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Isles of Scilly - Design for Off Islands Coastal Erosion Defence and Dune Management

Climate Adaptation Scheme - detailed design report - St Agnes

DKR6499-RT005-R02-00

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Project director	Dr Tim Pullen

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Andy Campbell	Aurora Orsini	Aurora Orsini

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1 Introduction

The Isles of Scilly have received funding from the European Regional Development Fund and the Environment Agency to complete a range of climate change adaptation works in the Isles of Scilly of St Agnes, Bryher and St Martins. These include interventions, such as coastal protection works, renourishment of existing beaches and dunes, upgrade or/and construction of new defences, aiming to reduce the impact of coastal erosion and wave overtopping exacerbated by future climate change scenarios.

The Isles of Scilly are one of the areas in Europe most vulnerable to the effects of climate change, sea level rise and consequent increased risk of inundation, overtopping and coastal erosion.

The council of the Isles of Scilly has commissioned HR Wallingford to undertake this work to evaluate the risk at the sites identified as being most vulnerable and develop designs for the coastal works proposed.

HR Wallingford has developed the preliminary design of the coastal works, which included identification and appraisal of the proposed alternative options for the sites identified for intervention, from the OBC (2020), the selection of the preferred option and the development of the designs for planning application.

The present report presents the development to detailed design stage of the preferred options for the three coastal sites located on the island of St Agnes, the southernmost inhabited of the Isles of Scilly.

The sites are located on the north west of the Island as shown in Figure 1.1:

- Site 48/49 - Pereglis Beach
- Site 50 - Porth Coose
- Site 51 - Porth Killier.

Figure 1.1: Location of St Agnes sites

2 Report Structure

This document is the RIBA Stage 4 detailed design report for the proposed climate adaptation coastal protection works on the three islands under the scope of this study.

The structure of the present report is the following:

- Section 3 presents the received data used for the design and design basis for the scheme and the list of the detailed design drawings, which are referred to in the following sections;
- Section 4 presents the design basis and key design assumptions;
- Section 5 presents the design of the defences;
- Section 6 presents the materials used and relevant considerations;
- Section 7 presents the ground investigation information;
- Section 8 presents the health, safety and welfare assessment for the design;
- Section 9 presents the Bill of Quantities (BoQ) and cost estimates for the proposals;
- Section 10 includes a summary of the constructability of the proposed designs;

- Section 10 lists the references used in this report.

The following information are presented in the Appendices:

- Appendix A – Design basis
- Appendix B – Design calculations
- Appendix C – Drawings
- Appendix D – CDM (2015) risk assessment
- Appendix E – Services layout
- Appendix F – Bills of Quantity
- Appendix G – Cost estimate
- Appendix H – Product information.

3 Input data

3.1 Reference documents

The designs and layouts for the island of St Agnes have been developed and presented through a series of HR Wallingford reports, initially during the inception stage studies following a site visit and subsequently during the preliminary design stage (RIBA Stage 3). Relevant HR Wallingford reports are listed below. In addition, listed below are all the relevant references and data provided to HR Wallingford and used in the development of the detailed design.

Table 3.1: Input data and reference documents

Reference Number	Document Title	Published	Provided by
1	Scope of Work- RFP- Annex B_Brief for Off-Island Coastal Defence Works_Final	2021	Council of the Isles of Scilly
2	Adaptive Scillies – Natural Dune Restoration & Flood Resilience – FCERM Outline Business Case	JBA, Arcadis, Council of the Isles of Scilly, April 2020	Council of the Isles of Scilly
3	Isles of Scilly – Coastal Flood Modelling – Final Main Report	JBA, Environment Agency, February 2019(a)	Council of the Isles of Scilly
4	Isles of Scilly – Coastal Flood Modelling- Model development Report	JBA, Environment Agency, February 2019(b)	Council of the Isles of Scilly
5	DKR6499_RT01-Site Visit Notes	HR Wallingford 2021	HR Wallingford
6	SMP2	2010	Council of the Isles of Scilly
7	SMP2 interim review	2016	Council of the Isles of Scilly
8	DKR6499-RT002-R03-00 At Agnes Preliminary Design report	HR Wallingford 2021	HR Wallingford
9	LiDAR point cloud data	2007, 2014, 2020	National LiDAR Programme
10	JBA wave datasets	JBA, Environment Agency, February 2019	Council of the Isles of Scilly

Reference Number	Document Title	Published	Provided by
11	JBA outputs (JBA_Overtopping_Schemitisation_QA_Sheet_2016s4861 Bryher 1 to 11_v2, (JBA_Overtopping_Schemitisation_QA_Sheet_2016s4861 St Agnes 48 to 51_v2, (JBA_Overtopping_Schemitisation_QA_Sheet_2016s4861 St Martins 26 to 29)	JBA, Environment Agency, February 2016	Council of the Isles of Scilly
12	Isles of Scilly 2021 Environmental Agency asset inspection	2021 (DRAFT)	Plymouth Coastal Observatory

3.2 Data assumptions

The main assumptions made during these design studies are summarised below:

- The Port Killier sea wall appear to be structurally sound, from a visual inspection, and the addition of a revetment does not impact the foundations. The Plymouth Coastal Observatory (PCO) Asset inspection rated the wall as in Good condition, refer to Section 5.1 for description of the condition rating.
- Armourflex protected slope at Porth Coose is stable. The PCO asset inspection rated the whole defence as Poor, but it is assumed that this is the general level of protection and the armourflex slope is in reasonable condition.
- LiDAR data is a true representation of absolute ground levels to Ordnance Datum.
- Local cobbles and rock can be sourced in sufficient quantities to supplement the armourstone required for the works.
- Excavated embankment/Ridge material is uncontaminated and suitable for reuse without any remediation.

3.3 Site design data

Site design data has been provided by others and is listed in Table 3.1 and the key data are summarised below. No new site data was collected for these design works:

- Design waves (Ref 10) – Data sets for each site were provided with H_s, T_p and water level ranked in order of severity of overtopping event. These have been taken as the waves at the toe of the structures as assumed in the JBA assessment. The elevations for the toes have been extracted from the JBA spreadsheets provided.
- LiDAR (Ref. 9) – 2007, 2014, 2018 and 2020 data sets were compared to check correlation. There was good correlation between the data sets at the sample locations checked and the 2020 data set has been taken as the baseline levels for this design.

It is noted that there was a Ordnance Datum shift in 2015, but the LiDAR data for St Agnes showed good correlation between the data sets at the locations checked, so it is assumed that the earlier data had been corrected.

3.4 HOLDS

Several HOLD items were included in the Preliminary Design report (Ref 8) and several of these remain as HOLD items to be confirmed prior to start of construction.

- Detailed topographic survey, including ground truthing of LiDAR data. This is needed to confirm extent of works and quantities required. Due to this, typical sections rather than full package of detailed section drawings have been produced as the levels and hence final extent of the proposed works are to be confirmed.
- Ground investigation information.

As-built drawings for Port Killier sea wall and Porth Coose Armourflex slope are not expected to be available, but it is assumed that the structures and foundations can accommodate the proposed works as no excavation is proposed at either site.

3.5 Drawing list

This report should be read in parallel with the drawings in Table 3.2 below, which illustrate the detailed engineering design of the coastal works at the identified locations around the island.

Drawings are provided in Appendix C.

Table 3.2: St. Agnes drawings

Drawing number	Title
DKR6499/D000/101	Project Location Map
DKR6499/D000/102	General Notes
DKR6499/D000/103	St. Agnes LIDAR Survey Layout
DKR6499/D110/110	General Arrangement St Agnes- Periglis -48 & 49
DKR6499/D110/111	General Arrangement St Agnes- Porth Coose- 50
DKR6499/D110/112	General Arrangement St Agnes- Porth Killier - 51
DKR6499/D110/310	St. Agnes - Periglis -48&48- Ridge protection - Typical Cross section
DKR6499/D110/320	St. Agnes - Porth Coose -50- Ridge protection - Typical Cross section
DKR6499/D110/330	St. Agnes - Port Killier -51- Rock toe protection - Typical Cross section

4 Design Basis

4.1 General

The design basis for the works are presented in the Preliminary Design Report, DKR6499-RT002, and have been reproduced here in Appendix A. The waves at the toe of the proposed designs at each site have been assessed based on data provided by JBA (Ref. 4) and are included as Table 4.1.

Design waves and combined extreme water levels for the 150 year return period flood event have been estimated from the methodology outlined in the preliminary design report (Ref.8). These include consideration of 25 year sea level rise for the 25 year design life required. The wave and water level combinations provide the return period for the overtopping assessment. For stability assessments the extreme water levels have been considered with a depth limited wave as described in Section 4.3.1.

The significant wave height provided by JBA is referred to as Hs. For the purposes of design Hmo, the spectral significant wave height, is assumed to be equal to Hs.

Table 4.1: Design waves and water levels

Location	Hs (m)	Tp (s)	Water Level
48	1.7	7.7	4.1
49	1.6	7.5	3.9
50	1.5	7.5	4.0
51	1.2	9.9	3.9

The location of the beach toes, as defined by JBA, where the waves have been extracted are illustrated in Figure 4.1.

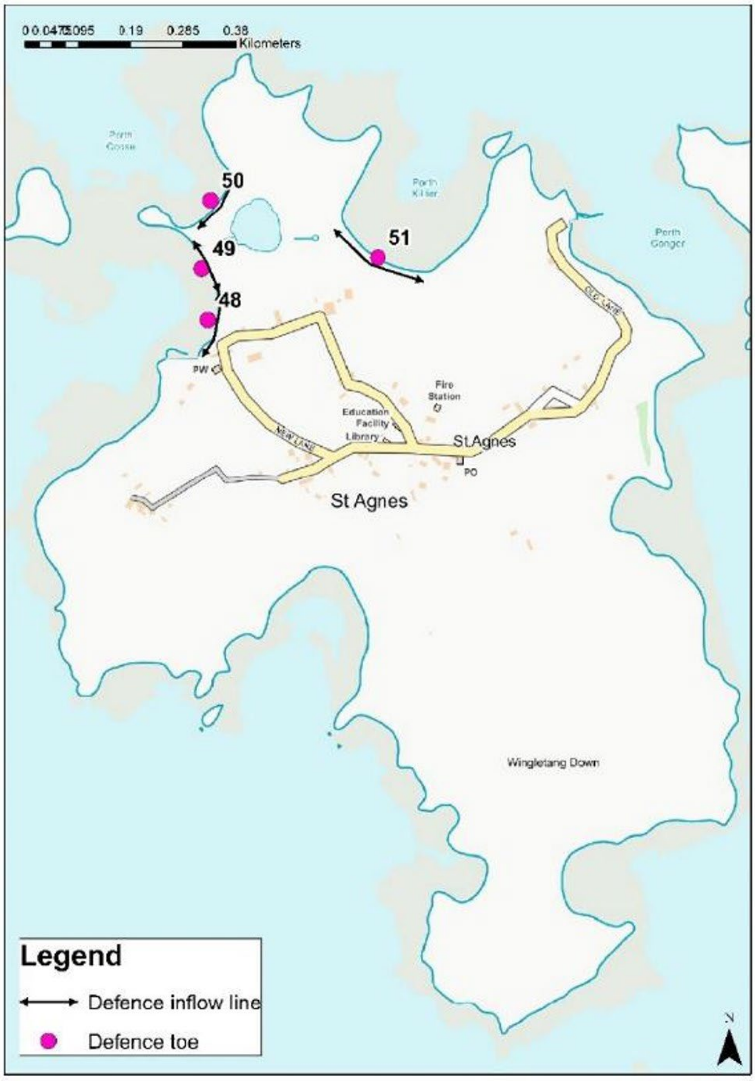

Figure 4.1: Location of wave extraction points

Source: Council of Isles of Scilly (OBC, 2020)

4.2 Codes and Standards

The design of the coastal works has been carried out in accordance with the codes, standards and guidance documents as listed below:

- British Standards, BS6349 suite, Maritime Structures;
- BS EN 1991-1-1:2002. Eurocode 1: Actions on structures - Part 1-1: General actions. BSI;
- BS EN 1997-1:2004 Eurocode 7: Geotechnical design - Part 1: General rules. BSI;
- BS EN 13383 Parts 1 and 2 European Armourstone Specification;
- BS6349-1-2:2016: Maritime Works General. Code of Practice for Assessment of Actions.

In addition to the standards above, the following international guides for good practice have also been adopted:

- CIRIA; CUR; CETMEF, (2007). The Rock Manual. The Use of Rock in Hydraulic Engineering; (2nd Edition), London;

- CIRIA, (2010). Beach management manual. (2nd Edition), London. PUB C685;
- Geosystems Design Rules and Applications, CRC Press (2013);
- EurOtop II (2016) Wave overtopping of sea defences and related structures. Assessment Manual. www.overtopping-manual.com.

4.3 Design assumptions

4.3.1 Waves

The RFP did not require wave modelling and instructed the tenderers to extract the required input data from "The Isles of Scilly Coastal Flood Modelling" (JBA for the EA, 2019).

Upon request, EA provided a first set of data, which was considered insufficient. A further more extensive set of data was subsequently provided. This was reviewed and design wave conditions were extracted.

As instructed by the Client, HR Wallingford have utilised the data provided from the above mentioned study. HR Wallingford has duly reviewed the information provided and confirms that they appear reasonable. However, without access to the raw data, and repeating the full analysis, we note that HR Wallingford are unable to take responsibility for any existing data quality and quantity provided by others. The following text is repeated in Appendix A, but it is important that the basis of the design waves is understood.

The data supplied to HR Wallingford from the JBA modelling study consists of a sub-set of 10,000 years' of modelled extreme conditions, which has been set-up for extreme overtopping conditions. This sub-set of data contains the combinations of wave and sea level parameters that give the largest overtopping rates, although not necessarily the largest wave heights. However, the method adopted to generate these data was developed by HR Wallingford (see for example Gouldby et. Al., 2017), and it is considered that a reliable estimate of the extreme wave heights at the site(s) could be determined from the data provided.

Two sets of data were provided:

- Defended
- Defended NPPF 2117.

Where NPFF stands for "National Planning Policy Framework".

It is assumed that:

- "Defended" is the current day (2017) estimate of wave heights and overtopping rates with existing sea defences.
- "Defended NPPF 2117" is the 2117 estimate of wave heights and overtopping rates which includes a 10% increase in offshore wind speed and wave heights, though no adjustment seems to be made to the wave period to maintain the input wave steepness. Sea level rise from 2017 to 2117 is given as 1.037m. This seems to be consistent with guidance given for the higher central allowance for sea level rise as currently given in the following link:

https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#sea-level-allowances

The information for the relevant sites at St Agnes were extracted from these datasets. As part of the present study, a SLR allowance has been included in the water level to update the data to present day water levels (@2021) and to calculate water levels in 2046 (25 years life).

It is assumed that the waves are provided at the toe of the relative structures, as set in JBA's Report (JBA for the EA, 2019), for each location.

As part of this detailed design, the waves were then transformed to the toe of the designed structures and overtopping calculations were performed with this data.

The assessment of hydraulic stability requires the 1 in 150 year extreme wave conditions, which are not available for this project. The JBA waves are 1 in 150 year overtopping wave and water level combinations. Therefore waves at the toe of the structures have been calculated using a combined approach. Depth limited wave conditions for the 1 in 150 year return period were propagated to the toe of the structures, including 25 years of allowance for sea level rise.

Then the results were compared with the JBA waves at the toe of the structure. The comparison highlighted that the depth limited waves (calculated from the 150 years extreme water level) were mostly lower. Therefore the transformed JBA waves were used for conservatism.

A 12 hour storm has been considered for the design of the rock armour proposed, this is representative of the storms experienced in the Isles of Scilly.

It should be noted that the design waves do not include the long period component (bimodal waves) that was most likely one of the main factors that caused much of the flooding during the 2014 storms. Therefore some engineering judgement has been applied with design decisions; for example, increasing the armour size.

4.3.2 Ground conditions

No previous ground investigation is currently available at or near the location of the proposed works. A site visit was recently carried out by HR Wallingford. Based on the findings of the site visit, the beach at the sites of the proposed works generally comprised of sand and cobbles from local igneous rock. Evidence of boulders placed in previous attempts to stabilise the area and prevent erosion has also been found.

The findings of the site visit suggest that the ground conditions are suitable to accommodate the proposed coastal protection works. However, due to the lack of geotechnical information, no assessment was carried out to verify this assumption. The suitability of the ground will need to be confirmed prior to construction.

The text in this document refers often to the erosion of “ram” along the coast of the Isles of Scilly. It is therefore considered helpful to give a brief description of the meaning of “ram” in the context of the Isles of Scilly.

> *During the last Ice Age a large glacier flowed southwards down the Irish Sea Basin. Some authors indicate that this reached as far as the northern extremities of Bryher, Tresco and St Martin’s.*
>
> *The northern glacial deposits contain flint eroded from the floor of the Irish sea. (…) The moraines at the north end of St Martins (Pernagie bar and White Island bar) provide visible evidence of the southern tip of this glacier. South of this ice limit, cold tundra conditions resulted in the accumulation of orange-brown deposits known locally as “ram”.*

The text above has been extracted from: http://naturalhistoryofscilly.info.websitebuilder.prositehosting.co.uk/geology.

The “ram” is also described by others as rockfall and slope deposit, two lithostratigraphic units of different ages. Some authors also call this as “Porthloo Breccia” (Brian John, 2018, Evidence of extensive ice cover on the Isles of Scilly, Quaternary Newsletter, N.146).

The above is intended as background information and is not to be relied upon. The ground conditions will need to be verified with a site specific ground investigation prior to construction.

5 Detailed Design

Note - all design extents, levels and details of transitions to existing levels are to be confirmed with detailed site surveys prior to construction works.

5.1 Description of the coastal protection works

5.1.1 Site 48/49 Periglis Beach

To protect the rear of the beach from erosion, and to reduce the risk of overtopping, a 130m long stretch of beach (Chainage 170 to 300), identified as the section most at risk, will be partially excavated at the top of the beach on the seaward side of the existing ridge. Geobags will replace part of the ridge's core to provide an unerodable barrier to waves and overtopping. These bags will be wrapped in geotextile and covered with the excavated material. On the crest a geomat will be laid, as shown in Figure 5.2, to stabilise the rear fill and encourage revegetation of the slope. At each end of the bund the excavation is to be graded to existing levels.

This beach is classed as a defence asset by the Environment Agency. In the September 2021 inspection of the defence assets, undertaken by the Plymouth Coastal Observatory (PCO), has classified the condition of the defence as 'fair', which means that defects may affect the performance of the asset (see Figure 5.1 for the definition of condition grade in the EA's Condition Assessment Manual). The proposed works aim to enhance the performance of the asset and the level of protection here, noting that the beach has been identified by the previous studies and the residents as a priority for coastal defence improvements.

Grade	Rating	Description
1	Very Good	Cosmetic defects that will have no effect on performance
2	Good	Minor defects that will not reduce the overall performance of the asset
3	Fair	Defects that could reduce the performance of the asset
4	Poor	Defects that would significantly reduce the performance of the asset
5	Very Poor	Severe defects resulting in complete performance failure

Figure 5.1: Definition of condition grade in the EA's Condition Assessment Manual

Source: Environment Agency (2014), Asset performance tools – asset inspection guidance, Report SC11008/R2

The general arrangement of the works are shown in drawing DKR6499/D110/110 and the typical cross section for the proposed works is shown in drawing DKR6499/D110/310. Both drawings are included in Appendix C.

The transitions at either end of the works are to slope to existing levels at a maximum 1 in 3 gradient. The geobags have been checked and confirmed as stable under wave action in case they are exposed, though for a short period of time. It is important that if the bags are exposed during storm events they need to be covered as soon as possible, within 4 weeks to protect the fabric from UV degradation and any further direct wave attack.

The excavated slope is shown is indicative and a shallower slope may be required for construction.

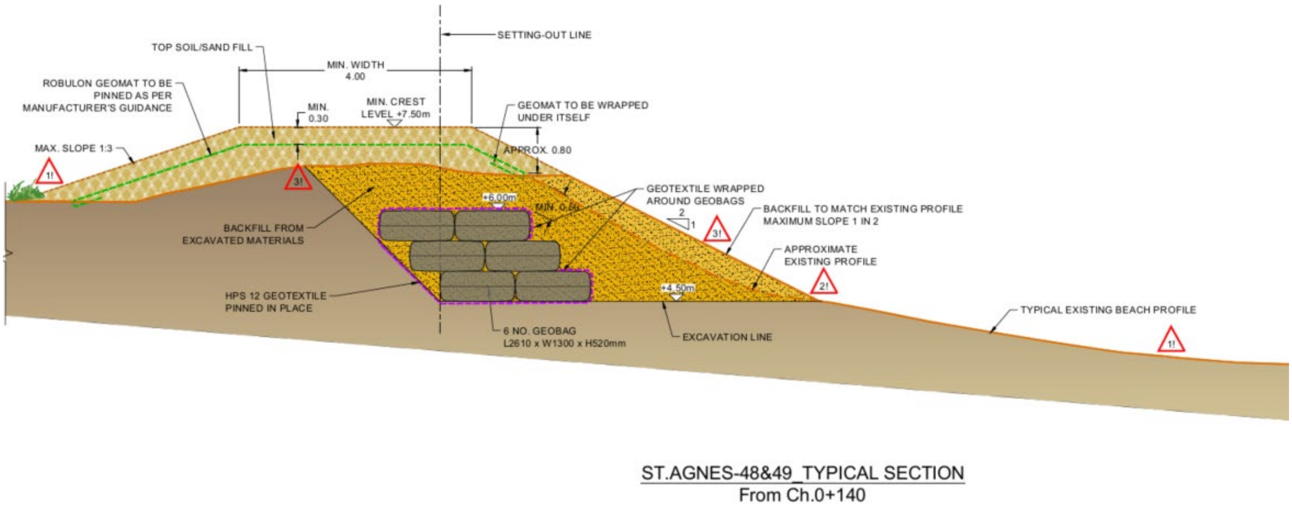

Figure 5.2: Site 48/49- Typical Section

5.1.2 Site 50 – Porth Coose

Porth Coose has previously had Armourflex concrete mattress slope protection installed to protect against erosion, but further protection against overtopping is now required. The full extent of the main beach from chainage 0 - 140m is to retain the Armourflex slope and the crest is to be protected with the placement of rock bags with the rear filled with to grade to existing levels. The bags will be placed on a prepared surface at the top of the armourflex slopes and fill material is to be placed behind to tie in the top of the bags to the ground behind. A geomat will be placed to stabilise this slope and encourage establishment of vegetation. Sand fill will also be placed on top of the bags to cover and encourage plant growth.

The condition of the beach defence has been described as 'poor' in the September 2021 asset inspection undertaken by the PCO. Full details of the inspection are not yet available as to what specifically determined the classification of this asset as 'poor', which from the definitions above, would suggest that the defects are such that they would significantly reduce the performance of the asset. Though it may refer to the general level of protection rather than just the condition of the armourflex matting. A detailed condition survey was not undertaken as part of this design, but, as identified in a visual inspection carried out during the walkover survey, overall the slope appeared in fair condition; although along some sections some of the crest mesh had been exposed. Therefore, as part of the surface preparation for the placement of the rock bags, some localised repair/preparation works are required to bury the armourflex crest detail ahead of placing.

The general arrangement of the works are shown in drawing DKR6499/D110/111, and the typical cross section for the proposed works is shown in drawing DKR6499/D110/320. Both drawings are included in Appendix C. The transitions at either end of the works are to transition to existing levels with placement of a single rock bag and slope to existing levels at a maximum 1 in 3 gradient. slopes.

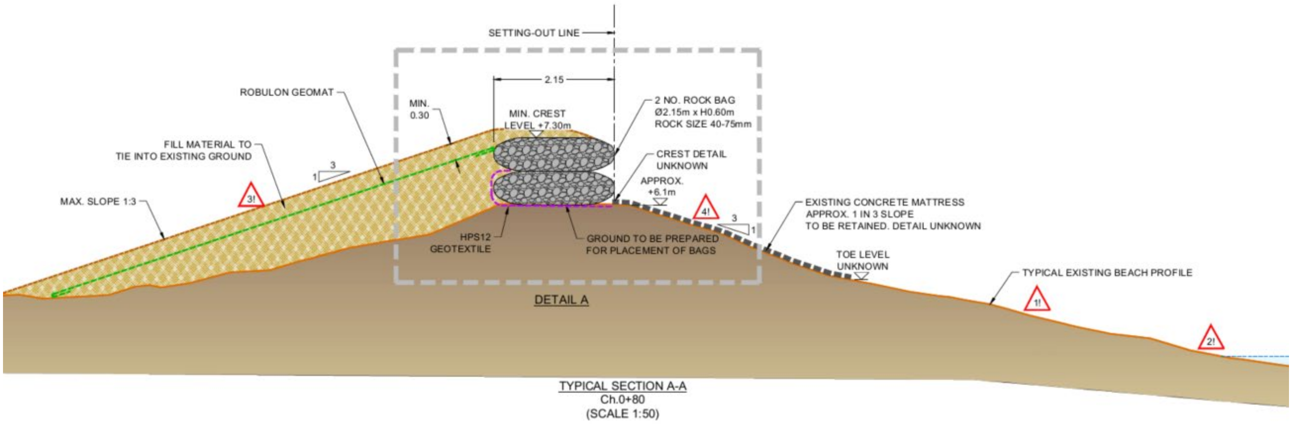

Figure 5.3: Site 50 – Typical section

5.1.3 Site 51 – Porth Killier

The seawall at this site is experiencing toe erosion and a recharge of rock to form a rock toe is proposed to protect the toe of the seawall that has become exposed. It is proposed to place the rock along the most exposed section at the east of the bay, from Chainages 295 to 390. The largest rocks in the selected grading are to be placed at the seaward end of the toe to increase its stability. In addition to the rock armour, the material removed as part of preparation for placement of rock from the beach is to be placed in front of the new rock toe, see Figure 5.4. This material is likely to be mobile during large storms and will reshape but it will provide an initial scour protection and it is considered to be a good use of the available local cobbles and rocks.

The seawall is in reasonable condition but in some locations damage to the footings can be seen where they have been exposed to wave and stone action, see Photograph 5.1. Although the placement of the rock toe will cover this preventing further lowering, in some locations where damage is more severe local repairs may be required prior to placing the rocks. A detailed condition survey was not undertaken as part of the design so this is not included as a quantity included the BoQ, but it is recommended that the Contractor includes a price for repairs in their offer.

Photograph 5.1: Porth Killier exposed sea wall footing

At the eastern end of the beach, beyond the wall, there is also a short section of the beach where the ram material is being more severely eroded than the surrounding area and this is to be filled with rock and tied in to the surrounds.

The Porth Killier seawall was assigned as 'fair' by the 2021 PCO asset inspections, whereas the pocket beach with the exposed ram was classed as 'poor'. The proposed works will improve the performance of both defences and increase the level of protection to the standard required.

The general arrangement of the works are shown in drawing DKR6499/D110/112 and the typical cross section for the proposed works is shown in drawing DKR6499/D110/330. Both drawings are included in Appendix C. The transitions at either end of the works are to slope to existing levels at a maximum 1 in 2 gradient.

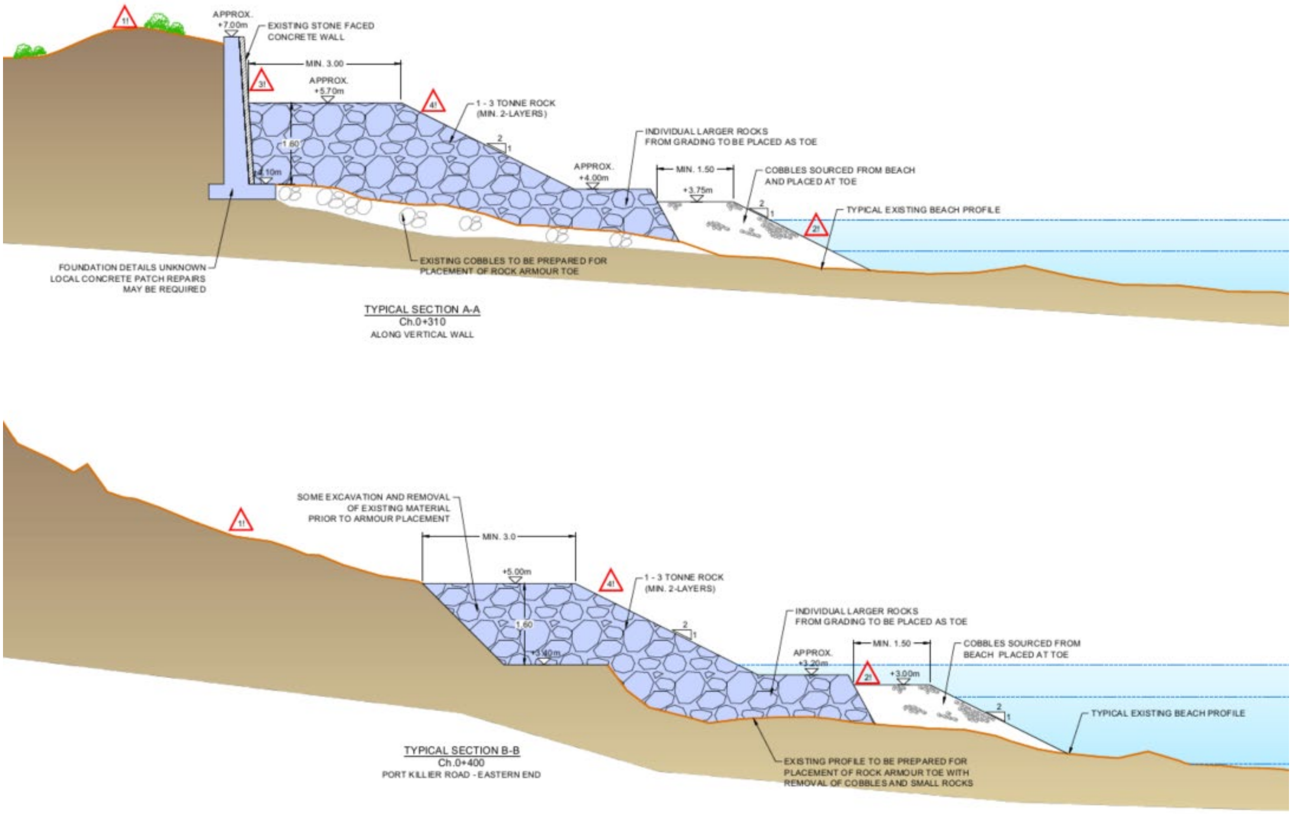

Figure 5.4: Porth Killier – Typical sections

5.2 Hydraulic Stability

5.2.1 Overtopping Assessment - Methodology (all sites)

JBA(2019) report provided recommendations on the required increase in crest elevation at the project locations to mitigate flood risk. These recommendations have been taken into account in the preliminary design. Since the JBA (2019) assessment gave recommendations on an average increase in elevation, further overtopping calculations were required to make sure that the resulting crest elevations met the design criteria.

The design section for each frontage has been schematised and a desk assessment has been carried out at each location and wave overtopping has been calculated by using the wave overtopping formulae presented in the EurOtop II Manual, at key cross sections for each frontage.

Appropriate roughness factors (γ_f) have been applied for the different proposed schemes as recommended in EurOtop II:

- 0.6 was adopted for rock armour considering rock with an impermeable core;
- 0.8 was adopted for vegetated slopes with Geobag cores and concrete mattress slope protection.

As discussed in the design basis; see Appendix A of this report; criteria for overtopping set a limit for mean overtopping of q = 5 l/m/s for the 150 year storm as ultimate limit state to minimize damage and avoid failure of the banks and of q = 1 l/m/s for the 1 year storm as serviceability limit state, considering that pedestrian access behind the beach is likely, even though discouraged, to minimize erosion of the crests.

Where Geobags are used, the crest levels are measured at the crest of the bag as if the fill on top had been eroded during the storm.

Table 5.1: St Agnes crest height design

Location	Required crest level (mOD)	Overtopping 150 yr return period (l/m/s)	Overtopping 1 yr return period (l/m/s)
Site 48/49 – Periglis Beach	+7.5	0.8	<0.01
Site 50 – Port Coose	+7.30	3.1	<0.01
Site 51 – Port Killier	+7.00	3.8	<0.01

The crest elevation of the section at Port Killier (Type 3) experiencing ram erosion has been assessed considering:

- Presence of rocky foreshore;
- Grass covering rear side.

5.2.2 Primary armour (Site 51)

Design of primary rock armour protection has been undertaken based on the Van der Meer equations, considering shallow foreshores, as recommended in the Rock Manual (CIRA, CUR, CETMEF 2007).

Waves and water level conditions for the 1 in 150 year events were used for the rock size calculation, considering a 25 year life, as discussed in Section 4.3.1.

In addition to the design parameters listed in Table 5.2, a nominal permeability factor P = 0.1 for the revetment has been adopted in the design in accordance with (CIRIA, CUR, CETMEF, 2007). No filter layer has been included.

Table 5.2: Rock armour design parameters

Parameter	Symbol	Value
H_s at the toe of the structure	H_s	1.23 & 1.3
$H_{2\%}$ at the toe of the structure	$H_{2\%}$	1.8
T_p	T_p	9.9
Water depth at the toe	d	1.48
Density of sea water	ρ_s	1,030 kg/m^3
Density of rock*	ρ_r	2,600 kg/m^3
Relative eroded area	S_d	2
N_o of waves in 12-hour storm	N_z	(12 x 3600) / T_m
N_o of rocks comprising layer	-	2
Slope of structure		1 in 2
Notional permeability	P	0.1

* *The rock density used was agreed with the Client, given the availability of material*

Standard gradings conforming to BS EN 13383 have been selected based on the M_{50} identified by these calculations.

Van der Meer's prediction method is usually based on use of H_s, but for shallow water (depth-limited) conditions, Van Gent el al. (2004) recommended modifications to the formulae that use $H_{2\%}$ for depth-limited foreshores:

$$\frac{H_{2\%}}{\Delta D_{n50}} = 8.4 \cdot P^{0.18} \cdot \left(\frac{S_d}{\sqrt{N}}\right)^{0.2} \cdot \xi_{s-1,0}^{-0.5}$$ for plunging waves ($\xi_m < \xi_{cr}$)

$$\frac{H_{2\%}}{\Delta D_{n50}} = 1.3 \cdot P^{-0.13} \cdot \left(\frac{S_d}{\sqrt{N}}\right)^{0.2} \cdot \sqrt{\cot\alpha} \cdot \xi_{s-1,0}^{P}$$ for surging waves ($\xi_m > \xi_{cr}$)

The input parameters for both formulae are as follows:

H_s	=	Significant wave height at the toe of the structure, [m]
$H_{2\%}$	=	Calculated using Battjes & Groenendijk method (2000), [m]
T_m	=	Mean wave period at the toe of the structure, [s]
$T_{m-1.0}$	=	(Spectral) mean energy wave period at the toe of the structure, [s]
Δ	=	Relative buoyant density, $(\rho_r / \rho_w) - 1$
ρ_r	=	Rock armour density, [t/m^3]
ρ_w	=	Water density, [t/m^3]
D_{n50}	=	Nominal diameter of armour unit [m]
α	=	Slope angle
P	=	Notional permeability of the structure
N	=	Number of incident waves at the toe
S_d	=	Damage parameter
ξ_m	=	Surf similarity parameter using mean wave period T_m [s]:

$$\xi_m = \frac{\tan\alpha}{\sqrt{2\pi H_s / gT_m^2}}$$

$\xi_{m-1,0}$ = Surf similarity parameter using (spectral) mean energy wave period $T_{m-1,0}$ [s]:

$$\xi_{m-1,0} = \frac{\tan\alpha}{\sqrt{2\pi H_s / gT_{m-1,0}^2}}$$

ξ_{cr} = Critical surf similarity parameter:

$$\xi_{cr} = \left(\frac{8.4}{1.3} \cdot P^{0.31} \cdot \sqrt{\tan\alpha}\right)^{\frac{1}{P+0.5}}$$

Based on the design parameters, the resulting M_{50} for the primary armour at both the typical sections of the seawall and where there is erosion of the Ram are within the standard grading of 1 – 3 tonne. This is in line with the standard rock gradings used elsewhere on the Islands.

The armour would be rough, angular rock and the quality of rock required will be specified in accordance with the European Armourstone Specification BS EN 13383 Parts 1 and 2.

Given the resulting M_{50}, the selected primary armour is standard grading 1 to 3 tonne graded rock, with a slope of 1V:2H.

Size distribution and specification of limit masses of a standard grading are given in Table 5.3 with the following definitions:

ELL (Extreme Lower Limit) – the mass below which no more than 5 per cent passing by mass is permitted.

NLL (Nominal Lower Limit) – the mass below which no more than 10 per cent passing by mass is permitted.

NUL (Nominal Upper Limit) – the mass below which no less than 70 per cent passing by mass is permitted.

EUL (Extreme Upper Limit) – the mass below which no less than 97 per cent passing by mass is permitted.

Table 5.3: Size distribution for 1-3t (standard grading)

ELL (kg)	NLL (kg)	NUL (kg)	EUL (kg)
700	1000	3000	4500

Source: *HR Wallingford*

A thickness coefficient (k_t) value of 0.9 was adopted giving a layer thickness of 1.6 m for 1 - 3 tonne rock armour.

5.2.3 Rock bags (Site 50)

The hydraulic stability of the proposed rock bags at Site 50, Porth Coose, has been assessed through consideration of various methodologies, and has used a combination of methods available to assess the wave loading on crest structures. Since no *ad hoc* method is available to calculate the hydraulic stability of this sort of design solution, engineering judgement has been used to draw conclusions from the comparison of the results. This approach considered the Goda (2010) formula for pressures on caissons, the conservative BS6349 Part 7 method for loading on crown structures, loading formulae on crown walls, as described in CIRIA(C683) and finally, the formula selected for this case, Camfield (1991) for structures located landwards of the shoreline.

Using formulae derived for crown walls and caissons is considered to give very conservative results, and physical model tests have confirmed this. Experiments, such as Camfield (1991) have indicated that Goda (1970) may give an overestimation of the loading by up to 30%.

Stability calculations were made ignoring the stabilising contribution of the fill behind. Results showed that the bags have been confirmed to be stable for both sliding and overturning considering a partial factor approach.

The stability of the bags is therefore confirmed, but it should be noted that some movement of rocks within the bags is to be expected in severe storm events.

Suggested supplier information is included as Appendix H.2. Rock for the bags to be sourced locally or imported and graded as per the manufacturer requirements. The supplier has advised that standard 40-70mm rock is most appropriate size for this solution.

5.2.4 Geobags (sites 48 & 49)

The “Geobags made core” at Sites 48/49 Periglis Beach are to provide a fixed crest level so that, if the top layer of the ridge, covering the Geobags, is eroded in a storm, they will remain in place and will continue to provide protection to the area behind from overtopping discharges.

The crest levels of the Geobags have been selected based on the required crest identified in the overtopping assessment, see Section 5.2.1 above.

The bags have been sized based on availability of products and stability of geotextile sand containers/structures and consideration of constructability. The bags are to be covered by a minimum 500mm of sand fill and as noted in Section 5.1.1 if the bags become exposed, they should be covered within 4 weeks to prevent deterioration from UV and the environment.

The engineering design was based on “Design rules and applications” by Bezuijen and Vastenburg (2013) and the work carried out by Oumeraci et al (2003, 2010) and Recio (2007).

The requirements for the Geobags is summarised below with calculations provided in Appendix B. Geobag material GB600MS form Tencate has been selected with the bag sizes to meet the minimum requriements of the size below. The supplier information and specification sheet is included in Appendix H.2.

Table 5.4: Geobag key parameters and sizes

Location	Permeability l/m²/s	Minimum bag dimensions
St Agnes – 48 & 49	20	2.6 x 1.3 x 0.5

5.2.5 Geomatting (Site 48 & 49)

To help stabilise the crest and rear of the ridge (raised embankments) geomatting is proposed. An example product, Robulon by Tencate has been identified with details contained in Appendix H. A minimum of 300mm cover is to be placed over the geomat to protect from pedestrian traffic. The general properties for geotextiles and geomatting are included in the project specifications.

5.2.6 Geotextile

The geotextile to be included at sites 48 & 49 and site 50 to act as a barrier between the rock bags or Geobags and fill material is to ensure permeability to allow water to pass through but have pore sizes sufficient to prevent clogging with fill material or prevent migration of material through the fabric. The geotextiles must also be durable enough to survive handling and installation and withstand UV exposure.

Assuming a mix of sand and shingles, the following characteristics have been used to select a geotextile:

- Particle size D_{50} = 2mm
- Permeability $k_s = 1 \times 10^{-3}$ m/s.

Using design charts from Geofabrics, a HPS geotextile HPS 12 has been selected based on its permeability. Checks on the durability and retention have confirmed this product: see Appendix H for the product details: but similar approved products from other suppliers can also be used. Further details on geotextile properties are included in the project specifications.

6 Materials

The material and general workmanship requirements are included in the design basis, Section A.8, and the project specifications.

7 Ground Investigation

A geotechnical survey scope of work and specification has been prepared in support of the design (DKR6499-RT008). It is important that this is undertaken ahead of construction to confirm the ground conditions and assumptions for material excavation and reuse as well as for the placement of additional sand and rock.

The scope of work for all three islands is provided in this document.

8 Health and Safety

It is HR Wallingford's intent in all design works to identify potential health and safety hazards and try to eliminate or mitigate the risk through the whole protect life cycle from construction to operation and to demolition. This is in line with our role as Designer under the CDM 2015 regulations. The Council of the Isles of Scilly also have a role as the Client and are ultimately responsible for health and safety at the works, part of this is through the appointment of a competent Contractor who will manage the health and safety risks during construction.

A health and safety risk register has been produced, building from the general risk register included in the Preliminary Design reports. This identifies the key risks relating to the proposed works, rather than generic risks, and identifies where these are addressed in the design, if applicable, and who will manage the risk during the project life cycle. This relates to all three islands and is contained as Appendix D.

The key hazards for these works are associated with the island location and the access to the sites for the equipment and materials needed for the construction. Inter-island transport and road networks are limited so beach landings may be utilised to access the sites for bringing in large and heavy items such as rock. Proper planning of the logistics for undertaking the works is important to ensure the appropriate equipment is used and monitoring of tides and weather ensures safe landing and offloading.

A preliminary review of the approaches to the island and the three sites has been undertaken using Navionics marine charts (www.navionics.com). This is reproduced below and illustrates that Site 51 Porth Killier is too shallow and rocky for barges or landing craft to safely access and beach, Porth Coose also would be very difficult to safely access.

The Ferry Quay is planned to be used as the principal access point, but if offloading directly onto the beaches at Periglis or adjacent to the Ferry Quay, it is very likely that there will only be a short tidal window to enter the bays and so the barges may need to beach for a tidal cycle. Therefore, adequate barges should be considered for the transportation of material. Periglis Beach seems to be accessible, noting Periglis Bay is used for leisure moorings so navigation here may be favoured. However, the site is very exposed on the west of the island and it is likely that much of the construction will need to be undertaken during winter months. In addition, there is a width restriction near the slipway which could restrict the vehicles used to transport materials and the equipment itself. Refer to Section 10 for further details on site access.

