Tarbert Flood Study

Phase 2: Baseline modelling

05 December 2019

Quality information

Prepared by	Checked by	Approved by
Morag Hutton and Adrian Wright	Walter Robison Senior Engineer	Dylan Huws Associate Director

Revision History

Revision	Revision date	Details	Authorized	Name	Position
1	19/12/18	Draft issue for comment			
2	19/02/19	Updates based on client meeting			
3	05/12/19	Final issue			

Distribution List

# Hard Copies	PDF Required	Association / Company Name

Prepared for:

Prepared by:

AECOM
E: morag.hutton@aecom.com

AECOM Limited
1 Tanfield
Edinburgh
EH3 5DA
UK

T: +44 131 301 8600
aecom.com

Table of Contents

Figures

Tables

1. Introduction

AECOM have been commissioned by Argyll and Bute Council to undertake a Flood Study for the village of Tarbert. This report outlines the work undertaken for Phase 2 (see list below).

The project will be undertaken using a phased approach, and includes the following main tasks:

- Phase 1 – Data review and gap analysis
- Phase 2 – Baseline existing flood conditions
- Phase 3 – Long list to short list selection
- Phase 4 – Option development and modelling

Phase 2 of the study, which is detailed in this report, contains the following elements:

- Background of the project
- Historic flooding
- Fluvial culvert capacity assessment
- Baseline coastal flooding assessment
- Recommended next steps

2. Project Background

The study area is outlined in Figure 2-1 below and encompasses the village of Tarbert which is centred around the harbour. The purpose of this study is to identify the areas at risk from tidal flooding during the current day and climate change scenarios.

Flood risk to the village is primarily tidal and was identified as the main source of flooding in the Flood Strategies. As part of this phase of work, although not within the scope so detailed in a separate report, the upstream fluvial catchments will also be assessed as several watercourses are culverted through the village and have the potential to causing flooding.

Further background data on the study and Tarbert can be found in the Phase 1 report.

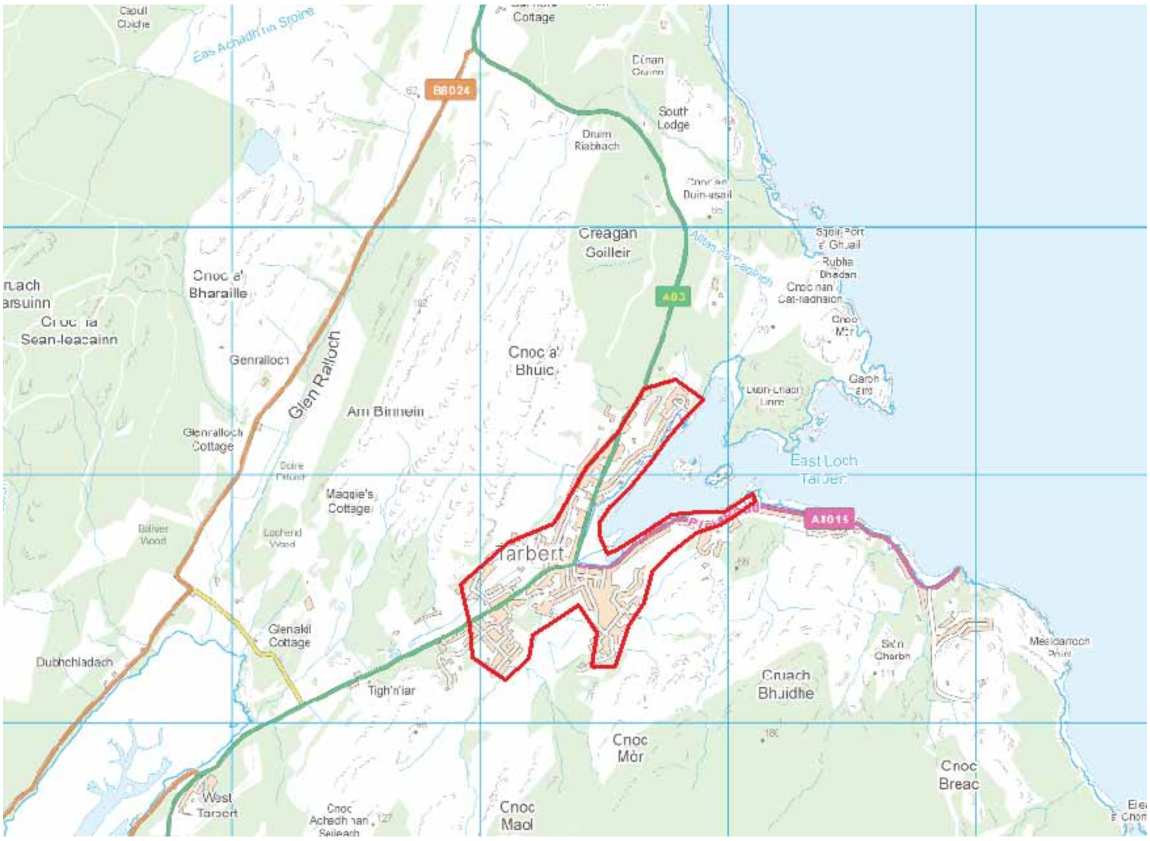


Figure 2-1: Study area

2.1 Historic Flooding

Coastal flooding is predicted by the SEPA online Flood Risk Management Maps[1] (FRM maps), encroaching on the roads around the harbour including Harbour Street and Barmore Road. These maps are backed up by the historic flood reports. Accounts detail flooding to the harbour area and adjacent properties as a result of high sea levels coupled with drainage systems that could not discharge, occurring in 2013 and 2014. During these events properties around Barmore Road and Harbour Street were affected.

Additional anecdotal and photographic evidence provided by Argyll and Bute council also identifies significant flooding along Harbour Street and Barmore Road in January 1991 which was due to a storm surge.

Accounts held by SEPA indicate frequent flooding from Loch Fyne, with examples in 2001, 2006 and 2010. Flooding during these events flooded carparking and the roads around the harbour, blockage of surface water systems and deployment of sandbags. Photographs can be found in Appendix A.

[1] http://map.sepa.org.uk/floodmap/map.htm

3. Coastal Modelling

3.1 Introduction

The main objective of the coastal modelling exercise is to establish the nearshore extreme wave characteristics and extreme sea levels along the frontage at Tarbert. In order to achieve this, AECOM has undertaken a numerical modelling study to investigate the existing and future (up to the year 2100) wave climate. The information on wave conditions will be used to provide wave overtopping volumes which will then subsequently be used to support the inundation mapping stages.

Specifically, this exercise includes the following:

- Review of existing information available to support the study including previous investigations;
- Long-term (38 years) wave transformation modelling to determine local marginal wave extremes;
- Joint probability analysis of waves and water levels local to Tarbert for present day and future (2100) epoch; and
- Overtopping assessment at two key sites within Tarbert Harbour.

3.2 Data review

The first step in the coastal modelling study was to establish any relevant information over the project area and wider environment. As part of the data review, AECOM undertook a site visit to establish first-hand the conditions and constraints affecting conditions at the site. Photographs can be found in Appendix A.

AECOM identified a number of key bathymetric and topographic datasets that were available for use in the study which are outlined in the following sections.

3.2.1 Bathymetry and Topographic Data

A topographic survey was undertaken as part of this study and this data was used in combination with existing data. The key datasets that have been used include:

- C-MAP data - The bathymetry data has been obtained through the C-MAP digital archive which AECOM has access to under licence. The C-MAP dataset is derived from digitized contours and sounding data taken from published Admiralty charts. Datasets are provided in XYZ format. Figure 3-1 shows the coverage and density of data points included the C-MAP dataset;
- NEXTMap – land elevation data covering the harbour area in a 5x5m grid. Data extent in Appendix D;
- Bathymetric survey from Tarbert Port Authority pre and post dredging. Data shown in Appendix D; and
- Topographic long sections of representative cross sections along the harbour frontage as well as spot heights surveyed in 2018 as part of this study. Data shown in Appendix D.

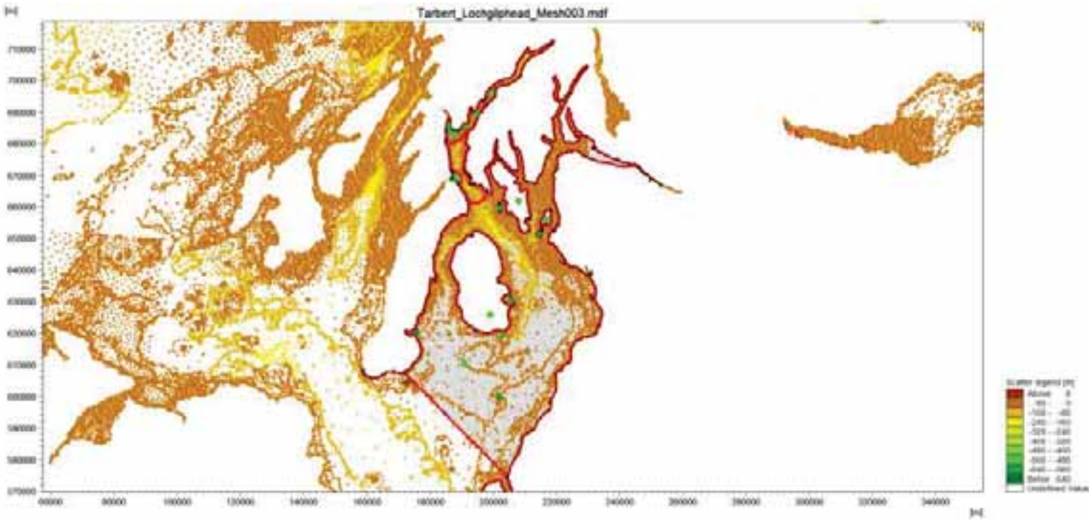


Figure 3-1: Tarbert and Lochgilphead Offshore Bathymetry Data – Scatter Data Vertical Datum m ODN

3.2.2 Offshore Wave Conditions

Offshore wave conditions have been obtained under licence from the Met Office WaveWatch III European Waters model. The model has a grid resolution of approximately 8 km which is adequate for representing wave fields in the deep waters of the Atlantic and Continental Shelf. The model provides a 38 year dataset for the period January 1980 to December 2017 with wind and wave parameters provided at 3 and 1-hourly intervals, depending on the period. The wave component of the hindcast is generated using the WaveWatch III third-generation spectral wave model (Tolma, 2009)[2]. The model uses a WAM Cycle-4 source term scheme as described by Bidlot (2012)[3] and includes parameterizations for shallow water effects on the wave field.

Information has also been provided to AECOM from the Met Office wave model at three positions (Table 3-1 and Figure 3-6) for use on the project, specifically as input conditions for the regional wave model. Also shown are the times of the predicted largest peak Hs and Tp values.

Table 3-1: Met Office data extract

Position	Latitude	Longitude	Largest Significant Wave Height (Hs)	Maximum Peak Period (Tp)
2161	55.1970	-5.3880	5.69m (8.48 sec, 5th December 2013)	19.23 sec (4.50m, 10th December 2014)
2309	55.6057	-4.9930	3.93m (8.20 sec, 15th January 2015)	18.18 sec (0.01m, 31st August 2011)
2345	55.7597	-5.2860	3.22m (5.78 sec, 5th December 2013)	8.55 sec (0.002m, 6th January 1999)

3.2.3 Water Levels

3.2.3.1 CFB levels

Extreme water levels include contributions from tides, sea level rise and surge.

The extreme values for present day (2018) at Tarbert are available from the Coastal Flooding Boundary (CFB) dataset, Scottish Environment Protection Agency (SEPA). The CFB dataset has been developed to provide a

[2] Tolman, 2009. User Manual and System Documentation of WaveWatch III Version 3.14. Environmental Modelling Centre Marine Modelling and Analysis Branch
[3] Bidlot, J.R. (2012). Present Status of Wave Forecasting at ECMWF. ECMWF Workshop on Ocean Waves

consistent set of information for use in coastal flood modelling, scheme design, strategic planning and flood risk assessments and this dataset is SEPA's preferred means of applying extreme water levels. Figure 3-2 shows available data points of still water level in the Tarbert area. The point labelled 'Main-1884' has been selected for Tarbert.

The present day sea levels were calculated by adjusting the CFB values, with a baseline year of 2008, and adding an appropriate allowance for sea level rise. In order to consider climate change for the future time epoch in 2100, the present day extreme water levels were factored with UKCP09 95th percentile high emission scenario (including surge) sea level rise projections. The UKCP18 data was not available at the start of the project and SEPA had not issued any guidance on the use of these updated projections at the time of writing. Therefore, this data source has not been used in this study. The results show that the corresponding increase in sea level is approximately 630 mm in 2100 at Tarbert.

Table 3-2 provides extreme water levels for present day (2018) and the long term epoch in 2100.

Revised climate change uplift guidance from SEPA, incorporating the UK Climate Projections (UKCP18) was made publicly available during this phase of work; coming after the modelling was largely completed. UKCP18 provides the most up-to-date consideration of how the climates change up to 2100 and beyond. The UKCP18 guidance is now reviewed to consider any implications to the modelling completed in this study.

To make a comparison between the work undertaken to date and the UKCP18 output, AECOM has downloaded the sea level rise (SLR) from the UKCP18 website (https://ukclimateprojections-ui.metoffice.gov.uk/). Sea level rise for UKCP18 RCP8.5 50th percentile scenario is 474mm for long term epoch in 2100. The previous SEPA data based on UKCP09 95th percentile high emission scenario was 630mm, which has led to a conservative input of water level. Considering the small differences in projected still water level, repeating the calculations for wave overtopping and updating the inundation modelling is not considered to be necessary.

Water level profiles are required to provide an estimate of the duration of a flood inundation event occurring along the study frontage. The water level profiles at Tarbert were derived using the CFB database.

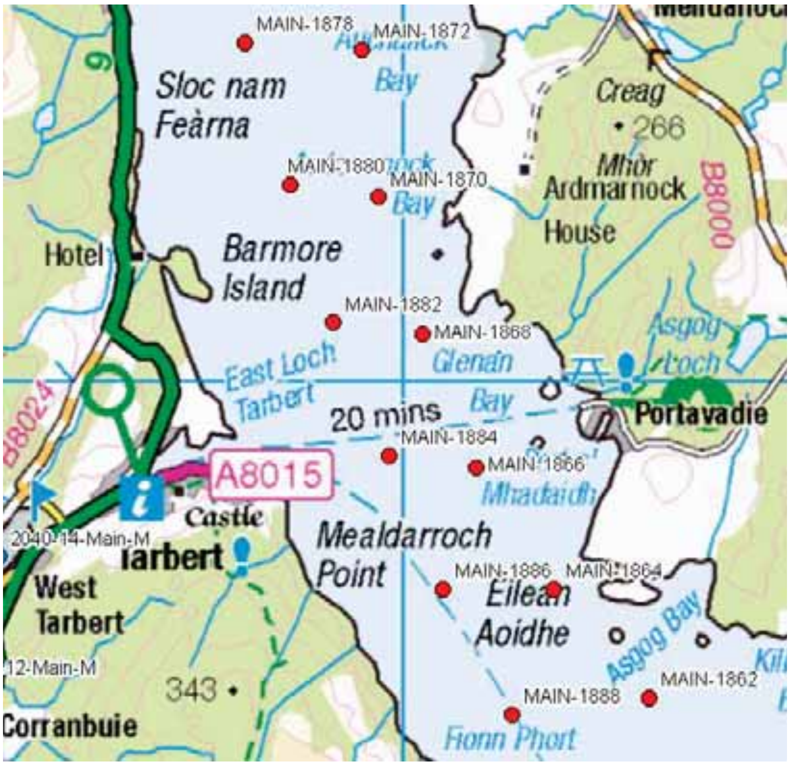


Figure 3-2: Local Extreme Sea Level Prediction Points from the SEPA Database

Table 3-2: Coastal Flood Boundary extreme water levels for chainage 1882

% Annual Exceedance Probability (Return Period)	Present Day (2018) Level m AOD	Future (2100) High Emission Level m AOD
50 (2)	2.86	3.47
20 (5)	3.03	3.65
10 (10)	3.16	3.78
5 (20)	3.31	3.94
2 (50)	3.48	4.11
1 (100)	3.62	4.26
0.5 (200)	3.77	4.41
0.1 (1000)	4.13	4.78

3.2.3.2 SEPA Tarbert tidal gauge

It is generally best practice to use the CFB dataset for determining tidal conditions. However, if local data exists at the site this can be used to verify and improve confidence in the CFB extreme water levels.

The full record from the SEPA Tarbert tidal gauge was obtained and covered a period from 1995 – 2018 with gaps in the data during 1997 and between 2010-2013, resulting in approximately 16 years of data.

The maximum recorded level over this 16 year time period was 3.02mAOD which is equivalent to the 20% AEP event (1 in 5yr RP) level given in the CFB dataset. From this comparison, the CFB data may slightly overestimate the water level by 10cm-20cm. Considering the relatively short length of recorded data and effect of seal level rise, the CFB levels are appropriate for this modelling study as a conservative approach.

3.2.4 Wind Data

A 38-year record of wind data at 3-hourly intervals was also obtained from the UK Met Office European Wave model covering the period 1980 to 2017. Figure 3-3 shows the predicted wind rose at the closest available position to Tarbert based on a directional resolution of 20°. Winds are seen to be predominately from the South to North Westerly direction. Average wind speeds are around 6m/s with a maximum wind speed of 30 m/s predicted.

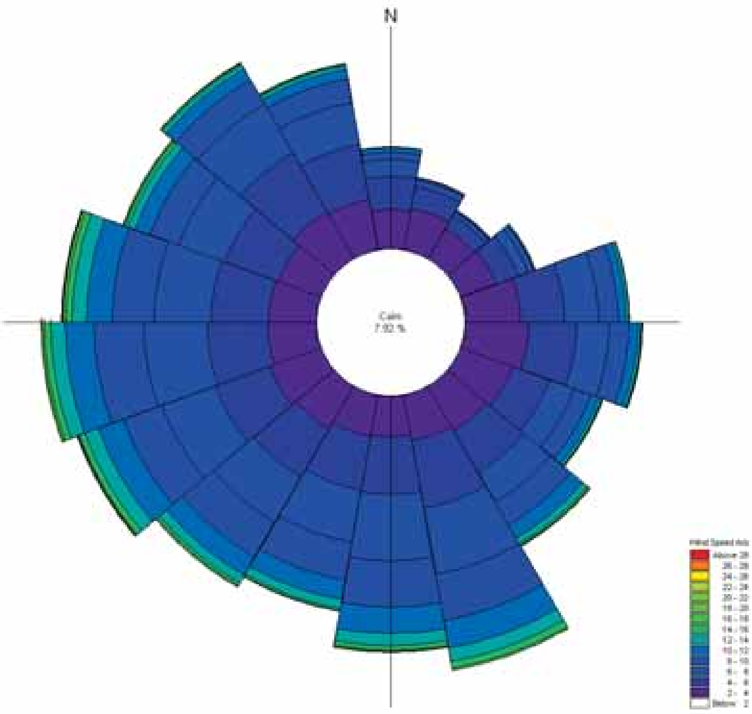


Figure 3-3: Wind rose plot at position 2345

Wind time-series data were also obtained from the Allt Dearg Windfarm, located to the north of Tarbert, and compared against the Met Office data (Position 2345, Figure 3-6) for the same available period (2013-2017). Generally, the pattern of wind direction was consistent but with larger variations in speeds seen. This difference was attributed to the positioning of the Allt Dearg Windfarm gauge at some 420-450m AOD.

Allt Dearg windfarm is located well above sea level (approx.. 300mAOD), which reduces the confidence in the data when considering wind at sea level. The longer time-series Met Office data was therefore deemed suitable for use in the subsequent modelling exercise and was generally consistent with the measured data noting that differences between the data are likely to be attributed to the significant difference in elevation.

3.2.5 Climate Change

As agreed in the proposed methodology (AECOM, July 2018), climate change has been considered based on the current UKCP09 / Defra guidance on changes to relative sea levels, wind and wave climate in the future. All data was downloaded from the Defra website (http://ukclimateprojections-ui.metoffice.gov.uk/ui/) Cell ID 12585 for Tarbert. Relative sea levels are shown to rise from a baseline year of 2018 based on the ‘High Emissions Change Factor 95th percentile’ (Table 3-3).

Table 3-3: Mean sea level relative to 2018 for the 1%AEP event

Year	Increase in MSL [m] relative to 2018		Year	Increase in MSL [m] relative to 2018
2008	0		2068	0.37
2018	0.05		2078	0.45
2028	0.10		2088	0.53
2038	0.16		2098	0.63
2048	0.22		-	-
2058	0.29		-	-

3.3 Joint Probability Analysis

3.3.1 Correlation coefficient

Joint probability refers to the chance of two or more conditions occurring at the same time. In this instance, with flood risk management in mind, the coincidence of extreme wave condition and extreme water level is of interest. A Joint Probability Analysis (JPA) of wave and water level was therefore undertaken to provide the possible combination of wave and water level. The simplified JPA approach, as described in the guidance (Use of Joint Probability Methods in Flood Management: A Guide to Best Practice – R&D Technical Report FD2308/TR2, 2005), has been used for the standard set of return periods. The guidance provides two images (Figure 3-4 and Figure 3-5) showing the strength of correlation between waves and sea level in UK water area. Although no information of correlation coefficient is specifically given at Tarbert, the correlation has been classified as 'well' on the basis of data within the water area nearby.

Excel spreadsheets provided with the guidance were used to calculate the tables of joint exceedence extremes and curves, using available information on marginal (single variable) extremes and an estimate of the dependence between the two variables. Inputs supplied by the user include:

- Marginal extremes of wave height and water level;
- Dependence parameters (well);
- Number of records per year;
- Joint exceedence return periods required.

