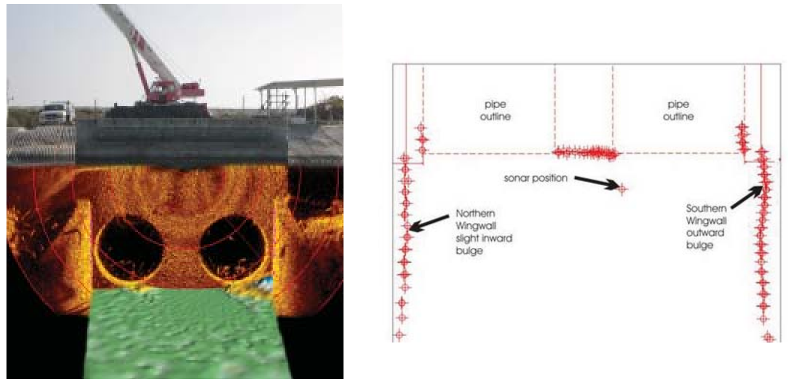

Figure 5: This composite image of headwall structure was produced by combining a regular photograph with sonar images collected using a dual-axis system, as well as the bathymetric data obtained form the scan.

more advanced presentation of the sonar data collected. This figure shows a sonar image scan of two pipe openings in a headwall structure that was combined with a regular photograph of the above water structure and the rendered bathymetric data collected using a dual-axis sonar system. The image scan shows a slight offset (or bulge) of the two pipes (see right side of figure). The inspection team was not convinced that this was an accurate interpretation of the image. However, there was no means of verifying or proving it otherwise because the pipe outlets were active and no manned entry was allowed.

Because all the other dimensions made from the sonar data matched the construction drawings, the sonar technicians and engineers question the interpretation of the offset. The 3-dimensional point cloud data from the headwall structure was further examined and a horizontal slice of data at the pipe spring lines was extracted from the data set. This revealed a "one in a thousand" scenario that caused this type of image. The slight bow in the wing wall just in front of the headwall was a construction feature that was in line with where the image scan was completed. Because the sonar equipment was measuring the distance from the head to the target, this deformation made it appear that the pipe opening was offset. Only the point cloud data collected from the dual-axis system could provide this type of information and confirm that "gut instinct". (Divers who were involved with construction work on the headwall later confirmed this deformation.)

Four-dimensional sonar

An extension of this 3-dimensional data is the fourth dimension that sonar data can provide – intensity of the return echo. Amongst other variables, the strength and quality of the echo is dependant on the geometry of the target, the incident angle at which the acoustic pulse strikes the target and the density of the target material. There are several acoustic bottom classification software packages that are used with single beam echo sounders to analyze a variety of characteristics of the return echo, then use that data to define the bottom type (sand, grass, mud, or rock). However, using just the basic intensity value of the return signal can supply valuable information.

Figure 6 shows a dual axis survey of an underwater intake structure. In this instance, the echo intensity was plotted as a fourth dimension using just two values that would equate to a "strong" and "soft" return. The red collection of dots at the bottom and just in front of the structure (see image on left in figure) was very prominent even though it was virtually buried amongst thousands of other points. A vertical slice of points taken through the area where the anomaly was located showed a distinct 3-dimensional feature, separate from the structure (see image on right in figure). Because of the density of the point cloud, identification of this debris by colour was made during the preliminary review immediately after the data had been collected. This item was targeted during an ROV survey and identified as a large log.

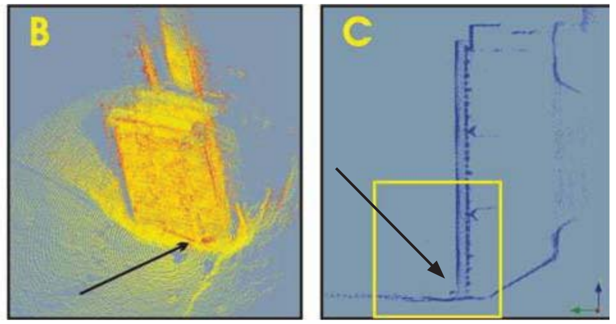

Figure 6: A dual-axis survey of an intake structure revealed debris in front of the structure (see arrow at left). A vertical sliced of points through the area showed a three-dimensional structure (see arrow at right) that was later identified as a large log.

A square low-lying feature, also mapped as a collection of red points was also suspected to be foreign material but was not accessed during the ROV inspection. This feature was not readily discernible in the dimensional aspect of the data and was suspected to be a flat sheet of material lying on the intake apron.

Conclusion

The selective use of the appropriate tools for underwater inspection can provide owners with vast amounts of data that was previously unavailable or could only be obtained at great cost. The various forms of scanning sonar provide methods that are extremely cost-effective, primarily because these types of inspections often can be conducted without taking a facility out of service.

