HYDROGRAPHIC DIGITAL TERRAIN MODEL OF THE SOUTH FORD

Acquisition of acoustic bathymetric and ground-truthing data and production of bathymetric model for South Ford, Outer Hebrides

DRAFT REPORT
MAY 2009

Ref: TSE/SA/865/68-P/01

For
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CONTROLLED DOCUMENT

Topaz Environmental and Marine No:		**HYDROGRAPHIC DIGITAL TERRAIN MODEL OF THE SOUTH FORD** ENV02-09			
Status:			*Copy No:*		

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1. INTRODUCTION

Comhairle nan Eilean Siar requested a digital hydrographical terrain model (digital bathymetric model, DBM) of the South Ford area, Outer Hebrides. The DBM was requested as part of the development of a hydrodynamic and sediment transport model in order to address the erosion and associated flooding from recent storms. Further use of the model will be to assess the potential impact of future storms across the shores of South Ford behind Gualan Island. This report details the bathymetric and land survey conducted by Topaz Environment and Marine Ltd. (TEAM, University of St Andrews) from 4.6.09 to 12.6.09.

2. BACKGROUND AND OBJECTIVES

In 1983 an open deck bridge connecting South Uist and Benbecula was replaced by a narrow causeway. It has been suggested that the restricted tidal flow through the causeway may have changed the sedimentation patterns in South Ford thus exacerbating the flood risk to land in the immediate vicinity. Severe storms in 2005 were associated with extensive marine flooding across the low-lying areas of the Outer Hebrides which prompted local and Scottish Government action to evaluate the areas. In 2007 Comhairle nan Eilean Siar commissioned an evaluation of the sedimentation levels onshore to produce a digital terrain model, DTM together with an assessment of the history of sedimentation. These new data will be used together with bathymetry information to construct a hydrodynamic and sediment transport model for the area. It is anticipated that the final DTM will have a spatial resolution of 1-5m with a likely height resolution over the extrapolated model of 10-20cm.

The principal objective of this investigation was the production of a bathymetric survey of the South Ford area, Outer Hebrides for inclusion in the land-marine digital model. New bathymetric data was required both to the west and east of the causeway. Both areas shallow to intertidal flats that are exposed at low tide and represent a significant challenge to surveying due to navigation hazards.

3. METHODOLOGY FOR ACOUSTIC SURVEY

3.1 Data Acquisition

High resolution bathymetric surveys are typically acquired today using techniques that allow full seafloor data coverage rather than by using digital information from single beam sonar (Bates et al., 2001). Such acoustic technology includes multibeam sonar and swathbathymetry sonar. Both of these techniques rely on making acoustic measurements using hull-mounted acoustic transducers to measure a swath of seafloor on either side of the survey vessel. The swathbathymetry system is an extension of high-resolution digital sidescan that not only enables a picture of the seafloor to be produced across a swath sampled by the transducers along the boat track (known as the backscatter or amplitude map), but also measures the bathymetry across the swath through the use of multiple transducers. The method has found widespread application for mapping large swaths of gently undulating seafloor as the width of survey is approximately 7 to 10 times the depth of water to the transducers (Bates and James, 2003; Bates and Moore, 2002). Since the transducers are hull mounted with the addition of a motion reference unit and dGPS it is possible to locate features on the seafloor with a high degree of certainty. Multibeam sonar uses a combination of hardware and software control of multiple transducers to produce a number of sonar signals or beams that propagate from the sonar head in a fan and return a bathymetric and amplitude measure of the seafloor along the swath covered by the boat track. The method, as with swathbathymetry, produces a bathymetric map of the seafloor, which can be mosaiced into a full 3D chart, while the amplitudes can be used for seafloor discrimination. Multibeam sonar are particularly effective at mapping areas with rapidly undulating seafloor however they have relatively limited coverage in very shallow water whereas swathbathymetry systems are particular effective at covering large areas of gently undulating sea floor in particular in shallow areas.

For the South Ford survey it the following swathbathymetry system was used:
Swath system – SEA SwathPlus High Frequency System. The chosen sonar system has a central frequency of 468kHz and a ping rate of up to 30 pings per second giving a potential footprint of less than 5cm at standard survey speeds. Data was acquired with this system using SwathPlus acquisition software. SwathPlus was also used for the initial stages of data processing.
Motion Reference – TSSDMS05. This system was mounted immediately above the sonar transducer heads to ensure that no lever arm motions are encountered that could degrade the final bathymetry solution.
Sound Velocity – Applied Microsystems MicroSV sound velocity probe mounted at the sonar head to record changes in velocity due to mixing of different water (and thus potential salinity changes) in the enclosed waters of the bay.
Positioning – real time positioning was provided in real time by a Leica RTK dGPS solutions. A base station site was chosen for occupation on the causeway during the entire survey in order to provide a continuous RTK solution. The exact location of the base station was post-processed using Rinex corrections from the Ordnance Survey. This data not only ensured accurate positioning (to +/-2cm) but also allowed for tidal variations to be recorded in real time during the survey. It was vital that these were recorded and compensated for given the intertidal nature of the site.