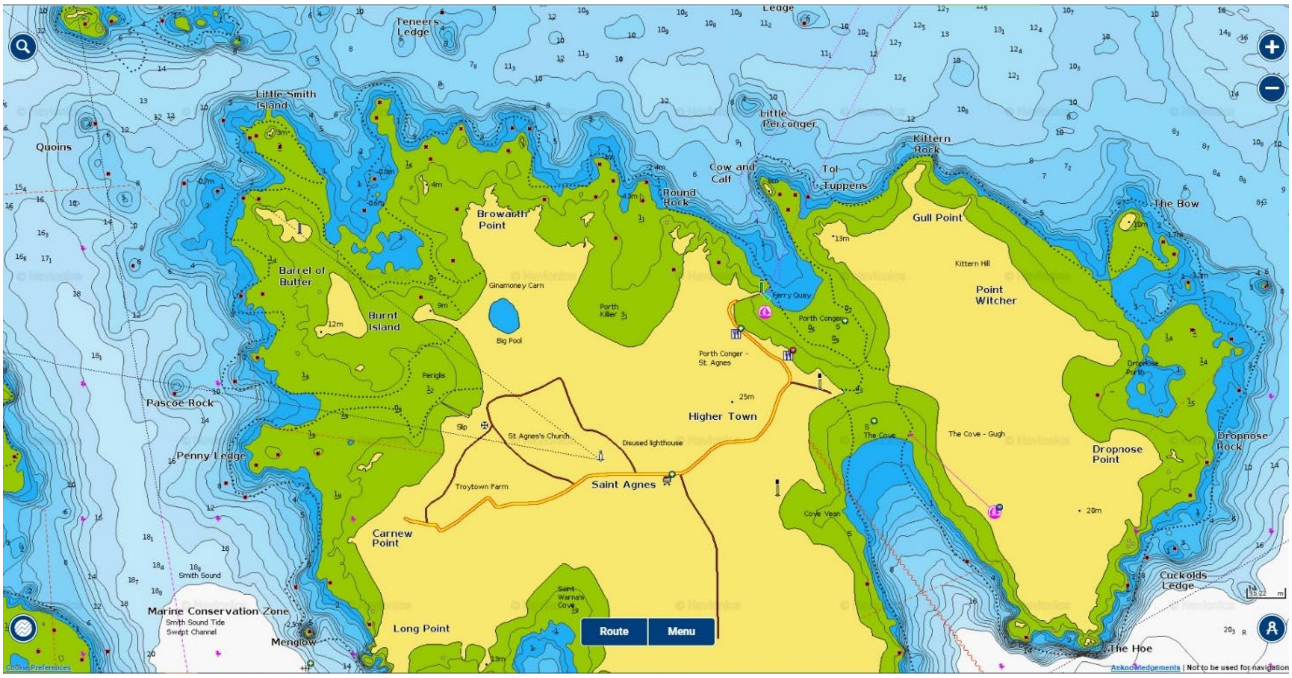

Figure 8.1: St Agnes marine chart

Source: www.navionics.com

The Contractor and Client are expected to work closely as the local pilots and fisherman will have the best sense of what can be done for marine access to each site, in safety for personnel and equipment.

A services check has been undertaken for gas and electricity lines for St Agnes and the plans received from the providers are included in Appendix E. No main service lines have been identified in the vicinity of the proposed works but the Contractor is to carry out their own assessments prior to start of works on site as there may be unmarked or old cabling and pipes.

9 Bills of Quantity & cost estimates

9.1 Indirect costs

Bills of quantity and cost estimates have been produced for the construction elements and for the total cost estimate the indirect costs for managing and undertaking the works need to be added to the construction costs. These are added as a % of the total construction costs and for large projects these % can be small but for smaller projects these will be higher.

The following additional indirect contractors' costs are included in the construction cost estimates:

- Management and supervision;
- Contractors preliminaries including management and mobilisation/demobilisation costs;
- Continency due to unforeseen design changes/site conditions.

9.1.1 Management and supervision

The engineering and project management is the input required support to the construction activities and as such is not directly involved with physical construction. This includes:

- Office management;

- Construction management;
- Design and documentation; and,
- Procurement, inspections and surveys.

For complex civil engineering projects, the engineering design and project management, including logistics support, can be as high as 25% of all construction costs for small complex works, but can be as low as 5% for large repetitive projects. For the proposed works, the design and logistics support is considered to cost approximately 18% of the total measured construction cost. Although the proposed works are technically not complex, the need for survey and site support has increased the assumed percentage.

Packaging up the works into large construction packages may bring some savings but each site is assumed as discrete at this stage.

9.1.2 Contractors preliminaries (Mob/Demob)

The cost of preliminary items for marine construction projects varies depending on:

- the type and number of plant items to be mobilised;
- whether modifications are required to plant items;
- how long it will take to mobilize and demobilize the equipment from its last project or its home base;
- ease of access to the site;
- security.

Preliminaries can be less than 10% for repetitive long duration projects but can be more than 30% for short duration specialist projects.

Considering the remote location of the Isles of Scilly, the mobilisation and demobilisation preliminaries in this location are considered to represent approximately 30% of all measured construction costs.

9.1.3 Contingency

Considering the location of the Isles of Scilly, and potential logistical challenges, a contingency of 30% on the cost estimates has been added to reflect the potential uncertainty with supply of materials and equipment.

This contingency also allows for additional works that may be required as part of any Environmental approvals. These approvals have also not yet been received from the Client and these may impose conditions for the works that may require restorative or compensatory works not considered in these estimates.

9.2 Direct costs

The bills of quantity (BoQ) have been generated from the drawings created for each island. Volumes and areas have been taken from the AutoCAD drawings to populate the BoQ. The key assumptions for the quantities and the cost estimates are listed here.

Quantities

- Ground levels are based on existing Lidar data at a representative section for each beach and proposed intervention;
- Bulking factors included for bulk rather than placed material;
- Geotextile and geogrid areas include 20% allowance for overlap, surfacing geomats and biomats include a 10% allowance.

Rates

- The rates used are from a combination of sources:
  - An inhouse database for similar marine projects.
  - Similar recent UK project costs.
  - Specific rates have been requested from suppliers for this project.
  - SPONS (2020) construction database – These are benchmarked for larger scale works, and so a 25% uplift has been applied to all SPONS rates considering the scale of the works. These rates have not been developed considering marine or coastal works, but as much of the construction work is above HAT these are seen as appropriate rates for excavation works.
  - The unit rates included in the OBC (Reference 2) have also been considered in the selection of rates.

9.3 Summary costs

Detailed bills of quantity for each site are included in Appendix F and full cost estimates in Appendix G. The overhead and contingency percentages of the construction works are as listed below and the total costs for each site are included in Table 9.1.

- Management, design and supervision - 18%
- Contractor preliminaries - 30%
- Contingency - 30%.

Table 9.1: St Agnes cost summary

Site	Cost (GBP)
48/49 - Periglis beach	380,780
50 - Porth Coose	297,201
51 - Porth Killier	321,747
TOTAL	**999,728**

Note this does not include signage and fencing to manage access onto the beaches, nor any boardwalks at the back of the beach.

10 Constructability

10.1 General logistics

The location of the Isles of Scilly presents logistical challenges for any construction works and also represents a significant hazard to the works, see Section 8. Equipment and materials need to be brought to the islands and the existing island infrastructure on St Agnes limits what can be brought to the island through the island's Ferry Quay. St Agnes, as with each of the Isles of Scilly, is very exposed to waves, swell and winds so sea conditions will need to be carefully monitored to ensure safe cargo arrival and offloading operations. The JBA (2019) wave analysis report does not include operational conditions so the Contractor should do their own assessment for seasonal extreme wave conditions, but only for information on a 0.22 year return period event, i.e. 5 times per year storm, give an estimated Hs of 0.5m.

The work boundaries, site access routes and location for work compound have been identified by the Client in discussion with the Environmental Consultant and communicated to HR Wallingford. The access and work boundaries and proposed work compound are shown in Figure 10.1. These boundaries are subject to review and possible changes and are to be agreed by the Client prior to starting any works. Two areas to note are the track behind Porth Killier seawall does narrow, though plant can pass, and the ground on the proposed route past the pool can get soft, so some temporary roadway may need to be considered.

Alternative access via Periglis beach may be possible, but it is constrained by access depths and a 2.4 m wide track off the beach as well as being on the more exposed western side of the island. It is not recommended to land on either Porth Coose or Porth Killier.

There are likely to be seasonal constraints due to the tourist season and bird nesting, and therefore work during winter months is likely to be required. CDM (2015) regulations require that the health and safety of the workers as well as the public is to be fully considered in the logistical and construction approach. The scheduling of construction during the winter months requires that bad weather is to be considered in all plans.

Figure 10.1: St. Agnes site boundaries, access routes and location of hazards

Source: Google Earth & Council of the Isles of Scilly

10.2 Plant & labour

The accessibility of the Isles of Scilly means that there is not a regular and simple supply chain for delivery of materials and hire of equipment. It has been the intent of the design to detail works that do not require large construction plant and can be constructed by standard axle width equipment such as JCB back hoe and small excavators that can use existing access tracks and routes to each location, though the 1-3T rock will require larger equipment for delivery and placement.

All construction works will be from the back of the beach, limiting the need for plant to be placed in tidal areas. A long arm excavator with grab with the required reach will be needed for the armour placement at Porth Killier. It is assumed that all materials will arrive through the existing quay and planning of the logistics for the works is essential as the allocated site compound is only 50 m x 40 m. This is to house contractor facilities as well as store plant and materials.

Rock placement is skilled labour as rocks need to be individually selected and placed, but much of the other general works can be carried out by workers from the Isles of Scilly where possible to support the local economy.

10.3 Materials

One of the main challenges to the works is the supply and delivery of materials. To reduce the reliance on importing, the intent is to reuse rock and fill materials where possible. Assessments carried out by the Client has identified limited volumes of available material so much of the fill, in addition to rock will need to be imported.

A proportion of existing rock on the beaches can be reused, but new material will need to be imported to the island considering the size of the proposed rock armour. It is assumed that this will be sourced from Cornwall and shipped by barge directly to the island. The Contractor should combine deliveries into these barges wherever possible to reduce the number of trips.

It is recommended that as part of the Construction tender, the contractor includes consideration for the sourcing and delivery of materials.

The identified areas for the work compound and stockpiling of material are limited in size, particularly for stocking material. This is a constraint to be considered in the construction schedule.

10.4 Environment

The Isles of Scilly is an Area of Outstanding Natural Beauty (AONB), a conservation area and a heritage coast, so the construction will need to fully consider methods and routing of access to the sites. An environmental impact assessment (EIA) is being carried out by others and the requirements identified from this need to be incorporated into the construction methodology. Although it is understood that the works are not themselves located in specific environmentally designated areas (such as site of special scientific interest (SSSI) or RAMSAR) the methodology needs to consider access, scheduling of works, noise and any other aspects identified in the EIA.

10.5 Summary

Some of the key construction points to note are summaries below:

- The existing quay was constructed in 2016 and is capable of handling trucks and large plant needed for the works as is used to offload similar loads. All materials are proposed to come through here or via the beach adjacent to the quay. This is not favoured due to the poor access up to the island roads.
- Porth Killier requires very large rocks. Appropriate transport to the storage area and worksite needs to be planned to minimise vehicle movements.
- A work compound has been identified back from the quay. This is where all plant and materials are to be stored as well as for worker facilities.
- Access to all three sites is to be via a track to the north that avoids residential areas. This is currently used for tracking equipment to the western side of the island and is away from the Porth Killier wall.
- Periglis beach is an option for offloading but there is a 2.4m width restriction to get off the beach so is not favoured.
- The construction works will be planned around the bird nesting season, where relevant, and whether or not the residents want the work to be undertaken during tourist season. It is therefore anticipated that the construction will likely be from October to April.
- It is therefore not recommended to land on Coose or Periglis beach as the available tidal window is small and there is risk of being exposed to rough seas whilst approaching and also once beached between high tides.

- All construction is proposed from the back of the beach. This means that equipment with appropriate reach will be required but no plant will be exposed to tidal working.
- The placement of rock at Porth Killier will need the contractor to select a long arm excavator capable of placing the large rocks at the toe of the proposed works. The equipment to be used should be proposed in all method statements.
- The rock bags proposed for Porth Coose are to be 2T and is anticipated that they will arrive filled, either by contractor or supplier, and will be transported to the beach via truck. These have lifting eyes to aid moving and installation.
- The route to the west will go over soft ground, temporary mats can be used to allow vehicles to pass safely over.

11 References

Goda, Y., "Random seas and design of maritime structures", Advanced series on ocean engineering - Volume 15, 2000.

Camfield, F. E. 1991. "Wave Force on Wall," Journal of Waterway. Port, Coastal, and Ocean Enqineerinq, American Society of Civil3.

Pedersen, J. 1996. Wave Forces and Overtopping on Crown Walls of Rubble Mound Breakwaters: an Experimental Study. Aalborg: Aalborg Universitetsforlag, No. 12.

Jensen OJ (1984) A Monograph on Rubble Mound Breakwaters. Danish Hydraulic Institute, Horsrolm, DenmarkBezuijen and Vastenburg.

Gouldby, B., Wyncoll, D., Panzeri, M., Franklin, M., Hunt, T., Hames, D., Tozer, N., Hawkes, P., Dornbusch, U. and Pullen, T. 2017 Multivariate extreme value modelling of sea conditions around the coast of England. Maritime Engineering. Volume 170 Issue 1.

BAKKER, J.J., MOM, R.J.C. and STEENDAM, G.J., (2008). Factual Report: Golfoverslagproeven Zeeuwse dijken. INFRAM, Marknesse, The Netherlands.

LOCK, M., (2008). Early colonization of littoral communities on PU coated substrates: a field and laboratory study. ARCADIS, Hoofddorp, The Netherlands.

McConnell, 1998, Revetment Systems against wave attack: A design Manual, HR Wallingford Thomas Telford London.

Oumeraci, H., Hinz, M., Bleck, M., Kortenhaus, A. 2003. Sand-filled geotextile containers for shore protection, COPEDEC VI, Colombo, Sri Lanka.

Oumeraci, H., Recio, J. 2010, Geotextile Sand Containers for shore protection, Invited Chapter in Handbook of Coastal and Ocean Engineering, World Scientific Publishing, Singapore, 553-600.

Pilarczyk, 2000. Geosynthetics and Geosystems in Hydraulic and Coastal Engineering, Routledge, UK.

Recio, J. 2007. Hydraulic stability of geotextile sand containers for coastal structures- effect of deformations and stability formulae, *PhD Thesis,* Leichweiss-Institute for Hydraulic Engineering and Water Resources, Braunschweig, Germany.

Environment Agency., 2018. Coastal flood boundary conditions for UK mainland and islands. Project: SC060064/TR2: Design sea levels.

Bradley, S.L., Milne, G.A., Tefernle, F.N., Bingley, R.M. and Orliac, E.J., 2009. Glacial isostatic adjustment of the British Isles: new constraints from GPS measurements of crustal motion. Geophysical Journal International, 178(1), pp.14-22.

University of Colorado, 2021. Sea Level Research Group, Global Mean Sea Level Rise Release 2021_rel2, https://sealevel.colorado.edu/.

Appendices

A Design Basis

A.1 Design life

The design life for the coastal scheme is 25 years.

A.2 Coordinate system

National Grid for plane coordinates.

A.3 Vertical datum

All levels are shown in m OD.

A.4 Data

A.4.1 Topographic and Bathymetric data

The following topographic data was used:

- LiDAR downloaded from: https://environment.data.gov.uk/DefraDataDownload/?Mode=survey:
  - Digital Surface Model (DSM) - this LiDAR data type was chosen for consistency and better understanding when displaying data in Excel plots. Generally a DTM would be preferable but in this case, not available for all years of interest.
  - Years used: 2011, 2014, 2018 and 2020.

During the analysis of the LiDAR data, ‘discrepancies’ were apparent between surveys regarding elevation (‘z’ values). To address this issue, an additional elevation check was carried out using profile data from the Channel Coastal Observatory (CCO). The CCO data provided topographical coastline profiles using the same vertical datum (m ODN) as the LiDAR, therefore a local comparison could be made against the LiDAR datasets. This allowed an informed decision to be made regarding what was a ‘realistic’ elevation for a particular match of survey year. Following on from this, it was decided that the 2011 LiDAR (earliest year) values should be used as the baseline to adjust the other LiDAR survey to, thus making all the datasets nominally comparable. Hard point elevation values (roads surfaces, concrete slipways) were extracted from the same positions in all LiDAR datasets in order to work out an average difference (adjustment) between a baseline year and the other years of interest. The average adjustment values were applied to the 2014/18/20 datasets so these could be brought in line with the 2011 baseline LiDAR.

A.5 Water Levels

A.5.1 Sea and tidal levels

Table A.1: Tide Tables

Level	Elevation (m CD) -	Elevation (m OD) -
MHWS	5.68	2.77
MHWN	4.35	1.44
MLWN	2.04	-0.87
MLWS	0.73	-2.18
LAT	0.09	-2.82

Source: HR Wallingford

A.5.2 Extreme water levels

Extreme sea levels were based on predictions published in the Environment Agency's Coastal Flood Boundaries report, Environment Agency (2018). These were updated to the present (2021) to account for likely rises on sea levels since 2017, the base date for these levels, University of Colorado (2021), and estimated changes in land levels since this date, Bradley *et. al.* (2008).

Site CFB Chainage	Extreme still water level for the year 2017 per AEP (mODK)										
	50%	20%	10%	5%	4%	3.33%	2%	1.33%	1%	0.5%	0.1%
ESL 0	3.51	3.59	3.64	3.69	3.71	3.72	3.75	3.78	3.80	3.84	3.95

Figure A.1: Extreme sea level data

Source: JBA (2019)

A.6 Waves

The RFP did not require wave modelling and instructed the tenderers to extract the required input data from "The Isles of Scilly Coastal Flood Modelling" (JBA (2019)). A preliminary review of this document showed that the report did not provide suitable wave data for detailed design. More information on extreme waves and water levels data were required. The Client requested the data, in electronic copy, from the Environment Agency at the start of the project.

The EA provided an initial first set of data, which was considered insufficient. A further more extensive set of data was subsequently provided. This was reviewed and design wave conditions were extracted.

As instructed by the Client, HR Wallingford have utilised the data provided from the above mentioned study. HR Wallingford has duly reviewed the information provided and confirms that they appear reasonable. However, without access to the raw data, and repeating the full analysis, we note that HR Wallingford are unable to take responsibility for any existing data quality and quantity provided by others.

The data supplied to HR Wallingford from the JBA modelling study consists of a sub-set of 10,000 years' of modelled extreme conditions, which has been set-up for extreme overtopping conditions. This sub-set of data contains the combinations of wave and sea level parameters that give the largest overtopping rate, although not necessarily the largest wave heights. However, the method adopted to generate these data was developed by HR Wallingford (see for example Gouldby et. al., 2017), and it is considered that a reliable estimate of the extreme wave heights at the site(s) could be determined from the data provided.

Two sets of data were provided:

- Defended
- Defended NPPF 2117.

Where NPFF stands for "National Planning Policy Framework".

It is assumed that:

- "Defended" is the current day (2017) estimate of wave heights and overtopping rates with existing sea defences.
- "Defended NPPF 2117" is the 2117 estimate of wave heights and overtopping rates which includes a 10% increase in offshore wind speed and wave heights, though no adjustment seems to be made to the wave period to maintain the input wave steepness. Sea level rise from 2017 to 2117 is given as 1.037m. This seems to be consistent with guidance given for the higher central allowance for sea level rise as currently given in this link:

https://www.gov.uk/guidance/flood-risk-assessments-climate-change-allowances#sea-level-allowances

The information for the relevant sites at St Agnes were extracted from these datasets. As part of the present study, a SLR allowance has been included in the water level to update the data to present day water levels (@2021) and to calculate water levels in 2046 (25 years life).

A.6.1 Extreme wave heights and water levels

The design return period for St Agnes has been confirmed by the Client as a 1 in 150 year return period. Based on the review of the data as described above and through interpolation between the 2017 and 2117 defended epochs, the following criteria have been selected for the design wave conditions and associated water levels at each of the sites considering the 25 year design life for overtopping.

Table A.2: Design waves and water levels

Point	Hs (m)	Tp (s)	Water Level
48	1.69	7.73	4.10
49	1.56	7.50	3.95
50	1.48	7.55	4.00
51	1.23	9.90	3.88

Source: HR Wallingford

Extreme wave heights with 1 in 150 return period have been calculated as depth limited waves, using the extreme water levels provided, see Section 4.3.1 above, including 25 years sea level rise. The depth limited wave was calculated at the -1m OD bed level and then propagated using Goda's methodology to the toe of each new structure. A Tp=8s was assumed for all sites, which compares well with most of the waves above.

The results from this analysis gave smaller waves that those in Table A.2 and so the larger more conservative waves were used in the design.

A.7 Overtopping assessment

A wave overtopping study was carried out as part of the JBA (2019) study for the EA. This study provided as output the flood extent and recommendations for the increase in crest elevation required along the coastal frontages. In addition, indications were given for flood alerts related to water levels and overtopping discharges.

As part of the present study, overtopping calculations are undertaken to assess the stability of the coastal/flood protection. No flood modelling is performed for the selected options, since this is outside the present scope of work.

The recommendations given in JBA (2020) and JBA (2019a), based on flood modelling, are considered as part of the assessment. Wave overtopping at the revetments is assessed using the empirical formulations reported in the EurOtop II (2016) manual.

A.8 Materials

A.8.1 Quarry rock properties

A quarry rock density of 2650kg/m^3 is assumed in the design of the rock revetment. This is the lower end of typical values for granite, so is a conservative value to use.

A.8.2 Concrete properties

A minimum concrete density of 2350kg/m^3 is assumed for concrete, for any flood or wave wall incorporated in the design.

A.8.3 Dune/Ridge recharge material

It is assumed that sand and recharge material to match existing ground can be locally sourced from the island.

A.8.4 Geotextile properties

The geotextiles to be used should be designed to meet the following criteria:

- A permeability criterion to ensure the geotextile is permeable enough to allow liquid to pass through relatively unhindered;
- A retention criterion to ensure the geotextile openings are small enough to prevent excessive migration of soil particles ("piping");
- An anti-clogging criterion to ensure the geotextile is porous enough so when soil particles become entrapped in, or on, the geotextile its permeability will not be adversely affected;
- A survivability criterion to ensure the geotextile survives installation; and,
- A durability criterion to ensure the geotextile is durable enough to withstand the effects of chemicals, UV light and abrasive conditions for the life of the project.

A.9 Design criteria

A.9.1 Ultimate limit states

Rock armour

For stability, a return period event of 1:150 year (0.5% probability per annum) is used for the preliminary design. The target damage level at this return period is selected as per the Rock Manual guidelines (CIRIA/CUR/CETMEF (2007)):

- Start of Damage: Sd = 2 – corresponds to “no damage” with approximately less than 5% armour rock displacement.

Overtopping

Guidance on methodologies and maximum allowable overtopping rates along the frontage will follow the recommendations in EurOtop II (2018), though consideration will also be given to acceptable flooding and acceptable damage following the conclusions and recommendations provided in JBA (2020) and JBA (2019a).

The crest level/configuration of the flood protection will be designed in such a way to limit mean wave overtopping and minimize risk of flooding and damage to the banks. Overtopping discharges obtained along the frontage will be reviewed considering the stability of the structures.

Based on extensive research on the resistance of grass covered slopes under overtopping events, EurOtop II (2018) provides the following suggestions:

- A good closed grass cover without open holes is very resilient to wave overtopping for wave heights H_{m0} < 3m.
- A badly maintained grass cover with open holes and a lot of moss may fail well below q < 5 l/s/m.

These limits are summarised in Table A.3.

Table A.3: Design return periods for the quay walls and the maximum allowable overtopping

Hazard type and reason	Mean discharge q (l/s per m)
Grass covered crest and landward slope; maintained and closed grass cover; Hm_0 = 1 – 3 m	5
Grass covered crest and landward slope; not maintained grass cover, open spots, moss, bare patches; Hm_0 = 0.5 – 3 m	0.1
Grass covered crest and landward slope; Hm_0 < 1 m	5-10

Source: EurOtop II (2018)

Geotextile sand containers

It is envisaged that geotextile tubes/containers, referred to as geocontainers in this report, will be used as part of the proposed material. Geotextile sand containers are a low cost, soft and reversible solution for a cost effective shore protection and have a history of more than 50 years in hydraulic and marine applications. Coastal structures built with geotextile sand containers are obtained by substituting rocks or concrete units with containers made of geotextile and filled with locally available sand.

The hydraulic processes affecting the stability of geotextile sand containers / structures will be assessed using Geosystems. Design rules and applications" by Bezuijen and Vastenburg and the work carried out by Oumeraci et al (2003, 2010) and Recio (2007).

A.9.2 Serviceability limit states

Sea defence overtopping conditions with a 1 in 1 year joint probability return period will be used as the SLS design criterion. The sea defence will be designed in such a way that it will limit wave overtopping over the public footpath with a target maximum not to exceed q = 1 l/s/m in order to not cause danger to pedestrians who are assumed to be aware of the weather conditions, see Figure A.2 extracted from EurOtop (2018). The limit applicable for all the sites refers to Hm_0 < 2m.

No damage criteria are necessary for this serviceability limit state.

Hazard type and reason	Mean discharge q (l/s per m)	Max volume V_{max} (l per m)
People at structures with possible violent overtopping, mostly vertical structures	No access for any predicted overtopping	No access for any predicted overtopping
People at seawall / dike crest. Clear view of the sea. H_{m0} = 3 m H_{m0} = 2 m H_{m0} = 1 m H_{m0} < 0.5 m	0.3 1 10-20 No limit	600 600 600 No limit
Cars on seawall / dike crest, or railway close behind crest H_{m0} = 3 m H_{m0} = 2 m H_{m0} = 1 m	<5 10-20 <75	2000 2000 2000
Highways and roads, fast traffic	Close before debris in spray becomes dangerous	Close before debris in spray becomes dangerous

Figure A.2: Limits for overtopping for people and vehicles

Source: Extracted from EurOtop II (2018) Table 3.3

A.10 Code and standards

The design of the coastal works has been carried out in accordance with the codes, standards and guidance documents as listed below:

- British Standards, BS6349 suite, Maritime Structures;
- BS EN 1991-1-1:2002. Eurocode 1: Actions on structures - Part 1-1: General actions. BSI;
- BS EN 1997-1:2004 Eurocode 7: Geotechnical design - Part 1: General rules. BSI;
- BS EN 13383 Parts 1 and 2 European Armourstone Specification.

In addition to the standards above, the following international guides for good practice have also been adopted:

- CIRIA; CUR; CETMEF, (2007). The Rock Manual. The Use of Rock in Hydraulic Engineering; (2nd Edition), London;
- CIRIA, (2010). Beach management manual. (2nd Edition), London. PUB C685;
- CIRIA, (2020). Groynes in coastal engineering – Guide to design, monitoring and maintenance of narrow footprint groynes, London;
- EurOTop II (2018).

B Calculations

COVER SHEET

Project	Isles of Scilly Climate Adaptation	Calc no.	-	Project Engineer	MLO
Contract	DKR6499	Filename ref	-	Designer	-
Section	St. Agnes	Job No.	-	Department	Engineering
Subject	Rock size design – St Agnes				

	Total Sheets	Mathcad Made by	Date	Cal Made by	Date	Checked by	Date		
ORIGINAL		MJJ	25 / 10 / 11	MLO	06/07/2021				
REV				MLO	21/07/2022	AGC	22/07/2022		
REV									
REV									
REV									
REV									
Superseded by Calculation no.					Date				

Objective of Calculation:

Rock Sizing

Description of Calculation:

Van der Meer rock armour calculation marginally overtopped structures, based on: The Rock Manual (2007), p567

Van der Meer rock armour calculation emergent structures, based on: The Rock Manual (2007), p600

INPUT

Wave conditions used are:

Waves at the toe provided by JBA

Waves propagated to the toe of the structures using Goda (2010)

A 12 hours storm has been considered

It is expected that some reshaping may occur even if a Sd=2 has been used, due to potential settlement of the toe following major storms.

TO BE READ IN CONJUNCTION WITH INPUT FILE

…\dkr6499$\3_technical\Detailed_Design(Stage4-RIBA)\1_Bryher\1 - Greatpar South\ 1_ Van_der_Meer_multi_calculation_input.xlsx

INPUT DATA

Input data can be directly entered into table below or imported from an Excel spreadsheet

data :=

	0	1	2	3	4	5	6	7	8	9
0	"ID"	s max(m)"	H2% (m)"	"Tm (s)"	"Tme (s)"	"Nw"	"P"	"Sd"	"Slope"	"Rc (m)"
1	ier-Goda"	1.33	1.81	8.118	9	5.322·10³	0.1	2	2	1.82
2	lcCowan"	1.123	1.494	8.118	9	5.322·10³	0.1	2	2	1.82

To calculate H2% use "H2%_calculation_2008.xls"

Peak wave period Tp is estimated using Tm/0.82

Energy wave period (Tme) can be estimated using Tp/1.1

ht is the depth of water at the toe of the structure

$$input := \begin{pmatrix}
data_{1,0} & data_{1,1} & data_{1,2} & data_{1,3} & data_{1,4} & data_{1,5} & data_{1,6} & data_{1,7} & data_{1,8} & data_{1,9} & data_{1,10} \\
data_{2,0} & data_{2,1} & data_{2,2} & data_{2,3} & data_{2,4} & data_{2,5} & data_{2,6} & data_{2,7} & data_{2,8} & data_{2,9} & data_{2,10} \\
data_{3,0} & data_{3,1} & data_{3,2} & data_{3,3} & data_{3,4} & data_{3,5} & data_{3,6} & data_{3,7} & data_{3,8} & data_{3,9} & data_{3,10} \\
data_{4,0} & data_{4,1} & data_{4,2} & data_{4,3} & data_{4,4} & data_{4,5} & data_{4,6} & data_{4,7} & data_{4,8} & data_{4,9} & data_{4,10} \\
data_{5,0} & data_{5,1} & data_{5,2} & data_{5,3} & data_{5,4} & data_{5,5} & data_{5,6} & data_{5,7} & data_{5,8} & data_{5,9} & data_{5,10} \\
data_{6,0} & data_{6,1} & data_{6,2} & data_{6,3} & data_{6,4} & data_{6,5} & data_{6,6} & data_{6,7} & data_{6,8} & data_{6,9} & data_{6,10} \\
data_{7,0} & data_{7,1} & data_{7,2} & data_{7,3} & data_{7,4} & data_{7,5} & data_{7,6} & data_{7,7} & data_{7,8} & data_{7,9} & data_{7,10} \\
data_{8,0} & data_{8,1} & data_{8,2} & data_{8,3} & data_{8,4} & data_{8,5} & data_{8,6} & data_{8,7} & data_{8,8} & data_{8,9} & data_{8,10} \\
data_{9,0} & data_{9,1} & data_{9,2} & data_{9,3} & data_{9,4} & data_{9,5} & data_{9,6} & data_{9,7} & data_{9,8} & data_{9,9} & data_{9,10} \\
data_{10,0} & data_{10,1} & data_{10,2} & data_{10,3} & data_{10,4} & data_{10,5} & data_{10,6} & data_{10,7} & data_{10,8} & data_{10,9} & data_{10,10} \\
data_{11,0} & data_{11,1} & data_{11,2} & data_{11,3} & data_{11,4} & data_{11,5} & data_{11,6} & data_{11,7} & data_{11,8} & data_{11,9} & data_{11,10} \\
data_{12,0} & data_{12,1} & data_{12,2} & data_{12,3} & data_{12,4} & data_{12,5} & data_{12,6} & data_{12,7} & data_{12,8} & data_{12,9} & data_{12,10} \\
data_{13,0} & data_{13,1} & data_{13,2} & data_{13,3} & data_{13,4} & data_{13,5} & data_{13,6} & data_{13,7} & data_{13,8} & data_{13,9} & data_{13,10} \\
data_{14,0} & data_{14,1} & data_{14,2} & data_{14,3} & data_{14,4} & data_{14,5} & data_{14,6} & data_{14,7} & data_{14,8} & data_{14,9} & data_{14,10} \\
data_{15,0} & data_{15,1} & data_{15,2} & data_{15,3} & data_{15,4} & data_{15,5} & data_{15,6} & data_{15,7} & data_{15,8} & data_{15,9} & data_{15,10} \\
data_{16,0} & data_{16,1} & data_{16,2} & data_{16,3} & data_{16,4} & data_{16,5} & data_{16,6} & data_{16,7} & data_{16,8} & data_{16,9} & data_{16,10} \\
data_{17,0} & data_{17,1} & data_{17,2} & data_{17,3} & data_{17,4} & data_{17,5} & data_{17,6} & data_{17,7} & data_{17,8} & data_{17,9} & data_{17,10} \\
data_{18,0} & data_{18,1} & data_{18,2} & data_{18,3} & data_{18,4} & data_{18,5} & data_{18,6} & data_{18,7} & data_{18,8} & data_{18,9} & data_{18,10} \\
data_{19,0} & data_{19,1} & data_{19,2} & data_{19,3} & data_{19,4} & data_{19,5} & data_{19,6} & data_{19,7} & data_{19,8} & data_{19,9} & data_{19,10} \\
data_{20,0} & data_{20,1} & data_{20,2} & data_{20,3} & data_{20,4} & data_{20,5} & data_{20,6} & data_{20,7} & data_{20,8} & data_{20,9} & data_{20,10} \\
data_{21,0} & data_{21,1} & data_{21,2} & data_{21,3} & data_{21,4} & data_{21,5} & data_{21,6} & data_{21,7} & data_{21,8} & data_{21,9} & data_{21,10} \\
data_{22,0} & data_{22,1} & data_{22,2} & data_{22,3} & data_{22,4} & data_{22,5} & data_{22,6} & data_{22,7} & data_{22,8} & data_{22,9} & data_{22,10} \\
data_{23,0} & data_{23,1} & data_{23,2} & data_{23,3} & data_{23,4} & data_{23,5} & data_{23,6} & data_{23,7} & data_{23,8} & data_{23,9} & data_{23,10}
\end{pmatrix} *$$

$$\begin{pmatrix}
data_{23,0} & data_{23,1} & data_{23,2} & data_{23,3} & data_{23,4} & data_{23,5} & data_{23,6} & data_{23,7} & data_{23,8} & data_{23,9} & data_{23,10} \\
data_{24,0} & data_{24,1} & data_{24,2} & data_{24,3} & data_{24,4} & data_{24,5} & data_{24,6} & data_{24,7} & data_{24,8} & data_{24,9} & data_{24,10} \\
data_{25,0} & data_{25,1} & data_{25,2} & data_{25,3} & data_{25,4} & data_{25,5} & data_{25,6} & data_{25,7} & data_{25,8} & data_{25,9} & data_{25,10} \\
data_{26,0} & data_{26,1} & data_{26,2} & data_{26,3} & data_{26,4} & data_{26,5} & data_{26,6} & data_{26,7} & data_{26,8} & data_{26,9} & data_{26,10} \\
data_{27,0} & data_{27,1} & data_{27,2} & data_{27,3} & data_{27,4} & data_{27,5} & data_{27,6} & data_{27,7} & data_{27,8} & data_{27,9} & data_{27,10} \\
data_{28,0} & data_{28,1} & data_{28,2} & data_{28,3} & data_{28,4} & data_{28,5} & data_{28,6} & data_{28,7} & data_{28,8} & data_{28,9} & data_{28,10} \\
data_{29,0} & data_{29,1} & data_{29,2} & data_{29,3} & data_{29,4} & data_{29,5} & data_{29,6} & data_{29,7} & data_{29,8} & data_{29,9} & data_{29,10} \\
data_{30,0} & data_{30,1} & data_{30,2} & data_{30,3} & data_{30,4} & data_{30,5} & data_{30,6} & data_{30,7} & data_{30,8} & data_{30,9} & data_{30,10} \\
data_{31,0} & data_{31,1} & data_{31,2} & data_{31,3} & data_{31,4} & data_{31,5} & data_{31,6} & data_{31,7} & data_{31,8} & data_{31,9} & data_{31,10}
\end{pmatrix}$$

$H_s := input^{\langle 1 \rangle} \cdot m$ $H_{2\%} := input^{\langle 2 \rangle} \cdot m$ $T_m := input^{\langle 3 \rangle} \cdot s$ $T_{m\_e} := input^{\langle 4 \rangle} \cdot s$ $N_w := input^{\langle 5 \rangle}$ $P := input^{\langle 6 \rangle}$

$S_d := input^{\langle 7 \rangle}$ $slope := input^{\langle 8 \rangle}$ $Rc := input^{\langle 9 \rangle} \cdot m$ $ht := input^{\langle 10 \rangle} \cdot m$

Structure and material properties

$$ r := 2.60 \frac{tonne}{m^3} $$ Rock density

$$ w := 1.025 \frac{tonne}{m^3} $$ Water density

$$:= \left(\frac{r}{w}\right) - 1 \qquad = 1.54 $$ Buoyant density

CALCULATIONS FOR DEEP WATER MARGINALLY OVERTOPPED STRUCTURES

$$ s_m := \frac{2 \cdot \ \cdot H_s}{g \cdot T_m^{\ 2}} $$ Wave steepness

$$ s_{op} := \frac{2 \cdot \ \cdot H_s}{g \cdot \left(\frac{T_m}{0.82}\right)^2} $$ Wave steepness in deep water

Structure slope; slope = cotα

$$:= \frac{\ }{2} - \text{atan(slope)} $$

Plunging - surging waves (Deep water)

Expand table if required:

$$ m := \frac{slope^{-1}}{\sqrt{s_m}} $$ Iribarren number

m =

	0
0	4.4
1	4.78
2	...

The transition from plunging to surging waves occurs when the Iribarren number is above a critical value

Transition value for Iribarren number:

$$ mcr := \text{for } i \in 0..\text{last}\left(input^{\langle 1 \rangle}\right) $$

$$ mcr_i \leftarrow \left[6.2 \cdot \left(P_i\right)^{0.31} \cdot \left[\left(\tan(\ )_i\right)^{\frac{1}{2}}\right]\right]^{\frac{1}{P_i + 0.5}} $$

Expand table if required:

mcr =

	0
0	3.57
1	3.57
2	...

Armour layer stone size (Deep Water)

Stone size for plunging waves:

$$ D_{n50pl\_D} := \text{for } i \in 0..\text{last}\left(input^{\langle 1 \rangle}\right) $$

$$ D_{n50pl\_D_i} \leftarrow \frac{H_{s_i}}{\cdot 6.2 \cdot \left(P_i\right)^{0.18} \cdot \left(\frac{S_{d_i}}{\sqrt{N_{w_i}}}\right)^{0.2} \cdot \left(\ m_i\right)^{-0.5}} $$

Stone size for surging waves:

$$D_{n50su\_D} := \text{for } i \in 0..\text{last}\left(input^{\langle 1\rangle}\right)$$
$$D_{n50su\_D_i} \leftarrow \frac{H_{s_i}}{\cdot 1.0 \cdot (P_i)^{-0.13} \cdot \left(\frac{S_{d_i}}{\sqrt{N_{w_i}}}\right)^{0.2} \cdot (slope_i)^{0.5} (m_i)^{P_i}}$$

$$D_{n50\_D} := \text{for } i \in 0..\text{last}\left(input^{\langle 3\rangle}\right)$$
$$\begin{array}{l} D_{n50\_D_i} \leftarrow D_{n50pl\_D_i} \text{ if } m_i < mcr_i \\ D_{n50\_D_i} \leftarrow D_{n50su\_D_i} \text{ otherwise} \end{array}$$

$$check\_d := \text{for } i \in 0..\text{last}\left(input^{\langle 3\rangle}\right)$$
$$\begin{array}{l} check\_d_i \leftarrow \text{"plunging waves" if } m_i < mcr_i \\ check\_d_i \leftarrow \text{"surging waves" otherwise} \end{array}$$

ARMOUR LAYER RESULTS
DEEP WATER MARGINALLY OVERTOPPED STRUCTURES

check_d =

	0
0	"surging waves"
1	"surging waves"
2	"plunging waves"
3	"plunging waves"
4	"plunging waves"
5	"plunging waves"
6	"plunging waves"
7	"plunging waves"
8	"plunging waves"
9	"plunging waves"
10	"plunging waves"
11	"plunging waves"
12	"plunging waves"
13	"plunging waves"
14	"plunging waves"
15	"plunging waves"
16	"plunging waves"
17	"plunging waves"
18	"plunging waves"
19	"plunging waves"
20	"plunging waves"
21	"plunging waves"
22	"plunging waves"
23	"plunging waves"
24	"plunging waves"
25	"plunging waves"
26	"plunging waves"
27	"plunging waves"
28	"plunging waves"
29	"plunging waves"
30	"plunging waves"

D_{n50_D} = (m)

	0
0	0.803
1	0.673
2	0.117
3	0.117
4	0.117
5	0.117
6	0.117
7	0.117
8	0.117
9	0.117
10	0.117
11	0.117
12	0.117
13	0.117
14	0.117
15	0.117
16	0.117
17	0.117
18	0.117
19	0.117
20	0.117
21	0.117
22	0.117
23	0.117
24	0.117
25	0.117
26	0.117
27	0.117
28	0.117
29	0.117
30	0.117

$$M_{50\_D} := r D_{n50\_D}^{\ 3}$$

M_{50_D} = (kg)

	0
0	1348
1	791
2	4
3	4
4	4
5	4
6	4
7	4
8	4
9	4
10	4
11	4
12	4
13	4
14	4
15	4
16	4
17	4
18	4
19	4
20	4
21	4
22	4
23	4
24	4
25	4
26	4
27	4
28	4
29	4
30	4

CALCULATIONS FOR SHALLOW WATER MARGINALLY OVERTOPPED STRUCTURES

Plunging - surging waves (Shallow water)

$$s := \frac{\tan(\ )}{\sqrt{\dfrac{2\cdot\ \cdot H_s}{g T_{m\_e}^{2}}}}$$

surf similarity parameter

Expand table if required:

s =

	0
0	4.875
1	5.305
2	1.249
3	...

The transition from plunging to surging waves occurs when the Iribarren number is above a critical value

Transition value for Iribarren number:

$$scr := \text{for } i \in 0..\text{last}\left(input^{\langle 1\rangle}\right)$$

$$scr_i \leftarrow \left[\frac{8.4}{1.3}\cdot\left(P_i\right)^{0.31}\cdot\left[\left(\tan(\ )_i\right)^{\frac{1}{2}}\right]\right]^{\frac{1}{P_i+0.5}}$$

Expand table if required:

scr =

	0
0	3.83
1	3.83
2	3.47
3	...