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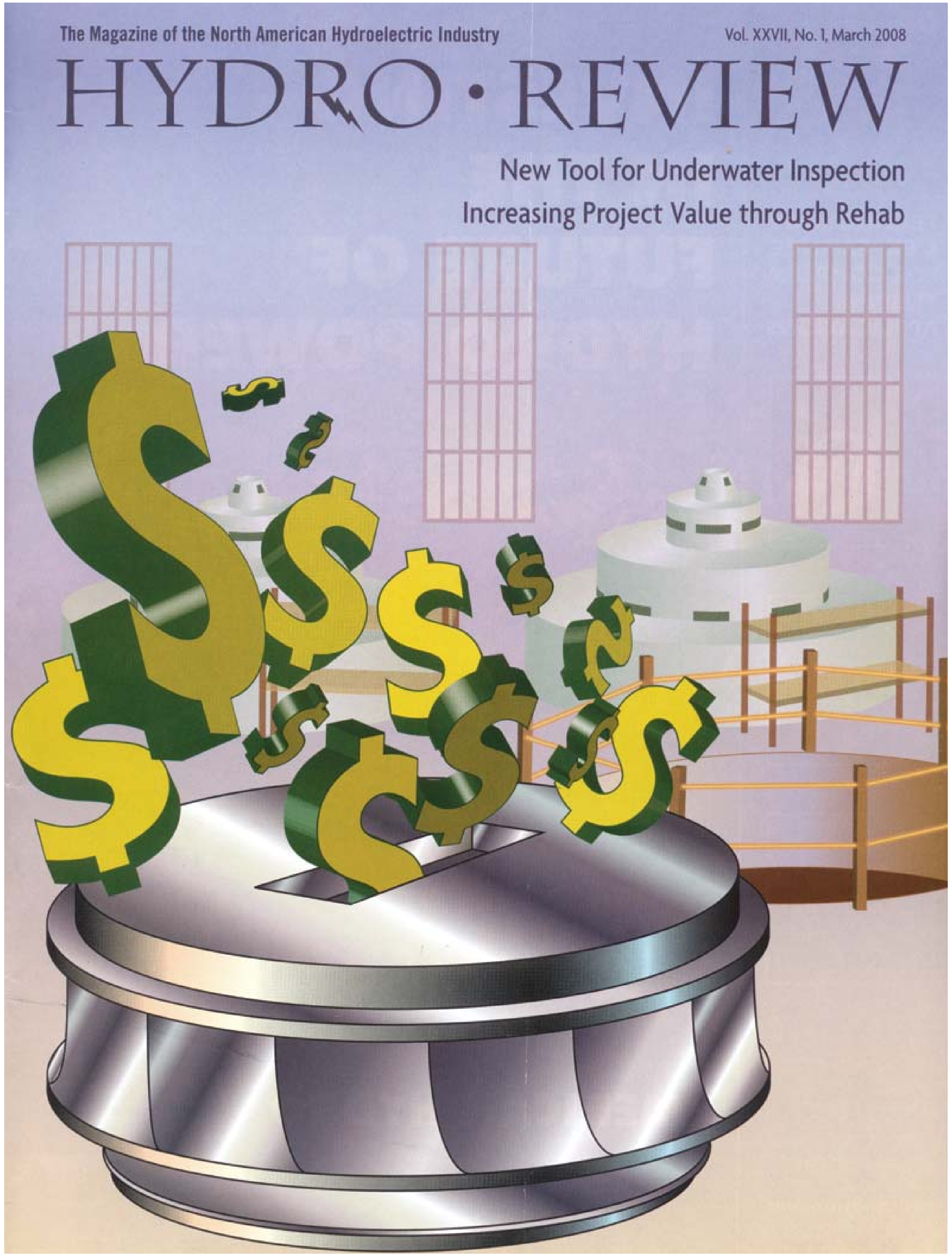

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HYDRO · REVIEW

New Tool for Underwater Inspection

Increasing Project Value through Rehab

Dual-Axis Sonar:
A New Tool for Underwater Surveys

Dual-axis sonar technology uses sonar signals to provide a three-dimensional representation of submerged structures. The technology can be used for inspecting intakes, surge shafts and headwall structures at an operating hydro project - without the cost of a plant shutdown.

By Robert O. Clarke

Inspection and monitoring of underwater infrastructure is challenging. Because these components are submerged, they are not subject to the casual but daily scrutiny of personnel working at the facility.

Inspection of submerged structures is an expensive undertaking because the plant must be shut down to ensure a safe work area for the tow most common inspection modes: commercial divers and remotely operated vehicles (ROVs). In addition to the lost revenues directly associated with the shutdown, typical costs include labor, as well as regulatory and in-house administrative work required to bring units off line and then re-start them when the inspection is complete.

