Michigan Surveyor

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"In the end, it's not the years in your life that count. It's the life in your years."
-Abraham Lincoln

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Massive Data Fusion Yields Award-Winning I-75 Design Survey

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Two miles of eight-lane highway and two bridge structures, including the largest concrete bridge deck in Michigan, were quickly and cost-effectively mapped for MDOT to design future deck replacements. (Image credit Google Earth)

With replacement of the I-75 bridge decks over both the Rouge River and Fort Street in Detroit, MI, scheduled for 2017, a design survey was needed to collect data and map the 1967 bridges, approaches and ramps. A massive amount of survey data was collected on 2 miles of 8-lane highway, including the 1.5-mile bridge over the Rouge River that boasts the largest concrete deck surface in Michigan comprising more than 1 million square feet, including ramps. This bridge is supported by 105 piers up to 100 feet high and connects to the 822-foot bridge over Fort Street to create the 2-mile span. The data was quickly and cost-effectively collected and fused to provide the Michigan Department of Transportation (MDOT) with a comprehensive, detailed and highly accurate dataset for use by design and construction engineers during reconstruction. The project received a 2016 Eminent Conceptor Award for Surveying Excellence from the American Council of Engineering Companies of Michigan.

A combination of Mobile Terrestrial Lidar (MTL) scanning, Stationary Terrestrial Lidar Survey (STLS) scanning, and conventional surveying technologies was used; the largest application of its kind that has been completed in Michigan. The 3D coordinate system, upon which all mapping data would be referenced, was set up in both State Plane Coordinate (NAD83-MI-South NAVD 88) and local ground coordinate datum for ease of design and construction of critical bridge beams.

All hard surface highway mapping was completed using MTL scanning to quickly capture data for the bridge decks while minimizing impacts to traffic. This technology was also a safety benefit, limiting surveyors' exposure to a high traffic highway with narrow median (5-foot) and outside (7-foot) shoulder widths.

The STLS scanning component of this project was enormous, taking nine weeks to capture all substructure and superstructure elements. Locations of the beams and piers were determined so the design engineer can calculate the rebound of the beams when the existing decks are removed and the deflection of the beams when the new decks are placed.

Wade Trim led a complex design survey of I-75 over the Rouge River and Fort Street in Detroit that required the largest application of MTL scanning, STLS scanning, and conventional surveying ever completed in Michigan.

Conventional static scans and mapping were used for terrain under the bridges and up to 100 feet on either side of the bridges for features like street curb and gutter, drainage structures, driveways, sidewalks, poles, fences and hydrants. Conventional mapping also captured areas with trees and brush where scanning could not be used.

Wade Trim managed the project, led the survey team, applied for permits, coordinated the subconsultants, completed all STLS scanning beneath the bridges and obtained measurements on the highest bridge bearings. In addition, we completed field checks on control and digital level loops, provided quality control and statistical adjustment of the control that was used by all surveyors, and completed final editing and merging of mapping from all sources. Surveying Solutions, Inc., completed primary control work, digital leveling and all MTL scanning and mapping of hard surfaces. OHM Advisors completed intermediate control work, digital leveling, conventional mapping under the bridges and all alignment/right-of-way tasks. Highway Service Company provided traffic control and maintenance services.

Survey Techniques Minimize Impacts to Bridge Users

Impacts to the bridges' 115,000 daily drivers were minimized by maintaining this critical, north-south link between Detroit, the Downriver area and the Ambassador Bridge to Canada throughout the project. This need was intensified due to the closure of two nearby spans over the Rouge River that resulted in motorists being rerouted to the I-75 crossing. Numerous surveying challenges were addressed to minimize lane closures, obtain detailed superstructure data at great heights, and work in difficult and congested urban ground conditions. To keep the span open as much as possible, survey preparation work was limited to the outside lane and shoulder on the northbound and southbound sides during 10-hour periods on two successive Sundays during low traffic times. Also, weekends were chosen to avoid major sporting event traffic. Six field crews set survey targets and completed GPS and leveling tasks. Once the targets were set, MTL scanning was used to collect all deck area data from a vehicle at near highway speeds without any disruption to traffic flow.

