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MEMORANDUM

24 February 2014

To	Tony Lickiss		
Copy to	Webber Esplanade Rock Revetment		
From	[redacted]	Tel	33163736
Subject	'As-Constructed' Rock Revetment	Job no.	[redacted]

Background

The Webber Esplanade rock revetment located within Cooktown and previously designed by GHD, received tidal works approval in late 2005 / early 2006. The GHD design drawings have been provided for ease of reference in Appendix A. The wall was subsequently constructed under the supervision of the Cook Shire Council and it is our understanding that there were a number of variations to the design. A typical 'as-constructed' cross section sketch was provided by Cook Shire Council (see Appendix B).

Approval from Great Barrier Reef Marine Park Authority (GBRMPA) for Department of Transport and Main Roads (TMR) to commence dredging in the Endeavour River is imminent and TMR have requested advice regarding the certification of construction of the revetment wall and the ability of the wall to hold the dredge spoil without leaching into the adjacent waterway.

Scope

Cook Shire has requested GHD compare the criteria adopted within the approved design against that of the 'as-constructed' revetment. It is our understanding that the area behind the revetment wall and the existing foreshore is to be filled with dredge material from the nearby Endeavour River navigational channel. We also understand that TMR requires an assessment of the 'as-constructed' rock revetment prior to them accepting dredge spoil placement.

The proposed scope of works is as follows:

1. Assessment of the design wave height against the 'as-constructed' revetment wall.
2. Assessment of the degree of wave overtopping for the as-constructed wall and advice on the likely qualitative effects of any increases in overtopping compared to the original design.
3. Assessment of the geotextile requirements along the landward side of the wall in preparation for the deposition of dredge spoil from the channel dredging.
4. Geotechnical assessment of the as-constructed wall taking into account the construction of the wall over the soft bed layer that was to be removed in the original design.

As no design work has been undertaken for this review, Safety in Design did not form part of this scope.

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Scope Limitation

GHD has provided technical advice regarding the overall stability of the structure to wave action and storm tide based on as-constructed information provided by Cook Shire Council. The basis of this assessment has been limited due to the level of detail provided. In order to carry out the assessment, reasonable assumptions have been made in terms of materials used, rock size and grading, rock layer thickness and levels and foundation conditions, to the extent possible. GHD takes no responsibility for the accuracy of the information provided and/or the assumptions made in order to carry out the assessment. Due to variations to the original design and the lack of GHD site presence during construction, GHD is unable to provide any certification regarding the as-constructed wall. In addition, this assessment does not constitute certification of the Webber Esplanade rock revetment wall.

As Constructed Revetment

A comparison of the following information has been undertaken;

- GHD design drawings provided in Appendix A
- 'As-constructed' sketch provided in Appendix B.
- The 'as-constructed' survey supplied by Cook Shire Council as highlighted in Appendix C, SK-001 to SK-004.

The following summary of changes made during construction is noted;

a. SK-001 shows that the plan alignment of the 'as-constructed' revetment deviates slightly from the plan alignment shown on the design drawings.

b. SK-001 shows that the rock revetment may not be complete.

c. The 'as-constructed' sketch provided in Appendix B is not consistent with the supplied 'as-constructed' survey (see SK-002 to SK-004). In particular;

    i. The two large rocks (1.5 to 1.8 m) cannot be confirmed.

    ii. The crest of the 'as-constructed' rock revetment is substantially lower than the level of +4.237 m LAT provided in the Appendix B sketch.

d. Geotextile layer was not placed beneath the filter layer, according to the sketch provided in Appendix B.

e. It is our understanding that core material of '100-300 mm clean rock' was placed with the intent of negating the need for a geotextile layer beneath the filter rock as shown in photos 1 to 3 below. It has been confirmed by Cook Shire Council that the core material was placed within the entire length of the structure.

Photo 1 – Core material

Photo 2 – Core material

Photo 3 – Core material

Information Gaps

The following gaps within the information supplied have been identified from the 'as-constructed' survey supplied by Cook Shire Council which does not provide information on the following;

- Thickness of the armour and filter rock layers.
- Grading of the armour and filter rock layers.
- Voiding / packing density of the armour and filter rock layers.
- Rock revetment toe layer thickness and corresponding finish levels.

Design Criteria Review

GHD adopted the following design criteria for the revetment wall as shown on drawing 42-12740-C001;

- 50 year storm event
- 50 year storm tide level = +1.95m AHD
- Significant wave height, Hs = 2.75m
- Peak wave period, Tp = 6.35s

'As-constructed' Rock Revetment Stability Under Design Wave Loading

Stability checks of the armour and filter rock layers has been undertaken in accordance with Van der Meers' formulas. Table 1 below provides the basis of for our assessment of the 'as-constructed' structure. Due to the limited information provided, we have assumed that the armour and filter rock layers have been constructed in accordance with the GHD design.

Table 1: Adopted 'As-Constructed' Characteristics

	Dn50 (mm)	**Minimum Layer Thickness (m)**
Amour rock	900	1.8
Filter rock	450	0.9

We have assumed that the core material has the following grading.

Table 2: Core Rock Grading

Core rock	**(mm)**
D_{85}	300
D_{50}	235
D_{15}	175

In the absence of construction records, the following additional assumptions have also been made in relation to the 'as-constructed' structure;

- Quarry rock density is equal to or greater than 2600 kg/m3.
- Porosity of the placed rock armour is equal to or greater than 37%.

The sections taken from the 'as-constructed' survey, as shown in SK-002 to SK-004 within appendix C, shows that the rock armour slope varies from 1 in 1.1 at the western end trending up to 1 in 2 at the eastern end. If the survey is a true reflection of the 'as-constructed' rock amour slope, it is recommended that additional rock is placed on the armour face in order to obtain the 1 in 2 design slope.

Received photos of the rock armour are shown below in photos 4 and 5.

Photo 4 – Rock Armour Layer

Photo 5 – Rock Armour Layer

As an outcome of our assessment, the following comments are made on the stability of the rock revetment;

- Photos 4 and 5 seem to show that the grading of the rock armour seems wider than expected. There appears to be small rock mixed in with the large rock armour, particularly at the crest. This is an interpretation based on the supply of photos and no visual inspection has taken place to confirm this assessment.
- It is expected that during the design storm event, the steeper slope along the rock armour layer will likely suffer greater damage (greater than 5%). Consequently this may lead to higher maintenance costs for Cook Shire Council and an increased risk of filter rock exposure.
- To achieve rock armour stability in line with the original design, the equivalent significant wave height reduces approximately 45% to 1.55 m for those areas where the slope is steeper than the original design slope of 1 vertical to 2 horizontal.

Wave Overtopping

Wave overtopping (see Figure 1) calculations has been completed in accordance with Owen's (1980) method.

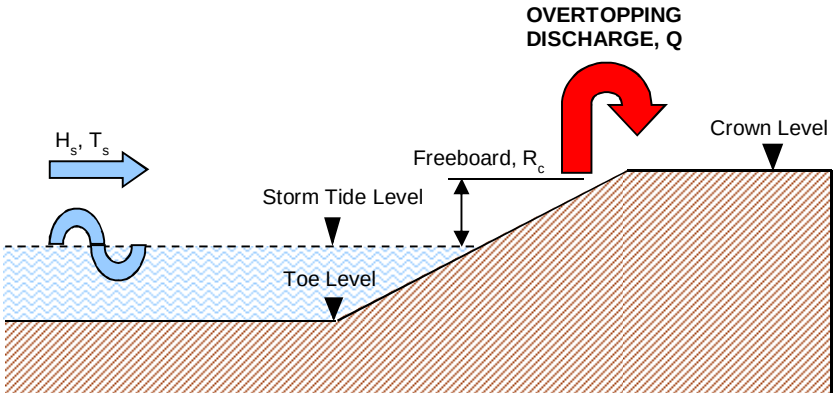


Figure 1: Overtopping Discharge

The revetment wall has been designed for an overtopping discharge of 135 litres per second per metre length of wall.

