14,000-square-mile island in the Pacific Ocean, about 100 miles off the coast of China—has a tropical and subtropical climate. This means it is prone to heavy rains and flooding.

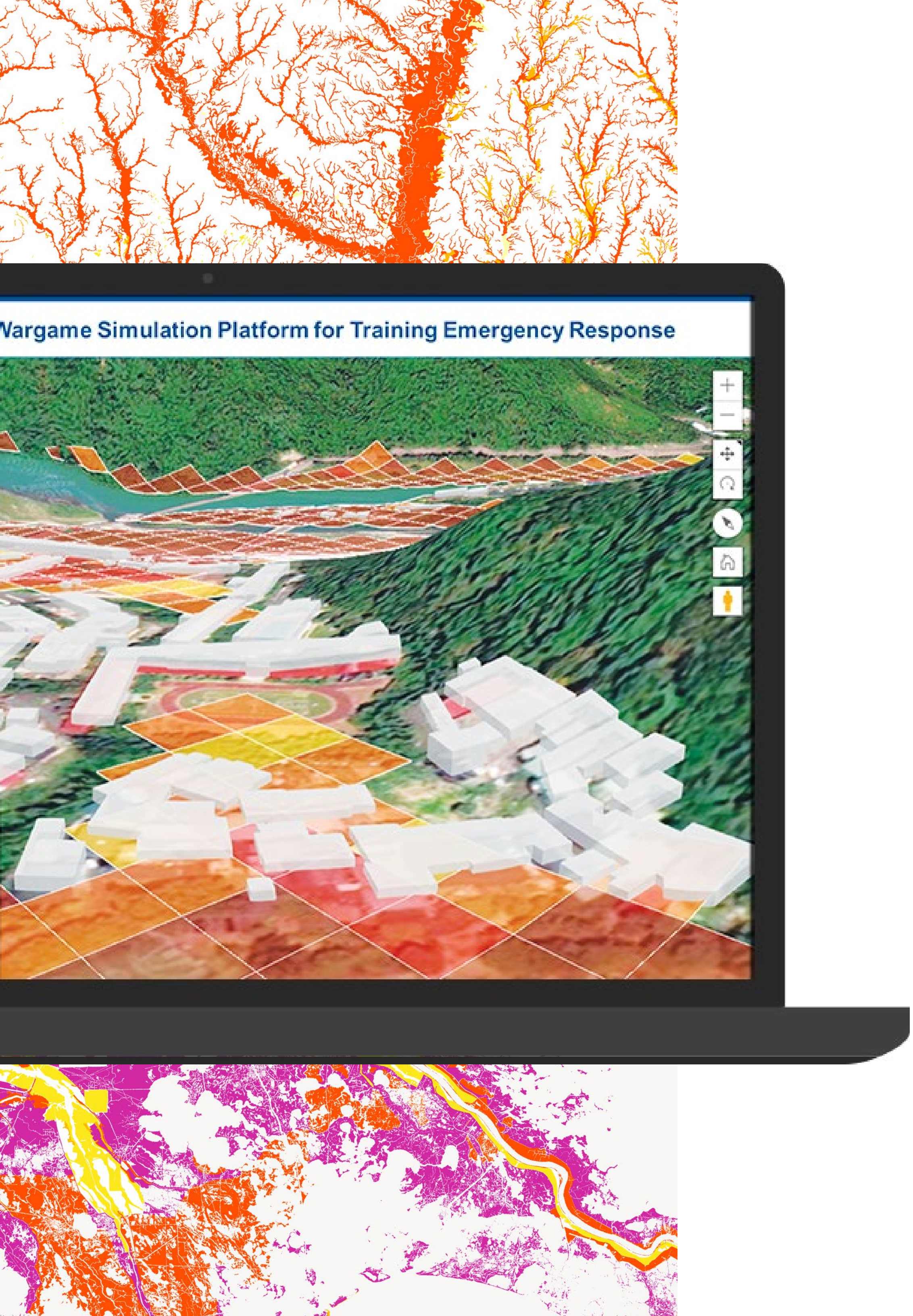
Challenge

Taiwanese officials needed to understand various disaster situations and determine whether their emergency response plans and procedures—including resources deployment, evacuation support, and route planning for distributing relief supplies—were suitable for reducing the impact of a flood-based disaster. The key to these kinds of drills is to make the simulation as similar to a real disaster as possible. Enter the digital twin.

Solution

To help evaluate the viability of flood-based emergency response plans and procedures, the National Science and Technology Center for Disaster Reduction built a simulation for flooding, using a 3D digital twin. The Flooding Wargame Simulation Platform for Training and Emergency Response draws on military battle drills that outline how soldiers will enact specific maneuvers when they encounter certain situations.