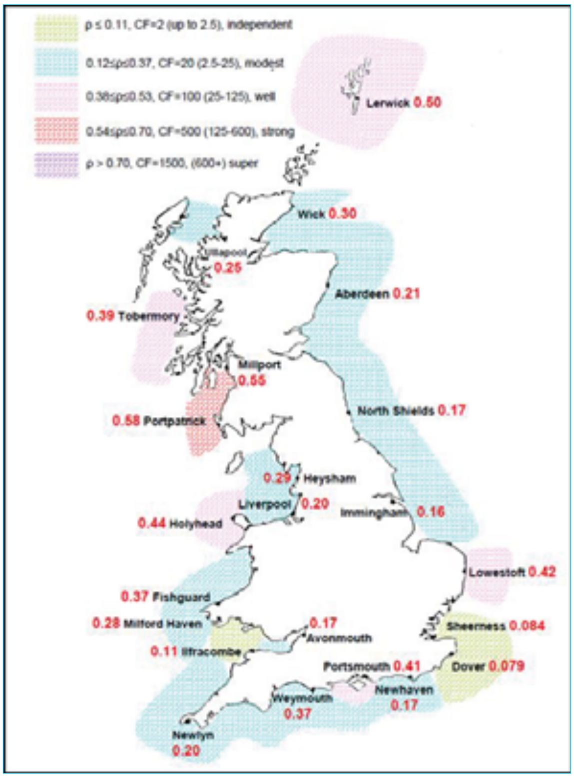


Figure 3-4: Correlation coefficient (Wave height and Sea level), All wave direction combined

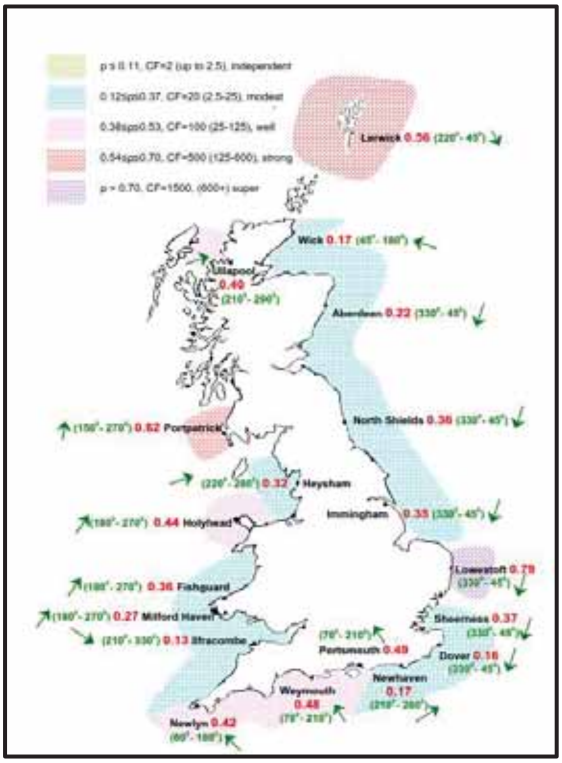


Figure 3-5: Correlation coefficient)p, wave height & sea level) wave direction where dependence is highest

3.4 Spectral Wave Modelling

3.4.1 Overview

AECOM has used the MIKE21 Flexible Mesh Spectral Wave (SW) model in the present modelling study. The software was developed by the Danish Hydraulics Institute (DHI). It is a state-of-the-art wave transformation model based on triangular mesh elements which are able to provide enhanced resolution covering important features such as local variations in bathymetry. The wave model simulates growth, decay and transformation of wind-generated waves and swells in offshore and coastal areas. The model is capable of reproducing the combined effects of shoaling, refraction, diffraction, reflection, wave breaking and directional spreading.

Detailed wave transformation modelling and assessment work have been carried out to estimate the wave overtopping rates along Tarbert coastal frontage. The study derived the wave climate and extreme sea levels for the required range of return periods of 2, 5, 10, 20, 50, 100, 200 and 1000 years, with and without climate change. Extreme wave heights have been estimated based on the Weibull probability distribution involving the selection of individual storm events from the peaks over threshold method. Joint probability analysis was then undertaken to establish the possible combinations between wave heights and water levels.

The calculations of wave overtopping were undertaken using EurOtop (2018) 'Manual on wave overtopping of Sea Defences and Related Structures' to determine the mean overtopping discharge (l/s/m) for a range of structure types. The manual incorporates new techniques to predict wave overtopping at seawalls, flood embankments, breakwaters and other shoreline structures. Wave overtopping rates along the Tarbert defence structures were provided to establish the extent of flooding and identify the level of risk from coastal flooding for a range of return periods.

3.4.2 Model setup

The regional wave model mesh (Figure 3-6) has a resolution of between 1000 and 100 m, with the highest mesh resolution applied in the areas of interest adjacent to Tarbert. The MIKE SW model was used to simulate the full data period available from the Met Office (38 years) Wave Watch III European Wave Model.

The model has been configured based on the recommended default parameters within the MIKE SW model setup. A directionally decoupled approach was adopted in which the full directional spectrum of wave directions were considered. This approach allows for waves coming from any direction to be considered within the model.

3.4.3 Regional modelling results

The model domain covers the entire Firth of Clyde (Figure 3-6). Figure 3-6 shows the model flexible mesh generated using the MIKE-Zero Mesh Generator. The model is based on two types of bathymetric data sources, C-MAP and survey data. In the large area, the water depth information was taken from C-Map digital chart data. This has been supplemented with local survey data made available by the client. These datasets were interpolated onto the model mesh. The bathymetry is referenced to the British National Grid horizontal projection and ODN vertical datum.

Hindcast offshore wave data (wave height, period and direction) and wind conditions (speed and direction) have been taken from the Met Office WaveWatch III (WW3) model. The time-series data is available at hourly intervals for the years 2001 to 2017 and 3-hourly between 1980 and 2001. Figure 3-7and Figure 3-8 show wave and wind rose at the model boundary. The directional resolution in each wave and wind rose plot is 15º.

In the absence of a long time-series of water levels (tide and surge), the regional wave transformation modelling was initially undertaken with a constant water level of 2.7m ODN equivalent to a 1 in 1 year return period. Wave data at Point B (187283.99, 668954.56) near the entrance of Tarbert were extracted for the local wave transformation.

Wave statistics along the study frontage are simulated using a near field SW model, as described later.

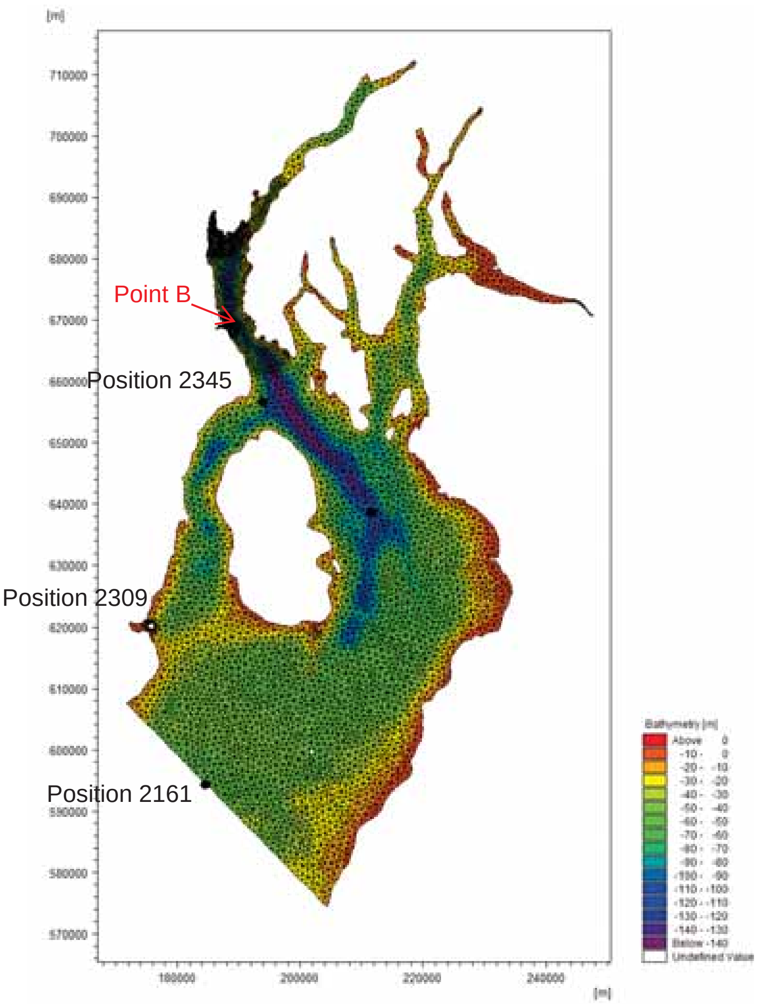


Figure 3-6: Locations of Met Office wave and wind WaveWatch III data points

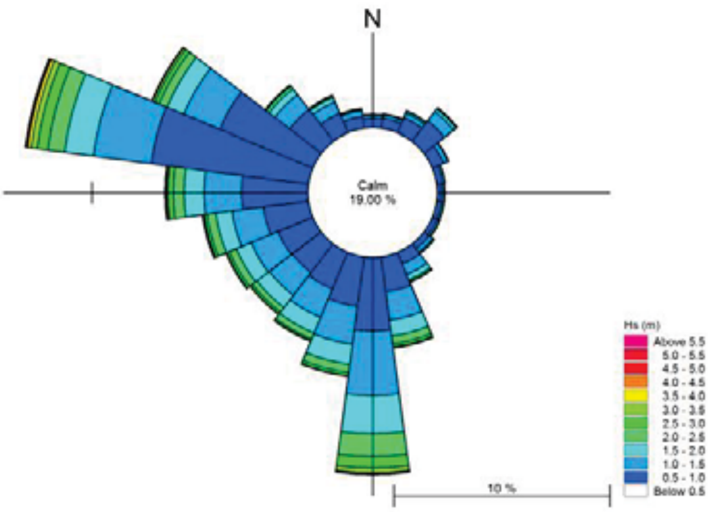


Figure 3-7: Wave rose at Position 2161

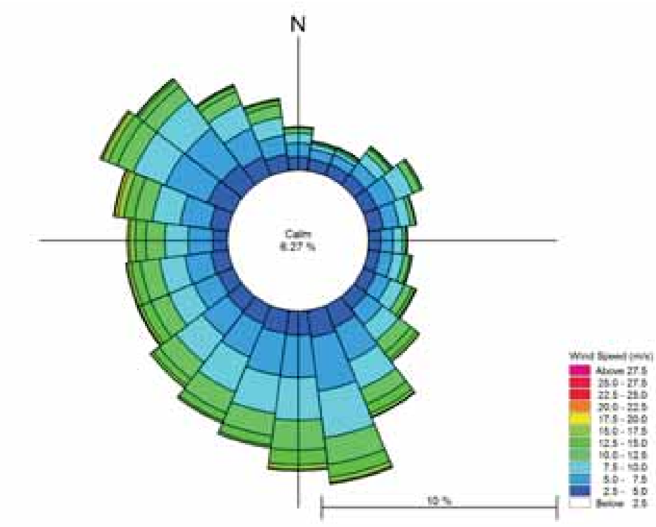


Figure 3-8: Wind rose at Position 2161

Figure 3-9 show wave rose at the local model boundary (Point B). The directional resolution of the rose plot is 15º. The wave rose indicates that prevailing waves come from the sector between south-east and south. Wave and wind conditions have been investigated for six sectors: 45°, 60°, 75°, 90°, 105°and 120°N.

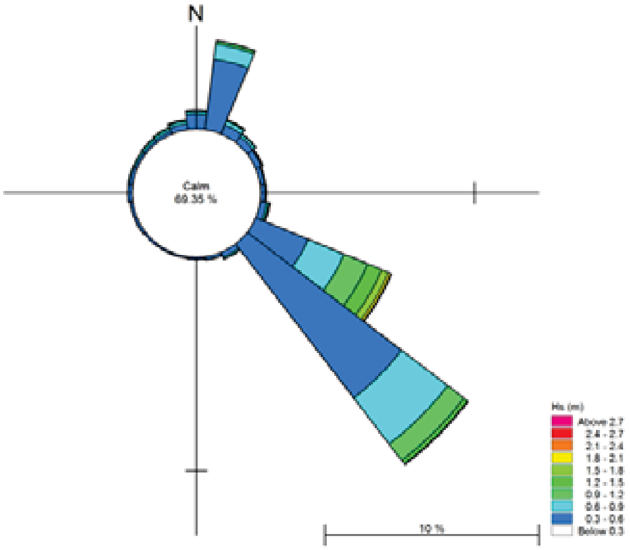


Figure 3-9: Wave rose at the local boundary (Point B)

3.4.4 Joint probability analysis

Directional extreme wave heights have been estimated based on the Weibull probability distribution involving the selection of individual storm events for the peaks over threshold method. This includes wave heights for seven return periods of 2, 10, 20, 50, 100, 200 and 1000 years. The results of a joint probability analysis for the direction sector centred on 60°N are given in Table 3-4-Table 3-7. The tables present the joint exceedance return periods for a combination of extreme wave height and water level for the present day (2018) and time epoch in 2100. Sensitivity tests on the local model have shown that the 60°N direction represents the worst case in terms of significant wave heights (and therefore overtopping) into Tarbert Harbour.

Table 3-4: Marginal Wave and Water Level Extremes for the Worst Case 60°N direction (present day)

RP (years)	Significant Wave Height [m]	Still Water Level [m ODN]
2	0.96	2.86
5	1.19	3.03
10	1.38	3.16
20	1.57	3.31
50	1.82	3.48
100	2.02	3.62
200	2.23	3.77
1000	2.71	4.13

Table 3-5: Distribution of Wave and Water Level for the Worst Case 60°N direction (present day)

Hs (m)	Joint exceedence return period (years)							
	2	**5**	**10**	**20**	**50**	**100**	**200**	**1000**
	Still water Level from SEPA [m ODN]							
0.18	2.84	3.03	3.16	3.31	3.48	3.62	3.77	4.13
0.30	2.72	2.97	3.16	3.31	3.48	3.62	3.77	4.13
0.56	2.51	2.81	3.00	3.20	3.48	3.62	3.77	4.13
0.78	2.37	2.67	2.87	3.07	3.35	3.55	3.77	4.13
0.96	2.23	2.51	2.76	2.94	3.21	3.42	3.63	4.13
1.19		2.33	2.54	2.78	3.03	3.24	3.44	3.97
1.38			2.40	2.62	2.90	3.10	3.32	3.81
1.57				2.47	2.78	2.97	3.17	3.66
1.82					2.57	2.80	2.99	3.47
2.02						2.66	2.86	3.34
2.23							2.75	3.20
2.71								2.89

Table 3-6: Marginal Wave and Water Level Extremes for the Worst Case 60°N Direction (2100)

RP (years)	Significant Wave Height [m]	Still Water Level [m ODN]
2	1.05	3.47
5	1.31	3.65
10	1.52	3.78
20	1.73	3.94
50	2.01	4.11
100	2.23	4.26
200	2.45	4.41
1000	2.98	4.78

Table 3-7: Distribution of Wave and Water Level for the Worst Case 60°N direction (2100)

Hs (m)	Joint exceedence return period (years)							
	2	**5**	**10**	**20**	**50**	**100**	**200**	**1000**
	Still water Level from SEPA [m ODN]							
0.20	3.46	3.65	3.78	3.94	4.11	4.26	4.41	4.78
0.33	3.33	3.59	3.78	3.94	4.11	4.26	4.41	4.78
0.61	3.11	3.42	3.62	3.82	4.11	4.26	4.41	4.78
0.86	2.97	3.28	3.48	3.69	3.98	4.18	4.41	4.78
1.05	2.83	3.12	3.37	3.55	3.83	4.05	4.26	4.78
1.31		2.93	3.14	3.39	3.65	3.86	4.07	4.61
1.52			3.00	3.23	3.51	3.72	3.94	4.45
1.73				3.08	3.39	3.58	3.79	4.29
2.01					3.18	3.42	3.61	4.10
2.23						3.27	3.48	3.97
2.45							3.36	3.82
2.98								3.51

Figure 3-10 and Figure 3-11 show the plots of joint probability distribution for present day scenario and climate change scenario in 2100.

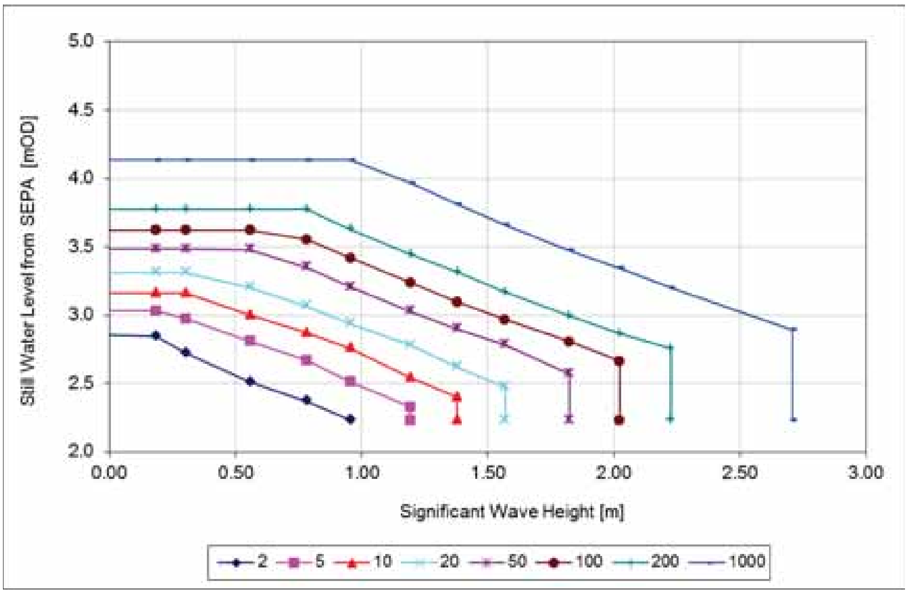


Figure 3-10: Weibull probability distribution for waves at Tarbert

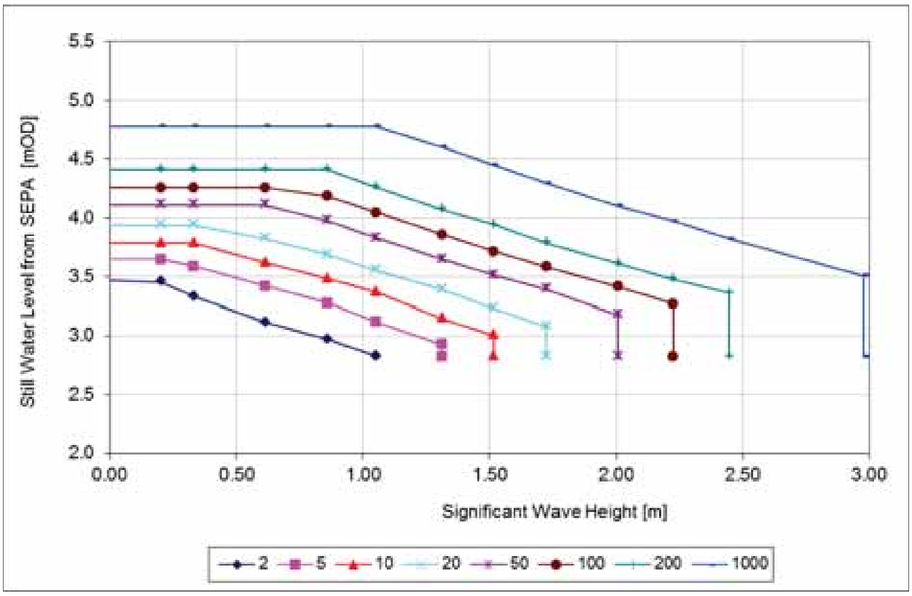


Figure 3-11: Joint probability distribution of wave and still water level for the 60°N direction (2100)

3.4.5 Local wave model

The results from the regional modelling were then used as boundary conditions for a local high resolution model.

In some circumstances wave heights at the toe of the defence structure will be depth limited and the use of a fixed water level may lead to an underestimate of wave heights at the toe. Wave statistics were analysed and derived at Point B (Figure 3-6) (-22.0m ODN contour line) where no depth-limited wave breaking occur. Joint probability analysis generated all combinations of water level and wave height at water depth of -22.0m ODN.

A local model (Figure 3-12) was to be set up to transform offshore wave into the toe of structure under all conditions of water level and waves. Resolution across the local model domain is variable with high resolution around Tarbert. In the offshore area this resolution is around 20m increasing to 10m for the areas of most interest (Figure 3-13).

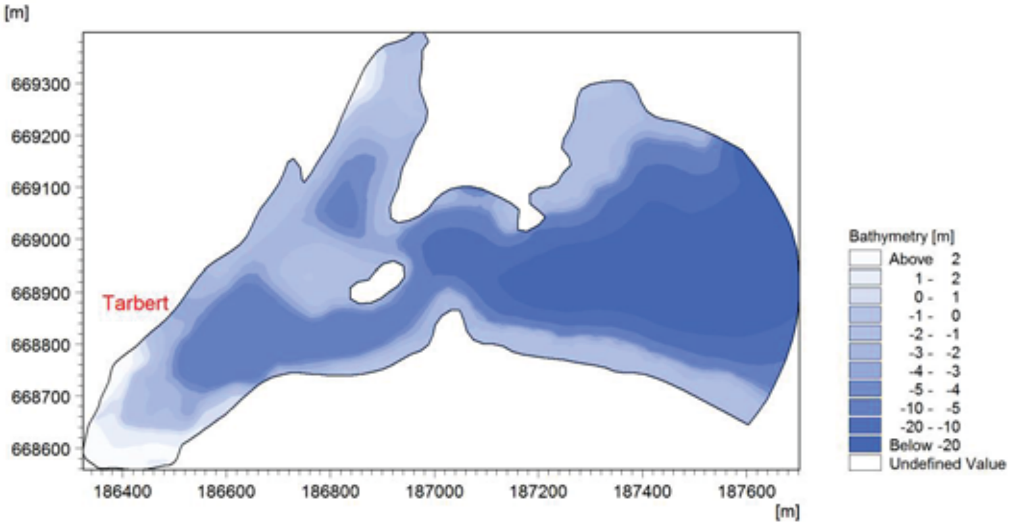


Figure 3-12: local wave model domain

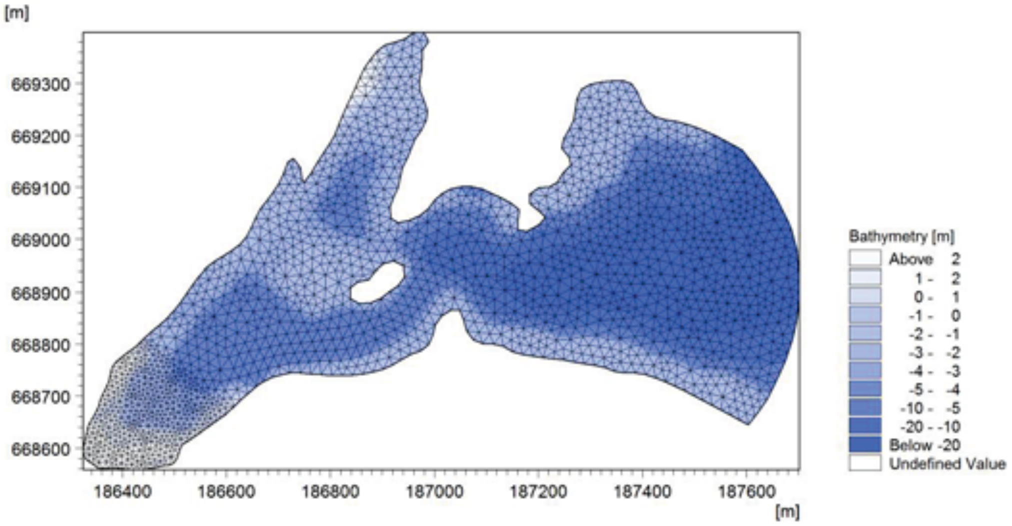


Figure 3-13: Local wave model mesh

For winds and waves there is no specific guidance available to estimate their increase for climate change under a high emission scenario. The allowances provided in Environment Agency Guidance 'Flood risk assessments: climate change allowances' (https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances) were adopted to estimate the increase. This requires a 10% increase in wind speed and waves. The present and future predicted extreme water levels and waves at the local model boundary are presented in Table 3-8.