Guidance by CIRIA on allowable critical discharge is provided below in Figure 2. It should be noted that this gives allowable mean overtopping discharge, which may actually be exceeded by maximum overtopping discharge during the design storm event. Figure 2 shows that assuming the area immediately behind the revetment wall is paved/sealed, as a minimum, an overtopping volume of 300 litres / second / metre of wall would be considered acceptable.

In order to meet this overtopping criterion, the rock revetment crest level would need to be uniformly raised along the structure to +3.5 m AHD or +4.98 m LAT. The 'as-constructed' survey shows that currently the crest level varies from +1.78 m LAT to approximately +4.0 m LAT. Overtopping discharge per metre length of wall during the design event is expected to exceed 300 litres per second for the current 'as-constructed' crest.

Plans for the works behind the revetment wall have not been provided, hence the effects of the increased overtopping volumes cannot be evaluated. However, one of the keys to mitigating the effects of overtopping is to provide adequate drainage capacity to safely channel the water away from the landward side of the wall. Therefore, careful consideration of the drainage infrastructure required is recommended in order to ensure the integrity of the rock revetment during the design storm event.

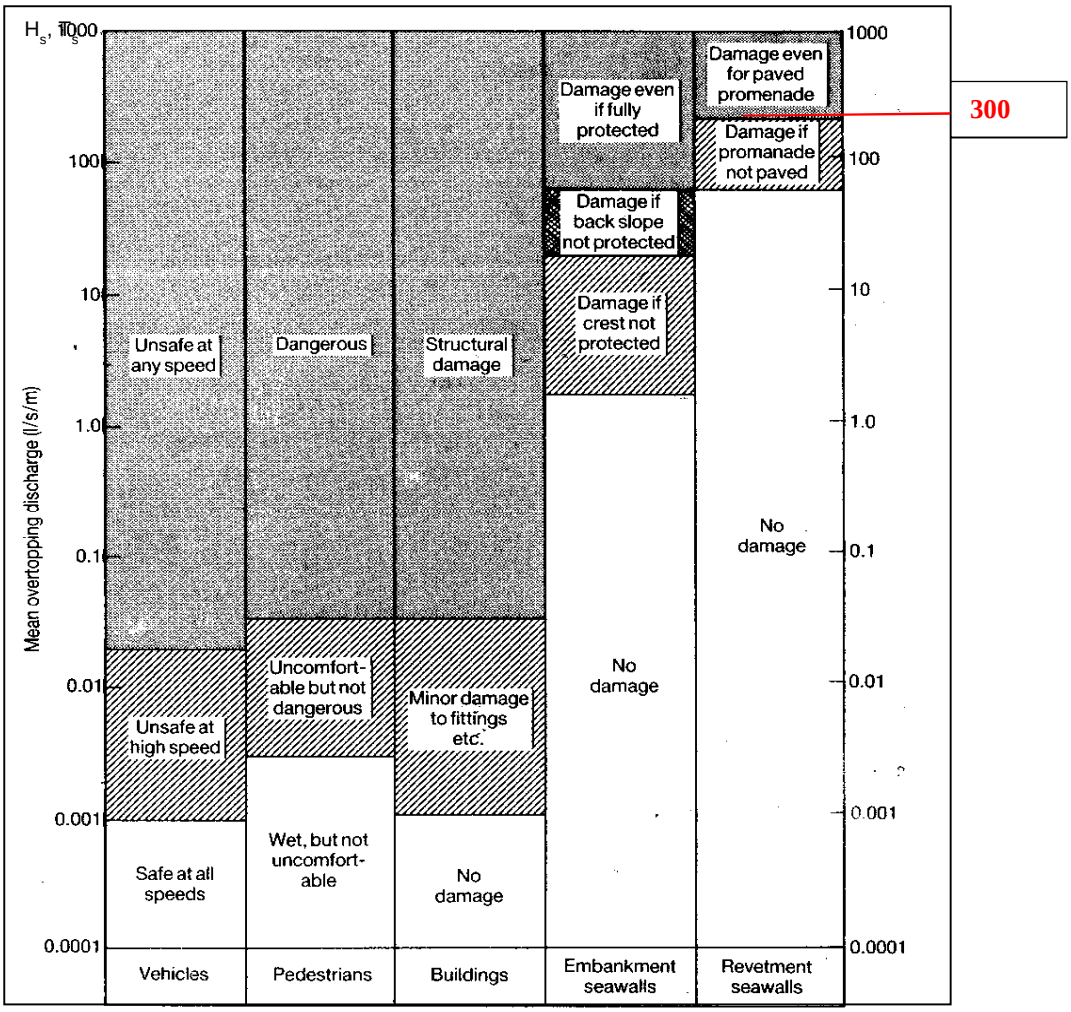


Figure 2: CIRIA/CUR (1991), Manual on the use of rock in coastal and shoreline engineering, CIRIA Special Publication 83/CUR Report 154, pg. 253-257.

Geotextile

Elcomax 1200R geotextile is recommended for placement along the landward side of the rock revetment to contain the fill material (dredge spoil) to be placed in this area.

The following addition recommendations are also made for the geotextile installation;

- It is recommended that the geotextile extend 1 metre above the crest to allow for expected creep and slip down the back face of the wall on loading of dredge material. On completion of spoil placement, any excess geotextile above the crest can simply be cut flush at the appropriate finish level.
- Geotextile sheets should be placed vertically down the slope and not longitudinally. A 1 metre overlap between the geotextile sheets should be shown vertically down the slope.
- Based on the photo 6 below, it is evident that there is some large rock on the revetment slope back face. Due to the risk of elongation and even tearing of the geotextile on application of spoil load, adoption of one of the following options is recommended;
    - The back face is re-worked to remove the large rock, thereby leaving a 'smooth' slope with rock of uniform grading.
    - Place a uniform graded rock (Dn50 = 50 mm), up to an appropriate thickness to achieve a 'smooth' slope.

Photo 6 – Revetment Back Face

Geotechnical Stability Analysis

Geotechnical Stability Analysis - General

The primary focus of the geotechnical stability analysis is to assess the relative impact of the filling of dredge spoil behind the current revetment wall on the slope stability of the wall as compared to the current unloaded conditions (i.e. without filling of dredge spoil).

It should be noted that any stability factors of safety (FoS) calculated as part of the assessment are based on an array of assumptions and qualifications given the variations to the original GHD design, lack of as-constructed information and extremely limited geotechnical investigation data. Therefore, these factors of safety do not necessarily represent the safety conditions in absolute terms, which is not possible without further geotechnical investigation, testing and analysis. The geotechnical assessment is made on the relative impact due to the proposed filling of dredge spoil behind the revetment wall.

The slope stability analyses were primarily carried out using software GEO-SLOPE GeoStudio 2007 Version 7.19. Circular and non-circular failure modes were both considered.

Geotechnical Stability Analysis - Methodology

It is understood that one of the main variations to the original GHD design is that the toe of the revetment wall may not have been founded on competent residual or weathered rock as specified in the original GHD design.

One available geotechnical report (carried out by Douglas Partners in 2005 for the purpose of the original GHD design) indicates that a layer of compressible lower strength soils up to 1.3 m thickness existed in-situ prior to the construction of the revetment wall. These soils comprised very soft clays and very loose sands in some of the worst cases. From a geotechnical stability point of view, the very soft clays would represent the greatest risks and therefore was the critical case to consider in the geotechnical assessment.

Two cases were considered in the geotechnical assessment:

- Case 1 – Toe of revetment wall founded on competent material, core fill and reclamation fill founded on very soft clay
- Case 2 – Toe of revetment wall founded on very soft clay, core fill and reclamation fill founded on very soft clay

The slope stability analysis was based on cross-sections produced from topographic surveys dated Oct 2013 and Feb 2014 provided to GHD. Cross-section E (Sketch SK-003) was selected for slope stability analysis as it represents the highest part of the revetment wall and has a maximum crest-to-toe height of approximately 5 m.

