Infrastructure

A good deal of local government spending aimed at pandemic recovery is going toward hardening infrastructure and building in resilience in the face of growing impacts from climate change. Mitigation of climate vulnerabilities and preparedness for all types and sizes of disaster have become a central consideration for all new infrastructure projects.

A resilient system is a system that can survive shocks, especially ones that are hard to anticipate. GIS technology has played many critical roles in dealing with devastation from hurricanes and other disasters, including modeling consequences in real time to guide responders to the most urgent needs. Geospatial tools have allowed many vulnerable areas to achieve new levels of preparedness, with mitigation measures determined through GIS analysis. With the contextual awareness of GIS, communities can rebound more quickly with fewer long-term effects.

In recent years, the concept of geodesign has put a finer focus on sustainability. It's a growing practice that combines design with the more scientific task of assessing impacts. With this datacentric approach, designers and engineers implement projects to design with nature, not against it. Careful analysis yields design that best supports natural systems and enhances livability. Geodesign practitioners take advantage of the geographic knowledge contained in GIS and the detailed designs created in building information modeling (BIM) to visualize and model sustainability in multiple dimensions.

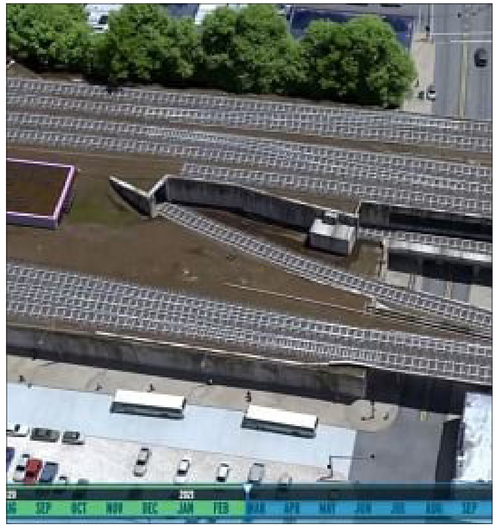
Geodesign supports urban planners, landscape architects, designers, engineers, and stakeholders with a blend of science- and value-based information for understanding the complex relationships between human-designed structures and the changing environment.

Using geospatial tools, geodesign practitioners look at census and mobile data to consider the human dimensions of a place; compile and query environmental data to quell impacts on nature; and model and run scenarios to consider the economic aspects and benefits of a project. The methodology helps assess risk, develop strategies, adapt to changes, test scenarios, and monitor the results. Geodesign also facilitates community feedback on the most suitable, environmentally friendly, and sustainable options for a space.

Geodesign is equal parts analysis, design, and iteration. At the outset, it promotes the careful consideration of a place using data and analytical tools. It facilitates design input from a cadre of disciplines working through a shared geographic perspective. And it seeks to iterate and test scenarios in the digital world to avoid making mistakes in the real world.

When using GIS to design infrastructure, the goal is to imagine the best possible purpose of a place, and to consider what the world could become. GIS places an emphasis on understanding all the consequences of development or infrastructure construction before those consequences become impacts. Geodesign factors in natural networks and impacts to ecosystems, along with renewable energy and carbon neutrality. It imagines what's best for the present and into the future, with the design of infrastructure that will support the sustainability of communities.

5D: The New Frontier for Digital Twins



When the Long Island Rail Road (LIRR) began the latest phase of renovations on Jamaica Station—the fourth-busiest rail station in North America—designers knew they needed to take a digital twin approach to project management.

A virtual 3D model of the rail line would help the interdisciplinary project team visualize the complex choreography of construction stages unfolding in a dense urban environment. The latest phase of the $1 billion Jamaica Capacity Improvements (JCI) project would involve large-scale repairs, including replacing critical power and signal systems, extending station platforms, and building two new tracks, all aimed at increasing capacity and expanding ridership through the bustling Long Island transit hub.

The infrastructure firm HNTB Corporation won the LIRR design contract in part because it put forth an innovative solution that went beyond a 3D digital twin. Using GIS technology, HNTB pioneered a 5D project management strategy that integrated interactive 3D models with the additional dimensions of time and cost.