Table 3-8: Wave conditions in Sector 60° (present day and 2100)

RP (years)	Significant Wave Height [m] (present day)	Significant Wave Height [m] (2100)
2	0.96	1.05
5	1.19	1.31
10	1.38	1.52
20	1.57	1.73
50	1.82	2.01
100	2.02	2.23
200	2.23	2.45
1000	2.71	2.98

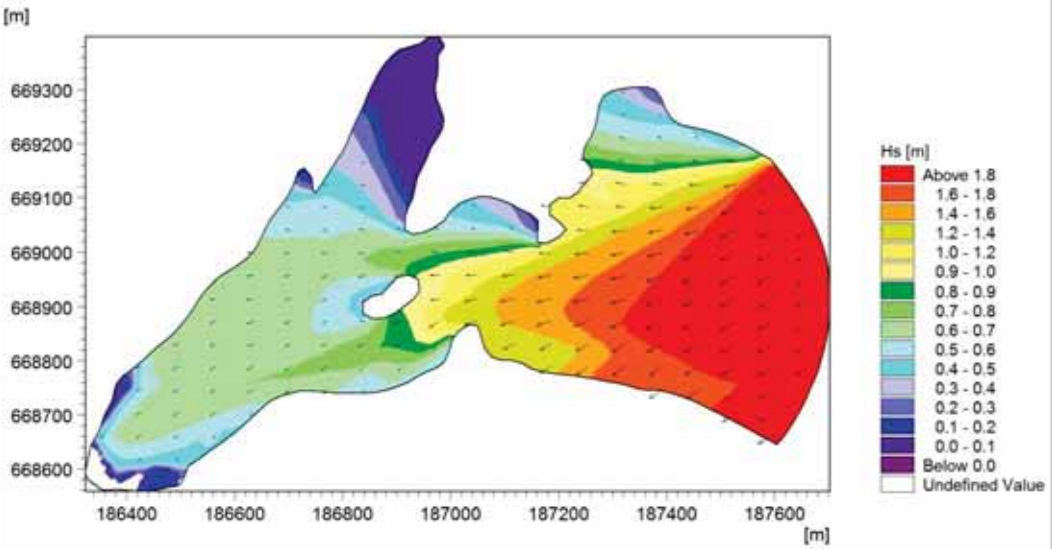


Figure 3-14: Example of Significant Wave Heights and Directions predicted for a 1 in 100 Return Period Event

3.5 Wave Overtopping Assessment

Wave overtopping calculations for the coastal defence structures were undertaken to identify the level of risk from coastal flooding for a range of return periods. The calculations were carried out using the empirical formulae provided in EurOtop (2018) 'Manual on wave overtopping of Sea Defences and Related Structures' to determine the overtopping discharge (l/s/m) along the Tarbert frontages.

At present, the EurOtop guidance (2018) is regarded as best practice within the industry. The required inputs to the calculation vary according to structure type. For the vertical defence structure at Tarbert, the inputs typically consist of:

- Significant wave height (m);
- Mean wave period (s);
- Wave direction;
- Structure freeboard (m);
- Water depth at the structure toe (m).

Table 3-9: Cross-Section Extraction Location

Extraction Start Position	Easting (km)	Northing (km)
LS1 (XS 001)	186385.885	668684.890
LS2 (XS 002)	186554.376	668637.103

For each cross-section identified in Table 3-9 and Figure 3-15 the typical geometry of the defence structure (crest height, bed level, slope etc.) was established using the detailed topographical survey information.

The estimated wave overtopping rates based on EurOtop (2018) for each of the cross sections are presented in Table 3-12 and Table 3-13.

These waves may therefore encroach onto the road and may affect properties before the extreme still-water tide level exceeds the harbour wall. However, due to the topography in Tarbert, with land rising up from the harbour, flooding relating to waves would fall back out to sea if the tide level were below the harbour wall level . Wave overtopping will not materially alter maximum flood levels on land.

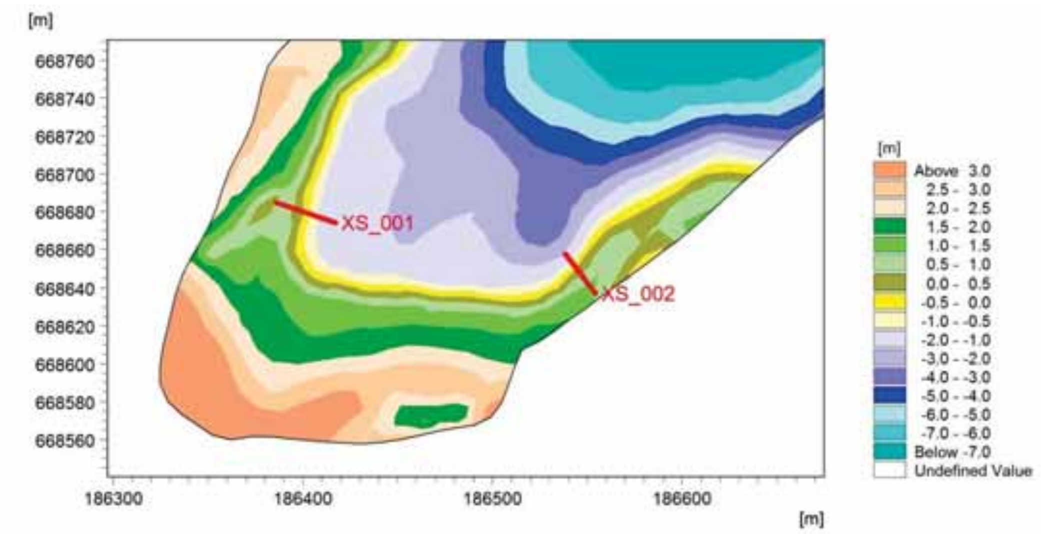


Figure 3-15: Two Sections for Wave Overtopping

Table 3-10: Present Day (2018) Wave Conditions at Cross-Sections LS1 and LS2

2018

RP (yrs)	LS1 (XS_001)			LS2 (XS_002)		
	Hs (m) (wave height)	Tm (s) (mean wave period)	WL(m) (wave length)	Hs (m) (wave height)	Tm (s) (mean wave period)	WL(m) (wave length)
2	0.19	1.6	2.7	0.10	1.2	2.8
5	0.27	1.9	2.8	0.24	1.8	2.8
10	0.37	2.1	2.8	0.28	1.9	2.8
20	0.43	2.2	2.8	0.33	2.0	2.8
50	0.52	2.4	2.8	0.41	2.1	2.8
100	0.58	2.4	2.8	0.46	2.2	2.8
200	0.64	2.5	2.9	0.55	2.3	2.9
1000	0.81	2.6	2.9	0.68	2.4	2.9

Table 3-11: Future (2100) Wave Conditions at Cross-Sections LS1 and LS2

2100

RP (yrs)	LS1 (XS_001)			LS2 (XS_002)		
	Hs (m) (wave height)	Tm (s) (mean wave period)	WL(m) (wave length)	Hs (m) (wave height)	Tm (s) (mean wave period)	WL(m) (wave length)
2	0.43	2.2	2.8	0.34	1.9	2.8
5	0.51	2.3	2.9	0.40	2.0	2.9
10	0.57	2.4	3.0	0.45	2.1	3.0
20	0.63	2.4	3.1	0.51	2.2	3.1
50	0.72	2.5	3.2	0.59	2.3	3.2
100	0.78	2.7	3.3	0.65	2.4	3.3
200	0.86	2.7	3.4	0.72	2.4	3.4
1000	1.04	2.8	3.5	0.89	2.6	3.5

Table 3-12: Present Day (2018) Maximum Overtopping Rates (l/s/m)

RP	LS1 (XS_001)	LS2 (XS_002)
2	7.5	1.8
5	15.9	12.8
10	30.4	17.5
20	40.0	24.1
50	56.1	36.4
100	68.4	46.2
200	79.2	63.4
1000	120.2	89.5

Table 3-13: Future (2100) Maximum Overtopping Rates (l/s/m) (2100)

RP	LS1 (XS_001)	LS2 (XS_002)
2	40.5	25.6
5	54.0	35.5
10	65.3	44.4
20	77.9	54.2
50	96.9	69.9
100	113.0	83.3
200	131.0	98.1
1000	179.3	139.5

3.6 Conclusions

A regional wave model was run to establish the offshore wave heights at Tarbert under present day conditions. The regional modelling results show that the wave climate at the entrance to Tarbert Bay is generally small (< 1 m) although a maximum significant wave height of 2.77 m was predicted over a period of 38 years. A joint probability analysis of wave heights and water levels was undertaken for present day condition and a future (2100) epoch. The results from this extremes analysis were then used as boundary conditions for a local high resolution model.

The findings from the local model for the present day scenario show that wave conditions within Tarbert are small, with a 1% AEP event producing wave heights in the region of 0.4 m. The small waves can be attributed to the shallow bathymetry and the sheltering effect of island in the harbour.

Wave overtopping was undertaken to consider the impact on the nearshore environment around Tarbert where current crest elevations (around +2.8m ODN) are similar to current day highest astronomical tidal levels, therefore, these smaller wave events will have a notable impact on local flood risk.

The final analysis from the coastal modelling is then the calculation of the overtopping values based on the findings from the local modelling results. These results have shown overtopping volumes of up to about 100 l/s/m for an extreme 1 in 100yr event can be expected at Tarbert under both present day and future scenarios. These waves may therefore encroach onto the road and to properties before extreme water levels exceed the harbour walls. However, due to the topography in Tarbert, with land sloping up from the harbour, flooding relating to wave overtopping would fall back out to sea if extreme levels were below the harbour wall. Wave overtopping will not materially alter maximum flood levels on land, again due to the topography.

The extreme water levels established in this section were used in the subsequent inundation mapping exercise.

4. Inundation Mapping

To understand the tidal flood risk to Tarbert, the extreme sea levels as detailed in Section 4 were applied to the ground surface.

It should be noted that whilst tidal flooding is the sole focus of this Flood Study, other sources of flooding may be present. A high level assessment of the watercourse culverts that run underneath Tarbert was undertaken but was not within the Flood Study scope. Further details of this assessment can be found in 'Tarbert Culvert Capacity- Technical note'

4.1 Method

No LiDAR was available for this study, with ground levels represented by NEXTMap data at a resolution of 5x5m cells. The vertical accuracy of this data is 1m, and can therefore significantly over or under represent the true topography. The NEXTMap data was improved around the harbour area with surveyed spot heights, which were stamped onto the NEXTMap.

Due to the shallow bathymetry and island within the harbour, wave heights were not found to be significant, and extreme water levels taken from the CFB dataset were applied to the prepared ground surface. Overtopping inflows were not included in the assessment due to the topography around the harbour and the minimal wave action noted. The topography slopes upwards from the harbour wall, meaning waves have the potential to travel further than the flood contour shown but wouldn't pond and cause any significant flood depth. Modelling the wave momentum on this topography is not possible in standard modelling softwares.

Given that surveyed levels were stamped onto the less accurate NEXTMap data, areas around the join have notable jumps in elevation due to the steep topography, resulting in a sharp edge to the flood contour. These joins are located along the back of the properties on Harbour Street and Barmore Road, where ground rises sharply. Flood contours in these areas are indicative, as they are based on lower resolution NEXTMap data. However their location is deemed sufficiently accurate given the steep topography in the gardens behind the shorefront properties. All sections of the flood contours that are based on NEXTMap data are clearly shown in the drawings.

4.2 Results

4.2.1 Current Day

A full range of current day flood contour maps are displayed in Appendix E.

The 50% AEP event flood contour affects areas around the harbour wall, including the footpath and parking bays. It is not seen to extend onto Harbour Street or Barmore Road.

From the 20% AEP event onwards, coastal waters extend across sections of Harbour Street and Barmore Road up to the front elevations of a number of properties. Coastal flooding is also seen to extent across the harbour and docking areas to the east of Tarbert. Further east, buildings on the northern side of Pier Road, including the ferry terminal, are at some risk of coastal flooding.

As event probability decreases, flood extents are seen to extend past the houses on Barmore Road and Harbour Street into areas surrounding Brunswick Street and Campeltown Road. Flooding of the areas around Pier Road is also seen to increase.

4.2.2 Climate Change

A full range of climate change flood contour maps are displayed in Appendix E.

Climate change uplifts for 2100 were applied to current day extreme sea levels as outlined in Section 4.

From the 50% AEP event onwards, coastal waters are seen to extend across large sections of Harbour Street and Barmore Road, as well as sections of Campbeltown Road and Brunswick Street. The docking areas at the east extent of Tarbert and properties to the north of Pier Road are also affected. Flood levels are high enough that they exceed many of the finished floor levels in the properties on Harbour Street and Barmore Road.

Flood extents continue to spread in a south easterly direction as event magnitude increases, affecting greater portions of Brunswick Street, Campbeltown Road and Church Street.

The greater extents experienced in the climate change scenarios can be attributed to the significant rise in sea levels, which are predicted to rise by between 0.6 – 0.65m over the next 80 years. This rise will mean that sea levels currently associated with rare events will become a lot more frequent resulting in an increase in the frequency of disruptive flooding as 2100 approaches. Table 4-1 sets out what a current day AEP event will correspond to in 2100.

Table 4-1: Comparison AEP events – current day vs 2100 prediction

Current day AEP event	Equivalent AEP event in 2100
50%	-
20%	-
10%	-
3.33%	-
2%	50%
1%	20%
0.5%	10%
0.1%	2%

5. Conclusions and Recommendations

5.1 Conclusions

5.1.1 Coastal Modelling

The main objective of the coastal modelling exercise is to establish the nearshore extreme wave characteristics along the frontage at Tarbert during existing and future wave climates. In order to achieve this, a spectral wave model was constructed using surveyed bathymetry, C-MAP data and topographic data.

A regional wave model was run to establish the offshore wave heights at Tarbert under present day conditions. The Regional modelling results show that the wave climate at the entrance to Tarbert is generally small, however, maximum significant wave heights of 2.77 m are predicted over a period of 37 years. An extremes analysis of wave heights shows that for present day conditions a significant wave height of 2.0 m could be expected for a 1% AEP event.

A local wave model was constructed under both a present day and with climate change for the 2100 epoch using boundary conditions established in the regional model. The local wave model was used to consider the wave heights within Tarbert at a much higher resolution. The findings from the present day show that wave conditions within Tarbert are negligible, with a 1% AEP event producing wave heights in the region of 0.1m. These negligible waves can be attributed to the shallow bathymetry and island structures in the harbour.

Wave overtopping is therefore not considered a significant issue at Tarbert. Increases in still water levels as predicted in the coastal Flood Boundary data represent the greatest source of flooding to the lower lying areas surrounding Tarbert.

5.1.2 Inundation mapping

To understand the tidal flood risk to Tarbert, the extreme sea levels output from the coastal modelling exercise were applied to the ground surface. This ground surface was a combination of NEXTMap data and topographic survey, with the survey data covering the area around Harbour Street and Barmore Road.

In the current day scenario, tidal flooding is seen to affect areas around the harbour wall and parking bays from the 50% AEP event. As event magnitude increases, sections of Harbour Street, Barmore Road, Brunswick Street and Cambeltown Road as well as the docking areas become inundated. Areas to the north of Pier Road, around the ferry terminal are also seen to be at flood risk.

During the climate change scenario, many of the same areas are affected that were in the current day scenario, albeit more frequently. Due to the increase in sea levels of approximately 600mm, the current day 0.5% AEP event (a rare event) is seen to correspond to a 10% AEP event in 2100, meaning that the frequency of disruptive flooding will increase as 2100 approaches.

6. Next Steps

The next phase of work to be undertaken the long list to short list selection. Using the baseline conditions set out in this study, a long list of feasible options will be developed. This option development will aim to:

- address the flooding issues;
- consider the wider benefits;
- Identify the cost, environmental and legal implications.

As part of this stage of work, stakeholders and the public consultation will be undertaken.

Appendix A – Photographs

Photograph 1: Outfalls into harbour for Back Road and Ileene Road culverts

Photograph 2: Tarbert Harbour

Photograph 3: Tarbert Harbour

Photograph 4: Flooding in 1991 – Harbour Street

Photograph 5: Flooding in 2014 – Harbour Street

Photograph 6: Flooding in 2014 – Harbour Street

Appendix B – Joint Probability Analysis

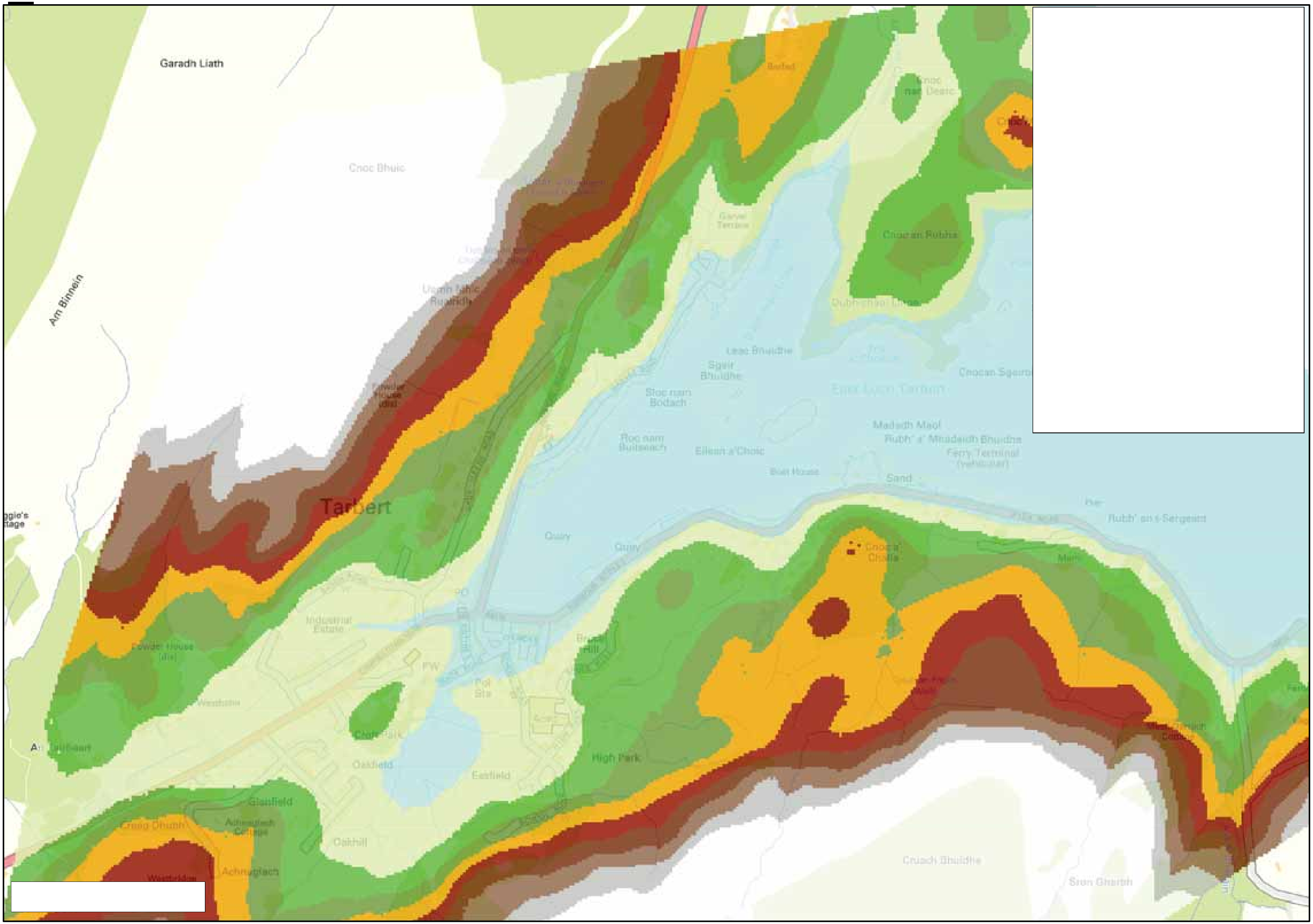
Table 1: Return Period Output

			Joint exceedence return period (years)							
			2	10	20	50	100	200	1000	#N/A
			Marginal return period (years) for			Sea Level				
		0.08	0.031	0.781	3.125	19.531	78.125	200.000	1000.000	#N/A
		1	0.003	0.063	0.250	1.563	6.250	25.000	625.000	#N/A
Marginal return period (years) for		2	0.001	0.031	0.125	0.781	3.125	12.500	312.500	#N/A
		2	0.001	0.031	0.125	0.781	3.125	12.500	312.500	#N/A
		10	#N/A	0.006	0.025	0.156	0.625	2.500	62.500	#N/A
		20	#N/A	#N/A	0.013	0.078	0.313	1.250	31.250	#N/A
River Flow		50	#N/A	#N/A	#N/A	0.031	0.125	0.500	12.500	#N/A
		100	#N/A	#N/A	#N/A	#N/A	0.063	0.250	6.250	#N/A
		200	#N/A	#N/A	#N/A	#N/A	#N/A	0.125	3.125	#N/A
		1000	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0.625	#N/A
		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
		#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

