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Bathyswath-2 PSM Technical Information

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Voids

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List of modifications

Version	Date	Modifications	Pages	Writer	Checker
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1 INTRODUCTION

1.1 REFERENCES

Ref. 1 ITER Systems website, at www.iter-systems.com

1.2 GLOSSARY & ACRONYMS

ACRONYMS	DEFINITION
DTM	Digital Terrain Model
FGPA	Field-Programmable Gate Array
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
PDBS	Phase Differencing Bathymetric Systems
PRF	Ping (or Pulse) Repetition Frequency
PSM	Permanent Siltation Monitoring
RIB	Rigid Inflatable Boat
STD	Standard
SU	Subsea Unit
SVS	Sound Velocity Sensor
USV	Unmanned Surface Vehicle
UW	Underwater

1.3 SCOPE

This document describes the technical aspects of the Bathyswath-2 PSM system, its options, components and performance.

2 INTRODUCTION

Sediment build-up or scouring can cause rapid changes in the bottom of lakes and rivers, and can cause severe problems for the operation of hydro-electric plants and cooling water inlets. These bottom changes can be monitored using sonar systems fixed to boats, but repeating these surveys often enough to understand the changes can be expensive and inconvenient. To help solve this problem, ITER Systems has developed Bathyswath-2 PSM, a sonar system that is fixed to the dam wall and scans the lake bottom at regular intervals. It autonomously processes the data and creates a report file, which it emails to interested personnel.

3 BACKGROUND

Sedimentation of hydroelectric lakes can reduce the life of the reservoir and damage turbines. Similarly, cooling water inlets for nuclear power plants can be blocked by sediments. Many hydroelectric sites have facilities and strategies for dealing with sedimentation, e.g. by flushing through doors in the dam. However, planning such actions needs the sediment level and distribution to be carefully monitored. This is commonly done using acoustic survey equipment fitted to boats, which can be expensive and inconvenient, particularly when the site is difficult to reach with a manned boat. When siltation levels are changing quickly, at flood times or storms, manned surveys may not provide information quickly enough, or give enough information on rates of change.

To facilitate the task of monitoring this sedimentation, ITER Systems, working with Electricité de France (EDF), has developed a fixed-scanning sonar system, called “Bathyswath-2 PSM” (permanent siltation monitor).

The Division Technique Générale (DTG) of EDF, in Grenoble, France, has been using standard Bathyswath systems (Bathyswath-2 STD) and their predecessor, SWATHplus, on manned survey boats for many years. They first started conversations with members of the ITER Systems team to develop fixed scanning system in 2009. The first fixed scanning systems were installed in 2011, and the design has been continuously refined since then, as new systems have been installed around France.

4 BATHYSWATH-PSM

4.1 WHAT IT DOES

Bathyswath-2 PSM measures the depth of the lake in a segment of a circle around a fixed position. If it is fixed to a flat wall, then the area scanned is a semi-circle. The depth data is processed and compared with depth data from previous scans, and the results are put into an easy-to-read report document, which is emailed out to the client team. This all happens at completely automatically at pre-programmed intervals.

4.2 HOW IT DOES IT

The system uses a sonar sensor that measures a profile of the lake bed in one direction. The sonar sensor is then rotated, using a “pan-head” motor, causing the profiles in depth measurement to be swept in an arc. Fully automated software schedules the scans, collects and stores the data, processes it, and creates human-readable report documents. The system then transmits the data and system status over wireless mobile or wired communications. A server computer stores the data and provides access for further analysis. User-friendly web interfaces are provided to set up the system and access data. The report documents are automatically emailed out to interested engineers and managers.

4.3 USES

Bathyswath-2 PSM was originally designed to monitor the lake bottom near the intake of hydroelectric facilities. It has been installed in both conventional dams and run-of-river sites. It has also been fitted at the cooling water inlet of a nuclear power plant, to ensure that the flow of cooling water is not at risk from sediment build-up.

Figure 1 Bathyswath-2 PSM At a Run-of-River Hydroelectric Site

The system is also ideal for monitoring scour, where flow of water around a structure causes the bottom to be eroded away, rather than building up with sediment deposits. Bridge piers in a fast-flowing river are a typical example.