The methodology of analysis is best illustrated by the flow chart in Figure 3.

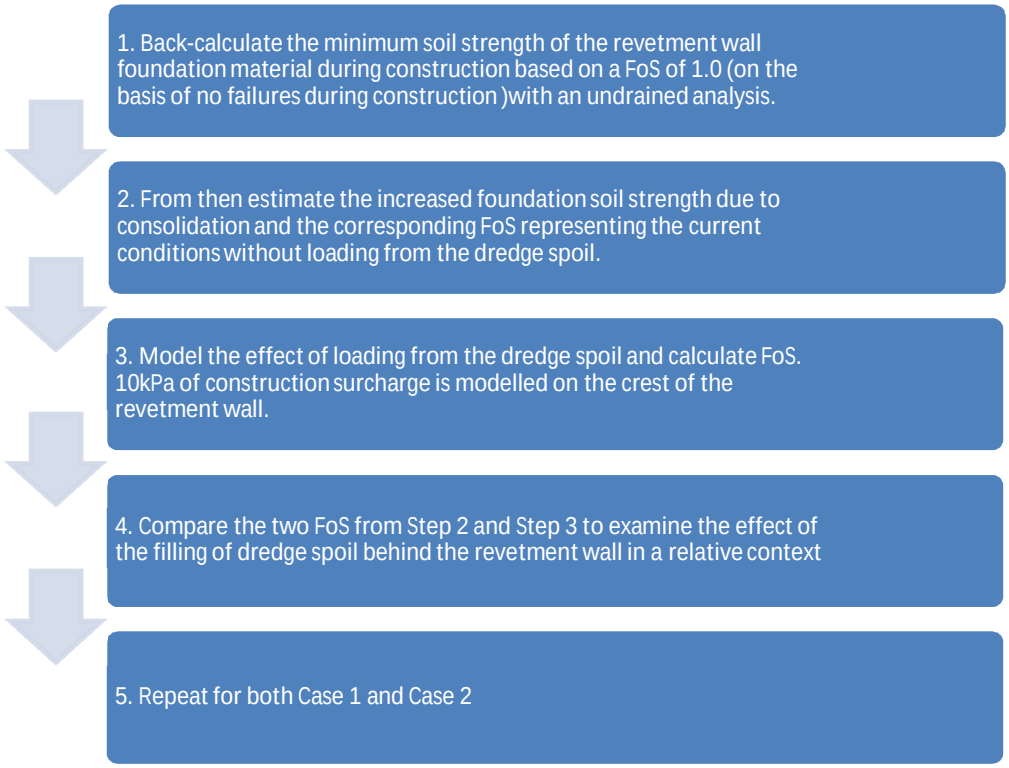


Figure 3 Methodology of geotechnical assessment

The geotechnical parameters used in the slope stability analyses are summarised in Table 1.

Table 1 Geotechnical parameters

Material	Unit weight γ (kN/m3)	Effective friction angle ϕ' (degrees)	Effective cohesion c' (kPa)	Undrained shear strength Su (kPa)
Silty CLAY	16	-	-	(see note)
Filter rock	17	40	0	-
Armour rock	17	40	0	-
Core fill	18	34	0	-
Reclamation fill	18	28	0	-
Weathered Argillite	20	35	0	-
Dredge spoil (pre-densification)	13	-	-	2

Note 1: undrained shear strength of alluvial clays back-calculated for individual cases and strength gain based on consolidation and increase in Su of 0.2 times the increase in vertical effective stress after construction.

The geotechnical subsurface profile adopted is summarised in Table 2.

Table 2 Geotechnical subsurface profile

Layer/structure	Depth (m)	RL (mAHD)
Very soft silty CLAY	0 to 1.0	-2.0 to -3.0
Residual and weathered argillite	1.0 to 8.0	-3.0 to -10.0

Geotechnical Stability Analysis - Qualifications and assumptions

The following qualifications and assumptions were made for the purpose of the geotechnical assessment.

- The “very soft silty clay” and the “very loose sand” identified in the geotechnical report (2005) were not completely removed under the revetment core fill and reclamation fill during construction.
- The revetment wall and foundation have not undergone any distress or failure during and after construction i.e. no pre-existing failure or distress.
- The core fill was constructed using clean granular material.
- Groundwater conditions modelled in the analyses were:
  - Mean Sea Level of 1.49 mCD/0.01 mAHD behind the wall
  - Mean Low Water Springs of 0.63 mCD/-0.81 mAHD in front of the wall
- Cross-sections modelled were based on surveys dated Oct 2013 and Feb 2014.
- Dredge spoil will be placed in a progressive and uniform manner.
- Whilst the dredge spoil is expected to comprise mainly sands, cohesive clays were assumed for the purpose of geotechnical stability analysis in a worst case scenario.
- No reliable soil strength testing data other than the extremely limited information in the geotechnical report (2005) was available for input into the slope stability analysis.
- Seismic stability presents an inherent and existing risk associated with the foundation material underneath the revetment wall. The risk would be significantly higher if some of the very loose sands identified in the geotechnical report (2005) were left in place during construction.

Geotechnical Stability Analysis - Results and discussion

A summary of the slope stability analysis results is provided in Table 3.

Table 3 Summary of slope stability analysis results: relative change to FoS

Case	Lower bound FoS prior to filling of dredge spoil	Lower bound FoS after filling of dredge spoil	
		Filling to 0.5m below crest	Filling to crest
Case 1 – toe founded on competent material	1.15	1.10	1.08
Case 2 – toe founded on very soft clay	1.11	1.06	1.06

The results of the lower bound analyses (based on FoS of 1 at end of construction) suggest that the proposed filling of dredge spoil behind the existing revetment wall would have a marginal impact (approximately 6%) on the risk of wall instability. This is provided that the filling of dredge spoil does not exceed the crest height of the revetment wall as well as that no additional surcharge is to be placed on the finished platform formed by the dredge spoil. In other words, the risk of failure is increased very marginally over the inherent risks existing at present. This is also likely to apply to the situation with earthquake and if such an extreme event was considered of significance, more detailed investigations would be required to assess the actual foundation conditions.

An assessment on the actual factor of safety and risk of instability can only be made with further detailed geotechnical site investigation and field and laboratory testing to determine the revetment wall materials and foundation properties and effectiveness of foundation preparation.

It is also recommended that the revetment wall be monitored during the proposed filling of dredge spoil to observe any signs of movement or distress such as tension cracking signifying the possible onset of large scale movements, as one of the main assumptions of the geotechnical assessment carried out is that there is no pre-existing failure in the foundation layers under the revetment wall.

Recommendations

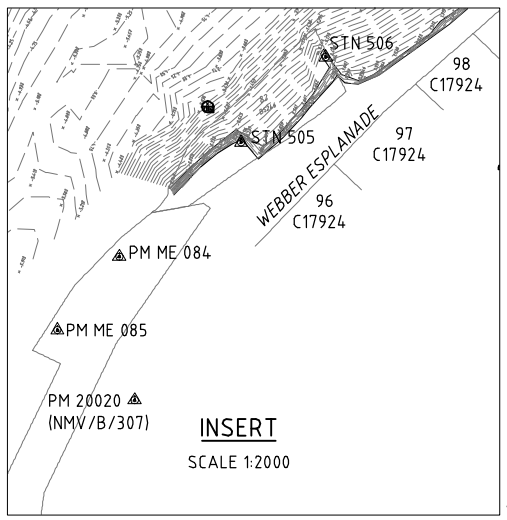
Based on the information provided and the subsequent assessment of the rock revetment, the following comments and/or recommendations are made;

- Photos taken during construction and QA site records, if available, should be provided in order to confirm the assumptions made during the assessment.
- It is recommended that the seaward face of the revetment be topped up with rock armour to achieve a 1 in 2 slope uniformly along the full length of the revetment.
- Raising the crest finish level with rock armour to +4.98 m LAT is recommended in order to ensure overtopping volumes are within the guidance values provided by CIRIA.
- In the process of raising the crest, the existing small graded rock as shown in photo 4 and 5 should be removed and replaced with rock armour.
- Install the 1200R Elcomax geotextile as per the recommendations provided above.