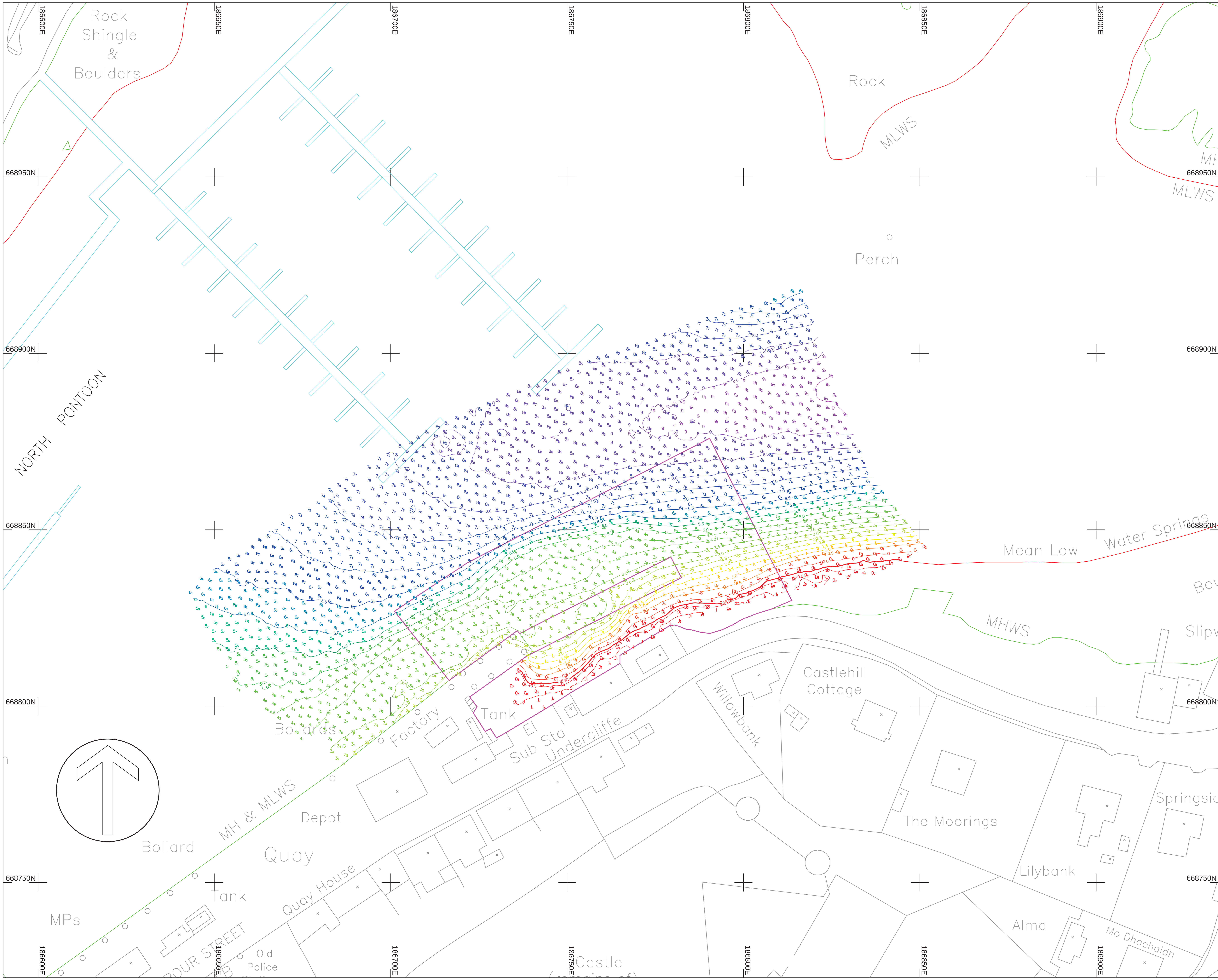
Table 2: Source Variable Output

Value of first variable:	Joint exceedence return period (years)							
	2	10	20	50	100	200	1000	#N/A
	Value of second variable:			Sea Level				
River Flow								
-0.29	2.08	2.68	2.94	3.30	3.57	3.77	#NUM!	#N/A
0.43	1.61	2.21	2.47	2.81	3.07	3.35	4.02	#N/A
0.55	1.48	2.08	2.34	2.68	2.94	3.21	3.87	#N/A
0.70	1.48	2.08	2.34	2.68	2.94	3.21	3.87	#N/A
1.19	#N/A	1.78	2.04	2.38	2.64	2.90	3.53	#N/A
1.40	#N/A	#N/A	1.91	2.26	2.51	2.77	3.39	#N/A
1.69	#N/A	#N/A	#N/A	2.08	2.34	2.60	3.21	#N/A
1.95	#N/A	#N/A	#N/A	#N/A	2.21	2.47	3.07	#N/A
2.25	#N/A	#N/A	#N/A	#N/A	#N/A	2.34	2.94	#N/A
3.35	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	2.64	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A

Appendix C – Survey and LiDAR data



Garadh Liath
Cnoc Bhuic
Am Binnein
Tarbert
Industrial Estate
Powder House (dis)
Powder House (dis)
Uamh Mhic Ruaridh
Garvel Terrace
Cnocan Rubha
Leac Bhuidhe
Sgeir Bhuidhe
Sloc nam Bodach
Roc nam Buileach
Eilean a'Choic
Madadh Maol
Rubh' a' Mhadaidh Bhuidhe
Ferry Terminal (vehicular)
Boat House
Sand
Pier
Rubh' an t-Sergeant
Quay
Quay
Croft Park
Oakfield
Eastfield
High Park
Glenfield
Creag Dhubh
Achnaglach Cottage
Achnaglach
Oakhill
Cruach Bhuidhe
Sron Gharbh



Legend

4.56	Heights relative to ORDNANCE DATUM.
12_2	Depths relative to CHART DATUM.
(blue line)	Sea+bed contour relative to CHART DATUM.
(green line)	Mean High Water Springs
(red line)	Mean Low Water Springs

Survey Parameters & Equipment	
Survey Vessel:	Coastal Sensor (MCA Cat III)
Positioning System:	Trimble SPS 855 RTK GPS
GPS Correction Source:	TRIMBLE VRS NOW Network RTK
Positioning System Spheroid & Datum:	ETRS89
Echosounder:	R2Sonic 2022 Multibeam System 400kHz
Grid System:	National Grid of Great Britain
Geoid Model:	OSGM02
Transformation Paramaters:	OSTN02
Spheroid:	Airy
Semi Major Axis:	6377563.396
Flattening (1/f):	299.324964600
Vertical Datum (Topographic):	Ordnance Datum
Vertical Datum (Hydrographic):	Chart Datum
Distance Unit:	Metre

Chart Datum is 1.62m below Ordnance Datum.

The datum was established using corrected OS Rinex data and post-processed using Trimble Business Centre Software.

Coloured Depth Bands:

- < 0.00
- 0.00 – 0.49
- 0.50 – 0.99
- 1.00 – 1.49
- 1.50 – 1.99
- 2.00 – 2.49
- 2.50 – 2.99
- 3.00 – 3.49
- 3.50 – 3.99
- 4.00 – 4.49
- 4.50 – 4.99
- 5.00 – 5.49
- 5.50 – 5.99
- 6.00 – 6.49
- 6.50 – 6.99
- 7.00 – 7.49
- 7.50 – 7.99
- 8.00 – 8.49
- 8.50 – 8.99
- 9.00 – 9.49
- 9.50 – 9.99
- >= 10.00

Notes:

Horizontal and vertical datums were referenced to control stations on site.

Heights in metres above Chart Datum (East Loch Tarbert)			
MHWS	MHWN	MLWN	MLWS
3.6	2.9	1.0	0.3

CONTROL STATION COORDINATES (OD)			
STN	EASTING	NORTHING	LEVEL
Base	187102.715	668910.375	3.635

Aspect
Land + Hydrographic Surveys
CHARTERED SURVEYORS
Thornhouse Business Centre
Ballot Road
Irvine
KA12 OHW
Tel : 01294 313399
Fax : 01294 313389
E-mail: mail@aspectsurveys.com
Web: www.aspectsurveys.com

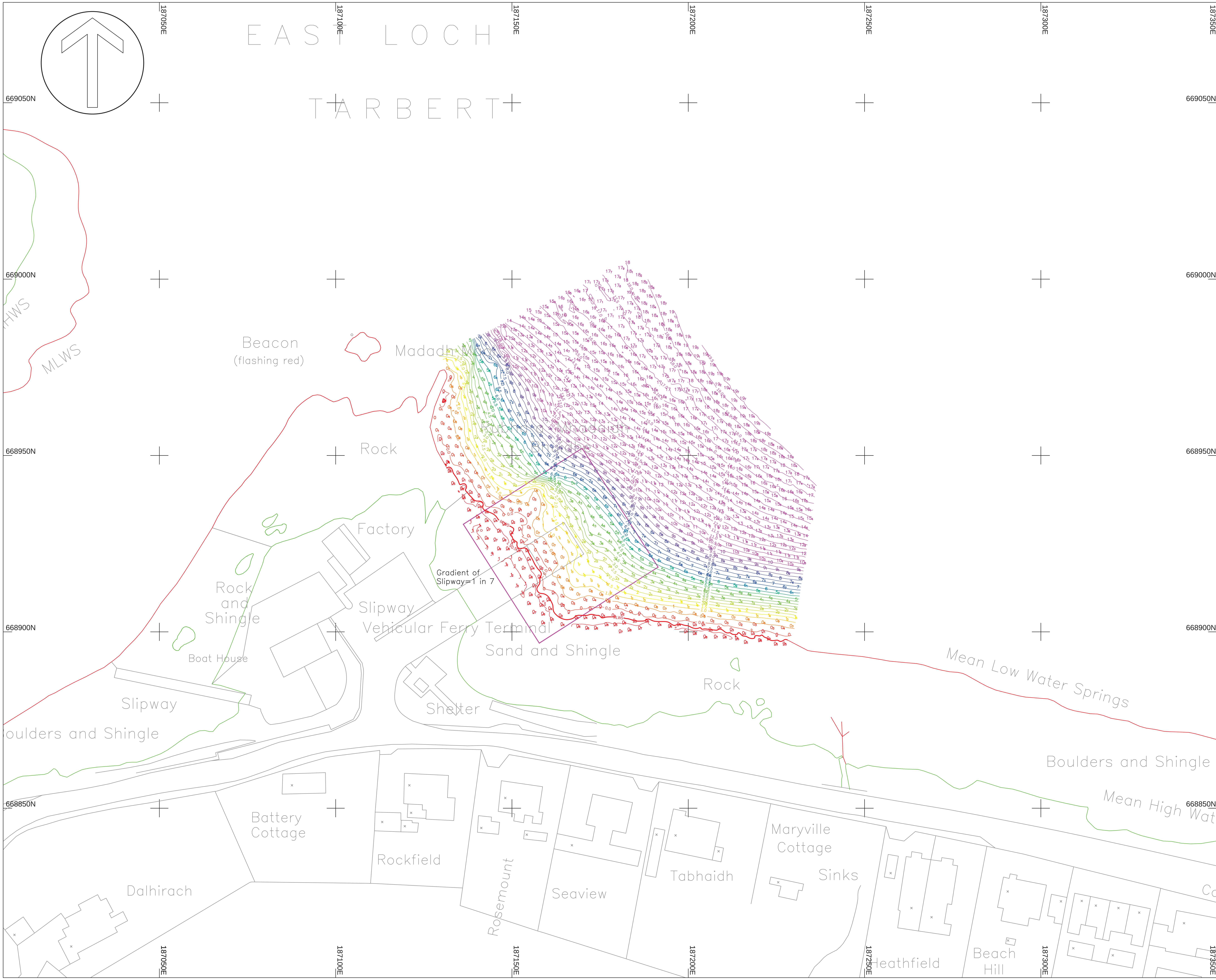
Client :

MOTT MACDONALD
1 ATLANTIC QUAY
BROOMIELAW
GLASGOW
G2 8JB

Project Title :

MULTIBEAM BATHYMETRIC SURVEY
EAST LOCH TARBERT PIER & SLIPWAY
TARBERT
ARGYLL & BUTE

Project No: A5293	Scale : 1:500
Surveyed date : 25th April 2014	Issued date : 28th April 2014
Surveyed by : CKS	Checked by: GJC
Sheet No. : 1 of 2	Plot Scale: 1:1 @ A1



Legend

4.56	Heights relative to ORDNANCE DATUM.
12_2	Depths relative to CHART DATUM.
(blue line)	Sea+bed contour relative to CHART DATUM.
(green line)	Mean High Water Springs
(red line)	Mean Low Water Springs

Survey Parameters & Equipment

Survey Vessel:	Coastal Sensor (MCA Cat III)
Positioning System:	Trimble SPS 855 RTK GPS
GPS Correction Source:	TRIMBLE VRS NOW Network RTK
Positioning System Spheroid & Datum:	ETRS89
Echosounder:	R2Sonic 2022 Multibeam System 400kHz
Grid System:	National Grid of Great Britain
Geoid Model:	OSGM02
Transformation Paramaters:	OSTN02
Spheroid:	Airy
Semi Major Axis:	6377563.396
Flattening (1/f):	299.324964600
Vertical Datum (Topographic):	Ordnance Datum
Vertical Datum (Hydrographic):	Chart Datum
Distance Unit:	Metre

Chart Datum is 1.62m below Ordnance Datum.

The datum was established using corrected OS Rinex data and post-processed using Trimble Business Centre Software.

Coloured Depth Bands:

- < 0.00
- 0.00 – 0.49
- 0.50 – 0.99
- 1.00 – 1.49
- 1.50 – 1.99
- 2.00 – 2.49
- 2.50 – 2.99
- 3.00 – 3.49
- 3.50 – 3.99
- 4.00 – 4.49
- 4.50 – 4.99
- 5.00 – 5.49
- 5.50 – 5.99
- 6.00 – 6.49
- 6.50 – 6.99
- 7.00 – 7.49
- 7.50 – 7.99
- 8.00 – 8.49
- 8.50 – 8.99
- 9.00 – 9.49
- 9.50 – 9.99
- >= 10.00

Notes:

Horizontal and vertical datums were referenced to control stations on site.

Heights in metres above Chart Datum (East Loch Tarbert)

MHWS	MHWN	MLWN	MLWS
3.6	2.9	1.0	0.3

CONTROL STATION COORDINATES (OD)

STN	EASTING	NORTHING	LEVEL
Base	187102.715	668910.375	3.635

Aspect
Land + Hydrographic Surveys
CHARTERED SURVEYORS
Thornhouse Business Centre
Ballot Road
Irvine
KA12 OHW
Tel : 01294 313399
Fax : 01294 313389
E-mail: mail@aspectsurveys.com
Web: www.aspectsurveys.com

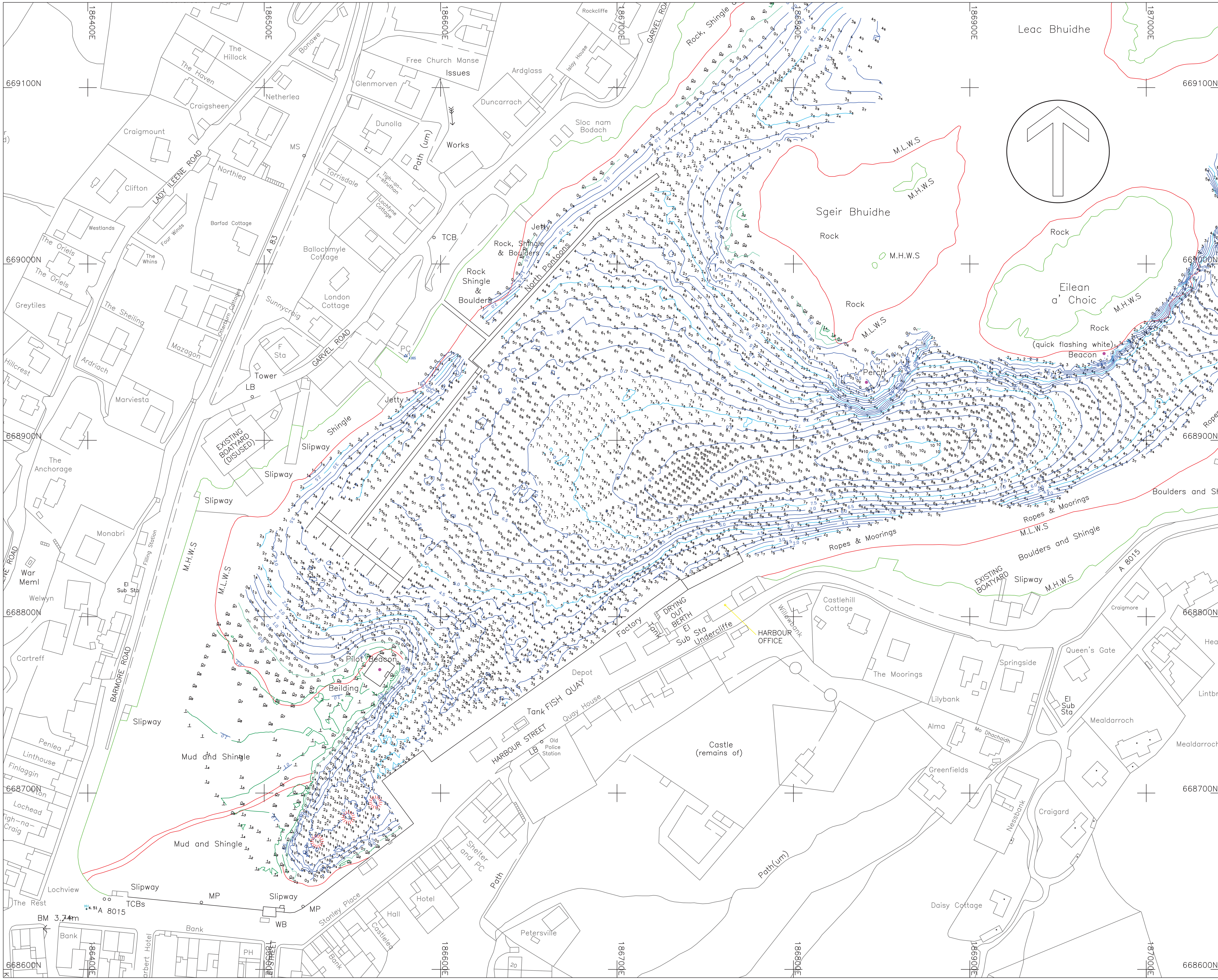
Client :

MOTT MACDONALD
1 ATLANTIC QUAY
BROOMIELAW
GLASGOW
G2 8JB

Project Title :

MULTIBEAM BATHYMETRIC SURVEY
EAST LOCH TARBERT PIER & SLIPWAY
TARBERT
ARGYLL & BUTE

Project No: A5293	Scale : 1:500
Surveyed date : 25th April 2014	Issued date : 28th April 2014
Surveyed by : CKS	Checked by: GJC
Sheet No. : 1 of 2	Plot Scale: 1:1 @ A1



Legend

4.56	Heights relative to CHART DATUM.
12_2	Depths relative to CHART DATUM.
	Sea-bed contour relative to CHART DATUM.
	Prominent Sea-bed contour relative to CHART DATUM.
	Mean High Water Springs (OS)
	Mean Low Water Springs (OS)
	High Spot (Dredging)

Heights in metres above Chart Datum

MHWS	MHWN	MLWN	MLWS
3.6	2.9	1.0	0.3

Notes:

Horizontal Control points are relative to the NATIONAL GRID. (OSTN02)

All levels are relative to CHART DATUM.

Ordnance Datum is 1.62m above Chart Datum

1. The survey was carried out from the 7m Harbour Launch "MV Sorcha".
2. Horizontal positioning was acheived by Trimble 5700 RTK GPS.
3. A heave compensated, Kongsberg Simrad EA400 Dual Frequency Echosounder (38/200kHz) was utilised for the project.
4. Data was post processed within Trimble HydroPro Navigation & NavEdit hydrographic software.
5. A Valeport 740 tide gauge was installed at Tarbert Harbour Pier, for the duration of the survey.

