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COUNCIL NOTICES

PORT STEPHENS COUNCIL

Coastal Protection Act 1979, Section 55H

Gazettal and Commencement of a Coastal Zone Management Plan

PORT STEPHENS COUNCIL, with the certification of the Minister for the Environment, have prepared and adopted the Sandy Point / Conroy Park Foreshore Erosion and Drainage Management Plan 2018 as a Coastal Zone Management Plan in accordance with Section 55 of the *Coastal Protection Act 1979*.

The Plan outlines long term foreshore management actions for the shoreline between The Anchorage Marina and Bagnalls Beach in Corlette, and gives balanced consideration to the environmental, social and economic demands on the coastline.

Notice is hereby given, under Section 55H of the *Coastal Protection Act 1979*, of the commencement of the plan which will remain in force until such time as it is repealed by a Coastal Management Program under the *Coastal Management Act 2016*.

The plan may be viewed on Port Stephen's Council's website at www.portstephens.nsw.gov.au. For more information call 49880255

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Sandy Point/Conroy Park Foreshore

Erosion and Drainage Management Plan

Revised July 2018
Original Final Report February 2016

Prepared for	Port Stephens Council
Prepared by	Dr David Wainwright, Doug Lord and Benjamin Crawley Whitehead & Associates Environmental Consultants Pty Ltd & Coastal Environment Pty. Ltd. 197 Main Road CARDIFF NSW 2285
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Document Control Sheet

<table>
<tr><td colspan="6">Document and Project Details</td></tr>
<tr><td>Document Title:</td><td colspan="5">Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan</td></tr>
<tr><td>Author:</td><td colspan="5">David Wainwright (W&A) / Doug Lord (CE) / Benjamin Crawley (W&A)</td></tr>
<tr><td>Project Manager:</td><td colspan="5">David Wainwright</td></tr>
<tr><td>Date of Issue:</td><td colspan="5">02/02/2016</td></tr>
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<tr><td>Synopsis:</td><td colspan="5">The Sandy Point / Conroy Park Foreshore Erosion and Drainage Management Study aims to identify a preferred solution for the management of the shoreline between The Anchorage Marina and Bagnalls Beach in Corlette, on the southern side of Port Stephens. The consideration of various management options, community consultation, and conceptual designs and costs are discussed.</td></tr>
<tr><td colspan="6">Client Details</td></tr>
<tr><td>Client:</td><td colspan="5">Port Stephens Council</td></tr>
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<tr><td colspan="3">Checked by:

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</table>

Disclaimer

The information contained in this report is based on independent research undertaken by David Wainwright and Ben Crawley of Whitehead & Associates Environmental Consultants Pty Ltd (W&A), and Doug Lord of Coastal Environment Pty. Ltd. To our knowledge, it does not contain any false, misleading or incomplete information. Recommendations are based on an appraisal of the site conditions subject to the limited scope and resources available for this project, and follow relevant industry standards. We highlight that the coastal zone is a highly dynamic environment, particularly in areas where processes are causing ongoing notable erosion. Accordingly, the relevance of this plan will decrease with time and the results should be considered in this light.

Copyright Note

REVISED DOCUMENT CONTROL SHEET

Title :	Sandy Point / Conroy Park Foreshore Erosion and Drainage Management Plan
Revised by :	Port Stephens Council
Purpose of Revision :	This document has been revised from the original report prepared by Whitehead & Associates to reflect the updated requirements for the preparation of Coastal Zone Management Plans outlined in Part 4A of the *Coastal Protection Act 1979* and the supporting NSW Guidelines for Preparing Coastal Zone Management Plans (OEH, 2013). This plan is to be considered a Coastal Zone Management Plan for the area in question.

REVISION/CHECKING HISTORY

REVISION NUMBER	DATE OF ISSUE	REVISION	CHANGES BY
4	13/3/2018	Amendment as requested by Dept of Industry – Lands and Foresty and the NSW Coastal Panel.	PH
5	31/7/2018	Amendments as requested by Dept of Industry – Lands & Forestry. Summary of amendments provided in appendix I.	PH

Executive Summary

The Sandy Point / Conroy Park Foreshore Erosion and Drainage Management Study aims to identify a preferred solution for the management of the shoreline between The Anchorage Marina and Bagnalls Beach in Corlette, on the southern side of Port Stephens.

Detailed investigations of coastal and drainage processes were completed. The resulting reports are appended. The foreshores were first subdivided and settled in the 1940's and 1950's. At that time, sand was plentiful along the foreshore.

Unfortunately, the whole of lower Port Stephens (east of Corlette Point) is changing as a large sand feature known as a "Flood Tide Delta" moves slowly in to the Port. The foreshore in our study area was not stable and has been subject to erosion and attack by waves ever since it was settled.