Users can use the platform to visualize simulated flooding disasters in 3D, using data from a digital terrain model, satellite images, street maps, and 3D building models. The platform also integrates real-time video feeds from Taiwan's closed-circuit television monitors. ►



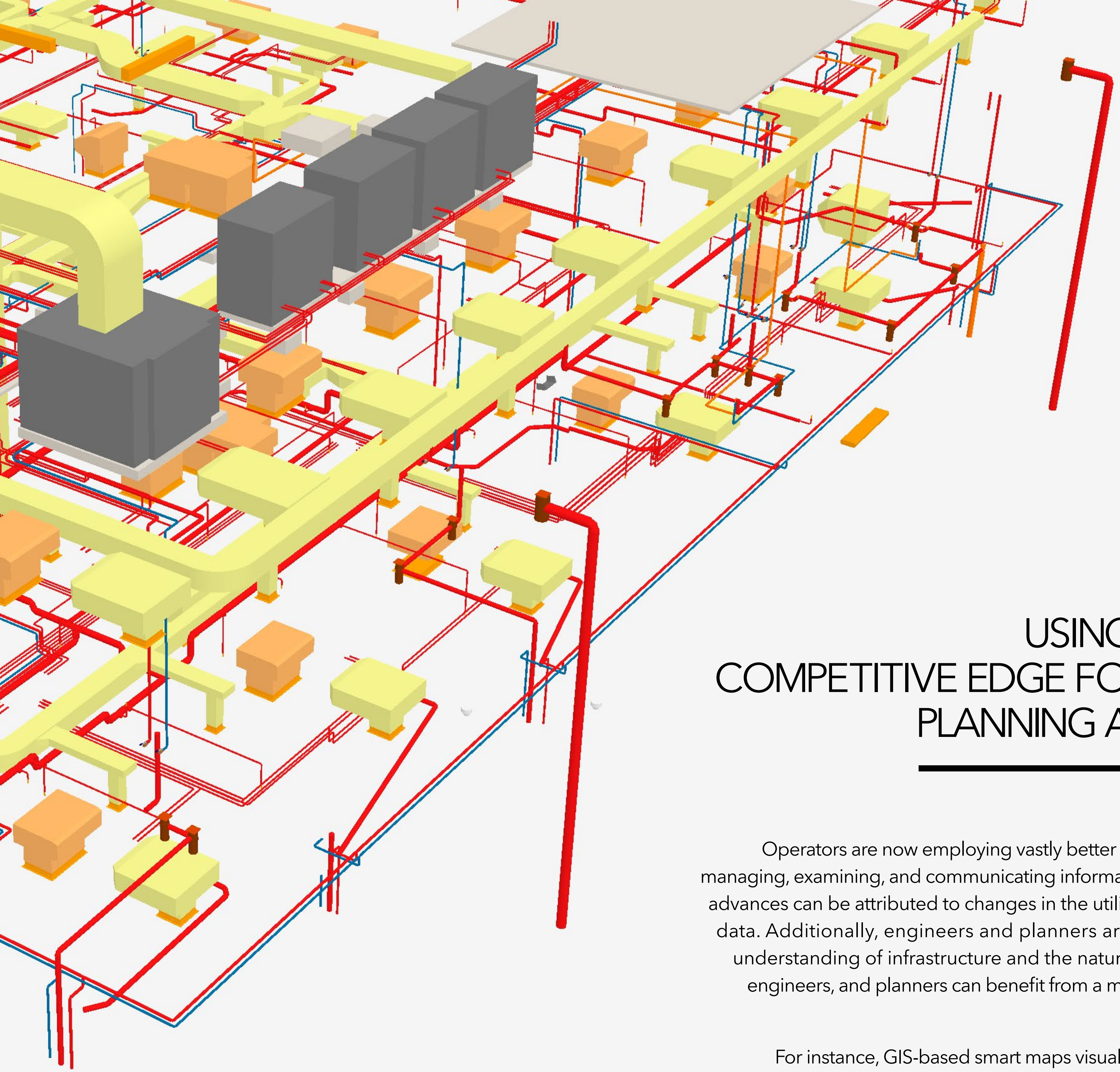
Results

During flood simulation exercises, on-site rescue units use GIS to communicate and coordinate with each other so they can develop emergency solutions that take into consideration the potential severity of building damage, flooding, and traffic as well as the viability of potential rescue and escape routes.

The simulations, data, and model aid in disaster response planning and help inform municipalities of flooding vulnerabilities. Engineering firms can also use the data and model to simulate the efficacy of different solutions and devise a stormwater strategy that improves resiliency.

Additionally, teams can engage in flood disaster planning for especially vulnerable populations. For example, all senior-citizen welfare institutions are displayed on a GIS map, and those located on a building's first floor are marked specifically to take into consideration elderly people who have diminished physical abilities. These details can then help social welfare institutions evaluate their own disaster risk levels and aid other organizations in setting up the government's disaster prevention and evacuation program, arranging emergency housing, and training rescue and response teams.