This 5D approach empowers project leaders to track and predict how design changes might affect scheduling or construction costs and to adjust their decisions accordingly. It's a strategy that illustrates the direction that many firms across industries are beginning to take, in fields from supply chain management to ski resorts. Pairing the insights of GIS—known as location intelligence—with digital twin models, business leaders can combine easy-to-understand visuals with a powerful geospatial engine for data analysis.

Press Play to View Your Project in 5D

With HNTB now nearing the finish of the design submittal stage, the design team is using the 5D digital twin model as it prepares for the construction phase. While looking at a virtual replica of Jamaica Station tracks, project planners can pull a slider along the bottom of the screen and scroll through 36 months of forecast progress, seeing how far a new section of rail will extend by March 2022, for example.

Alternatively, an executive can press Play on a three-month period of construction and watch a split screen that pairs an animation of a pier being built with a graph that charts the costs tied to that portion of the project.

The ability of GIS to integrate different types of data and software in a cloud-native environment makes it possible for anyone associated with the LIRR project to access the visualizations via a web browser.

"A solution like this was critical because trying to convey these complex designs and this complex phase of construction is always a challenge for all the stakeholders," said Jeff Siegel, a vice president and the Technology Solutions Center director at HNTB. "Now, because of the way we've done this, they can pull up and play what the actual construction phasing will be and what the outlay of cash will be based on estimates down to the unit level."

A Web-First Philosophy of GIS Fuels 5D Interactivity

Jamaica Station is part of a heavily trafficked transit corridor that transports over 200,000 passengers a day. The redesign project was important to many stakeholders, including partner agencies, local politicians, and transit officials. A 5D digital twin that was opaque or designed only for those with engineering backgrounds wouldn't work—city council members might not be knowledgeable in AutoCAD.

After Siegel and the HNTB team surveyed the options, they concluded that GIS was the best foundation for executing a 5D digital twin plan of the JCI project.

The 5D digital twin created for the project includes details on the rail line's connections to the community.

"GIS is really the only platform that can truly provide that sophisticated integration or convergence of both the location of something as well as the attributes," Siegel said. "That enables such a strong coupling of the analytics when you want to pull all of that together."

The importance of communication and collaboration on JCI led Siegel and Darin Welch, the project lead and associate vice president of geospatial and virtual engagement solutions, to prioritize a cloud-based, web-first approach. In the past, shareable maps were sometimes among the last things to be produced as a project was wrapping up. That set the stage for a new era, with GIS as a key part of digital innovation delivery.

Welch, Siegel, and their team of technologists established a web-based GIS strategy to drive the 5D project from the start, acting as a centralized, authoritative data source where information would be updated continuously and open to any team member—internal or external—who needed access. With that model in place, workers who went into the field to perform inspections of the track and take photos were able to upload such data directly into the GIS platform, making it available within a 5D view.

"It's really changed the way many people in our organization think of GIS, because location is such a critical dimension of the data we leverage within the AEC space, and it's an approach we continued perfecting on Jamaica Station," Welch says. "We see much more openness and willingness to leverage the power of GIS because we can take, with confidence, design information overlaid with other rich GIS datasets and tapestry, then allow that to influence our decision-makers, who are sometimes public."

Geospatial Problem-Solvers

It was this proclivity to pursue new ideas that landed Siegel and Welch the assignment to implement the 5D digital twin approach. The original idea for the 5D digital twin came from HNTB's New York-based design team to help LIRR manage the complex schedule and budget of the Jamaica Station project.

The 3D animators on the HNTB marketing team created an animation for the company's pitch to LIRR decision-makers. Once HNTB won the project, it was up to Siegel, Welch, and their colleagues to turn the concept into reality.

Siegel and Welch are part of the Technology Solutions Center, an HNTB center of excellence aimed at seeding digital infrastructure solutions throughout the company. Centers of excellence are an increasingly common unit at forward-thinking organizations.

Created by Siegel, a 27-year veteran of the company, the center provides consulting, advisory services, and implementation on many cutting-edge fronts across the company. Its members help other departments think through questions such as how to streamline an asset management solution or govern data better.