CONTROL STATION COORDINATES

STN	EASTING	NORTHING	LEVEL (CD)
1	186580.205	668947.824	4.865

Aspect
Land & Hydrographic Surveys
Chartered Surveyors
Thornhouse Business Centre
Ballot Road
Irvine
Tel : 01294 313399 KA12 OHW Fax : 01294 313389
E-mail: mail@aspectsurveys.com
Web: www.aspectsurveys.com

Client :

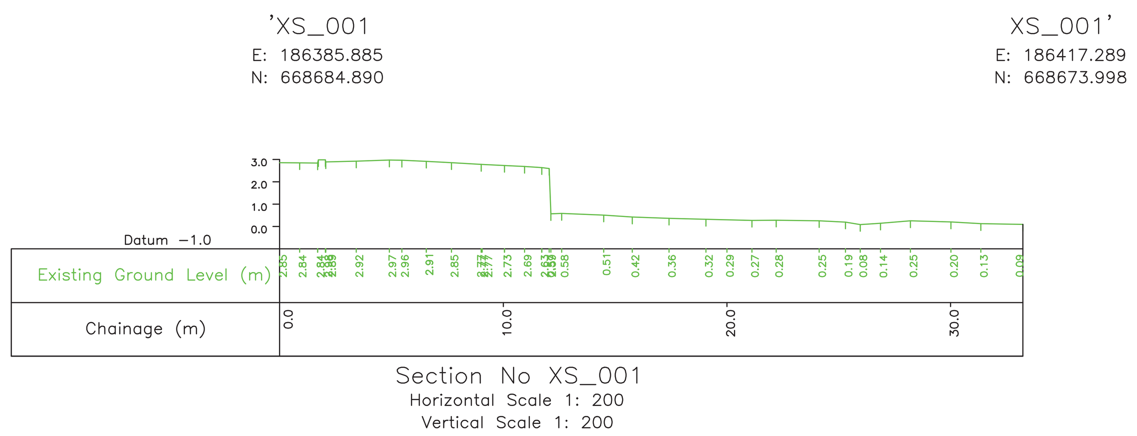
TARBERT (LOCH FYNE) HARBOUR AUTHOURITY
HARBOUR OFFICE
HARBOUR STREET
TARBERT
ARGYLL PA29 6UD

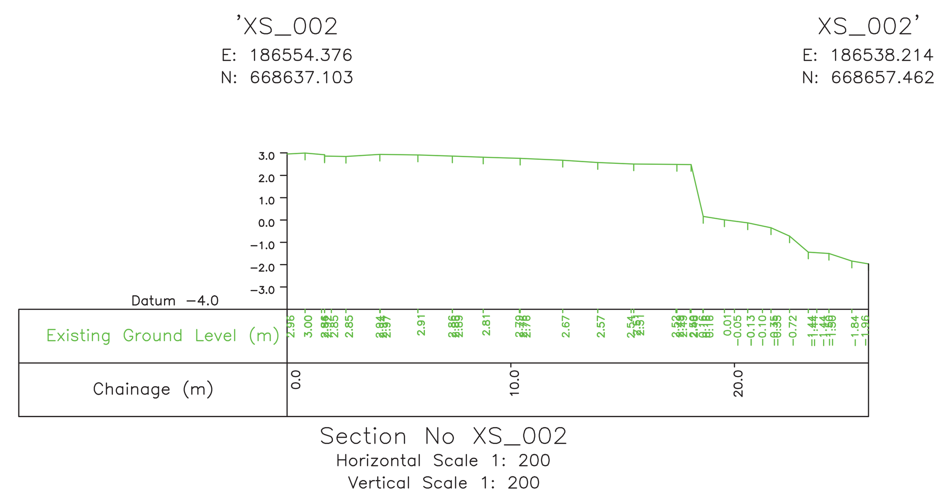
Project Title :

POST-DREDGE BATHYMETRIC SURVEY
TARBERT HARBOUR
TARBERT
ARGYLL

Project No: A3629_PD	Scale : 1:1000
Surveyed date : 12th May 2006	Issued date : 14th May 2006
Surveyed by : G J Campbell	Checked by: GWT

Plot Scale 1:1@A1





Link Feature Legend

- Ground Level
- Water Level
- Wall
- Fence
- Footpath Level
- Road Level

Notes:

Horizontal Control points are relative to the NATIONAL GRID.

All levels are relative to ORDNANCE DATUM.

RTK corrections were obtained using the Trimble VRS Active Network.

CONTROL STATION COORDINATES			
STN	EASTING	NORTHING	LEVEL

Aspect
Land + Hydrographic Surveys
CHARTERED SURVEYORS
Thornhouse Business Centre
Ballot Road
Irvine
KA12 OHW
Tel : 01294 313399
Fax : 01294 313389
E-mail: mail@aspectsurveys.com
Web: www.aspectsurveys.com

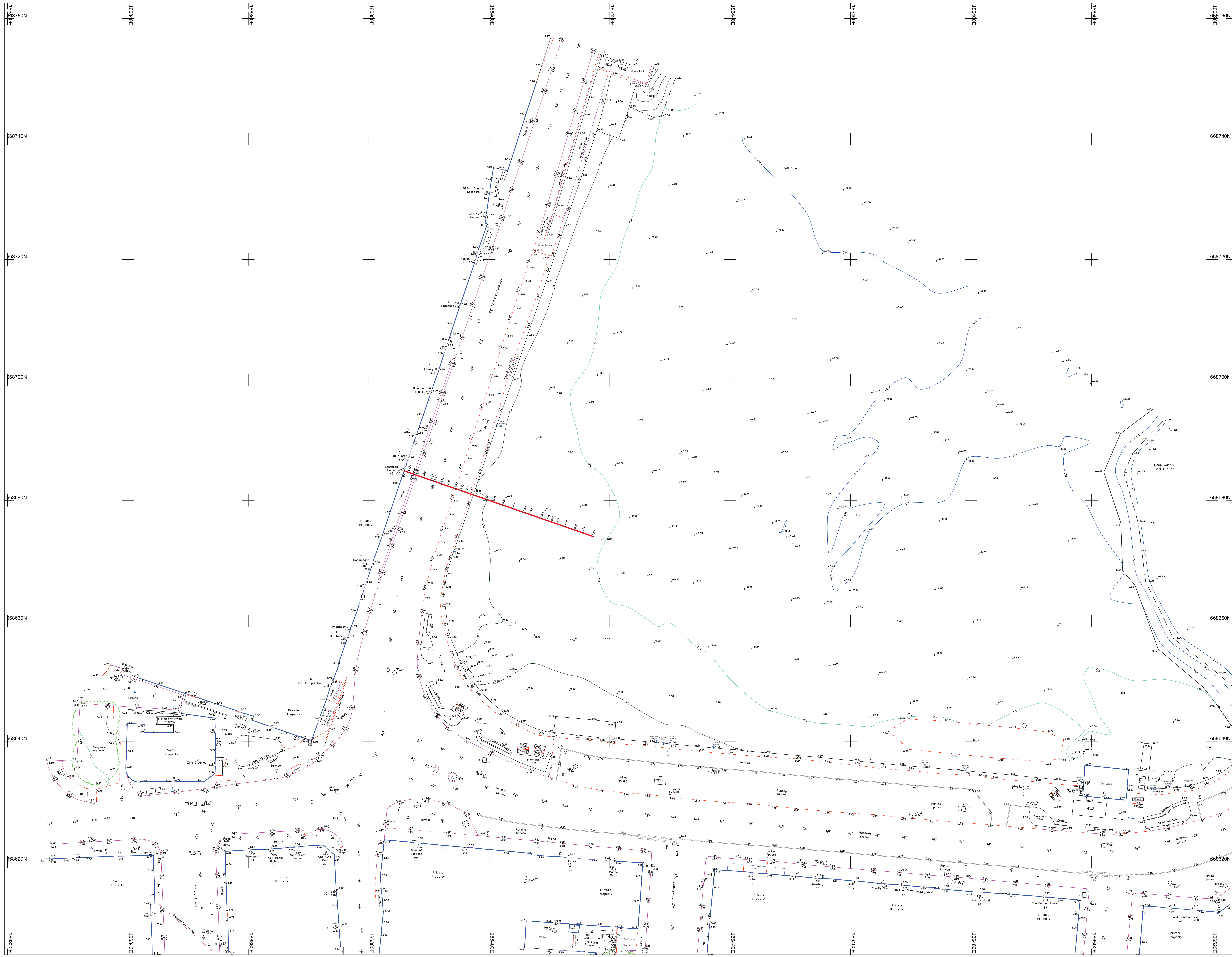
Client :

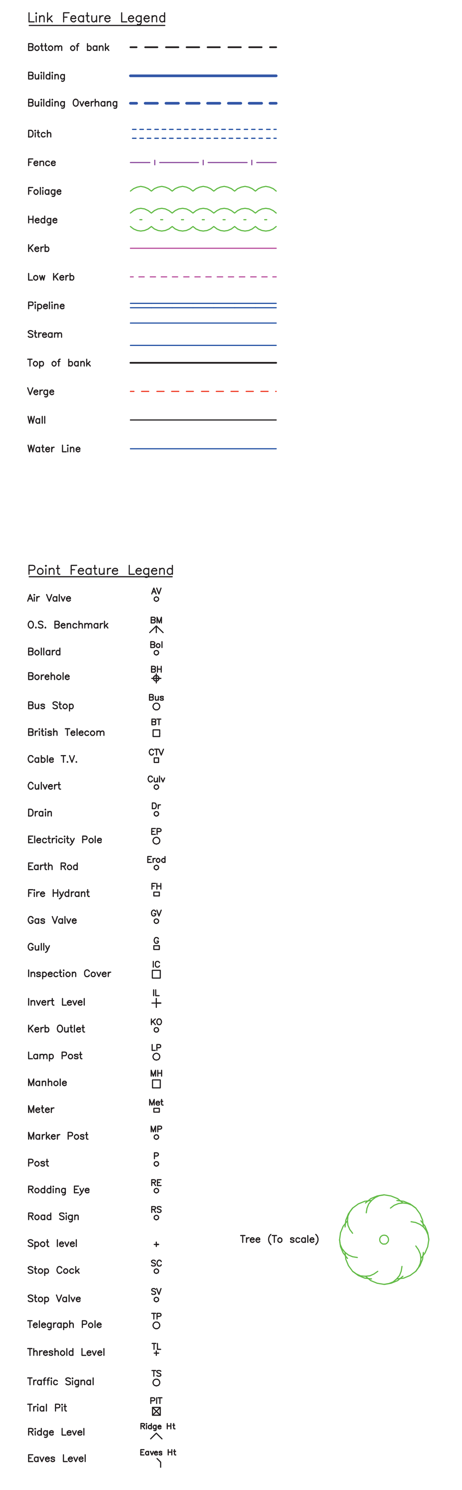
AECOM
1 TANFIELD
EDINBURGH
EH3 5DA

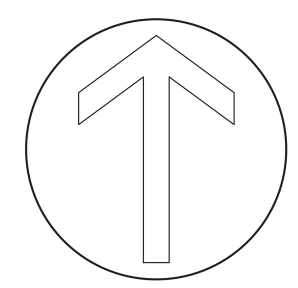
Project Title :

TOPOGRAPHIC SURVEY
ARGYLL & BUTE COUNCIL FLOOD STUDIES
TARBERT

Project No: A6761_Tarbert_Sections	Scale : 1:200
Surveyed date : 17th August 2018	Issued date : 22nd August 2018
Surveyed by : SD	Checked by: RM
Sheet No. : 1 of 1	Plot Scale: 1:1 @ A0







SURVEY IS ROTATED TO GRID NORTH.

Notes:

Horizontal Control points are relative to the NATIONAL GRID.

All levels are relative to ORDNANCE DATUM.

RTK corrections were obtained using the Trimble VRS Active Network.

CONTROL STATION COORDINATES			
STN	EASTING	NORTHING	LEVEL
1	186429.707	668638.303	2.702
2	186401.722	668697.849	2.602
3	186369.922	668636.487	3.375
4	186347.411	668631.780	4.268
5	186351.370	668557.312	5.157
6	186368.819	668534.758	6.355
7	186398.476	668559.786	5.516
8	186432.034	668574.357	5.172
9	186433.652	668590.592	4.350
10	186470.869	668587.288	4.923
11	186497.303	668584.962	4.379
12	186506.269	668627.321	2.846

Aspect
Land + Hydrographic Surveys
CHARTERED SURVEYORS
Thornhouse Business Centre
Ballot Road
Irvine
KA12 OHW
Tel : 01294 313399
Fax : 01294 313389
E-mail: mail@aspectsurveys.com
Web: www.aspectsurveys.com

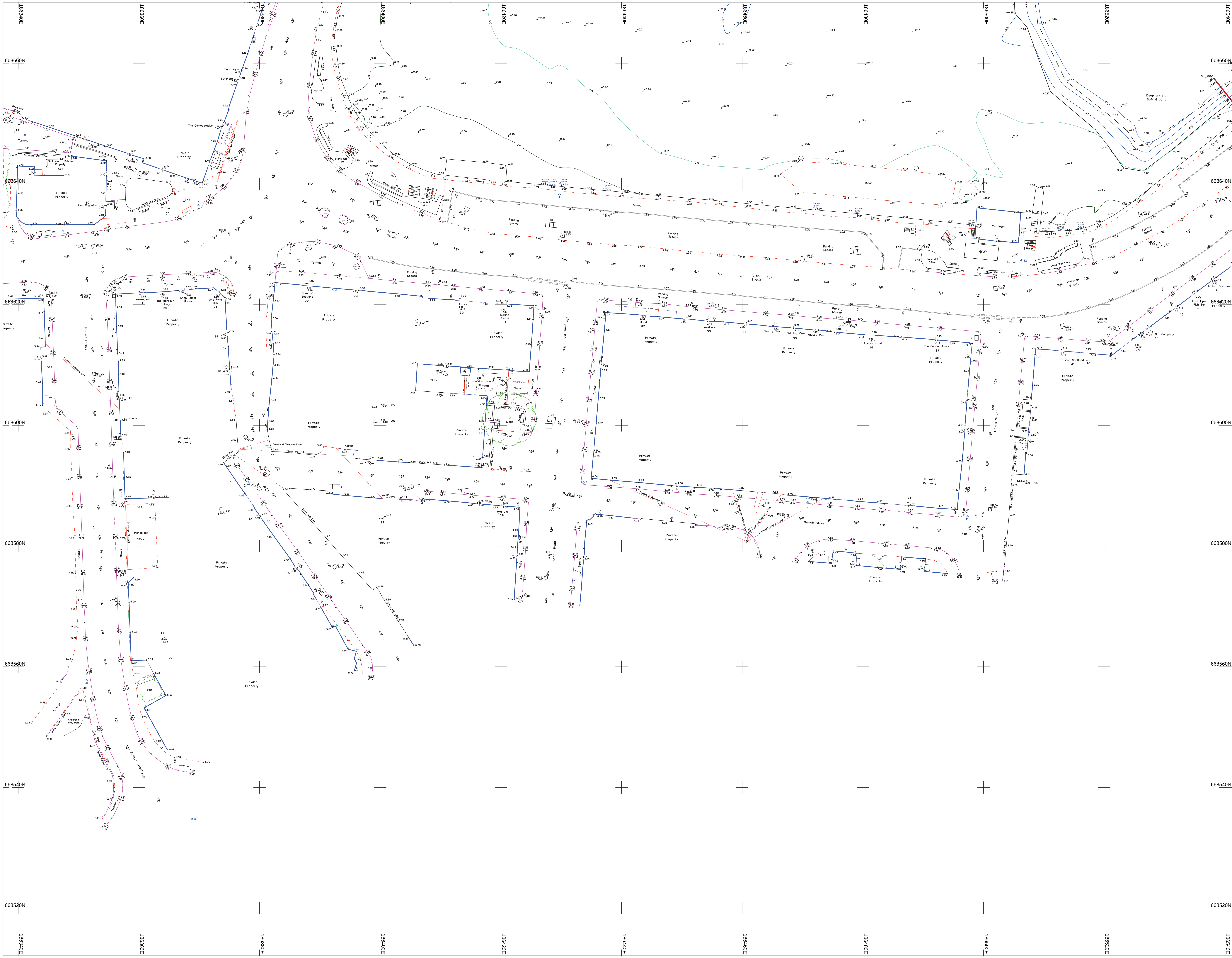
Client :

AECOM
1 TANFIELD
EDINBURGH
EH3 5DA

Project Title :

TOPOGRAPHIC SURVEY
ARGYLL & BUTE COUNCIL FLOOD STUDIES
TARBERT

Project No: A6761_Tarbert	Scale : 1:200
Surveyed date : 17th August 2018	Issued date : 22nd August 2018
Surveyed by : SD	Checked by: RM
Sheet No. : 1 of 3	Plot Scale: 1:1 @ A0



Link Feature Legend

- Bottom of bank
- Building
- Building Overhang
- Ditch
- Fence
- Foliage
- Hedge
- Kerb
- Low Kerb
- Pipeline
- Stream
- Top of bank
- Verge
- Wall
- Water Line

Point Feature Legend

- Air Valve — AV
- O.S. Benchmark — BM
- Bollard — Bol
- Borehole — BH
- Bus Stop — Bus
- British Telecom — BT
- Cable T.V. — CTV
- Culvert — Culv
- Drain — Dr
- Electricity Pole — EP
- Earth Rod — Erod
- Fire Hydrant — FH
- Gas Valve — GV
- Gully — G
- Inspection Cover — IC
- Invert Level — IL
- Kerb Outlet — KO
- Lamp Post — LP
- Manhole — MH
- Meter — Met
- Marker Post — MP
- Post — P
- Rodding Eye — RE
- Road Sign — RS
- Spot level — +
- Stop Cock — SC
- Stop Valve — SV
- Telegraph Pole — TP
- Threshold Level — TL
- Traffic Signal — TS
- Trial Pit — PIT
- Ridge Level — Ridge Ht
- Eaves Level — Eaves Ht

Tree (To scale)

SURVEY IS ROTATED TO GRID NORTH.

Notes:

Horizontal Control points are relative to the NATIONAL GRID.

All levels are relative to ORDNANCE DATUM.

RTK corrections were obtained using the Trimble VRS Active Network.

CONTROL STATION COORDINATES

STN	EASTING	NORTHING	LEVEL
1	186429.707	668638.303	2.702
2	186401.722	668697.849	2.602
3	186369.922	668636.487	3.375
4	186347.411	668631.780	4.268
5	186351.370	668557.312	5.157
6	186368.819	668534.758	6.355
7	186398.476	668559.786	5.516
8	186432.034	668574.357	5.172
9	186433.652	668590.592	4.350
10	186470.869	668587.288	4.923
11	186497.303	668584.962	4.379
12	186506.269	668627.321	2.846

Aspect
Land + Hydrographic Surveys
CHARTERED SURVEYORS
Thornhouse Business Centre
Ballot Road
Irvine
KA12 OHW
Tel : 01294 313399   Fax : 01294 313389
E-mail: mail@aspectsurveys.com
Web: www.aspectsurveys.com

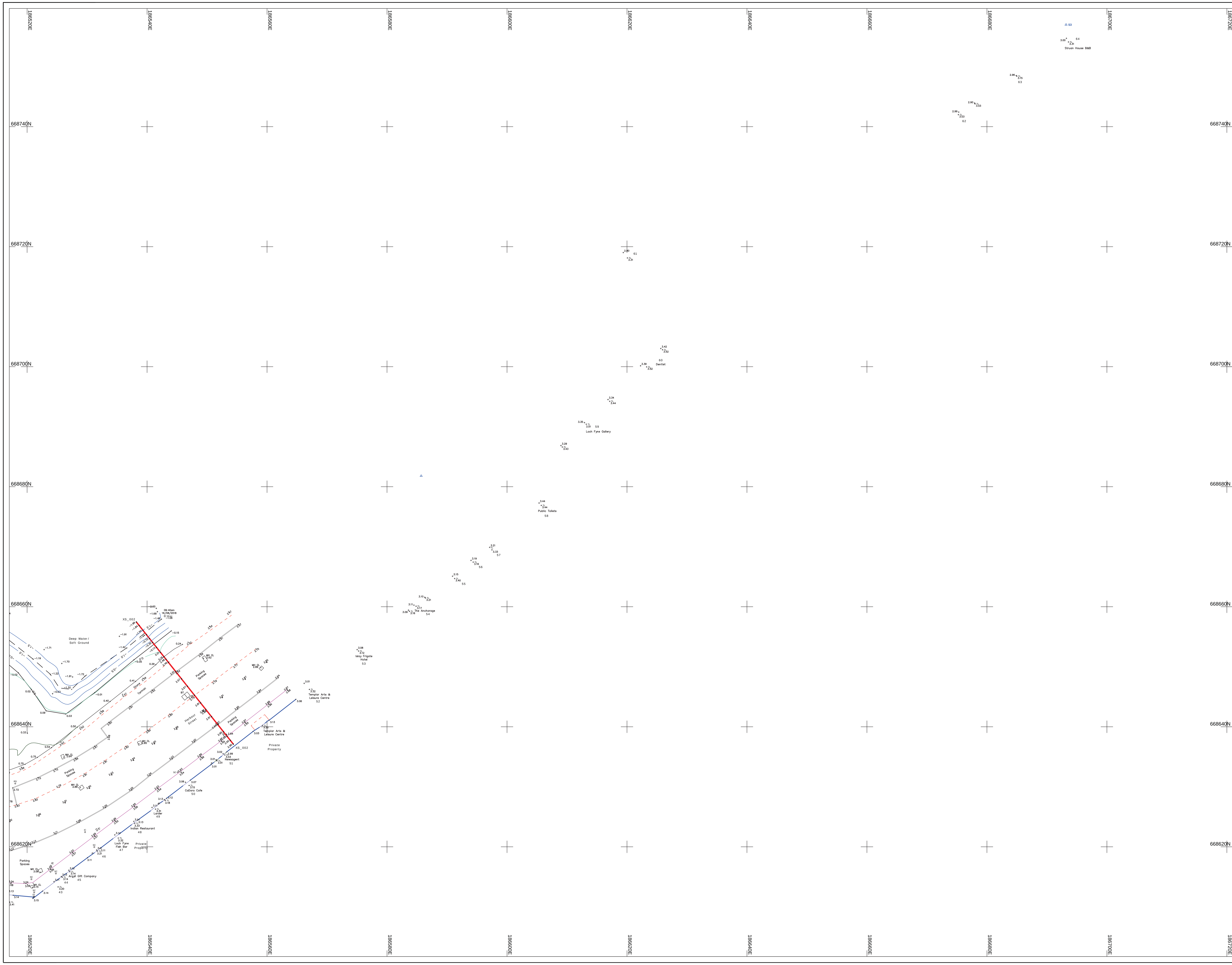
Client :

AECOM
1 TANFIELD
EDINBURGH
EH3 5DA

Project Title :

TOPOGRAPHIC SURVEY
ARGYLL & BUTE COUNCIL FLOOD STUDIES
TARBERT

Project No: A6761_Tarbert	Scale : 1:200
Surveyed date : 17th August 2018	Issued date : 22nd August 2018
Surveyed by : SD	Checked by: RM
Sheet No. : 2 of 3	Plot Scale: 1:1 @ A0



Link Feature Legend

- Bottom of bank
- Building
- Building Overhang
- Ditch
- Fence
- Foliage
- Hedge
- Kerb
- Low Kerb
- Pipeline
- Stream
- Top of bank
- Verge
- Wall
- Water Line

Point Feature Legend

- Air Valve
- O.S. Benchmark
- Bollard
- Borehole
- Bus Stop
- British Telecom
- Cable T.V.
- Culvert
- Drain
- Electricity Pole
- Earth Rod
- Fire Hydrant
- Gas Valve
- Gully
- Inspection Cover
- Invert Level
- Kerb Outlet
- Lamp Post
- Manhole
- Meter
- Marker Post
- Post
- Rodding Eye
- Road Sign
- Spot level
- Stop Cock
- Stop Valve
- Telegraph Pole
- Threshold Level
- Traffic Signal
- Trial Pit
- Ridge Level
- Eaves Level
- Tree (To scale)

SURVEY IS ROTATED TO GRID NORTH.

