



# BRIDGES

## UNDER TROUBLED WATERS

New methodology for inspecting the health of our underwater infrastructure

**BY KENNETH LABRY**

According to the Federal Highway Administration's National Bridge Inventory, there are approximately 502,000 bridges that span across a waterway in the United States. A significant number of these have foundations that sit below the water.

To ensure the safety of the traveling public, the FHWA established the National Bridge Inspection Standards as a formalized way to monitor and evaluate existing bridge deficiencies. For bridges with substructures located in water with a depth greater than four feet, the standards require that underwater inspections be conducted at least every five years.

Historically, divers who conduct underwater bridge inspections have faced some challenging environmental conditions. Often murky waters offer poor visibility, while the rapidly flowing water presents hazardous diving conditions. Without good visibility, divers must perform

the entire inspection underwater by literally feeling the structure, and with vast surface areas, this becomes impractical. Compounding these issues, divers often must contend with intense commercial shipping traffic in close proximity to the structures being inspected. These conditions pose a significant risk, making substructure inspections not only dangerous, but in some cases, impossible to complete with diving alone.

### Trends in Safety and Technology

In recent years, we have seen a societal initiative to use robotic and remote sensing systems for tasks that previously put individual safety at risk. Rapid advances in technology have provided a way to produce imagery from sound reflections that are more representative of a photo image than a sonogram. Interpreting high-resolution images is not only an easier process, but the end result is more evident.

In 2005, Fenstermaker, our firm which specializes in surveying, mapping, engineering and environmental consulting, took the initiative to develop a better solution for capturing underwater imagery. By modifying methods developed primarily for oil exploration and production, the company developed techniques suitable for inspecting submerged infrastructure components. Using underwater acoustic remote sensing, primarily sound navigation and ranging (sonar), a process was developed to acquire, process and analyze scan data. This process would not only provide the information necessary for a general investigation, but a detailed inspection of submerged infrastructure as well.

Using this technology, Fenstermaker has successfully performed underwater inspections on bridges, dams, flood control structures, docks and wharfs for railroad companies, state agencies, municipal entities and port authorities.

Initial forays into underwater bridge inspections with underwater acoustic imaging evolved in support of emergency inspections that arose. This kind of imaging proved especially practical when severe weather events like hurricanes made conditions too hazardous and high risk for divers. It was also used when a commercial vessel collided with a bridge structure, and the surrounding substructure area became particularly vulnerable. The results from these efforts provided exemplary results in rendering imagery of the bridge supports and their junction with the water bottom.

## Louisiana Bridges Lay the Foundation

The State of Louisiana is known for having some of the largest bridges over the most rapidly flowing, deepest and murkiest waterways in the nation. The water conditions of the Mississippi River Delta and many of its tributaries make inspections of these substructures problematic by traditional diving methods. The poor visibility had made it difficult to perform a tactile inspection of 100 percent of the structure surface in a reasonable amount of time. Faced with this situation, the Louisiana Department of Transportation approached the FHWA with a proposal to use underwater acoustic imaging, in conjunction with diving, on these problematic bridges. It was recommended that this method be implemented for inspecting 70 bridges in Louisiana, all of which were in similar challenging environments.

Fenstermaker was selected to lead this project, primarily because of our proven capabilities in using this technology for pilot projects and post-collision damage assessments for underwater inspections of highways, railroad bridges and dam structures. Over the course of two and a half years, we successfully completed all of the inspections, working in conjunction with bridge engineers and dive teams including Huval and Associates, Inc. and Infrastructure Engineers, Inc.

Since future inspections are required at a minimum of five-year intervals

and must be performed in the month of the five-year anniversary of renewal, Fenstermaker performed the Louisiana bridge inspections in manageable groups, resulting in practical distribution for future inspection schedules. The inspections were executed with the supervision of a certified bridge inspection team leader. A dive team was available in the event the observations required further investigation.