In a company of 5,000, the center employs 45 individuals who focus on specific "patterns," including infrastructure solutions, civil integrated solutions, asset management and resiliency, and geospatial and virtual engagement—the group Welch runs. As opposed to a Skunk Works group, they're a profit-making center, meaning their innovations must produce bottom-line value.

Because of that profit drive—and because so much of HNTB's work is grounded in location—GIS and geospatial intelligence are often the lens through which the team views challenges and solutions.

"Darin coined the term 'geospatial problem-solvers,' and that's the common thread we're looking for, whether it's a new GIS analyst that we just hired or a senior developer we recruited," Siegel says. "We're constantly looking for somebody who has that mindset of, 'OK, here's the problem. How do we solve it using the latest, greatest tools that are proven?'"

Capitalizing on the Wisdom of the Crowd for Tech Integration

Due in part to client demand, HNTB was already using digital twins on projects including airports and wastewater facilities. A coastal resiliency program for New York City had even employed 5D visualization. But Jamaica Station would be one of the company's most comprehensive applications of digital twin technology and 5D elements, incorporating both horizontal and vertical infrastructure.

Two new tracks are being added to Jamaica Station.

To sketch out possible approaches, Siegel convened a lunch meeting at HNTB's Chicago office that ended up stretching across four hours. With boxes of deep-dish pizza on the conference table, the diverse team pulled up potential apps on a projector and filled dry-erase boards with scribbled ideas. They brainstormed what the best toolsets would be, how to enable them to work together, and how to make it all accessible via the web.

Welch's management philosophy—which reflects the interdisciplinary nature of GIS—is to bring together multiple points of view, and the meeting included specialists in several digital technologies. His team of 10 includes urban planners, transportation engineers, developers, senior analysts, and a geo-tech engineer.

"Diversity has always been important to me—bringing insights from lots of different backgrounds and interests to see how we can leverage these technologies to make our processes and deliverables more efficient," Welch said.

By the lunch's end, they knew GIS would be the hub of the wheel, fed by numerous software spokes responsible for replicating the surfaces, objects, and streets in the digital twin visualization. Although much of the design data was provided directly from the project team, a GIS-based "world building" tool gave the 5D immersive experience more real-world context by adding surrounding buildings and features.

An interdisciplinary team brought the vision to life. Senior GIS developer Ian Grasshoff became the visionary behind the web-based viewer; senior GIS architect Bill Cozzens helped design the realistic environment and city blocks around the rail's digital twin; and Scott Lecher, lead BrIM specialist from HNTB's civil integrated solutions team, helped align the visual elements into a smooth, scripted process.

To create the 5D view, the team built cost and calendar estimates from the ground up, taking advantage of the fact that each infrastructure element on the project had a cost and activity ID assigned to it. As the digital twin moves through time and a piece of a bridge pier or a track tie is set into place, that unit is added to the cumulative cost and tied to that section of timeline, synchronizing the three main elements of project management—scope, cost, and time.

With the digital model available to all stakeholders, planners can rally around a holistic view of the project, with communication grounded in a shared understanding of the plan.

"We've often referred to GIS as a natural integrator," Welch says. "We're using it as a way to visualize multiple components from nearly every discipline in a meaningful way. We're taking data, which these projects have vast amounts of, then turning it into information. But more important is turning that information into knowledge that supports decision-making."

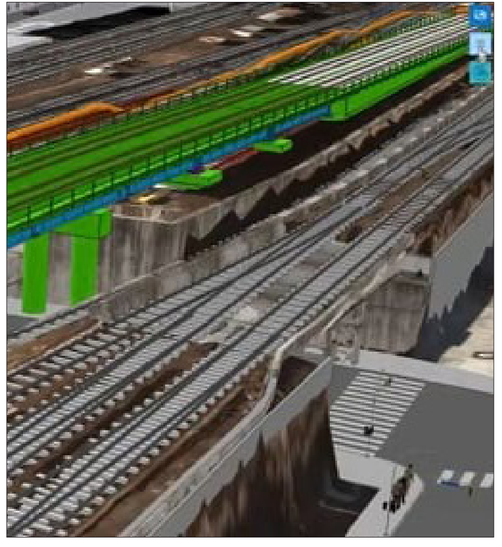
A 5D Digital Twin Strategy Sets a New Standard

Siegel anticipates that projects such as this will raise the expectations for consultants such as HNTB. "I have calls every week about a client asking, 'I heard about this digital twin strategy. Should I be doing it?'" Siegel said. "We're seeing this concept really get a lot of interest."