The ability to identify and enact these precautions and others in advance of a real flood-based disaster strengthens the country's ability is to be prepared for major weather events. ■

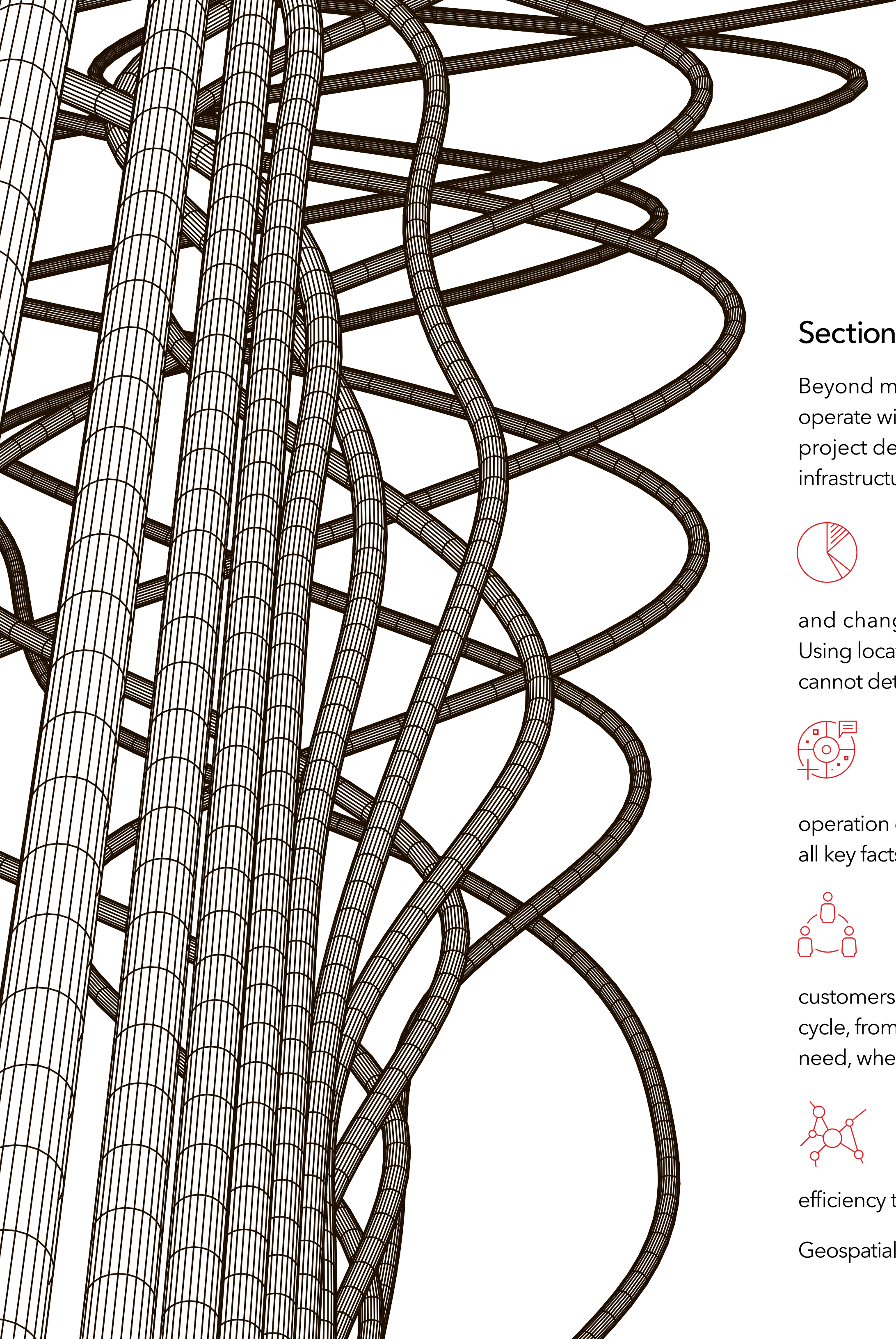


SECTION 2

USING GIS TO PROVIDE A COMPETITIVE EDGE FOR INFRASTRUCTURE PLANNING AND MAINTENANCE

Operators are now employing vastly better ways of designing utility infrastructure and managing, examining, and communicating information about existing systems. Most of these advances can be attributed to changes in the utility environment and greater availability of data. Additionally, engineers and planners are relying more on GIS to gain a holistic understanding of infrastructure and the natural environment. In all aspects, operators, engineers, and planners can benefit from a modern data model, out-of-the-box analytic tools, and easy-to-use maps and apps.

For instance, GIS-based smart maps visualize data from countless sources—including spreadsheets, satellites, IoT, and information databases. Using any source of relevant data, utilities can build an interactive 3D map.



Section 2 (continued)

Beyond mapping, GIS enables an entire project team, customers, and stakeholders to operate within a secure, data-driven analytical environment designed specifically for utility project development and management. The value provided by enterprise GIS for water infrastructure planning and maintenance touches four key areas:

Visualization of assets–Assets are spatial because they all have a location. They influence and are influenced by where they are located as well as by the following: their criticality; their relationship to other assets, customers, and external influences; and changing conditions such as emergencies, severe weather, and security issues. Using location visualization, teams can uncover patterns and trends that simple reporting cannot detect.

Improved operational intelligence–It's not possible to design a sustainable solution without first understanding existing operations, challenges, and shortcomings as well as strengths. Activities of a geographically dispersed operation can be brought together in a map-based view, providing decision-makers with all key facts in one place, eliminating confusion, and saving time.

Empowered customers–AEC firms provide a wide range of valuable services for customers along the full life cycle of infrastructure, ranging from strategic planning to design to operations and maintenance. AEC firms can enable customers to access data, documentation, and updates for all projects at all stages of the life cycle, from a single GIS platform. Empowering customers to access the information they need, when they need it, increases customer satisfaction.