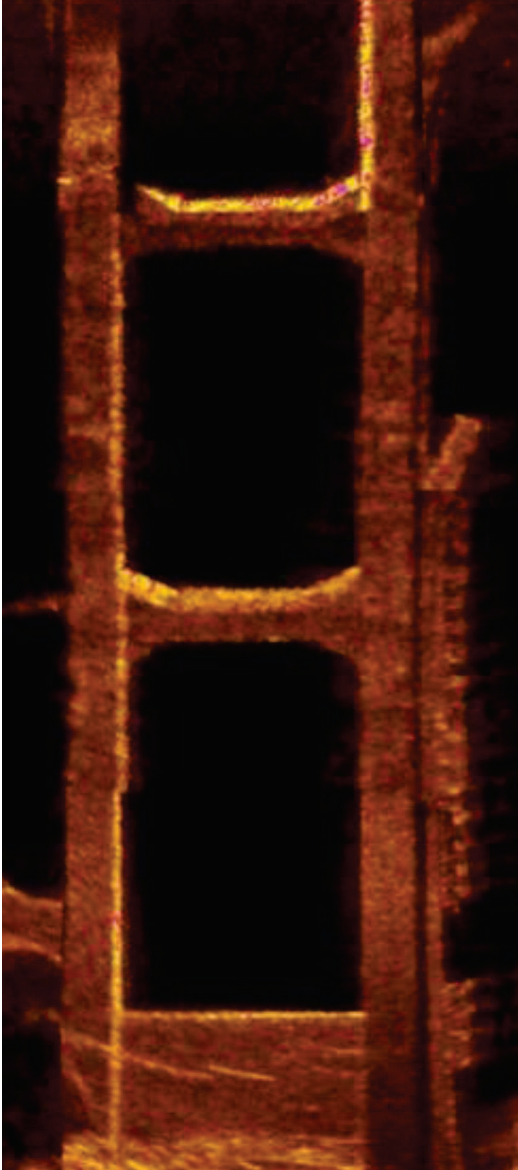
Localized scour profiles at the pier noses were generated, and the imaging data was processed and mosaicked while maintaining spatial accuracy. A project team meeting was then held to discuss the results and direct any necessary diving follow-up inspections to investigate identified anomalies.

When needed, follow-up dive investigations and inspections were scheduled, and the conditional and environmental assessment was provided by the underwater acoustic imaging investigation. This ensured an additional element of diver safety because it informed the dive teams of potential underwater challenges and where they were positioned. Multiple types of bridge support structures were inspected in different types of inclement environments. The underwater acoustic imaging system performed well, irrespective of weather and environmental conditions. High turbidity, rapid water flow and close proximity of commercial vessel traffic, such as ships and barges, had little impact on our results.



For submerged bridge inspections where diving conditions are hazardous, Fenstermaker has proven the effectiveness of underwater acoustic imaging.

In areas that are difficult to reach, a remote control robotic surface vessel carries the sonar sensor to the pier face.

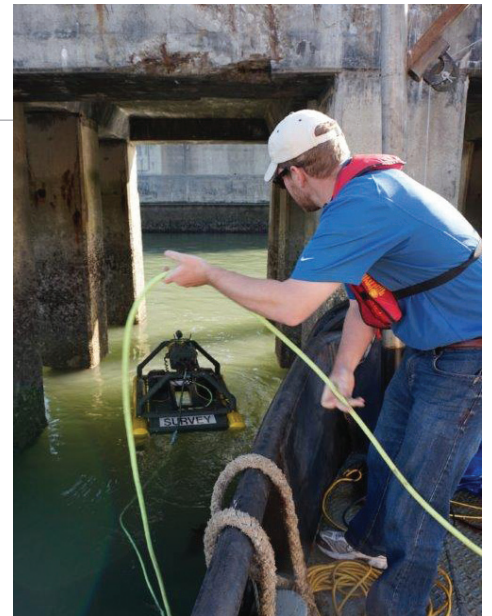


When underwater video proved completely ineffective for Alabama's Duncan Bridge, Fenstermaker was contracted to conduct underwater acoustic imaging.

Fenstermaker's specialized techniques made the evaluation of these Louisiana bridges a pioneer project. This was the first time the FHWA approved the methodology of remote-sensing technologies for submerged bridge inspections. Subsequently, a solution was developed for the underwater inspection of flooded culvert bridges. Several of these were added to Fenstermaker's project scope, and were recently completed. The culvert projects required that the current instrumentation be adapted to allow the sonar to capture the image along the walls of the culvert conduit. A robotic deployment platform and a remote-controlled survey vessel were added. In order to expedite data collection, customized deployment mechanisms were developed and implemented over the last two years.