Advances in scanning sonar technology and its application are enabling several types of inspection surveys to be conducted under operational flows, providing great cost savings owners. The latest advance in this technology involves the use of three dimensional data collected using a wide range of investigations of underwater structures at hydro facilities.

Bob Clarke, P. Eng., is a senior operations manager in the Marine Service Group of ASI Group Ltd.

Using sonar to perform underwater inspections

Essentially, sonar technology involves a pulse of sound, then measurement of the time lapsed between the transmission of this signal and receipt of the reflected echo off a target. Multiplying this time lapse by the relevant speed of sound, an accurate determination of the distance to the target can be calculated. By collecting several thousand points that define a surface (location of a pier nose, lake bottom, dam face), the as-built geometry of the structure and present condition can be identified.

For example, sediment depths relative to the structure can be plotted to illustrate areas of deposition that requires cleaning. Another example includes determining as-built configurations and dimensions. Quite frequently, as-built drawings are not available. This is a very effective means of collecting measurements that be used to generate them.

Two-dimensional sonar

Standard two-dimensional scanning sonar equipment repeats this pulse-echo process as the transducer head is rotated through pre-set increments. In effect . This technology allows the user to scan a line.

In the standard imaging mode of sonar scanning, the acoustic pulse is configured in a fan-shaped pattern and is used to sweep across the area of interest. Use of this technology can produce images that provide relative distances in two dimensions (up-down, left-right) somewhat like a photograph.

Three-dimensional sonar

However, just like in a photograph, the third dimension (distance in or out) cannot be determined from a single image. To accurately quantify the volume of debris in front of an intake structure, the extent of a scour or actual structure dimensions, measurements in the third dimension have to be obtained. Scanning sonar that has been configured for profiling instead of imaging can be used to obtain these measurements.

When a survey is being conducted using a profiling sonar, the sonar unit typically must be re-positioned several times to cover an area of interest for anything other than a single cross-sectional scan. Figure 1 on page 48, shows an example of the data collected from this type of deployment.

For a plan view, X is the east-west direction, Y is the north-south direction and Z is the elevation.

The data collected using the scanning sonar provides a range and bearing to each point, which can be easily translated to Y and Z. The X location is added to the data set after each scan and represents some assigned survey station along the area of interest. The XYZ data set is typically referred to as a point cloud data set. These points can be viewed, manipulated and rendered with a variety of software packages. The selection of one or more the software packages is dependant on technical expertise, budgets and end use of the survey.

Dual-axis three-dimensional sonar

To enhance the results from a three dimensional scanning survey, a second axis of rotation on the sonar head can be incorporated. Once the head has completed a scan line along the first axis, the actuator (a mechanical device that provides rotation based on electrical input) rotates the head through a set increment, selected based on the level of detail required (from less than 1 degree to 3 to 5 degrees), and the scan is conducted again. This arrangement creates a radial pattern in the data collected, significantly increasing the amount of data collected from a single deployment (Figure 2).

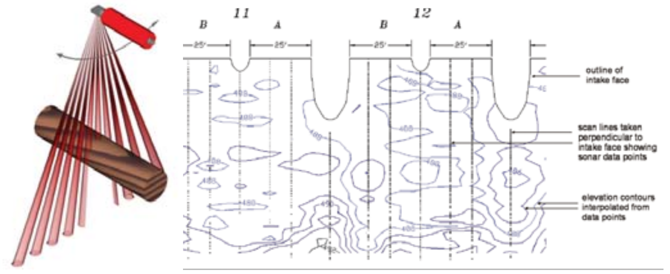

Figure 1: The data collected using three-dimensional sonar equipment allows the production of a bathymetric survey image of a hydro plant intake.

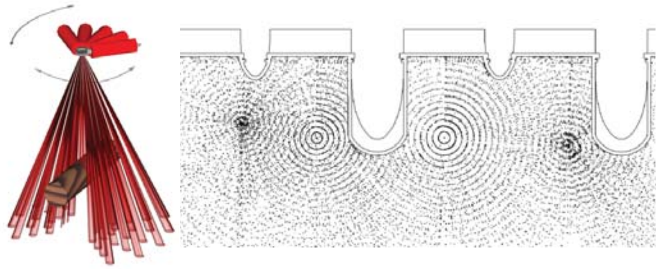

Figure 2: Using dual-axis three-dimensional sonar equipment to survey the same area shown in Figure 1 provides 15,000 data points with four deployments, compared with 1,200 data points with 12 deployments.