Regards

[redacted]

Appendix A



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ARRANGMENT PLAN

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DESIGN CRITERIA

ROCK ARMOUR REVETMENT DESIGNED TO:
Hs = 2.75m
T = 6.35 SECONDS
RETURN PERIOD = 50 YEARS

CONTROL STATIONS

STN	EASTING	NORTHING	RL	REMARKS
ME084	517.768	9984.532	2.757	PERMANENT MARK
ME085	471.147	9964.403	2.478	PERMANENT MARK
505	602.391	10009.89	2.456	PIN (NS)
506	662.483	10030.169	1.404	NAIL IN CONC REMAINS JETTY

LEGEND

- •39 DENOTES SETOUT POINT
- △ DENOTES CONTROL STATION
- DENOTES NEW REVETMENT WALL REFER SECTIONS ON DWG No. 42-12740-C002 FOR DETAILS
- DENOTES AREA ENCLOSED BY SEAWALL AND TOP OF BATTER

NOTES

1. REFER TO DOUGLAS PARTNERS GEOTECHNICAL INVESTIGATION REPORT DATED 16.09.05
2. CORE MATERIAL TO BE:
   - SANDY GRAVEL WITH CLAY BINDER (5% TO 20% PASSING 75µm SIEVE) WITH MAXIMUM PARTICLE SIZE 50mm OR,
   - CBR15 STRUCTURAL FILL

SEAWALL SETOUT TABLE

MARK	EASTING	NORTHING	MARK	EASTING	NORTHING	MARK	EASTING	NORTHING
1	592.407	10014.901	17	942.818	10061.253	33	889.97	10048.73
2	603.115	10017.122	18	942.158	10057.71	34	839.937	10054.003
3	998.719	10017.012	19	991.882	10049.711	35	839.946	10050.4
4	995.121	10016.784	20	991.059	10046.207	36	789.662	10052.079
5	616.532	10029.313	21	994.914	10041.38	37	789.894	10048.485
6	617.87	10025.966	22	998.514	10041.409	38	739.529	10047.535
7	686.546	10053.705	23	998.792	10006.997	39	740.016	10043.964
8	687.482	10050.22	24	995.205	10006.77	40	690.03	10038.49
9	737.266	10062.972	25	991.618	10006.543	41	690.855	10034.981
10	737.737	10059.4	26	992.377	10030.657	42	621.362	10015.787
11	788.354	10068.127	27	988.802	10030.232	43	622.632	10012.417
12	788.63	10064.536	28	987.178	10036.337	44	604.293	10007.704
13	839.834	10069.6	29	986.439	10032.814	45	603.489	10011.214
14	839.74	10066.001	30	940.245	10046.182	46	994.028	10016.715
15	891.123	10067.497	31	939.655	10042.628	47	990.44	10016.488
16	890.834	10063.908	32	890.251	10052.323			

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Note: * indicates signatures on original issue of drawing or last revision of drawing

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SCALE 1:2000 AT ORIGINAL SIZE

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Date 20 SEPT 2005

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Client COOK SHIRE COUNCIL

Project WEBBER ESPLANADE - COOKTOWN

Title NEW REVETMENT WALL
GENERAL ARRANGEMENT PLAN

Original Size A1

Drawing No: [redacted]

Rev: 0

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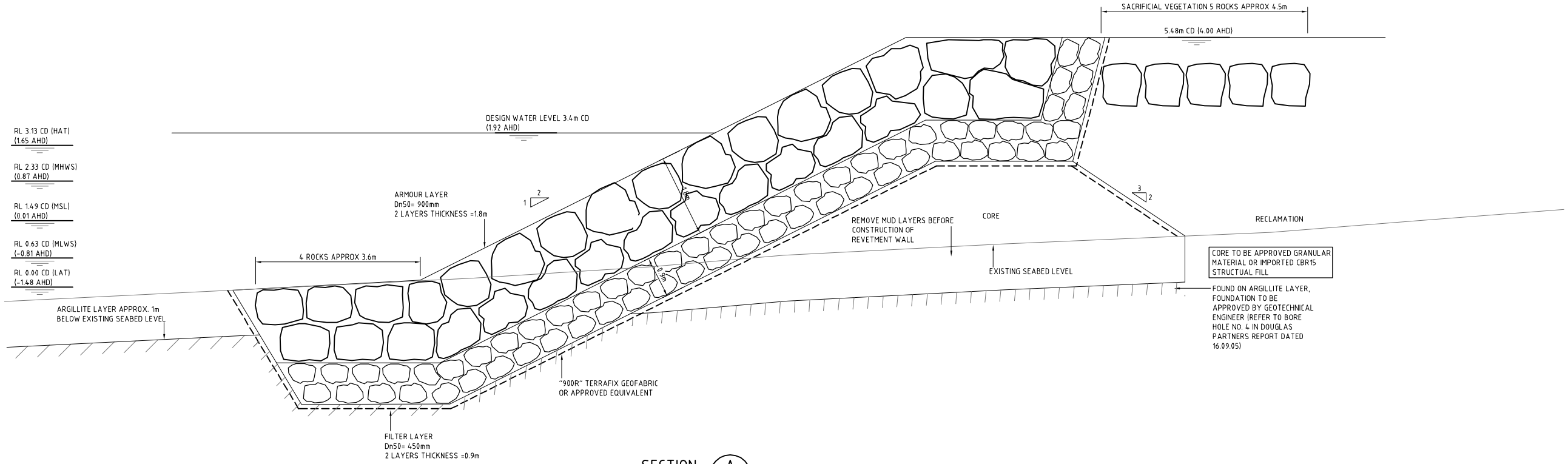

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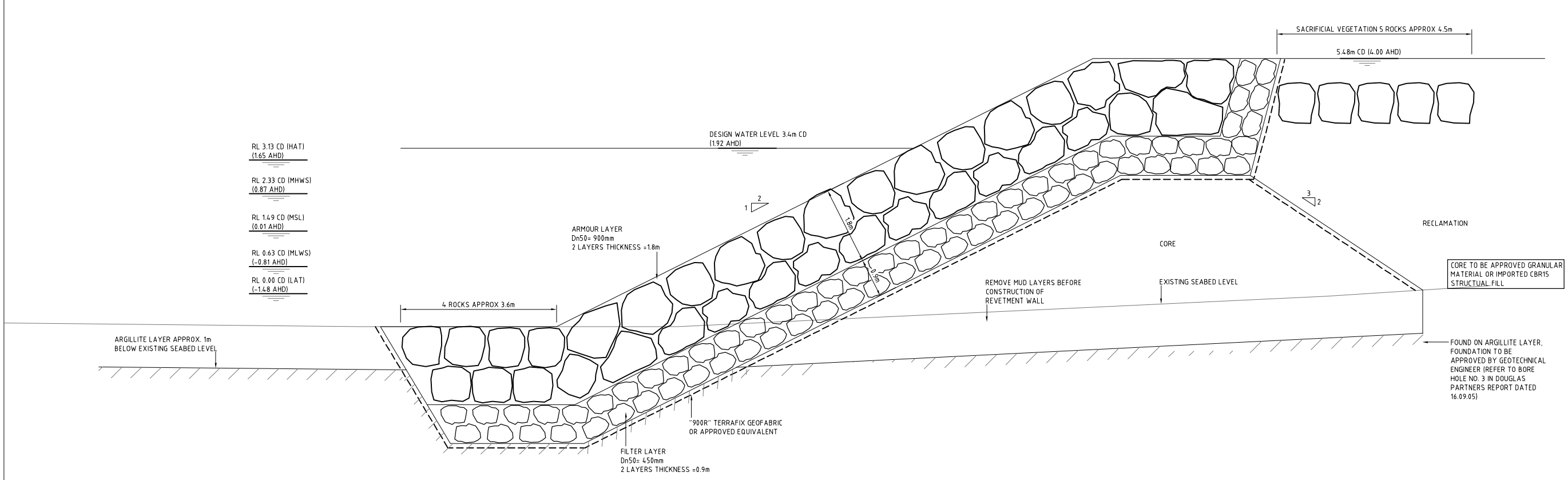

