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Side Scan and ROV Based Sonar for Locating Submerged Cadavers

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TECHNICAL REPORT
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NOTE: Further information about this report can be obtained by calling the CPRC information number (613) 998-6343

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Executive Summary

In this project, the authors investigated and compared the use of side scan sonar and ROV based sonar in the location of submerged cadavers. Although this equipment had been used successfully to locate hard objects or objects with height above the bottom, it was not known if the same could be used to locate submerged bodies.

The results of this study indicate that sonar is an affordable, useful tool which permits detection of submerged cadavers at depths beyond the safe diving limits and in strong currents or rough water.

Sommaire

Dans le cadre du projet, les auteurs ont examiné et comparé l'utilisation d'un sonar latéral et d'un sonar de type engin télécommandé pour la recherche de cadavres immergés. Bien que les sonars ont permis de retrouver des objets durs ou des objets faisant saillie par rapport au fond, on ignore s'ils pourraient aider à retrouver des corps immergés.

Selon les résultats de l'étude, le sonar s'avère un outil utile à prix abordable permettant de détecter des cadavres se trouvant au-delà des profondeurs sécuritaires de plongée et dans de forts courants ou en eau agitée.

Side Scan and ROV Based Sonar for Locating Submerged Cadavers

Report and photos by:
Bill Wiley - Niagara Regional Police Service Diving Supervisor
Darren Keyes - Senior Operations Manager-Aquatic Sciences Inc.

Introduction

In Canada, the search and recovery of submerged cadavers or any evidence from crime is the sole responsibility of the police service having jurisdiction over a particular body of water. Some departments have their own underwater search units that are trained and equipped to extend the police function to the marine environment, operating in most cases to depths of up to 100 feet where statistics show the majority of incidents occur. When the search involves a large area, depths beyond 100 feet, strong currents or heavy seas, the use of divers may not be feasible due to operating restrictions or hazards. Remote sensing equipment is now available that permits police to fulfil their mandates at affordable cost with minimal draw on personnel and resources.

Part of the Niagara Regional Police USRU deep-water major incident response plan includes the use of side scan sonar and ROVs (remotely operated vehicle) to locate submerged evidence such as a downed aircraft or vessel. Side scan sonar and ROVs have been successfully utilized by law enforcement in Canada to locate and survey crash sites or accident scenes. Although proven to work well on hard objects or large objects with height above the bottom, little information was available on the feasibility of using this technology to locate submerged humans. No scientific data is available to determine if decomposition, body position, clothing, bottom composition or depth will affect a sonar image of a submerged cadaver.

The NRPS 24' Limestone in the foreground was used to tow the Klien 595 Sonar Towfish. Note the small generator mounted on the bow to power the electronic equipment.

The Port Weller Coast Guard provided its cutter "CGR 100" for use as a working platform to deploy the ROV and house the control box and monitors.

Photo by Bill Wiley

The Niagara Regional Police Service, like many Ontario law enforcement agencies that have large amounts of water within their boundaries, is responsible for carrying out investigations, enforcement and search and rescue duties on their waterways. Most police agencies are using patrol vessels in the 20 to 30 foot range, which is small when it comes to sonar based searching and ROV deployment.

Other goals of the study were to determine:

1. Whether a 24-foot *Limestone* would provide enough work area and deck space to support two sonar technicians, a coxswain and the sonar equipment.
2. The set up time to mobilize and deploy for disaster management planning and preparation.

NRPS police divers prepare to submerge a pig cadaver in 75 feet of water in Lake Ontario as part of a forensic entomology study.

The death sites provided an excellent testing target for the sonar and ROV study.

Photo by Bill Wiley

The first phase of the study was the side scan sonar testing on Lake Ontario, near Jordan Ontario. The three sites selected were part of a forensic entomology study carried out by the Niagara Regional Police Service, entomologist Dr. Gail Anderson of Simon Fraser University in British Columbia and project manager Julie Graham of the Canadian Police Research Centre (CPRC). Pig cadavers displaying various stages of decomposition were attached to 700-pound mooring blocks at depths of 50, 75, and 100 feet of water. Scientific buoys marked the sites making it easy to verify the results under such controlled conditions.

The NRPS and St. Catharines-based company Aquatic Sciences Inc. (ASI) aligned as community partners and have worked together successfully in the past on large-scale victim recovery operations where specialized equipment or extra personnel were required. ASI provided the author with the following equipment:

1. *Klien 595* high resolution, dual frequency (100/500 kHz) side scan sonar system consisting of:
   a. Topside processing unit
   b. cable for electronic transmission and towing
   c. subsurface towfish (transmits and receives acoustic energy for imaging)
2. *Starlink* sub-metre differential global positioning system (DGPS)
3. Laptop computer with navigation and data collection software
4. 110-volt portable generator

The lap top computer featured electronic charts linked to the Starlink DGPS. This made navigating simple as well as providing a permanent record of the search area covered.