An important aspect of this type of data is that every point collected from the single deployment is plotted using a spherical coordinate system. Data points collected include range and two bearing angles. This information is readily translated to an appropriate XYZ value. The data in Figure 2 is a subset of the data and was used for making a bathymetric plot of the area just in front of an intake structure. The full data set collected includes points for the pier noses, intake headwalls, intake openings and other vertical surfaces.

At this dam, the ability to measure the sides and front of the pier noses provided additional valuable detail. The results indicated the pier noses were stepped and not straight as previously assumed. (See Figure 3) (Subsequent reference to additional drawings confirmed the findings from the sonar survey.)

Most point cloud viewing software can directly import an XYZ file that has been created in ASCII format or some other common delimited file type. Immediate viewing can be a quick form of quality control to verify positioning of the head, area of coverage and quality of data collected (effects of heave pitch and roll).

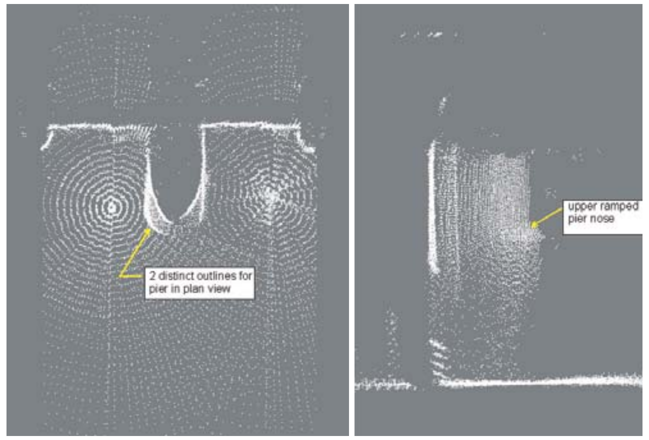

Figure 3: Us of dual-axis three-dimensional sonar scanning indicated that the pier noses in front of the intake structure scanned in Figures 1 and 2 were stepped, not straight (see side view). A subsequent review of construction drawings confirmed this finding.

Applications of this technology

This 3-dimensional aspect of sonar scanning can provide valuable in many different applications. For example, a shaft survey was conducted at one hydroelectric project to determine the maximum clear vertical opening of a 600 foot high surge shaft that connected to the headrace tunnel. A dual-axis 2.25 MHz sonar system was deployed to measure the 500 foot submerged portion of the shaft. (A laser measurement system was used for the upper 100 feet and the surge tank around the top of the shaft. The two data sets were merged to provide an overall set.)

In all, 67 sonar scan sets were collected over 4 days to generate over 483,000 points (after filtering to remove extraneous data points that could be generated by particles or matter in the water) that defined the inside surface of the submerged shaft. Figure 4 shows the lower 9 scan sets collected, which covered the lower portion of the shaft, a construction adit and the intersection with the main tunnel. This set of scans revealed a small offset in the shaft, a slight change in diameter of the lower section. All of the sets were combined into one coherent presentation that defined the inside surface of the 600-foot shafts. Using this representation, the goal of determining the maximum clear vertical opening of the shaft was accomplished.

Proper presentation of the sonar data collected is one of the keys to the success of this technology. While it is valuable for the sonar technician to be able to interpret the point cloud, the hydro project of dam owner is paying for information and must be able to use and interpret it. Using animated versions greatly helps with viewing the 3-dimensional aspect of the data. An easier solution that is commonly used in hard-copy reporting is rendering the data into a wire frame or digital terrain model.

Figure 5 shows an example of the

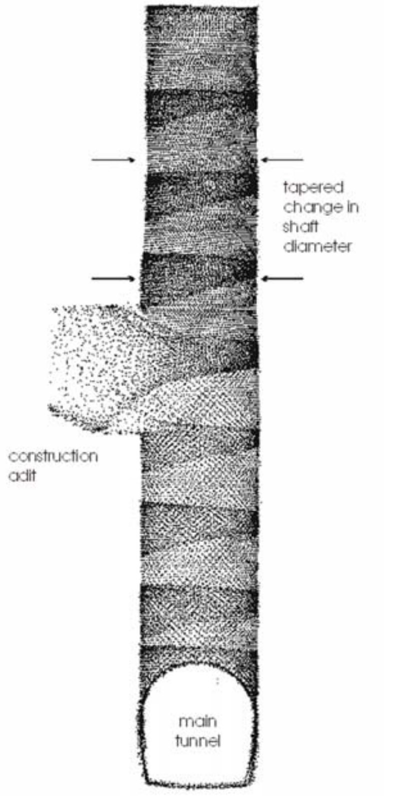

Figure 4: During a survey of a surge shaft, the use of dual-axis three-dimensional sonar imaging revealed a slight change in diameter of the shaft.