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Scale 1:50
[redacted]
Date 20 SEPT 2005
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Project WEBBER ESPLANADE - COOKTOWN
Title NEW REVETMENT WALL
SECTIONS SHEET 1 OF 2

Original Size A1
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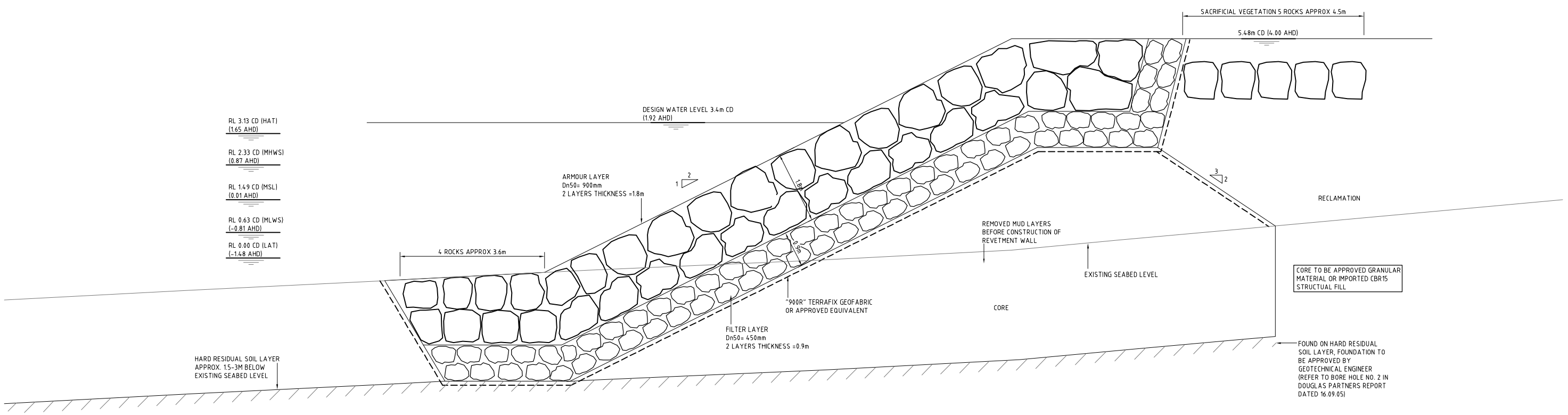

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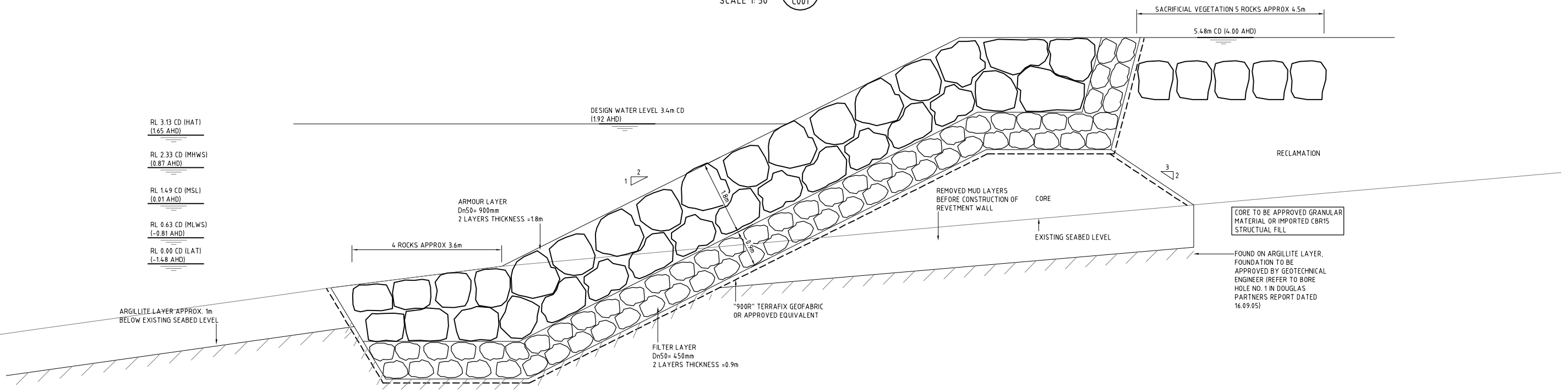

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Client COOK SHIRE COUNCIL
Project WEBBER ESPLANADE - COOKTOWN
Title NEW REVETMENT WALL
SECTIONS SHEET 2 OF 2

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Rev: 0

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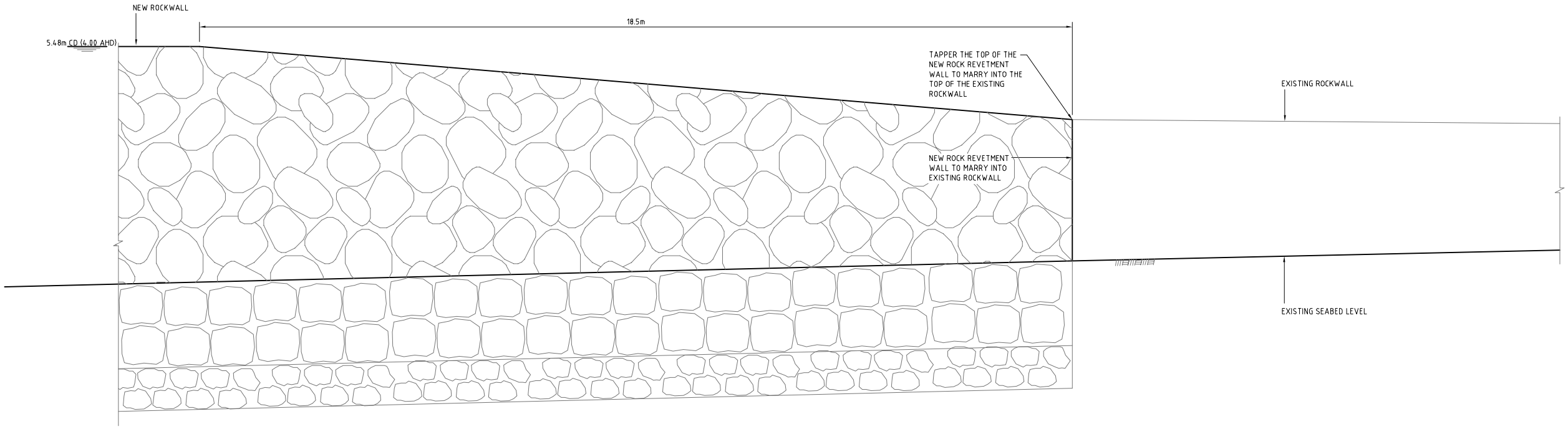