Holistic project management–With GIS, internal teams can view every relevant project the company is working on, to leverage insights from staff teams across the enterprise. This single source of truth improves transparency and drives efficiency that can benefit customers.

Geospatial technology empowers teams to create real business value across the enterprise. ■

CASE STUDY

EFFICIENT PROJECT MANAGEMENT

SAVES TIME AND COST IN TEXAS

Situation

Since 1956, the North Texas Municipal Water District (NTMWD) has provided wholesale water services to growing communities in its region. Today there are over 575 miles of water transmission lines and six water treatment plants with capacity for more than 806 million gallons per day. The district's current wastewater collection and treatment system is composed of 13 treatment plants, including 4 regional plants.

Challenge

To keep up with increased water demand, the company needed to start building a new reservoir. Bois d'Arc Lake will help meet the region's growing needs through 2040, when the population is projected to reach 2.5 million people. As this is the first major reservoir to be built in Texas in over 30 years, information about all aspects of reservoir development needs to be readily available—parcels, road closures, mitigation, pipeline alignment, and shoreline management.

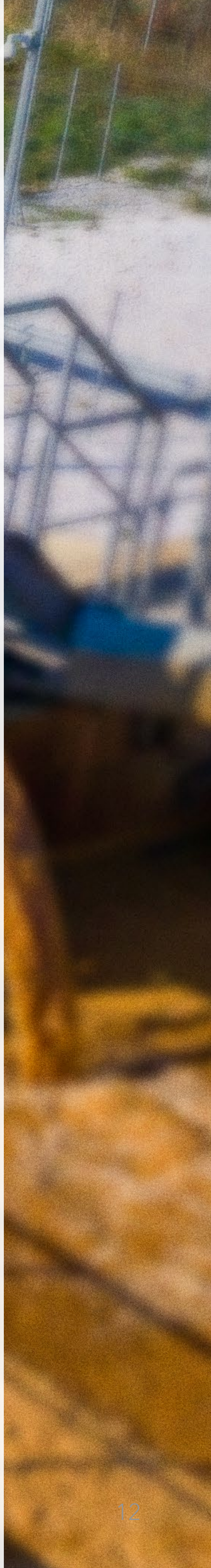
Like many utility companies, teams relied on printed paper maps managed by several departments as well as different iterations of maps from consultants on the various lake project components. This required weekly check-in meetings for each aspect of the project. However, the pace of the project and nonlake-related work in the GIS group's queue could trigger a map to change multiple times a week. Frequent updates became increasingly problematic. It was important for those involved to gain access to maps that accurately reflected the status of the project. ▸

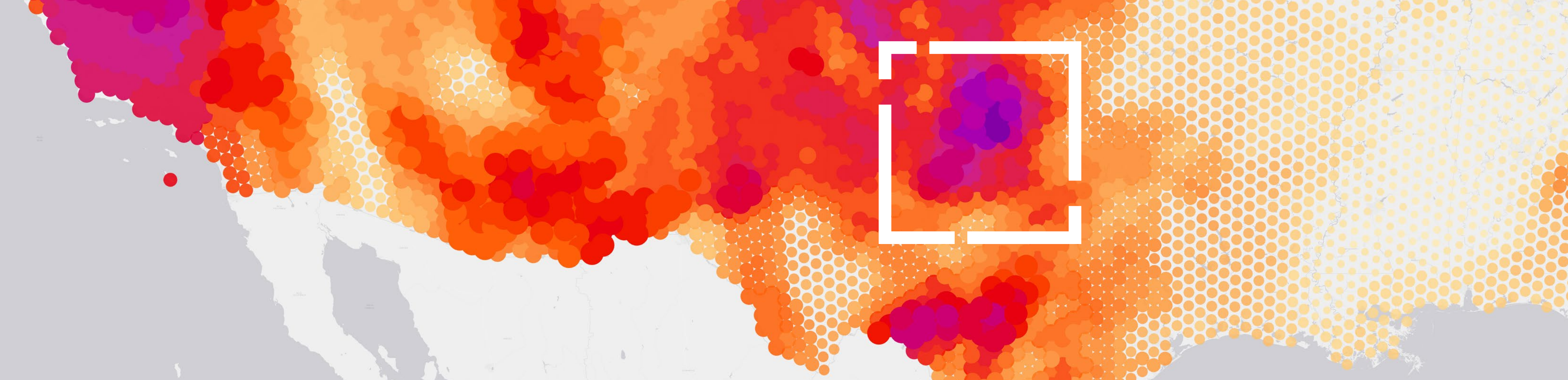
Solution

NTMWD decided to use an enterprise GIS to create a single source of truth for the project and enable multiple stakeholders to access maps updated in real time. Users were given custom viewer roles to see the shared site and maps, and the GIS staff member from each organization was given administrator access to the site for making changes quickly and easily.