Armour layer stone size (Shallow water)

Stone size for plunging waves:

$$D_{n50pl\_S} := \text{for } i \in 0..\text{last}\left(input^{\langle 1\rangle}\right)$$

$$D_{n50pl\_S_i} \leftarrow \frac{H_{s_i}}{\cdot 8.4\cdot\left(P_i\right)^{0.18}\cdot\left(\dfrac{S_{d_i}}{\sqrt{N_{w_i}}}\right)^{0.2}\cdot\dfrac{H_{s_i}}{H_{2\%_i}}\cdot\left(\ s_i\right)^{-0.5}}$$

Stone size for surging waves:

$$D_{n50su\_S} := \text{for } i \in 0..\text{last}\left(input^{\langle 1\rangle}\right)$$

$$D_{n50su\_S_i} \leftarrow \frac{H_{s_i}}{\cdot 1.3\cdot\left(P_i\right)^{-0.13}\cdot\left(\dfrac{S_{d_i}}{\sqrt{N_{w_i}}}\right)^{0.2}\cdot\dfrac{H_{s_i}}{H_{2\%_i}}\cdot\left(slope_i\right)^{0.5}\left(\ s_i\right)^{P_i}}$$

$$D_{n50\_S} := \text{for } i \in 0..\text{last}\left(input^{\langle 3\rangle}\right)$$
$$\quad D_{n50\_S_i} \leftarrow D_{n50pl\_S_i} \text{ if } s_i < scr_i$$
$$\quad D_{n50\_S_i} \leftarrow D_{n50su\_S_i} \text{ otherwise}$$

$$check\_s := \text{for } i \in 0..\text{last}\left(input^{\langle 3\rangle}\right)$$
$$\quad check\_s_i \leftarrow \text{"plunging waves" if } s_i < scr_i$$
$$\quad check\_s_i \leftarrow \text{"surging waves" otherwise}$$

ARMOUR LAYER RESULTS
SHALLOW WATER MARGINALLY OVERTOPPED STRUCTURES

check_s =

	0
0	"surging waves"
1	"surging waves"
2	"plunging waves"
3	"plunging waves"
4	"plunging waves"
5	"plunging waves"
6	"plunging waves"
7	"plunging waves"
8	"plunging waves"
9	"plunging waves"
10	"plunging waves"
11	"plunging waves"
12	"plunging waves"
13	"plunging waves"
14	"plunging waves"
15	"plunging waves"
16	"plunging waves"
17	"plunging waves"
18	"plunging waves"
19	"plunging waves"
20	"plunging waves"
21	"plunging waves"
22	"plunging waves"
23	"plunging waves"
24	"plunging waves"
25	"plunging waves"
26	"plunging waves"
27	"plunging waves"
28	"plunging waves"
29	"plunging waves"
30	"plunging waves"

D_{n50_S} = (m)

	0
0	0.832
1	0.681
2	0.087
3	0.087
4	0.087
5	0.087
6	0.087
7	0.087
8	0.087
9	0.087
10	0.087
11	0.087
12	0.087
13	0.087
14	0.087
15	0.087
16	0.087
17	0.087
18	0.087
19	0.087
20	0.087
21	0.087
22	0.087
23	0.087
24	0.087
25	0.087
26	0.087
27	0.087
28	0.087
29	0.087
30	0.087

$$M_{50\_S} := {}_{r}D_{n50\_S}^{\;3}$$

M_{50_S} = (kg)

	0
0	1499
1	822
2	2
3	2
4	2
5	2
6	2
7	2
8	2
9	2
10	2
11	2
12	2
13	2
14	2
15	2
16	2
17	2
18	2
19	2
20	2
21	2
22	2
23	2
24	2
25	2
26	2
27	2
28	2
29	2
30	2

CALCULATIONS FOR LOW CRESTED EMERGENT STRUCTURES

Rock armour 'Dn50' on low crested emergent structures can be calculated using the Van Der Meer calculations used above and applying a reduction factor 'rD', see page 600, Eq 5.164.

$$rD := \text{for } i \in 0..\text{last}\left(input^{\langle 1 \rangle}\right)$$
$$rD_i \leftarrow \left(1.25 - 4.8 \cdot \frac{Rc_i}{H_{s_i}} \cdot \sqrt{\frac{s_{op_i}}{2 \cdot}}\right)^{-1}$$

Expand table if required:

rD =

	0
0	0.994
1	1.016
2	-145.292
3	...

Limit of above equation for deep and shallow formulas

$$check\_1 := \text{for } i \in 0..\text{last}\left(input^{\langle 1 \rangle}\right)$$
$$\left| \begin{array}{l} check\_1_i \leftarrow \text{"OK"} \quad \text{if } 0 \le \frac{Rc_i}{H_{s_i}} \cdot \sqrt{\frac{s_{op_i}}{2 \cdot}} < 0.052 \\ check\_1_i \leftarrow \text{"OUT OF RANGE"} \quad \text{otherwise} \end{array} \right.$$

check_1 =

	0
0	"OK"
1	"OUT OF RANGE"
2	"OUT OF RANGE"
3	"OUT OF RANGE"
4	"OUT OF RANGE"
5	"OUT OF RANGE"
6	"OUT OF RANGE"
7	"OUT OF RANGE"
8	"OUT OF RANGE"
9	"OUT OF RANGE"
10	"OUT OF RANGE"
11	"OUT OF RANGE"
12	"OUT OF RANGE"
13	"OUT OF RANGE"
14	"OUT OF RANGE"
15	"OUT OF RANGE"
16	"OUT OF RANGE"
17	"OUT OF RANGE"
18	"OUT OF RANGE"
19	"OUT OF RANGE"
20	"OUT OF RANGE"
21	"OUT OF RANGE"
22	"OUT OF RANGE"
23	"OUT OF RANGE"
24	"OUT OF RANGE"
25	"OUT OF RANGE"
26	"OUT OF RANGE"
27	"OUT OF RANGE"
28	"OUT OF RANGE"
29	...

$$check\_1a := \text{for } i \in 0..\text{last}\left(input^{\langle 1 \rangle}\right)$$
$$check\_1a_i \leftarrow \frac{Rc_i}{H_{s_i}} \cdot \sqrt{\frac{s_{op_i}}{2 \cdot}}$$

check_1a =

	0
0	0.051
1	0.055
2	0.262
3	0.262
4	...

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ARMOUR LAYER CALCULATION AND RESULTS
LOW CRESTED EMERGENT STRUCTURES (DEEP WATER)

$$D_{n50\_rDD} := \text{for } i \in 0..\text{last}\left(input^{\langle 1 \rangle}\right)$$
$$\quad D_{n50\_rDD_i} \leftarrow rD_i \cdot D_{n50\_D_i}$$

$$M_{50\_rDD} := {}_{r}D_{n50\_rDD}^{\;3}$$

$D_{n50\_rDD} =$ (m)

	0
0	0.799
1	0.684
2	-17.046
3	-17.046
4	-17.046
5	-17.046
6	-17.046
7	-17.046
8	-17.046
9	-17.046
10	-17.046
11	-17.046
12	-17.046
13	-17.046
14	-17.046
15	-17.046
16	-17.046
17	-17.046
18	-17.046
19	-17.046
20	-17.046
21	-17.046
22	-17.046
23	-17.046
24	-17.046
25	-17.046
26	-17.046
27	-17.046
28	-17.046
29	...

$M_{50\_rDD} =$ (kg)

	0
0	1324.953
1	830.275
2	-12878207.372
3	-12878207.372
4	-12878207.372
5	-12878207.372
6	-12878207.372
7	-12878207.372
8	-12878207.372
9	-12878207.372
10	-12878207.372
11	-12878207.372
12	-12878207.372
13	-12878207.372
14	-12878207.372
15	-12878207.372
16	-12878207.372
17	-12878207.372
18	-12878207.372
19	-12878207.372
20	-12878207.372
21	-12878207.372
22	-12878207.372
23	-12878207.372
24	-12878207.372
25	-12878207.372
26	-12878207.372
27	-12878207.372
28	-12878207.372
29	...

HR Wallingford

ARMOUR LAYER CALCULATION AND RESULTS
LOW CRESTED EMERGENT STRUCTURES (SHALLOW WATER)

$$D_{n50\_rDS} := \text{for } i \in 0..\text{last}\left(input^{\langle 1 \rangle}\right)$$
$$\quad D_{n50\_rDS_i} \leftarrow rD_i \cdot D_{n50\_S_i}$$

$$M_{50\_rDS} := r\,D_{n50\_rDS}^{\;3}$$

$D_{n50\_rDS} =$ (m)

	0
0	0.828
1	0.692
2	-12.582
3	-12.582
4	-12.582
5	-12.582
6	-12.582
7	-12.582
8	-12.582
9	-12.582
10	-12.582
11	-12.582
12	-12.582
13	-12.582
14	-12.582
15	-12.582
16	-12.582
17	-12.582
18	-12.582
19	-12.582
20	-12.582
21	-12.582
22	-12.582
23	-12.582
24	-12.582
25	-12.582
26	-12.582
27	-12.582
28	-12.582
29	...

$M_{50\_rDD} =$ (kg)

	0
0	1324.953
1	830.275
2	-12878207.372
3	-12878207.372
4	-12878207.372
5	-12878207.372
6	-12878207.372
7	-12878207.372
8	-12878207.372
9	-12878207.372
10	-12878207.372
11	-12878207.372
12	-12878207.372
13	-12878207.372
14	-12878207.372
15	-12878207.372
16	-12878207.372
17	-12878207.372
18	-12878207.372
19	-12878207.372
20	-12878207.372
21	-12878207.372
22	-12878207.372
23	-12878207.372
24	-12878207.372
25	-12878207.372
26	-12878207.372
27	-12878207.372
28	-12878207.372
29	...

RESULTS

MARGINALLY OVERTOPPED DEEP WATER

D_{n50_D} =

	0
0	0.803
1	0.673
2	0.117
3	0.117
4	0.117
5	0.117
6	0.117
7	0.117
8	0.117
9	0.117
10	0.117
11	0.117
12	0.117
13	0.117
14	...

m

M_{50_D} =

	0
0	1348
1	791
2	4
3	4
4	4
5	4
6	4
7	4
8	4
9	4
10	4
11	4
12	4
13	4
14	...

kg

MARGINALLY OVERTOPPED SHALLOW WATER

D_{n50_S} =

	0
0	0.832
1	0.681
2	0.087
3	0.087
4	0.087
5	0.087
6	0.087
7	0.087
8	0.087
9	0.087
10	0.087
11	0.087
12	0.087
13	0.087
14	...

m

M_{50_S} =

	0
0	1499
1	822
2	2
3	2
4	2
5	2
6	2
7	2
8	2
9	2
10	2
11	2
12	2
13	2
14	...

kg

EMERGENT STRUCTURES DEEP WATER

D_{n50_rDD} =

	0
0	0.799
1	0.684
2	-17.046
3	-17.046
4	-17.046
5	-17.046
6	-17.046
7	-17.046
8	-17.046
9	-17.046
10	-17.046
11	-17.046
12	-17.046
13	-17.046
14	...

m

M_{50_rDD} =

	0
0	1324.953
1	830.275
2	-12878207.372
3	-12878207.372
4	-12878207.372
5	-12878207.372
6	-12878207.372
7	-12878207.372
8	-12878207.372
9	-12878207.372
10	-12878207.372
11	-12878207.372
12	-12878207.372
13	-12878207.372
14	...

kg

EMERGENT STRUCTURES SHALLOW WATER

D_{n50_rDS} =

	0
0	0.828
1	0.692
2	-12.582
3	-12.582
4	-12.582
5	-12.582
6	-12.582
7	-12.582
8	-12.582
9	-12.582
10	-12.582
11	-12.582
12	-12.582
13	-12.582
14	...

m

M_{50_rDS} =

	0
0	1473.714
1	862.271
2	-5178364.591
3	-5178364.591
4	-5178364.591
5	-5178364.591
6	-5178364.591
7	-5178364.591
8	-5178364.591
9	-5178364.591
10	-5178364.591
11	-5178364.591
12	-5178364.591
13	-5178364.591
14	...

k

MARGINALLY OVERTOPPED DEEP WATER

$D_{n50\_D} =$ (m)

	0
0	0.803
1	0.673
2	0.117
3	0.117
4	0.117
5	0.117
6	0.117
7	0.117
8	0.117
9	0.117
10	0.117
11	0.117
12	0.117
13	0.117
14	...

m

$M_{50\_D} =$

	0
0	1348
1	791
2	4
3	4
4	4
5	4
6	4
7	4
8	4
9	4
10	4
11	4
12	4
13	4
14	...

kg

MARGINALLY OVERTOPPED SHALLOW WATER

$D_{n50\_S} =$

	0
0	0.832
1	0.681
2	0.087
3	0.087
4	0.087
5	0.087
6	0.087
7	0.087
8	0.087
9	0.087
10	0.087
11	0.087
12	0.087
13	0.087
14	...

m

$M_{50\_S} =$

	0
0	1499
1	822
2	2
3	2
4	2
5	2
6	2
7	2
8	2
9	2
10	2
11	2
12	2
13	2
14	...

kg

EMERGENT STRUCTURES DEEP WATER

$D_{n50\_rDD} =$

	0
0	0.799
1	0.684
2	-17.046
3	-17.046
4	-17.046
5	-17.046
6	-17.046
7	-17.046
8	-17.046
9	-17.046
10	-17.046
11	-17.046
12	-17.046
13	-17.046
14	...

m

$M_{50\_rDD} =$

	0
0	1324.953
1	830.275
2	-12878207.372
3	-12878207.372
4	-12878207.372
5	-12878207.372
6	-12878207.372
7	-12878207.372
8	-12878207.372
9	-12878207.372
10	-12878207.372
11	-12878207.372
12	-12878207.372
13	-12878207.372
14	...

kg

EMERGENT STRUCTURES SHALLOW WATER

$D_{n50\_rDS} =$

	0
0	0.828
1	0.692
2	-12.582
3	-12.582
4	-12.582
5	-12.582
6	-12.582
7	-12.582
8	-12.582
9	-12.582
10	-12.582
11	-12.582
12	-12.582
13	-12.582
14	...

m

$M_{50\_rDS} =$

	0
0	1473.714
1	862.271
2	-5178364.591
3	-5178364.591
4	-5178364.591
5	-5178364.591
6	-5178364.591
7	-5178364.591
8	-5178364.591
9	-5178364.591
10	-5178364.591
11	-5178364.591
12	-5178364.591
13	-5178364.591
14	...

k

$$\text{Which\_Van} := \text{for } i \in 0..\text{last}\left(\text{input}^{\langle 1 \rangle}\right)$$
$$\quad \text{Which\_Van}_i \leftarrow \text{"Deep water"} \quad \text{if } ht_i > 3 \cdot H_{s_i}$$
$$\quad \text{Which\_Van}_i \leftarrow \text{"Shallow water"} \quad \text{otherwise}$$

$$OM\_temp := \left| \begin{array}{l} \text{for } i \in 0..\text{last}\left(input^{\langle 1 \rangle}\right) \\ \quad \left| \begin{array}{l} a_{i,0} \leftarrow \left(input^{\langle 0 \rangle}\right)_i \\ a_{i,1} \leftarrow Which\_Van_i \\ a_{i,2} \leftarrow \left(\frac{ht}{3 \cdot H_s}\right)_i \\ a_{i,3} \leftarrow \frac{M_{50\_D_i}}{kg} \\ a_{i,4} \leftarrow \frac{M_{50\_S_i}}{kg} \\ a_{i,5} \leftarrow check\_1_i \\ a_{i,6} \leftarrow input_{i,9} \\ a_{i,7} \leftarrow \frac{M_{50\_rDD_i}}{kg} \\ a_{i,8} \leftarrow \frac{M_{50\_rDS_i}}{kg} \end{array} \right. \end{array} \right.$$

Re :=

"Defense Length"	"Which formula valid due to ht "	"Factor for ht/3Hs"	"M50 Deep W [kg]"	"M50_Shallow W [kg]"	"Che
$OM\_temp_{0,0}$	$OM\_temp_{0,1}$	$OM\_temp_{0,2}$	$OM\_temp_{0,3}$	$OM\_temp_{0,4}$	OM_
$OM\_temp_{1,0}$	$OM\_temp_{1,1}$	$OM\_temp_{1,2}$	$OM\_temp_{1,3}$	$OM\_temp_{1,4}$	OM_
$OM\_temp_{2,0}$	$OM\_temp_{2,1}$	$OM\_temp_{2,2}$	$OM\_temp_{2,3}$	$OM\_temp_{2,4}$	OM_
$OM\_temp_{3,0}$	$OM\_temp_{3,1}$	$OM\_temp_{3,2}$	$OM\_temp_{3,3}$	$OM\_temp_{3,4}$	OM_
$OM\_temp_{4,0}$	$OM\_temp_{4,1}$	$OM\_temp_{4,2}$	$OM\_temp_{4,3}$	$OM\_temp_{4,4}$	OM_
$OM\_temp_{5,0}$	$OM\_temp_{5,1}$	$OM\_temp_{5,2}$	$OM\_temp_{5,3}$	$OM\_temp_{5,4}$	OM_
$OM\_temp_{6,0}$	$OM\_temp_{6,1}$	$OM\_temp_{6,2}$	$OM\_temp_{6,3}$	$OM\_temp_{6,4}$	OM_
$OM\_temp_{7,0}$	$OM\_temp_{7,1}$	$OM\_temp_{7,2}$	$OM\_temp_{7,3}$	$OM\_temp_{7,4}$	OM_
$OM\_temp_{8,0}$	$OM\_temp_{8,1}$	$OM\_temp_{8,2}$	$OM\_temp_{8,3}$	$OM\_temp_{8,4}$	OM_
$OM\_temp_{9,0}$	$OM\_temp_{9,1}$	$OM\_temp_{9,2}$	$OM\_temp_{9,3}$	$OM\_temp_{9,4}$	OM_
$OM\_temp_{10,0}$	$OM\_temp_{10,1}$	$OM\_temp_{10,2}$	$OM\_temp_{10,3}$	$OM\_temp_{10,4}$	OM_
$OM\_temp_{11,0}$	$OM\_temp_{11,1}$	$OM\_temp_{11,2}$	$OM\_temp_{11,3}$	$OM\_temp_{11,4}$	OM_
$OM\_temp_{12,0}$	$OM\_temp_{12,1}$	$OM\_temp_{12,2}$	$OM\_temp_{12,3}$	$OM\_temp_{12,4}$	OM_
$OM\_temp_{13,0}$	$OM\_temp_{13,1}$	$OM\_temp_{13,2}$	$OM\_temp_{13,3}$	$OM\_temp_{13,4}$	OM_
$OM\_temp_{14,0}$	$OM\_temp_{14,1}$	$OM\_temp_{14,2}$	$OM\_temp_{14,3}$	$OM\_temp_{14,4}$	OM_
$OM\_temp_{15,0}$	$OM\_temp_{15,1}$	$OM\_temp_{15,2}$	$OM\_temp_{15,3}$	$OM\_temp_{15,4}$	OM_
$OM\_temp_{16,0}$	$OM\_temp_{16,1}$	$OM\_temp_{16,2}$	$OM\_temp_{16,3}$	$OM\_temp_{16,4}$	OM_
$OM\_temp_{17,0}$	$OM\_temp_{17,1}$	$OM\_temp_{17,2}$	$OM\_temp_{17,3}$	$OM\_temp_{17,4}$	OM_
$OM\_temp_{18,0}$	$OM\_temp_{18,1}$	$OM\_temp_{18,2}$	$OM\_temp_{18,3}$	$OM\_temp_{18,4}$	OM_
$OM\_temp_{19,0}$	$OM\_temp_{19,1}$	$OM\_temp_{19,2}$	$OM\_temp_{19,3}$	$OM\_temp_{19,4}$	OM_
$OM\_temp_{20,0}$	$OM\_temp_{20,1}$	$OM\_temp_{20,2}$	$OM\_temp_{20,3}$	$OM\_temp_{20,4}$	OM_
$OM\_temp_{21,0}$	$OM\_temp_{21,1}$	$OM\_temp_{21,2}$	$OM\_temp_{21,3}$	$OM\_temp_{21,4}$	OM_
$OM\_temp_{22,0}$	$OM\_temp_{22,1}$	$OM\_temp_{22,2}$	$OM\_temp_{22,3}$	$OM\_temp_{22,4}$	OM_
$OM\_temp_{23,0}$	$OM\_temp_{23,1}$	$OM\_temp_{23,2}$	$OM\_temp_{23,3}$	$OM\_temp_{23,4}$	OM_
$OM\_temp_{24,0}$	$OM\_temp_{24,1}$	$OM\_temp_{24,2}$	$OM\_temp_{24,3}$	$OM\_temp_{24,4}$	OM_
$OM\_temp_{25,0}$	$OM\_temp_{25,1}$	$OM\_temp_{25,2}$	$OM\_temp_{25,3}$	$OM\_temp_{25,4}$	OM_
$OM\_temp_{26,0}$	$OM\_temp_{26,1}$	$OM\_temp_{26,2}$	$OM\_temp_{26,3}$	$OM\_temp_{26,4}$	OM_
$OM\_temp_{27,0}$	$OM\_temp_{27,1}$	$OM\_temp_{27,2}$	$OM\_temp_{27,3}$	$OM\_temp_{27,4}$	OM_
$OM\_temp_{28,0}$	$OM\_temp_{28,1}$	$OM\_temp_{28,2}$	$OM\_temp_{28,3}$	$OM\_temp_{28,4}$	OM_
$OM\_temp_{29,0}$	$OM\_temp_{29,1}$	$OM\_temp_{29,2}$	$OM\_temp_{29,3}$	$OM\_temp_{29,4}$	OM_
$OM\_temp_{30,0}$	$OM\_temp_{30,1}$	$OM\_temp_{30,2}$	$OM\_temp_{30,3}$	$OM\_temp_{30,4}$	OM_

RESULTS TABLE FOR ARMOUR ROCK

The Van der Meer deep water formulae is viable when the water depth at the toe of the structure is larger than three times the significant wave height at the toe, otherwise the Van der Meer shallow water formula should be used. The formula which is valid is highlighted in table below. If the factor for ht/3Hs is almost 1 which formula is used should be carefully considered.

Re =

	0	1	2	3	4	5	6	7	8
0	efense Length"	alid due to ht "	ctor for ht/3Hs"	Deep W [kg]"	hallow W [kg]"	"Check EM "	"Rc (m)"	Em D W [kg]"	_Em S W [kg]"
1	_Killier-Goda"	Shallow water"	0.371	1347.586	1498.888	"OK"	1.82	1324.953	1473.714
2	lier-McCowan"	Shallow water"	0.439	791.341	821.837	T OF RANGE"	1.82	830.275	...

Project	Isles of Scilly Climate Adaptation	Calc no.	-	Project Engineer	MLO
Contract	DKR6499	Filename ref	-	Designer	-
Section	St. Agnes	Job No.	-	Department	Engineering
Subject	Overtopping over revetments in section 48&49 Periglis				

		Mathcad Made by	Date	Cal Made by	Date	Checked by	Date		
ORIGINAL		CCN	25 / 05 /11						
REV	2	Text updated for external use (18/10/11)							
REV	3	LBG	14/06/16	MLO	06/07/21				
REV				MLO	21/12/21	APO	22/12/21		
REV									
REV									
Superseded by Calculation no.					Date				

<u>Objective of Calculation:</u>

Check that the overtopping remains within the accepted limits.

<u>Description of Calculation:</u>

For this site is selected a cotg(α) of 4 to take account the slope of the beach and the revetment. The crest width (Gc) is set as 0 and the waves are perpendicular to the revetment. The crest is at +7.50 mOD and the overtopping is calculated at this crest. Also it is made another cases for overtopping considering the crest at +6.00 mOD. It is considered the protection as impermeable, so the friction coefficient is 0.9.

ENVIRONMENTAL DATA

Insert wave condition at structure toe, wave direction and water level in the table below:

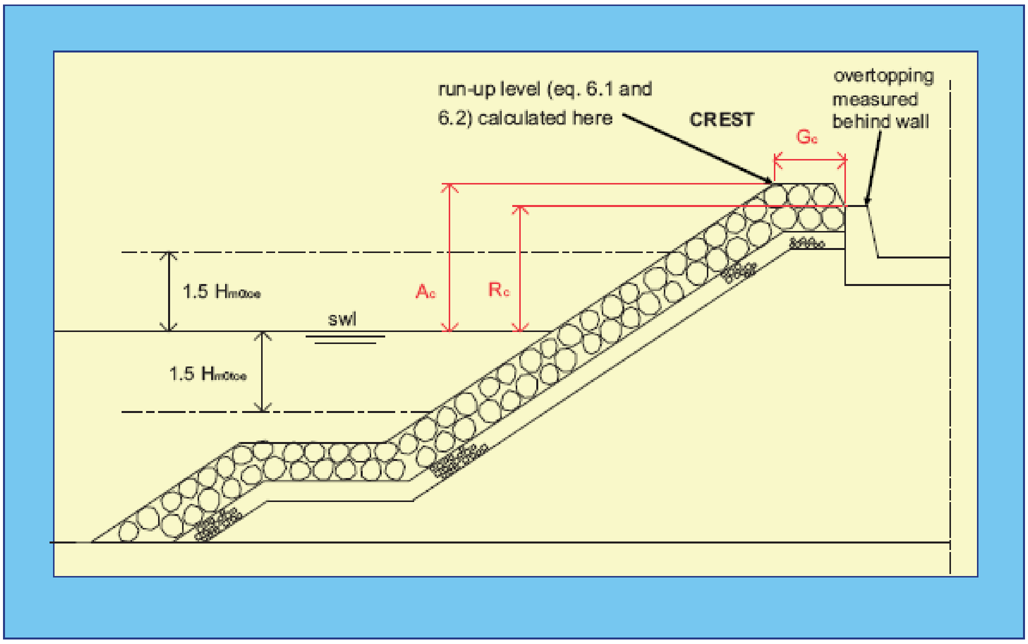


Figure 1: example of breakwater cross-section

Input data - wave conditions and structure parameters

Definition of input parameters:

Hm0	(m)	Significant wave height calculated from the spectrum, Hm0 = 4*sqrt(m0)
Tm-1,0	(s)	Mean energy wave period calculated from the spectrum, Tm-1,0 = m-1/m0. If not available assume Tm-1,0 = Tp/1.1
SWL	(mDatum)	Sea Water Level
Ncrest	(mDatum)	Crest level
Gc	(m)	Crest width
cotg(α)	(-)	Slope of the structure
γf	(-)	Friction coefficient
β	(deg)	Angle of wave attack

Input parameters values:

data :=

	0	1	2	3	4	5
0	""	"Hm0"	"Tm-1,0"	"SWL"	"Ncrest"	"
1	48_49_Case_1"	1.69	6.936	4.1	6	
2	48_49_Case_2"	0.86	6.936	4.1	6	
3	48_49_Case_3"	1.56	6.818	3.95	6	
4	48_49_Case_4"	0.72	6.818	3.95	6	
5	48_49_Case_1"	1.69	6.936	4.1	7.5	
6	48_49_Case_2"	0.86	6.936	4.1	7.5	
7	48_49_Case_3"	1.56	6.818	3.95	7.5	
8	48_49_Case_4"	0.72	6.818	3.95	7.5	
9	48_49_Case_5"	0.35	6.627	3.5	7.5	

Nb_cases := rows(data) − 1

Input_case := submatrix(data, 1, Nb_cases, 0, 0)

Hm0 := submatrix(data, 1, Nb_cases, 1, 1)

Tm10 := submatrix(data, 1, Nb_cases, 2, 2)

SWL := submatrix(data, 1, Nb_cases, 3, 3)

Ncrest := submatrix(data, 1, Nb_cases, 4, 4)

Gc := submatrix(data, 1, Nb_cases, 5, 5)

cotg := submatrix(data, 1, Nb_cases, 6, 6)

f := submatrix(data, 1, Nb_cases, 7, 7)

:= submatrix(data, 1, Nb_cases, 8, 8)

Definition of output parameters:

$$sm10 := \frac{2\cdot \quad \cdot Hm0}{9.81\cdot Tm10^{2}}$$

wave steepness (-)

Output parameters values:

sm10 =

	1
1	0.022
2	0.011
3	0.021
4	$9.92 \cdot 10^{-3}$
5	0.022
6	0.011
7	0.021
8	$9.92 \cdot 10^{-3}$
9	$5.104 \cdot 10^{-3}$
10	$4.134 \cdot 10^{-3}$

STRUCTURE AND MATERIAL PROPERTIES

BREAKWATER PARAMETERS

$Rc := Ncrest - SWL$ freeboard

$tg := \frac{1}{cotg}$ structure slope [tanα]

$m10 := \frac{tg}{sm10^{0.5}}$ Irribarren number

Rc =

	1
1	1.9
2	1.9
3	2.05
4	2.05
5	3.4
6	3.4
7	3.55
8	3.55
9	4
10	4.17

tg =

	1
1	0.125
2	0.125
3	0.125
4	0.125
5	0.125
6	0.125
7	0.125
8	0.125
9	0.125
10	0.125

m10 =

	1
1	0.833
2	1.168
3	0.853
4	1.255
5	0.833
6	1.168
7	0.853
8	1.255
9	1.75
10	1.944

COEFFICIENTS

Roughness (or friction) coefficient

Table 6.2 page 115 of the EurOtop (2007) suggests several values of f, depending on the type of armour layer. However in case of long waves and/or steep slopes ($m > 1.8$), or impermeable cores, the friction effect of the armour layer may reduce. The Irri
In those cases the EurOtp proposes a linear interpolation of f for values of m above 1.8, between its original value (f0) and its maximum value (1.0), thus increasing the resultant overtopping discharge. Indeed, most of the experimental data from which the formulae have been extracted are based on short period waves ($m < 1.8$), therefore many uncertaintes subsists for long waves and increasing the roughness coefficient is a conservative approach.

Do you want to take the effect of long waves and/or steep slopes into account?
Set Variable **Influence** = y if so, set to "n" otherwise.

Influence_ f := "y" **Yes or No**

ORIGIN := 1 Set the tables and arrays first index at 1

_f := for i ∈ 1 .. Nb_cases

$$\begin{aligned} &PROG\_output_i \leftarrow f_i \text{ if } m10_i < 1.8 \\ &PROG\_output_i \leftarrow f_i + (1 - f_i)\cdot\frac{m10_i - 1.8}{10 - 1.8} \text{ if } 1.8 < m10_i < 10 \\ &PROG\_output_i \leftarrow 1 \text{ otherwise} \\ &PROG\_output_i \leftarrow f_i \text{ if Influence\_ f = "n"} \end{aligned}$$

_f =

	1
1	0.8
2	0.8
3	0.8
4	0.8
5	0.8

final roughness coefficient

6	0.8
7	0.8
8	0.8
9	0.8
10	0.804

Oblique waves coefficient

Reduction coefficient

/! Please note that for wave approach angles beta>110 overtopping rates may be set to zero. However to ensure stability and convergence of the calcsheet a small value of 0.0005 is here considered as input

Do you want to take the effect of the angle of wave attack into account?
Set Variable **Influence** = y if so, set to "n" otherwise.

Influence_ := "y" **Yes or No**

_ := for i ∈ 1 .. Nb_cases

$PROG\_output_i \leftarrow 1 - 0.0033 \cdot (\ \ _i)$ if $0 \leq \ \ _i \leq 80$

$PROG\_output_i \leftarrow 1 - 0.0033 \cdot (|80|)$ if $80 \leq \ \ _i \leq 110$

$PROG\_output_i \leftarrow 0.0005$ otherwise

$PROG\_output_i \leftarrow 1$ if Influence_ = "n"

_ =

	1
1	1
2	1
3	1
4	1
5	1
6	1
7	1
8	1
9	1
10	1

oblique wave coefficient

***Linear reduction of {H_s;T_p} due to refraction for* 80<β<110**

/! Please consider if this is relevant to the geometry of your structure (see EurOtop section 5.3.3 and 6.3.3)

Reduction_coeff := for i ∈ 1 .. Nb_cases

$$\text{PROG\_output}_i \leftarrow \frac{110 - {}_i}{110 - 80} \quad \text{if } 80 \le {}_i \le 110$$

$$\text{PROG\_output}_i \leftarrow 0.00001 \quad \text{if } {}_i \ge 110$$

$$\text{PROG\_output}_i \leftarrow 1 \quad \text{otherwise}$$

$$\text{PROG\_output}_i \leftarrow 1 \quad \text{if Influence\_} = \text{"n"}$$

Please note that also in this case for wave approach angles beta>110 overtopping rates may be set to zero. However to ensure stability and convergence of the calcsheet a small value of 0.00001 is here considerd as input

Reduction_coeff =

	1
1	1
2	1
3	1
4	1
5	1
6	1
7	1
8	1
9	1
10	1

H_s reduction coefficient (T_p reduction coefficient = (H_s reduction coefficient)$^{0.5}$)

Hm0 =

	1
1	1.69
2	0.86
3	1.56
4	0.72
5	1.69
6	0.86
7	1.56
8	0.72
9	0.35
10	0.35

tan((Tm10)) =

	1
1	0.765
2	0.765
3	0.593
4	0.593
5	0.765
6	0.765
7	0.593
8	0.593
9	0.358
10	1.873

Reduced wave conditions

Crest width coefficient

WARNING

1) Crest width reduction factor to be used only for **rubble mound breakwater with permeable core**, therefore for smooth slopes such coefficients is to be set equal to 1. However, as sensitivity study, the user may decide to investigate the effect of a different crest width of the embankement or slope, in that case, please select the right value of Gc and set the variable Influence_Gc="y" (see below)

2) For long-period waves extra-precaution has to be taken

Do you want to use Crest reduction? if **not** please write Influence_Gc=**n** otherwise type **y** (or leave the field blank)

Influence_Gc := "y" **Yes or No**

Crest_reduction := for i ∈ 1 .. Nb_cases

$$Cr_i \leftarrow 3.06 \cdot \exp\left(-1.5 \cdot \frac{Gc_i}{Hm0_i}\right) \text{ if } \frac{Gc_i}{Hm0_i} > 0.75$$

$$Cr_i \leftarrow 1 \text{ otherwise}$$

$$Cr_i \leftarrow 1 \text{ if Influence\_Gc} = \text{"n"}$$

Crest_reduction =

	1
1	1
2	1
3	1
4	1
5	1
6	1
7	1
8	1
9	1

Crest width coefficient

10	1

BREAKING OR NON-BREAKING WAVES

$$
\begin{aligned}
Regime := \ & \text{for } i \in 1..Nb\_cases \\
& \quad PROG\_output_{i,1} \leftarrow m10_i \\
& \quad PROG\_output_{i,2} \leftarrow \text{"breaking / non-breaking"} \quad \text{if} \quad m10_i < 5 \\
& \quad PROG\_output_{i,2} \leftarrow \text{"interpolation"} \quad \text{if} \quad 5 < m10_i < 7 \\
& \quad PROG\_output_{i,2} \leftarrow \text{"shallow foreshores"} \quad \text{if} \quad m10_i > 7
\end{aligned}
$$

Regime =

	1	2
1	0.833	"breaking / non-breaking"
2	1.168	"breaking / non-breaking"
3	0.853	"breaking / non-breaking"
4	1.255	"breaking / non-breaking"
5	0.833	"breaking / non-breaking"
6	1.168	"breaking / non-breaking"
7	0.853	"breaking / non-breaking"
8	1.255	"breaking / non-breaking"
9	1.75	"breaking / non-breaking"
10	1.944	"breaking / non-breaking"

MEAN WAVE OVERTOPPING

$A := 0.067$ $B := 4.3$ $C := 0.2$ $D := 2.3$ $A1 := 0.21$ Coefficients for deterministic calculation of overtopping

The discharge are in l/s/m

$$q\_breaking := \text{for } i \in 1..Nb\_cases$$

$$PROG\_output_i \leftarrow 1000\,Crest\_reduction_i \cdot \sqrt{9.81 \cdot \left(Hm0_i\right)^3} \cdot \left[\left(\frac{A}{\sqrt{tg\ \ _i}}\right) \cdot \ m10_i \cdot e^{B \cdot \frac{Rc_i}{Hm0_i} \cdot \frac{-1}{m10_i \cdot \ \_f_i \cdot \ \_\ _i}}\right]$$

$$q\_non\_breaking := \text{for } i \in 1..Nb\_cases$$

$$PROG\_output_i \leftarrow 1000\,Crest\_reduction_i \cdot \sqrt{9.81 \cdot \left(Hm0_i\right)^3} \cdot C \cdot e^{\frac{1}{\_f_i \cdot \ \_\ _i} \cdot - D \cdot \frac{Rc_i}{Hm0_i}}$$

$$q\_breaking\_non\_breaking := \text{for } i \in 1..Nb\_cases$$

$$PROG\_output_i \leftarrow \min\left(q\_breaking_i, q\_non\_breaking_i\right)$$

$$q\_shallow\_foreshores := \text{for } i \in 1..Nb\_cases$$

$$PROG\_output_i \leftarrow 1000\,Crest\_reduction_i \cdot \sqrt{9.81 \cdot \left(Hm0_i\right)^3} \cdot A1 \cdot e^{\frac{-1}{\_f_i \cdot Hm0_i\ \ \_\ _i} \cdot \frac{Rc_i}{0.33+0.022 \cdot \ m10_i}}$$

q_breaking =

	1
1	0.771
2	0.021
3	0.249
4	$2.303 \cdot 10^{-3}$
5	$2.517 \cdot 10^{-3}$
6	$6.968 \cdot 10^{-6}$
7	$5.803 \cdot 10^{-4}$
8	$3.072 \cdot 10^{-7}$
9	$1.216 \cdot 10^{-13}$
10	$1.364 \cdot 10^{-12}$

q_non_breaking =

	1
1	54.318
2	0.871
3	27.91
4	0.107
5	4.234
6	$5.785 \cdot 10^{-3}$
7	1.759
8	$2.67 \cdot 10^{-4}$
9	$6.971 \cdot 10^{-13}$
10	$2.004 \cdot 10^{-13}$

q_breaking_non_breaking =

	1
1	0.771
2	0.021
3	0.249
4	$2.303 \cdot 10^{-3}$
5	$2.517 \cdot 10^{-3}$
6	$6.968 \cdot 10^{-6}$
7	$5.803 \cdot 10^{-4}$
8	$3.072 \cdot 10^{-7}$
9	$1.216 \cdot 10^{-13}$
10	$2.004 \cdot 10^{-13}$

q_shallow_foreshores =

	1
1	25.572
2	0.223
3	11.541
4	0.019
5	1.058
6	[illegible]

Regime =

	1	2
1	0.833	"breaking / non-breaking"
2	1.168	"breaking / non-breaking"
3	0.853	"breaking / non-breaking"
4	1.255	"breaking / non-breaking"
5	0.833	"breaking / non-breaking"
6	1.168	"breaking / non-breaking"
7	0.853	"breaking / non-breaking"
8	1.255	"breaking / non-breaking"
9	1.75	"breaking / non-breaking"
10	1.944	"breaking / non-breaking"

6	$4.853\cdot10^{-4}$
7	0.368
8	$1.316\cdot10^{-5}$
9	$1.984\cdot10^{-15}$
10	0

q_final := for i ∈ 1 .. Nb_cases

$PROG\_output_{i,1} \leftarrow q\_breaking\_non\_breaking_i$ if $Regime_{i,2}$ = "breaking / non-breaking"

if $Regime_{i,2}$ = "interpolation"

$$b_i \leftarrow \frac{7 - m10_i}{7 - 5}$$

$$PROG\_output_{i,1} \leftarrow b_i \cdot q\_breaking\_non\_breaking_i + (1 - b_i)\cdot q\_shallow\_foreshores_i$$

$PROG\_output_{i,1} \leftarrow q\_shallow\_foreshores_i$ if $Regime_{i,2}$ = "shallow foreshores"

FINAL TABLE

Results =

	0	1
0	"Input Case"	"Hm0"
1	"48_49_Case_1"	1.69
2	"48_49_Case_2"	0.86
3	"48_49_Case_3"	1.56
4	"48_49_Case_4"	0.72
5	"48_49_Case_1"	1.69
6	"48_49_Case_2"	0.86
7	"48_49_Case_3"	1.56
8	"48_49_Case_4"	0.72
9	"48_49_Case_5"	0.35
10	"48_49_Case_6"	...

COVER SHEET

Project	Isles of Scilly			
Contract	Design Services for Off Islands	Calc No.		1
Section	St Agnes - Site 48/49	File		
Subject	Geobags stability	Job No.	DKR6499	
Department	Engineering	Project Engineer		

	Total Sheets	Made by	Date	Checked by	Date			
ORIGINAL	1	APO	04/07/2021					
REV 1	1	MLO	22/02/2022	AGC	19/08/2022			
REV 2								
REV								
REV								
REV								
REV								

Superseded by Calculation No. Date

Subject: **Geobag calculation**

1 Assessment of the geobag dimensions

Assumptions:

The following assumptions have been used:

1. Waves cases 48_49_Case_2 and 48_49_Case_4 have been used for sensitivity
2. Crest level at +6.00 m OD
3. Initial design was done using waves at 0 m OD from JBA and crest level at +7.50 m OD

The more conservative initial design has been used for sizing the geobags

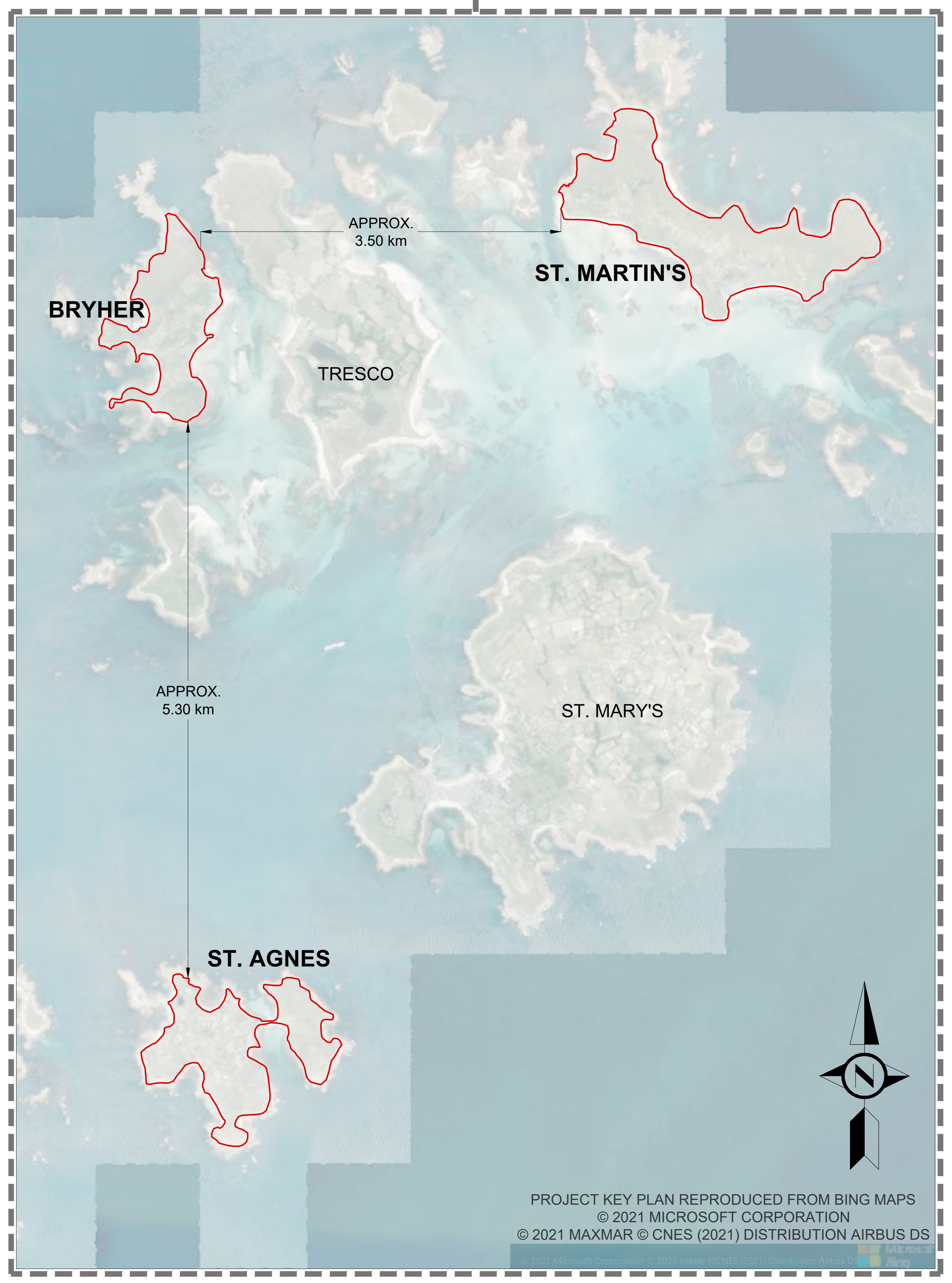
References

1. Pilarczyk, K.W., 1999, Geosynthetics and geosystems in hydraulic and coastal engineering,, A.A. Balkema Publisher,
Rotterdam, balkema@balkema.nl.
2. Oumeraci, Hocine & Hinz, M. & Bleck, M. & Kortenhaus, Andreas. (2003). Sand-filled Geotextile Containers for Shore Protection.