4.4 PARTS OF THE SYSTEM

The system has three main parts:

- **The Wet End**: the part that is installed in the water. It contains a Bathyswath-2 UW (underwater) sonar system, pan head motor, and mounting hardware.
- **The Cabinet**: this contains the computer, communications equipment, power supplies, etc. It is placed close to the Wet End. The computer runs the automation scripts, sonar software to run the sonar and pan head scanning sequence and process the sonar data, and reporting software to create an elevation model and create the report.
- **The Remote System**: this is a server computer, which stores the data collected from the Bathyswath-2 PSM system, and emails out the reports. ITER Systems and its associates can provide this server facility, or clients may use their own servers.

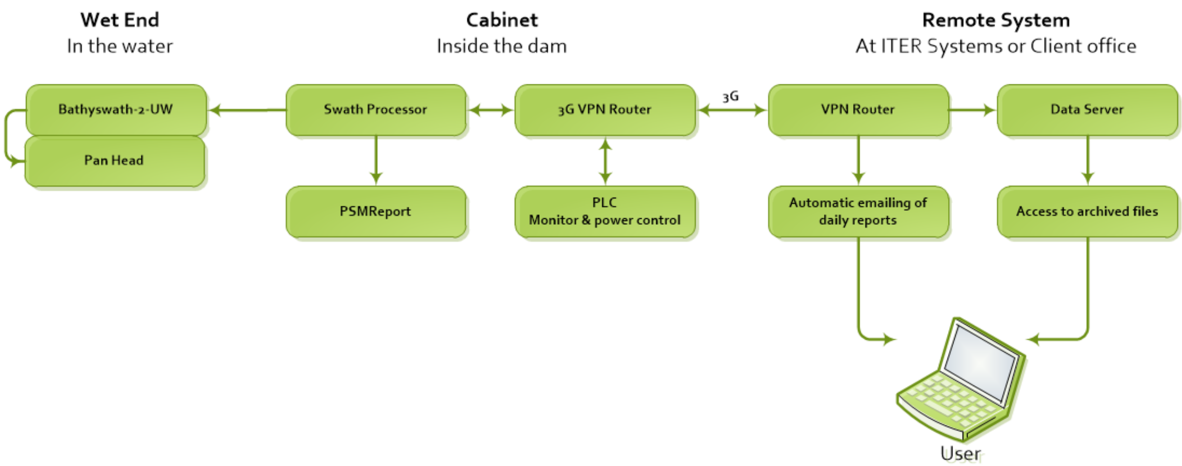

Figure 2 Bathyswath-2 PSM Components

4.5 WET END

The Wet End includes:

- **A Bathyswath-2 UW (underwater) sonar system**: this is a modified version of the system that is used at sea on underwater vehicles or at the end of a pole over the side of a boat. A watertight bottle contains the electronics that runs the sonar system, a motion sensor to measure the angle of the sensor relative to vertical, and a sound velocity sensor. The sound velocity is needed to convert the data recorded from the sonar transducer into range and angle to the lake bottom. A sonar transducer is fixed to the bottle.
- **A pan head:** this is a motor that rotates the sonar system in angular steps, with a resolution of a tenth of a degree or better. The pan head provides an accurate feedback of the angle, which is used to put the data from each sonar “ping” in the correct place in the elevation model.
- **A framework** to fix the system to the dam wall.

The Wet End is connected to the Cabinet using an umbilical cable, providing electrical power and Ethernet communications. This cable can be up to 200 metres long using standard Ethernet, and can be further extended using ADSL communications.