Results

Implementing GIS for this project saved approximately 30 percent of staff time that previously had been spent reprinting maps, sharing data, and maintaining updates between all the groups. In addition to providing time-efficiency benefits, the new process has saved money through the reduction of map-printing costs. Everyone with access, including field users, can use the web map to see the most accurate information along with changes in real time. ■





SECTION 3

EMPOWERING SMARTER WATER ACCESS SOLUTIONS

As human activity and climate change create patterns of extreme deluge and drought, already-fragile conditions are exacerbated and the matter of water scarcity is reaching a new level of urgency. It's an issue that affects people across every region and at all levels of socioeconomic status. Effective response to this global crisis requires swift action informed by reliable, real-time data about water resources and usage, population growth, climate patterns, and geography.

Planners can improve water access by using GIS to

- Map current water access points and infrastructure.
- Leverage demographic data to propose new water access solutions.
- Conduct environmental assessments to reduce impact.
- Remotely capture data to reduce personnel time in the field, improving safety and efficiency.
- Combine GIS with machine learning to predict water point failure.
- Layer data such as topography, subterranean water tables, resident demographics, and weather patterns on a single, interactive 3D map.
- Monitor water use versus availability.

Many clean drinking water projects undertaken by engineering and design firms are incredibly large and complex. From creating a groundwater recharge wetlands system in northern Florida to constructing desalination plants in the United Arab Emirates, every project requires flawless collaboration and innovative problem solving. When internal project teams and customer decision-makers are separated geographically with multiple projects under way simultaneously, GIS can act as a single source of truth.

Teams can facilitate easier data sharing and collaboration within a single organization and across different parts of the enterprise by using GIS tools. For instance, teams can use GIS maps and analysis to understand the history of water access projects in a certain region—what has worked and continues working—and where new investments in water infrastructure will have the greatest impact.

Also, targeted groups can access critical information. Rather than relying on manually generated updates, GIS can automatically pull key data points and generate interactive maps that visualize changes for important areas of any project, enabling smarter decisions during fieldwork. These same interactive maps and models can illustrate important points in meetings with key decision-makers, both on-site and off-site.

Armed with reliable data, powerful analytics, and storytelling tools, water project planners can make great impact, cut costs, and further the goal of enabling universal access to safe water for drinking, sanitation, and hygiene. ■

CASE STUDY

MANAGING SCARCE WATER RESOURCES
IN A DESERT COMMUNITY OUTSIDE LOS ANGELES

Situation

Located outside Los Angeles County, Coachella Valley is an area that is prone to low annual rainfall but has high water demand for agriculture, golf courses, and neighborhoods with swimming pools. The region's water resources must be carefully managed.

The valley has one significant advantage–an enormous aquifer hidden beneath the valley floor that has served as the desert's main water source for centuries. Stretching 65 miles from the Whitewater River to the Salton Sea, the aquifer gets replenished by snow melt from the San Gorgonio Mountains and the Colorado River.

The Coachella Valley Water District (CVWD) manages the aquifer and the complex infrastructure that delivers drinking and irrigation water to nine cities in the 1,000-square-mile area. CVWD works in collaboration with other local water agencies to ensure that the aquifer is protected.

Challenge

Harsh weather conditions, including dust storms and prolonged drought, make locating and maintaining a water utility system incredibly challenging. Coachella Valley is home to many resort communities including 121 golf courses–the highest concentration in the United States–and supports an annual crop yield valued at $730 million, all of which place a high demand on water. ▶

Solutions

Infrastructure mapping—Before they can inspect or fix any water pipe, pump, valve, or hydrant, CVWD field crews and contractors have to be able to find it. Crews are guided by GIS-based smartphone apps that reveal key details on data-driven GIS maps. The utility added high-resolution imagery, so its maps and apps have a horizontal accuracy of 10" (25.3 cm) and a spatial resolution of under 3" (7.63 cm).

Water conservation and reuse—CVWD developed a recycled-water system for golf course irrigation that reduces the cost and energy required for water treatment and shifts courses from direct well withdrawal. CVWD also offers cash rebates to encourage customers to remove lawn grass and replace it with desert landscaping that doesn't require as much irrigation. Satellite imagery visualized on a GIS map plays a role in both of these programs. When a customer expresses interest in participating, CVWD team members view imagery of the property, measure and map the area, and calculate the rebate based on square footage.

Aquifer protection—The Colorado River and three large, strategically placed replenishment ponds on the east and west ends of the valley provide all water to the underground lake. The team uses GIS to measure withdrawal and renewal levels to help sustain the invaluable resource for the long term.

Results

By mapping the valley infrastructure using GIS and equipping field team members with mobile apps that sync updates with the CVWD office, the team was able to significantly reduce errors and speed communication. Water conservation and reuse initiatives have been largely successful, thanks to GIS and high-resolution imagery. This technology helps the team meet program requirements remotely, without costly trips to the field.

Thomas Hasselbeck, GIS specialist at CVWD, described the progress being made with aquifer preservation. "We created a three-dimensional terrain model and animated the water levels per year going back to 1960," Hasselbeck said. "That gave us a clear picture of the health of the aquifer through the years. Now, we have a number of computer systems and sensors that help monitor withdrawal and replenishment, and the aquifer is in a much healthier state."

