



Churchill Barrier 2 Orkney



High Definition Laser Scan Survey Report

December 2013



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CHURCHILL BARRIER 2

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HIGH DEFINITION LASER SCAN SURVEY REPORT

PROJECT NO: 457

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CLIENT: ORKNEY ISLANDS COUNCIL

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Authorised for Distribution by: Paul Sharman	Date: 17/12/2013

EXECUTIVE SUMMARY

This report sets out the results of a High Definition Laser Scan undertaken by Orkney Research Centre for Archaeology (ORCA) Marine of the east side and top of Churchill Barrier 2 on behalf of Orkney Islands Council (OIC). It sets out the methodology used, the results, lessons learned and the creation of appropriate deliverables for further use by OIC.

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1 INTRODUCTION

Orkney Islands Council (OIC) commissioned Orkney Research Centre for Archaeology (ORCA) Marine to conduct a High Definition Laser Scan Survey of the east side and top of Churchill Barrier 2 (hereafter referred to as 'the site'). This was to enable OIC to come up with options regarding wave overtopping and tidal flow energy capture at Churchill Barrier 2. This report sets out the methodology, survey results and reporting strategy that ORCA Marine used to achieve the stated objectives of the project.

2 SITE LOCATION, TOPOGRAPHY

The site is situated between, and links the islands of Lambs Holm and Glimps Holm in the Orkney Islands at National Grid reference ND 4803 9974. Churchill Barrier 2 is one of four barriers which span the sounds between the Orkney mainland, Lamb Holm, Glims Holm, Burray and South Ronaldsay. Built during the Second World War to block enemy access to the four eastern approaches to the Royal Navy's Home Fleet in Scapa Flow, they consist of a rubble base enclosed within tumbledown concrete blocks with a single carriageway roadway on top (Ritchie 1996, 48). The road carriageway of the four barriers allows vehicle access between Mainland Orkney all the way to South Ronaldsay.

3 SURVEY AIMS AND OBJECTIVES

The project's key objectives were to:

- conduct a high resolution laser scan survey of the east side of Churchill Barrier 2;
- produce an accurate 3D model in point cloud format of the East Side of Churchill Barrier 2 for the creation of further deliverables; and
- produce accurate plans and elevations drawings of Churchill Barrier 2 in AutoCAD Civil 3D format.

4 SURVEY METHODOLOGY

The project was carried out in four key stages:

- Establishment of survey control stations, followed by full high definition laser scan survey;
- Processing and editing the laser scan survey data;
- Creation of accurate barrier plans, elevations and sections in AutoCAD Civil 3D;
- Submission of deliverables to client and archiving of raw survey data and post-processed deliverables;

There were two main priorities. The first priority was to capture the east side elevation of Churchill Barrier 2 from the initial start point on the North side to the end of the wave wall. Surveying at low tide enabled the maximum amount of possible elevation data to be acquired. The second priority was to survey the road deck, capturing the barrier crests, road centreline and the wave wall.

4.1 LASER SCAN SURVEY

The project utilised ORCA Marine's Leica ScanStation C10 and a hired Leica MS50 MultiStation alongside a Leica Viva RTK SmartNet GNSS (Global Navigation Satellite System) to conduct the digital documentation of Churchill Barrier 2. These produce a set of data points, with defined X, Y and Z coordinates in a chosen coordinate system, known as a pointcloud, representing the external surfaces of any surveyed features.

All scans were weather dependent, because a laser scanner will also record rain. Winds in excess of 20 mph (miles per hour) over the barrier, an exposed environment, also knock the laser scanner out of tilt compensation, thus preventing any laser scanning.