The first protective structures were built in the late 1950's/early 1960's. Ongoing erosion has gradually moved from east to west and the need to protect the foreshores has extended in the same direction.

During the past two decades, erosion has become particularly notable at Conroy Park. This pattern is consistent with other information that shows sand moves from east to west along the foreshore. The clearest evidence of this is the more recent widening of the beach next to "The Anchorage" at Corlette Point.

Areas that previously had a sandy beach are now exposed to direct attack by waves and overtopping during storms, such as the "Super Storm" of April 2015. The piecemeal foreshore protection that has been constructed in front of individual properties does not provide a suitable level of protection from waves to all residential properties in the area. Various stormwater outlets cross the foreshore and any foreshore plan needs to consider those outlets.

Following our review of background information and a detailed engineering site inspection, the study foreshore was divided into six different "Precincts" which are shown on Figure E.1.

These precincts have been used to develop and assess different management options. "Chainages" are used to identify the extent of these precincts and are measured in distance east from the Anchorage Marina eastern breakwater (Figure E.1). Briefly, the precincts are:

Precinct 1: (Between approximately 0m and 250m east of The Anchorage). Comprising the western end of Corlette Beach. This area has been accreting since construction of The Anchorage. A significant stormwater outlet crosses the beach near the eastern end.

Precinct 2: (Between approximately 250m and 520m east of The Anchorage). Comprising the Eastern end of Corlette Beach, transitioning from Precinct 1 to an actively eroding section of beach fronting Conroy Park. In the past few years, geotextile sand bags have been used to protect the eastern end of this precinct.

Precinct 3: (Between approximately 520m and 710m east of The Anchorage). Comprising a north-north westerly facing length of foreshore protected by a tipped rock revetment which is too steep and failing extensively. This reach stretches from the eastern end of Conroy Park through to the westernmost groyne (Groyne A), at the tip of Sandy Point, fronting properties between #70 and #48 Sandy Point Road.

Precinct 4: (Between approximately 710m and 810m east of The Anchorage). Comprising a north to north easterly facing length of foreshore revetment between the westernmost groyne, at the tip of Sandy Point (Groyne A), through to the next groyne east (Groyne B). Again there is significant revetment failure, particularly through loss of armour from the crest of the revetment. This precinct comprises the foreshore between #46 and #38 Sandy Point Road.

Precinct 5: (Between approximately 810m and 950m east of The Anchorage). Comprising a variable but heavily protected section of foreshore stretching between Groyne B and Groyne D. This section is the most “at-risk” length of foreshore within the study area. Swell waves tend to approach perpendicularly to the foreshore, maximising runup and overtopping during severe storm events. A significant stormwater outlet runs through the centre of Groyne D. This precinct comprises the foreshore between #36 and #20 Sandy Point Road.

Precinct 6: (Between approximately 950m and 1150m east of The Anchorage). Comprising the foreshore between Groyne D and the easternmost residence on Sandy Point Road (i.e. between addresses #18 and #2). This shoreline section is presently more sheltered than areas to the west, and is afforded some protection by Groyne D, which is acting to both reduce wave heights and also trap sand on its eastern side, creating a sandy beach buffer. Even so, there is photographic and field evidence of past damage to structures and overtopping along this length of foreshore, particularly at boat ramps which are “weak points” along the foreshore.

To support subsequent conceptual design activities detailed survey, including hydrographic and unmanned aerial vehicle (UAV or ‘drone’) surveys were undertaken. A summary of that data is provided in Appendix C.

Early contact was made with the local community through a questionnaire (online and print), followed by targeted interviews with interested parties that either lived along the foreshore or had a particular or long standing interest in the study foreshores.

Key issues identified by consultation included:

- There has been long term recognition of erosion problems along the study foreshores;
- There was a perception that the problems have worsened over time;
- Management options involving sand nourishment and rock revetments are most preferred by the community;
- While the broader response to questionnaires did not highlight the provision/retention of public access as being an important aim for management, the issues of public safety, variability and scouring of the pathway around Sandy Point are evident;
- The community sees a need for active intervention in the foreshore which goes beyond the piecemeal and reactive approach of the past and there was concern that the present effort was “just another study” that would not result in any meaningful action;
- Boat ramps are seen as a problem by many foreshore residents as they present weak points for wave runup during storms. However, some residents see the boat ramps as an asset which adds value to individual properties. Management of this issue will require further consultation with affected owners; and
- Poor drainage across the foreshore is seen as a problem which appears to be getting worse with time.