SECTION 4

USING CUTTING-EDGE WATER MANAGEMENT SOLUTIONS FOR FLOOD-PRONE AREAS

Wastewater and stormwater flooding presents incredible challenges for engineers. Design deficiencies or a lapse in infrastructure maintenance can result in residents quickly finding themselves wading through flooded streets, basements, and even raw sewage. Today, climate change is adding to the stress that population growth was already placing on aging infrastructure, by inflicting periods of drought followed by unprecedented rainfall. But recent advances in geospatial planning technologies open up opportunities for flood management. It's now possible to create intelligent, data-driven water management solutions that will effectively manage flooding issues today and for decades to come.

Planners can unify data from many different sources and analyze it through the lens of location. That means teams can remotely integrate hydraulic and hydrologic modeling data to provide a detailed analysis of water utility systems without sending an engineer into the field.

Teams can also combine data from customer information systems, water flow at various nodes, and historical records to understand the demographics of customers served in a project area and see how a proposed solution may affect them. To achieve this, utilities use 3D mapping with graphical and numerical data layers available at the click of a mouse.

During the planning process, engineers can place 3D building information models within a digital twin GIS environment to ensure the viability of plans in real-world conditions. For instance, combining terrain analysis with water surface elevation, rainfall runoff, hydrologic watershed, and historical flooding reports allows engineers to understand how a flood management model would perform against various scenarios.

Smart, location-aware water management solutions can effectively protect the viability of communities and the safety of all residents. ■

CASE STUDY

DUBUQUE TACKLES CHRONIC FLOODING, RESTORING RESILIENCE TO A DISADVANTAGED AREA

Situation

In Dubuque, Iowa, steep slopes and bluffs shed water quickly from the west to the east into flat areas adjacent to the Mississippi River. As a result of increasingly intense and localized rainstorms, devastating flash flooding became a recurring problem.

Property damage from frequent flooding prevented homeowners from building equity. During the five-year period from 2005 to 2009 when the assessed value of commercial property elsewhere in Dubuque increased by 39 percent, it decreased by 6 percent in the flood-prone area.

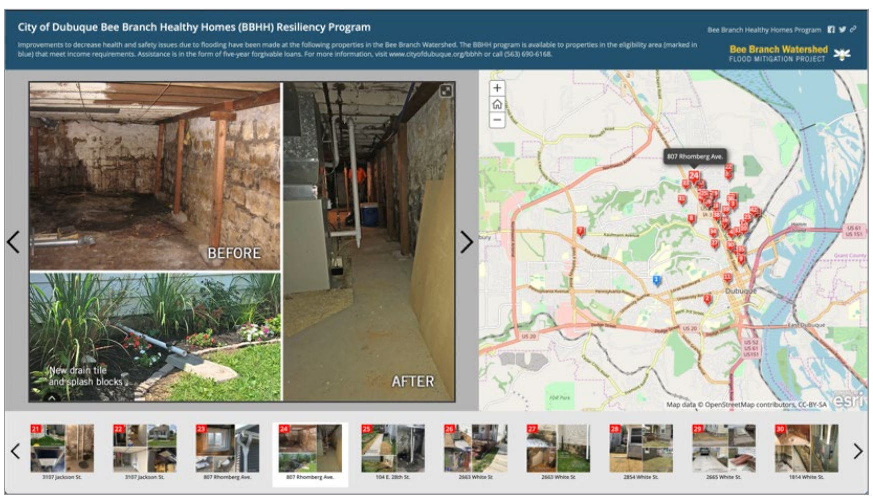
Initially, the floods affected only basements, but with growing development and climate change, the magnitude and frequency of flooding increased. Six presidential disaster declarations were declared between 1999 and 2011, when repeated flooding caused an estimated $70 million in damages to public and private property. It became clear that something needed to be done out of concern for public safety and the local economy.

Challenge

Dubuque received Iowa Watershed Approach funds, with $23.1 million for infrastructure improvements and $8.4 million for housing improvements. The plan included 275 housing unit restorations and three major stormwater improvements—known as the Bee Branch Healthy Homes Project and the Bee Branch Watershed Flood Mitigation Project, respectively. The city needed a way to manage the multiphase projects, including collecting, sharing, and reporting all data. ▸

Before

After



Solution

Workflows to capture all aspects of the Bee Branch projects began with a GIS-based smart survey app that crews used to capture information about people and places. Social workers used the app to collect data about the health and quality of life for affected residents. Home inspectors used the app to capture details, such as damages, about the interior and exterior of homes.

Since the work spanned many different departments in the city—ranging from public works to health and planning—the team also deployed a GIS dashboard to keep everyone aware of the progress on home repairs, the people impacted, and the demographics of residents served.