A Leica Viva RTK SmartNet GNSS was used to create a network of control points within British National Grid (BNG) to Ordnance Datum Newlyn (ODN). Control points were also established for the scanning targets. The scanning targets are circular blue and white targets with a diameter of six inches. They can be set up on their magnetic bases or on an optical tribrach on a tripod positioned over a control point. These targets allow a laser scanner to align itself to a known backsight position with BNG; a scanner's laser cannot use a standard Total Station Theodolite (TST) prism to achieve this. The C10 and MS50 were set up over the established control points allowing the point cloud to be geo-referenced within BNG. The survey points for the laser scans captured from the shore at the north and south ends of Barrier 2 consisted of 500mm long wooden stakes driven into the ground with a survey nail hammered into the end. These were placed with the due care and diligence necessary when

surveying and removed once the survey had been completed. For the road deck survey, targets were glued to the road surface using clear bathroom sealant. Both the targets and sealant can be removed easily without leaving any mark or residue on the road deck.

To allow for differing conditions when establishing the control points for the laser scanner, the survey team used an effective radius range of 150 metres rather than the actual on-site maximum range of 180 metres. Using this radius, each control point was set up so that the survey team could be confident that resulting pointclouds would overlap with their immediate neighbour thus making the creation of a unified point cloud easier without any noticeable gaps between the individual pointclouds. As the scans are acquired in BNG coordinates, the scan survey processing software, Leica Cyclone automatically places the pointclouds together in relation to each other and BNG in a process called registration. It is important to note that the control points were established using the inherent residual errors of an RTK GNSS as access and time issues did not allow for a joined up TST traverse from the north shoreline along the road deck and to the last control points on the southern shoreline. Plus or minus two centimetres was the maximum possible residual error that the survey team were prepared to accept for GNSS established control points and all surveyed control points had a residual error below this number. Therefore the initial registration created by Leica Cyclone can be tightened up further by pointcloud to pointcloud alignment if necessary.

The Leica ScanStation C10 scans 360 degrees in the horizontal plane and 270 degrees in the vertical plane, leaving a blindspot of 90 degrees immediately below its set-up position. Laser scanners can also only survey what they can see; an obstruction will create a shadow behind it in the pointcloud data. Therefore reverse angles from different setup positions were used to fill in the data gaps and supply the other sides of the features surveyed.

The specified survey required five scans spaced at regular intervals along the east carriageway of Barrier 2's road deck and scans from the land north and south of the barrier on its east side. ORCA Marine's Leica ScanStation has a range of 0.1 metres to 300 metres with a point spacing of 1mm through its full range and is capable of capturing 50,000 points per second. However the effective maximum range of the C10 in capturing the required resolution of the blocks and road surface of Churchill Barrier 2 proved to be roughly 180 metres.

The scans undertaken on the road deck required a traffic management system. A convoy system was adopted to control traffic passing north or south along the western carriageway of the barrier. With guidance from the traffic management crew the survey team arranged a

series of traffic cones and temporary signs to allow them to set up each laser scanning position and work safely on the barrier. The cones and traffic signs were established at an appropriate distance away from the laser scanner to allow it to capture the most data without having its point of view (POV) obscured by vehicles moving back onto the east carriageway beyond the limit of the section of road contained within the traffic cones. Furthermore this distance enabled the laser scanning targets to be set up at a suitable distance to enable the setting up of suitable survey baselines. The traffic cones and signs also enabled the survey team to work around the C10 safely without the risk of being hit by any road vehicles. Vibrations from passing vehicles did not appear to force the C10 out of tilt compensation.

The scans taken from the shoreline north and south of the barrier were aimed at capturing the east facing elevation of the structure. These scans were undertaken during the lowest, earliest tidal window possible within the project timeline. The extent of the tidal window imposed a time constraint within which to conduct this aspect of the survey.

As even the C10's maximum range is not enough to laser scan the whole of Barrier 2's side elevation from the shore a Leica Nova MS50 MultiStation was hired from Leica Geosystems. With a maximum range of 1000 metres it had the potential range to fill in the middle portion of Churchill Barrier 2 at a scan rate of 1000 points per second with a point spacing of 1mm, which is a slower rate than the C10. Due to the slower scanner speed of the MS50 colour images were not captured, the pointclouds from these scans are not coloured up by real Red Green Blue (RGB) values and are displayed in the figures using the intensity of the returned laser signal. Two scans were taken with the C10 from the north side of the barrier with a further two scans from the southern shoreline. A single scan using the MS50 was taken from the northern shoreline with a single scan from the southern shoreline.