He expects that in the future, elements such as 5D and digital twins will become part of other firms' offerings, even in fields beyond architecture, engineering, and construction. For example, with executives paying more attention to workforce development gaps, visual, interactive twins could be key to transferring knowledge from retiring workers to new hires who need to become productive quickly.

Anytime visual, location-based projects need to be shared with stakeholders, a GIS-based digital twin can be ideal for translating data into clear, digestible 3D—or 5D—formats.

"It really is a big difference maker," Siegel said. "It's not a prettied-up rendering. This is real data coming from the design …. in an effective manner that's still visually pleasing and readable, but navigable as well."



New tracks are highlighted in green in the 5D digital twin of the Jamaica Station project.

Expediting Water Relief for the Navajo Nation

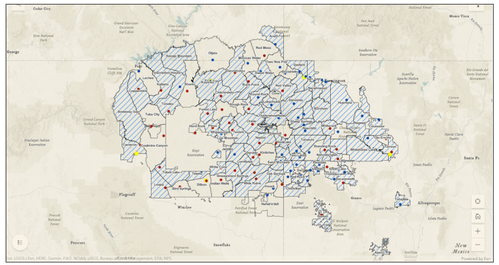
In April 2020, as the magnitude of the coronavirus pandemic and its impact were becoming readily apparent, Commander Ryan Clapp, a staff engineer with the Indian Health Service (IHS) in Washington, DC, flew to Albuquerque, New Mexico. Upon arrival, he bought eight pay-as-you-go cell phones from a retail store and loaded data collection apps on them. Within 48 hours, he had a team of Navajo Area IHS technicians spread out to map water access points on the trial nation using the mobile devices.

While he was in the air, IHS headquarters staff were developing a comprehensive field survey, talking to the Navajo Tribal Utility Authority, and doing all the background work. "We were building things as we were going, and it was moving very fast," said Captain Ramsey Hawasly, assistant director of the Division of Sanitation Facilities Construction at IHS and lead GIS program coordinator.

This rapid response was requested by the Navajo Nation president because of the COVID-19 public health emergency. At the time, the Navajo tribe was experiencing the highest incidence of COVID-19 cases in the United States, and the long-standing lack of in-home water access was assumed to be a driver of these infections.

Sandstone towers rise as high as 1,000 feet above the valley floor in Monument Valley, located within the Navajo Nation.

A total of 59 new water access points were created with CARES Act funding. (Image courtesy of the Indian Health Service)



Thev status of water access for each chapter on the Navajo Nation.

The heightened need for handwashing during the pandemic posed a challenge for the many homes without water. For many years, the rugged topography and remoteness of the Navajo Nation made piping water to homes challenging. Since 2003, IHS and a network of partners have reduced the number of Navajo homes without water access from 30 percent to 20 percent. New funding from the Coronavirus Aid, Relief, and Economic Security (CARES) Act provided the Navajo Area IHS with $5.2 million, targeted specifically to increasing water access on the Navajo Nation.

The IHS team used a GIS to map and share construction progress on new water access locations. Many are at or near chapter houses, which serve as county-level governments.

"We were able to collect data in all 110 chapters with just six surveyors, covering an area the size of West Virginia in just two weeks," said Captain David Harvey, deputy director of the Division of Sanitation Facilities Construction at IHS.

Immediate Short-Term Actions to Improve Water Access

Through the GIS data collection efforts, the CARES Act funds supported the installation of 59 new transitional water point (TWP) connections to existing public water systems; supplied 37,000 water storage containers; distributed 3.5 million water disinfection tablets; and subsidized the water for people living in homes with no piped water through February 2023.

The data that Commander Clapp and the team collected was critical in identifying locations for needed facilities. It set in motion additional mobile work to design each access point, calculate construction costs, and place orders for the right amount of pipe needed to make new connections.

A new water access point, now fully operational, was added near the Rock Springs Chapter house.