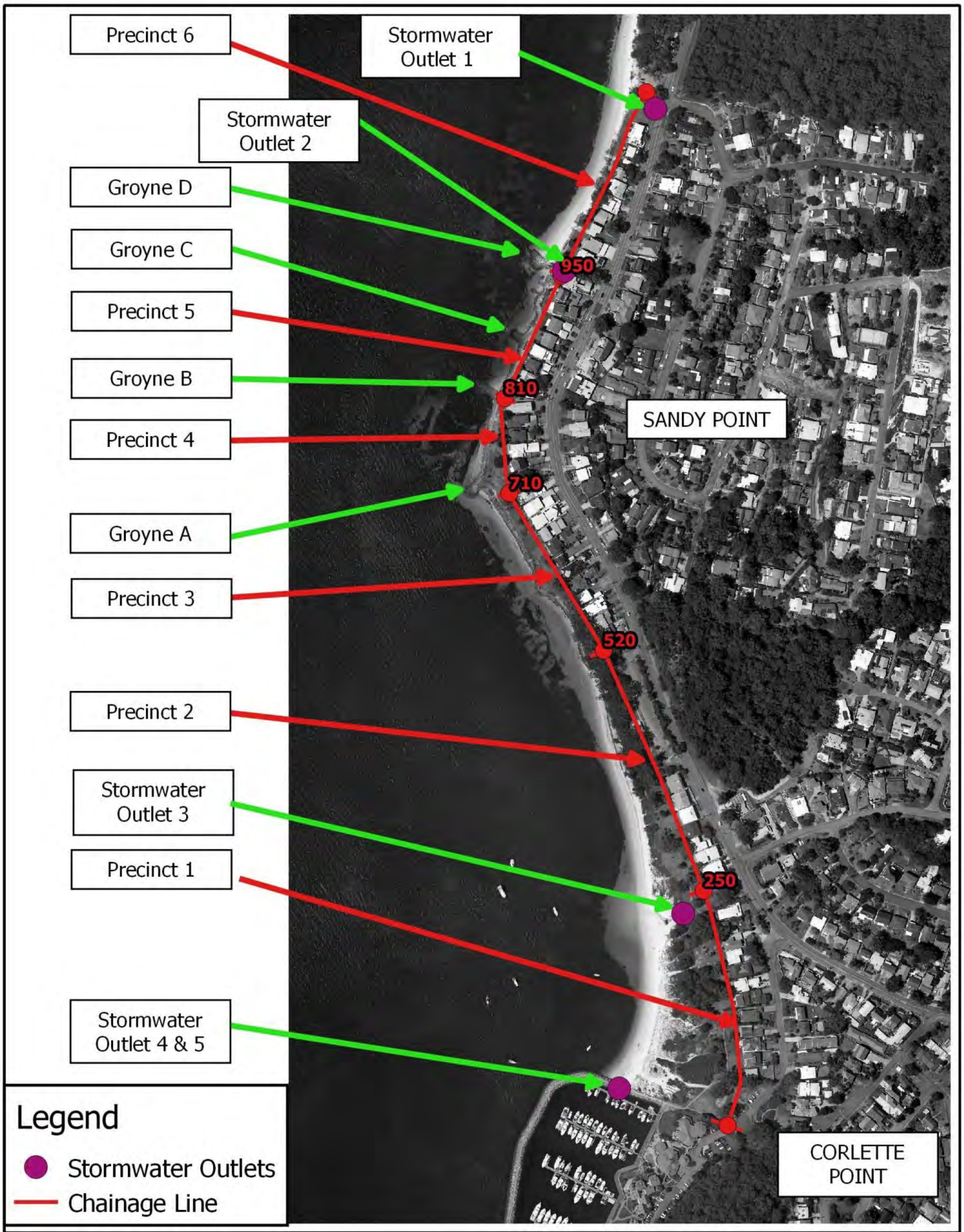

Figure E1 Study Area Precincts, Groyne and Stormwater Outlet Locations

Sandy Point - Conroy Park Foreshore Erosion and Drainage Management Plan

Whitehead & Associates
Environmental Consultants

Revision	A
Drawn	DW
Approved	DW

Utilising the findings of the background studies and community opinions, a long list of potential management options was developed for the site. Subsequently, a “Multi-criteria” analysis approach was adopted to short list the most preferable options.

This process resulted in the development of three comprehensive “schemes” for the entire foreshore, with each scheme comprising options for each precinct that were compatible with each other. These schemes are presented in Table E.1.

At the exhibition stage, the three schemes were presented to the community to seek feedback. To facilitate further consultation with the community, conceptual design cross sections and plans have been drafted, and cost estimates have been prepared. The cost estimates include an allowance for contingencies (20%) and inflation to bring the estimates forward to the beginning of 2016. Those estimates are also presented in Table E.1.

At the exhibition stage a community brochure was prepared to succinctly present the three schemes and summarise the project findings thus far. In addition, images illustrating the visual impact of all three schemes for two of the key precincts have been prepared. These were chosen in consultation with Council as follows:

- Precinct 5: On the eastern side of Sandy Point, this precinct is presently the most exposed to severe wave overtopping and scour;
- Precinct 2: Conroy Park, which has been subject to significant erosion over the past two decades.

