MEASURING RIVERS AND LAKES USING A MODEL BOAT

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Abstract: *This paper discusses the application of a radio controlled model boat to measure water depths and bed profiles on rivers and lakes using a Leica robotic total station and a Sonarmite echo sounder. Data from the Sonarmite and total station are time stamped and streamed to land based tablet PC running 4Site Sonar software, using long range Bluetooth connections. Real time views of the plan position of the boat and sonar log are displayed and corrections are made for Lag or Latency. Lag is where the position of the boat and echo sounding, based on time stamps, are offset. Our own trials have shown that this could be 2m or more. Once the data has been "cleaned" it can be passed onto a modelling package, like our own ^{n}4ce.*

Keywords: *Hydrographic Surveys, Model Boat, 4Site Sonar, ^{n}4ce*

1. Introduction

Water is one of our most important natural resources, essential for our health, for agriculture, lubricating the wheels of industry and of course our pleasure. We complain when we have too much and complain when we don't have enough. This precious resource needs to be carefully managed so that it can be made available where and when we need it, without the fear of flooding and collateral damage.

In the United Kingdom (UK) various agencies are responsible for water supply, maintenance and quality. These include the newly formed Canal and River Trust, Local and Water Authorities, the Environment Agency and Defra. The Environment Agency has produced on-line maps, Fig. 1, indicating the likelihood of flooding in different parts of the UK, using a one in a hundred year storm. These maps are used by insurance companies when providing quotes on household insurance. If you live within 1km of a water course with a history of flooding higher insurance premiums may be levied or rejected completely.

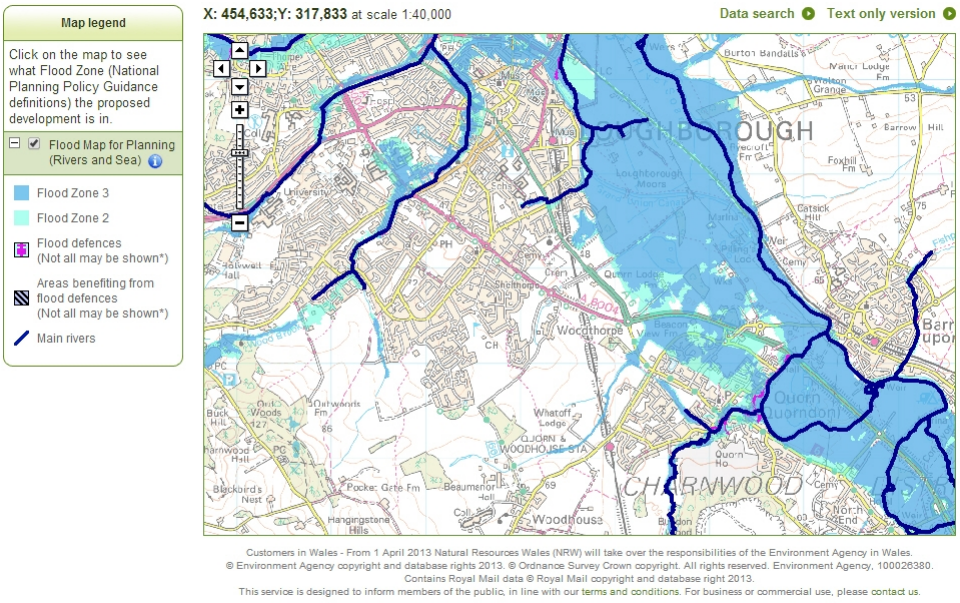

Fig. 1. On-line Flood Maps (Courtesy of the UK Environment Agency)

Planning officers in Local Authorities, working with the Environment Agency, have responsibility for Flood Risk Assessment (FRA) on all new building projects. This year's extensive flooding in the south of England has shown what can happen if we ignore the benefits of flood plains and maintenance (dredging) in the rush to save money and build more houses. Modelling of water courses is essential to predict likelihood of flooding, so that preventative measures can be taken with Sustainable Urban Drainage Systems (SUDS).