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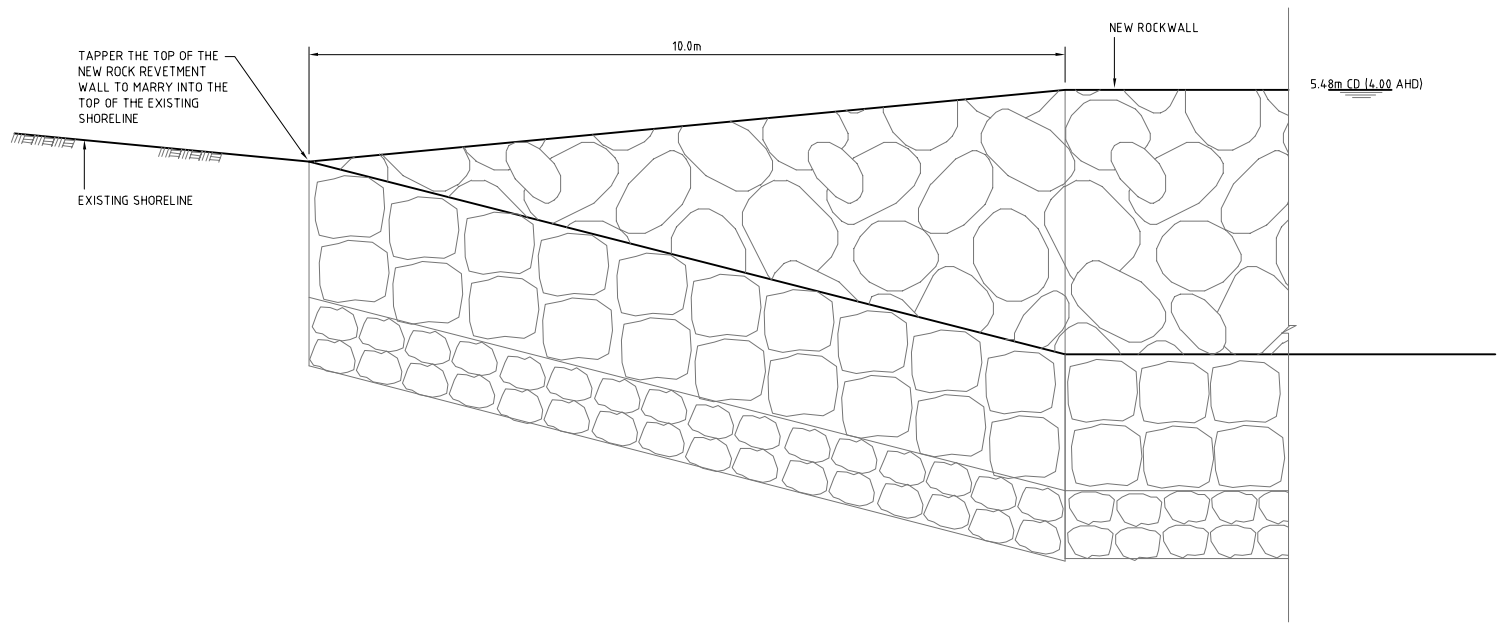

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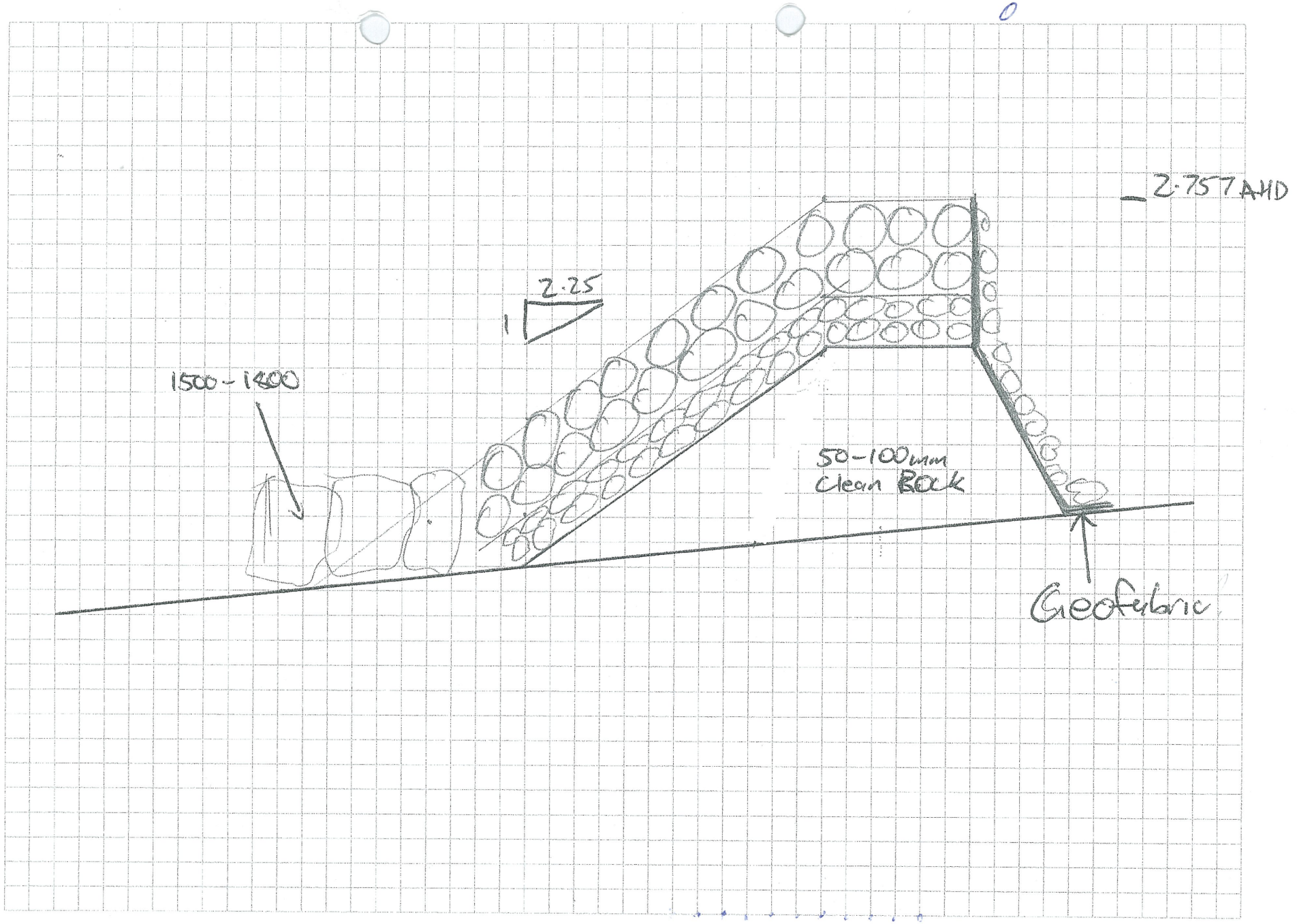
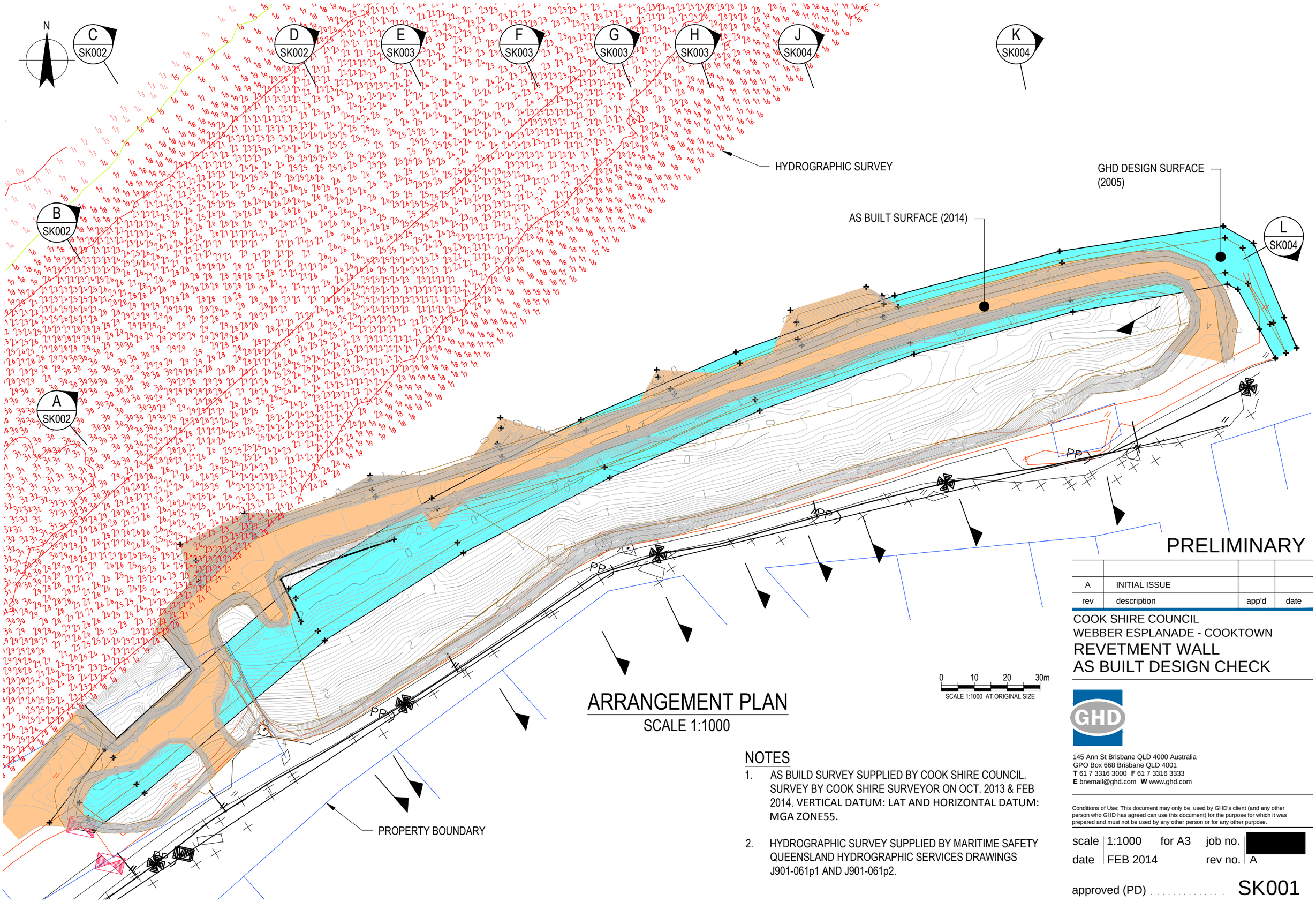
Title NEW REVETMENT WALL ELEVATIONS
Original Size A1
Drawing No: [redacted]
Rev: 0