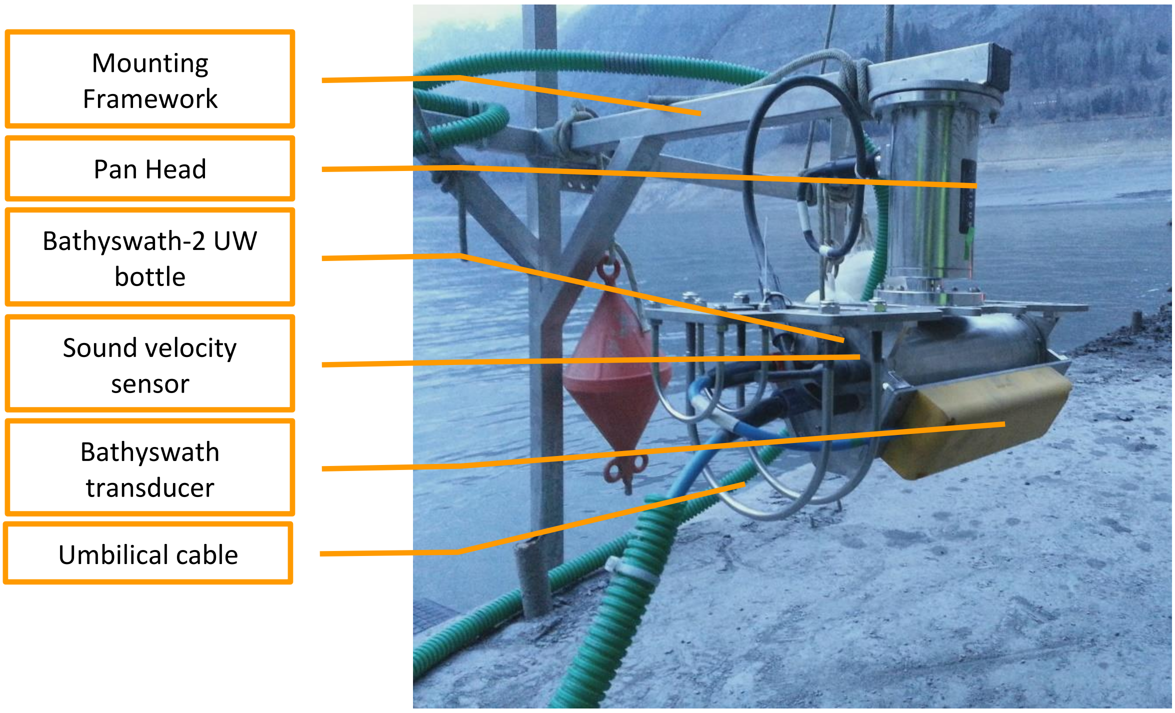

Figure 3 Bathyswath-2 PSM Wet End Before Deployment on the Dam Wall

4.6 CABINET

The Cabinet is placed in a room close to the Wet End. It contains:

- **A touch-panel industrial PC**, running the system software, on Windows.
- **Communications equipment**: 3G/4G or wired VPN routers and modems.
- **A programmable logic controller (PLC)** to control the hardware, switch power on and off, monitor system temperature and power status, etc. This can be accessed remotely through a web interface.
- **Air conditioning.**
- **Power supplies.**

Figure 4 PSM cabinet

4.7 SOFTWARE

The computer in the cabinet runs the system software:

- **Sonar processor**: controls the Bathyswath sonar system, processes its results, and displays the results for quality control and investigating any problems.

- **Report generator**: generates a digital terrain model (DTM) of the arc swept by the sonar system, filters it, extracts profiles at user-defined locations across the DTM, calculates the area between the profiles and reference profiles and levels, and builds a history of those areas. It then creates a PDF report from the data, including graphs of how the area between the latest profiles and reference profiles are changing with time.
- **Automation scripts**: a set of script files schedule the regular operation of the system, including starting the sonar processor and report generator functions, and transferring their output files to the Remote System.

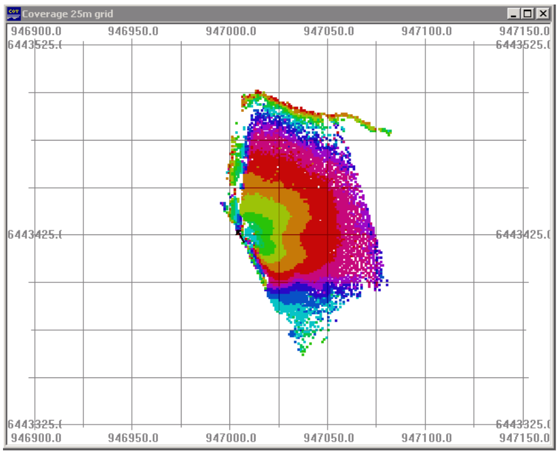

Figure 5 Coverage view, showing the area covered by a sweep

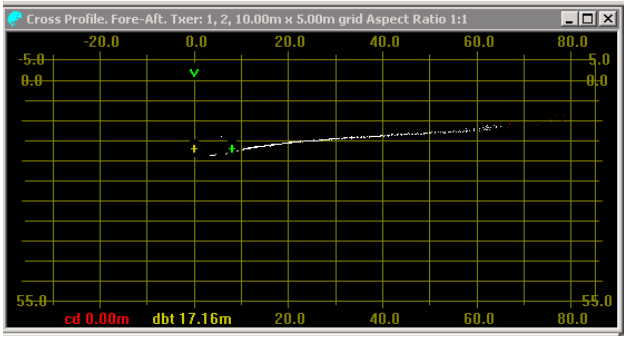

Figure 6 Profile view, showing depths for one sonar "ping"