With over 25 years in developing software, Applications in CADD Ltd (AiC) is one the UK's leading suppliers of software for the built environment, with many clients working in the water industry. In this paper we are going to discuss how our **n4ce** modelling and ***4*Site Sonar** data capture software is used for hydrographic surveying, with a model boat, Fig. 2, fitted with a 360 deg prism and a Sonarmite echo sounder.

Fig. 2. Model Sonar Jet Boat with 360 deg Prism and Sonarmite Echo Sounder

2. AiC Software for Hydrographic Surveying

At the heart of any modelling package is data, which can come from a number of different sources including digital maps, LiDAR or from traditional surveys using total stations and GNNS. Google and other aerial imagery are useful here to give an overview of the ground, especially where new developments are being proposed

AiC's popular n4ce desktop mapping and modelling package has features for processing survey data to create 3D models and section profiles with various export formats including Hec-Ras and ISIS, which are used in hydraulic modelling in the UK.

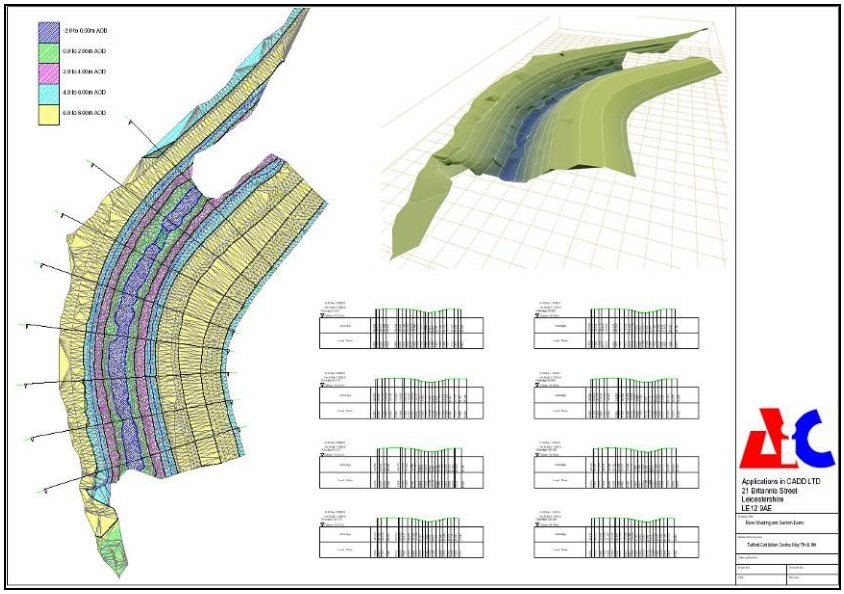

Fig. 3. n4ce Modelling and Final Presentation Drawings

***4*Site** is at the heart of a new range of products from AiC, for specialist data capture used with total stations and GNSS. Intelligent coding converts measurements into CAD detail using an AutoCAD™ DWG database, with raw data being displayed on a Project Tree. DWG drawings can also be taken into the field for setting out or as built survey comparisons.

***4*Site Sonar** has been designed to capture data from rivers and open water surveys providing real time displays and editing, Fig. 4. Standard options within *4*Site are used to provide control and traditional surveying tools for land based surveys including adjustments.