Cad File No: G:\Projects\42\12740\ACAD\ 42-12740-C004_rv0.dwg
Plot Date: 21 September, 2005 - 10:53 AM

Appendix B


2.757AHD
2.25
1
1500 - 1800
50-100mm
Clean Rock
Geofabric

Appendix C



ARRANGEMENT PLAN

SCALE 1:1000

0 10 20 30m

SCALE 1:1000 AT ORIGINAL SIZE

NOTES

1. AS BUILD SURVEY SUPPLIED BY COOK SHIRE COUNCIL. SURVEY BY COOK SHIRE SURVEYOR ON OCT. 2013 & FEB 2014. VERTICAL DATUM: LAT AND HORIZONTAL DATUM: MGA ZONE55.

2. HYDROGRAPHIC SURVEY SUPPLIED BY MARITIME SAFETY QUEENSLAND HYDROGRAPHIC SERVICES DRAWINGS J901-061p1 AND J901-061p2.

PRELIMINARY

rev	description	app'd	date
A	INITIAL ISSUE		

COOK SHIRE COUNCIL
WEBBER ESPLANADE - COOKTOWN

REVETMENT WALL AS BUILT DESIGN CHECK

145 Ann St Brisbane QLD 4000 Australia
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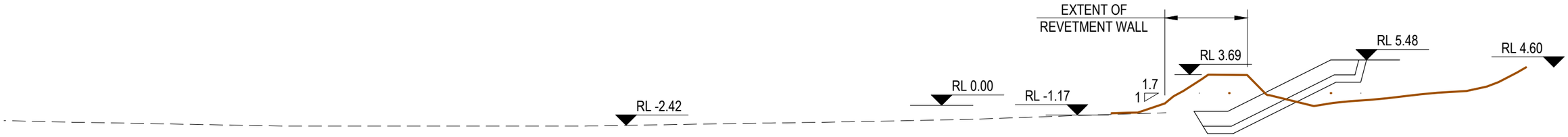
scale	1:1000 for A3	job no.	[redacted]
date	FEB 2014	rev no.	A

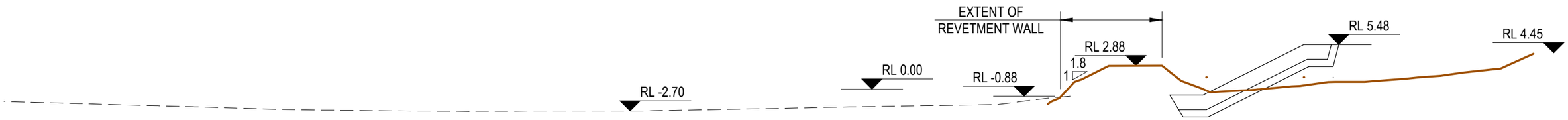
approved (PD) SK001

Plot Date: 27 February 2014 - 10:58 AM Plotted by: Jeremy Wilmot Cad File No: G:\41\27466\CADD\Drawings\41-27466-SK001.dwg



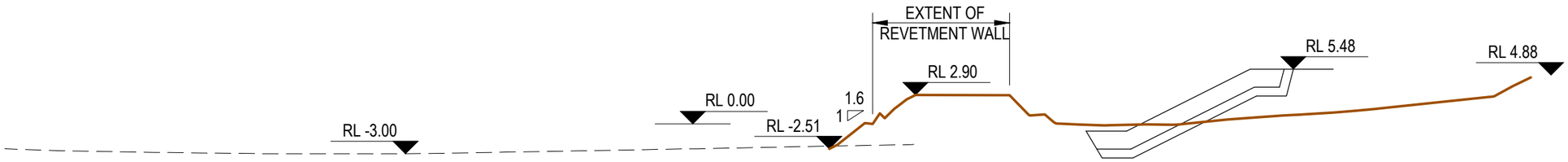
D SECTION

SK001 SCALE 1 : 500



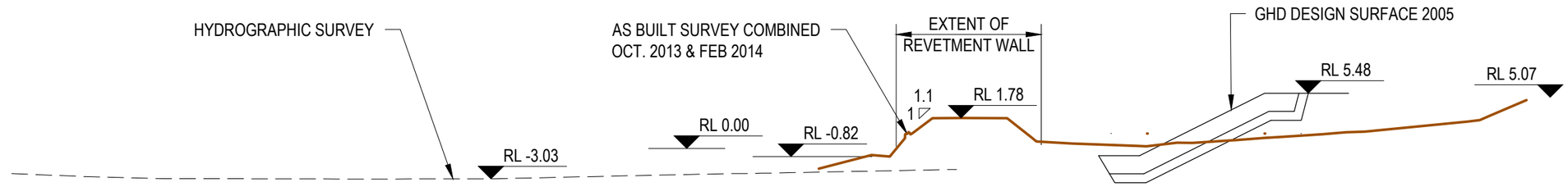
C SECTION

SK001 SCALE 1 : 500



B SECTION

SK001 SCALE 1 : 500



A SECTION

SK001 SCALE 1 : 500

0 5 10 15m

SCALE 1:500 AT ORIGINAL SIZE

PRELIMINARY

rev	description	app'd	date
A	INITIAL ISSUE		

COOK SHIRE COUNCIL

WEBBER ESPLANADE - COOKTOWN

REVETMENT WALL - AS BUILT DESIGN CHECK - SECTIONS SH1

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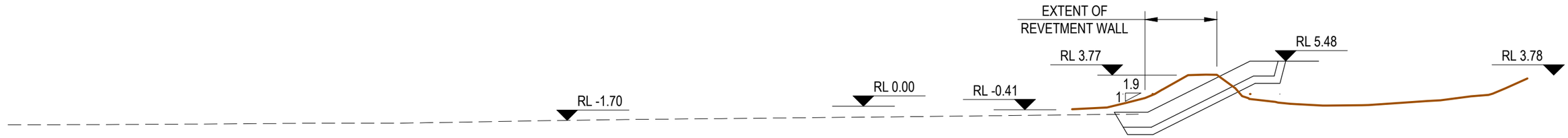
scale 1:500 for A3 job no. [redacted]