		Sensitivity cases	
	Initial design	**Case 2**	**Case 4**
Hs (m)	1.69	0.86	0.72
Tp (s)	7.73	6.94	6.82
L0 (m)	93.29	75.20	72.62
Crest Elevation (mODN)	7.5	6	6
SWL (mODN)	4.1	4.1	3.95
Rc (m)	3.4	1.9	2.05
Structure slope 1 in	1	1	1
Structure slope alfa	45	45	45
tan α (-)	1	1	1
ρw	1030	1030	1030
n	0.4	0.4	0.4
ρs	2650	2650	2650
ρE	2002	2002	2002
s	0.944	0.944	0.944
Irribarren	7.43	9.35	10.04
$N_{s,\ slope}$	1.01	0.90	0.87
$N_{s,\ crest}$	0.971065089	0.988837209	1.04625
SLOPE			
D	1.78	1.01	0.88
L (m)	2.51	1.43	1.24
W (m)	1.26	0.72	0.62
D(m)	0.50	0.29	0.25
weight (kg)	3167	589	385
Vmax (m3)	1.0	0.2	0.1
CREST			
D	1.84	0.92	0.73
L (m)	2.61	1.30	1.03
W (m)	1.30	0.65	0.52
D(m)	0.52	0.26	0.21
Run-up			
Ru (m)	16	10	9
OVERTOPPING			
q (l/s/m)	4	1	0

C Drawings

PROJECT KEY PLAN



PROJECT LOCATION MAP

NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS STATED OTHERWISE.

REV	DRAWING STATUS	DRN.	APPR.	AUTH.	DATE
02	ISSUED FOR REVIEW	EZA	AGC	AUO	20 JAN 22
01	ISSUED FOR REVIEW	MAA	APO	AGC	20 AUG 21

CLIENT:

THE COUNCIL OF THE ISLES OF SCILLY

MARINE CONSULTANT:

HR Wallingford
Working with water
www.hrwallingford.com

HR Wallingford
Howbery Park, Wallingford
Oxfordshire OX10 8BA
United Kingdom

Tel: +44(0)1491 835381
Fax: +44(0)1491 832233

PROJECT:

ISLES OF SCILLY DESIGN SERVICES FOR OFF ISLANDS COASTAL EROSION DEFENCE AND DUNE MANAGEMENT

DRAWING TITLE:

PROJECT LOCATION MAP

SCALE: NTS

SHEET SIZE: A1

DRAWING No: DKR6499-000-D101

REV: 02

GENERAL

1. ALL DIMENSIONS ARE IN METRES UNLESS STATED OTHERWISE.
2. HORIZONTAL DATUM IS REFERENCED TO OSGB 1936 BRITISH NATIONAL GRID.
3. VERTICAL DATUM IS IN METRES, ORDNANCE DATUM.
4. SETTING OUT POINTS TO BE AGREED FOLLOWING DETAILED SURVEYS.

ROCK ARMOUR

ROCK GRADINGS ARE STANDARD GRADINGS AS DEFINED IN BS EN 13383-1 SECTION 4.2. IMPORTED ROCK SHALL BE SUPPLIED IN THE STANDARD GRADING CLASS WITH THE ASSOCIATED LIMITS AS DEFINED BELOW FOR THE RESPECTIVE GRADINGS . THE PARTICLE DENSITY SHALL BE NO LESS THAN 2600 kg/m³

40 - 200 kg

- ELL - THE MASS BELOW WHICH NO MORE THAN 5 AND 2 PERCENT PASSING BY MASS IS PERMITTED FOR HEAVY AND LIGHT/COARSE GRADINGS, RESPECTIVELY = 15 kg
- NLL - THE MASS BELOW WHICH NO MORE THAN 10 PER CENT PASSING BY MASS IS PERMITTED = 40 kg
- NUL - THE MASS BELOW WHICH NO LESS THAN 70 AND 90 PERCENT PASSING BY MASS IS PERMITTED FOR HEAVY/LIGHT AND COARSE GRADINGS, RESPECTIVELY = 200 kg
- EUL - THE MASS BELOW WHICH NO LESS THAN 97 AND 98 PERCENT PASSING BY MASS IS PERMITTED FOR HEAVY/LIGHT AND COARSE GRADINGS, RESPECTIVELY = 300 kg
- THE EFFECTIVE MEAN MASS, MEM (LOWER AND UPPER LIMITS) = 80 kg - 120 kg

1.0 - 3.0 T

- ELL - THE MASS BELOW WHICH NO MORE THAN 5 AND 2 PERCENT PASSING BY MASS IS PERMITTED FOR HEAVY AND LIGHT/COARSE GRADINGS, RESPECTIVELY = 700 kg
- NLL - THE MASS BELOW WHICH NO MORE THAN 10 PERCENT PASSING BY MASS IS PERMITTED = 1,000 kg
- NUL - THE MASS BELOW WHICH NO LESS THAN 70 AND 90 PERCENT PASSING BY MASS IS PERMITTED FOR HEAVY/LIGHT AND COARSE GRADINGS, RESPECTIVELY = 3,000 kg
- EUL - THE MASS BELOW WHICH NO LESS THAN 97 AND 98 PERCENT PASSING BY MASS IS PERMITTED FOR HEAVY/LIGHT AND COARSE GRADINGS, RESPECTIVELY = 4,500 kg
- THE EFFECTIVE MEAN MASS, MEM (LOWER AND UPPER LIMITS) = 1,700 kg - 2,100 kg

WHERE ROCK IS TO BE LOCALLY SOURCED THE ROCK SHALL ONLY BE USED WITH APPROVAL FROM THE ENGINEER AND THE FOLLOWING SHALL APPLY FOR INDIVIDUAL ROCKS;

- M MIN - 500 kg
- M MAX - 5000 kg

ARMOUR ROCK SHALL BE INDIVIDUALLY PLACED TO ACHIEVE A DENSE, FULLY INTERLOCKED ARMOURED SLOPE SO THAT EACH ROCK IS SECURELY HELD IN PLACE BY ITS NEIGHBOURS. PLACING SHALL COMMENCE AT THE TOE AND PROCEED UPWARDS TOWARDS THE CREST. ROCKS SHALL BE LOWERED INTO PLACE INDIVIDUALLY.

TIDE TABLE

TIDE LEVELS mOD	
HAT	+3.40m
MHWS	+2.77m
MHWN	+1.44m
MLWN	-0.87m
MLWS	-2.18m
LAT	-2.82m

GEOTEXTILE

HPS12 OR EQUIVALENT

NONWOVEN GEOTEXTILE, STATIC PUNCTURE (CBR) 4 KN, PUSH THROUGH DISPLACEMENT 65 MM, TENSILE STRENGTH (MD/CMD) 25 KN/M, TENSILE ELONGATION (MD/CMD) 80%, CONE DROP 5 MM, PERMEABILITY M/S.

CHARACTERISTICS OF GEOTEXTILES SHALL BE DEFINED AND TESTED IN ACCORDANCE WITH BS EN 13253:2014. THE LABELLING OF THE ROLLS SHALL BE IN ACCORDANCE WITH EN 10320:1999.

FABRICS SHALL CONFORM TO THE FOLLOWING REQUIREMENTS:

- THE MATERIAL SHALL NOT SUFFER ANY SIGNIFICANT CHANGE TO ITS PHYSICAL, CHEMICAL OR ENGINEERING PROPERTIES UNDER THE INFLUENCE OF SULPHATES, CHLORIDES, ACIDS AND ALKALIS IN THE FORMS AND CONCENTRATIONS IN WHICH THEY ARE PRESENT IN THE SOILS, SEAWATER AND GROUND WATER TO BE FOUND AT THE WORKSITE.
- THE MATERIAL SHALL BE PROOF AGAINST BACTERIAL ATTACK.
- THE MARINE CONTRACTOR SHALL ENSURE THAT FILTER FABRIC IS NOT EXPOSED TO DIRECT SUNLIGHT FOR MORE THAN THE NUMBER OF DAYS WRITTEN IN THE GEOTEXTILE CE CERTIFICATE IN ACCORDANCE WITH EN 13253:2014 ANNEX B, OR A MAXIMUM OF ONE DAY IF NOT TESTED.
- THE MATERIAL SHALL PERFORM ACCORDING TO SPECIFICATION AT WORKING TEMPERATURES UP TO 55ºC. IT SHALL NOT BE PERMANENTLY IMPAIRED BY TEMPORARY EXPOSURE DURING CONSTRUCTION TO TEMPERATURES UP TO 60ºC.
- FILTER FABRICS SHALL BE SUPPLIED IN ROLLS AT LEAST 4.5 M WIDE. ROLL LENGTHS SHALL BE SUCH THAT THEY CAN BE LAID IN ONE OPERATION WITHOUT JOINTING, IN EACH OF THE SEPARATE SLOPING AND HORIZONTAL LENGTHS INVOLVED. ROLLS OF APPROPRIATE LENGTHS SHALL BE SUPPLIED FOR THIS PURPOSE.

FILTER FABRIC SHALL BE PLACED AND LAPPED IN ACCORDANCE WITH THE MANUFACTURER'S RECOMMENDATIONS. LAPS SHALL HAVE A MINIMUM WIDTH OF 1.0 M. WHERE THE FABRIC ABUTS A STRUCTURE, IT SHALL BE FOLDED UP AGAINST THE STRUCTURE BY A MINIMUM OF ONE LAP WIDTH. FILTER FABRIC SHALL BE SECURELY FASTENED DURING PLACING. GROUND ON WHICH FILTER FABRIC IS TO BE PLACED SHALL NOT CONTAIN UNDULATIONS WHICH MIGHT CAUSE DAMAGE TO THE FABRIC DURING PLACEMENT OF ROCK

ROCK BAGS

TYPE SPS 2T ROCK BAGS, SALIX AQUABAG OR SIMILAR APPROVED. MESH SIZE 25mm ; ROCK DIAMETER 40 - 80mm; DIAMETER = 2.1m; HEIGHT = 0.55m; VOLUME = 2.5m³; PARTICLE DENSITY MIN 2600 kg/m³.

GEOBAGS

GB600 WOVEN GEOBAGS WITH LIFTING STRAPS BY TENCATE OR SIMILAR APPROVED. OVERLAPPING PLACEMENT OF THE BAGS IS RECOMMENDED. GUIDELINES ON THE METHOD OF PLACEMENT WILL BE PROVIDED BY THE SUPPLIER.

FILL TO BE CLEAN AND SIEVED SITE WON SAND

GEOMAT

TENCATE GEOLON® ROBULON PP60 OR SIMILAR APPROVED. THE PRODUCT SHOULD BE MADE OF 100% HIGHLY DURABLE AND UV RESISTANT PP, WITH A 3 DIMENSIONAL STRUCTURE. THE MATT WILL BE PINNED FOR INSTALLATION AND 300mm COVER TO BE PROVIDED FOR PEDESTRIAN TRAFFIC.

REV	DRAWING STATUS	DRN.	APPR.	AUTH.	DATE
03	ISSUED FOR APPROVAL	PGU	AGC	AUO	11 JUL 22
02	ISSUED FOR REVIEW	EZA	AGC	AUO	20 JAN 22
01	ISSUED FOR REVIEW	MAA	APO	AGC	20 AUG 21

CLIENT:

THE COUNCIL OF THE ISLES OF SCILLY

MARINE CONSULTANT:

HR Wallingford
Working with water
www.hrwallingford.com

HR Wallingford
Howbery Park, Wallingford
Oxfordshire OX10 8BA
United Kingdom

Tel: +44(0)1491 835381
Fax: +44(0)1491 832233

PROJECT:

ISLES OF SCILLY DESIGN SERVICES FOR OFF ISLANDS COASTAL EROSION DEFENCE AND DUNE MANAGEMENT

DRAWING TITLE:

GENERAL NOTES

SCALE: NTS

SHEET SIZE: A1

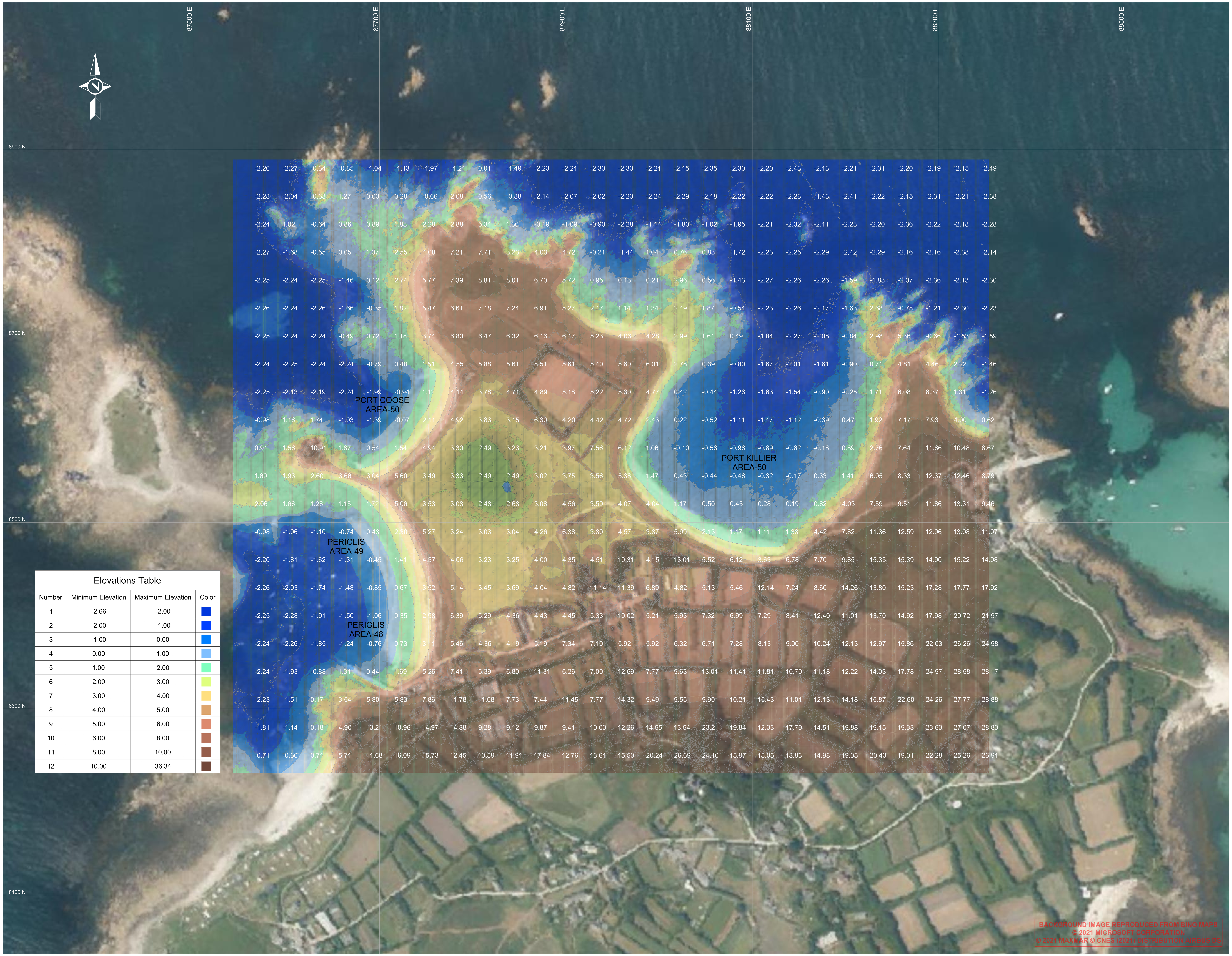
DRAWING No: DKR6499-000-D102

REV: 03

\\hrw-uk.local\projects\live\dkr6499\5_deliverables\drawings\Current Drawings\DKR6499-000-D102 [02]_General Notes_01.dwg

PGU

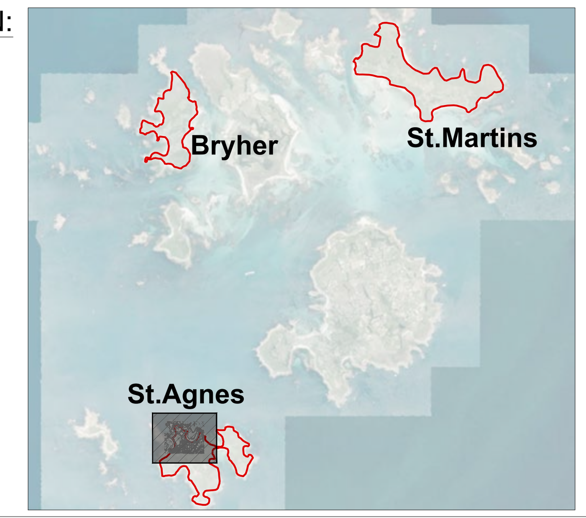
08/07/22



Elevations Table

Number	Minimum Elevation	Maximum Elevation	Color
1	-2.66	-2.00	
2	-2.00	-1.00	
3	-1.00	0.00	
4	0.00	1.00	
5	1.00	2.00	
6	2.00	3.00	
7	3.00	4.00	
8	4.00	5.00	
9	5.00	6.00	
10	6.00	8.00	
11	8.00	10.00	
12	10.00	36.34	

KEY PLAN:



NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS STATED OTHERWISE.
2. HORIZONTAL DATUM IS REFERENCED TO OSGB 1936 BRITISH NATIONAL GRID.
3. VERTICAL DATUM IS IN METRES, ORDNANCE DATUM.
4. LIDAR SURVEY PROVIDED BY DEFRA, SURVEY DATED 18th SEPTEMBER 2018.

TIDE LEVELS	
mOD	
HAT	+3.40m
MHWS	+2.77m
MHWN	+1.44m
MLWN	-0.87m
MLWS	-2.18m
LAT	-2.82m

0 20 40 60 80 100m
SCALE 1:2000

REV	DRAWING STATUS	DRN.	APPR.	AUTH.	DATE
02	ISSUED FOR REVIEW	EZA	AGC	AUO	20 JAN 22
01	ISSUED FOR REVIEW	MAA	APO	AGC	20 AUG 21

CLIENT:

THE COUNCIL OF THE ISLES OF SCILLY

MARINE CONSULTANT:

HR Wallingford
Working with water
www.hrwallingford.com

HR Wallingford
Howbery Park, Wallingford
Oxfordshire OX10 8BA
United Kingdom

Tel: +44(0)1491 835381
Fax: +44(0)1491 832233

PROJECT:

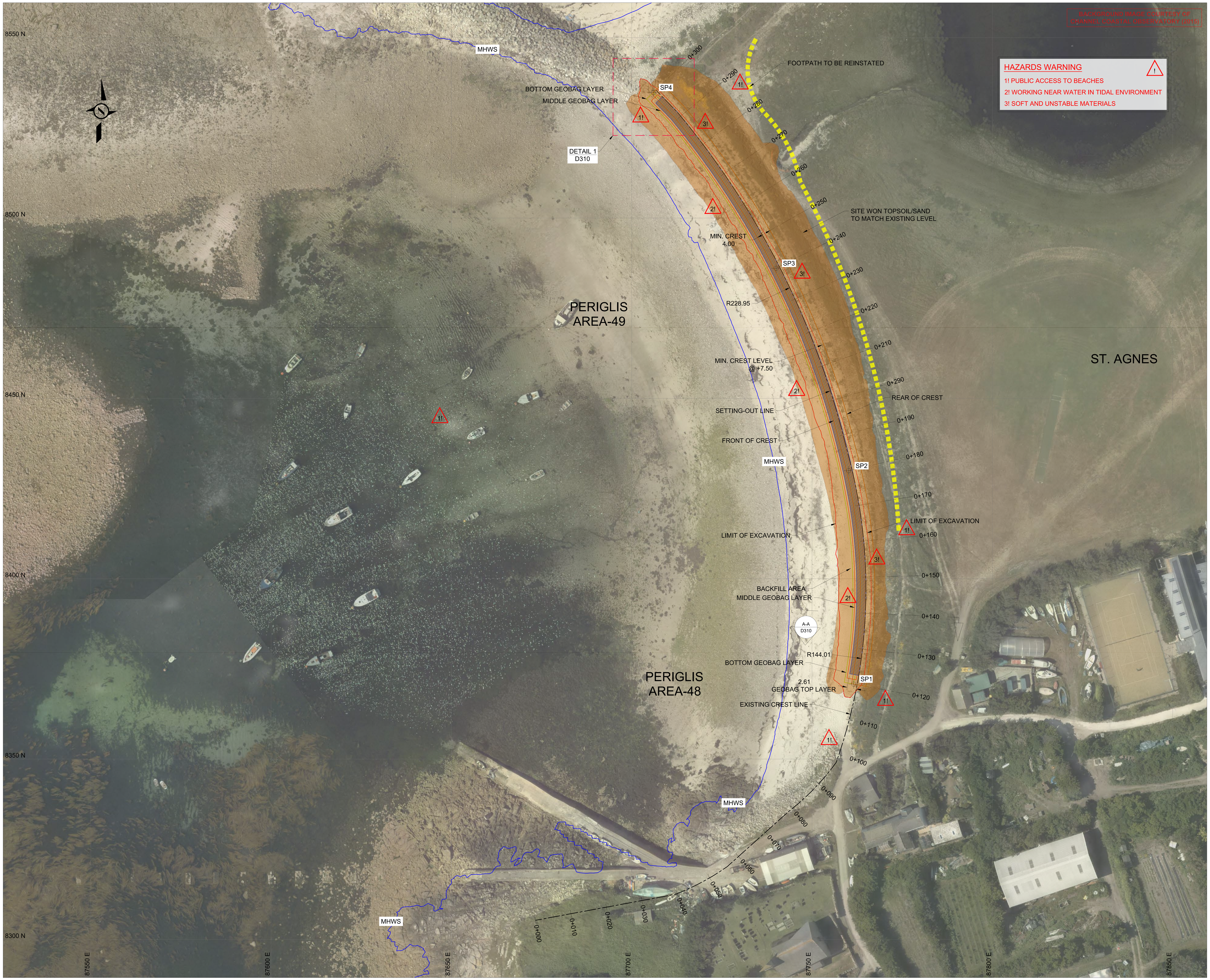
**ISLES OF SCILLY
DESIGN SERVICES FOR OFF ISLANDS
COASTAL EROSION DEFENCE AND
DUNE MANAGEMENT**

DRAWING TITLE:

LIDAR SURVEY LAYOUT
ST. AGNES

SCALE: 1:2000 SHEET SIZE: A1

DRAWING No: DKR6499-000-D103 REV: 02



KEY PLAN:

NOTES:

1. ALL DIMENSIONS ARE IN METRES UNLESS STATED OTHERWISE.
2. HORIZONTAL DATUM IS REFERENCED TO OSGB 1936 BRITISH NATIONAL GRID.
3. VERTICAL DATUM IS IN METRES, ORDNANCE DATUM.
4. SETTING OUT POINTS TO BE AGREED FOLLOWING DETAILED SURVEYS.
5. FOR GENERAL NOTES REFER TO DRAWING No. DKR6499-000-D102.
6. FOR TYPICAL SECTIONS REFER TO DRAWING No. DKR6499-110-D310.
7. BACKGROUND IMAGE REPRODUCED FROM BING MAPS, © 2021 MICROSOFT.

LEGEND:

- FILL
- GEOBAG
- FOOTPATH
- MHWS= 2.77 mOD

SP	Easting	Northing	Elevation
SP1	87.7615	8.3708	7.500
SP2	87.7601	8.4299	7.500
SP3	87.7400	8.4861	7.500
SP4	87.7060	8.5348	7.500

0 5 10 15 20 25m
SCALE 1:500

REV	DRAWING STATUS	DRN.	APPR.	AUTH.	DATE
01	ISSUED FOR APPROVAL	WST	AGC	AUO	14 SEP 22

CLIENT:

THE COUNCIL OF THE ISLES OF SCILLY

MARINE CONSULTANT:

HR Wallingford
Working with water
www.hrwallingford.com

HR Wallingford
Howbery Park, Wallingford
Oxfordshire OX10 8BA
United Kingdom

Tel: +44(0)1491 835381
Fax: +44(0)1491 832233

PROJECT:

ISLES OF SCILLY DESIGN SERVICES FOR OFF ISLANDS COASTAL EROSION DEFENCE AND DUNE MANAGEMENT

DRAWING TITLE:

ST. AGNES 48&49 PERIGLIS GENERAL ARRANGEMENT LAYOUT

SCALE: 1:500

SHEET SIZE: A1

DRAWING No: DKR6499-110-D110

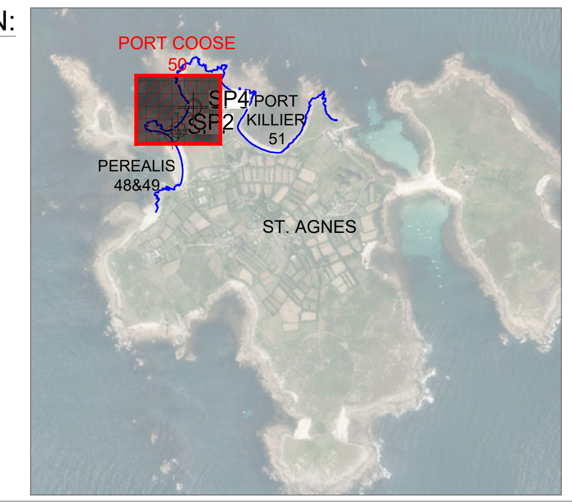
REV: 01

\\hrw-uk.local\projects\live\dkr6499\5_deliverables\drawings\Current Drawings\DKR6499-110-D110 [01]_General Arrangement-St.Agnes-Periglis 48&49_00_0.3.dwg

WST

14/09/22

KEY PLAN:



NOTES:

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2. HORIZONTAL DATUM IS REFERENCED TO OSGB 1936 BRITISH NATIONAL GRID.
3. VERTICAL DATUM IS IN METRES, ORDNANCE DATUM.
4. SETTING OUT POINTS TO BE AGREED FOLLOWING DETAILED SURVEYS.
5. FOR GENERAL NOTES REFER TO DRAWING No. DKR6499-000-D102.
6. FOR TYPICAL SECTIONS REFER TO DRAWING No. DKR6499-110-D320.
7. BACKGROUND IMAGE REPRODUCED FROM BING MAPS, © 2021 MICROSOFT.

LEGEND:

- GEOMAT
- ROCK BAG
- FOOTPATH
- MHWS

SP	Easting	Northing	Elevation
SP1	87.7023	8.5400	7.300
SP2	87.7247	8.5560	7.300
SP3	87.7851	8.6404	7.300
SP4	87.7859	8.6479	7.300

REV	DRAWING STATUS	DRN.	APPR.	AUTH.	DATE
01	ISSUED FOR APPROVAL	PGU	AGC	AUO	09 SEP 22

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HR Wallingford
Working with water
www.hrwallingford.com

HR Wallingford
Howbery Park, Wallingford
Oxfordshire OX10 8BA
United Kingdom

Tel: +44(0)1491 835381
Fax: +44(0)1491 832233

PROJECT:

ISLES OF SCILLY DESIGN SERVICES FOR OFF ISLANDS COASTAL EROSION DEFENCE AND DUNE MANAGEMENT

DRAWING TITLE:

ST. AGNES 50 - PORT COOSE - GENERAL ARRANGEMENT LAYOUT

SCALE: 1:500

SHEET SIZE: A1

DRAWING No: DKR6499-110-D111

REV: 01

\\hrw-uk.local\projects\live\dkr6499\5_deliverables\drawings\Current Drawings\DKR6499-110-D111 [02]_General Arrangement-St.Agnes-Port Coose 50_00_0.1.dwg

PGU

09/09/22

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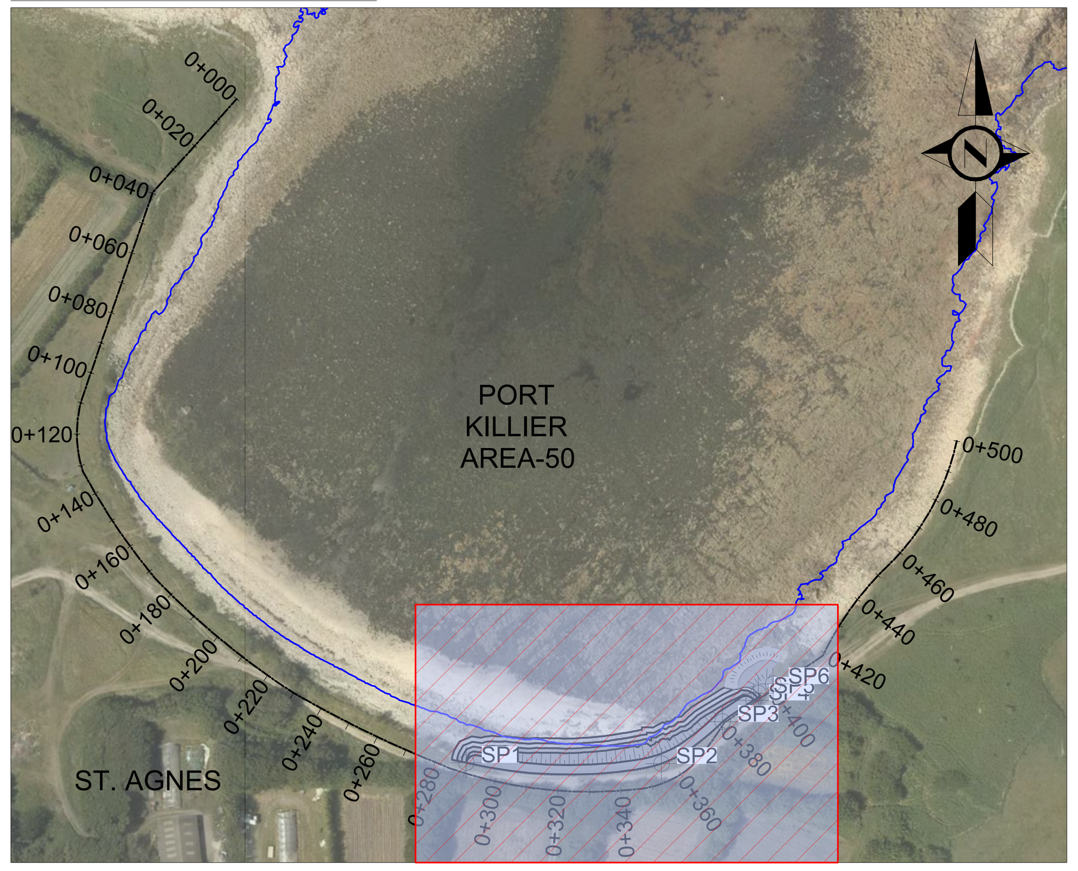
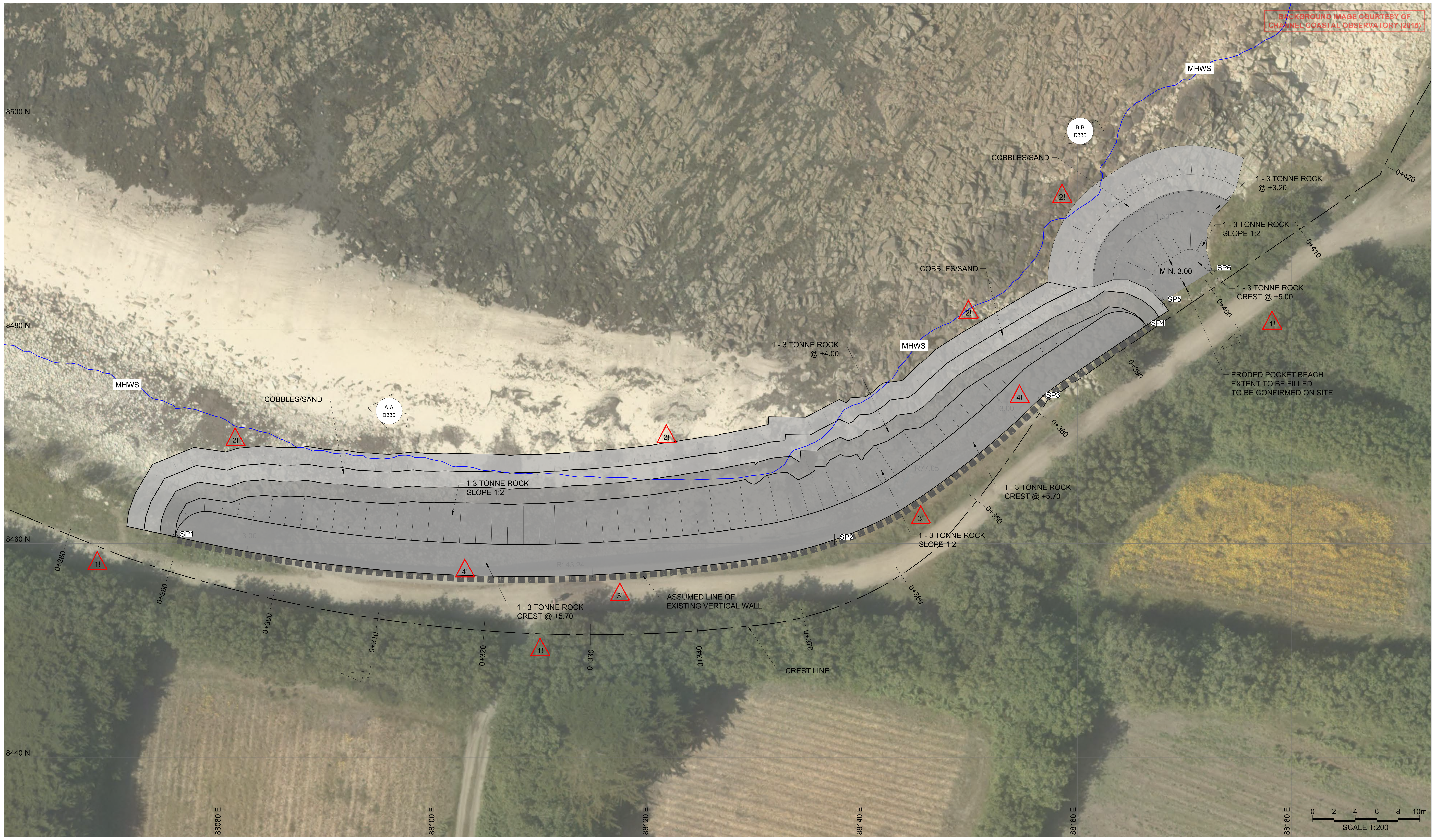
LOCATION PLAN:



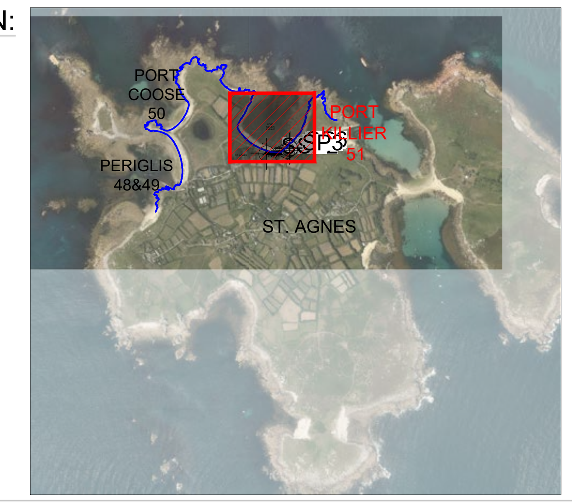
0 20 40 60 80 100m
SCALE 1:2000

HAZARDS WARNING

1! PUBLIC ACCESS TO BEACHES
2! WORKING NEAR WATER IN TIDAL ENVIRONMENT
3! UNKNOWN DETAIL OF EXISTING WALL
4! LARGE ROCKS & VOIDS



KEY PLAN:



NOTES:

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3. VERTICAL DATUM IS IN METRES, ORDNANCE DATUM.
4. SETTING OUT POINTS TO BE AGREED FOLLOWING DETAILED SURVEYS.
5. FOR GENERAL NOTES REFER TO DRAWING No. DKR6499-000-D102.
6. FOR TYPICAL SECTIONS REFER TO DRAWING No. DKR6499-110-D330.
7. BACKGROUND IMAGE REPRODUCED FROM BING MAPS, © 2021 MICROSOFT.

LEGEND:

- COBBLE/SAND
- 1 - 3 TONNE ROCK
- ASSUMED WALL LINE
- MHWS= 2.77 mOD

SP	Easting	Northing	Elevation
SP1	88.0756	8.4606	5.000
SP2	88.1373	8.4604	5.000
SP3	88.1566	8.4736	5.000
SP4	88.1664	8.4804	5.000
SP5	88.1679	8.4826	5.700
SP6	88.1726	8.4856	5.700

0 2 4 6 8 10m
SCALE 1:200

REV	DRAWING STATUS	DRN.	APPR.	AUTH.	DATE
01	ISSUED FOR APPROVAL	PGU	AGC	AUO	09 SEP 22

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MARINE CONSULTANT:

HR Wallingford
Working with water
www.hrwallingford.com

HR Wallingford
Howbery Park, Wallingford
Oxfordshire OX10 8BA
United Kingdom

Tel: +44(0)1491 835381
Fax: +44(0)1491 832233

PROJECT:

**ISLES OF SCILLY
DESIGN SERVICES FOR OFF ISLANDS
COASTAL EROSION DEFENCE AND
DUNE MANAGEMENT**

DRAWING TITLE:

ST. AGNES 51 - PORT KILLIER
GENERAL ARRANGEMENT LAYOUT

SCALE: AS SHOWN
SHEET SIZE: A1

DRAWING No: DKR6499-110-D112
REV: 01

\\hrw-uk.local\projects\live\dkr6499\5_deliverables\drawings\Current Drawings\DKR6499-110-D112 [02]_General Arrangement-St.Agnes-Port Killier 51_00_0.2.dwg

PGU

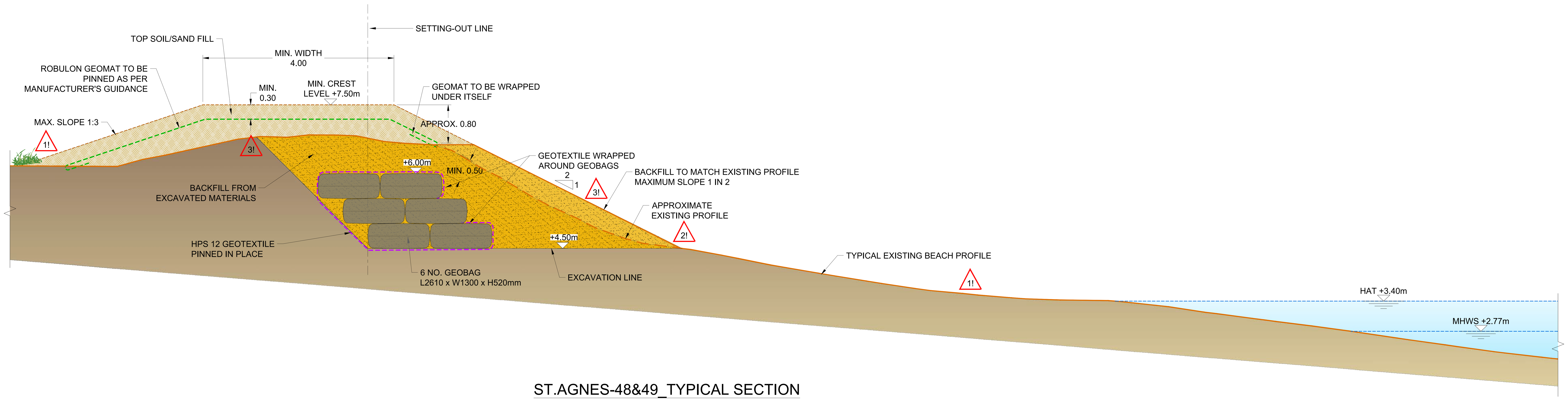
09/09/22

HAZARDS WARNING

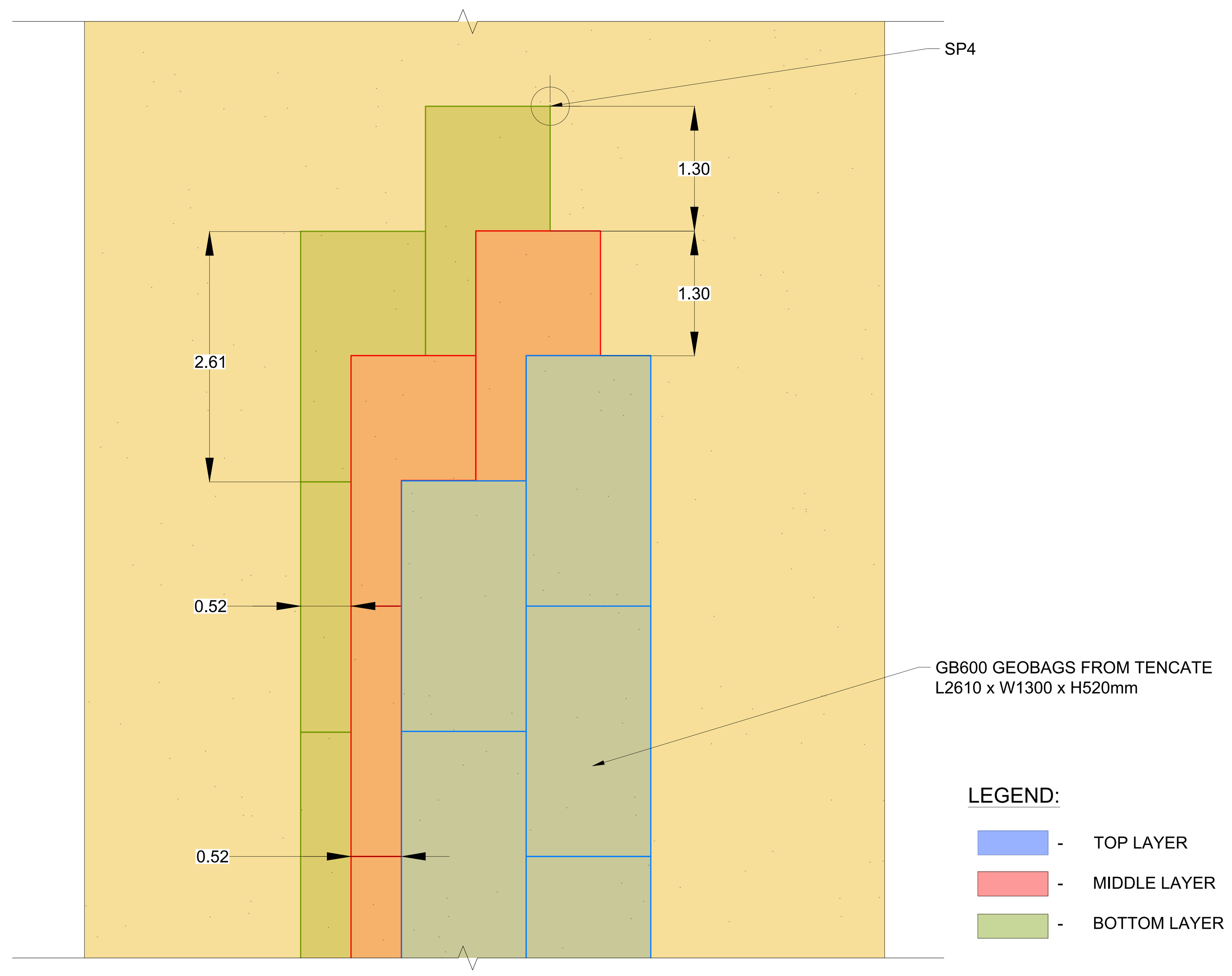
1! PUBLIC ACCESS TO BEACHES

2! WORKING NEAR WATER IN TIDAL ENVIRONMENT

3! SOFT AND UNSTABLE MATERIALS

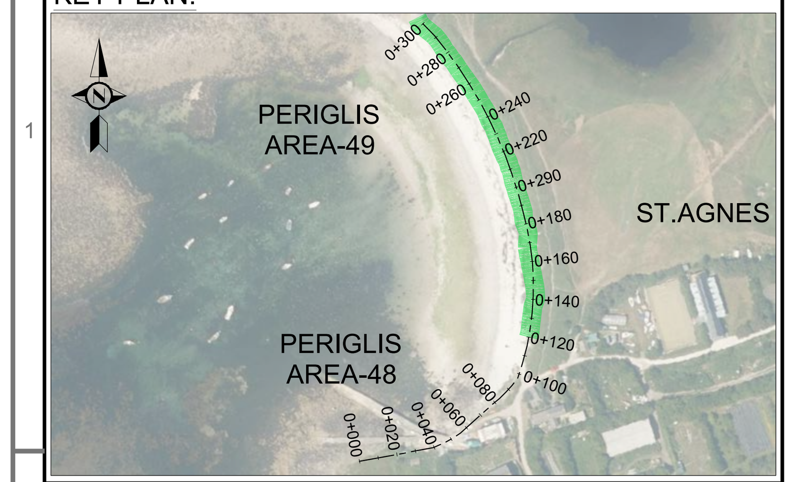


ST.AGNES-48&49_TYPICAL SECTION
From Ch.0+140



DETAIL 1
SCALE: 1:50

KEY PLAN:



NOTES:

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2. HORIZONTAL DATUM IS REFERENCED TO OSGB 1936 BRITISH NATIONAL GRID.
3. VERTICAL DATUM IS IN METRES, ORDNANCE DATUM.
4. BACKGROUND IMAGE REPRODUCED FROM BING MAPS, © 2021 MICROSOFT.
5. SETTING OUT POINTS TO BE AGREED FOLLOWING DETAILED SURVEYS.
6. ALL LEVELS TO BE CONFIRMED FOLLOWING ON SITE SURVEY.
7. FOR GENERAL NOTES REFER TO DRAWING No. DKR6499-000-D102.
8. FOR GENERAL ARRANGEMENT LAYOUT REFER TO DRAWING No. DKR6499-110-D110.