Cost estimates for the conceptual designs have been prepared. Details are provided in Appendix H, but a summary is provided in Table E2. The base estimate values have been adjusted upwards for a contingency amount of 20% and for inflation to place the estimates at the end of 2015. The methods used to estimate quantities are based on conceptual cross sections and modifications at detailed design stage, and changes to the economic situation prior to construction means that these estimates must be considered as preliminary, but reasonably indicative. The cost for additional investigation, detailed design and environmental impact assessment activities has not been included in these estimates, and would typically be somewhere around 10% of the capital cost.

The final chapter of this document was completed once community feedback from the exhibition had been reviewed and comprises a plan with recommended options and guidance for subsequent detailed design and implementation. Importantly, it is not necessary that all precincts would be treated at the same time and some areas will be prioritised over others in the order of execution of any works to optimise available funding and local concerns. Furthermore, it is likely that the management plan, when finalized and fully implemented, will comprise a mixture of elements from the different schemes outlined.

Table E1 Shortlisted Management Options for 6 Foreshore Precincts

Precinct	Scheme 1 Treatments	Scheme 2 Treatments	Scheme 3 Treatments
1	Relocate sand to Precincts 2 and 3.	Retain sand and install twin gross pollutant traps to existing stormwater line.	Retain sand and construct groyne to convey stormwater line across beach. Install twin gross pollutant traps to existing stormwater line.
2	Use Precinct 1 sand to nourish and construct groyne at western end of Conroy Park	Nourish with sand imported from elsewhere.	Nourish with sand imported from elsewhere.
3	Relocate Fence. Remove stairs and ramps. Batter slope back and reconstruct revetment to engineered standard. Nourished using sand from Precinct 1.	Relocate Fence. Remove stairs and ramps. Batter slope back and reconstruct revetment to engineered standard. Repair, bolster and extend Groyne A. Nourishment from imported sand.	Relocate fence. Remove stairs and ramps. Batter slope back and reconstruct revetment to engineered standard. Repair, bolster and extend Groyne 'A'. Enhance existing "headlands" to form pocket beaches and nourish.
4	Rebuild and bolster foreshore revetment (mainly along existing alignment but will require some reclamation).	Rebuild and bolster foreshore revetment (will require some reclamation). Extend and reconstruct Groyne B.	Rebuild and bolster foreshore revetment (will require some reclamation). Extend and reconstruct Groyne B. Nourish beach between Groynes A and B.
5	Remove boat ramps, Reconstruct wall, reclaiming where necessary to provide for 2.4m path landward and allowance for raised crest elevation to accommodate sea level rise.	Provide for "mega" nourishment of beach profile offshore, to the east of and in the vicinity of Precinct 5. Aims to replicate historical beach conditions. Extend Groynes B and C to anchor beaches.	Remove boat ramps, Reconstruct wall true to present alignment and provide a robust, suspended walkway around the front of the new revetment.
6	Remove boat ramps, reconstruct path and replace with a low revetment with adequate space for future crest heightening as required. Reconstructed revetment along existing alignment. Retain eastern stormwater line as is.	Extend Groyne D and nourish to the south to provide a future source of sand for east to west transport around Sandy Point. Ongoing nourishment would be required. Remove boat ramps and rebuild back beach. Install two pollution traps upstream of Groyne D, Formalise eastern stormwater crossing	Remove boat ramps, reconstruct path and replace with a low revetment with allowance for a wave deflector wall to be installed in future. Formalise stormwater crossing with shallow dish drain and infiltration trench.

Table E2 Preliminary Cost Estimates.
(Annualised Maintenance Cost in Brackets)

Location	Scheme 1	Scheme 2	Scheme 3
Precinct 1	$0.085M ($8,500)	$0.38M ($11,000)	$1.3M ($6,300)
Precinct 2	$0.51M ($500)	$0.26M ($21,000)	$0.26M ($21,000)
Precinct 3	$1.1M ($1,100)	$1.65M ($9,000)	$2.7M ($10,000)
Precinct 4	$0.43M ($430)	$0.91M ($1,000)	$0.94M ($4,300)
Precinct 5	1.3M ($1300)	$2.23M ($9,500)	$1.53M ($1,500)
Precinct 6	0.81M ($850)	$0.85M ($31,000)	$0.82M ($800)

Following exhibition, consultation and reconsideration of the options presented, the strategies summarised in Table E3 are recommended for management of the foreshores within the study area. These typically involve a mixture of elements from the schemes presented to the community.

Nourishment in front of Conroy Park is prioritised first due to the benefit in protecting the park and relatively low costs. Priorities 2 and 3, dealing with Precincts 5 and 3 respectively, are considered critical with regards to public safety and the protection of property.