Notes:

Horizontal Control points are relative to the NATIONAL GRID.

All levels are relative to ORDNANCE DATUM.

RTK corrections were obtained using the Trimble VRS Active Network.

CONTROL STATION COORDINATES

STN	EASTING	NORTHING	LEVEL
1	186429.707	668638.303	2.702
2	186401.722	668697.849	2.602
3	186369.922	668636.487	3.375
4	186347.411	668631.780	4.268
5	186351.370	668557.312	5.157
6	186368.819	668534.758	6.355
7	186398.476	668559.786	5.516
8	186432.034	668574.357	5.172
9	186433.652	668590.592	4.350
10	186470.869	668587.288	4.923
11	186497.303	668584.962	4.379
12	186506.269	668627.321	2.846

Aspect
Land + Hydrographic Surveys
CHARTERED SURVEYORS
Thornhouse Business Centre
Ballot Road
Tel : 01294 313399 Irvine Fax : 01294 313389
KA12 OHW
E-mail: mail@aspectsurveys.com
Web: www.aspectsurveys.com

Client :

AECOM
1 TANFIELD
EDINBURGH
EH3 5DA

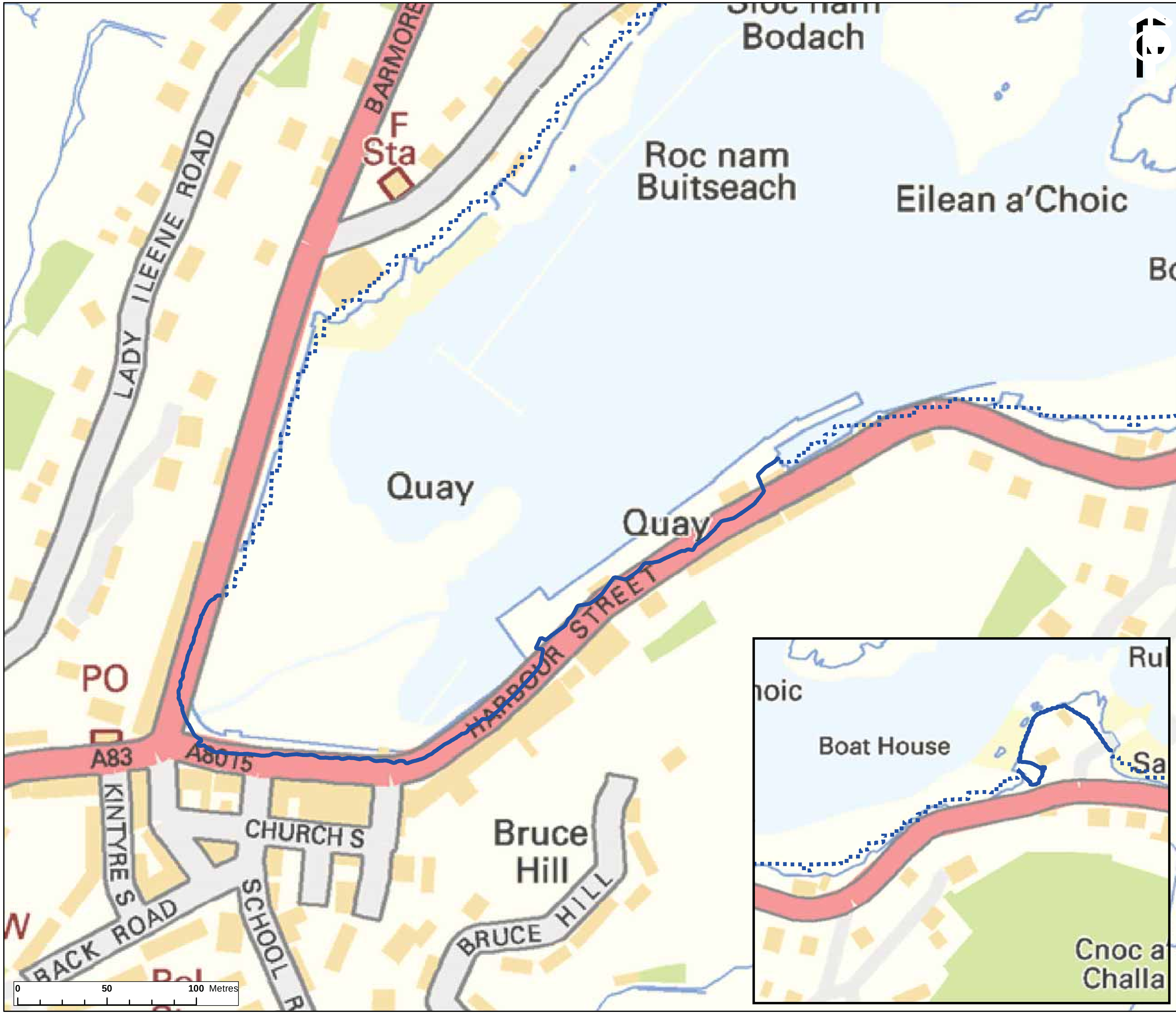
Project Title :

TOPOGRAPHIC SURVEY
ARGYLL & BUTE COUNCIL FLOOD STUDIES
TARBERT

Project No: A6761_Tarbert	Scale : 1:200
Surveyed date : 17th August 2018	Issued date : 22nd August 2018
Surveyed by : SD	Checked by: RM
Sheet No. : 3 of 3	Plot Scale: 1:1 @ A0

Appendix D – Flood Contour Maps

Project Management Initials: DH Designer: MH Checked: HH Approved: DH



Scale 1:2000 @ A3

AECOM

PROJECT

Tarbert Flood Study

CLIENT

Argyll & Bute Council

KEY:

50% AEP Tidal Flood Extent

- Flood levels based on NEXTMap (dotted line)
- Flood levels based on survey (solid line)

PROJECT NUMBER

60578115

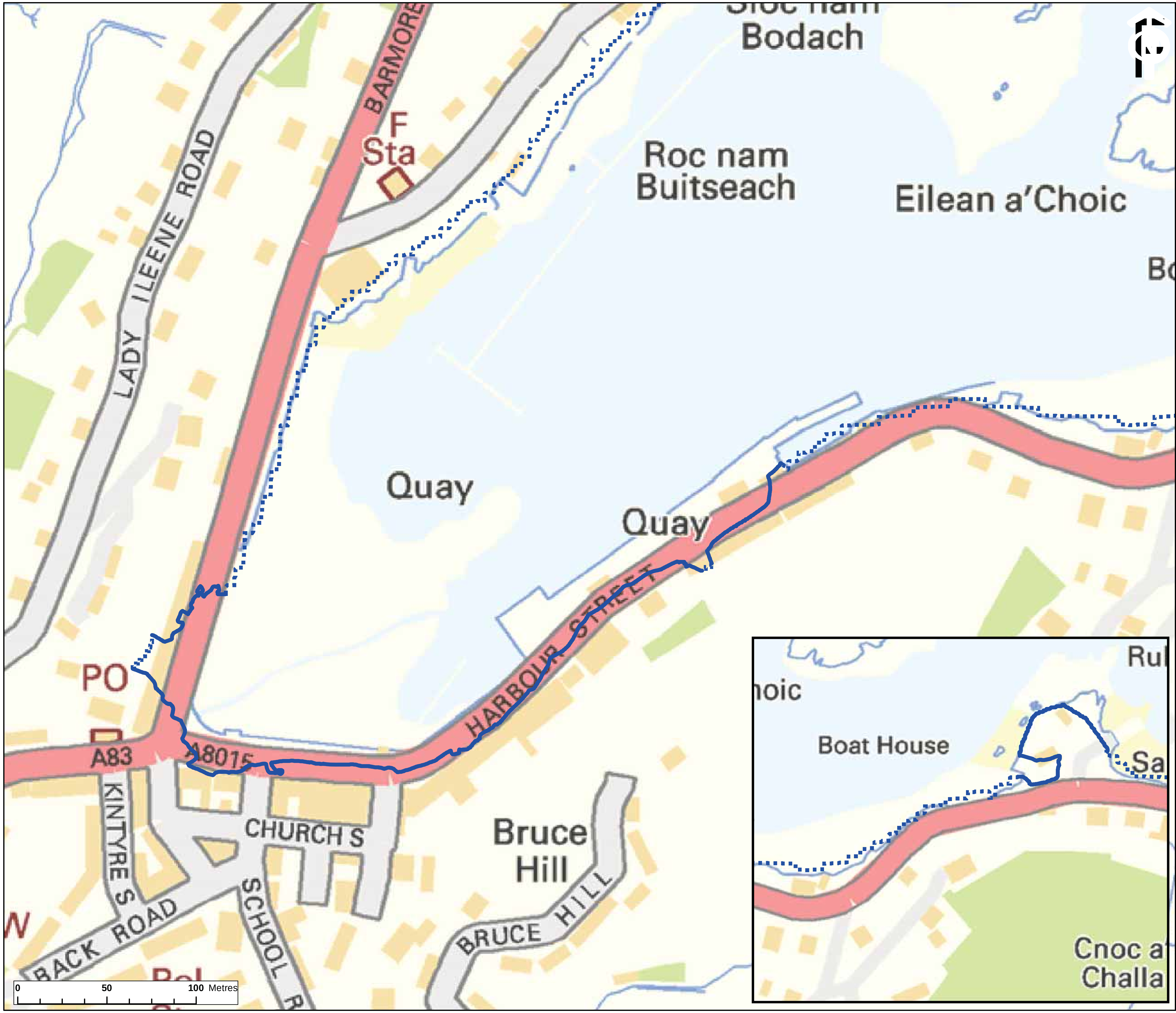
SHEET TITLE

Figure 1: 50%AEP tidal flood extent

SHEET NUMBER

1 of 8

Project Management Initials: DH Designer: MH Checked: HH Approved: DH



Scale 1:2000 @ A3

AECOM

PROJECT

Tarbert Flood Study

CLIENT

Argyll & Bute Council

KEY:

20% AEP Tidal Flood Extent

- Flood levels based on NEXTMap (dotted line)
- Flood levels based on survey (solid line)

PROJECT NUMBER

60578115

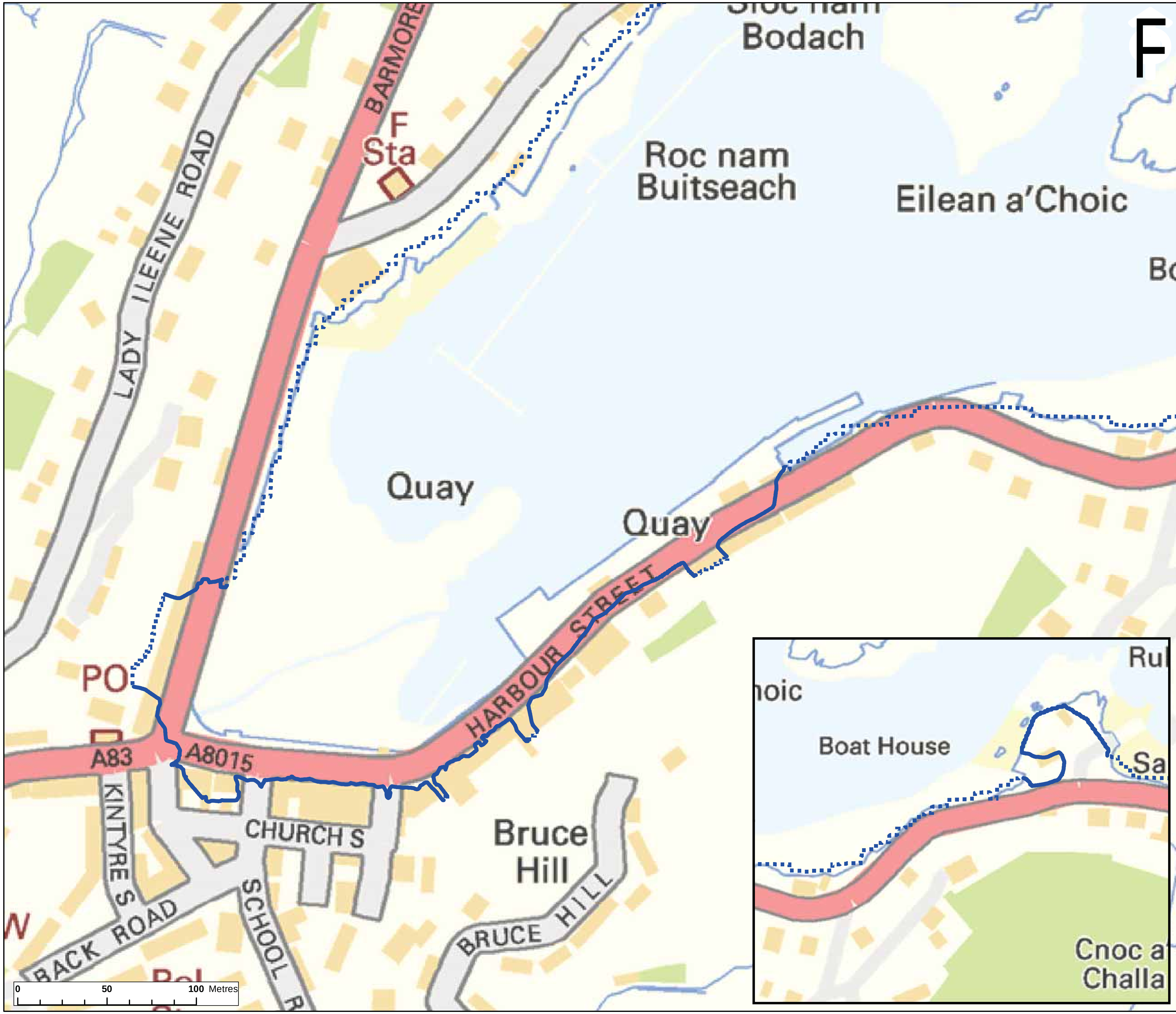
SHEET TITLE

Figure 2: 20% AEP tidal flood extent

SHEET NUMBER

2 of 8

Project Management Initials: DH Designer: MH Checked: HH Approved: DH



Scale 1:2000 @ A3

AECOM

PROJECT

Tarbert Flood Study

CLIENT

Argyll & Bute Council

KEY:

10% AEP Tidal Flood Extent

- Flood levels based on NEXTMap (dotted line)
- Flood levels based on survey (solid line)

PROJECT NUMBER

60578115

SHEET TITLE

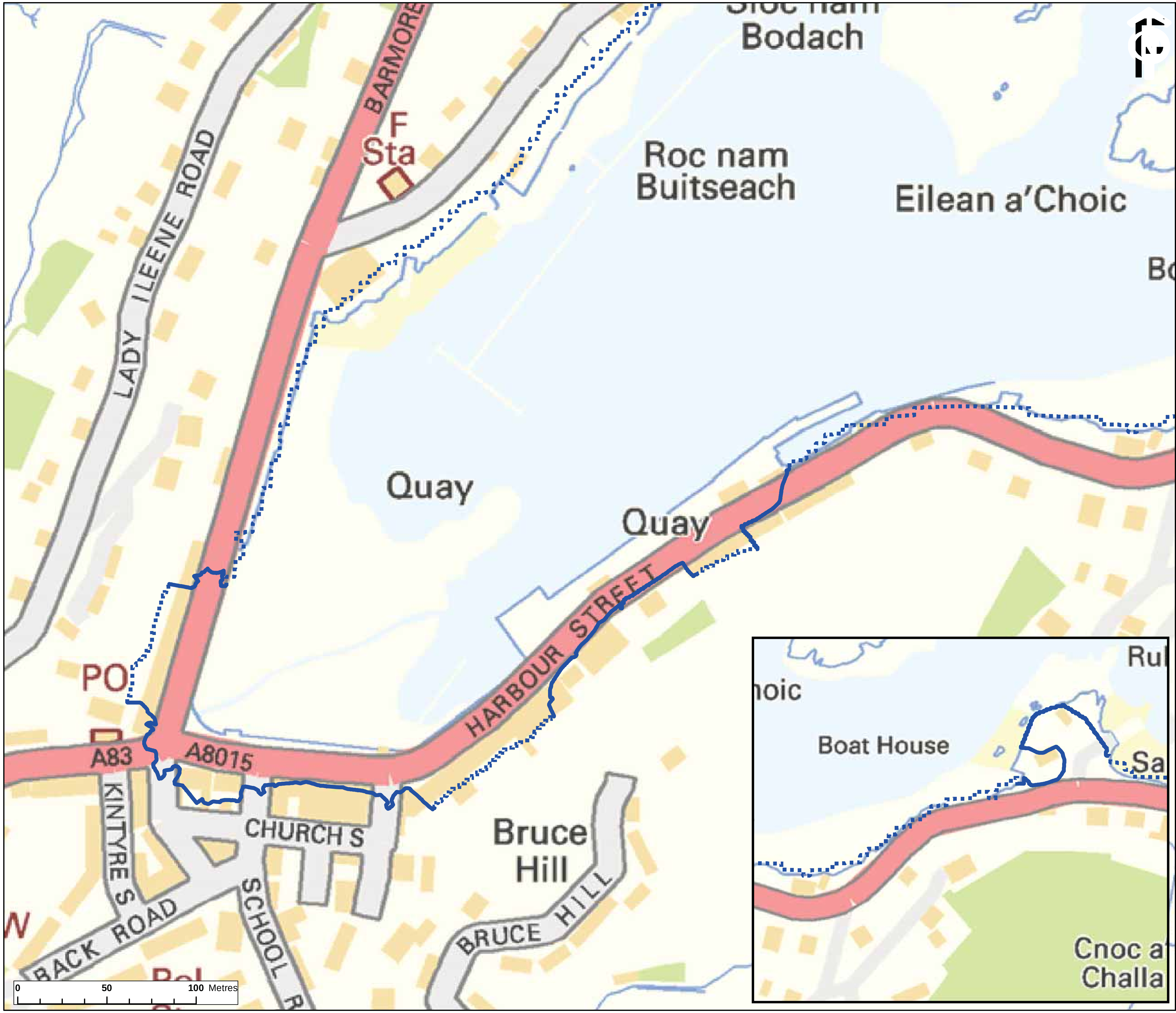
Figure 3: 10% AEP tidal flood extent

SHEET NUMBER

3 of 8

Project Management Initials: DH Designer: MH Checked: HH Approved: DH

Scale 1:2000 @ A3



AECOM

PROJECT

Tarbert Flood Study

CLIENT

Argyll & Bute Council

KEY:

5% AEP Tidal Flood Extent

Flood levels based on NEXTMap

Flood levels based on survey

PROJECT NUMBER

60578115

SHEET TITLE

Figure 4: 5% AEP tidal flood extent

SHEET NUMBER

4 of 8

Project Management Initials: DH Designer: MH Checked: HH Approved: DH

Scale 1:2000 @ A3

AECOM

PROJECT

Tarbert Flood Study

CLIENT

Argyll & Bute Council

KEY:

2% AEP Tidal Flood Extent

- Flood levels based on NEXTMap (dotted line)
- Flood levels based on survey (solid line)

PROJECT NUMBER

60578115

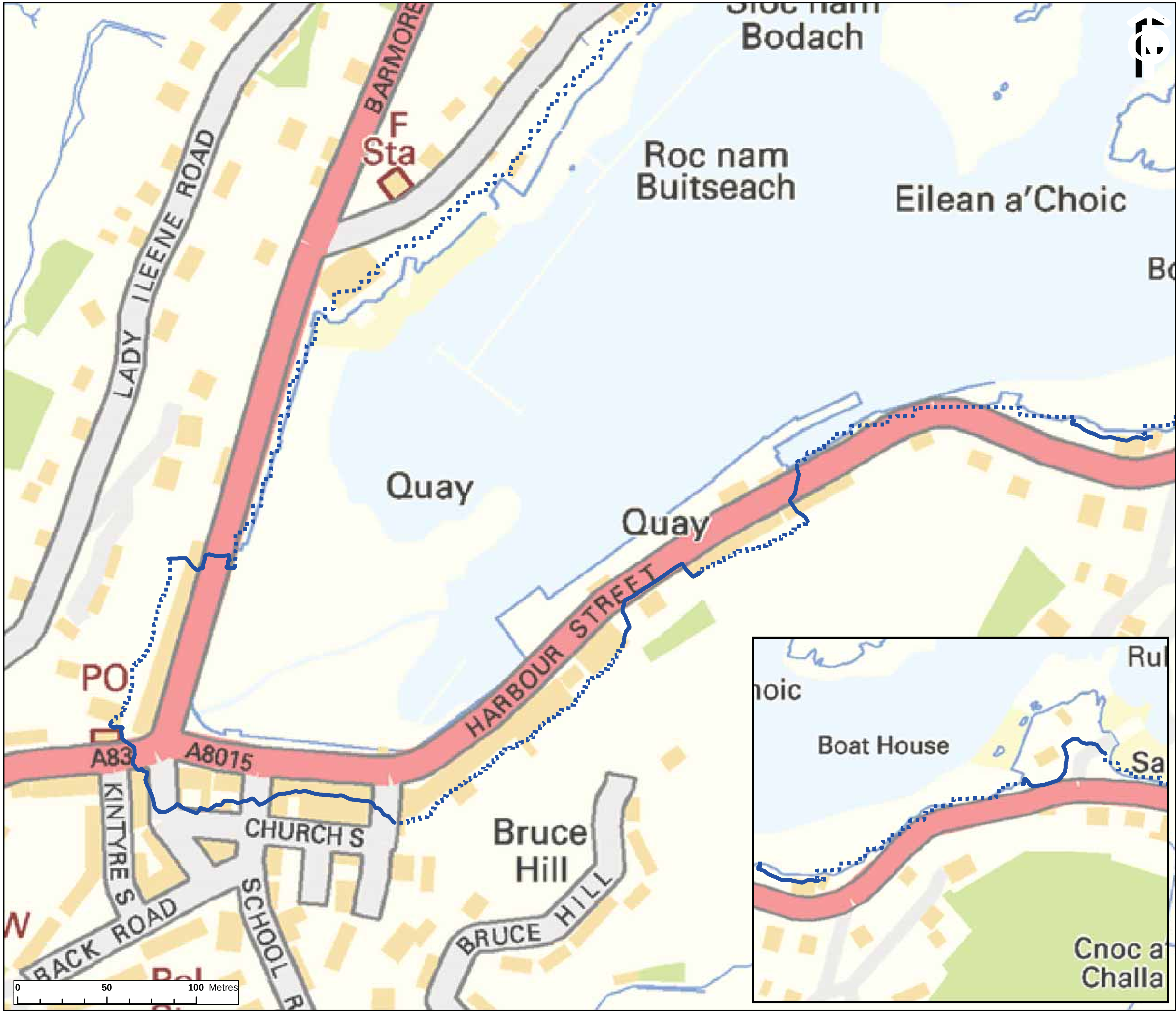
SHEET TITLE

Figure 5: 2% AEP tidal flood extent

SHEET NUMBER

5 of 8

Project Management Initials: DH Designer: MH Checked: HH Approved: DH



Scale 1:2000 @ A3

This drawing has been produced for the use of AECOM's client. It may not be used, modified or relied upon by third parties, except as agreed by AECOM or as required by law. AECOM accepts no responsibility, and denies any liability whatsoever, to any party that uses or relies upon this drawing without AECOM's express written consent. Do not scale this document.