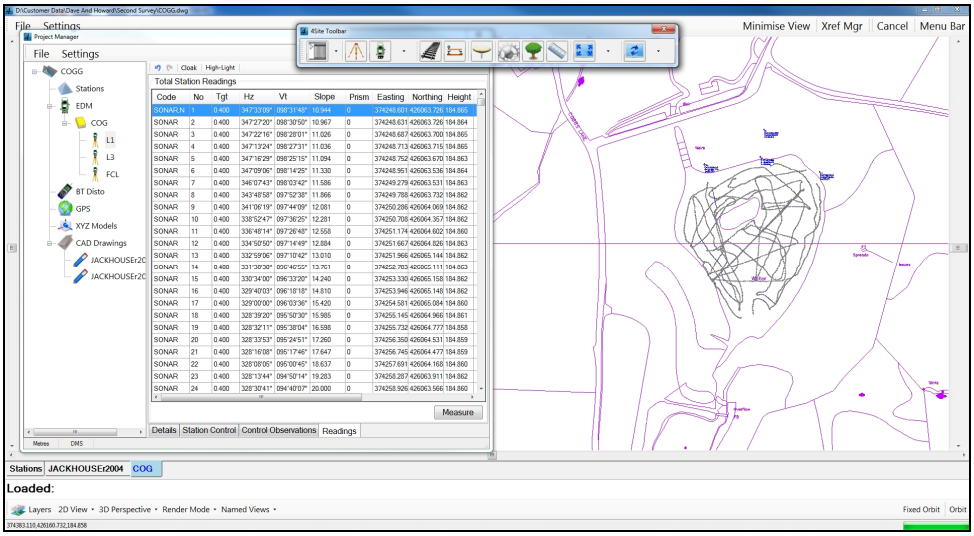

Fig. 4. *4*Site Sonar Data Capture - Real Time Updated Displays

A radio controlled twin engine catamaran, 0.8m long weighing 15kg fully loaded has been adapted to carry a 360 degree prism used for positioning. Fitted directly below this prism is a Sonarmite [1], [2] survey grade echo sounder with a long range blue tooth transmission. The boat is tracked using a Leica robotic total station, with a radio handle, which recognises Advanced Geocom commands used by *4*Site Sonar. Readings from the total station and Sonarmite are time stamped and sent to a shore based tablet PC running *4*Site Sonar, for processing and real time displays of the boats position and sonar log.

Fig. 5. Hands Free to Control the Model Boat – River Tyne Newcastle

Being fully robotic, the operator has their hands free to operate the radio controlled boat, view data displayed on the tablet screen and walk along the water course, away from the instrument, tracking the movement of the boat to avoid obstacles Fig. 5. A quality reflective transmission reading is provided by the Sonarmite.

3. Corrections for Latency

Our trials have confirmed well documented issues when linking echo soundings to positional measurements. Latency (time lag) is the difference between the recorded position of the boat and the depth sounding and is due to data buffering and other internal influences within the equipment being used, recording two seconds or more. This problem exists in current measurements techniques including both total stations and GNNS and is ignored by many surveyors carrying out hydrographic surveys. If static measurements are taken over 3-5 seconds the latency effect is negligible, but if recordings are taken whilst tracking, corrections must be made. The faster the boat travels the greater the latency effect. Patch tests exist for correcting but these have been for ocean going survey vessels.

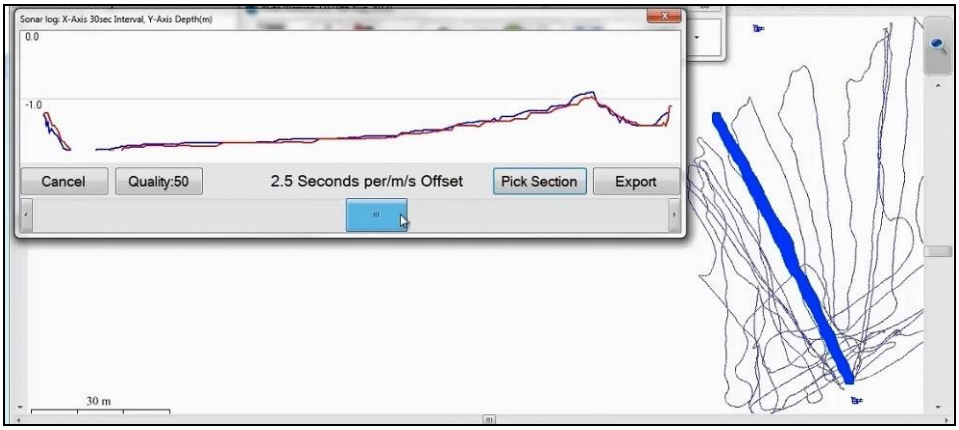

Fig. 6. Profiling Along the Same Line for Lag Calibration – Outgoing and Return

*4*Site Sonar has tools to remove lag by calibration. This involves running the boat along a fixed bearing and returning along the same line Fig. 6. This calibration can also help to identify and compensate for temperature and turbidity effects and should be carried out every time a survey is undertaken.