Table E3 Selected Strategies, Prioritisation and Costs[1]

Priority	Works	Design Timing	Detailed Design Costs	Construction Timing	Construction Costs	Maintenance Cost (/annum)
1	Precinct 1 & 2 (Nourishment)	Complete	$15,000	Mid 2018-19	$0.06M	$10,000
Description: Move sand from Precinct 1 (around 15,000m^3) and place in front of Precincts 2 (and 3). Restores beach width fronting Conroy Park and allows proper operation of Outlets 4 and 5 (adjacent to The Anchorage). Maintenance of geotextile sand bags.						
2	Precinct 5	2019	$110,000[2]	2019-2020	$1.65M	$1,500
Description: Construct robust revetment with some realignment to enable construction of a shared pathway. Install twin gross pollutant traps to Outlet 2. Determine foreshore access requirements in consultation with community.						
3	Precinct 3 (Pedestrian Management)	2019	$5,000	2019	$0.06M	$5,000
Description: Construct pathway and fence to divert pedestrians from the steep foreshore. Monitoring and maintenance required until full option is adopted (see below).						
4	Precinct 4	2020	$50,000	2021	$0.43M	$1,000
Description: Demolish foreshore protection and reconstruct revetment. Some reclamation required at eastern end (adjacent to Precinct 5). Consolidate foreshore accesses in consultation with community.						
5	Precinct 1 (Stormwater)	2021	$30,000	2022 (or later)	$1.35M	$1,500
Description: Construct Twin Gross Pollutant Traps and extend the stormwater line in the form of a groyne across Corlette Beach. Construction tothe scale of the groyne wherever possible.						
6	Precinct 3 (Revetment)	2023	$100,000	2024 (or later)	$1.00M	$1,000
Description: Demolish existing structures, batter back foreshore and construct new revetment. Note that path and fencing will have been constructed as part of Priority 3.						
7	Precinct 6[3]	As Required	$50,000	As Required	$0.83M	$1,000

[1] Costs are approximate and based on the detailed estimates provided for the three schemes exhibited. Costs exclude GST but include a contingency of 20%. Costs relevant to late 2015/early 2016 and an allowance for inflation needs to be applied to future costs. All works are subject to the identification of a suitable funding source.
[2] This figures includes an allowance to complete a distributional and cost benefit analysis for all proposed rock revetment works under priority 2, 4, 6 and 7.

[3] Note that preliminary works to remove existing weak points (boat ramps, foreshore crossings) from this precinct could be undertaken initially, possibly in conjunction with the Precinct 5 construction. Refer to text.

Priority	Works	Design Timing	Detailed Design Costs	Construction Timing	Construction Costs	Maintenance Cost (/annum)
Description: Demolish existing structures and construct continuous revetment with appropriate pedestrian crossings. Construct dish drain and infiltration trench to outlet 1. Note that the dish drain is relatively cheap and could be constructed as a separable piece of work.						

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1 Introduction

The foreshores of Sandy Point and Conroy Park, along the southern shoreline of Port Stephens at Corlette, have experienced erosion for a number of years. Furthermore, the ground immediately landward of the foreshore is low and flat, meaning that effectively draining stormwater from this area is a challenge.

Port Stephens Council (PSC) engaged Whitehead & Associates (W&A), in consultation with Coastal Environment Pty. Ltd. (CE) to investigate both of these issues and to formulate a management plan which addresses them. This document describes the work completed and issues considered in developing an appropriate plan. The report concludes with a detailed description of the management strategy ultimately recommended to PSC.

The location of the study area along the southern foreshore of Eastern Port Stephens is shown in Figure 1. The site is around 3km west of Nelson Bay and some 40km and 150km north of Newcastle and Sydney respectively.

A more detailed view of the foreshore in question is presented in Figure 2. The foreshore of interest to the present study extends from “The Anchorage” Marina at Corlette Headland eastwards along Corlette Beach and around Sandy Point for a distance of nearly 1200m. Figure 3a outlines the tenure of the area. A strip of Council owned reserve (Lot 256 DP 27048) extends along the entire foreshore. The northern boundary is the the mean high water mark (MHWM) below which is Crown Land. The stretch of beach immediately to the east of The Anchorage is presently accreting, owing to the construction of the eastern breakwater of The Anchorage in the early 1990’s. That breakwater interrupted the natural (east to west) longshore transport along Conroy Beach, causing sand to accumulate on the eastern side of the breakwater and subsequent widening of the beach in this location. Two separate stormwater lines exist near the eastern breakwater. One drains the residential tourist accommodation associated with the marina and runs up the spine of the breakwater, discharging through an outlet located on the eastern face of the breakwater. The other drains a small residential sub catchment to the south of the western end of the study area. Both outlets are presently subject to inundation and burial by the build-up of sand against the breakwater.