TIDE LEVELS	
	mOD
HAT	+3.40m
MHWS	+2.77m
MHWN	+1.44m
MLWN	-0.87m
MLWS	-2.18m
LAT	-2.82m

0 0.5 1 1.5 2 2.5m

SCALE 1:50

REV	DRAWING STATUS	DRN.	APPR.	AUTH.	DATE
01	ISSUED FOR APPROVAL	PGU	AGC	AUO	09 SEP 22

CLIENT:

THE COUNCIL OF THE ISLES OF SCILLY

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HR Wallingford
Working with water
www.hrwallingford.com

HR Wallingford
Howbery Park, Wallingford
Oxfordshire OX10 8BA
United Kingdom

Tel: +44(0)1491 835381
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PROJECT:

ISLES OF SCILLY DESIGN SERVICES FOR OFF ISLANDS COASTAL EROSION DEFENCE AND DUNE MANAGEMENT

DRAWING TITLE:

ST. AGNES - PERIGLIS 48&49 - TYPICAL SECTION AND DETAIL

SCALE: 1:50

SHEET SIZE: A1

DRAWING No: DKR6499-110-D310

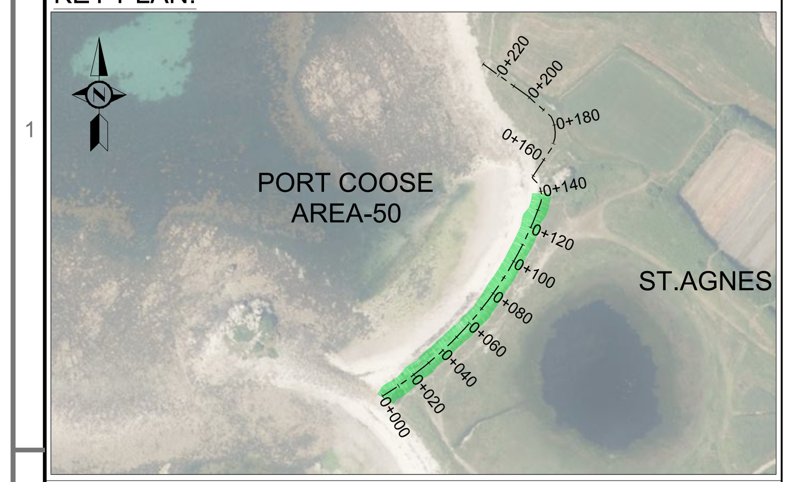
REV: 01

\\hrw-uk.local\projects\live\dkr6499\5_deliverables\drawings\Current Drawings\DKR6499-110-D310 [02]_St.Agnes-Periglis 48&49-Ridge Protection Typical Section_00_0.1.dwg

PGU

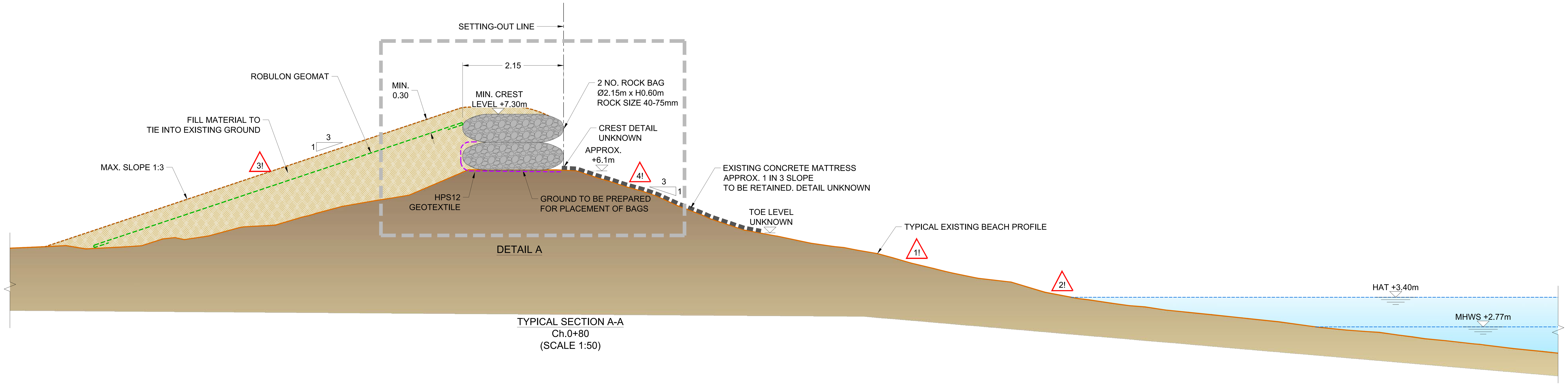
09/09/22

KEY PLAN:



HAZARDS WARNING

1! PUBLIC ACCESS TO BEACHES
2! WORKING NEAR WATER IN TIDAL ENVIRONMENT
3! SOFT AND UNSTABLE MATERIALS
4! UNKNOWN DETAIL OF EXISTING SLOPE PROTECTION.

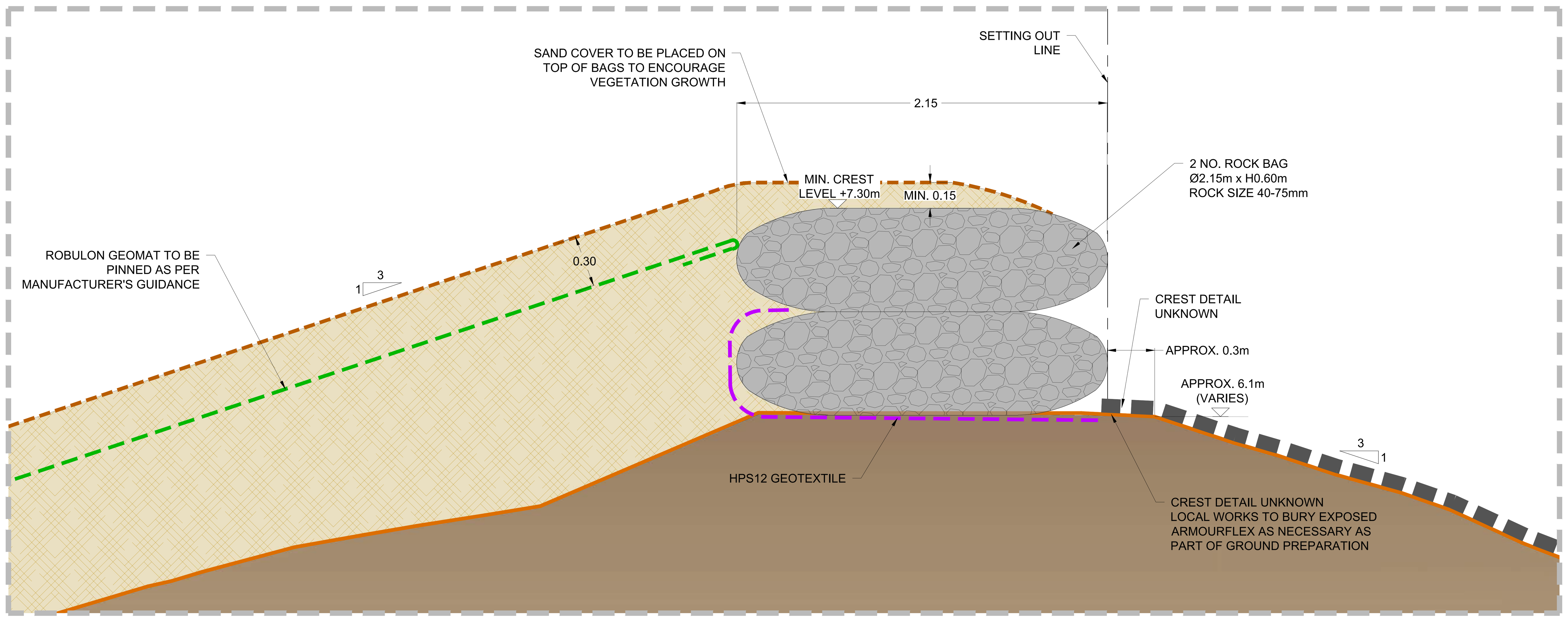


TYPICAL SECTION A-A
Ch.0+80
(SCALE 1:50)

TIDE LEVELS	
mOD	
HAT	+3.40m
MHWS	+2.77m
MHWN	+1.44m
MLWN	-0.87m
MLWS	-2.18m
LAT	-2.82m

0 0.2 0.4 0.6 0.8 1m
SCALE 1:20

0 0.5 1 1.5 2 2.5m
SCALE 1:50



DETAIL A
(SCALE 1:20)

NOTES:

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4. BACKGROUND IMAGE REPRODUCED FROM BING MAPS, © 2021 MICROSOFT.
5. SETTING OUT POINTS TO BE AGREED FOLLOWING DETAILED SURVEYS.
6. ALL LEVELS TO BE CONFIRMED FOLLOWING ON SITE SURVEY.
7. FOR GENERAL NOTES REFER TO DRAWING No. DKR6499-000-D102.
8. FOR GENERAL ARRANGEMENT LAYOUT REFER TO DRAWING No. DKR6499-110-D111.
9. ROCK BAGS TO BE 2 TONNE SALIX ROCK BAGS OR SIMILAR APPROVED PRODUCT TO BE PREFILLED.

REV	DRAWING STATUS	DRN.	APPR.	AUTH.	DATE
01	ISSUED FOR APPROVAL	PGU	AGC	AUO	09 SEP 22

CLIENT:
THE COUNCIL OF THE ISLES OF SCILLY

MARINE CONSULTANT:
HR Wallingford
Working with water
www.hrwallingford.com
HR Wallingford
Howbery Park, Wallingford
Oxfordshire OX10 8BA
United Kingdom
Tel: +44(0)1491 835381
Fax: +44(0)1491 832233

PROJECT:
ISLES OF SCILLY DESIGN SERVICES FOR OFF ISLANDS COASTAL EROSION DEFENCE AND DUNE MANAGEMENT

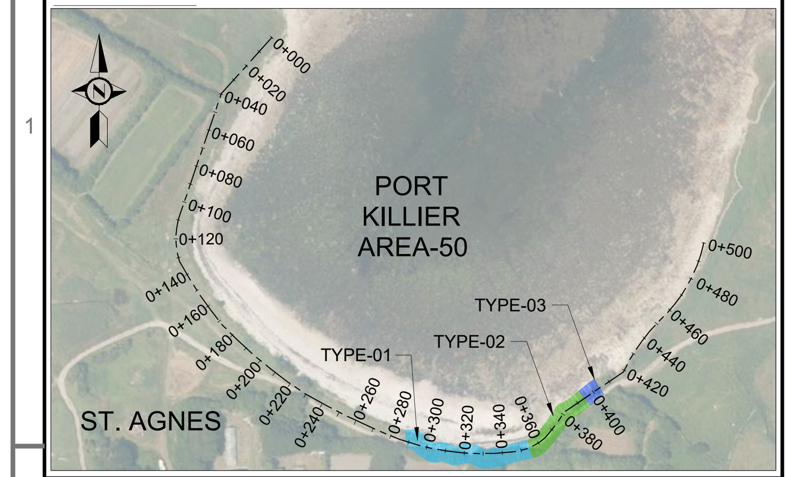
DRAWING TITLE:
ST. AGNES - PORT COOSE 50 - TYPICAL SECTION

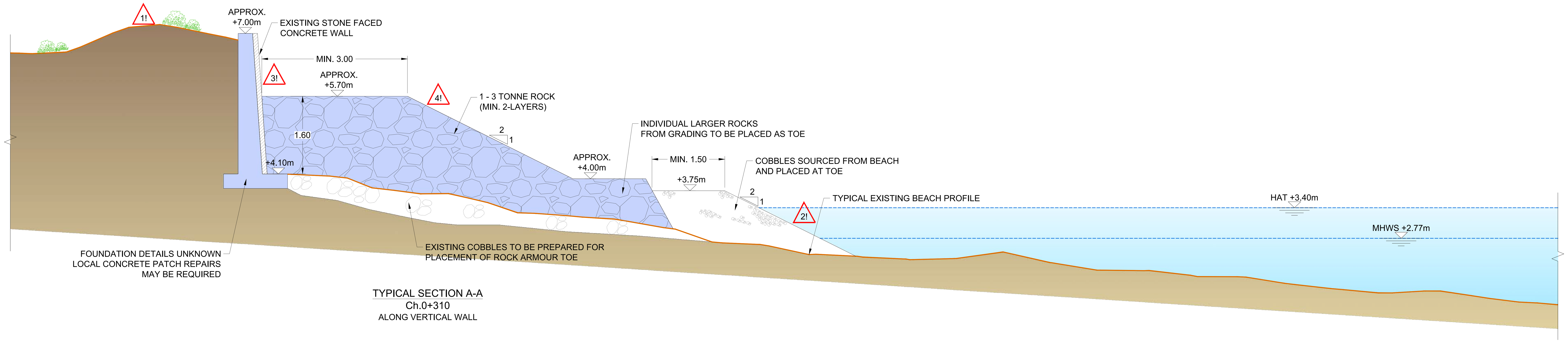
SCALE: VARIES
SHEET SIZE: A1
DRAWING No: DKR6499-110-D320
REV: 01

HAZARDS WARNING

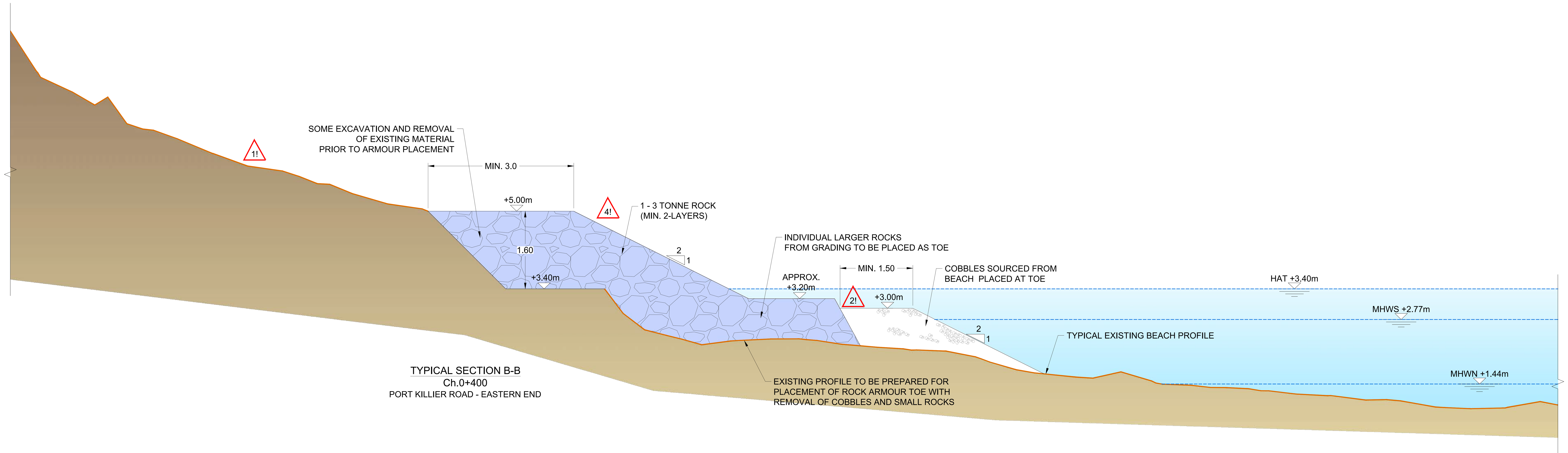
1! PUBLIC ACCESS TO BEACHES
2! WORKING NEAR WATER IN TIDAL ENVIRONMENT
3! UNKNOWN DETAIL OF EXISTING WALL
4! LARGE ROCKS & VOIDS

KEY PLAN:





TYPICAL SECTION A-A
Ch.0+310
ALONG VERTICAL WALL



TYPICAL SECTION B-B
Ch.0+400
PORT KILLIER ROAD - EASTERN END

NOTES:

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4. BACKGROUND IMAGE REPRODUCED FROM BING MAPS, © 2021 MICROSOFT.
5. SETTING OUT POINTS TO BE AGREED FOLLOWING DETAILED SURVEYS.
6. ALL LEVELS TO BE CONFIRMED FOLLOWING ON SITE SURVEY.
7. EXISTING WALL SECTION SHOWN IS ILLUSTRATIVE OF A FIXED STRUCTURE ONLY.
8. SOURCES FOR SAND AND COBBLES TO BE APPROVED BY THE ENGINEER.
9. FOR GENERAL NOTES REFER TO DRAWING No. DKR6499-000-D102.
10. FOR GENERAL ARRANGEMENT LAYOUT REFER TO DRAWING No. DKR6499-110-D112.

TIDE LEVELS	
mOD	
HAT	+3.40m
MHWS	+2.77m
MHWN	+1.44m
MLWN	-0.87m
MLWS	-2.18m
LAT	-2.82m

0 0.5 1 1.5 2 2.5m
SCALE 1:50

REV	DRAWING STATUS	DRN.	APPR.	AUTH.	DATE
01	ISSUED FOR APPROVAL	PGU	AGC	AUO	09 SEP 22

CLIENT:

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MARINE CONSULTANT:

HR Wallingford
Working with water
www.hrwallingford.com

HR Wallingford
Howbery Park, Wallingford
Oxfordshire OX10 8BA
United Kingdom

Tel: +44(0)1491 835381
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PROJECT:

ISLES OF SCILLY DESIGN SERVICES FOR OFF ISLANDS COASTAL EROSION DEFENCE AND DUNE MANAGEMENT

DRAWING TITLE:

ST. AGNES - PORT KILLIER 51 - TYPICAL SECTIONS

SCALE: 1:50
SHEET SIZE: A1

DRAWING No: DKR6499-110-D330
REV: 01

\\hrw-uk.local\projects\live\dkr6499\5_deliverables\drawings\Current Drawings\DKR6499-110-D330 [02]_St.Agnes-Port Killier 51-Rock Toe Protection Typical Section_00_0.1.dwg
PGU
09/09/22

D CDM (2015) Hazard Register

Isles of Scilly Climate Resilience		Design Risk Register	Receptor	RISK LEVEL BEFORE MITIGATION			Mitigation Measure	RISK LEVEL AFTER MITIGATION			Construction, maintenance and demolition control	Proj Ref:
No.	**Works/Condition**	**HAZARD and CONSEQUENCE (RISK) IDENTIFIED**	**Site staff, Public**	L	C	L*C	**INTENDED ACTION OR MITIGATION - DESIGN STAGE**	L	C	L*C	**ANTICIPATED MEASURE THAT COULD BE APPLIED BY CONTRACTOR (OR OTHERS)**	**Action By**
1	**General**											
1.1	Availability of Surveys	Availability of Surveys, Topographic, Geotechnical and Environmental Surveys, resulting in delay, costs and potential alteration to methods of delivery and construction	Site personnel and project schedule	2	4	8	Identify surveys required prior to start of Construction	2	4	8	Undertake Surveys to inform Risk	Contractor & Owner
1.2	Work Near Water	Risk to equipment and personnel. Risk of hypothermia or drowning	Site personnel and equipment	3	5	15	Raise awareness of risk in Engineering Report; include information on waves and tidal levels in Engineering Report and tidal levels in drawings. Reduce need for excavation in the intertidal area in the design.	1	5	5	Contractor to have competent experience of working in tidal environment. Contractor to develop safe systems of work in intertidal areas including the provision of appropriate PPE. Obtain frequent weather reports to predict tidal conditions. Contractor to ensure all plant is adequately serviced and maintained. Monitoring and Early planning of construction schedule. Store Equipment safe away from intertidal area	Contractor
1.3	Extreme high tides and storm events -	Adverse weather conditions resulting in plant being unable to track along foreshore. Weather (wind, waves, inundation of working areas). Leading to personnel and plant trapped by tidal conditions. Risk of drowning or hypothermia to site personnel.	Site personnel and equipment	2	5	10	Expected tidal ranges to be put on drawings. Controls to be investigated for weather forecast/warnings. Limit need to work near water.	1	5	5	Obtain weather forecast information on a daily basis, prepare emergency escape plan. Supervisor monitors weather forecasts and amends work accordingly. Teams to be issued with foul weather clothing. Provide plant bays and ensure adequate access. Provide appropriate PPE and link up to weather predictions for severe weather warnings.	Contractor
1.4	Unexploded Ordnance (UXO) - Possible presence on site of unexploded ordnance.	Loss of life, injury (including hearing damage) due to explosion	Site Personnel and equipment	2	5	10	Preliminary desk based assessment indicates LOW/MEDIUM risk.	1	5	5	Detailed assessment to be obtained by Contractor. Contractor to set out mitigative measures for excavations in method statement. Detailed design review to limit excavation if possible. Contractor to prepare Appropriate Site Management documentation should be held on-site to guide and plan for the actions which should be undertaken in the event of a suspected or confirmed UXO discovery. UXO Safety and Awareness briefing for all site personnel. Ordnance team to be included on emergency contact list.	Contractor
2	**Construction Phase**											
2.1	**Site conditions**											
2.1.1	Public access to the site	Potential for incidents with plant (beach users)	Site personnel and public	2	4	8	None applicable	2	4	8	Signage and fencing to isolate work areas where possible, whilst minimising impact to public access to the beach. Control access into area and restrict to work crews and authorised personnel only. Close access gates when area is unmanned	Contractor
2.1.2	Soft ground	Potential for plant or personnel to become stuck in pockets of soft ground the positions of which may vary. Damage to plant and injury to personnel.	Site personnel	2	4	8	Trial pits to be located in areas of possible concern	2	4	8	Walkover survey in advance of bringing plant to beach areas. Ensure appropriate plant is used	Contractor
2.1.3	Availability of services	Capacity of existing networks unlikely to be able to accommodate power and water demands from site. Availability of water and toilet facilities	Site personnel	3	3	9	None applicable	1	3	3	Owner to assist contractor in plans for site water and toilet facilities.	Contractor & owner
2.1.4	Increased flood risk during works	Flood risk due to temporary lowering of defence crest levels	Site personnel and public	2	3	6	None applicable	2	3	6	Maintain a storm and extreme water level warning system and Contractor to plan for works when risk of storms is lower	Contractor & Owner
2.2	**Access**											
2.2.1	Site access/delivery	Access to islands in small craft/barges through challenging seas. Risk to crew, equipementy and public	Logistics personnel, public	3	5	15	Minimise hard engineering works to minimise required import of materials to the different sites and consideration of likely plant in the scale of the works	2	4	8	Limit site delivery numbers, and use of appropriate barges and ships for the selected delivery sites. Maintain a storm and extreme water level warning system and Contractor to plan for deliveries when risk of storms is lower	Contractor
2.2.2	Marine access - General	There is challenging marine access to the Isles of Scilly due to weather and tidal restrictions. This will pose challenges for marine deliveries. There will be limiting bathymetry, hazards or rocky foreshores that is not appropriate to beach barges	Site and logistics personnel	3	4	12	High level review of each site to identify challenges to marine access and identify alternative delivery sites. Use www.navionics.com charts or similar for preliminary assessment Client has undertaken assessment of site access to identify appropriate delivery locations	2	4	8	Fuller assessment to be done to consider tide and seasonal and annual climate in addition to extremes. Bathymetry survey to be carried out and contractor to produce logistics plan for each island and identify delivery plan	Contractor & Owner
2.2.3	Marine Acess - St Agnes	Porth Killier is likely to be unsuitable for marine access as has a narrow entrance to the bay and rocky foreshore. Porth Coose is difficult for marine access, with narrow entry to the beach. Narrow tidal windows for access and risk of grounding	Site and logistics personnel	3	3	9	As above	1	3	3	Assessment of suitability of deliveries via the Ferry Quay or alternatively Periglis Beach	Contractor & Owner
2.2.4	Marine Acess - Bryher	Bryer is the most exposed of the project islands, western sites are likely to be unsuitable for marine access into the bays and eastern access will be tidally restricted	Site and logistics personnel	3	3	9	See 2.2.2	1	3	3	Assessment of suitability of Client identified delivery sites on the east of the island and plan timing of vessel access in advance for tidal access	Contractor & Owner
2.2.5	Island infrastructure	Existing quays condition and capacities are unknown. May not be safe to bring materials and equipment through these quays and via the island roads	Site personnel, public	3	3	9	Client has undertaken assessment for options for deliveries to identify favoured landing sites and access routes on the islands	1	3	3	Owner to assist Contractor in assessing capabilities of existing island infrastructure	Contractor & Owner
2.3	**Earthworks**											
2.3.1	Stockpiling of existing rocks	Individual rocks may be supporting other large rocks that could be destabilised	Site personnel	2	3	6	Include requirements for stockpile in specifications	1	3	3	Contractor to conduct walk over survey to agree which rocks to be moved and where to stockpile.	Contractor
2.3.2	Unstable excavation	Slope instability during excavation works	Site personnel	2	4	8	Shallow excavations where possible and max. excavated profile of 1 in 1 selected	1	4	4	Contractor to make site operatives aware of dangers prior to working on new profiles/slopes, via tool box talks and daily briefings. Contractor to undertake visual assessment of new slopes to check for signs of deterioration, particularly after storms or periods of high rainfall.	Contractor
2.3.3	Utilities	Uncovering electrical and telephone cabling at St Martin's with potential risk to power supply and possible electrocution Unknown and unmarked services may be uncovered during excavations	Site personnel and public	1	5	5	Searches have been undertaken to identify pipes and cabling and approximate routing. Where known, approximate locations have been marked on drawings	1	5	5	Contractor to carry out CAT scans and excavate by hand in areas of possible pipes and cabling	Contractor

Isles of Scilly Climate Resilience		Design Risk Register	Receptor	RISK LEVEL BEFORE MITIGATION			Mitigation Measure	RISK LEVEL AFTER MITIGATION			Construction, maintenance and demolition control	Proj Ref:
No.	**Works/Condition**	**HAZARD and CONSEQUENCE (RISK) IDENTIFIED**	**Site staff, Public**	L	C	L*C	**INTENDED ACTION OR MITIGATION - DESIGN STAGE**	L	C	L*C	**ANTICIPATED MEASURE THAT COULD BE APPLIED BY CONTRACTOR (OR OTHERS)**	**Action By**
2.3.4	Plant movements	Movement and operation of construction vehicles risk to site personnel and public	Site personnel and public	2	4	8	Footprints of proposed works to be kept clear from footpaths/tracks as far as possible Client has identified access routes and compound and stockpile areas on each island	1	4	4	Full briefing to Contractor drivers, site fencing and signage and use of banksmen as appropriate. Signage and fencing to isolate work areas from public access Control access into area and restrict to work crews and authorised personnel only. Close access gates when area is unmanned	Contractor & Owner
2.4	**Rockworks**											
2.4.1	Unstable rock stockpile	The rock stockpile is not a designed structure and the stability can therefore not be relied upon. Hazard of crushing from moving rock in proximity to the stockpile	Site personnel	2	5	10	Include requirements for stockpile in specifications	2	3	6	Contractor to make site operatives aware of dangers prior to working on in proximity to rock stockpiles, via tool box talks and daily briefings. Contractor to undertake visual assessment of stockpile, particularly after rock extraction, storms or periods of high rainfall.	Contractor
2.4.2	Rock delivery	Rock delivery by barge and interaction with public and exposure to storm conditions	Public, personnel	2	4	8	Plan for re-use of existing rock where possible to minimise need to import	1	4	4	Contractor to cordon off areas during these operations. Contractor to make site operatives aware of dangers of rock transportation, via tool box talks and daily briefings. Contractor to maintain marshals at key access points to ensure safe transportation and interaction with public. Contractor to monitor storm conditions and avoid transportation of rock during storms.	Contractor
2.4.3	Rock placing	Rock unstable during and following placement or due to degradation of slope profiles.	Public, personnel	2	4	8	Flatten slopes and place in 2 layers to get good interlock	1	4	4	Contractor to make site operatives aware of dangers prior to working on new profiles/slopes, via tool box talks and daily briefings. Inspection by Contractor and Owner after storms to assess slopes.	Contractor
3	**Operation**											
3.1	Flood risk (permanent situation)	Flood risk due to overtopping waters.	Public	2	3	6	Critical sections of beaches to have interventions to protect infrastructure behind. Some areas will still be vulnerable to flooding	2	2	4	Maintain a storm and extreme water level warning system	Owner
3.1	Operation of flood barrier	Flood barrier protects the slipway crest at Great Porth beach on Bryher, if not inserted ahead of a storm the area behind could flood	Public	2	3	6	Gates are to be light units that can be quickly installed by 1 person with apporpriate training	1	3	3	Maintain a storm and extreme water level warning system and identify individuals responsible for installing the gates and provide any necessary training	Owner
3.1	Public access to beaches	The proposed works will introduce rock at previous beach access points. Risk to public from falling on and between rocks	Public	2	4	8	Highlight paths and access points to be changed Signage adjacent to rock structures warning of the hazards to be considered	1	4	4	Introduce signage and fencing to manage beach access points and access to rock revetments	Owner
4	**Demolition**											
4.1	General	The hazards set out in Section 2 apply equally to the demolition.	Site personnel, public	2	3	6	As above	2	3	6	As above.	Owner
	NOTES											

The hazards and risks listed here are the key H&S risks identified for the proposed works.
Generic risks such as slips, trips and falls or remote working that are relevant for any construction works are not included here but should form part of contractor's risk assessment and environmental risks need to be covered separately

Key:		
	Likelihood	**1 - Unlikely to occur in relevant period.** **2 - Likely to occur in relevant period.** **3 - Likely to occur several times in the relevant period**
	Consequence	**5 - Death or total systems loss** **4 - Major injury or illness. Major damage or environmental impact.** **3 - Lost time injury or illness. Damage or environmental impact.** **2 - First aid incident. Routine maintenance repair.** **1 - Very minor. Little consequence.**
	Likelihood x Consequence (See also CIRIA SP125).	**10-15 Very High Risk - not acceptable. Apply mitigation. Seek approval if significant risk remains.** **6-9 High Risk - Apply mitigation. Seek approval if risk cannot be reasonably and practically be reduced below "this" level.** **1 - 5 Low Risk - May be accepted if all reasonably practicable control measures in place.**

Prepared by:	AGC	**Title:**	Project Engineer
Checked by:	AUO	**Title:**	Project Manager
Approved by:	AUO	**Title:**	Project Manager

E Gas and Electricity service layouts

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Contact Us

Mapping Enquiries: All areas 0121 623 9780

General Enquiries: All areas 0800 096 3080

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0800 6783 105

Date Requested: 21/07/2021
Job Reference: 22746863
Site Location: 87926 8513
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Your Scheme/Reference: CAS

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HV (132kV)

SURF Telecoms

Pilot Cables

Link Box

PME Earth

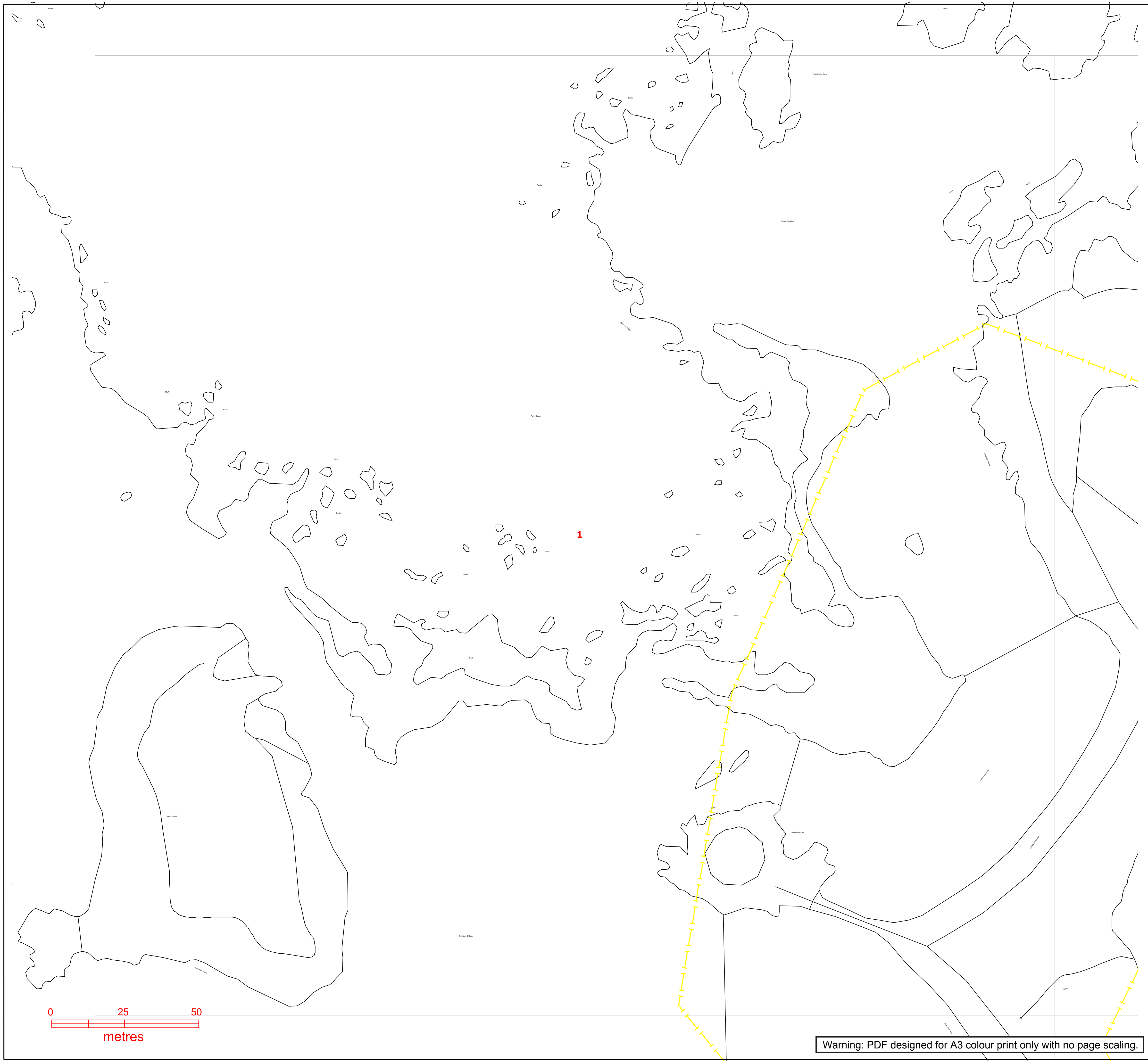
Pole Mounted Transformer

Site Location

Line/Area

Underground Earth

Ground Mounted Transformer



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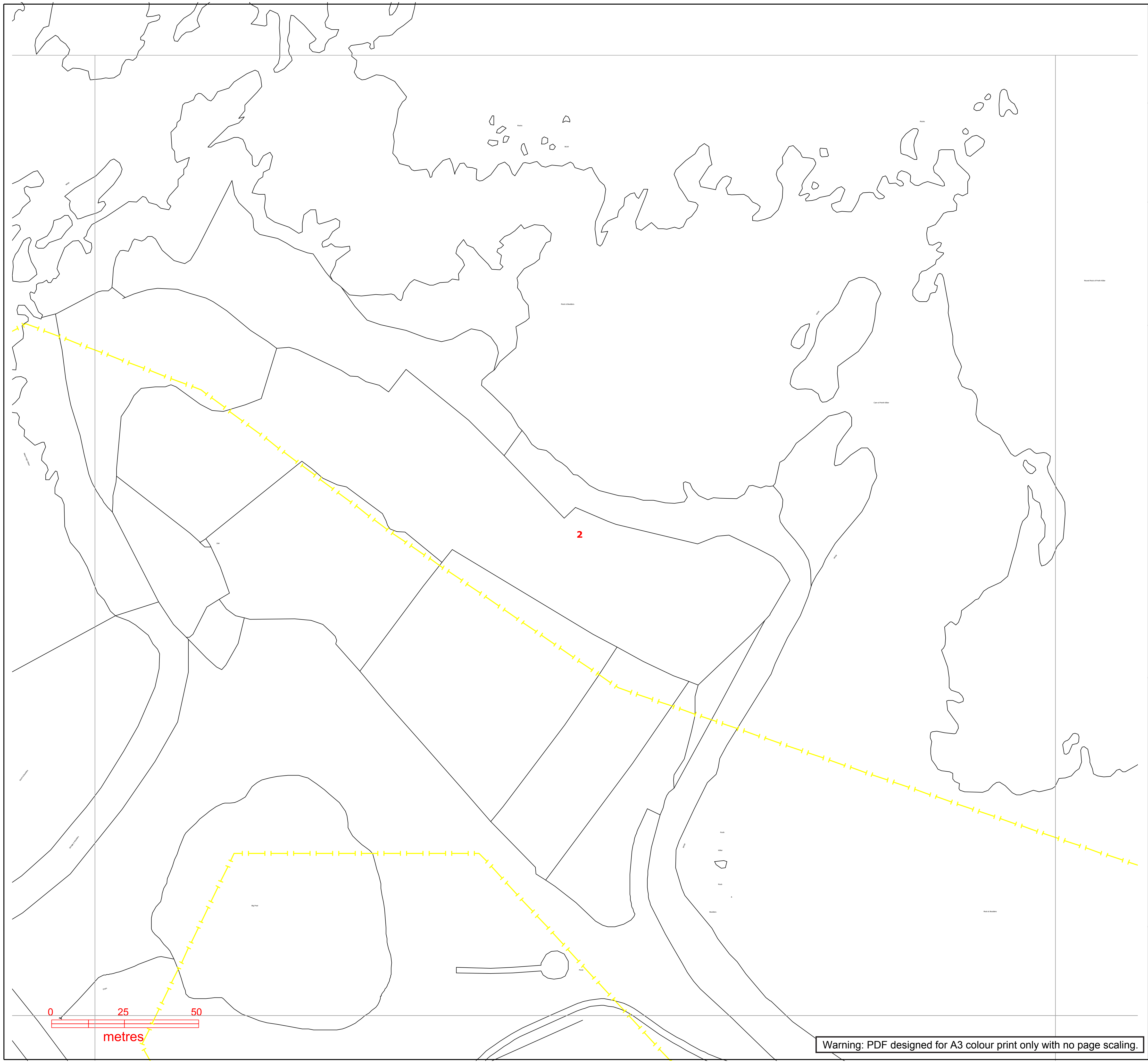

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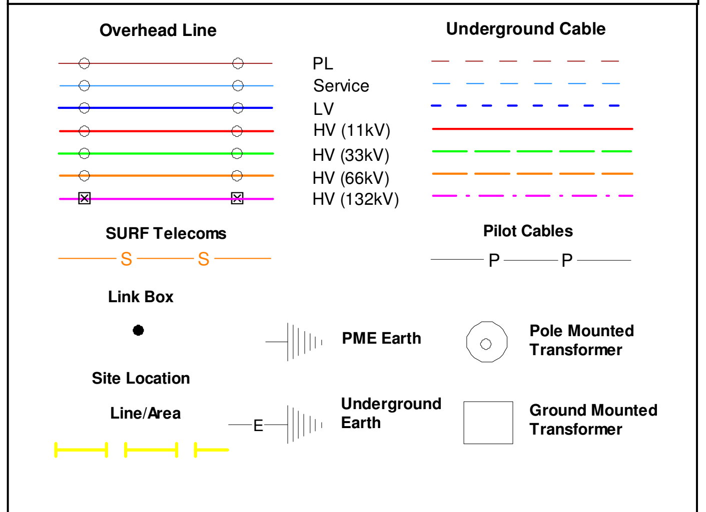