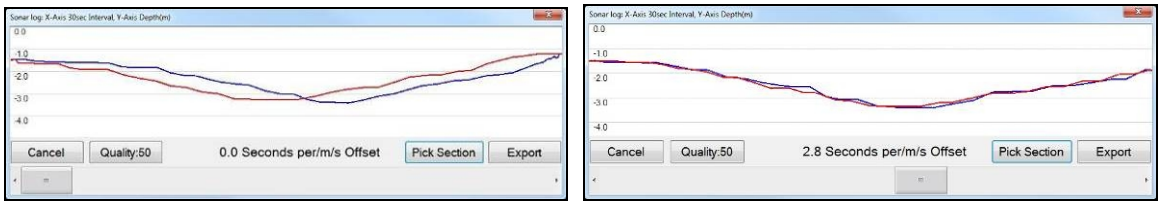

Fig. 7. Correcting for Lag with Before and After Adjustment

Section profiles outgoing and return are overlaid graphically and adjusted manually using a slider bar to remove this lag Fig. 7. The resulting lag correction is then applied to all measured points and is independent of the boat speed.

The positional time stamp is compared to the sonar log time stamp, with the time offset correction applied. A linear interpolation from this reference point is then taken to time stamps either side in the sonar log to establish the corrected depth.

Latency has be recognised in other studies and corrections made by taking a mean measurement from crossing runs; but this seems arbitrary. In other trials, on larger sea going vessels, a gradually sloping sea bed is identified and the boat runs at two different speeds to identify the lag. This is part of a general Patch Test [3], [4], [5] which can also take account of pitch, roll and yaw on multi beam scanning systems. Our trials have proved that corrections made for latency on our single beam system resulted in repeat measurements being well within tolerances (+/- 25mm), including crossing runs.

4. Worked Example

In the example shown here, Fig. 8, a river bank has collapsed and the Environment Agency needed a survey of both the bank and subterranean surface so that they could design a protective barrier, using sheet piling.

A total station was setup using predefined control points and the sonar boat calibrated for latency by traversing across two points in the river. The operator then moved away from the instrument to track the route of the model boat more closely zigzagging across the river.

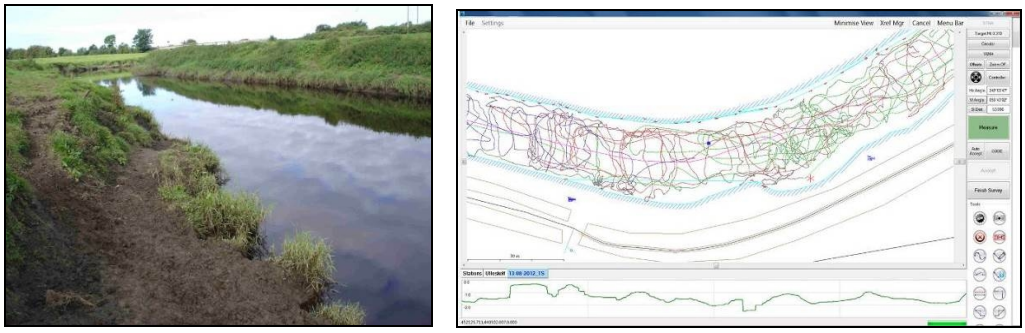

Fig. 8. *4*Site Sonar River Bank Survey

All this was done very quickly without putting individuals at risk, collecting 5k points in less than 2hrs. Before leaving site the data can be validated and spikes in the sonar log smoothed out or re-measured should the need arise. These spikes could be caused by sonar reflections off weeds, bubbles and fish Fig. 9. The quality of the return signal from the Sonarmite reflecting off the bed is constantly displayed.