From The Anchorage, the beach extends eastwards for some 450m in front of 21 residential properties and then Conroy Park. Along this length, the beach gradually narrows, transitioning from an accreting beach to an eroding beach with distance.

Erosion is most pronounced at the eastern end of Conroy Park, a location where a geotextile sand bag revetment was constructed in May 2013. That revetment is presently showing signs of significant deterioration, with undermining of the toe and tearing of the fabric acting as an anchor for the toe back into the main bulk of the placed geobag containers. The wall has also been “out flanked” by erosion at its western end and erosion continues to impact the beach to the west, in front of Conroy Park.

Midway along Corlette Beach, a significant stormwater drainage path crosses the foreshore. Discharge from this outlet washes sand from the beach and deposits it in a nearshore fan which can be readily identified on aerial photography, and in the field. Localised erosion around this stormwater discharge is present but presently disconnected from the erosion occurring across the front of Conroy Park.

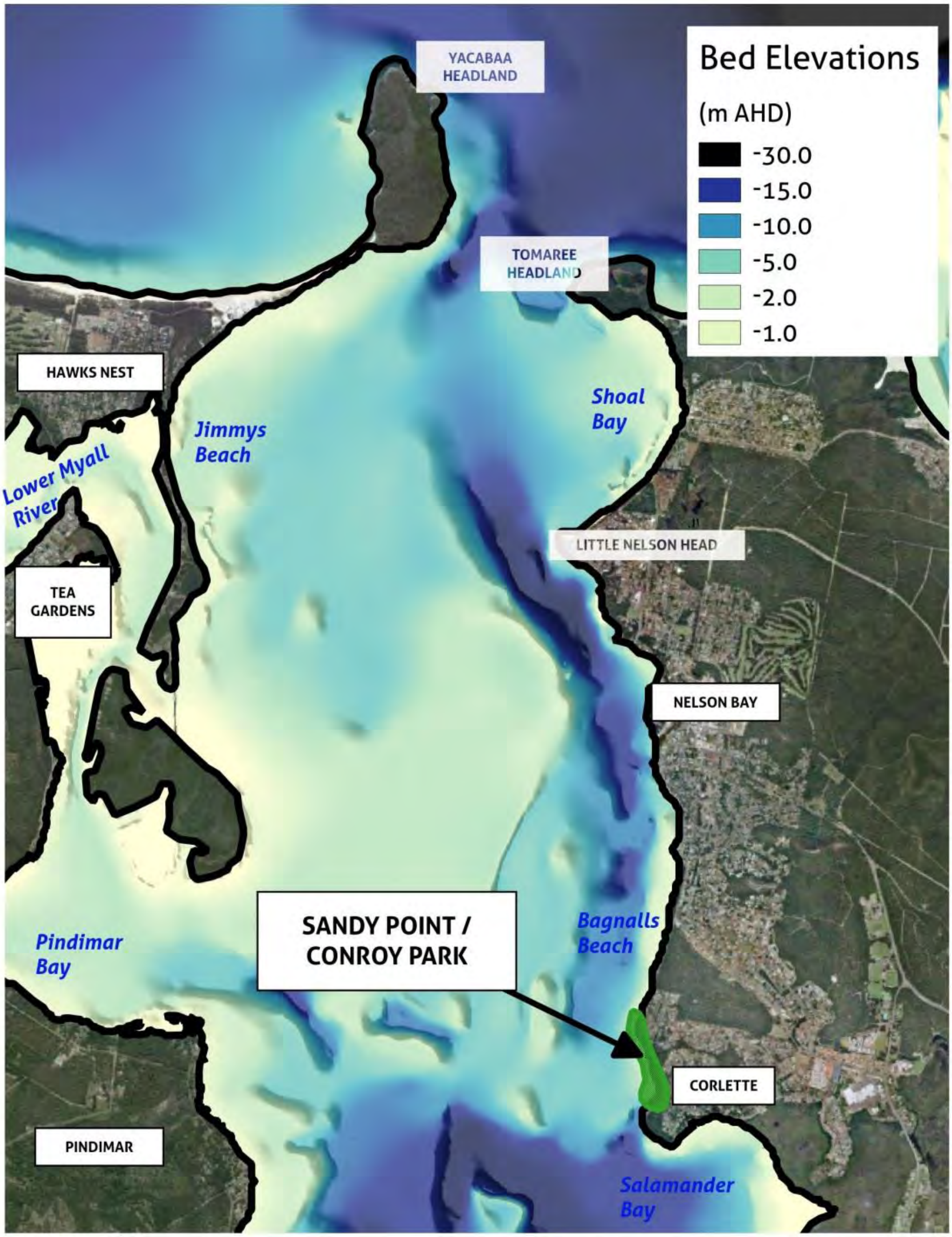

Figure 1: Location of Study Area within Port Stephens

Sandy Point / Conroy Park Foreshore Erosion and Drainage Management Plan

Whitehead & Associates Environmental Consultants

Revision	A
Drawn	DJW
Approved	DJW

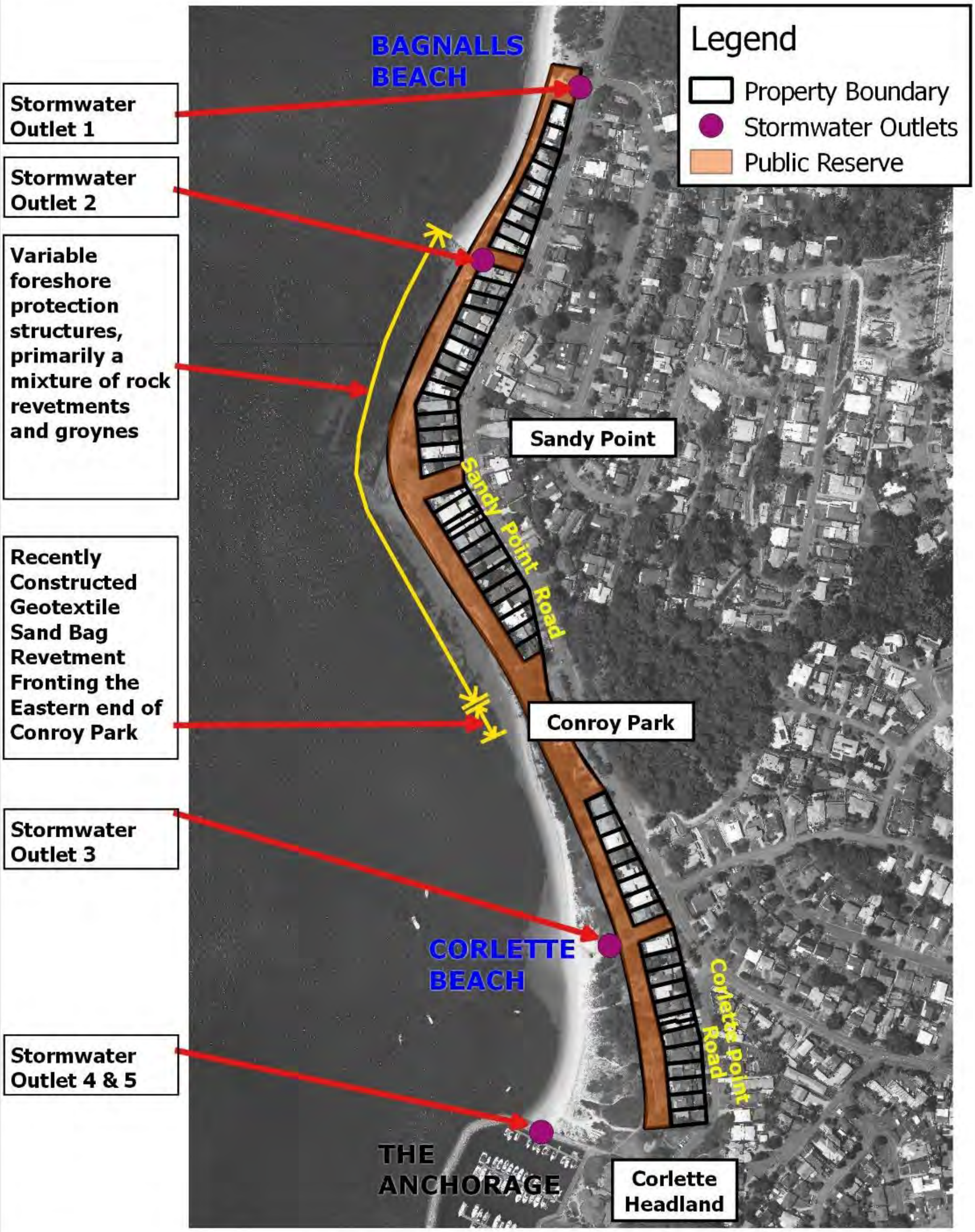

Figure 2 Site Features

Sandy Point - Conroy Park Foreshore Erosion and Drainage Management Plan

Whitehead & Associates
Environmental Consultants

0 75 150 225 300 m
(Approx Scale)

Revision	A
Drawn	DW
Approved	DW

Figure 2a - Land Tenure

MGA 56

PORT STEPHENS
COUNCIL

DISCLAIMER

Port Stephens Council accepts no responsibility for any errors, omissions or inaccuracies whatsoever contained within or arising from this map. Verification of the information shown should be obtained from an appropriately qualified person(s).