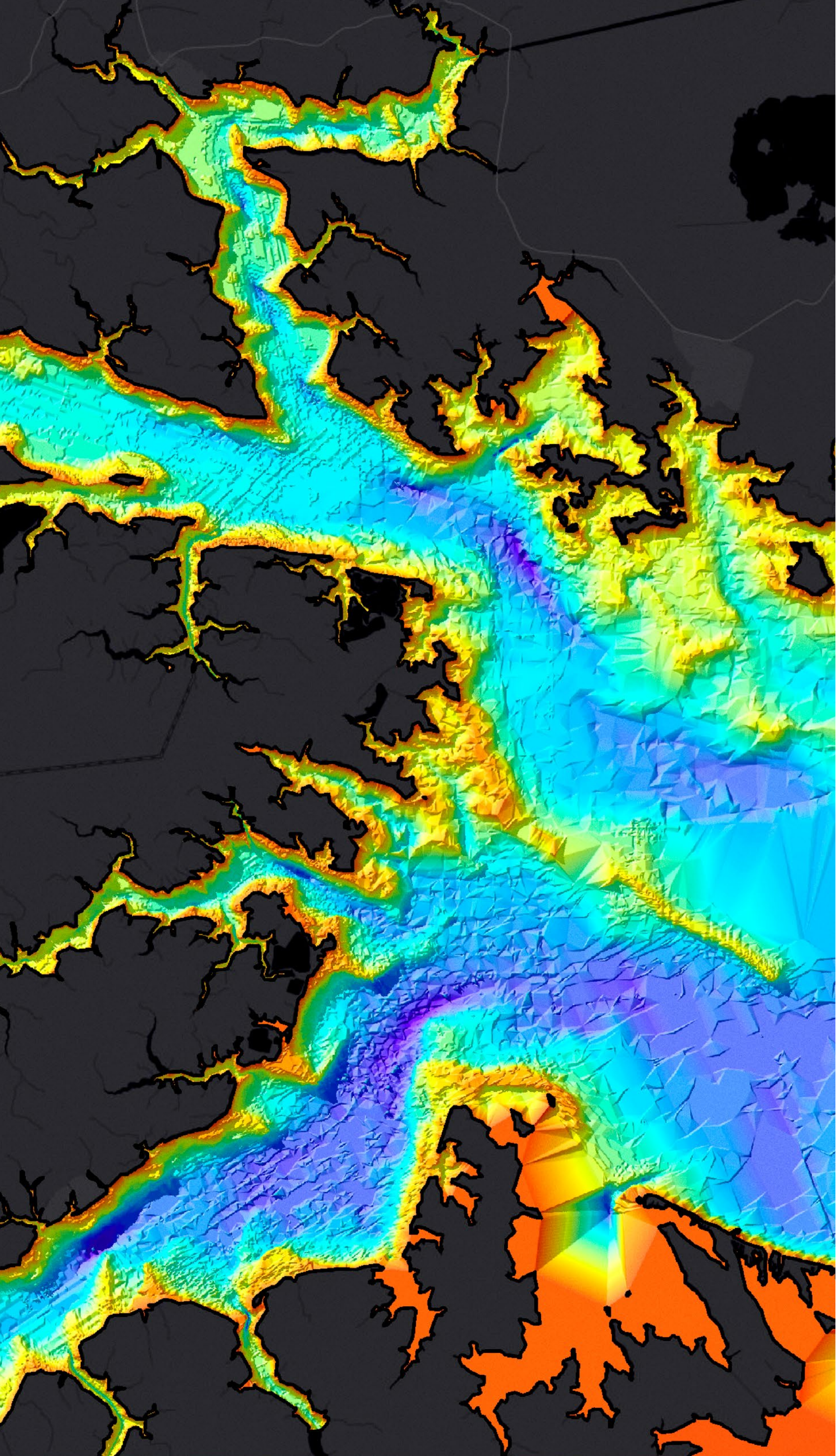
Results

Capturing all the data for display in a GIS provides a number of important outputs for city departments and reporting as well as a shared situational awareness.

"The data is at everyone's fingertips now," said Nikki Rosemeyer, GIS coordinator/analyst with the City of Dubuque. "If information would have been siloed the way it used to be, we wouldn't be able to see and share the work as it happened."

City and agency officials also gained greater understanding of Dubuque's people to better serve the community.

"GIS has been the tool to meld all the information," said Sharon Gaul, grants project manager for the city's housing and community development department. "We can aggregate to get overall details on the demographics of who has been served and disaggregate as we need to look at subgroups. It has helped us assess any gaps in services to address the challenges people face in their lives."