AECOM

PROJECT

Tarbert Flood Study

CLIENT

Argyll & Bute Council

KEY:

1% AEP Tidal Flood Extent

- Flood levels based on NEXTMap
- Flood levels based on survey

PROJECT NUMBER

60578115

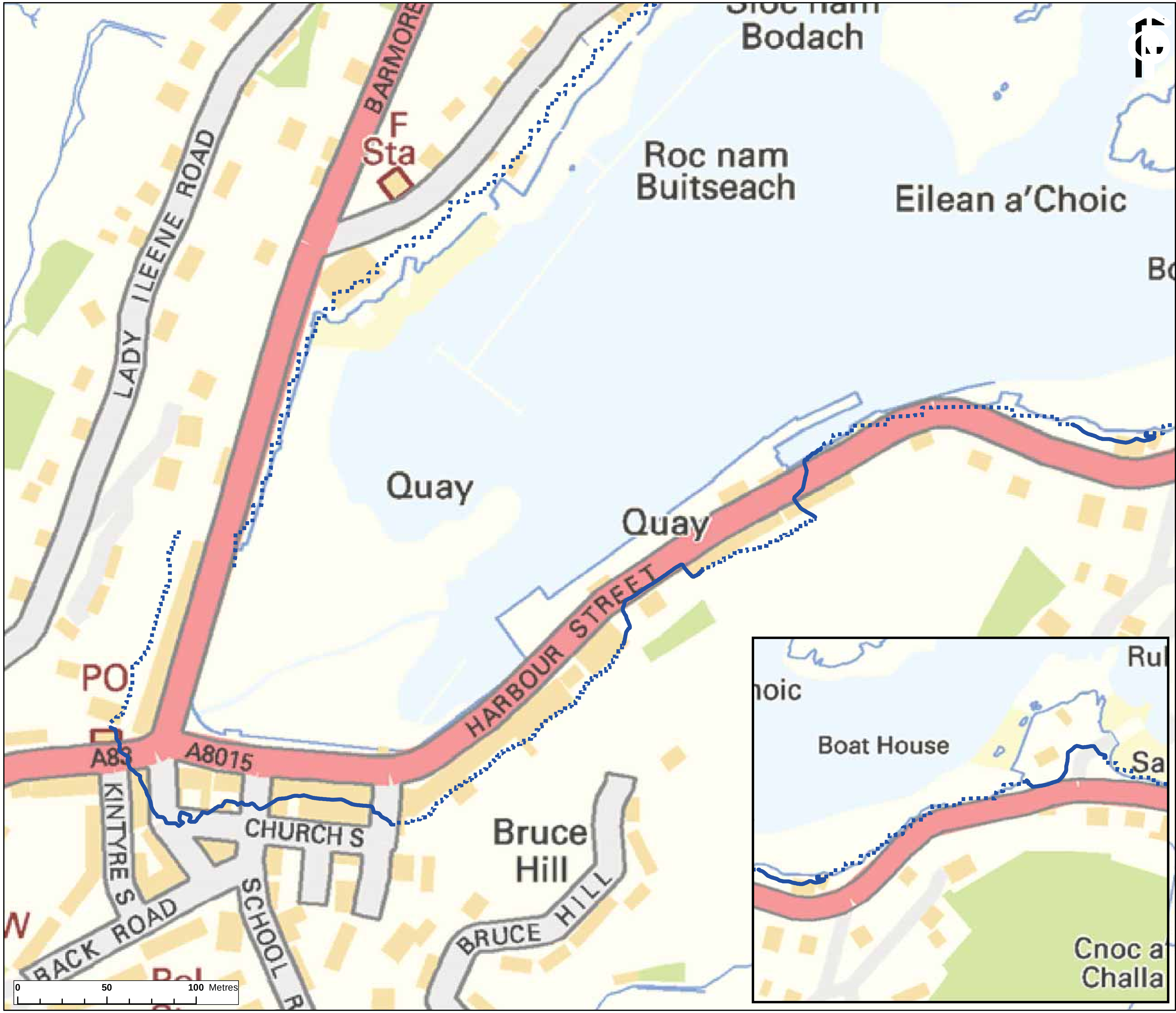
SHEET TITLE

Figure 6: 1% AEP tidal flood extent

SHEET NUMBER

6 of 8

Project Management Initials: DH Designer: MH Checked: HH Approved: DH



Scale 1:2000 @ A3

AECOM

PROJECT

Tarbert Flood Study

CLIENT

Argyll & Bute Council

KEY:

0.5% AEP Tidal Flood Extent

- Flood levels based on NEXTMap (dotted line)
- Flood levels based on survey (solid line)

PROJECT NUMBER

60578115

SHEET TITLE

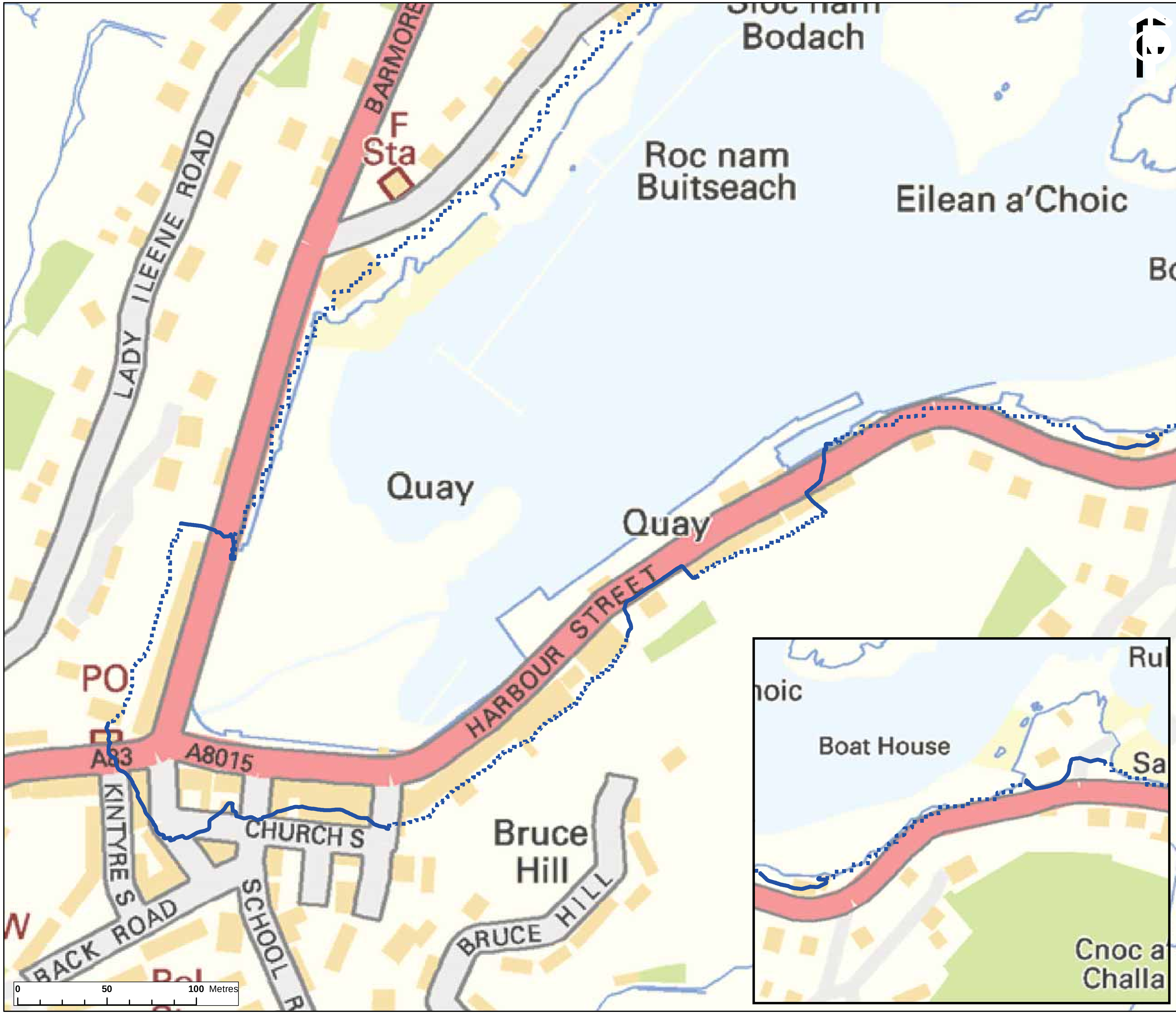
Figure 7: 0.5% AEP tidal flood extent

SHEET NUMBER

7 of 8

Project Management Initials: DH Designer: MH Checked: HH Approved: DH

Scale 1:2000 @ A3



AECOM

PROJECT

Tarbert Flood Study

CLIENT

Argyll & Bute Council

KEY:

0.1% AEP Tidal Flood Extent

- Flood levels based on NEXTMap
- Flood levels based on survey

PROJECT NUMBER

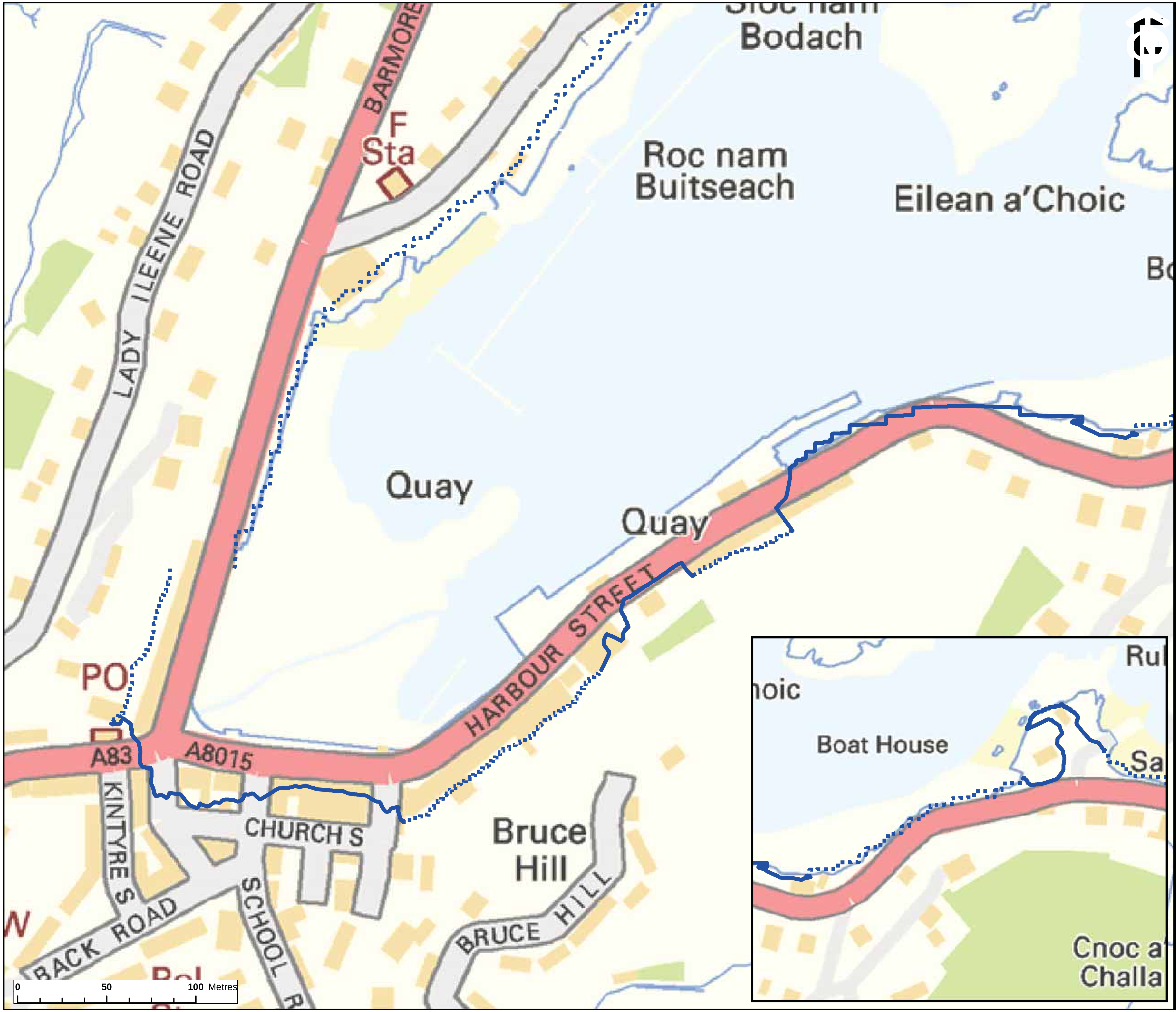
60578115

SHEET TITLE

Figure 8: 0.1% AEP tidal flood extent

SHEET NUMBER

8 of 8



Scale 1:2000 @ A3

AECOM

PROJECT

Tarbert Flood Study

CLIENT

Argyll & Bute COUNCIL

KEY:

50% AEP +CC Tidal Flood Extent

- Flood levels based on NEXTMap
- Flood levels based on survey

PROJECT NUMBER

60578115

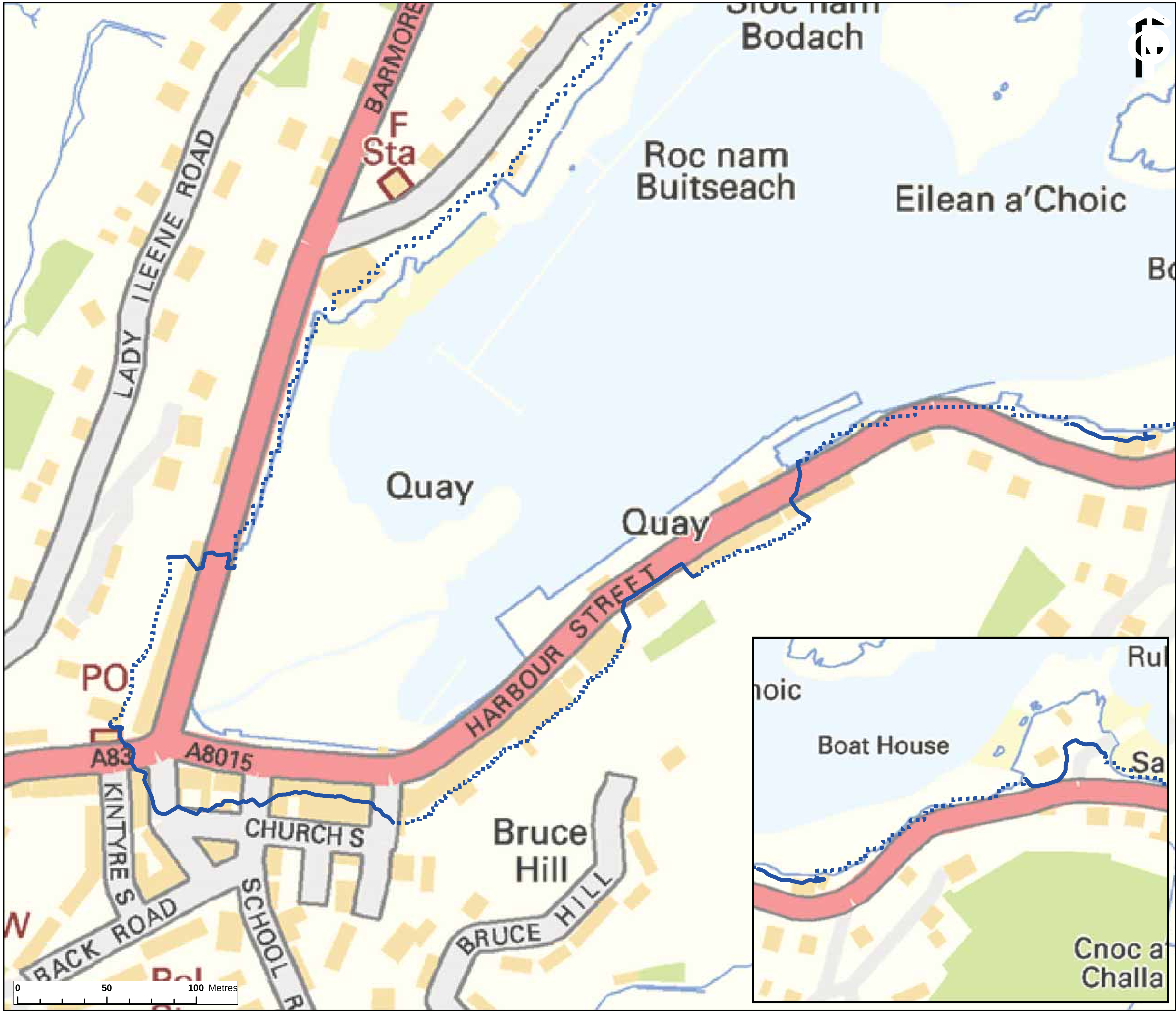
SHEET TITLE

Figure 9: 50% AEP +CC tidal flood extent

SHEET NUMBER

1 of 8

Project Management Initials: DH Designer: MH Checked: HH Approved: DH



Scale 1:2000 @ A3

AECOM

PROJECT

Tarbert Flood Study

CLIENT

Argyll & Bute COUNCIL

KEY:

20% AEP +CC Tidal Flood Extent

- Flood levels based on NEXTMap
- Flood levels based on survey

PROJECT NUMBER

60578115

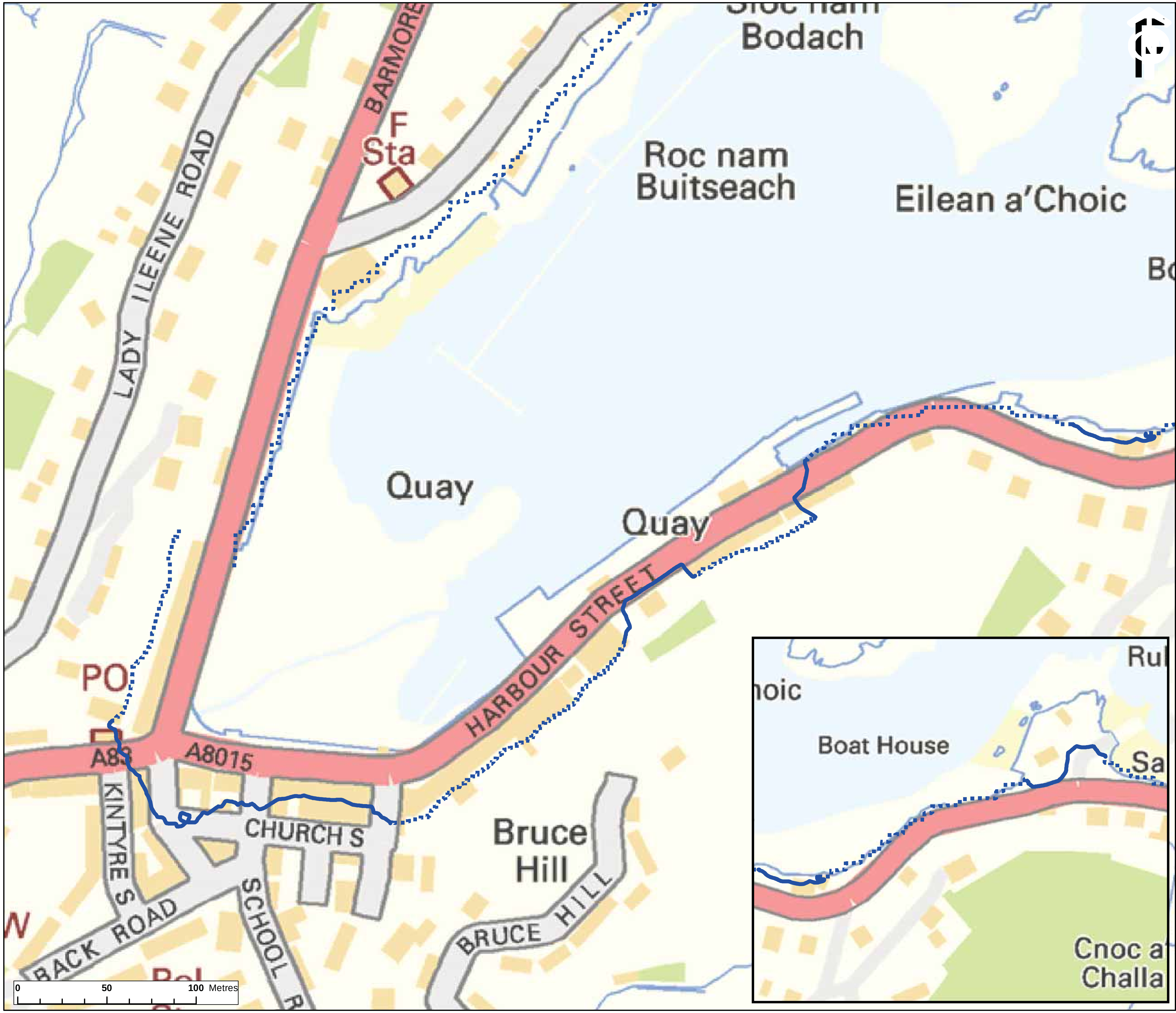
SHEET TITLE

Figure 10: 20% AEP +CC tidal flood extent

SHEET NUMBER

2 of 8

Project Management Initials: DH Designer: MH Checked: HH Approved: DH



Scale 1:2000 @ A3

AECOM

PROJECT

Tarbert Flood Study

CLIENT

Argyll & Bute Council

KEY:

10% AEP +CC Tidal Flood Extent

- Flood levels based on NEXTMap (dotted line)
- Flood levels based on survey (solid line)

PROJECT NUMBER

60578115

SHEET TITLE

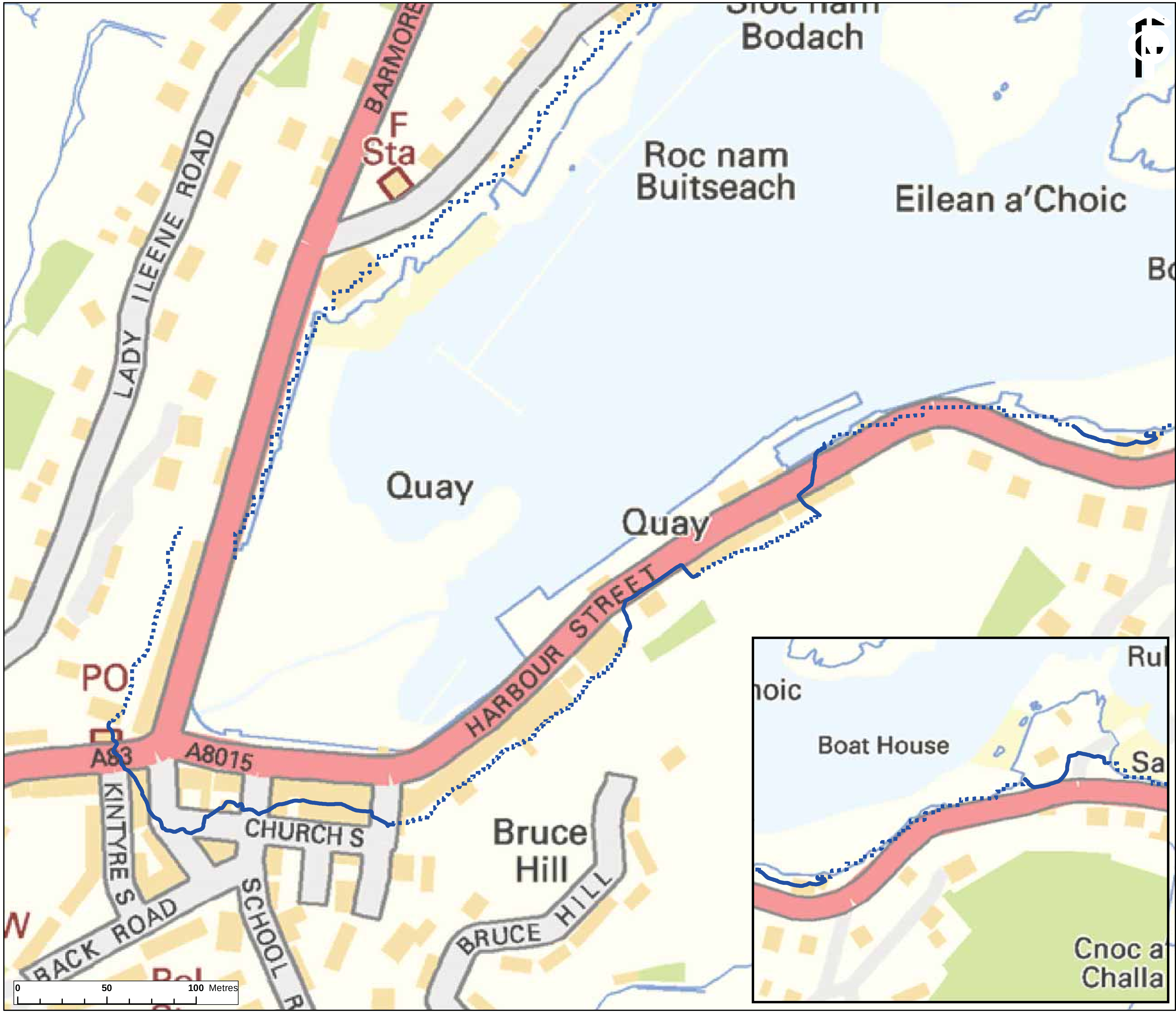
Figure 11: 10% AEP +CC tidal flood extent

SHEET NUMBER

3 of 8

Project Management Initials: DH Designer: MH Checked: HH Approved: DH

Scale 1:2000 @ A3



AECOM

PROJECT

Tarbert Flood Study

CLIENT

Argyll & Bute Council

KEY:

5% AEP +CC Tidal Flood Extent

- Flood levels based on NEXTMap (dotted line)
- Flood levels based on survey (solid line)

PROJECT NUMBER

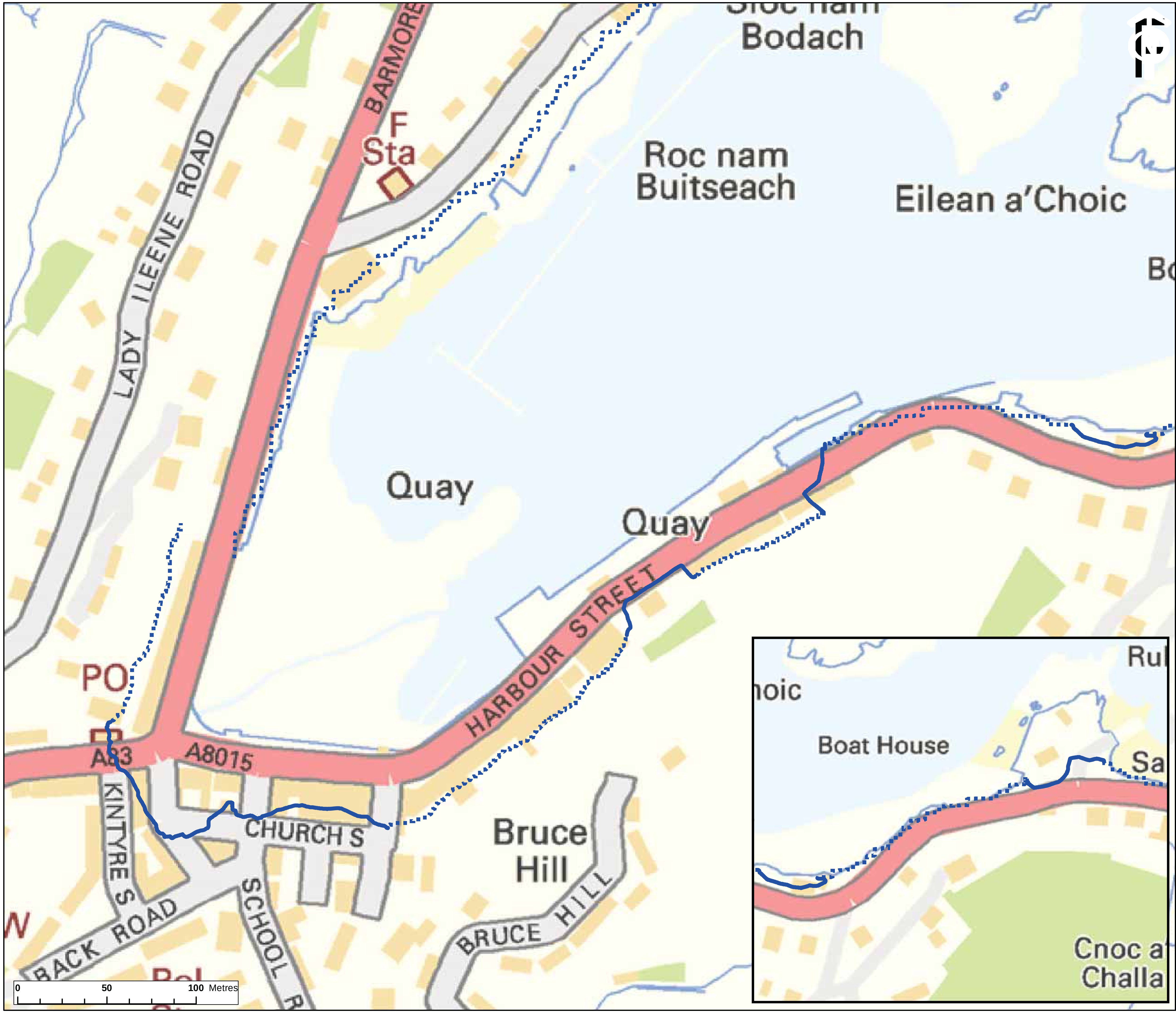
60578115

SHEET TITLE

Figure 12: 5% AEP +CC tidal flood extent

SHEET NUMBER

4 of 8



Project Management Initials: DH Designer: MH Checked: HH Approved: DH

Scale 1:2000 @ A3

AECOM

PROJECT

Tarbert Flood Study

CLIENT

Argyll & Bute Council

KEY:

2% AEP+CC Tidal Flood Extent

- Flood levels based on NEXTMap (dotted line)
- Flood levels based on survey (solid line)

PROJECT NUMBER

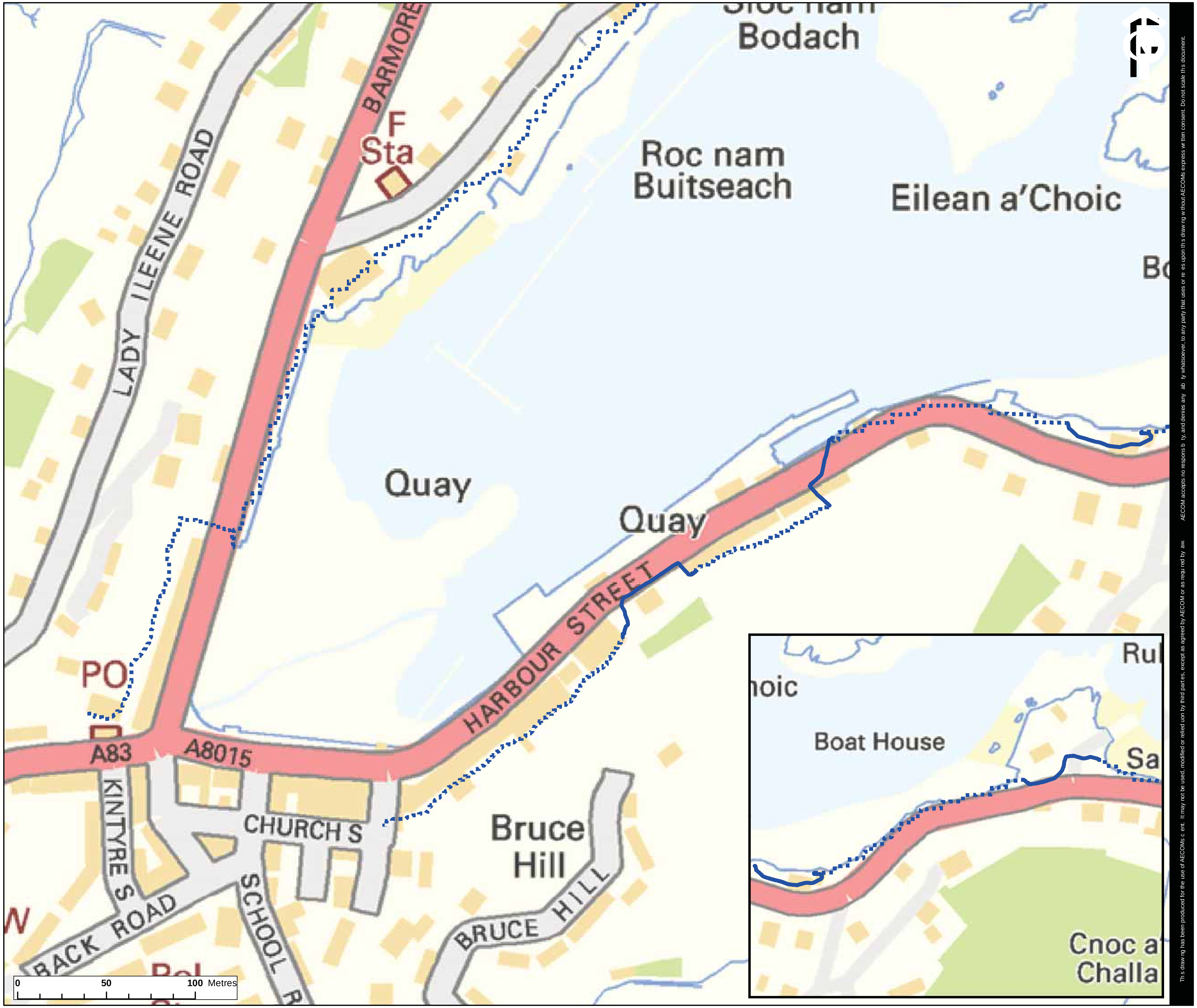
60578115

SHEET TITLE

Figure 13: 2% AEP +CC tidal flood extent

SHEET NUMBER

5 of 8



Project Management Initials: DH Designer: MH Checked: HH Approved: DH

Scale 1:2000 @ A3

AECOM

PROJECT

Tarbert Flood Study

CLIENT

Argyll & Bute Council

KEY:

1% AEP+CC Tidal Flood Extent

- Flood levels based on NEXTMap (dotted line)
- Flood levels based on survey (solid line)

PROJECT NUMBER

60578115

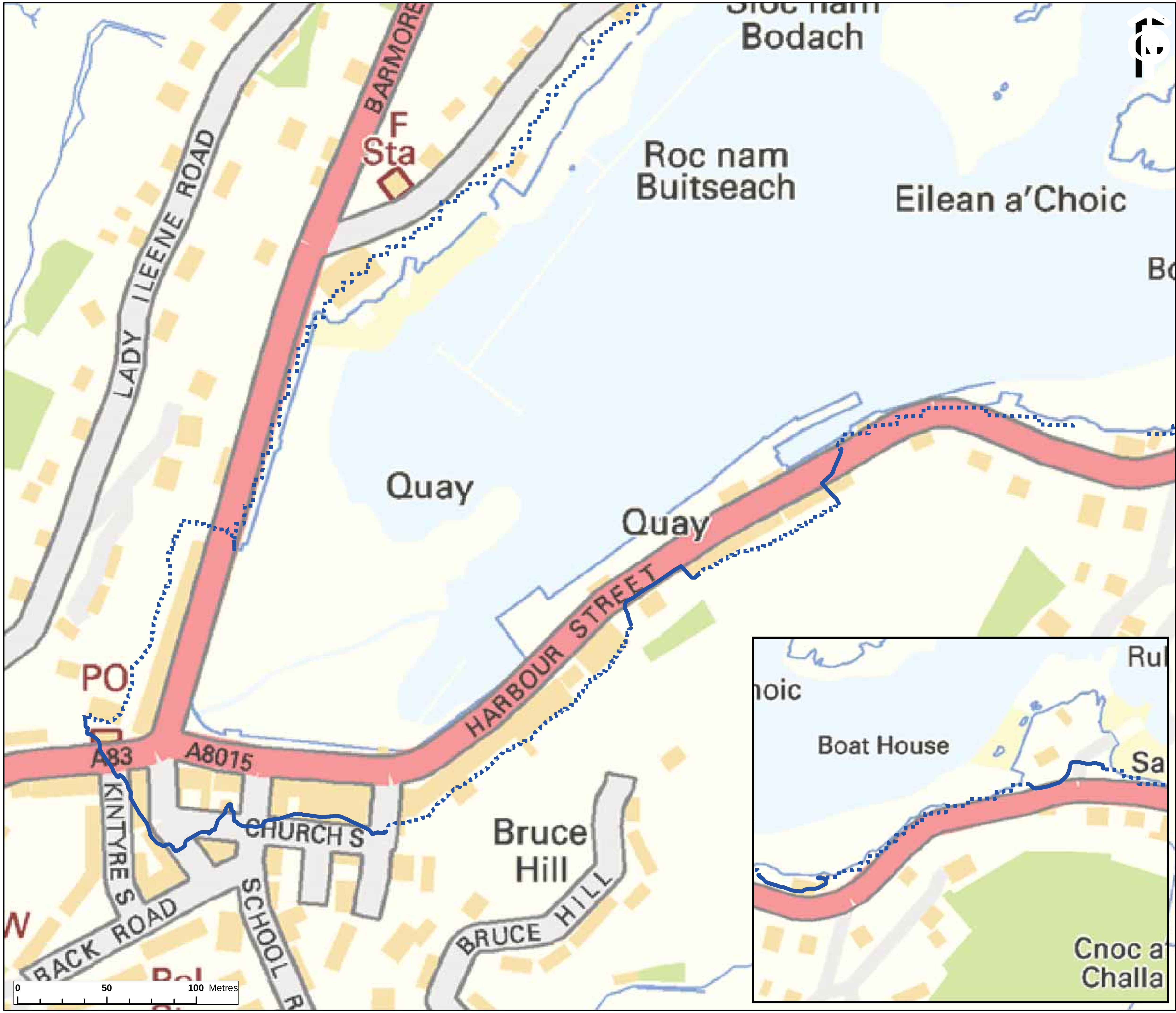
SHEET TITLE

Figure 14: 1% AEP +CC tidal flood extent

SHEET NUMBER

6 of 8

Project Management Initials: DH Designer: MH Checked: HH Approved: DH



Scale 1:2000 @ A3

AECOM

PROJECT

Tarbert Flood Study

CLIENT

Argyll & Bute Council

KEY:

0.5% AEP +CC Tidal Flood Extent

Flood levels based on NEXTMap

Flood levels based on survey

PROJECT NUMBER

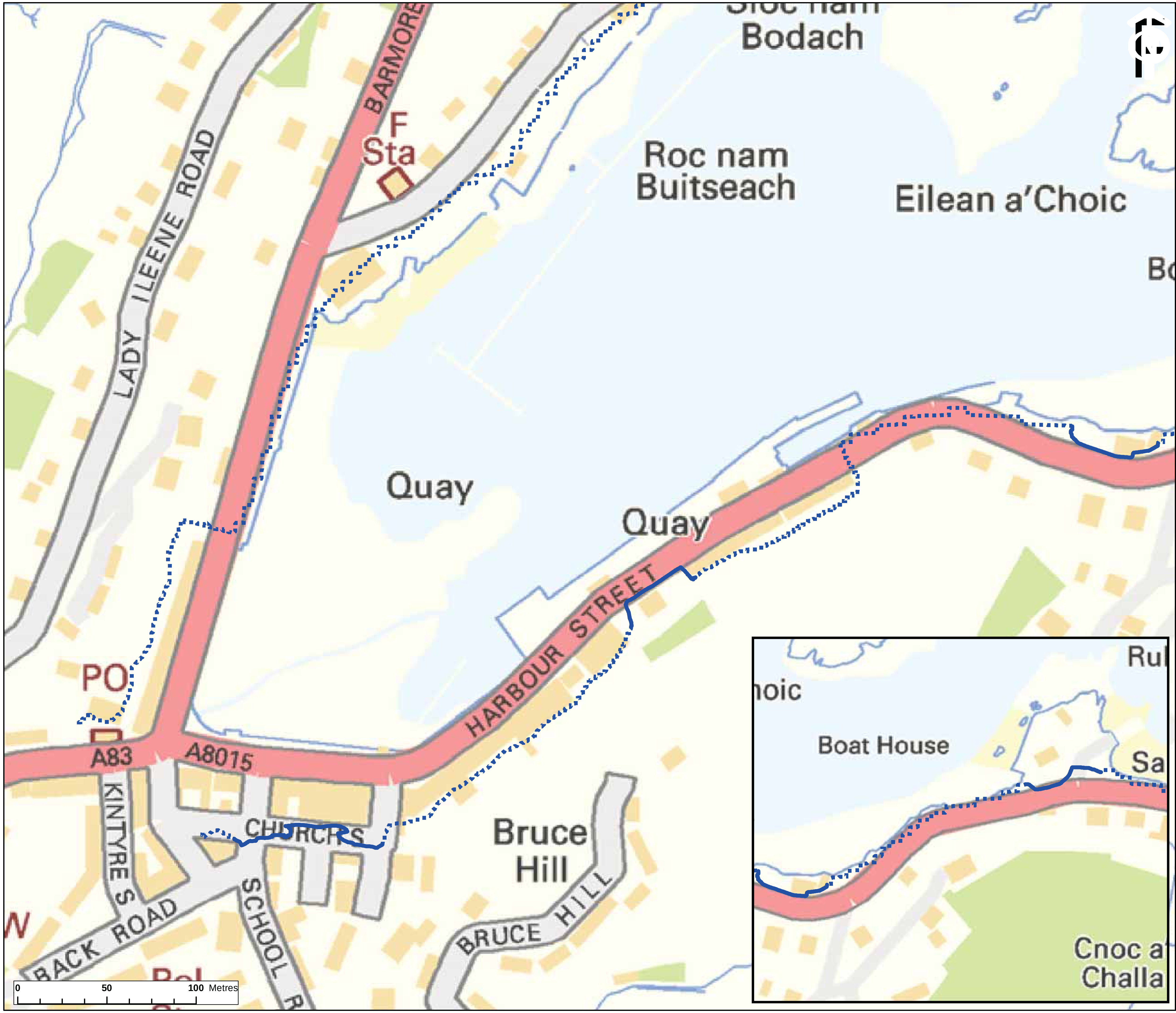
60578115

SHEET TITLE

Figure 15: 0.5% AEP +CC tidal flood extent

SHEET NUMBER

Project Management Initials: DH Designer: MH Checked: HH Approved: DH



Scale 1:2000 @ A3

AECOM

PROJECT

Tarbert Flood Study

CLIENT

Argyll & Bute COUNCIL

KEY:

0.1% AEP +CC Tidal Flood Extent

Flood levels based on NEXTMap

Flood levels based on survey

PROJECT NUMBER

60578115

SHEET TITLE

Figure 16: 0.1% AEP +CC tidal flood extent

SHEET NUMBER

8 of 8

aecom.com