3.2 Data Acquisition

The swathbathyemtry system and associated positioning equipment was deployed for this survey on the RV Envoy. The Envoy is a shallow draft survey vessel owned by the School of Geography and Geosciences, University of St Andrews that is ideally suited to shallow water survey. However, despite the shallow draft the vessel was not able to survey all of the intertidal areas safely. This was a particular problem on the west of the causeway where conflicting currents together with the narrow channel made for very hazardous conditions. In order to obtain topographic information in the shallow areas to the east of the causeway that had not previously been surveyed a ground-based GPS survey was conducted using a RK Leica instrument. During the marine survey navigation was accomplished using Hypack Max (Coastal Inc). Pre-planned survey lines were followed across the site using a 40m line spacing or less where possible. Figure 1 shows a map of the boat-surveyed track lines and the land-surveyed data points.

3.3 Data Processing

Data processing followed the steps outlined below:

- Replay of Data – the raw sonar data was replayed and filtered for along track and across track noise. All data was recorded using a RTKdGPS solution to compensate for tidal changes.
- Export data to mosaic package – Fledermaus (IVS) and editing of data to remove single data point noise spikes
- Save data in X,Y, Z format
- Grid data at bin size recommended by land survey team of 2m
- Save data in X,Y, Z format
- Convert saved X,Y,Z files from WGS84 to OSGP using the OSGB36 datum (origin 49ºN and 2ºW)
- Export of amplitude map for west and east areas
- Export and save point locations for land survey (for QA and extrapolation of bathymetric survey into the intertidal areas)

3.4 Data Integration with Land Surveys

The tender document requested that the survey contractor place two poles in the sediment between mid and high tide levels so that they can be surveyed during the bathymetry survey and also on foot at low tide. After review of the intertidal area, and in particular because of the absence of survey data to the east of the causeway a separate and extensive land-based survey was conducted over this area to include numerous rocks. The rocks form more permanent markers than wooden poles which it was anticipated would likely have been moved by the strong daily tidal regime.

3.5 Additions to Survey - *Sub-bottom Profiling*

In previous surveys similar to this one for sand transportation modelling we have acquired sub-bottom data on a number of specific survey lines during the project (see for example Bates and Oakley, 2005). This was attempted during the survey but the acquisition methods did not prove suitable to the field site due to a combination of survey conditions and sediment type. No useable data was therefore recoded.

4. RESULTS

Results for the bathymetric survey are given in the attached CD as x,y,z, point files, both raw, un-edited and edited. Additional files are also given for the sidescan amplitudes for both the east and west surveys. Appropriate files are listed as follows:

Name	Area	Type
SouthfordE2m.DBF	East	.dbf file edited data
SouthfordE2m.txt	East	.txt file edited data
SouthfordE.txt	East	.txt file un-edited data
SouthfordW2m.DBF	West	.dbf file edited data
SouthfordW2m.txt	West	.txt file edited data
SouthfordW.txt	West	.txt file un-edited data
land_East.txt	East intertidal	.txt file un-edited data
Ampwest.tif	West	.tif image of sidescan amplitudes
Ampeast.tif	East	.tif image of sidescan amplitudes

Each area (west, east and east-intertidal) are also presented as a digital bathymetry (terrain) model in figure 2. Coverage for the area to the east of the causeway was achieved through a combination of ground survey and the boat survey. The boat survey work was extended to the east beyond the original requested survey area as it was noted in the field that the bathymetry showed a rapid fall-off from the shallow depths around the causeway to a base level depth at 20-25m. This rapid drop-off will likely be significant for any subsequent storm wave modeling. To the west of the causeway the channel network proved unsafe to survey but a full survey was obtained for the area to the west of the sand spit. The land-based survey was used for calibration and quality control on the marine survey data as it was possible to survey to low tide with the Leica instrument and to re-survey the same area (including upstanding rocks) with the boat-based survey.

5. RECOMMENDATIONS FOR FUTURE WORK

The survey area of Southford presented significant challenges to the bathymetric survey from the very shallow intertidal nature and the numerous navigation hazards. Despite these, through a combination of boat-based survey and land-based survey a substantial new part of the area was surveyed. This area covered represents the most significant, from a modelling point of view, area of the causeway. In order to survey the remaining areas of the channel to the west of the causeway it might be possible to use either an Autonomous Underwater Vehicle or to survey using a prototype platform such as has been recently built by SEA Ltd. based on a Jetski.