date FEB 2014 rev no. A

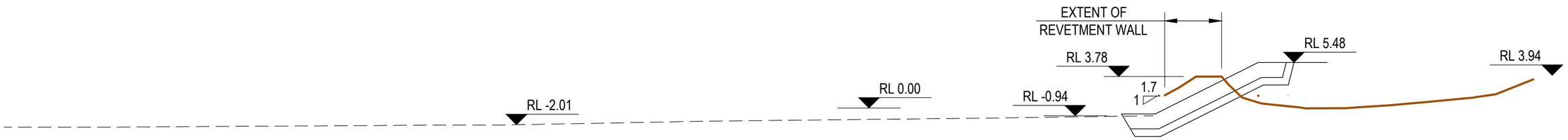
approved (PD) SK002

Plot Date: 26 February 2014 - 4:59 PM Plotted by: Jeremy Wilmot Cad File No: G:\41\27466\CADD\Drawings\41-27466-SK002-SK004.dwg



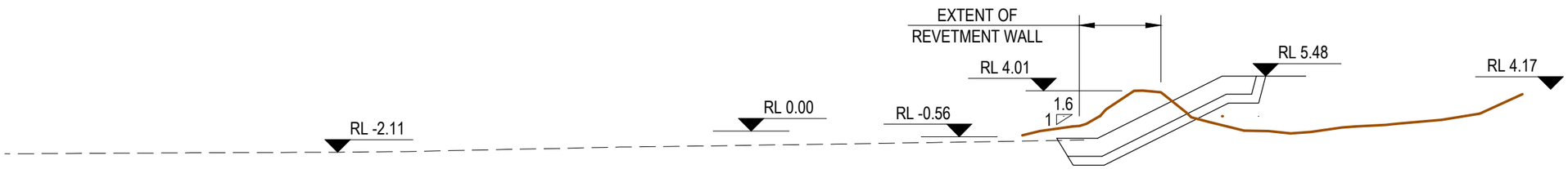
H SECTION

SK001 SCALE 1 : 500



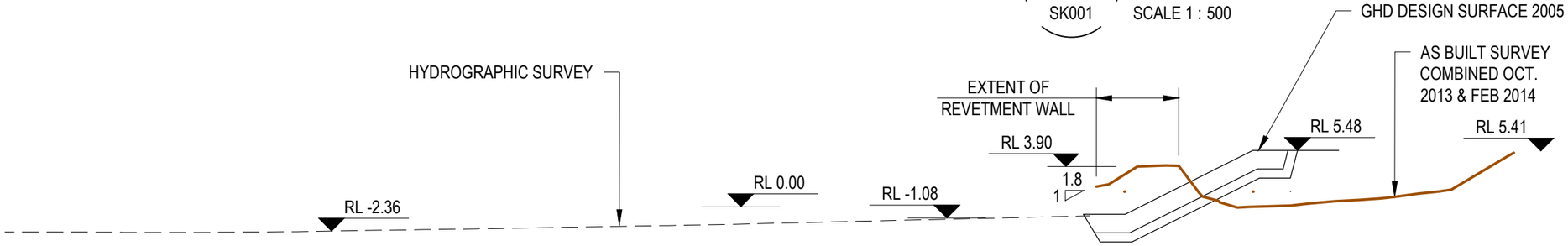
G SECTION

SK001 SCALE 1 : 500



F SECTION

SK001 SCALE 1 : 500



E SECTION

SK001 SCALE 1 : 500

0 5 10 15m

SCALE 1:500 AT ORIGINAL SIZE

PRELIMINARY

rev	description	app'd	date
A	INITIAL ISSUE		

COOK SHIRE COUNCIL

WEBBER ESPLANADE - COOKTOWN

REVETMENT WALL - AS BUILT DESIGN CHECK - SECTIONS SH2

145 Ann St Brisbane QLD 4000 Australia
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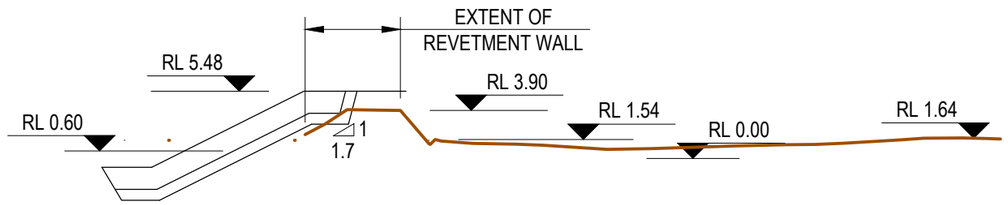
scale	1:500	for A3	job no. [redacted]
date	FEB 2014		rev no. A

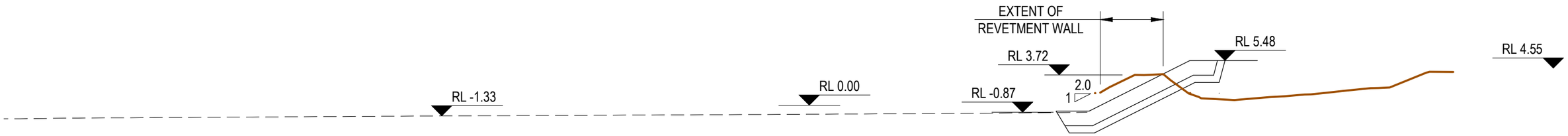
approved (PD) SK003

Plot Date: 26 February 2014 - 4:59 PM Plotted by: Jeremy Wilmot Cad File No: G:\41\27466\CADD\Drawings\41-27466-SK002-SK004.dwg



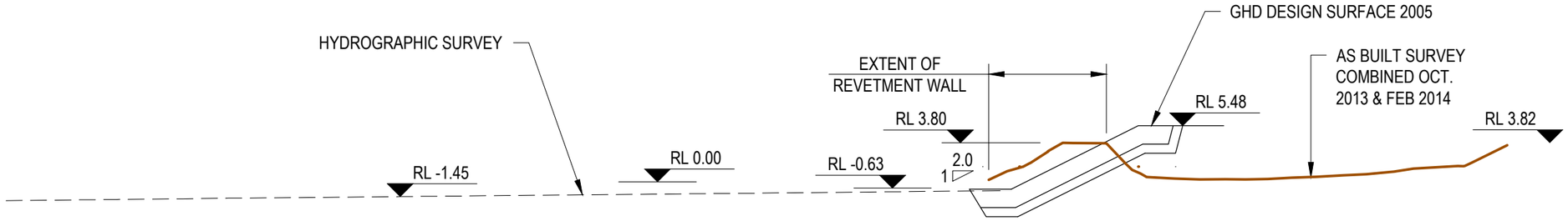
L SECTION

SK001 SCALE 1 : 500



K SECTION

SK001 SCALE 1 : 500



J SECTION

SK001 SCALE 1 : 500

0 5 10 15m

SCALE 1:500 AT ORIGINAL SIZE

PRELIMINARY

rev	description	app'd	date
A	INITIAL ISSUE		

COOK SHIRE COUNCIL

WEBBER ESPLANADE - COOKTOWN

REVETMENT WALL - AS BUILT DESIGN CHECK - SECTIONS SH3

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scale	1:500 for A3	job no.	[redacted]
date	FEB 2014	rev no.	A

approved (PD) SK004

Plot Date: 26 February 2014 - 5:00 PM Plotted by: Jeremy Wilmot Cad File No: G:\41\27466\CADD\Drawings\41-27466-SK002-SK004.dwg