Photo by Bill Wiley

The Klien 595 provides "real-time" high-resolution (203 dpi) permanent graphic records that are printed on a continuous paper roll. The resulting image builds up a black and white image of the lakebed as the tow vessel moves forward.

Side Scan Sonar Test

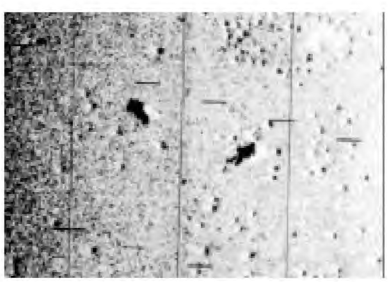
Two side scan sonar technicians from St. Catharines-based Aquatic Sciences Inc. met with the writer at the Port Weller Coast Guard Base to prepare the NRPS Limestone for the sonar test. Set up time took approximately 30 to 40 minutes.

The side scan sonar towfish was towed from the stern of the vessel with as much as 30 metres of towcable deployed at the 100-foot site. The towfish depth was experimented with in order to find the best depth for target (pig) detection. The optimum towfish height was found to be seven to eight metres above the lakebed.

The side scan interpretation by Darren Keyes of ASI was extremely accurate. He was able to determine changes in bottom composition, including patches of quagga mussels scattered around the pig cadavers.

Photos by Bill Wiley

Side scan sonar is a method of underwater imaging using narrow beams of acoustic energy (sound) transmitted out to the side of the towfish and across the bottom. Sound is reflected back from the bottom and objects to the towfish. Under certain conditions, some frequencies work better than others do. High frequencies such as 500 kHz give excellent resolutions but the acoustic energy only travels a short distance, thereby providing less coverage. Lower frequencies such as 100 kHz give lower resolution but the distance that the energy travels is greatly improved, resulting in much greater coverage. At times, there can be a distinct advantage to collecting both high and low frequency images simultaneously.



The image above is an example of a side scan sonar record showing two bodies that were located on the bottom of a Swiss lake using a Klein 595 side scan sonar system.

Image provided by Darren Keyes (ASI)

The towfish generates one pulse of energy at a time for the sound to be reflected back. The imaging range is determined by how long the towfish waits before transmitting the next pulse of acoustic energy. The image is thus assembled one line of data at a time. Hard objects reflect more energy, causing a dark signal on the image; soft objects that do not reflect energy as well and show up as lighter signals. The absence of an echo (sound), such as shadows behind or in front of objects, show up as white areas on a sonar image.

> A shadow in front of an object indicates a depression in the bottom, while a shadow behind an object indicates that the object has height above the bottom. The dimensions and heights of the objects can be determined from the side scan sonar records.
>
> Darren Keyes (ASI)

Side Scan Sonar Test Results

The small 24' *Limestone* proved to be a sufficient work platform to support the side scan sonar equipment, two technicians and a coxswain. Regardless of the size of the vessel, the laptop (navigation) computer, *Starlink* DGPS and *Klein 595* topside processing unit had to be protected from the weather (rain or snow). This was easily accomplished by mounting the equipment under the canvas boat top while the testing was underway. In heavy snow or rain, there would have been difficulty keeping the topside sonar equipment dry since the vessel is not equipped with a watertight wheelhouse or cabin.

Darren Keyes collected the hard copy results for further analysis and interpretation. At the 50-foot test site, Keyes concluded that the bottom composition was a stiff hard bottom consisting of sand, gravel/mussels, cobble and boulders. The record indicated that there was one pig cadaver at the site. The size of the shadow suggested the pig was buoyant and starting to lift off the bottom. The optimum detection range was 65 to 75 feet. His interpretation was found to be remarkably accurate during a post test dive by the NRPS USRU. The pig cadaver was bloated and about to refloat for a second time after being submerged for 44 days.

The 75-foot site was shown by the side scan sonar to be a softer bottom (sandy mud) without boulders or cobble. Patches of quagga mussels were randomly distributed around the site where four pigs rested on the bottom.

Bottom composition changes and the number of submerged pigs were accurately interpreted at both the 75 and 100 foot sites. The harder bottom at 100 feet, combined with changes in lakebed geology, made it more difficult to differentiate the two pig targets from boulders.