Building the Capacity to Act Together

Just four months before the start of the pandemic, IHS implemented technology that a group of GIS advocates had been excited to put into action for four years. This group took a change management class to learn how to prepare colleagues for significant process change.

"Luckily, we were already moving in the enterprise GIS direction before the pandemic hit," said Captain Shari Windt, engineering consultant for the Environmental Health Support Center at IHS. "We installed ArcGIS® Enterprise portal in 2019 and had been working to gain energy behind it."

The Navajo Water Project provided the opportunity to push digital workflows to the field using a suite of ArcGIS apps—ArcGIS® Survey123, ArcGIS® Collector, and ArcGIS® Dashboards—to equip field crews with the ability to collect data and provide updates on a central dashboard. The shared map led to new levels of collaboration.

"This project really helped the rest of the program see how beneficial this could be," Captain Windt said. "Rather than have information stuck in files or drawings, anybody with access can get to it."

The IHS made a digital leap forward in 2004 with the launch of the Sanitation Tracking and Reporting System (STARS). This move consolidated databases that track infrastructure deficiencies in homes and communities; requests for water service to home sites; documents and details of operations and maintenance projects; and service requests. STARS serves as an inventory of tribal sanitation needs, and it put 400,000 homes on the map because the program focuses on serving homes in communities.

A new water access point, now fully operational, was added near the Rock Springs Chapter house. (Image courtesy of Indian Health Service)

"With the STARS system, we were able to access a lot more data and understand costs really quickly," Captain Windt said. "Now with GIS, we have the opportunity to combine all individual project drawings into composite drawings and make them readily available to IHS staff as well as our partners. We envision that the tribes will be able to leverage the GIS information gathered by the IHS to improve their operation and maintenance capacity, which support the water and wastewater facilities constructed with funding from the IHS and other federal agencies. It will allow the IHS to better understand each water and wastewater system as a whole, which will improve the technical support IHS can provide tribes."

The fast-paced construction lasted from mid-July through September 2020. It was guided and communicated through shared maps and plans at each step. An online interactive map marked progress for each chapter. In addition to the online map, a regularly updated map appeared in tribal newspapers because the newspaper is the primary source of information for many homes.

"We were changing colors on the map, based on whether or not there was an identified transitional water point for each chapter," said Captain Windt. The map changed when water points were slated for construction, design was being done, the construction was complete, and the water point was open. A final color was used when a chapter had all the interventions available.

The map guided the workers and the people they were serving to the new TWPs. Using GIS analysis, IHS calculated that the travel distance dropped from 52 mi. to 17 mi., saving people an average of 38 minutes behind the wheel for each trip.

Supplying Off-the-Grid Resources

Just as the water access work was wrapping up, the Navajo Nation Department of Water Resources (DWR) reached out to IHS under a separate request for help on bridging the gap for remote homes without access to a piped water connection.

DWR requested that IHS provide detailed design project drawings for a water cistern and on-site wastewater disposal facilities. Again, IHS stepped into action, deploying 15 Commissioned Corps engineers and environmental health officers of the US Public Health Service to undertake data collection.

"The cistern project is really beneficial because you can have bathrooms with showers and toilets, and sinks in kitchens," Commander Clapp said. "The homeowners still have to haul water, but it's a bridge to more sustainable services, such as a connection to a piped water system."

The data in the STARS system combined with analysis in GIS allowed IHS to identify 900 top candidates and provide a map of those homes.

Commander Clapp led three teams made up of five people each that spent a month in the field on assessments. For each home visited, the team gathered design data from the site to determine where the water storage tank and sewer facilities should go. Team members also assessed any potential problems, such as the location of large rocks or obstacles that might hinder construction or site access.

"It was a collaborative effort, and it was done in a quick and efficient manner," Captain Hawasly said. "The Navajo Engineering and Construction Authority could access the data collected to quickly create plans and drawings for approximately 70 homes."

This pandemic work spurred the creation of the Water Access Coordination Group, which includes four Navajo government entities, six federal government agencies, three universities, and two nonprofits. Bringing water to homes is something that everyone working on these projects feels passionate about.

"It shouldn't have taken this disaster to get us here, but now there's a whole new recognition of what tribal resilience means and how the federal government can work together," Captain Harvey said.