Unique to a surveyor's typical equipment, a 135-foot-high boom lift was used to directly measure the distance between the top of piers and bottom of beams (for bearing dimensions) and top of pier to bottom of deck slab (to determine haunch heights) as well as complete laser scanning under the deck at limited locations north of the river. Surveyors were lifted up to 90 feet to collect data needed. Laser scanning was completed at these heights from a specially designed bracket hanging under the bridge beams to obtain detailed information about the dimensions of various elements, such as pin and hanger cross bracing and haunch depths, on certain areas of the bridge.

A boom lift was used to complete STLS scanning of superstructure elements at heights up to 90 feet. Challenges included maneuvering the equipment around fences, streets, saturated soil areas, power lines, and numerous railroad tracks.

Poor working conditions under the bridges intensified survey tasks. The surrounding area includes urban blight and several industries, such as a cement plant, that produce prodigious amounts of dust, dirt and smoke. Before STLS crews could tape paper targets on columns to control the STLS scanning, up to a half inch of grime had to be removed. Surveyors wore personal protection equipment, including respirators, to limit exposure to bird waste and nest debris. Vandalized fencing under the bridges contained dangerous steel stubs sticking out of the ground that impeded movement of trucks and equipment. A few areas near the river were used as a dumping ground for garbage and debris that hindered access with the lift. At one point, a stolen car left under the bridge prompted an emergency response that delayed work.

With several trains also using the tracks under the bridges each day, survey crews had to be in constant contact with two separate railroad companies who maintained full-time staff on-site. Crews would receive calls from the railroad to coordinate moving the boom lift near the tracks to obtain pier cap measurements and to inform the STLS scanning crew when they needed to avoid the tracks.

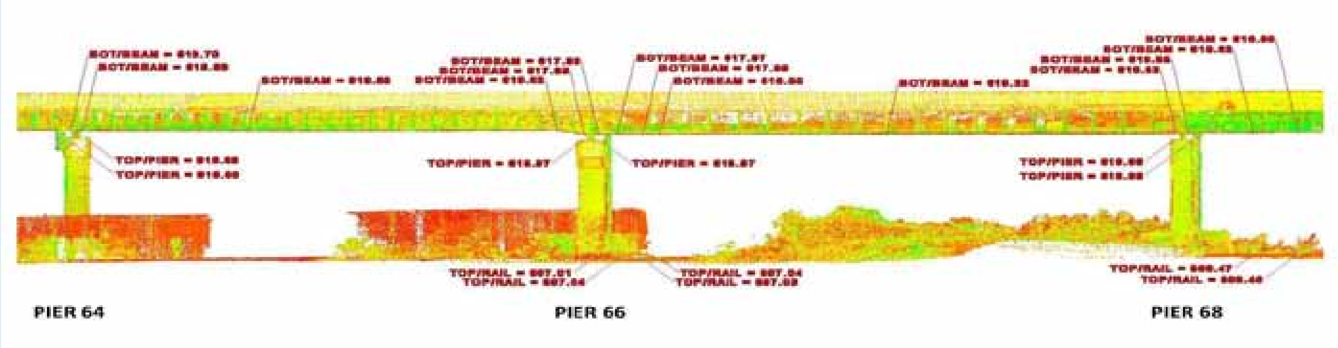
The 23-ton boom lift had to be maneuvered around fences, streets, saturated soil areas, power lines, and numerous railroad tracks. Several times, the lift broke through a thin, dry crust of soil to become stuck in previously unknown underlying saturated soil, and in a few instances, required a towing firm to pull the lift back out. The lift could not get close enough to the river piers due to steep terrain and fenced areas. These piers had to be laser scanned from the opposite side of the river using a tripod on top of caisson piers. In addition, the lift was vandalized which called for extra precaution at the end of each day to limit future risk.

Data Management and Control Approach Yields High Level of Accuracy

The project development process began with MDOT's original scope of work with general procedures for MTL, STLS and conventional survey methods while keeping the bridge open to traffic. Wade Trim worked with MDOT to modify and refine the STLS scanning procedures to be used under the bridge to give them a clearer understanding of scope and cost. The right mix of surveying technologies was used to cost-effectively detail all the elements critical to engineers designing the improvement project, eliminating the need to return to the field. Every aspect of the survey, from alignment retracement and control computations to boundary determination, mapping and terrain processing was thoroughly checked throughout the project.