> In all cases, the 500 kHz frequency provide the highest resolution and best records for detecting targets likes humans and pigs. The 100 kHz frequency data provides less resolution and more range. Data from both frequencies can be displayed simultaneously. The 100 kHz is better suited for searching for downed aircraft or boats where the targets are much larger and easily detected. Much greater search ranges can be achieved with the 100 kHz frequency.
>
> The ability of the Klein 595 side scan sonar to detect human or pig targets depends largely on the local geology and the surrounding bottom type. Soft muds will absorb most of the acoustic energy and reflect little energy back to the topside unit.

> Hard bottoms will reflect most of the acoustic energy back to the topside unit. Human and/or pig bodies consist mostly of water and, as a result, do not make good acoustic targets because they absorb most of the acoustic energy. In order to get a return from a human or pig body, the gain had to be increased to a very high level. This can work well in areas where the surrounding lakebed is soft mud. However, in areas where the lakebed is hard (stiff clays, sands, gravel, boulders, rock, etc.) increasing the gain level to the point where detection of human or pig bodies is possible will result in too much gain for the surrounding bottom type. The result will be a saturated record that most likely will not be favourable for cadaver detection.
>
> Darren Keyes (ASI)

The sonar shadow from a freshly submerged cadaver lying flat on the lakebed is small. If water temperatures are warm enough to promote decomposition and bloating, the body will increase in dimension and lift off the bottom slightly just prior to refloating. This stage offers a larger shadow for detection than a fresh cadaver offers.

The Klein 595 side scan sonar proved to be a useful tool for locating submerged cadavers. It was obvious that operator knowledge and competency with the equipment was extremely important when it came to interpreting the results accurately. Whether the pigs were clothed did not seem to make any difference with detection success or failure. However the stage of decomposition and cadaver position did have a potentially positive or negative effect on target detection.

ROV Mounted Sonar Test

The Simrad imaging sonar can be seen mounted on the top left corner of the Phantom HD2 ROV frame.

Photo by Bill Wiley

The second phase of the sonar test was to deploy a Deep Ocean Engineering *Phantom HD2* ROV equipped with a *Simrad* imaging sonar. The ROV was also outfitted with a pan and tilt video camera and a manipulator arm. The unit came equipped with a 700-foot umbilical and was depth rated to 1000 feet.

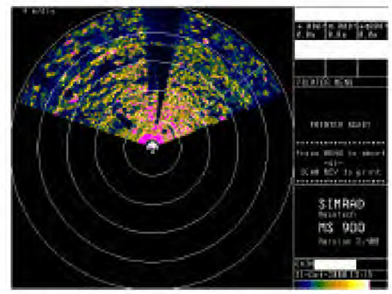
The set up of the ROV equipment onboard the Canadian Coast Guard cutter "CGR 100" took approximately two hours. Much of this time was spent organizing a space for the monitors and sorting out the power requirements for the ROV. Once the crew and technicians were familiar with the vessel layout, they predicted a one-hour set-up time for future operations.

The goals of the test were to determine if the ROV could:
1. Locate the pig cadavers using the imaging sonar as a navigation system.
2. Recover a pig cadaver using the video and manipulator arm.

ROV Mounted Sonar Test Results

The ROV was deployed from the drop down tailgate on the stern of "CGR 100". The ROV control box and monitors were housed inside the wheelhouse for protection from the elements.

Once deployed by Bob Clarke (ASI Project Engineer and ROV pilot,) the sonar image revealed the location of a police diver who was surveying four pig cadavers at a depth of 75 feet. The sonar's ability to detect human or pig targets works in the same manner as the side scan sonar described in this report. The main difference is the optimum detection range for the ROV mounted imaging sonar is approximate 10 to 15 metres, considerably less than the side scan sonar system.



The image captured from the topside monitor reveals four pig cadavers.

Photo by Bob Clarke (ASI)

The ROV mounted video captures the image of a pig hours before refloat. The ROV was easily manoeuvred to the pig and secured to the cadaver with the manipulator arm, permitting recovery.

Video capture by Bob Clarke (ASI)

The test proved that it was possible to locate and navigate to the pig targets using the imaging sonar system. Once on a target, the ROV pilot demonstrated that it was possible to use the video and manipulator arm to recover the cadaver.

Conclusion

The advantage of the ROV is that it has unlimited bottom time to depths of up to 700 feet combined with a 30 to 100-foot, 360 degree visual guidance image surrounding the ROV. The sonar does not rely on water clarity to function. In poor visibility, the system can be used in conjunction with divers to direct them to a target they cannot see visually. To guarantee a precise ROV search along a fixed search pattern, the ROV can be equipped with an underwater navigation system such as *Trackpoint II*.

Although the testing was brief, and much more study is required to develop a more formal framework for recovery of submerged bodies using remote sensing technology, the goals for this project were met. Sonar is a practical and affordable tool for law enforcement and can ensure the police function is fulfilled at depths that extend beyond safe diving limits or in adverse conditions.

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