4.8 COMMUNICATIONS

Internet communications are run over a secure Virtual Private Network (VPN) and password-protected, to prevent unauthorised access to data or control of the system. The maintenance engineers can log into the computer in the Cabinet by connecting to the VPN and using Windows Remote Desktop. Data can be downloaded and new program versions uploaded using FTP.

The cabinet computer is generally connected to the Internet, and from there to the users' computers and the server system, in one of two ways:

- **Wireless**: using a 3G/4G wireless VPN router direct from the dam; this is used when there is no wired connection on site.
- **Wired**: where there is a wired connection from the location of the cabinet to a control room on site, using a standard VPN router to the control room, using a pair of VDSL-2 modems over copper wire. An Internet box in the control room connects the system to the Internet.

4.9 REMOTE SERVER

The Remote Server is a computer system in a secure office location, which can be at the user's own site, or a server system maintained by ITER Systems or its associates. It connects to the PSM system using a VPN router and an Internet box, and allows:

- Secure access to the PSM system for test and maintenance,
- Storing the data from PSM, and providing access to it via web login,
- Sending PDF reports by email to registered users.

4.10 REPORTING

A typical PDF report, which is automatically created and emailed out with each sweep sequence, looks like this:

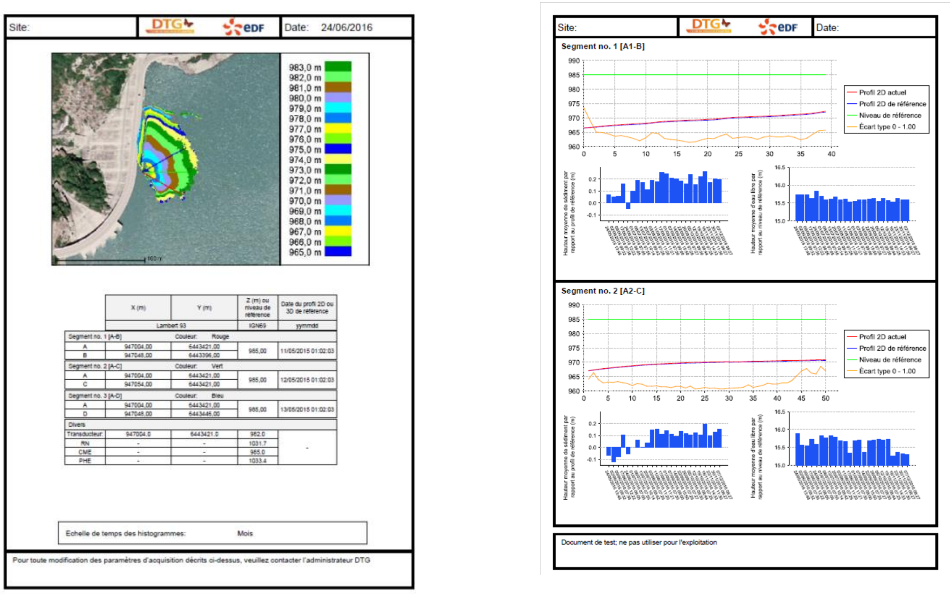

Figure 7 Examples of the PDF report pages

In two or three pages, it provides the essential information about the lake depth and its change, including:

- A plan view of the site, including a colour-height map of the latest scan of the lake, with height and distance scales.
- A summary of the locations of the main parts of the system and the key parameters of the lake.
- A set of reports derived from line segments across the area, including:
  - Height profiles of the lake bottom for the latest scan.
  - A reference profile, recorded at some previous time, and shown for comparison.
  - A reference level.
  - A data quality curve, showing how height data quality varies along the profile. This information is derived from the standard deviation of the DTM height model.
  - A histogram plot showing the change in the area between the reference profile and the latest profile with time. The time scale can be selected from day, week, month or year.
  - A similar plot showing the change in area between the reference level and the latest profile.