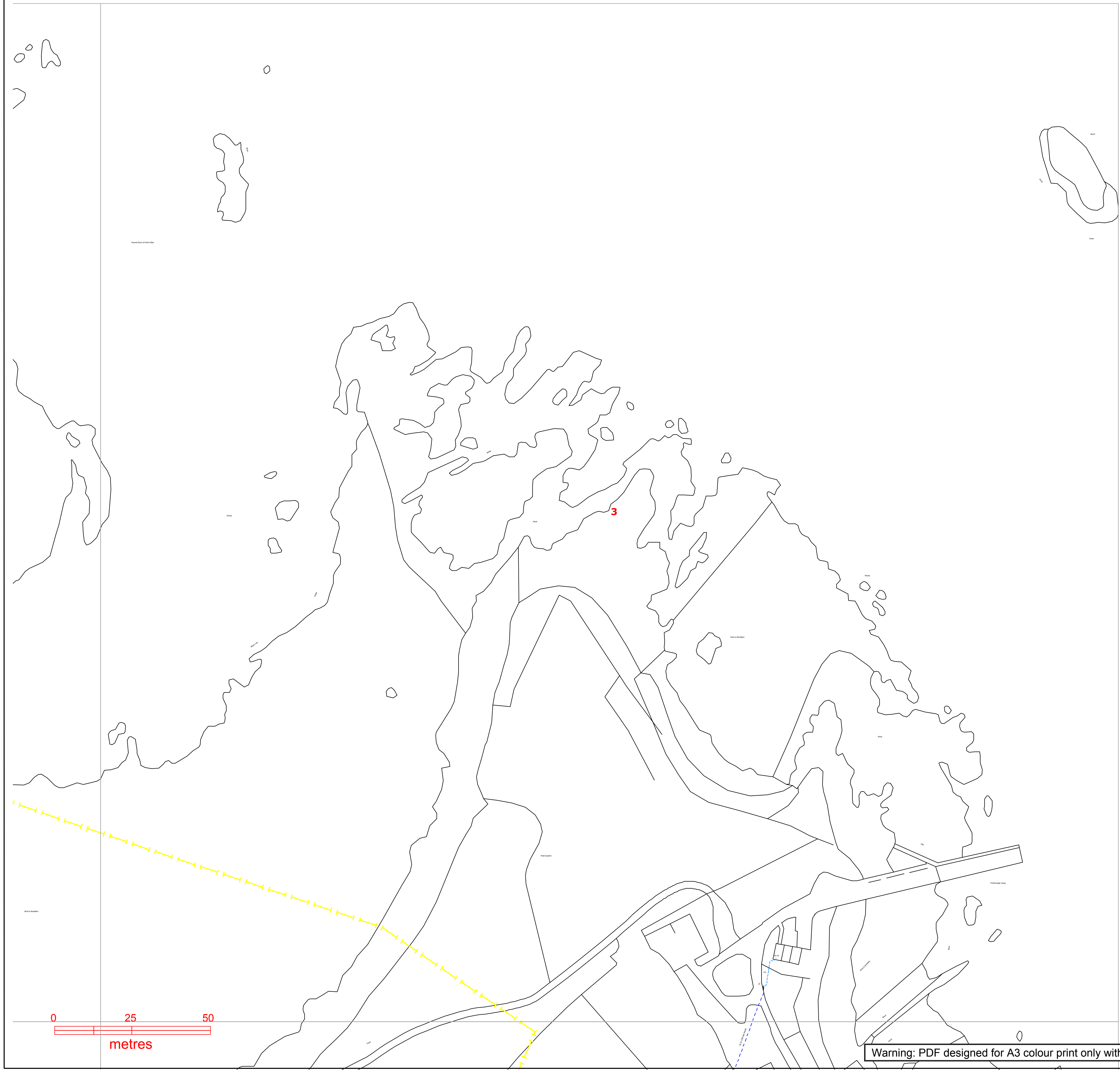

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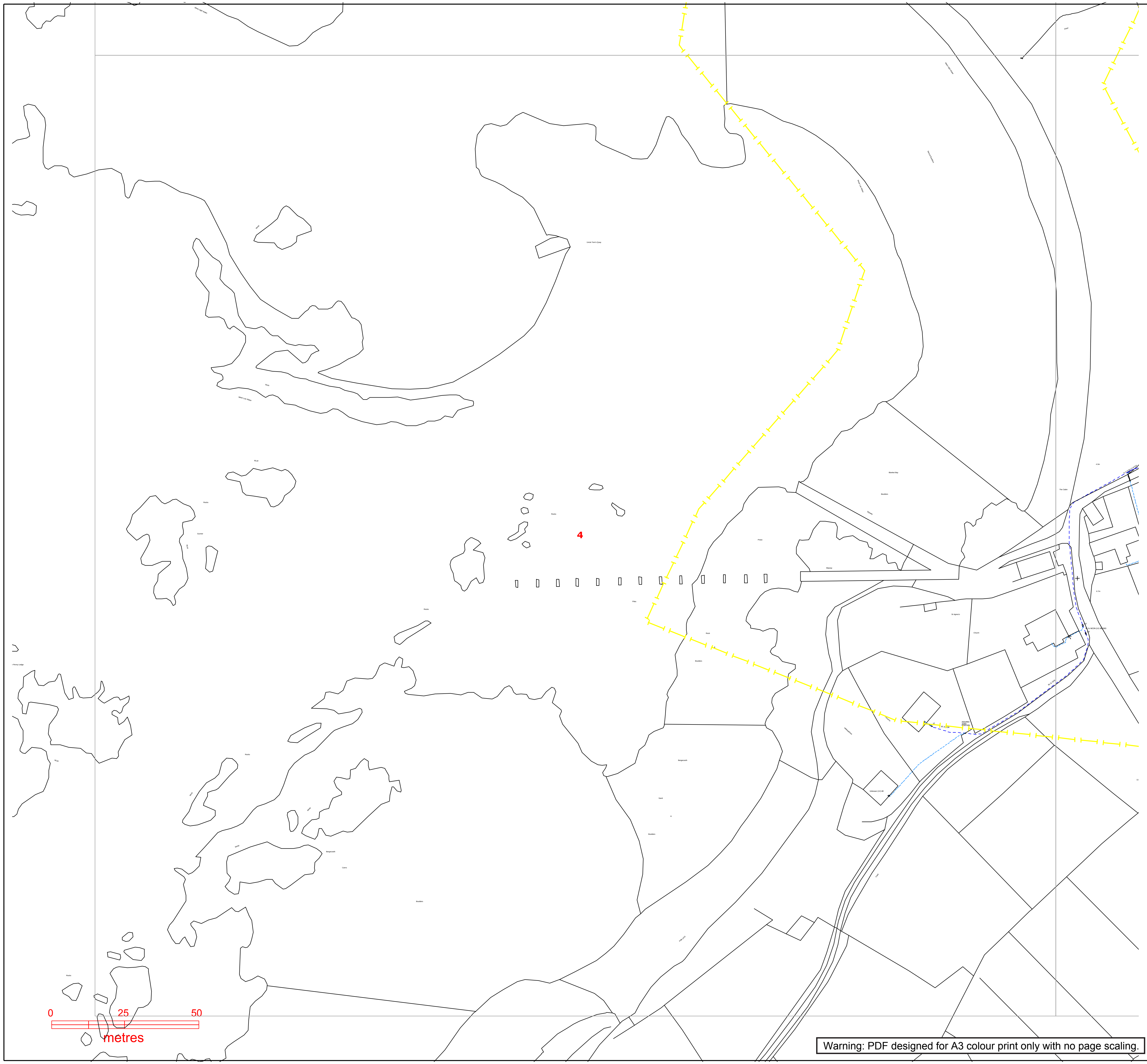

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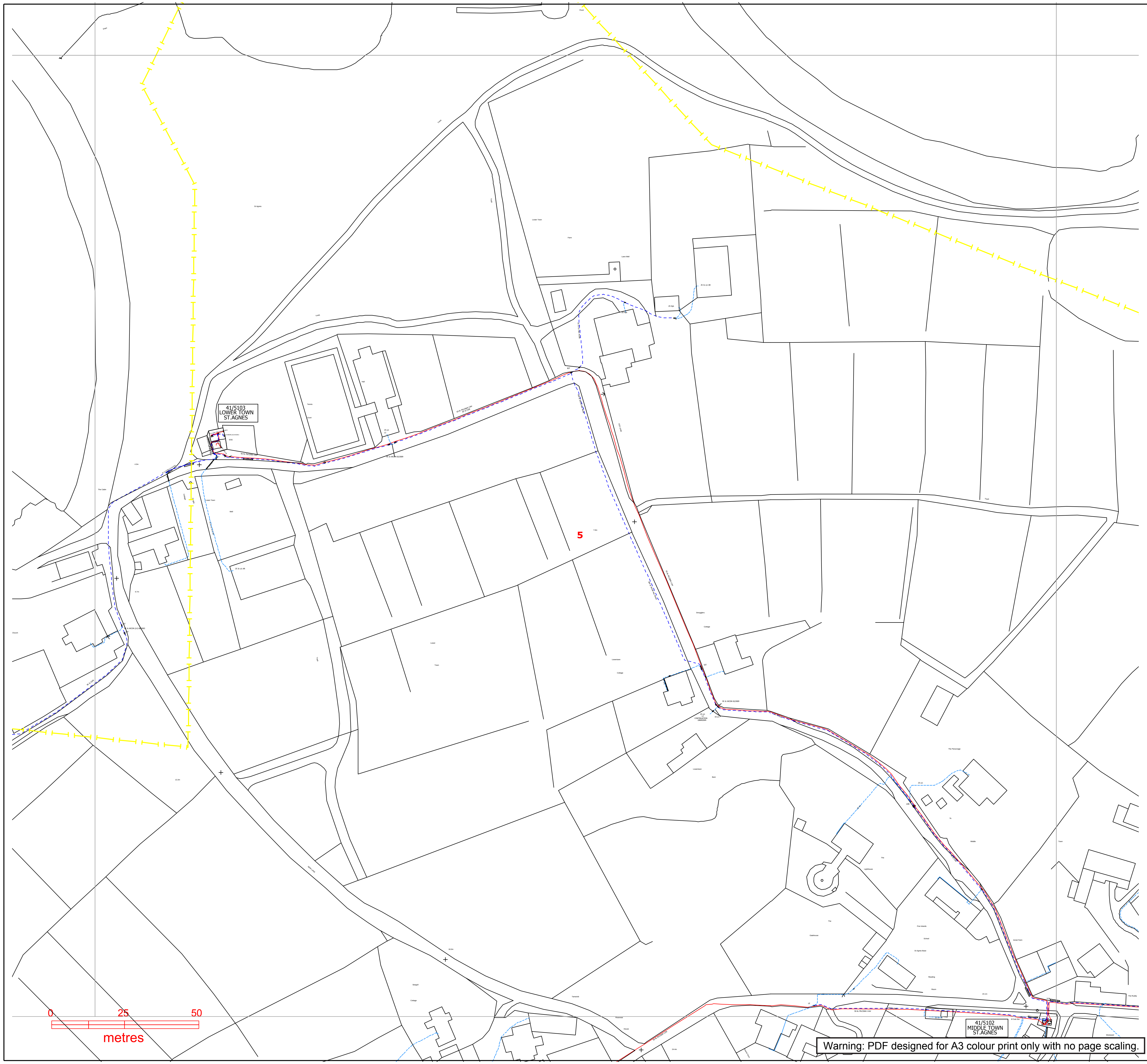

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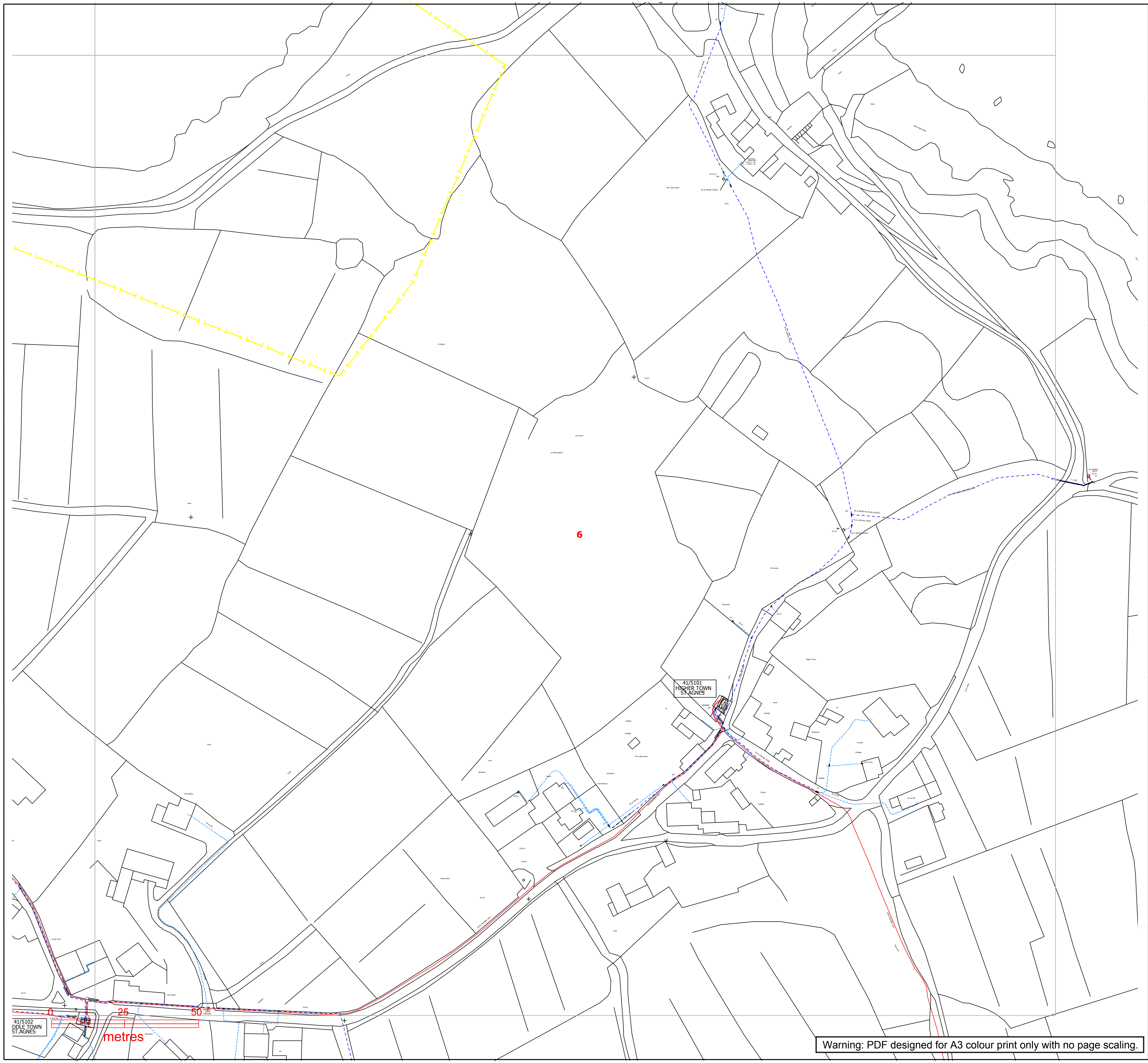

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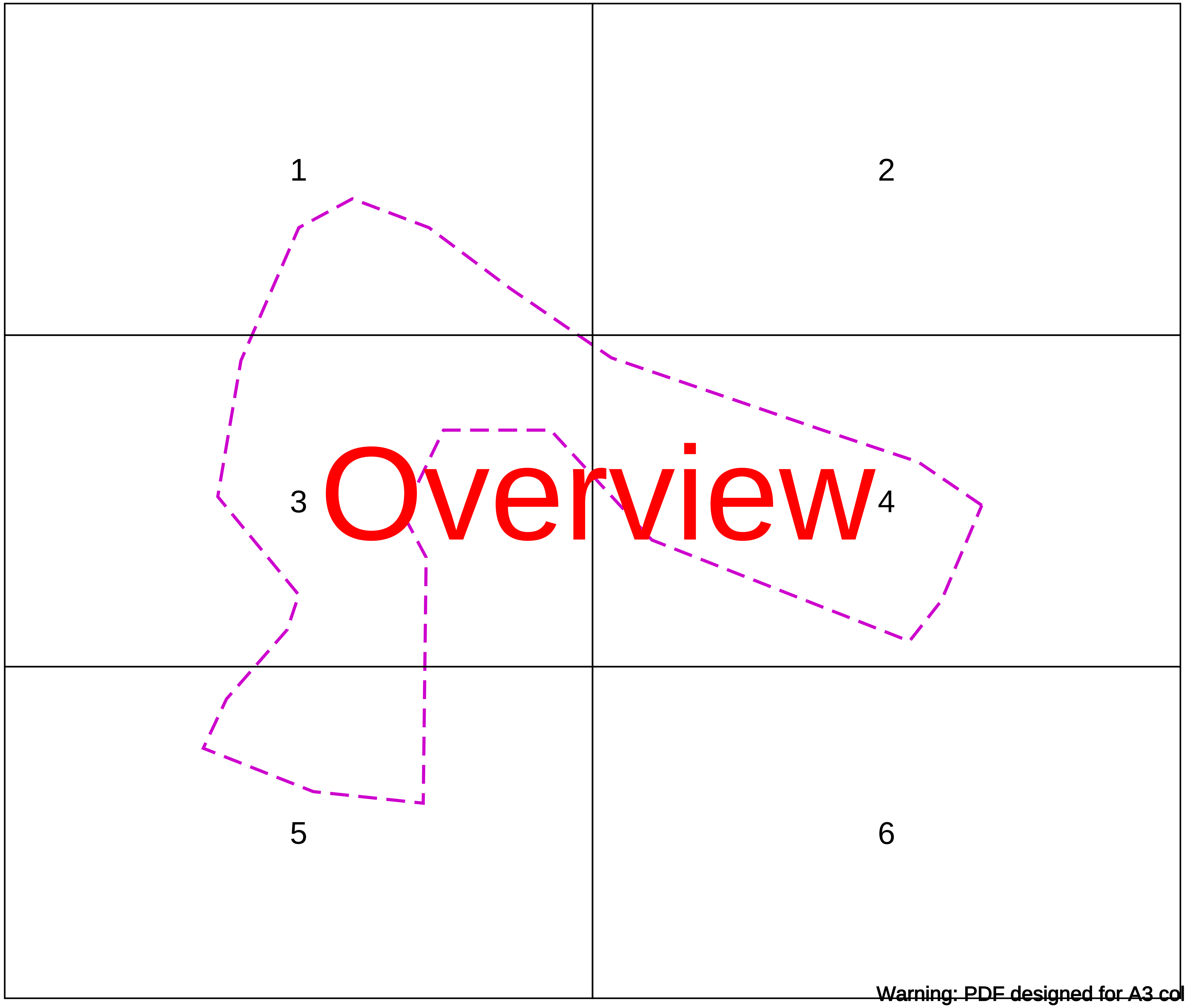

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Contact Us
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General Enquiries: 0800 912 2999

Date Requested: 21/07/2021
Job Reference: 22746863
Site Location: 88102 08504
Requested by:
Mr Andy Campbell
Your Scheme/Reference: CAS

Scale: 1:3844 (When plotted at A3)

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- If in doubt call the WWU dig team on 02920 278912

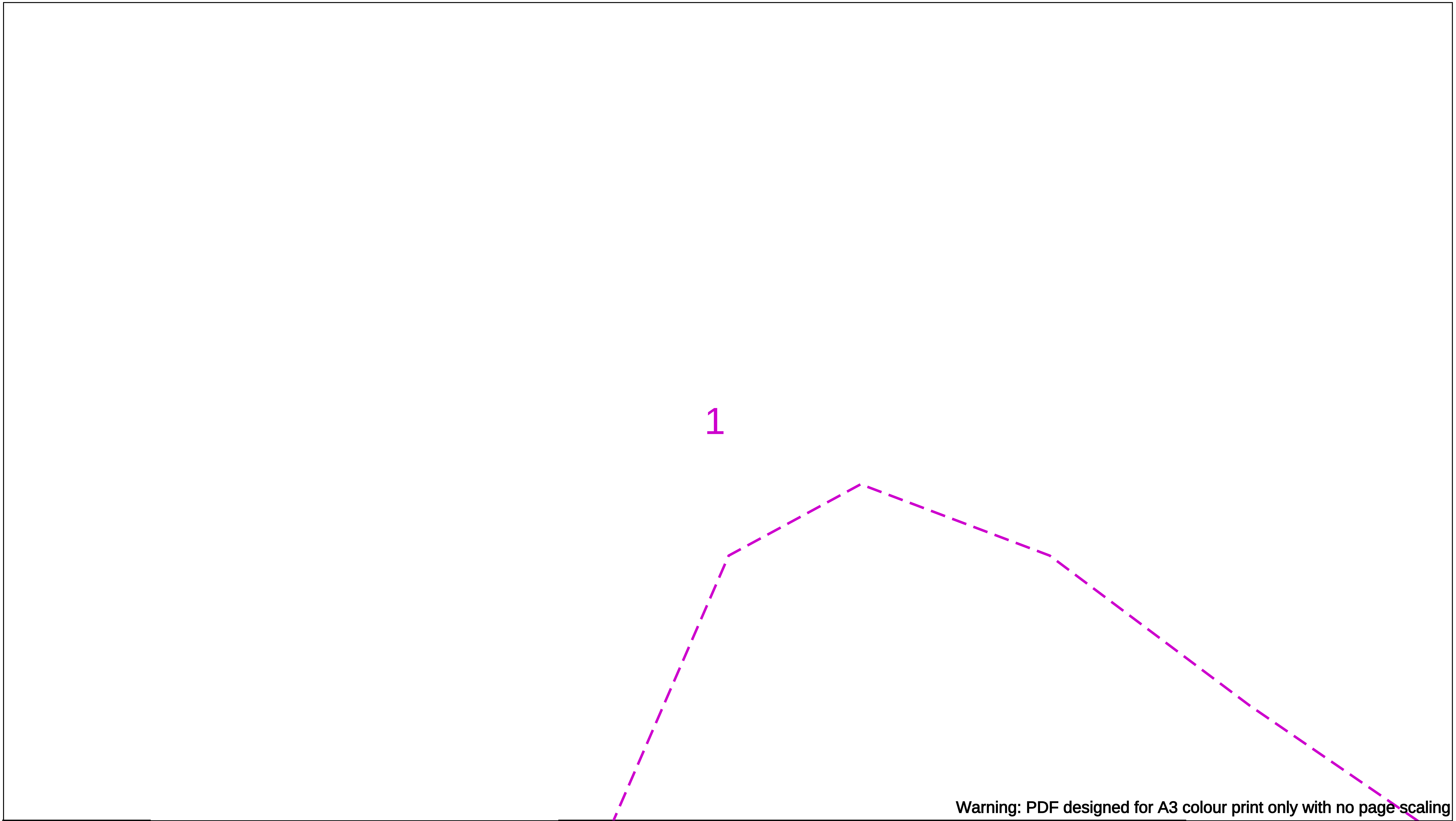
In case of an emergency call 0800 111 999

Dig Sites

Area: Line:

Low Pressure (LP) 21mbar – 75mbar
Medium Pressure (MP) 350mbar – 2bar
Intermediate Pressure (IP) 2bar – 7bar
High Pressure (HP) >7bar

Line/Fire Valve
Governor Station
Change of Diameter
End Cap
Depth of cover



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Site Location: 88102 08504
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Scale: 1:1250 (When plotted at A3)

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100m

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Line/Fire Valve
Governor Station
Change of Diameter
End Cap
Depth of cover

2

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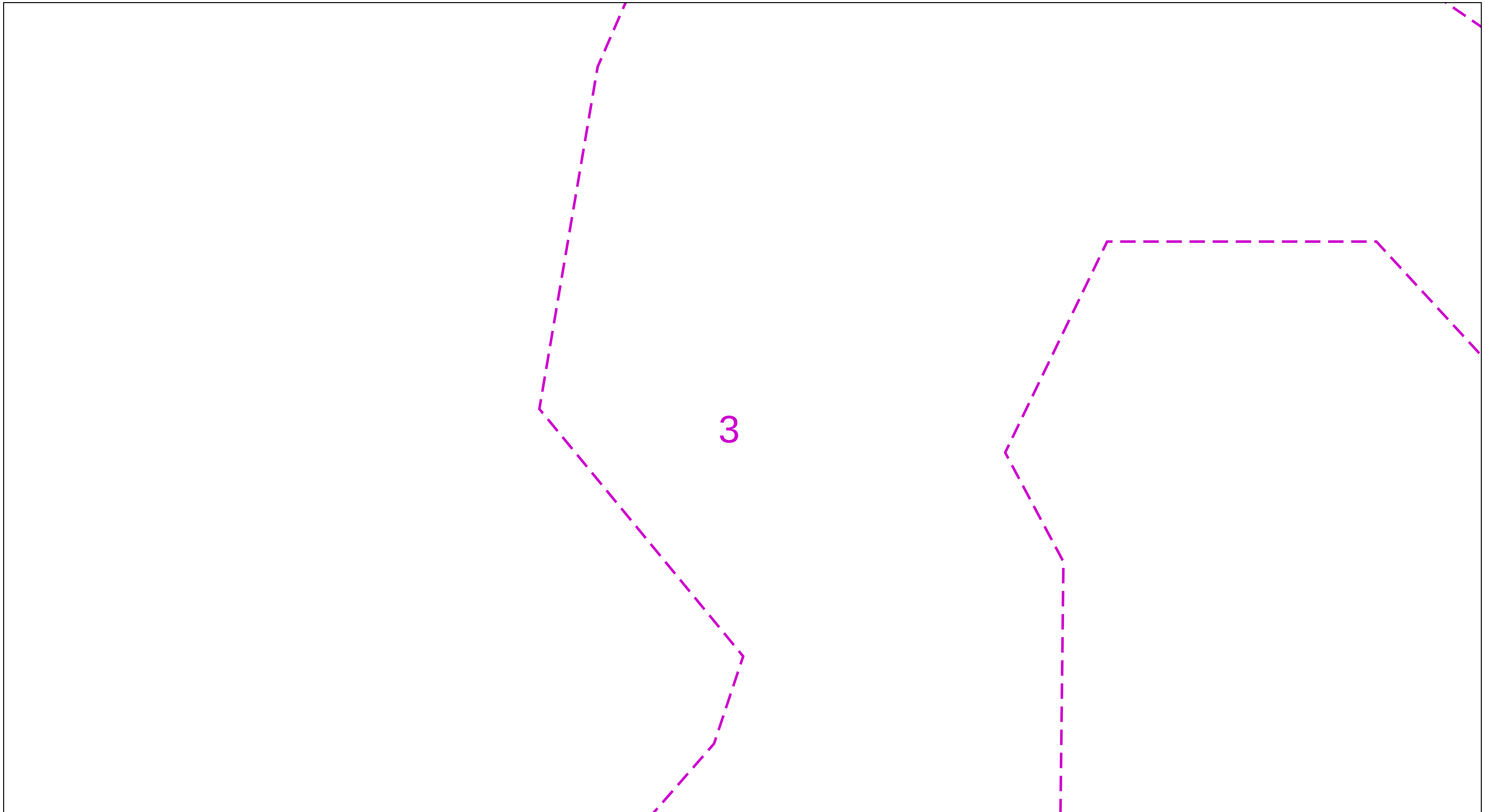
WALES&WEST UTILITIES



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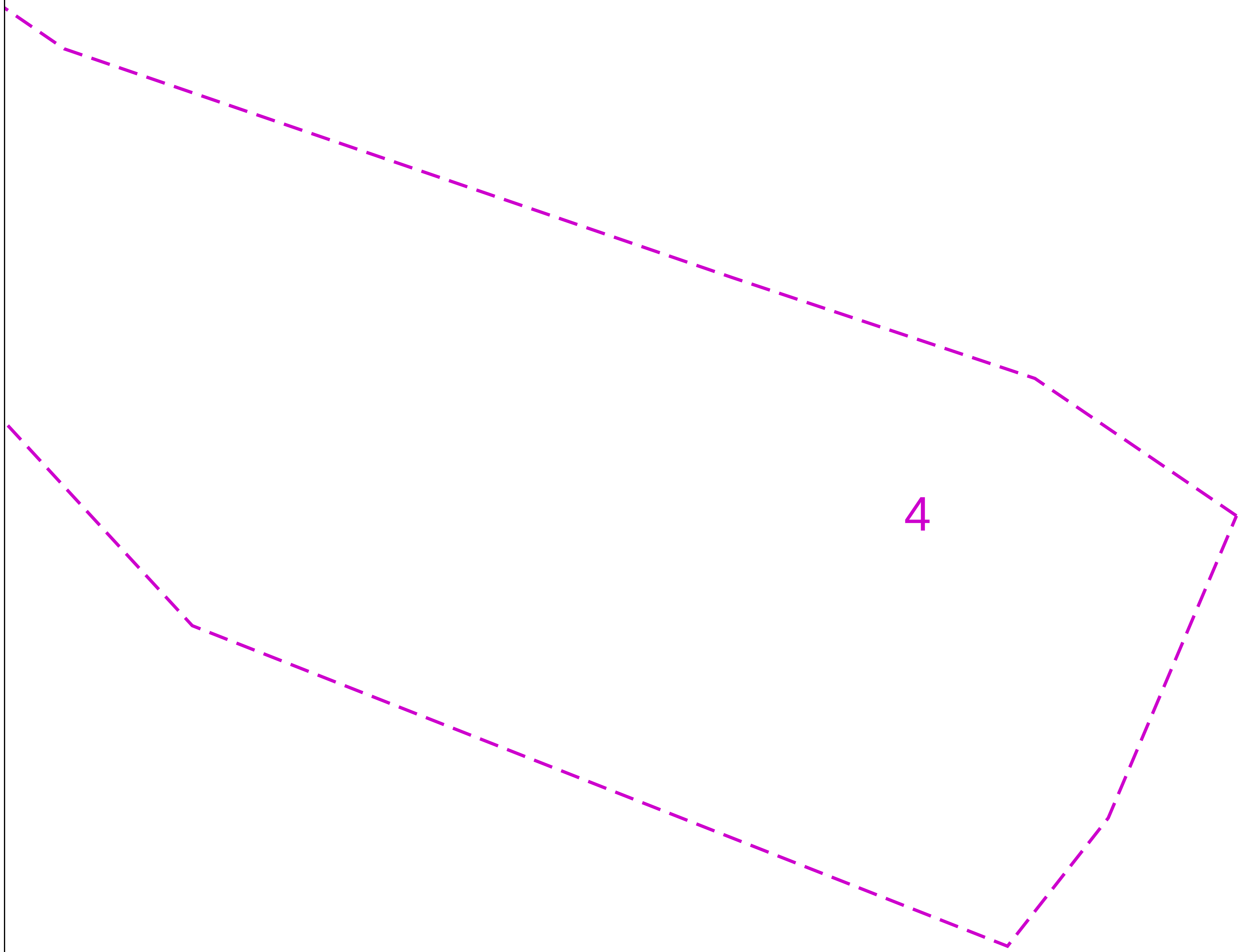
Line/Fire Valve
Governor Station
Change of Diameter
End Cap
Depth of cover

WALES&WEST UTILITIES

Smell gas?
Call the Gas Emergency Service on 0800 111 999.

Dial before you dig
We need 10 days' notice
Dial
Call 029 2027 8912 before you start work.
Investigate
Before you dig, make sure you know what's below.
Go ahead
Done your research? Now you can dig safely.



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Contact Us
Mapping Enquiries: 02920 278 912
General Enquiries: 0800 912 2999

Date Requested: 21/07/2021
Job Reference: 22746863
Site Location: 88102 08504
Requested by:
Mr Andy Campbell
Your Scheme/Reference: CAS

Scale: 1:1250 (When plotted at A3)

IMPORTANT NOTICES

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- The plan only shows those pipes owned by Wales & West Utilities (WWU) as its role as a licensed Gas Transporter
- Service pipes, valves, syphons, stub connections etc. may not be shown but their presence should be anticipated
- You must use safe digging practices in accordance with HS(G)47 to establish the actual position of mains, services and other apparatus before any mechanical excavation is used
- It is your responsibility to ensure this information is provided to all persons working near our plant
- If in doubt call the WWU dig team on 02920 278912

In case of an emergency call 0800 111 999

100m

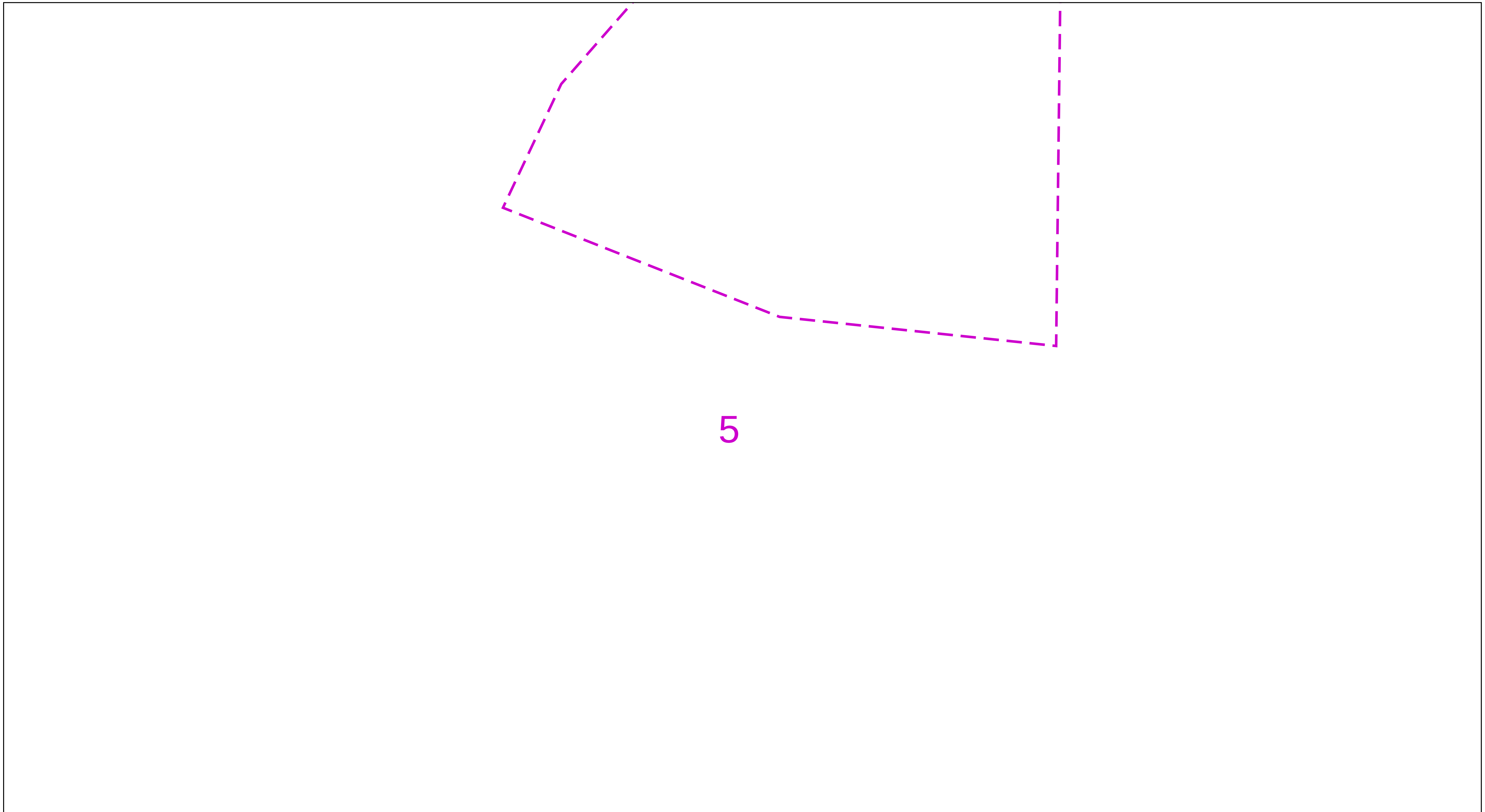
Dig Sites

Area:
Line:

Low Pressure (LP) 21mbar – 75mbar
Medium Pressure (MP) 350mbar – 2bar
Intermediate Pressure (IP) 2bar – 7bar
High Pressure (HP) >7bar

Line/Fire Valve
Governor Station
Change of Diameter
End Cap
Depth of cover

WALES&WEST UTILITIES



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Line/Fire Valve
Governor Station
Change of Diameter
End Cap
Depth of cover

6

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Dig Sites

Area: Line:

Low Pressure (LP) 21mbar – 75mbar
Medium Pressure (MP) 350mbar – 2bar
Intermediate Pressure (IP) 2bar – 7bar
High Pressure (HP) >7bar

Line/Fire Valve
Governor Station
Change of Diameter
End Cap
Depth of cover

WALES&WEST UTILITIES

F Bills of Quantity

Site	Item description	Unit	Quantity	Notes
48/49 - Periglis beach	Excavation and stockpile of topsoil	m^3	504	
	Bulk excavation, sorting material to stockpil	m^3	1,898	
	Surface trimming and preparation	m^2	1,781	
	Supply and place geotextile	m^2	1,935	Includes 20% allowance for overlap
	Geobags supply, fill & place	no.	416	Bags to be filled on site
	Bulk fill (additional/new fill material)	m^3	540	
	Bulk Backfilling (from bulk excavation)	m^3	1,898	
	Trimming and preparation of fill	m^2	1,471	
	Geomat, supply and installation	m^2	1,845	Includes 20% allowance for overlap
	Placement of topsoil	m^3	504	
	Trimming of Surface	m^2	2,650	
	Seeding of embankment	m^2	1,678	
50 - Porth Coose	Excavate and stockpile topsoil	m^3	258	
	Surface trimming and preparation	m^2	1,288	Includes burial of any exposedArmourflex crest detail
	Supply and place geotextile	m^2	471	Includes 20% allowance for overlap
	Rock bag, supply, fill and place	no.	131	Bags could be supplied full or be filled by Contractor
	Bulk backfill (additional/new fill material)	m^3	806	
	Trimming and preparation of fill	m^2	1,011	
	Geomat, supply and installation	m^2	1,112	Includes 20% allowance for overlap
	Placement of top soil	m^3	258	
	Seeding of embankment	m^2	1,011	
51 - Porth Killier	Surface trimming and preparation	m^2	1,197	Assumed not rock, cobble/sand removal listed separately
	Supply and placement of 1-3 T rock	m^3	1,136	
	Excavate and stockpile cobbles and sand	m^3	265	
	Place site won cobbles and sand	m^3	265	
	Repairs to wall footing	m	-	
	Bulk material balance	m^3	- 2,233	Total volume of fill to be imported

Notes

Top soil is 200mm depth from crestline landwards
Seeding to be on embankment from crestline landwards
No bulking factor assumed on excavated material

G Cost estimate

Site	Item No.	Description	Unit	Quantity	Rate	TOTAL (GBP)
48-49 - Periglis beach	**1**	**MANAGEMENT & SUPERVISION**				
	1.1	Head Office Management	%		4%	8,200
	1.2	Construction Management and Supervision	%		4%	8,200
	1.3	Engineering and Documentation	%		5%	10,200
	1.4	Procurement, Inspection and Surveys	%		5%	10,200
	2	**PRELIMINARIES**				
	2.1	Contract preliminaries	%		5%	10,200
	2.2	Mobilisation / demobilisation Fabrication & Installation Works	%		25%	50,900
	3	**CONSTRUCTION**				
	3.1	Excavation and stockpile of topsoil	m³	504	13	6,708
	3.2	Bulk excavation, sorting material to stockpiles	m³	1,898	16	30,649
	3.3	Surface trimming and preparation	m²	1,781	8	14,535
	3.4	Supply and place geotextile	m²	1,935	13	24,337
	3.5	Geobags supply, fill & place	m²	416	136	56,576
	3.6	Bulk fill (additional/new fill material)	no.	540	41	22,248
	3.7	Bulk Backfilling (from bulk excavation)	m³	1,898	7	12,644
	3.8	Trimming and preparation of fill	m³	1,471	10	14,232
	3.9	Geomat, supply and installation	m²	1,845	10	18,638
	3.1	Placement of topsoil	m²	504	6	2,892
	3.11	Trimming of Surface	m²	2,650	3	8,514
	3.12	Seeding of embankment	m²	1,678	47	78,449
		SUB-TOTAL CONSTRUCTION				**203,458**
		TOTAL INCLUDING INDIRECT COSTS				**301,358**
		TOTAL - CONTINGENCY - LOCATION FACTOR			**30%**	**391,765**

Section	Pay Item No.	Description	Unit	Quantity	Rate	TOTAL (GBP)
50 - Porth Coose	**1**	**MANAGEMENT & SUPERVISION**				
	1.1	Head Office Management	%		4%	6,300
	1.2	Construction Management and Supervision	%		4%	6,300
	1.3	Engineering and Documentation	%		5%	7,900
	1.4	Procurement, Inspection and Surveys	%		5%	7,900
	2	**PRELIMINARIES**				
	2.1	Contract preliminaries	%		5%	7,900
	2.2	Mobilisation / demobilisation Fabrication & Installation Works	%		25%	39,100
	3	**CONSTRUCTION**				
	3.1	Excavate and stockpile topsoil	m^3	258	13	3,427
	3.2	Surface trimming and preparation	m^2	1288	8	10,510
	3.3	Supply and place geotextile	m^2	471	13	5,922
	3.4	Rock bag, supply, fill and place	no.	131	255	33,366
	3.5	Bulk backfill (additional/new fill material)	m^3	806	41	33,218
	3.6	Trimming and preparation of fill	m^2	1011	10	9,784
	3.7	Geomat, supply and installation	m^2	1112	10	11,235
	3.8	Placement of top soil	no.	258	6	1,477
	3.9	Seeding of embankment	m^3	1011	47	47,287
		SUB-TOTAL CONSTRUCTION				**156,225**
		TOTAL INCLUDING INDIRECT COSTS				**231,625**
		TOTAL - CONTINGENCY - LOCATION FACTOR			**30%**	**301,112**

Section	Pay Item No.	Description	Unit	Quantity	Rate	TOTAL (GBP)
51 - Porth Killier	**1**	**MANAGEMENT & SUPERVISION**				
	1.1	Head Office Management	%		4%	6,700.00
	1.2	Construction Management and Supervision	%		4%	6,700.00
	1.3	Engineering and Documentation	%		5%	8,400.00
	1.4	Procurement, Inspection and Surveys	%		5%	8,400.00
	2	**PRELIMINARIES**				
	2.1	Contract preliminaries	%		5%	8,400.00
	2.2	Mobilisation / demobilisation Fabrication & Installation Works	%		25%	41,800.00
	3	**CONSTRUCTION**				
	3.1	Surface trimming and preparation	m^2	1,197	8	9,770.35
	3.2	Supply and placement of 1-3 T rock	m^3	1,136	129	146,538.84
	3.3	Excavate and stockpile cobbles and sand	m^3	265	20	5,394.32
	3.4	Place site won cobbles and sand	m^3	265	20	5,394.32
	3.5	Repairs to wall footing	m^3	0	0	0.00
		SUB-TOTAL CONSTRUCTION				**167,098**
		TOTAL INCLUDING INDIRECT COSTS				**247,498**
		TOTAL - CONTINGENCY - LOCATION FACTOR			**30%**	**321,747**

H Product information

H.1 Geotextile

Coastal and River Defence Systems: Design Guidance

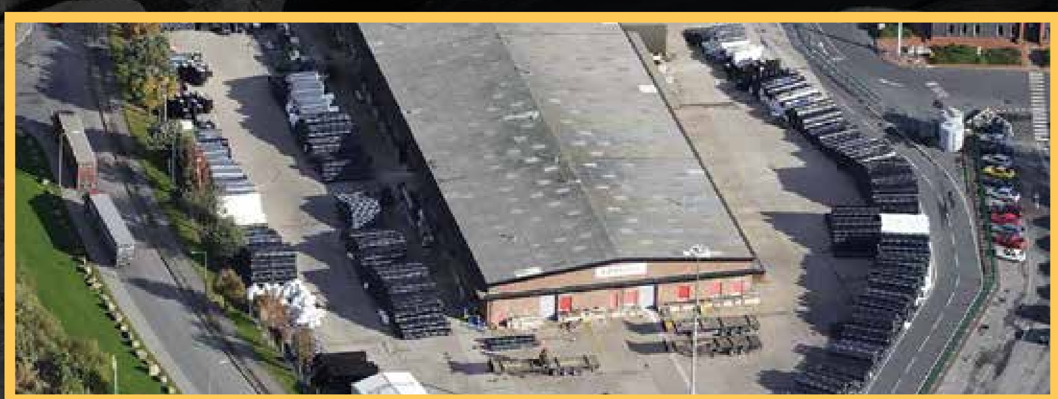
hps
HIGH PERFORMANCE SQUARE

GEOfabrics®

About Us

GEOfabrics Limited is the UK's leading manufacturer of geotextiles. Since its formation in 1992, millions of square metres of HPS geotextile have been deployed along coastlines and watercourses beneath rock armour and prefabricated concrete units.