All laser scanning survey work was carried out in accordance with industry standard laser scanning guidelines (Bryan et al, 2009).

Site work was carried out by ORCA staff who adhered to the Health and Safety regulations and procedures laid down in the most up to date version of the ORCA *Health & Safety Policy*. Appropriate Risk Assessments were undertaken before commencing the survey work.

4.2 DATA PROCESSING

The raw digital data of the individual scans were imported from the Laser Scanner into Leica Cyclone laser scanning software processing package for checking, editing and exportation of

outputs for use in AutoCAD Civil 3D. The registered BNG geo-referenced point cloud was cleaned up. This involved the deletion of sprites of passing vehicles created by passing vehicles captured by the laser scanner. Points can also be created when the laser scanner points at the sun as parts of sunlight are on the same wavelength as the scanner's laser and these anomalies were also deleted. Finally traffic cones, temporary road management signs, barriers that had been set up to allow the survey team to access and work on the east carriageway alongside any parked road management vehicles that had been captured during the survey were removed from the registered pointcloud.

4.3 DIGITISATION AND EXPORTATION OF POINTCLOUD DATA

All appropriate features scanned were digitised in Leica Cyclone and Leica Cyclone II Topo software. Due to the large number of features that make up Churchill Barrier 2 the ORCA Marine team concentrated on digitising the road deck, wave wall and the blocks that make up the barrier's rock armour. Features with complex shapes such as the crash barriers were not digitised.

OIC (Steven Miller and Neil Gauld) confirmed that the initial pointcloud registration was sufficient for the original project purposes, therefore the point cloud data was exported in a *.pts format without any further pointcloud to pointcloud alignment. A *.pcg pointcloud index file was created within AutoCAD Map 3D 2013 that will enable OIC to load the *.pts pointcloud file within AutoCAD Civil 3D. This will enable OIC to utilise the full pointcloud data within their own software programmes for editing and the creation of further deliverables.

5 SURVEY RESULTS

The survey team succeeded in capturing the priority areas at the north end of Barrier 2, including the wave wall, the rock armour blocks around this section and the road deck including the barrier crests and road centreline. After discussion with OIC (Steven Miller and Neil Gauld) it was agreed that enough useful data had been collected for the project's priorities.

5.1 LESSONS LEARNED

Many lessons about the limitations and constraints on laser scanning a complex structure like Churchill Barrier 2 were learned during the course of the project. The nature of Churchill Barrier 2 with the tumbledown rock armour blocks provides a difficult surface for a laser scanner to get a returning laser measurement from. The blocks create many different angles with resulting shadows behind which the laser scanner cannot scan. The concrete nature of the blocks and the grey colour also reduce the effective maximum range at which a laser scanner can record these objects.

These problems were not unanticipated, but it was hoped that the use of a Leica MS50 as recommended by Leica Geosystems would allow more data to be captured at longer range, albeit at a slower speed than was possible with the C10. The use of the MS50 was intended to fill in the central portion of the barrier. Unfortunately the results proved to be disappointing; the MS50 could survey at that distance but the survey was not able to capture enough points for blocks and other features to be identified. It is possible that such resolution on a similar feature built out of similar materials could be achieved for future projects with greater battery power and no time limitations. A test scan at such a resolution was started that indicated that 23 hours would be required. As the scanning of the east side elevation relied upon surveying at the lowest possible tidal window within the project timetable this means that even if enough battery power had been available to enable the MS50 to scan at the highest possible resolution, there would not be enough time within the tidal window to complete an ideal scan.