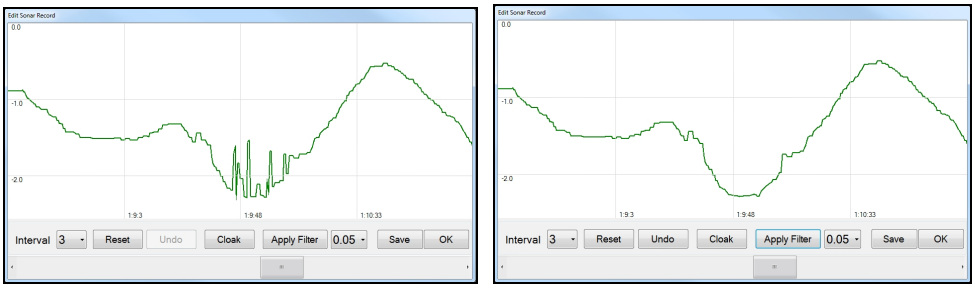

Fig. 9. Smoothing Out Spikes in Profiles

Data from *4*Site was then transferred into [n]4ce for modelling purpose Fig. 10.

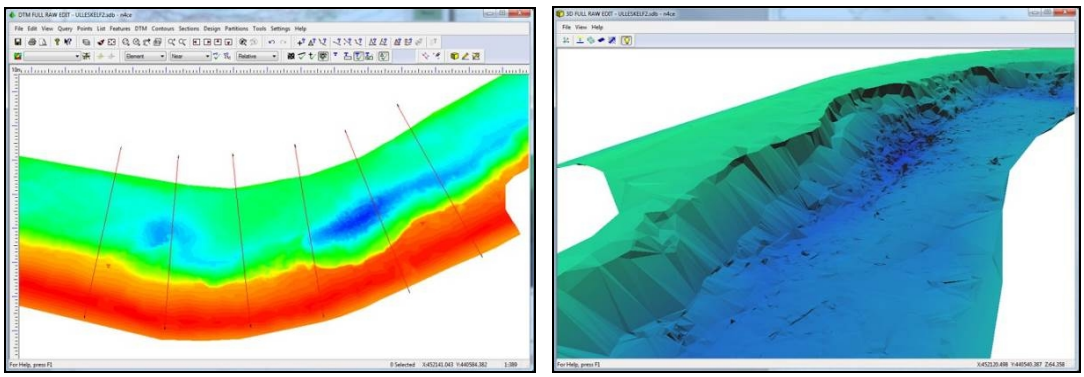

Fig. 10. Modelling in [n]4ce

5. Conclusions

In terms of its advantages, using a model boat can alleviate problems associated with health and safety, contamination, access, costs, and in our case data quality and accuracy. The model boat shown here has twin water jet motors minimising the problem of water contamination and snagging of the propeller on weeds. Further development work is being carried out to produce more powerful solutions, with upgraded motors, controllers, batteries and drives shafts. All the boats used have twin hulls which we have found to be stable in all conditions encountered, including fast flowing rivers.

The operator's safety is important. It's not always possible to launch a manned boat where you need to survey, necessitating a long detour to find a slipway which might also be affected by tides. There are situations where access to a water course is extremely hazardous and a manned boat is impractical. The model boat can also be taken into areas with restricted height (bridges) and into shallow waters where a manned boat could not go.

Most manned boat surveys require three operators; one shore based working the instrument and the other two in the boat, one being the coxswain. The model boat survey can be carried out by a single operator, but two would be recommended for health and safety reasons and, of course, to carry the survey equipment and model boat to the water course.

In conclusion we have created a safe, cost efficient method of carrying out land and hydrographic surveys. It's also very accurate as we have taken account of the latency issue. Videos of our sonar boat in action have been posted on YouTube. Search for ***4*Site Sonar**.

6. Acknowledgements

Development and testing of *4*Site Sonar has been carried with Dave Bulmer of Acorn Surveys in the UK. We would also like to acknowledge the contributions made by Ted Read of Ohmex Ltd.

7. References

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