The report is generated from a template file, which can be modified to suit by the client.

5 AUXILIARY MEASUREMENTS

In addition to the data from the Bathyswath sonar, additional measurements are needed to give an accurate measurement.

5.1 TRANSDUCER ANGLES

As the transducer rotates, its angle relative to horizontal changes a little. A vertical reference unit is used to measure this angle in three dimensions, and the Bathyswath software corrects for it. The standard Bathyswath-2 PSM systems use a SBG-Systems Ekinox sensor for this.

5.2 SOUND VELOCITY

The measurements made by the sonar system must be corrected for the velocity of sound. The sound velocity at the location of the sonar transducer is used to give an accurate angle for the sound waves. Sound velocity at different depths is needed to correct for refraction of the sound waves by layers of different sound velocity. In fresh water, this sound velocity profile can be computed using temperature measurements from a thermal array (temperature sensors mounted on a vertical cable).

Figure 8 Thermal array[1]

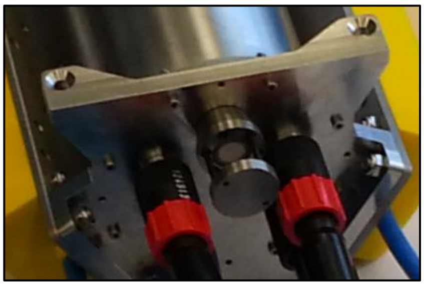

Figure 9 Continuous reading SVS[2]

5.3 TRANSDUCER POSITION

The location and height of the sonar transducer must be accurately measured using land survey techniques during installation. The Bathyswath software uses this information to give bottom heights relative to survey datum.

5.4 WATER DEPTH IN LAKE

The water level of most hydroelectric lakes changes a lot throughout the year, and it can be very useful to track that in the Bathyswath-2 PSM system. This can be done by using a pressure sensor at the end of the thermal array.

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[1] Thermal array laid out before installation
[2] miniSVS-OEM integrated in the Subsea Unit (SU)

6 INSTALLATION, SETTING TO WORK, TESTING AND CALIBRATION

6.1 INSTALLATION

The main challenge in installing the system at hydro-electric dams is fixing the Wet End to the dam wall. As the water level of the lake can change a lot through a yearly cycle, the Wet End needs to be fixed in a location where it is always below the surface. This can mean placing it 50 metres deep. Commercial divers are needed to do this. Run-of-river plants and cooling water inlet installations do not have this problem. A frame is made to carry the Wet End system and to make installation underwater as simple as possible. The frame is built to fix to known structures on the dam wall. Measurements of the frame and the components of the system are combined with the design drawings of the dam to obtain an accurate height of the installed system.

Figure 10 Examples of installation at a hydroelectric dam

Figure 11 Installation with divers

6.2 SETTING TO WORK

A set of configuration files stores the settings of the sonar system, reporting software and automation scripts. These files are prepared through graphical user interfaces. The configuration can be done remotely over the Internet if required. Each installed system is a little different from the others, due to differences in local conditions and equipment availability, so the configuration needs to reflect those differences.

The measurements made before installation are used to compute the location of the sonar head, and this information is used to configure the software so that the measurements made are put into the correct geographic locations.

6.3 TESTING

The sonar system is tested first at a temporary location close to the surface; it is very difficult to recover the Wet End for adjustments after installation deep in the lake. The system software includes a rich set of visualisation tools for assessing every aspect of its function, and these are used to check that the system is working well and to optimise the system settings. Data filters can be adjusted to minimise the effect of factors such as electrical interference and unwanted reflections of the sonar signal. Each time the system runs, the software runs checks and measures data quality, and any problems are reported to the maintenance team. Most problems can be resolved by logging in to the system over the Internet.

6.4 CALIBRATION

If the positions and angles of the system have been accurately and correctly measured, then the data provided by the system should be geographically accurate after processing in the system software. However, this is difficult to do in a diving suit 50 metres underwater, so some small deviations are to be expected. These deviations can be computed (and large differences from human error detected) by comparing the measurements from PSM with a survey from a boat, using a standard Bathyswath system. The small size and low power consumption of Bathyswath make it ideal for deployment from small manned vessels and radio-controlled or autonomous unmanned surface vehicles (USVs), which simplifies deployment to hydroelectric lakes in remote mountain locations. For example, a recent boat survey to calibrate a PSM system used a rigid inflatable boat (RIB) that was brought to site by helicopter, and a man-portable USV for some locations that were difficult and dangerous to reach with the RIB.