It was anticipated that scanning from the road deck would enable more data gaps to be filled in of the east side elevation's rock armour by capturing reverse angles that were not possible to achieve from the shoreline. This was achieved to an extent but there were still limitations and gaps in the resulting data; the results were not as complete as expected.

Contrary to initial expectations Leica Cyclone II Topo proved to be less user-friendly for digitisation of the features from the pointcloud data than Leica Cyclone itself. Significant improvements in the time taken to digitise features and the flexibility of chosen points were experienced when utilising Leica Cyclone instead.

The features digitised in AutoCAD from the pointcloud data also had distinct limitations. In part this is due to the limited coverage of the barrier that the laser scanning was able to achieve within the time and method allotted. It is difficult to create effective polygons of the rock armour blocks from the pointcloud data where the laser scanners have not fully captured them. This is less noticeable in plan, or even a 3D view but it does become a major issue if elevation slices are needed through the barriers from a purely 2D representation of the digitised CAD features. Even with the actual pointcloud data a full satisfactory 2D elevation slice through Churchill Barrier 2 remains unsatisfactory. In effect the Churchill Barriers are not the type of structure that enables satisfactory, completely 2D elevation slices either using digitised CAD data or indeed the original pointcloud. This effect can be clearly seen in Plate 1.

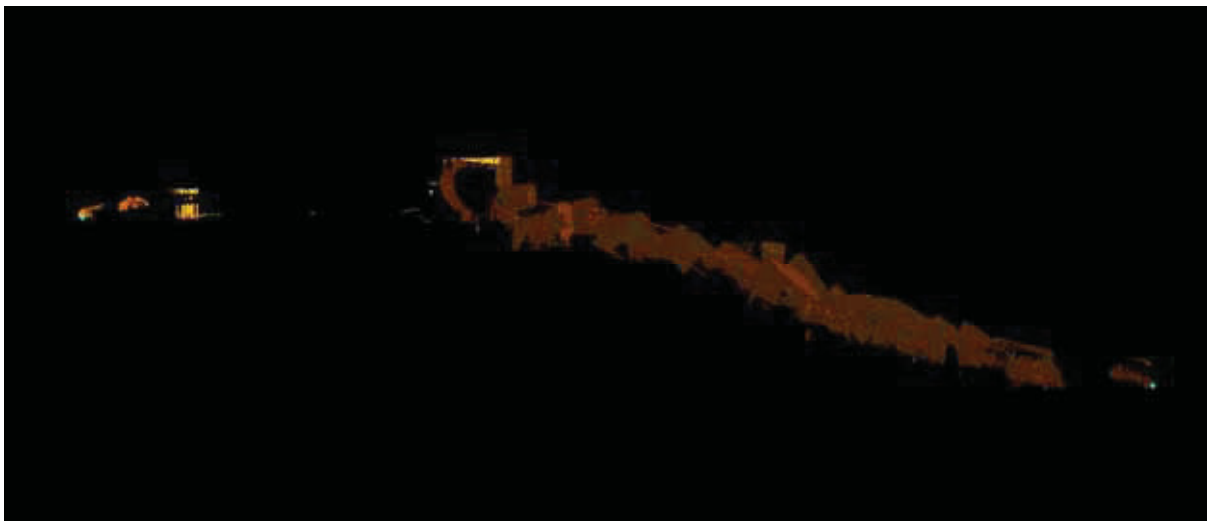


Plate 1: Elevation taken with Leica Cyclone data looking North through Churchill Barrier 2 and the wave wall.

6 CONCLUSIONS AND RECOMMENDATIONS

In retrospect, the surveying of the road deck required another day of surveying with at least five more scanner set-ups. Of course this would have had an impact on project time and cost. Survey time would also be affected by possible weather delays to this additional day of surveying. Such a delay may be mitigated by conducting the survey during spring and summer where there is a greater chance of better weather with lower winds and increasing daylight hours to enable surveying to be undertaken safely for longer.