6. REFERENCES

Bates, C. R., Davies, J and Foster-Smith, R. 2001. Using seabed visualisations from acoustic systems to support the monitoring and management of marine protected areas. SUT Underwater Science Symposium March 29 - April 1 2001, Southampton.

Bates, C. R. and James, B. 2003. Marine GIS for management of Scottish marine Special Areas of Conservation. Marine Geography: GIS for the Oceans and Seas, ed. Breman, J. ESRI Press.

Bates, C. R. and Moore, C. 2002, Acoustical Methods for Marine Habitat Surveys. HydroInternational, Vol. 6, No. 1, pp. 47-49.

Bates, C. R. and Oakley, D. 2004. Bathymetric sidescan investigation of sedimentary features in the Tay Estuary, Scotland. International Journal of Remote Sensing, v 25, pp. 5089-5104

Figures

Figure 1 – final survey acquisition lines

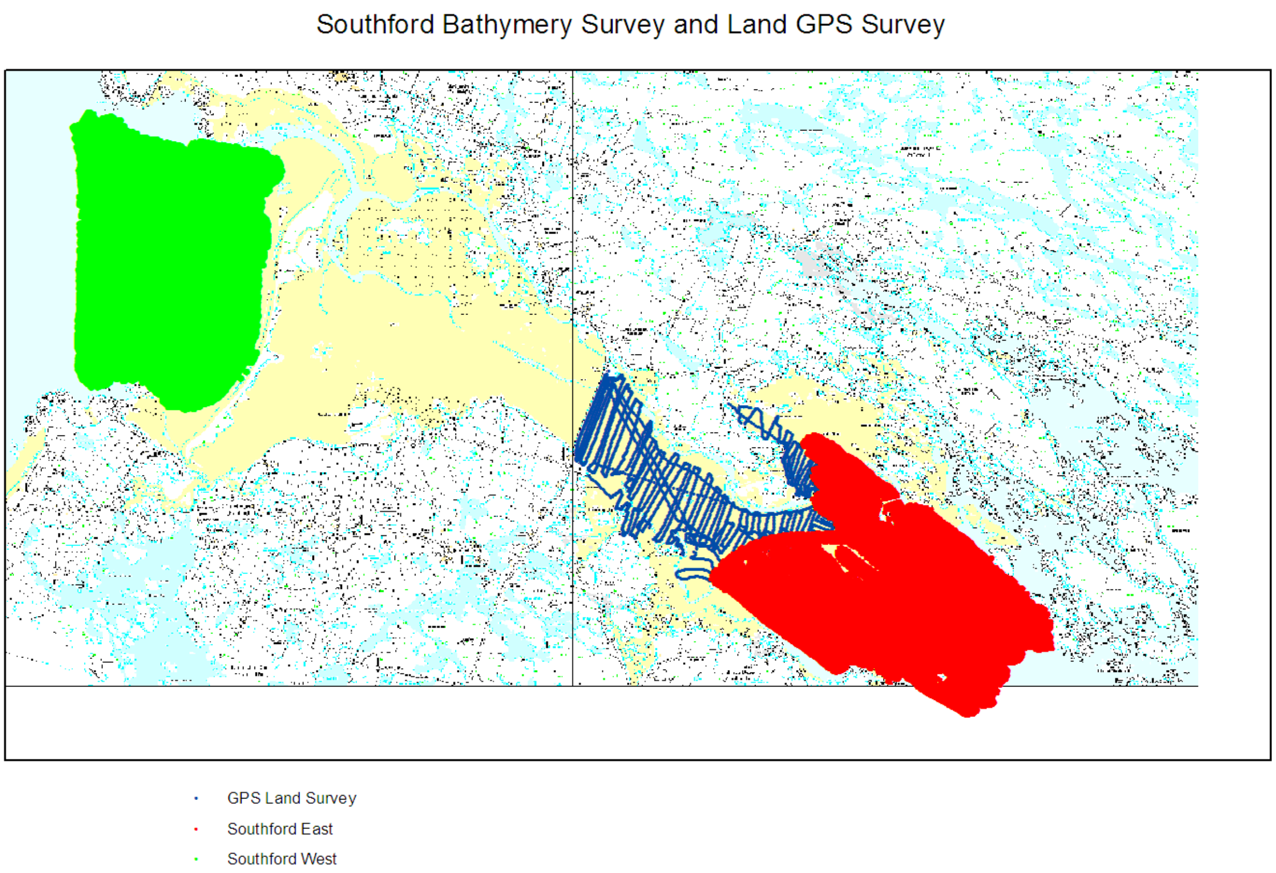

Figure 2 – final survey digital bathymetric model