Figure 12 Setting up Bathyswath sonar on a RIB

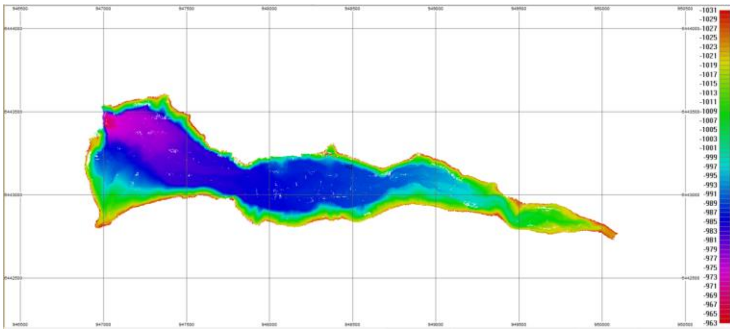

Figure 13 Colour map of a Bathyswath survey of a hydroelectric lake. The dam is at the top left.

To calibrate the offsets, DTMs are computed for the lake bottom using the Bathyswath software, separately for the PSM and boat systems. The two DTMs are then compared using Grid Processor, a module of the Bathyswath software, and the angles and positions of the components of the system are adjusted both manually and automatically to get a good agreement in position, height and angle for the PSM sonar head. Grid Processor includes software tools to compute angular and linear offsets between the PSM and boat surveys. Any differences found are carefully reviewed, and explanations found where possible. The adjusted locations and angles are entered into the PSM configuration.

7 MANUALS, TRAINING AND SUPPORT

7.1 MANUALS

Each Bathyswath system is supplied with a full set of manuals, describing the use of the system, how to install and maintain it, and how to operate the software. The software includes an on-line, context-sensitive help tool.

7.2 INSTALLATION SUPPORT

ITER Systems offers a full package of support for installation and setting to work.

7.3 TRAINING

Bathyswath team offers a training course. This generally takes place at the client's location. It takes about a week, and is a mixture of classroom training, operation at the client's site, and then processing back in the office. The idea is to get the customer's operators working with their own equipment in their own environment. An emphasis is placed on hands-on use of the system and software, including:

- Description of the system,
- Deployment,
- Real-time and post-processing software,
- Maintenance and troubleshooting.

7.4 SUPPORT

The warranty package that is included in the initial sale price includes replacement of faulty equipment and software upgrades. Major and minor software upgrades are distributed approximately every six months, although specific user issues may be addressed in interim releases. Extended maintenance arrangements are available and renewable on a yearly basis.

7.5 REMOTE LOGIN

Most Bathyswath-2 PSM systems can be accessed remotely, usually by using Windows Remote Desktop over a secure VPN connection. The ITER Systems support team can use such remote logins to help to diagnose and cure any problems found in operating the systems.

For example, the systems are set up so that they can be power-cycled using the PLC (programmable logic controller). The PLC monitors power supply voltages, etc.

7.6 QUALITY AND CERTIFICATION

Bathyswath systems are provided with certificates of quality and calibration.

7.7 MAINTENANCE AND CALIBRATION

Bathyswath requires very little maintenance and calibration. The transducers are extremely robust, and maintenance generally consists of a regular inspection for damage and fouling by marine life (cleaning if necessary).

8 SPECIFICATIONS

Operational slant range	200 m
Maximum slant range	300m
Maximum height of transducers above lake bed	150 m
Optimal height of transducers above lake bed	40 m
Along-beam resolution	2 cm
Azimuth beam-width (2-way)	0.55°
Transmit pulse length	8.5 to 4200 µs
Maximum umbilical cable length	200 m
Bottle and transducer dimensions	192 x 290 x 660 mm, 26.6 kg[3]
Pan head dimensions	292 x 246 x 137 mm, 20.0 kg[4]
Bottle depth rating	2000 m
Communications	3G/4G wireless mobile or VDSL-2 wired
Frequency of scans	Selectable, up to every 20 minutes[5]

[3] In air
[4] In air
[5] Limited by the time for a sweep and the time taken to upload the data from the cabinet computer to the remote server, which both depend on user settings and communications speeds.