There are other surveying methods that can be used in future:

- A laser scan set up on a gyroscopically stable platform on a boat enabling laser side of the side elevations from the water. This would entail the hiring of a boat;
- Use of Unmanned Aerial Vehicles (UAV). These can capture pointcloud data enabling the creation of Digital Terrain Models (DTM) and other outputs. They would require temporary road closures of a few minutes, in the order of 10 minutes or so. This would prevent any accidents if the UAV crashed into any road vehicles while flying over the barrier road deck itself;
- There are mobile hand held laser scanners available which can be used while moving such as 3D Laser Mapping's ZEB 1. However these do have a range limit and would still require the use of a boat to access the side elevations of any Churchill Barrier;
- And standard TST/GNSS profile survey. This type of survey would require temporary or partial road closures and appropriate health and safety protocols for accessing the rock armour blocks beyond the safety of the crash barriers.

7 PUBLICATION AND ARCHIVING

The project archive was prepared for deposition at the RCAHMS and the Archaeology Data Service (ADS) on completion of the full project. Where appropriate the Project Archive was submitted in hard copy format as well as digital format.

The Project Archive includes:

- The Project Design;

- Laser scan survey data in raw *.imp format, post-processed *.pts and AutoCAD Civil 3D format together with the survey methodology and any additional data formats such as meshes;
- Survey Project Report;
- And all correspondence related to the project.

8 ACKNOWLEDGEMENTS

The author would like to thank OIC (Peter Bevan), for commissioning the work, Steven Miller and Neil Gauld for coordinating the survey project and the advising on the deliverables that OIC required and OIC's road operations team who enabled the surveyors to work safely on the road deck of Churchill Barrier 2.