### Applications in Alabama

In March of 2013, the Alabama Department of Transportation contracted with Fenstermaker to perform an underwater bridge inspection on the Duncan Bridge over the Sipsey River. This bridge is supported by two piers on either side of the river, set on very steep slopes going down toward the channel center. The bridge was problematic because of the water depth and the lack of access by commercial vessels. With a water depth that exceeded 200 feet under the bridge, an underwater video was mounted on a remotely operated vehicle. However, because the video provided inconclusive results, there was concern over the disposition of the bridge footings. In light of the excessive depth, Fenstermaker utilized its underwater acoustic imaging system, which generated clear images of both piers and



generated a bank-to-bank water bottom profile between them. The excellent imagery of both piers and pier footing dispositions provided the level of detail necessary, and the data acquisition was completed in one day on-site.

### California Oversees Multi-State Testing

In March of 2014, Fenstermaker was contracted to participate in a study funded by several states and the FHWA, managed by GENEX Systems, with technical oversight and site provision by the California Department of Transportation. The purpose of this study was to capture sufficient data to substantiate the usefulness and validity of using only underwater acoustic remote sensing for Level 1 underwater bridge inspections.

The sites selected by the California Department of Transportation and GENEX were chosen to best represent two widely varying scenarios. The sites included the west span of the Oakland Bay Bridge from San Francisco to Yerba Buena Island, and the 3<sup>rd</sup> Street Bridge near AT&T Park in San Francisco, which serves as the Giants' baseball stadium. The two bridges provided multiple challenges, from significant tidal flow, to restricted access and close

With poor visibility and risky environmental conditions, technology offers more detailed inspections than divers alone can provide.

proximity to commercial and pleasure boat traffic.

An additional deployment platform was employed to allow proper implementation in the restricted access areas. This was the use of a small footprint, remote-controlled robotic surface vessel that carried the sonar sensor to the pier face. The underwater inspections as directed by GENEX were performed over the course of two days with no problems encountered.

### High-Definition Results

Remote sensing systems offer a cost-effective option for conducting underwater substructure inspections that delivers high-definition sonar imagery and precise acoustic profile measurements. With a control baseline for future surveys, the system provides accurate data that can be used to compare previously recorded structure conditions. It can also be used in providing a comprehensive spatial element image of underwater structure surfaces and their interface with the water bottom.

One reason why the methodology works so well is because the sensors record and process reflected acoustic responses, and this creates a continuous flow map rather than a field of sporadic acoustic responses. This continuous surface trace can be easily translated to a detailed image. The ability to scan the acoustic beam along the surface of interest allows for the detection of the smallest relief anomalies while generating the highest possible resolution in a translated acoustic image. Utilizing the dual capability of the instrumentation allows for accurate and quick mapping of the localized scour impact around bridge



piers. This offers an enhanced perspective of the bridge pier environment while maximizing resources.

The bridge inspection system also offers flexibility. If modifications to the basic sensor systems are necessary, these add little cost and expand the capabilities for underwater bridge inspections. The design, construction and implementation of custom deployment platforms, coupled with a fully articulated sensor mounting offers a unique opportunity to effectively and efficiently image bridge piers of all types and in all environments.

### Value-Added Benefits

As is evident from roughly 100 bridge inspections, the use of underwater acoustic imaging offers significant benefits when implemented properly. The technology and methodology reduces the risk to divers by minimizing the amount of diving needed. When a diving effort is necessary, it reduces the potential hazards by providing information regarding the condition and disposition of the underwater environment, informing the dive team about the position of obstructions, debris and possible hazardous features.

Underwater acoustic imagery provides an overall perspective of the bridge piers and adjacent water bottoms that is not achievable through diving alone. It also facilitates the assessment of localized scour impact that, in many cases, a diver is not able to attain because the impact extends too far from the pier for the diver to be able to determine the transition. Using underwater acoustic imaging for below surface bridge inspections minimizes risk, adds safety benefits and provides more detailed and precise information.

The ability to construct a repetitive methodology for underwater bridge inspections has proven its applicability to large-scale projects, which the FHWA has found acceptable. These methodologies are currently being studied, and if approved, can be utilized for mandated underwater bridge inspections going forward. 🌟



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