The company's ethos is to continually exceed the expectations of both existing and future customers with innovative and effective products supported by an established technical service. Successful product development is achieved by understanding the customer's problem, determining the necessary properties and functions that are required, manufacturing the solution and then rigorous quality testing to demonstrate that the product meets those requirements. GEOfabrics has a dedicated and experienced team of personnel that cover both commercial and technical departments and that work in unison to provide the necessary attributes to meet our global challenges.



Coastal Defence Structures Using HPS Geotextiles

For many years GEOfabrics have developed and provided a broad spectrum of tailored engineering HPS products that are specifically manufactured to address the many problematic challenges of coastal/river defence and erosion.

HPS Geotextiles Coastal Applications

- Artificial Islands
- Beaches
- Bridge Abutments
- Revetments
- River Protection
- Flood Bunds
- Harbours

- Lagoons, Lakes & Reservoirs
- Land Reclamation Offshore
- Wind Generators
- Rock Groynes
- Scour Control
- Submerged Breakwaters
- Coastal Defence

Typical primary rock armour revetment installation directly on HPS geotextile. Location: Colwyn Bay.

GEOfabrics HPS filter/separators have been designed to provide sustained permeability whilst maintaining structural stability. They provide excellent filtering efficiency, a high level of stress absorption and are highly resistant to abrasion.

Quality in Manufacturing

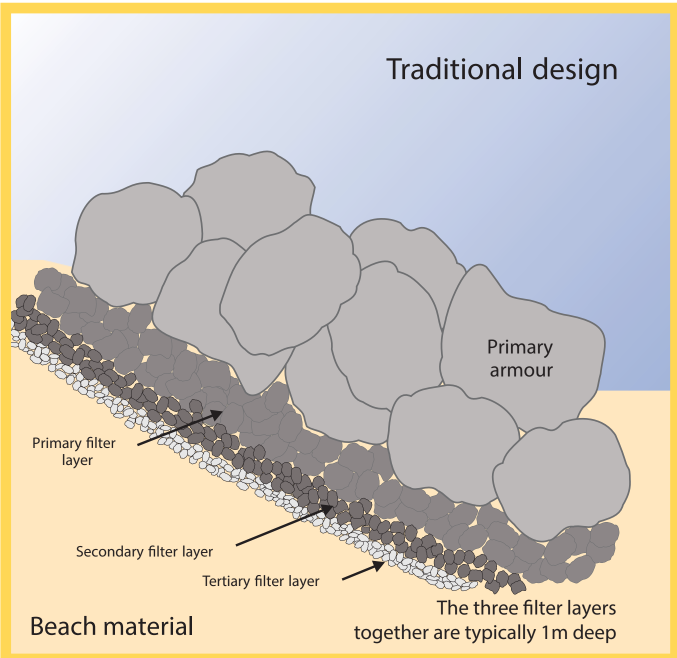
GEOfabrics Limited is the UK's leading manufacturer of geotextiles. Since its formation in 1992, millions of square metres of HPS geotextile have been deployed along coastlines and watercourses beneath rock armour and prefabricated concrete units. Their use is due to the quality of the products, their cost effectiveness and the comprehensive help provided to design engineers and contractors at every stage of a project.

Quality in Service

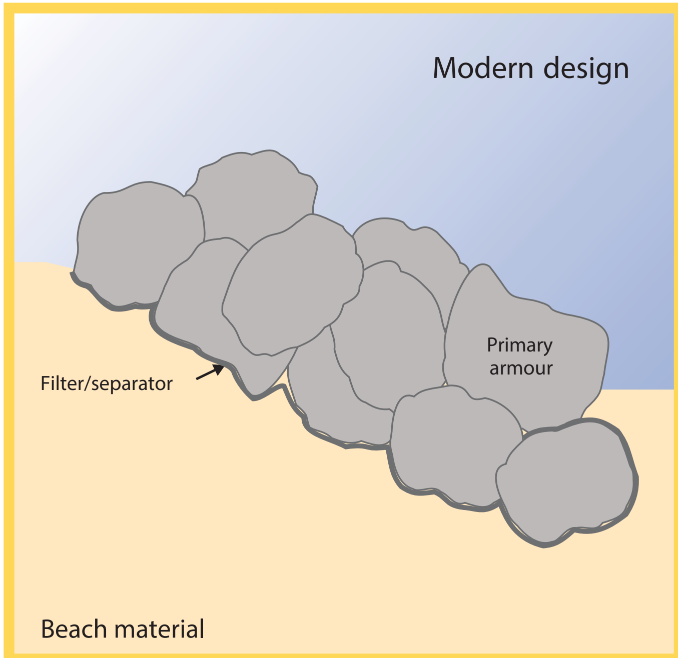
The HPS products have been designed and are manufactured to meet the most demanding performance levels. Using a modern computer-controlled plant, all products are manufactured in an ISO9001 environment and sampled and tested to the appropriate standards.

HPS Solutions – Preventing Erosion

The insidious effects of wave action and high-velocity water flow are a permanent reminder that the environment cannot be tamed. HPS geotextiles offer long-term protection against erosion in some of the most aggressive environments.



A graded stone filter is a complex, time-consuming and costly installation.



A high strength HPS geotextile replaces a multilayered stone filter system and is quicker to install when battling the tides.

On one hand, storms and flash flooding cause high-profile failures, but a slow-moving, low-level stream is just as capable of undercutting its banks and causing slope instability.

Protection to combat erosion currently tends towards soft and natural solutions including beach nourishment and rock armour, the size of which is determined by the anticipated wave or erosional scour action. Filter layers are required beneath rock armour to prevent erosion of the underlying soil. Otherwise, the armour would progressively drop into the increasing void and its effectiveness would be diminished.

Historically, graduated granular filter layers, with progressively larger grain size, were used to prevent this type of erosion.

Installation was time-consuming and they could be difficult to install, particularly if this involved inter-tidal working.

The environmental impact of importing thousands of tonnes of stone of the required gradings, often with restricted access, and their expense, meant that there was scope for alternative solutions.

Revetments constructed from rock armour or pre-cast concrete units require a filter to prevent mobilisation of underlying soil and to allow the free movement of water in both directions.

Without the ability to provide these functions over the entire life of the revetment, there is the potential for the armour to be undermined, as beach material is progressively eroded, or for a build up in hydrostatic pressure.

Of equal importance is the ability of the HPS filter/separator to withstand the rigours of installation and the in-service conditions. Materials susceptible to puncture, tearing and abrasion would exclude them from consideration.

HPS needlepunched, non-woven geotextiles provide all of the required functionality at the levels demanded for erosion prevention applications.

Case Study: Yas Island Race Track Marina, Abu Dhabi, UAE.

hps

HIGH PERFORMANCE SQUARE

- Our established HPS range of materials for construction consists of high performance geotextiles manufactured from high quality, high tenacity, 100% virgin polypropylene fibres.
- Oxidation tests indicate in excess of 150 years durability, as demonstrated on our product CE declarations.
- With a capability to manufacture up to a maximum width of 6m, GEOfabrics' HPS needlepunched geotextiles are specified by engineers due to their longevity and proven ability to work in the most demanding installations.
- High static and dynamic puncture resistance.
- High elongation to break.
- Superior abrasion resistance.
- Excellent filtration characteristics at all strains.
- UV resistance – 1% carbon black.
- Light weight and easy to handle.

Selecting the Most Appropriate HPS Grade

There is a diversity of geotextile types available. To make the appropriate selection a design engineer needs to match their functions and properties with the requirements of the project, to ensure the selected geotextile is both fit for purpose and will function as intended for the design lifetime.

Permeability

Classic filter rules state that each layer of a filter system must be more permeable than the layer beneath. Similar rules developed for geotextiles suggest a coefficient of permeability 10 to 100 times greater than that of the filtered soil. It is important that the geotextile should maintain or exceed its index permeability whilst under load, i.e. any re-orientation of the fibres should not increase or decrease permeability.

Filtration

The characteristic pore size of the geotextile has to be less than the average grain size of the soil to be filtered in order to prevent loss of material through the geotextile. Established design rules for reversing flow applications and a non-cohesive soil state that the geotextile's O_{90} should be less than the d_{50} of the soil to be filtered. For a cohesive soil, $O_{90} < 10 \times d_{50}$.

Both the permeability and filtration rules apply factors of safety to allow for reductions in these properties by soil particles clogging within the geotextile. A filter will be regularly flushed if the system is subject to reversing flows, thus minimising any reduction in filtering efficiency.

Static and Dynamic Puncture Resistance

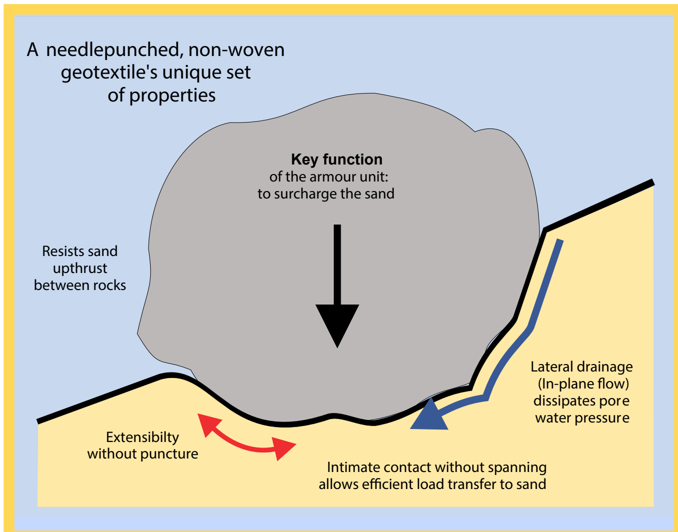
The geotextile must be able to withstand puncture loads imposed during installation and service. The rock weight, its angularity and the drop height all contribute to puncture load. This can be further intensified if due care is not taken during installation. Ideally, it will also possess isotropic (square) tensile properties in order to spread load consistently in all directions.

Elongation

Rock armour functions by virtue of its dead weight being transmitted over as wide an area as possible to consolidate the underlying soil and minimise particle movement. The load imposed on a geotextile by large rock is not evenly distributed. The highest stress concentration will be at the point of intimate contact which in turn will impose high localised strains. The geotextile needs to be sufficiently extensible to enable it to adapt to point loads without puncturing and without loss of hydraulic properties.

Thickness

Thickness is required to cushion potentially penetrating point loads and also to provide a lateral drainage path around any compressed areas. Lateral drainage capacity is defined by the geotextile's in-plane flow under load.



High elongation of HPS geotextile under aggressive rock armour loading.

Classic filter rules state that each layer of a filter system must be more permeable than the layer beneath. Similar rules developed for geotextiles suggest a coefficient of permeability 10 to 100 times greater than that of the filtered soil.

Case Study: Hulayla Marina Development. HPS filter/separator geotextiles preventing intermixing of fill layers behind quay wall structure.

Whilst standard index tests do not exactly simulate the performance of the filter/separator there needs to be some rationale for the specification. HPS geotextiles are manufactured such that the following key properties are maximised for coastal and river applications. A model specification should address the following properties:

- **Water Flow Normal to the Plane**
  Closely linked to permeability. Very important in dynamic, high-flow applications.
- **Pore Size**
  Defines the opening size of a geotextile and its ability to trap particles and prevent their passage.
- **Minimum Tensile Extension**
  Placing rock is potentially the greatest cause of damage and the extensibility of a geotextile is important to avoid localised damage.
- **Static Puncture Resistance (CBR)**
  Simulates the in-situ punching effect of rock, normal to a geotextile, during service.
- **Dynamic Perforation Resistance (Cone Drop)**
  Indicates the ability of a geotextile to accommodate dynamic puncture during rock placement.
- **Coefficient of Permeability**
  Related to the thickness of a geotextile. Expresses water flow as a k_g value allowing comparison with soil values (k_s).
- **Tensile Strength**
  Simulates a geotextile's ability to be handled on-site using heavy excavators. It is common for operators to spread and unroll the geotextile using the bucket of an excavator.
- **Push-through Displacement**
  Simulates biaxial strain caused by rock placed on the geotextile, and the capacity to resist localised damage.
- **Thickness Under Load**
  Ensures that there is a water path beneath the stone allowing dissipation of pore water pressure.

HPS Durability Considerations

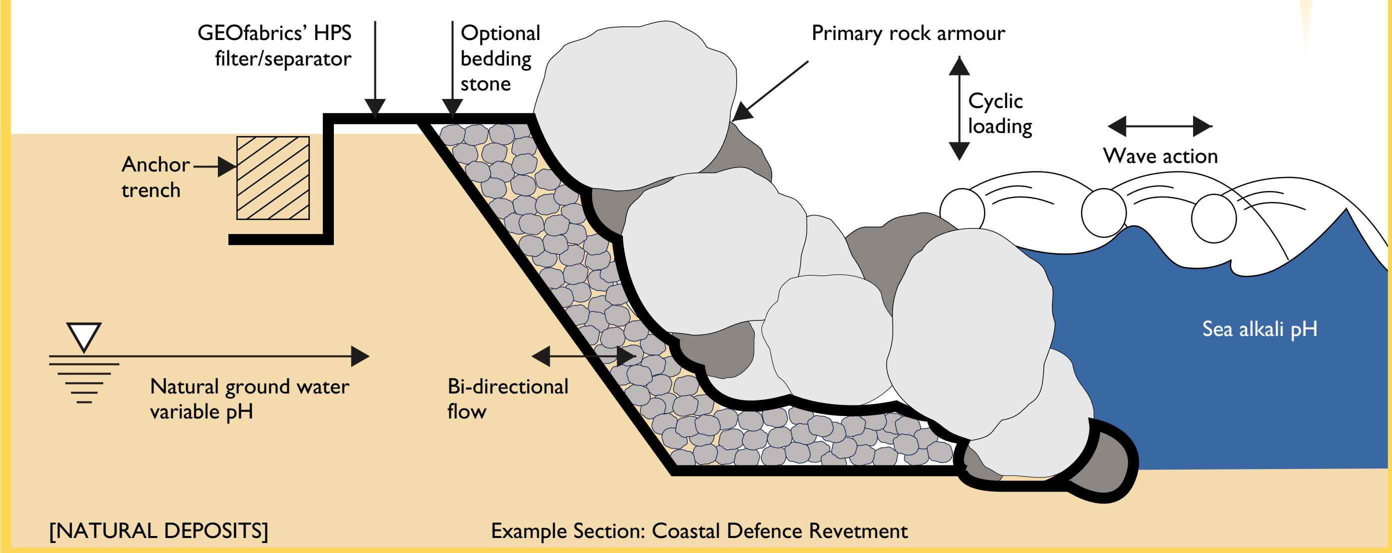
DURABILITY CONSIDERATIONS

Short Term: Construction

- UV stabilised to reduce effects of photo-chemical degradation while exposed.
- High isotropic mechanical performance to withstand puncture and extension during installation. HPS geotextiles are isotropic by manufacture ensuring optimum extension and puncture resistance to withstand abnormal rock armour shapes.

Long Term: Design Life

- Chemically resistant to the environment – both fresh and salt water.
- 100% virgin polypropylene used in HPS manufacture is generally considered inert.
- Mechanically resistant to the environment – able to withstand cyclic loading of tidal action.
- HPS geotextiles have mechanical extensibility up to 80%.



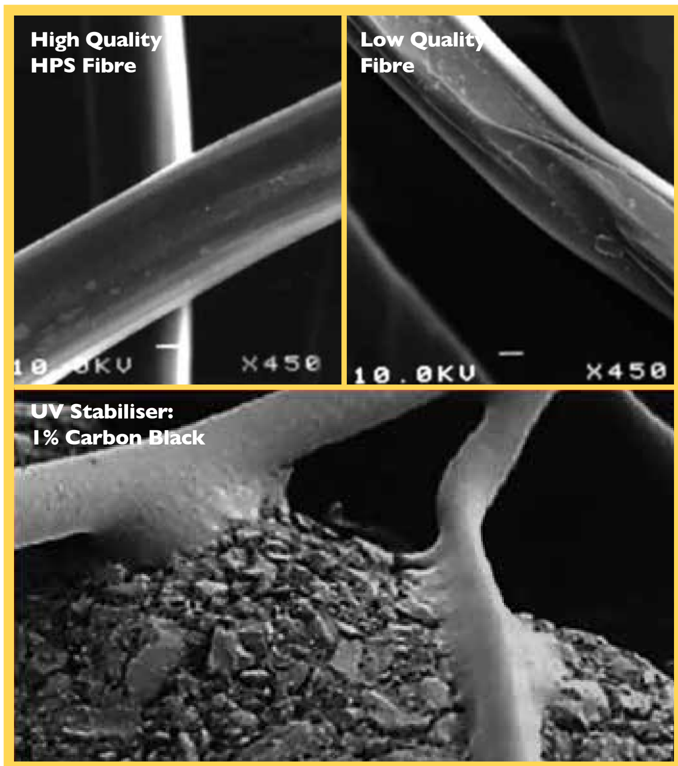
Application specific durability demands.

Raw Material

Fabrics can be produced from both post-industrial and post-consumer recycled fibres. Such fibre types can be of different thicknesses, and volume to surface ratios. Some types of degradation, such as oxidation and UV exposure, are dependent on surface area, whilst others such as diffusion and absorption are inversely related to thickness. It is strongly advised that the use of post-industrial/post-consumer fibre is avoided.

Another polymer fibre that is used within geotextile manufacturing is polyester, of which the most common type is polyethylene-terephthalate (PET) which is produced using condensation polymerisation. PET can offer good mechanical properties and is suitable for some applications, however the ester group can be hydrolysed in the presence of water which is accelerated by alkaline conditions such as salt water. Although polyester can have advantages over other polymers the alkaline sensitivity of this polymer through hydrolysis under long-term loadings, should be a major concern in coastal geotextile applications.

GEOfabrics' HPS range is manufactured from 100% virgin, staple length, high tenacity polypropylene fibres which have a high resistance to acids, alkalis and most solvents. Polypropylene can be considered as inert to acid and alkali attack and is suitable for most geotextile applications.



High resolution images of fibre morphology. GEOfabrics 'thinking about the fine detail'.

The Design Mechanism

The type of polymer and the fibre, together with the production process, define the inherent properties of a geotextile. GEOfabrics' needlepunched, non-woven geotextiles are manufactured using specially engineered fibres and these are bound to each other by mechanical needling.

The balance between hydraulic and mechanical properties is optimised for:

- High permeability with fine filtration.
- High isotropic puncture resistance with high strains to failure.
- Good cushioning ability and impact resistance.
- Good water flow performance.

Design methodology will consider whether the primary armour is to be placed directly or indirectly on the filter/separator. Armour can be placed directly on top of the HPS products so there is no need for an intermediate bedding layer of stone.

Step by Step Specification Procedure

STEP 1

Establish the primary armour weight from wave height predictions.

ROCK WEIGHT EXAMPLE:

4t Maximum Armour Size.

STEP 2

Establish the type and permeability of the underlying soil.

Table 1

Soil type	Filtration d_{50} (mm)	Permeability k_s (m/s)
Clayey silt	0.02	1×10^{-9}
Sandy silt	0.02	1×10^{-7}
Fine sand	0.30	1×10^{-5}
Coarse sand	0.50	1×10^{-4}
Mixed sand & shingle	2.00	1×10^{-3}

STEP 3

Provisionally select an HPS grade based upon its permeability e.g. if soil permeability is 10^{-5}m/s then the grade must have a permeability $>10^{-4}$m/s.

PERMEABILITY EXAMPLE:

Beach material is fine sand with a permeability (k_s) = 1×10^{-5}m/s.

The filter/separator should have a permeability (k_g) >10 x permeability of soil.

Therefore, geotextile k_g should be > 1×10^{-4}m/s.

- GEOfabrics' HPS filter/separators are in the range 3×10^{-3} m/s to 10×10^{-3} m/s.

STEP 4

Check that the grade's $O_{90} < d_{50}$ of the subsoil.
This requirement is satisfied by most of the HPS product range.

FILTRATION EXAMPLE:

d_{50} of fine sand is typically 0.3mm (see Table 1). The filter/separator O_{90} must be < d_{50}.

For d_{50} of 0.3mm – required O_{90} must be <0.3mm.

- GEOfabrics' geotextiles have an O_{90} in the range 0.2mm to 0.07mm.

STEP 5

Check that the selected grade can withstand installation loading without puncture.

INSTALLATION DAMAGE RESISTANCE EXAMPLE:

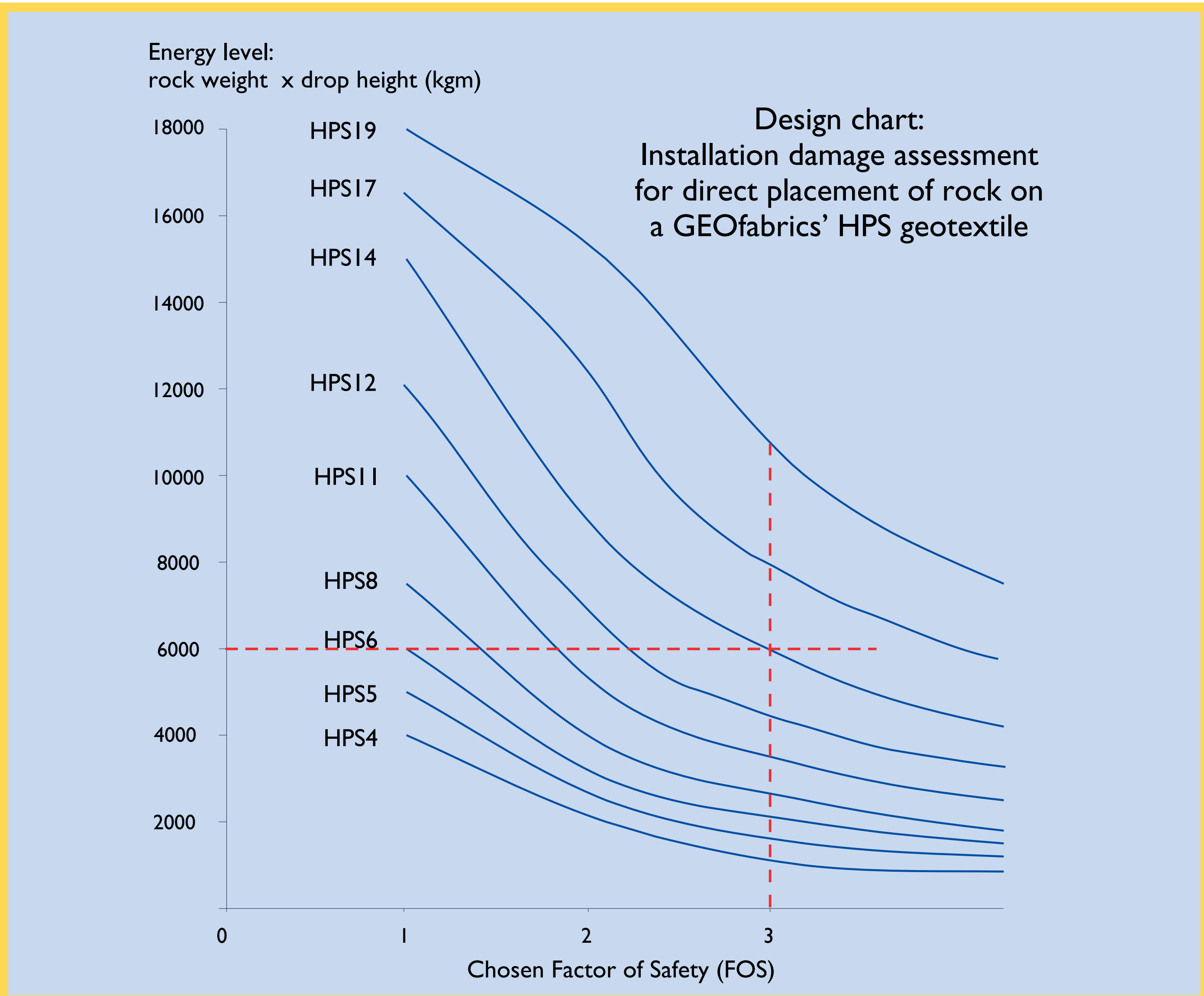
FOS against damage = 3.0.

Maximum likely drop height = 1.5m.

Maximum rock size in contact with geotextile = 4000kg.

Rock drop energy = 1.5 x 4000 = 6000kgm. From installation damage graph below.

- GEOfabrics HPS14 would be suitable in this instance.



STEP 6

Check that there is sufficient design elongation for the fabric to function without tearing. Assuming rock diameter is approx 1.5m, and the rock is depressed into subsoil to a third of its depth, i.e. 0.5m, the localised elongation in the geotextile due to the friction between subsoil and rough edges of the rock could be as much as 20%. To allow a FOS = 3, a minimum tensile extension would therefore be 60%.

ELONGATION EXAMPLE:

FOS against damage = 3.0.

Maximum likely rock diameter = 1.5m (OD).

Depression depth 0.5m (1/3rd OD).

Elongation approx. 20% x FoS 3.0 = 60% elongation required (Tensile Extension).

- GEOfabrics' HPS14 would be suitable in this instance.

Live Installation: 3t rock armour dropped from 2m height onto HPS14 overlying a sandy clay unconsolidated beach deposit.

Specification Considerations

A well-written specification for a filter/separator is of paramount importance as there are many geotextile types available with widely varying physical characteristics and production qualities. Testing and quality assurance is as important for geotextiles as it is for other materials incorporated in the works.

British Standard (BS) and European (EN) index tests are available to enable engineers to compare one geotextile with another. These tests and quality control schemes need to be referenced in the specification **(see example specification below)**.

The tests should then be used to assess the suitability of a proposed geotextile for the works. The manufacturer's Quality Control procedures should be made available and a Certificate of Conformance should cover each consignment. Additional samples may be taken from each consignment, by the contractor, to be tested as directed by the engineer.

As an example, a performance specification is provided based on HPS14 – the product identified in the worked example.

2.1 Physical Properties:				
Polymer type:	Prime-quality virgin polypropylene fibre containing 1% carbon black by weight.			
Geotextile type:	Needlepunched non-woven fabric manufactured from mechanically entangled staple fibre.			
	Approved test method	**Units**	**Typical mean value**	**Allowable tolerance to 95% confidence limits**
Thickness @ 2kPa:	EN ISO 9863-1: 2005	mm	7.8	n/a*
2.2 Mechanical Properties:				
Static puncture strength (CBR)	EN ISO 12236	kN	14	-10%
Push-through displacement	EN ISO 12236	mm	65	n/a*
Tensile strength	EN ISO 10319	kN/m	75	-10%
Tensile elongation	EN ISO 10319	%	80	+/-30%
Cone drop perforation hole diameter	BS EN 13433	mm	0	+3mm
2.3 Filtration Properties:				
Water flow normal to the plane of the geotextile @50mm head	EN ISO 11058	$l/s/m^2$	25	-30%
Characteristic opening size: 90% finer [O_{90}]	EN ISO 12956	μm	<69	+/-30%
** Indicates property not used for quality control as part of harmonised testing within EN 13253.*				

2.4 Durability (according to annex B: EN 13253):			
Resistance to weathering (UV) @ $50MJ/m^2$ radiant exposure	EN 12224	Retained strength	>80%
Resistance to oxidation (150 years)	EN 13438	Retained strength after 84 days	>80%
Microbiological resistance	EN 12225	Retained strength	>80%
Resistance to liquids	EN 14030	Retained strength	>80%
** Durability test data can be supplied by the manufacturer – test frequency must not exceed 3 years.*			

Model specifications are available to download from www.geofabrics.com

Performance Specification

- The geotextile to be used as a filter/separator beneath the rock armour shall be a non-woven fabric manufactured by needlepunching virgin, staple fibres of polypropylene incorporating a minimum of 1% by weight active carbon black. Geotextiles manufactured from fibres of more than one polymer will not be permitted.

- The geotextile shall have the following properties:
  - Geotextiles shall be delivered to site in packaging, which will protect the rolls from ultra-violet light degradation. The labelling shall clearly identify the product supplied in accordance with **BS EN 10320: 1999.** Geotextiles shall be protected at all times against physical or chemical damage. Geotextiles shall be kept in the wrappings provided by the manufacturer until required for use in the works.
  - The geotextile manufacturer shall provide production test certificates at the rate of one set of certificates per 6,000m^2 delivered to site and a minimum of one set per contract. Test methods employed shall be in accordance with the requirements of **BS EN ISO 13253:A1 2005** and be accredited by UKAS to carry out the required tests. Certificates relevant to a batch of geotextile shall be furnished to the engineer prior to that batch of geotextile being incorporated in the works.
  - The rolls of geotextile shall be stored on level ground and stacked not more than five rolls high and no other materials shall be stacked on top of the geotextiles.
  - The geotextile shall not be exposed to direct sunlight for longer than thirty days.
  - The geotextile shall be laid and installed in the positions and to the line and levels described on the drawings. Material, which will be in contact with the geotextile, shall not have protrusions which are likely to damage the geotextile during installation or in service. Construction plant must not operate directly on the geotextile.
  - Joints shall be formed by overlapping by a minimum of 1000mm. A reduction in overlap to 300mm may be considered by the engineer where the sub-layer is firm and above water level.

The following definitions shall apply when considering test results:

A *set of test results* shall be those results derived from specimens cut from one sample. The *mean value* for any set of test results shall be the arithmetic mean of that set of results.

The *characteristic value* is the value below which not more than 5% of the test results may be expected to fall. This represents the value at 1.64 standard deviations below the mean value.

Rock armour Groyne installation to inhibit 'Long Shore Drift' and protect the coastline.

Installation Guidance

The high strain capacity of the HPS products may be used to advantage when designing anchoring and edge details. Wrapping around a run of small stone or bedding stone, if available, is a proven toe detail. At the top of the revetment the geotextile should be anchored in a trench or fixed to a structure such as a sheet-piled wall. The sides should be treated in a similar fashion for the permanent works and suitable precautions taken to protect them at high tides during the progress of the works.

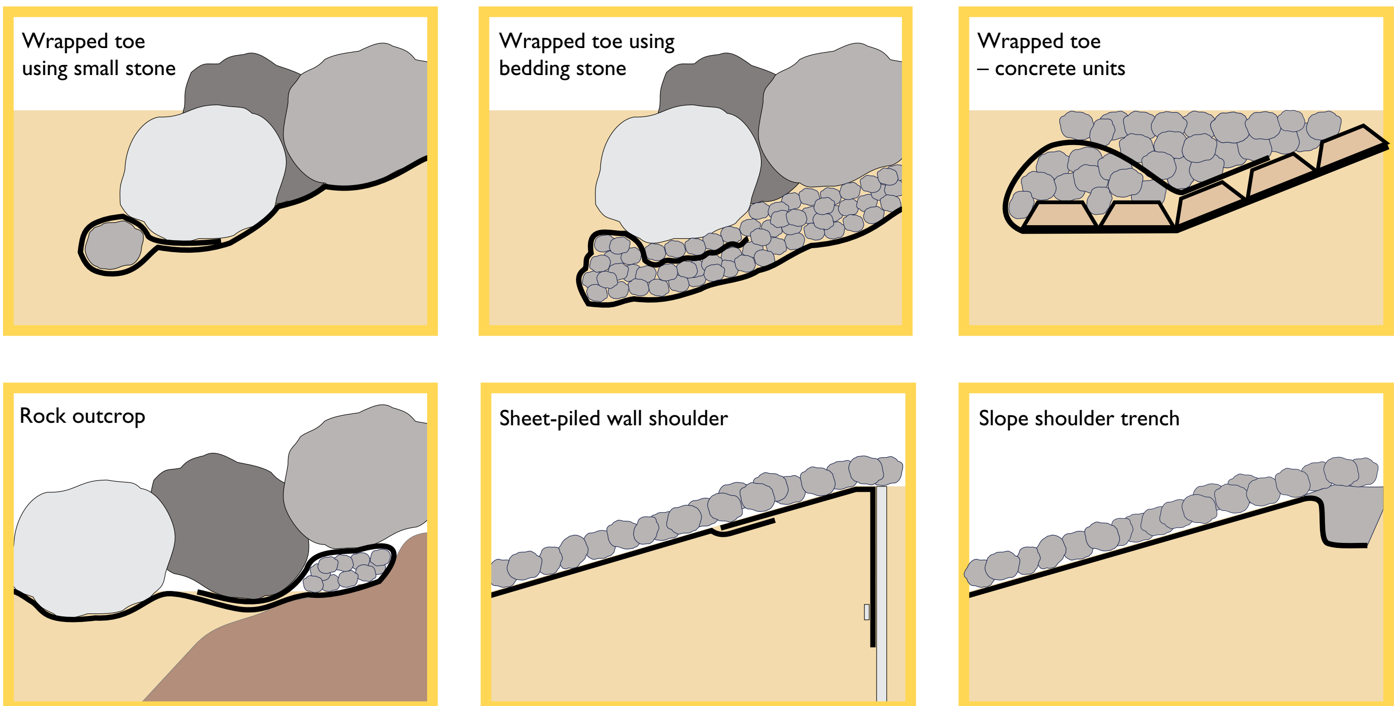
Joints

HPS geotextiles are produced up to 6m wide to minimise overlaps. Unbonded overlaps should be between 300mm and 1000mm (at the discretion of the engineer) depending upon the firmness of the underlying soil and the relative ease of working.

300mm overlaps are acceptable for above-water working on firm subsoil and 1000mm overlaps are recommended for under water working on soft silts.

Contractors placing the HPS products under water often prefer to joint and re-roll the product onto a metal core. This enables widths up to 12m to be pre-fabricated prior to installation.

Joints can be made by sewing a prayer seam using a bag-closing, handheld sewing machine. This procedure can achieve joints with 60% of the geotextile's strength.



Typical HPS installation details. *For further site specific installation details, please contact the GEOfabrics' technical team for assistance.*

Quality and Development

GEOfabrics continue as one of the main geosynthetic innovators in the industry with our highly active Research and Development department.

GEOfabrics has an extensive laboratory and test facilities. We have a wide range of UKAS accredited tests used for quality control and research and development.

Mechanical testing equipment for tensile strength and elongation.

Our continued success in new products is as a result of an experienced team and our ongoing relationships with an expanding list of professional clients who partner with us to produce bespoke geosynthetic solutions.

GEOfabrics' priority is to manufacture a high quality end product that provides the exact needs of our customers, in line with function, durability, value and in accordance with all current legislation and design standards.

HPS: Long-Term Durability

GEOfabrics manufacture from 100% virgin staple polypropylene fibre including 1% carbon black. Such fibres are generally considered chemically and biologically inert, in all but the most aggressive environmental applications.

GEOfabrics' HPS geotextiles are resistant to chemical and biological clogging, have UV stability to prevent degradation when exposed to sunlight and provide long-term strength without reduction in performance or function.

GEOfabrics' innovative products are produced using the latest manufacturing technology and UKAS accredited testing facilities.

Should you require any information or assistance in relation to this support service please contact us on +44 (0)113 202 5678.

Accreditations

BTTG ISO 9001:2008 UKAS MANAGEMENT SYSTEMS 0246

The ISO 9001 Management system uses customer feedback, continuous assessment and independent auditing to drive both improvement and the control required for a professional and quality based environment.

UKAS TESTING 1773

Accredited laboratories that operate in line with UKAS methodology, policy and audits to provide accurate performance information.

CE 0338

GEOfabrics Limited manufactures CE Marked products that meet the construction products directive.

Acknowledgements given to Ciria C683 'The Rock Manual':

CIRIA

GEOfabrics®

Global Supply Network

GEOfabrics Limited supply a world class range of engineering products for a diverse set of applications, across the UK and international markets. We pride ourselves on building strong, long-term and mutually beneficial partnerships with our agents and distributors, in order to provide a quality technical supply service to our clients.

UK EUROPE MIDDLE EAST NORTH AMERICA AFRICA ASIA

Further literature, in the form of case studies, design guides, installation procedures, product data sheets and model specifications **can be downloaded from www.geofabrics.com**

GEOfabrics Limited
Skelton Grange Road
Stourton
Leeds
LS10 1RZ
United Kingdom

Tel: +44 (0) 113 202 5678
Fax: +44 (0) 113 202 5655

Email: info@geofabrics.com
Web: www.geofabrics.com

CERTIFICATE NO. FM 31473 1773 0338

International distribution

BELGIUM FINLAND GREECE HONG KONG IRELAND OMAN INDIA ROMANIA
SAUDI ARABIA THE NETHERLANDS TURKEY UNITED ARAB EMIRATES USA BRAZIL

ICM 10167 03 2017

H.2 Geobags

TenCate Geotube®

Geobags

Woven fabric with lifting straps

The Geotube® Geobag is a containment product manufactured from engineered fabrics combined with high capacity seams that allow sand or other suitable material to be in-filled. They are engineered to provide strength, durability and soil tightness during installation and operational life. The bags are filled with sand through open top or through inlet fabric sleeve on top of the bags. The resulting filled bag can be easily handled and are used to replace rock for the construction of dyke structures or for erosion protection works.

This range of Geotube® Geobags is manufactured using engineered woven fabric with attached lifting straps for handling and installation convenience on site. They are ideal for constructing dyke structures of a temporary nature or used as core fill material in permanent dyke structures.

Properties of TenCate Geotube® Woven Geobags with Lifting Straps

Properties		Test Method	Unit	GB600 MSS1	GB600 MSS2	GB600 MSS3	GB600 MSS4
Colour				**Black**	**Black**	**Black**	**Black**
Nominal box dimensions (unfilled)							
Width			m	1	1	1.6	2
Length			m	1	2.5	1.6	3
Height			m	1	1	1.6	1.5
Lifting points							
Number of lifting points				4	6	10	10
Tensile strength per strap		ISO 10321	kN	55	55	55	55
Fabric							
Wide width tensile strength	MD	ISO 10319	kN/m	200	200	200	200
Wide width tensile strength	CD	ISO 10319	kN/m	200	200	200	200
Strain at nominal tensile strength	MD	ISO 10319	%	10	10	10	10
Strain at nominal tensile strength	CD	ISO 10319	%	10	10	10	10
CBR puncture strength		ISO 12236	kN	22	22	22	22
Abrasion resistance		ASTM D4886	% retained	80	80	80	80
UV resistance (at 500 hours)		ASTM D4355	% retained	90	90	90	90
Pore size O_{90}		ISO 12956	mm	0.35	0.35	0.35	0.35
Water permeability Q_{50}		ISO 11058	$l/m^2/s$	20	20	20	20

Other bag sizes tailored to project requirements may be available upon request.

300 614-td-02 | 20

TenCate Geotube® *is a registered trademark of TenCate Geosynthetics.*

The values given are indicative and correspond to average values obtained in accredited testing laboratories and institutes.

TenCate Geosynthetics Asia Sdn. Bhd. (264232-U)
14, Jalan Sementa 27/91, Seksyen 27,
40400 Shah Alam, Selangor Darul Ehsan, Malaysia.
Tel: +60 3 5192 8568 Fax: +60 3 5192 8575
Email: info.asia@tencategeo.com www.tencategeo.asia

MS ISO/IEC 17025 TESTING SAMM NO. 207

ISO9001 : 2015

Accreditation #: GAI-LAP-45-02

BUATAN MALAYSIA

TENCATE GEOSYNTHETICS

H.3 Geomatting

TENCATE
Geolon®

Robulon PP
Technical Data

TenCate Geolon® Robulon PP is a high strength geocomposite for erosion control purposes. The product is made of 100% highly durable and UV resistant PP, with a 3 dimensional structure. The combination of reinforcement and soil retention makes Robulon the ideal mat for erosion control in a variety of applications such as protection of slopes, geomembranes, canal and river beddings, and shorelines.


TenCate Geolon® Robulon PP

Characteristics Standard]		Unit	PP 40	PP 60	PP 80
Type of product			Geocomposite made of 100% polypropylene, consisting of a high strength woven base layer featuring inseparable loops for soil, gravel or concrete retention		
Product Properties					
Mass per unit area [EN ISO 9864]		g/m²	510	580	675
Thickness under 2kPa [EN ISO 9863-1]		mm	10	10	10
UV resistance (retained tensile strength) [EN ISO 12224]		%	> 80	> 80	> 80
Base Layer Properties					
Tensile strength [EN ISO 10319]	MD*	kN/m	40	63	84
	CD*	kN/m	40	57	84
Elongation at maximum strength [EN ISO 10319]	MD*	%	17	8	8
	CD*	%	12	8	8
CBR puncture resistance [EN ISO 12236]		kN	4	6	8
Dynamic perforation [EN ISO 13433]		mm	15	10	9
Forms of supply					
Width		m	5	5	5
Length		m	45 / 50	50	50
Roll diameter		m	0.78 / 0.8	0.85	0.85
Roll weight [indicative]		kg	125 / 140	160	180

* MD = Machine Direction CD = Cross Direction
The values given are average values obtained in our laboratories and in testing institutes. The right is reserved to make changes without notice at any time..

TENCATE GEOSYNTHETICS AUSTRIA GMBH
Schachermayerstr. 18 Tel. +43 732 6983 0, Fax +43 732 6983 5353
A-4021 Linz, Austria service.at@tencategeo.com, wwww.tencategeo.at

BeNeLux Tel. +31 546 544 811 service.nl@tencategeo.com
Central Eastern Europe Tel. +43 732 6983 0 service.at@tencategeo.com
Czech Republic Tel. +420 2 2425 1843 service.cz@tencategeo.com
France | Africa Fax +33 1 34 23 53 48 service.fr@tencategeo.com
Germany Tel. +49 30 3435 02 10 service.de@tencategeo.com
Italy Tel. +39 0362 34 58 11 service.it@tencategeo.com
Near Middle East Tel. +971 4810 3295 service.nme@tencategeo.com
Poland Tel. +33 1 34 23 53 63 service.pl@tencategeo.com
Russia | CIS Tel. +43 732 6983 0 service.ru@tencategeo.com
Scandinavia | Baltics Tel. +31 546 544 811 geonordic@tencategeo.com
Spain | Portugal Tel. +34 607 499 962 service.es@tencategeo.com
Switzerland Tel. +49 30 3435 02 10 service.ch@tencategeo.com
Turkey Tel. +43 732 5983 0 service.tr@tencategeo.com
UK | Ireland Tel. +44 1952 588 066 service.uk@tencategeo.com

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TenCate Geosynthetics Austria Gesm.b.H, TenCate Geosynthetics France S.A.S and TenCate Geosynthetics Netherlands b.v. are certified for the design, manufacturing and sales of geotextile and geotextile related products.