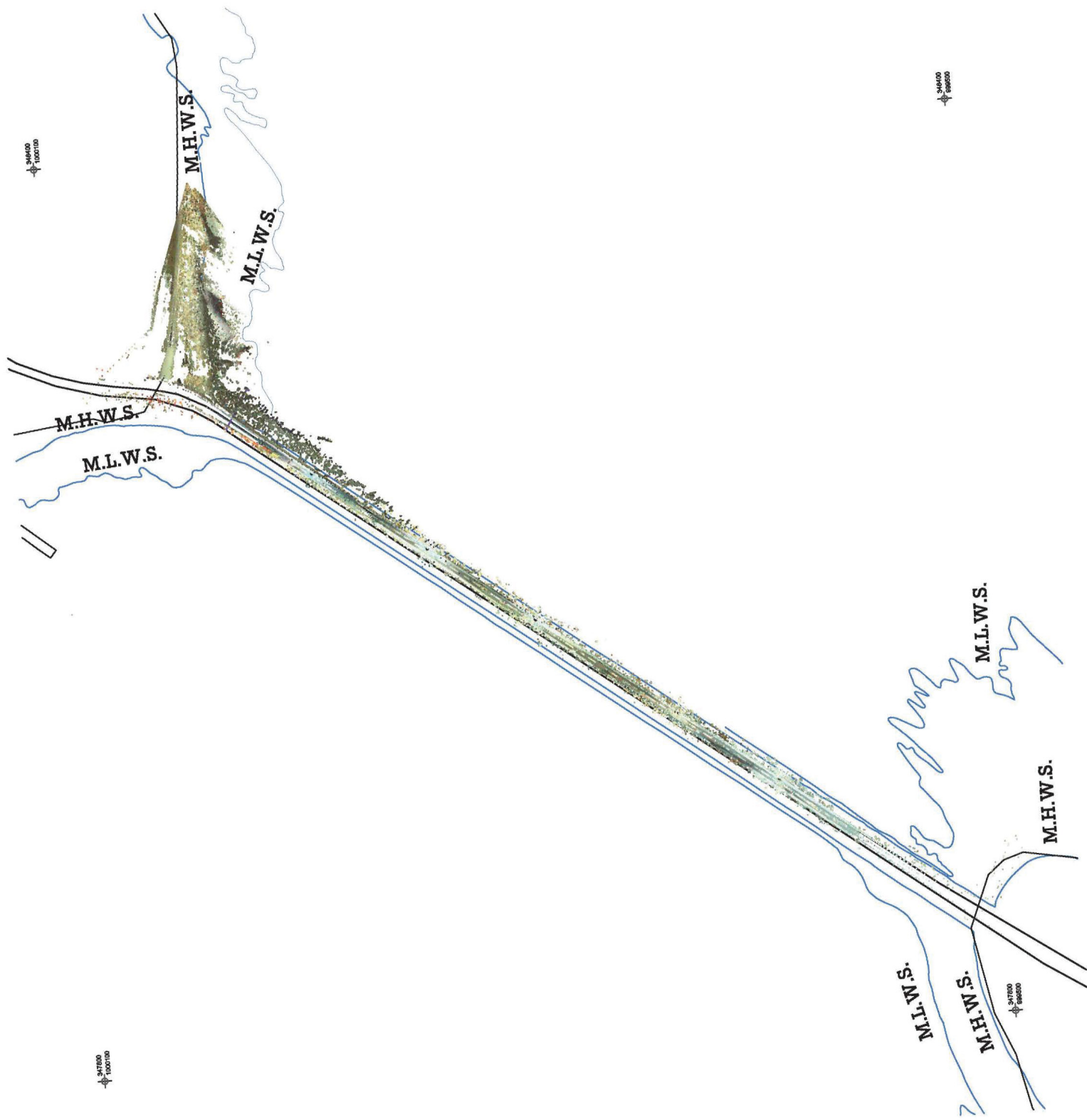
9 ABBREVIATIONS

ADS	Archaeological Data Service
BNG	British National Grid
DTM	Digital Terrain Model
GNSS	Global Navigation Satellite System
IfA	Institute for Archaeologists
MPH	Miles per Hour
ODN	Ordnance Datum Newlyn
OIC	Orkney Islands Council
ORCA	Orkney Research Centre for Archaeology
OS	Ordnance Survey
POV	Point Of View
RCAHMS	Royal Commission on the Ancient and Historical Monuments of Scotland
RGB	Red, Green, Blue
RTK	Real Time Kinematic
TST	Total Station Theodolite
UAV	Unmanned Aerial Vehicle

10 BIBLIOGRAPHY

Bryan, P., Blake, B and Bedford, J. (2009) *Metric Survey Specifications for Cultural Heritage*, English Heritage

Ritchie, A. (1996) *Orkney*, Edinburgh: The Stationery Office Ltd



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Relative strength of returning laser signal for Leica MS 50



Survey Data Supplied by: OIC/ORCA Marine



Figure.2. East Side Elevation

Project Name	Churchill Barrier 2 Laser Scan Survey
Project No.	457
Date	December/2013
Creator	MEL
Scale	1:2500 @ A3
Revision No.	1
ORCA, Orkney College, East Road, Kirkwall, KW15 1LX	

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SW

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Relative strength of returning laser signal for Leica MS 50



Survey Data Supplied by: OIC/ORCA Marine



**Figure.3. Sample of Northern
Portion of East Facing Elevation**

Project Name	Churchill Barrier 2 Laser Scan Survey
Project No.	457
Date	December/2013
Creator	MEL
Scale	1:400 @ A3
Revision No.	1
ORCA, Orkney College, East Road, Kirkwall, KW15 1LX	

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Relative strength of returning laser signal for Leica MS 50



Survey Data Supplied by: OIC/ORCA Marine



Figure 4. Sample of South Portion of East Facing Elevation

Project Name	Churchill Barrier 2 Laser Scan Survey
Project No.	457
Date	December/2013
Creator	MEL
Scale	1:500 @ A3
Revision No.	1
ORCA, Orkney College, East Road, Kirkwall, KW15 1LX	