Survey mobilization and coordination between three surveying firms was critical to completing this highly complex project. MDOT's Detroit TSC was involved with arrangements for the mobile scanning work and temporary I-75 lane shutdowns. The project's alignment had to be calculated along the entire corridor that features right-of-way with both partial and total takes of lots within plats dating back to 1889 along with railroad property. Permits were required from MDOT for the highway work and two railroad companies for terrain surveying under the bridges.

A complex control network with 6 primary control points was established using GPS and repeatedly verified to achieve the design survey's 0.02-foot primary control network accuracy requirement. Concrete monuments and iron pins set throughout the project enabled all surveyors to work off the same system. Control targets were set and located with RTK GPS twice to make sure they were correct and then levelled twice over the bridge decks to verify their elevations. MDOT requires topographic data to be within 0.05-foot accuracy and a 5% minimum check of all control points, benchmarks, MTL mapping points and STLS points. The team achieved these requirements to verify data accuracy and build confidence that the final mapping data would combine well. Spreadsheets were prepared showing the differences in coordinates and elevations on checked mapping points between the three surveying firms. To account for vibration impacts from traffic movement, MTL scanning crews ran digital level loops back and forth across the bridges four times, collecting a higher amount of data than usual to raise confidence in the average elevation for each control target. MTL scans were adjusted using a combination of automated and manual processes within the scanning software. These methods achieved very satisfactory results.



STLS scanning under the bridges allowed all underclearance and offset dimensioning to be shown on digital scans with near photographic quality.

Editing, merging and delivering this massive survey was complicated. The total number of collected laser scanning points from the MTL and STLS methods exceeded 200 million. Extracted mapping points exceeded 25,000 for MTL, 5,000 for STLS and 5,000 for conventional survey work. Survey data was gathered in multiple ways and merged with somewhat different but acceptable accuracies. Data management was further complicated by MDOT's requirement to deliver the project using the typical State Plane Coordinate system as well as a local, ground coordinate system to provide horizontal distances as close to real world as possible. Bridge beam to top of pier dimensions and elevations were shown by overlaying the actual measurements obtained by boom lift onto laser scanning imagery .pdf files.

The extensive amount of as-built information provided in the mapping and database exceeded what was required. MDOT normally requires drafted sketches showing railroad and street underclearances prepared from survey and scan data. For this project, the STLS scanning under the bridges allowed all underclearance and offset dimensioning to be shown on digital scans with near photographic quality. This provided MDOT with extensive information in each diagram. An added benefit was the digital scans also showed the vertical layout of downspouts attached to many of the piers that will be used for possible future redesign of the downspouts. The design survey will also serve as a source of information for future assessments of bridge deterioration.

This survey was completed using the largest combined application of Mobile Terrestrial Lidar (MTL) scanning, Stationary Terrestrial Lidar Survey (STLS) scanning, and conventional surveying ever completed in Michigan. Numerous challenges were overcome by developing a project approach that addressed heavy traffic, trains, difficult and congested working conditions, and impediments to equipment mobility. In addition, bridge heights up to 90 feet required surveyors to use a 135-foot-high boom lift to measure distances to determine bearing dimensions and haunch heights, and complete limited laser scanning. Data accuracy was critical. Control targets and mapping data were repeatedly verified to account for vibration impacts and achieve required accuracies. Data gathered from the various survey methods was edited, merged and delivered as comprehensive and detailed mapping that eliminates the need to return to the field during design.

The use of combined surveying techniques delivered as-built information within an expedited, four-month schedule, and enabled MDOT to let their 30% engineering design contract for deck replacement in Spring 2015. Scanning technologies supplemented conventional methods, saving time and money. A complete mapping survey using conventional GPS and total station methods was considered, however, it would have been far more expensive and time-consuming with significant impacts to traffic. In addition, the near photographic quality of the laser scan point clouds provide far more information than a conventional survey which will support investigation of design and construction alternatives as well as future assessment of bridge deterioration.

MTL scanning quickly captured all hard surface highway mapping from a vehicle at near-highway speeds, minimizing impacts to traffic and improving surveyor safety.

STLS scanning of substructure and superstructure elements was completed over nine weeks using an approach that overcame challenges posed by difficult and congested working conditions, rains and impediments to equipment mobility.