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TENCATE GEOSYNTHETICS

Dr.-Ing. Jan Retzlaff
as public appointed and sworn in expert by
the Chamber of Industry and Commerce of Erfurt
for construction textiles and geosynthetics

Client number	725111
Project number	173601

expert's statement

Verification of the environmental innocuousness geotextile TenCate Geolon PP 60

Ordered on:	04 September 2017
Auftrag von:	TenCate Geosynthetics Netherlands B. V. Hoge Dijkje 2 7442 AE Nijverdal The Netherlands
Erstellt am:	05 October 2017
Erstellt von:	Dr.-Ing. Jan Retzlaff c/o GEOscope GmbH & Co. KG Nordstr. 3 99427 Weimar Germany Tel.: +49 (0) 3643 251 9857 Email: j.retzlaff@geoscope.eu

This report contains 7 text pages including an enclosure.

0 Content

1 Order
2 Basic information
3 Background
4 Geosynthetics
5 Laboratory testing
6 Results
7 Evaluation

2 Order

On 2017-09-04 I have been asked by TenCate Geosynthetics Netherlands B. V. to assess the environmental innocuousness of the geotextile TenCate Geolon PP 60

3 Basic information

A product sample and further product information have been provided by the employer. Furthermore up to date standards and references have been used for the development of this statement.

[FGSV-535] FGSV (Hrsg.): Merkblatt über die Anwendung von Geokunststoffen im Erdbau des Straßenbaus. M Geok E. Köln: FGSV, 2016

[DGGT-2005] DGGT (Hrsg.): Empfehlungen zu Dichtungssystemen im Tunnelbau. EAG-EDT Empfehlungen des Arbeitskreises AK 5.1 „Kunststoffe in der Geotechnik und im Wasserbau“ der DGGT. Essen: VGE, 2005

[BBodSchVO-2009] BMJ: Bundes-bodenschutz- und Altlastenverordnung (BBodSchVO). www.juris.de. Stand: 31.07.2009

3 Background

Following general assumptions, polymeric raw materials are not water-soluble and hence do not affect soil or groundwater. There are water-soluble, flushing or edulcorating additives like stabilisers, auxiliary materials or pigments. These substances are in particular the reason of the demand of the verification of environmentally innocuousness following M Geok E [FGSV-2005] and EAG-EDT [DGGT-2005]. This verification can be given via ingredients and declaration of environmentally innocuousness on the safety data sheet for the corresponding product or via a chemical analysis. Both sources mentioned above are describing a procedure for this purpose. The procedure is referring to methods for the preparation of samples and the analysis mentioned in attachment 1 of BBodschVO [BBodSchVO-2009]. Unless the test values assessing the effect of soil on groundwater following § 8 para. 1 clause 2 No. 1 under point 3.1 of attachment 2 of [BbodSchVO-2009] are not undercut, the geosynthetic is graded as environmental innocuous if the global parameter TOC in the 5. eluate does not exceed the critical value of 20 mg/l.
According to point 7.6 para. 3 M Geok E the product can still be graded as environmental innocuous, if a small exceedance of the critical values in the fifth eluate is coming along with a significant decrease of the TOC concentration from the first to the fifth eluate.

4 Geosynthetics

Representative tested was a geosynthtetics of TenCate Geolon PP 60
This is a geotextile

Samples arrived on 2017-09-07

5 Laboratory testing

The preparation of the samples, the eluates and the chemical analysis of these has been carried out following the analysis mentioned in attachment 1 by a from DAP following
DIN EN ISO/IEC 17025:2005 with DAP-PL-3067.00 accredited laboratory for environmental analysis. The laboratory is for the test proceedures as listed in enclosure 1 of this report.

6 Results

The critical values shown in the following tables are relevant concerning to the assessment of environmental innocuousness.

Tabelle 1: Results for inorganic substances

Inorganic substances	Critical value [µg/l]	Measurement [µg/l]	Result [-]
antimony	10	< 5	o.k.
arsenic	10	< 5	o.k.
lead	25	< 5	o.k.
cadmium	5	< 0,5	o.k.
chromium, total	50	< 5	o.k.
chromate	8	< 5	o.k.
cobalt	50	< 5	o.k.
copper	50	< 5	o.k.
molybdenum	50	< 5	o.k.
nickel	50	< 5	o.k.
mercury	1	< 0,2	o.k.
selenium	10	< 5	o.k.
zinc	500	11	o.k.
tin	40	< 5	o.k.
cyanide, total	50	< 5	o.k.
cyanide, easily purgeable	10	< 5	o.k.
fluoride	750	< 10	o.k.

Tabelle 2: Results for organic substances

Organic substances	Critical value [µg/l]	Measurement [µg/l]	Result [-]
petroleum derived hydrocarbon	200	< 50	o.k.
arenes	20	< 5	o.k.
benzene	1	< 1	o.k.
volatile halog. hydrocarbon	10	< 8	o.k.
aldrine	0,1	< 0,005	o.k.
DDT	0,1	< 0,03	o.k.
phenole	20	< 10	o.k.
PCB, total	0,05	< 0,03	o.k.
PAH, total	0,2	0,071	o.k.
naphtalene	2	0,21	o.k.

Another criterion is the development of the total TOC from the first eluate to the fifth eluate. The critical value for the total TOC in the fifth eluate is 20 mg/l and shouldn't be exceeded.

Tabelle 3: Results for the development of TOC

Development of TOC	Critical value [µg/l]	Measurement [µg/l]	Result [-]
1st eluate		2,1	
3rd eluate		0,44	
5th eluate	20	0,24	o.k.

The following figure shows the development of the TOC concentration from the first to the fifth eluate:

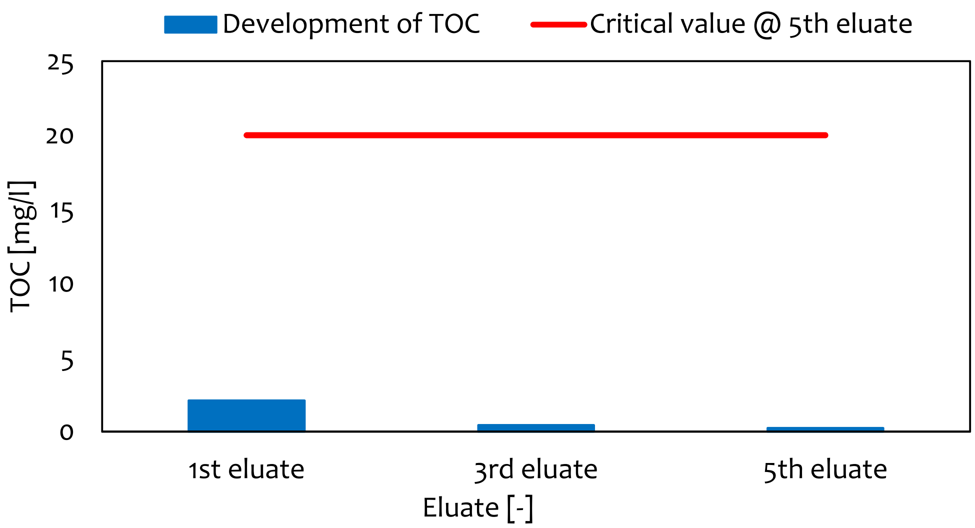


Figure 1: Development of TOC

7 Evaluation

The verification of every single value has shown that the representative tested product can be graded as environmentally innocuous following M Geok E.

This evaluation is valid for all members of the product family.

Dr.-Ing. Jan Retzlaff

Applied test proceedures:

Substances	Detection limit	Standard
antimony	< 5 µg/l	DIN EN ISO 11885
arsenic	< 5 µg/l	DIN EN ISO 11885
lead	< 5 µg/l	DIN EN ISO 11885
cadmium	< 0,5 µg/l	DIN EN ISO 11885
chromium, total	< 5 µg/l	DIN EN ISO 11885
chromate	< 5 µg/l	DIN 38405 - D24
cobalt	< 5 µg/l	DIN EN ISO 11885
copper	< 5 µg/l	DIN EN ISO 11885
molybdenum	< 5 µg/l	DIN EN ISO 11885
nickel	< 5 µg/l	DIN EN ISO 11885
mercury	< 0,2 µg/l	DIN EN 1483 - E12
selenium	< 5 µg/l	DIN EN ISO 11885
zinc	< 5 µg/l	DIN EN ISO 11885
tin	< 5 µg/l	DIN EN ISO 11885
cyanide, total	< 5 µg/l	DIN 38405 - D13
cyanide, easily purgeable	< 5 µg/l	DIN EN ISO 14403 - 1
fluoride	< 10 µg/l	DIN EN ISO 10304 - 1 - D20
petroleum derived hydrocarbon	< 50 µg/l	DIN EN ISO 9377 (GC/FID)
arenes	< 5 µg/l	ISO 11423 - 1
benzene	< 1 µg/l	ISO 11423 - 1
volatile halog. hydrocarbon	< 8 µg/l	DIN EN ISO 10301 - F4
aldrine	< 0,005 µg/l	DIN 38414 - S20
DDT	< 0,03 µg/l	DIN 38414 - S20
phenole	< 10 µg/l	DIN 38409 - H16
PCB, total	< 0,03 µg/l	DIN 38414 - S20
PAH, total	< 0,005 µg/l	DIN ISO 28540
naphtalene	< 0,005 µg/l	DIN ISO 28540
TOC	< 0,1 mg/l	DIN EN 1484 - H3

H.4 Rock bags

Salix AquaRockBag®

Salix

Building with Nature

Product Overview

The AquaRockBag® has been developed as a result of Salix's 25 years of soil bioengineering experience using high performance nets filled with graded rocks as flexible, but ecologically advantageous, revetments.

• The AquaRockBag nets have been proven to be the most robust nets in fresh and saline water environments and have the highest UV resilience and anti-abrasion properties of any net product. Aqua Rock bags complete the family of sustainable rock revetments that Salix manufacture, which also includes Rock Rolls and Rock Roll Mattresses - http://bit.ly/RockRolls, http://bit.ly/RockMattress.

• AquaRockBags are a flexible and sustainable solution that are suitable alternatives to concrete, gabions, blockstone and rip rap revetments.

• The smaller graded rock within the AquaRockBag reduces flow velocities by absorbing water energy into the high interstitial spaces between the rocks. These high interstitial spaces also provide enhanced habitat for invertebrates, accrete fines, gravels and silts which allow vegetation to establish naturally over time.

• AquaRockBags can be used independently or as part of a bioengineering design with Salix's vegetated systems above water level, providing the most effective scour and erosion control solutions available in the market. Working with nature rather than against it to provide habitat biodiversity simultaneously with an engineered approach for asset protection.

Applications

AquaRockBags® are used in both freshwater and saline conditions.

They are flexible, work far better with natural processes than other revetments, provide ecological benefits and can be vegetated over relatively short time scales.

AquaRockBags work best under water and can be combined with softer soil bioengineering solutions above water level.

Applications

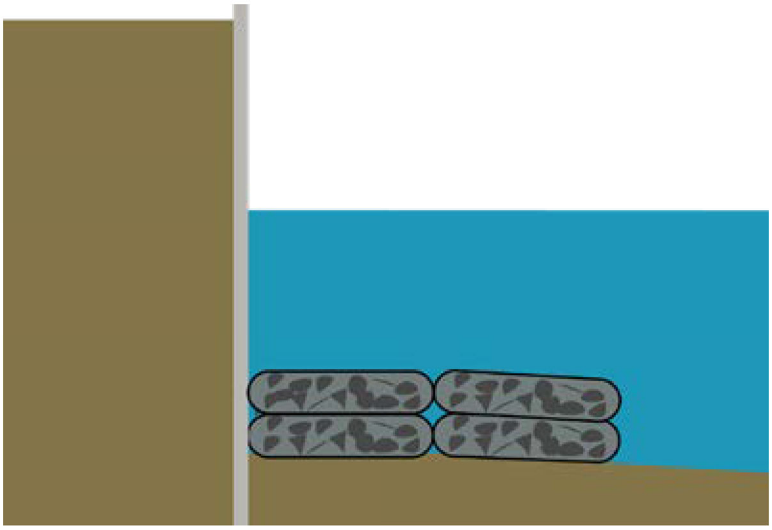
- River bank revetments
- Scour protection around bridges and other structures
- Temporary works solutions

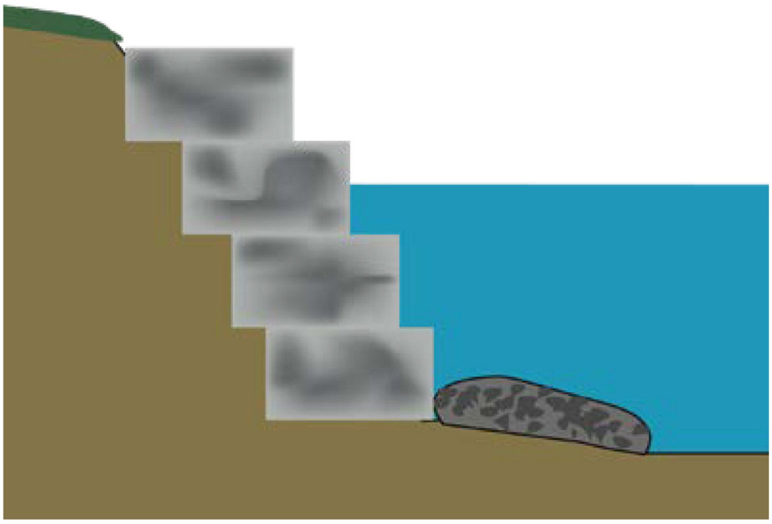
Applications

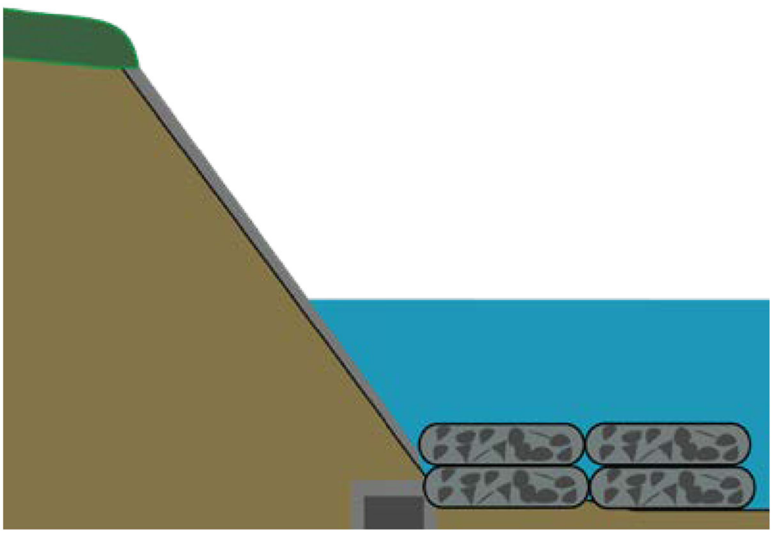
- Artificial reefs
- Shoreline protection
- Marine and coastal structures

Applications

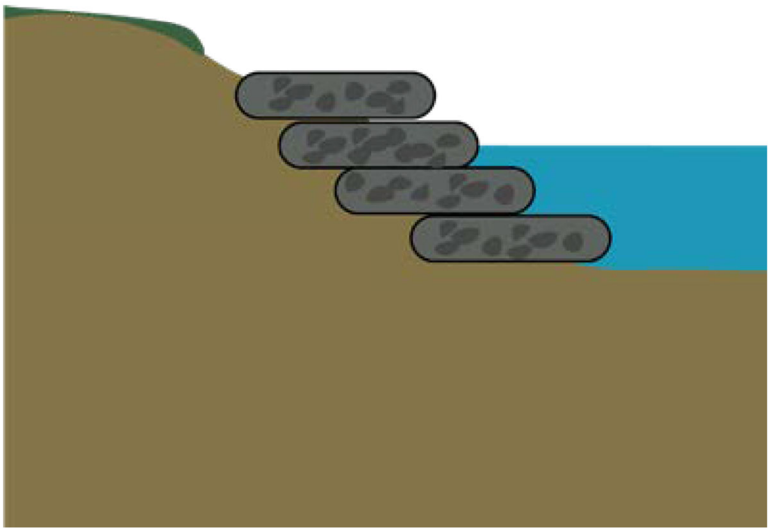
Protection of Bank Structures

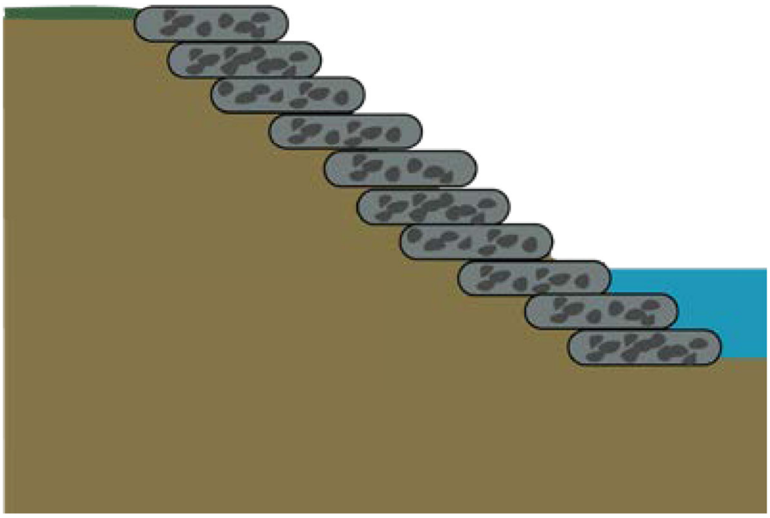


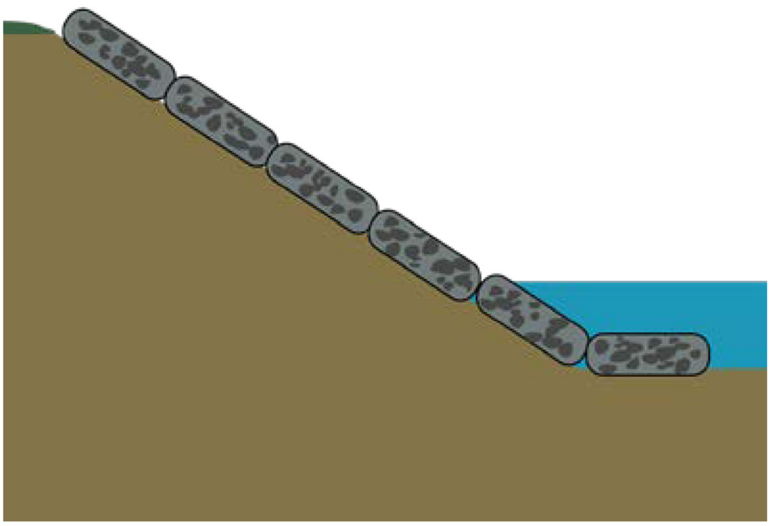


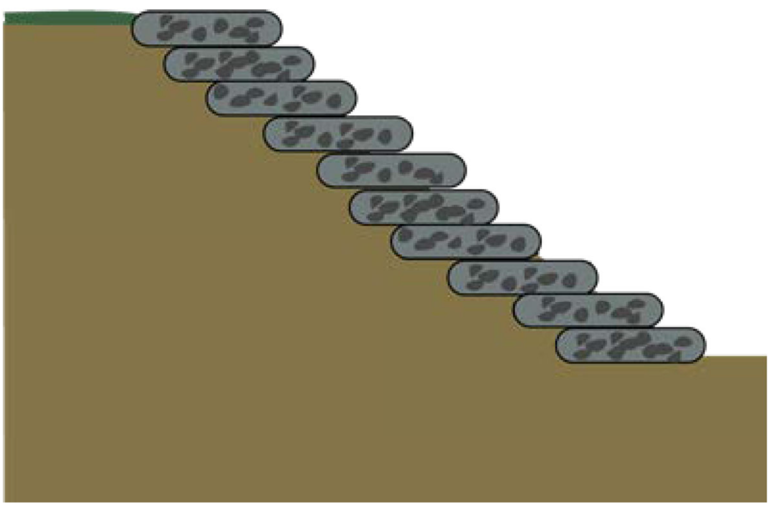


Bank Erosion Revetments



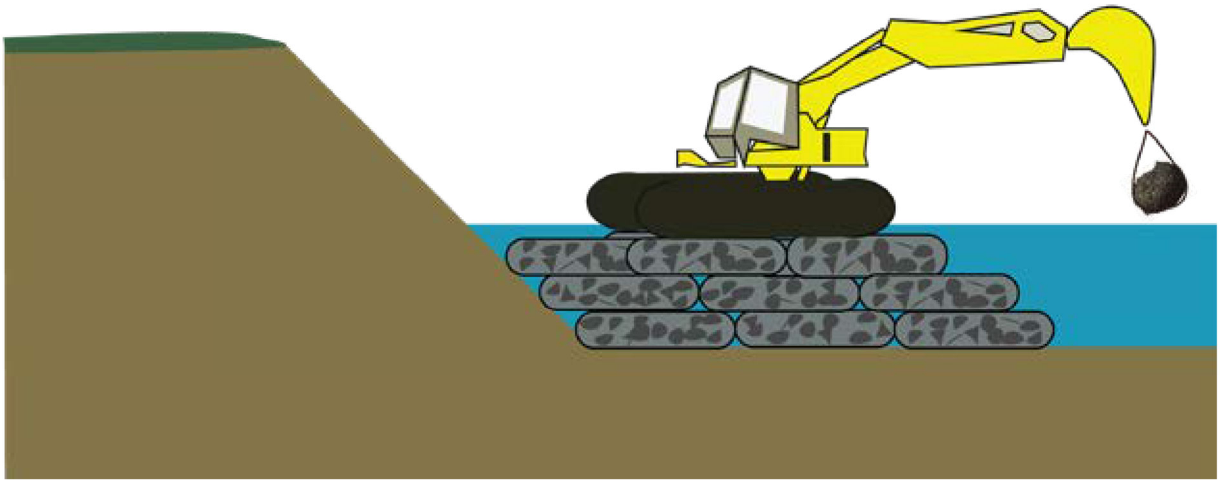




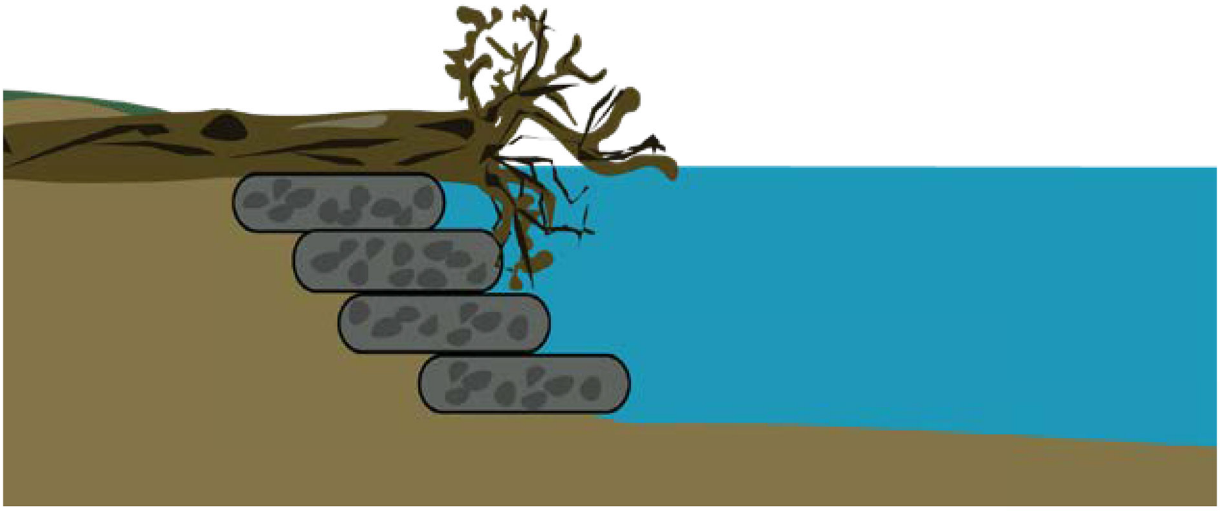


Applications

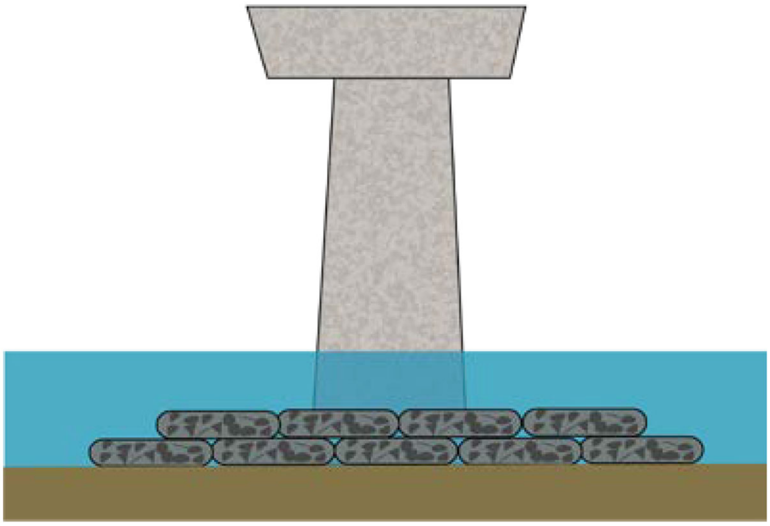
Temporary Works Solutions

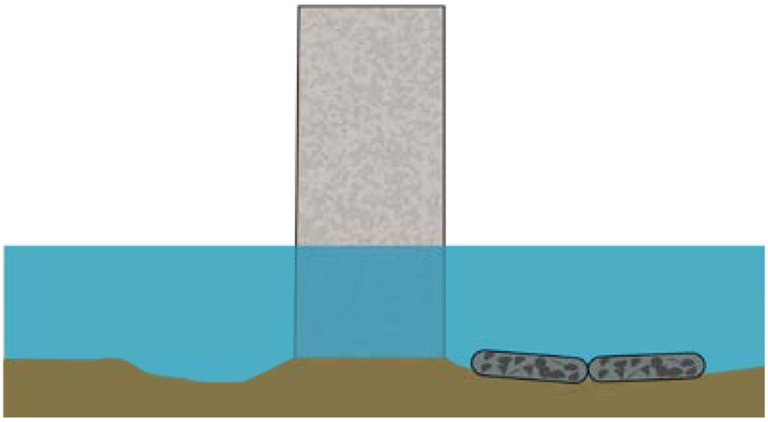


Combine with Soil Bioengineering Solutions

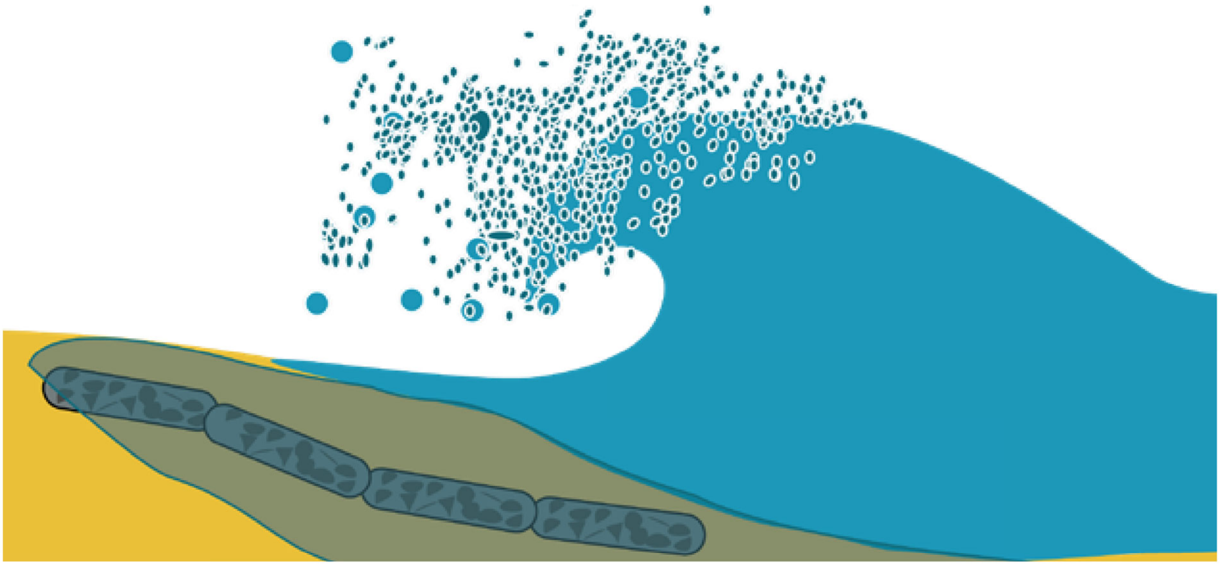


Scour Protection Around Bridges & Other Structures





Coastal Defence and Artificial Reefs



Benefits

Rapid and Safe Installation

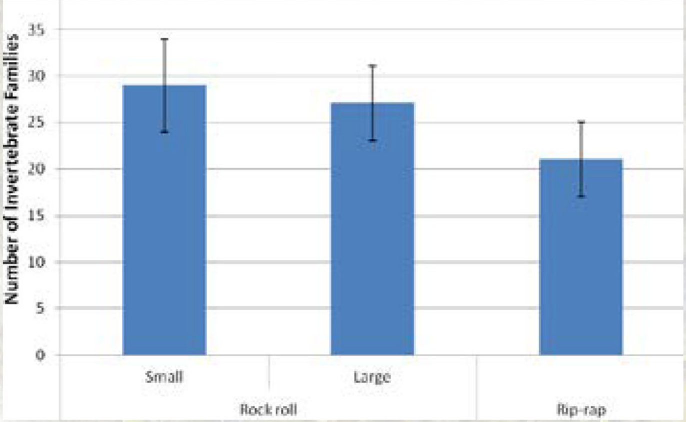
- Rapid installation compared to filling wire mattresses on site with big savings on labour costs
- Can be installed in flowing water or below water level
- Units are pre-filled so less labour is required to install (90% labour savings over gabions)
- Simple and quick to fill on site
- Can often replace large rock armour, concrete and rip rap plus provide long term protection for soft/green engineering solutions
- Can be used in fresh or salt water
- Flexible system that contours to the surface
- UV stabilised nets are abrasion resistant and do not suffer from corrosion
- Health & Safety benefits due to no fabrication on site reducing accident risks
- Easy to move on site

Resilient protection whilst also providing habitats

AquaRockBags® provide habitats for a diverse range of marine and freshwater invertebrates. Examples found in research from Swansea University include: Top left to right: Phyllodoce maculate , Capitella capitata , Scoloplos armiger; Bottom left to right : Melita palmate, Carcinus meanus, Idotha pelagica.

Ecological Benefits

- The stone sizing and grading within the AquaRockBag has been developed to provide a balance between the structural interlock needed to provide a robust revetment and the optimum grading for ecosystem development and diverse biotic community habitat
- AquaRockBag encourages fine accretion of sediment to enable vegetation establishment providing habitat for insects, molluscs and other invertebrates, which in turn supports fish and water bird populations
- Unvegetated Salix AquaRockBag blend in easily with natural freshwater and marine sediments and provide substratum for numerous faunal and invertebrate species
- Many hard revetments (e.g. concrete blocks, blockstone, rip-rap, gabions) deflect and reflect water energy which can cause erosion and scour issues elsewhere. AquaRockBags are absorptive rather than reflective due to the high interstitial spaces between the rocks. As such, water energy is absorbed, resulting in natural processes being retained and minimising the impacts downstream or around the AquaRockBag revetment
- AquaRockBags can be used in conjunction with Soil Bioengineering techniques as a hybrid solution to create genuine ecological enhancements within the revetment design.



Swansea University

Advanced Net Technology

- The AquaRockBags® are made from the most abrasion resistant and UV resistant materials available, ensuring the highest performance levels, greatest longevity and lowest risk to the natural environment
- Independent research has shown that the AquaRockBags nets are significantly more stable than nets made from recycled polymers, so last longest and are more abrasion resistant
- Constant investment is made in net technology to improve engineering performance and to ensure minimal environmental impact

Materials and dimensions

Salix AquaRockBag® products use HDPE or Polyester nets from virgin Polymers because of their lower risk of abrasion and fragmentation

AquaRockBag dimensions

Rock Bag XL	Rock Sizes	Height (m)	Diameter (m)	Volume (m^3)	Weight (Tonne)	Lifting height till ring (m)	Flow velocity (single bag)	Flow velocity (stacked bags)
2 ton	40-80 mm	0.55	2.1	1.25	1.86	2.2	3.1 m/s	4.7 m/s
2 ton	56-120 mm	0.6	2.15	1.25	1.92	2.4	3.1 m/s	4.7 m/s
2 ton	75-200 mm	0.6	2.15	1.25	1.92	2.4	3.5 m/s	5.3 m/s
4 ton	40-80 mm	0.67	2.6	2.5	3.74	3.13	3.1 m/s	4.7 m/s
4 ton	56-120 mm	0.7	2.7	2.5	3.86	3	3.1 m/s	4.7 m/s
4 ton	75-200 mm	0.7	2.7	2.5	3.86	3	3.5 m/s	5.3 m/s

Different stone types and grading will influence final bag dimensions +/- 10%

Filling AquaRockBags®

- AquaRockBags are typically filled at the job site using a portable filling jig
- AquaRockBags are very quick to fill and require basic site staff training
- Each net comes with a lifting eye and all ties

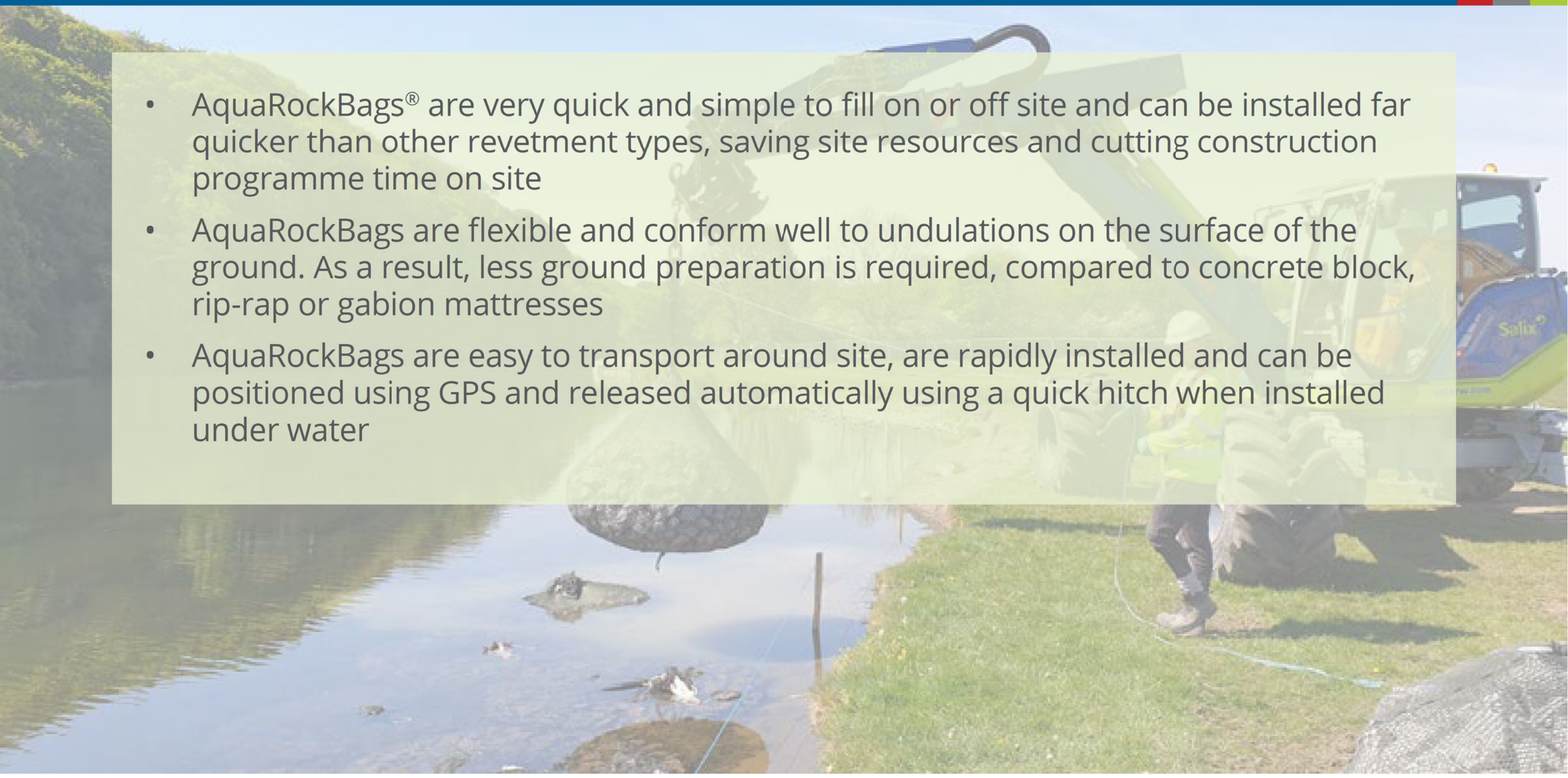
1.

2.

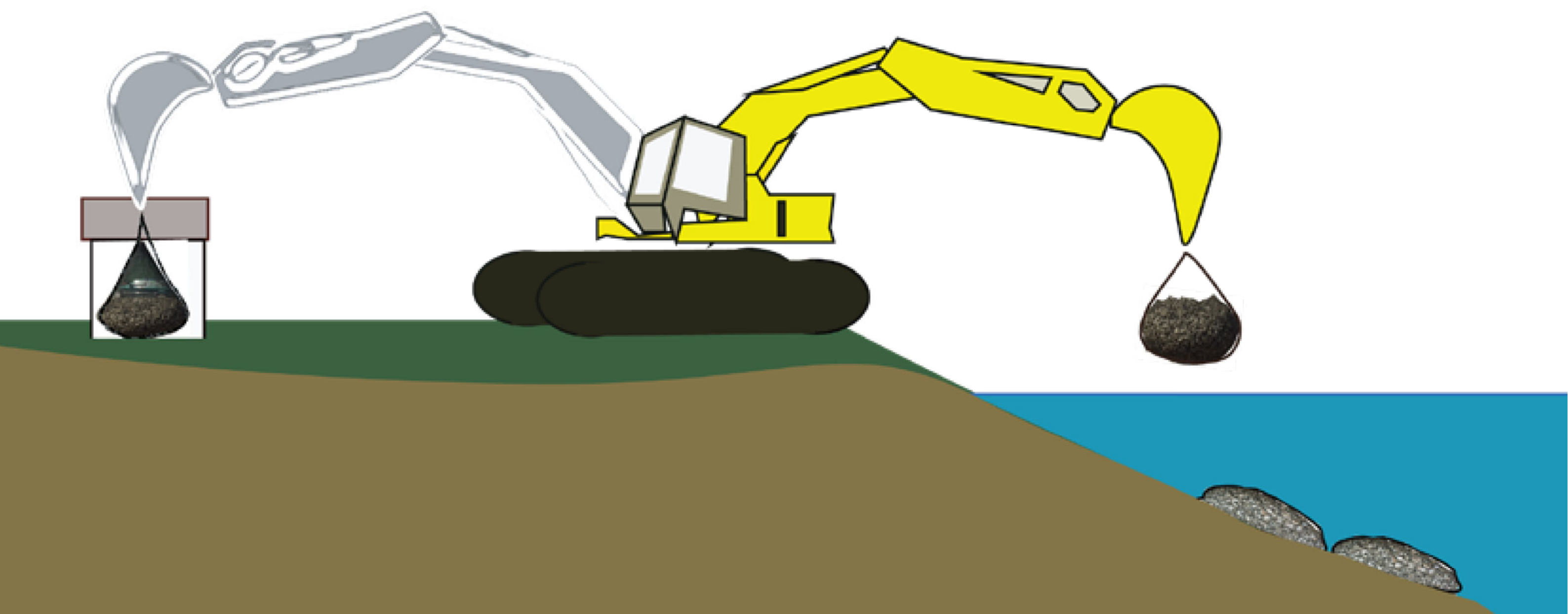
3.

4.

Installation



- AquaRockBags® are very quick and simple to fill on or off site and can be installed far quicker than other revetment types, saving site resources and cutting construction programme time on site
- AquaRockBags are flexible and conform well to undulations on the surface of the ground. As a result, less ground preparation is required, compared to concrete block, rip-rap or gabion mattresses
- AquaRockBags are easy to transport around site, are rapidly installed and can be positioned using GPS and released automatically using a quick hitch when installed under water



Pre-Filled Rock Solutions

Salix supply a range of pre-filled rock solutions including Rock Rolls and Rock Roll Mattresses. These robust and permanent revetments can be used on reservoirs, shorelines, lake edges, streams, riverbanks and spillways.

They are cost-effective revetments that are suitable alternatives to rip rap, blockstone, concrete and gabions in many scour applications.

Salix's ecologically sensitive rock solutions are quick and easy to install, saving time and money whilst blending quickly into the environment providing habitat for flora and fauna.

They are also flexible in design and absorb wave energy and flow velocity rather than reflect it like most traditional hard revetments. These systems often form part of a sustainable soil bioengineering solution below and above water level.

Pre-filled Rock Mattress installation before and after

Pre-filled Rock Rolls dissipating wave energy

Pre-filled Rock Rolls are easy to handle

Salix River & Wetland Services Limited
Salix, Croxton Park, Thetford, Norfolk IP24 1LS
Telephone **0370 350 1851** Fax **0370 350 1852**
info@salixrw.com **www.salixrw.com**

HR Wallingford

Working with water

PAS 99 Integrated Management Systems CERTIFIED IMR 719286

ISO 9001 Quality Management Systems CERTIFIED FS 516431

ISO 45001 Occupational Health and Safety Management CERTIFIED OHS 595357

ISO 14001 Environmental Management CERTIFIED EMS 558310

HR Wallingford is an independent engineering and environmental hydraulics organisation. We deliver practical solutions to the complex water-related challenges faced by our international clients. A dynamic research programme underpins all that we do and keeps us at the leading edge. Our unique mix of know-how, assets and facilities includes state of the art physical modelling laboratories, a full range of numerical modelling tools and, above all, enthusiastic people with world-renowned skills and expertise.

HR Wallingford Ltd, Howbery Park, Wallingford, Oxfordshire OX10 8BA, United Kingdom
tel +44 (0)1491 835381, email info@hrwallingford.com
www.hrwallingford.com