SECTION 5

UNITING ALL TECHNOLOGIES

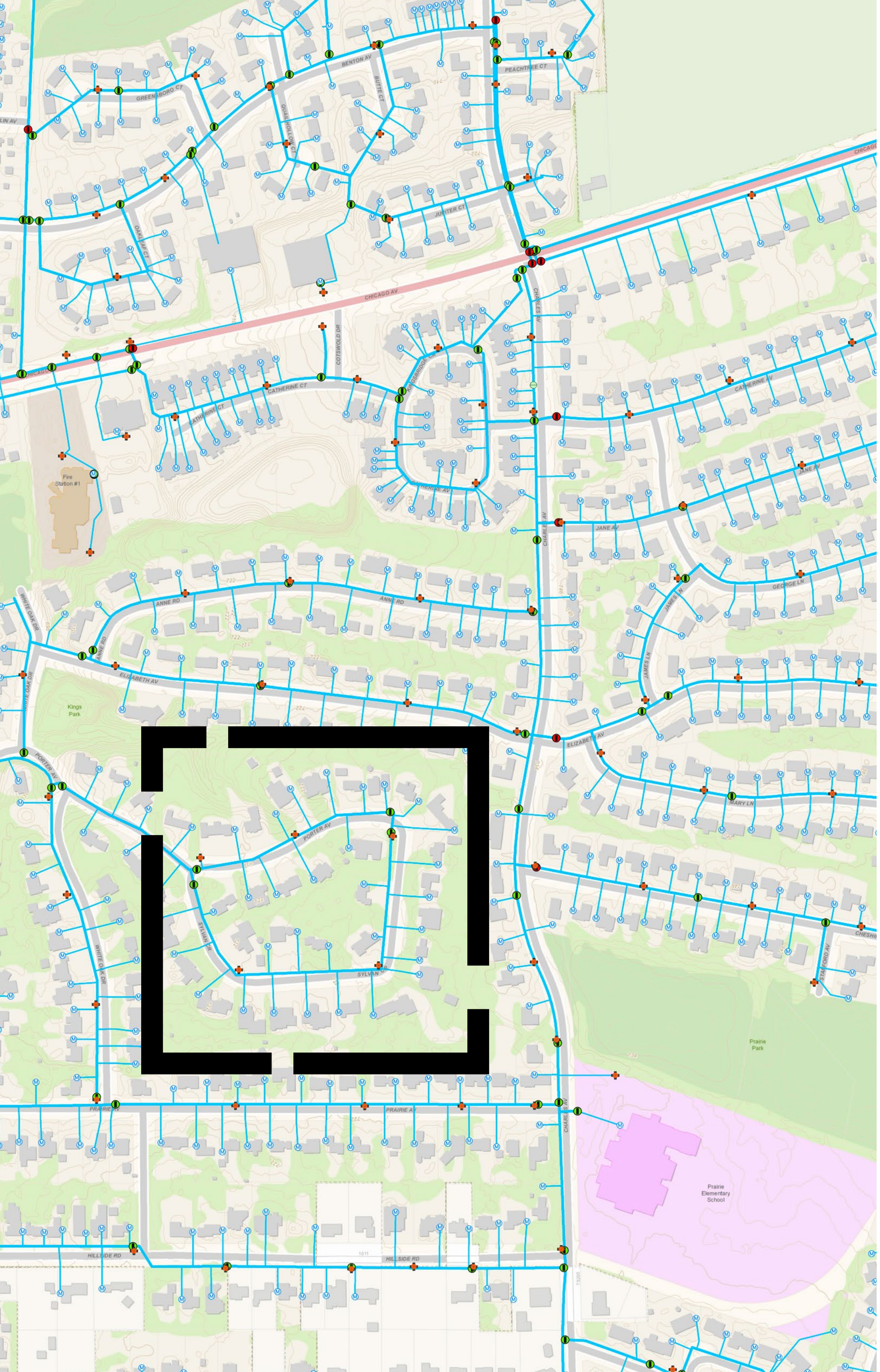
To make the smartest water management decisions and overcome increasing industry challenges, utility operators and engineers will need the most reliable data and a collection of technology tools. They will need sophisticated data collection techniques and analyses and to share it with technical and nontechnical users. Here are some of the ways smart water planning benefits from uniting technologies through GIS:

- **Watershed analysis–**Planners create graphical and numerical representations of various hydrological features within GIS to elevate watershed understanding. Examples include overland flow path models that indicate optimum water quality sampling locations, flow estimation models for all streams in an identified area, a water quality and loading model for pollutant levels, and a ranking model to prioritize treatment alternatives based on user-defined criteria and preferences. In providing consistent technical information related to natural watershed processes, planners and decision-makers can model various scenarios within a digital environment and make smarter conservation decisions.

- **Contextual modeling–**Stakeholders see a project modeled with interrelationships such as terrain and structures, including the ability to map subterranean utilities. BIM technology provides a detailed 3D view of the structure being built. Combining a BIM with GIS, planners can see a 3D model in context before they break ground—which can prevent repeated work and cost overruns. ▶

Section 5 (continued)

- **Water-loss detection–**Aging and leaky pipes, broken water mains, and faulty meters cause 2.1 trillion gallons of water loss each year. A combination of strategically placed IoT sensors, utility infrastructure data, average water usage data, and artificial intelligence (AI)–all viewed on a GIS smart map–can help engineers quickly locate leaks and determine water loss.
- **Water quality monitoring–**Real-time water quality sensors can pick up possible contamination in water supplies. A combination of sophisticated 3D maps and AI can help GIS users determine the source of the contamination and craft proposed solutions.
- **Remote sensing–**Remote sensing collects data from a distance, which can then be integrated into a GIS platform and analyzed using AI. Drones, aircraft, and satellites can carry sensors that feed GIS maps. Remote sensing also provides a detailed analysis of locations that may be otherwise difficult to access such as desert regions, areas of political unrest, or mountainous terrain.
- **Mobile apps–**Mobile apps improve efficiency and collaboration on a project by streamlining the collection of field notes. Teams can also use GIS apps to navigate, track, oversee, and explore the data collected in the field, whether online or disconnected. ■



Learn More

Esri, the global market leader in geographic information system (GIS) software, location intelligence, and mapping, offers the most powerful geospatial cloud available, to help customers unlock the full potential of data to improve operational and business results. Founded in 1969, Esri software is deployed in more than 350,000 organizations. With its pioneering commitment to geospatial information technology, Esri engineers the most advanced solutions for digital transformation, the Internet of Things (IoT), and advanced analytics.

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