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To the east of Conroy Park, the foreshore is characterised by a mixture of rock revetments in varying states of repair, crossed by some pathways and access stairs. This continues around the front of 13 properties along Sandy Point Road until it meets the northern most point of the foreshore (i.e. the present “apex” of Sandy Point) which is marked by the western most groyne of a series that have been constructed to protect the foreshore to the east of this point. The foreshore alignment changes here from a more north-westerly facing alignment to more north-easterly, and the buffer of public land between the foreshore and residential property boundaries rapidly narrows, over a distance of around 100m, eventually becoming extremely narrow.

The north easterly facing section of foreshore fronts properties that are most at threat from the impact of waves. The beach here is very narrow, and property owners have constructed a variety of protective structures, with varying degrees of effectiveness, in front of their properties. While somewhat effective, it is clear that none of these structures have been engineered to acceptable coastal engineering standards. The property by property approach is non-cohesive and, in some areas the nature of the construction has the potential to adversely impact on adjacent properties. Boat ramps along this length of foreshore present a particular weakness against wave uprush and overtopping and subsequent flooding of the backshore area during stormy conditions. A number of shore normal groyne type structures have been built in this area, with the most significant being the easternmost groyne. There are approximately 15 residential properties fronting the foreshore between the western and easternmost groynes, with the easternmost 10 of these properties having the most severe exposure to swell waves that are refracted towards this shoreline after propagating through the entrance of Port Stephens.

The easternmost groyne also provides protection for a stormwater pipe which runs up the spine of the groyne and is visible at low tide levels, protruding from the tip of the structure. This stormwater line drains the main eastern sub catchment (broadly, to the east of Conroy Park) of concern to the present study. From Figure 2, it is clear that sand has more recently accumulated on the updrift (eastern) side of the easternmost groyne. On this side of the groyne, properties presently have a wider sandy beach which acts to protect those properties from storm waves and runup. Properties in this area have adapted to these conditions by constructing protective structures that are much smaller in scale. The difference between the scale of structures to the east and west of the easternmost groyne is notable. The northern boundary of our study area is marked by a stormwater line which crosses the beach opposite the intersection of Pantowara Road with Sandy Point Road, adjacent to the western car park of Bagnalls Beach Reserve.

2 Background Information

This plan was developed as per a priority action of the *Foreshore Management Plan for Port Stephens* (2009) and is aligned with the objectives of the *Port Stephens / Myall Lakes Estuary Management Plan* (2000*), Foreshores – Generic Plan of Management* (2001) and *Urban Parks – Generic Plan of Management* (2004). All works will be managed in accordance with any Council policy or relevant legislations that is applicable at the time of implementation.

2.1 Coastal Zone Management Planning Requirements

The Sandy Point / Conroy Park Foreshore Erosion and Drainage Management Plan (2016) was originally prepared on behalf of Port Stephens Council, in co-operation with the NSW Office of Environment & Heritage (OEH), under the NSW Government's Estuary Management Program. The Plan is supported by a Coastal Processes Study and Drainage Processes Study (Appendix A) which describes the environmental processes of the area and their interactions. A range of feasible management options were identified for each precinct. The methodology and detail of this is outlined in section 4, 5 and 6. Section 7 outlines the prioritised implementation strategy for all works

The Sandy Point / Conroy Park Foreshore Erosion & Drainage Management Plan (2016) was submitted for certification as an Estuary Coastal Zone Management Plan (CZMP) under the NSW Coastal Protection Act 1979 on the 21st of October 2016. Feedback was received from Dept of Industry – Lands and Forestry on the 29 August 2017 and the Office of Environment & Heritage and the NSW Coastal Panel on the 26 September 2017. Negotiations' regarding subsequent amends continued until the final plan was submitted for certification in August 2018. All amendments were made by Port Stephens Council in discussion with Office of Environment & Heritage and Dept of Industry – Lands and Forestry.

The Plan describes how the area could be managed, gives recommended strategies to identified problems, and a schedule of activities for the implementation.

2.2 Existing State of the Study Foreshores

A full description of the study foreshores is provided in Chapter 2 of Appendix A. Within that appendix, the foreshore was divided into 6 separate precincts which are presented here as Figure 3. These precincts have been used to develop and assess different management options. "Chainages" are used to identify the extent of these precincts and are measured in distance east from the Anchorage Marina eastern breakwater (Figure 3). Briefly, they are characterised as:

Precinct 1: (Between approximately 0m and 250m east of The Anchorage). Comprising the western end of Corlette Beach. This area has been accreting since construction of The Anchorage. A significant stormwater outlet crosses the beach at the eastern end of this precinct.

Precinct 2: (Between approximately 250m and 520m east of The Anchorage). Comprising the Eastern end of Corlette Beach, transitioning from Precinct 1 to an actively eroding section of beach fronting Conroy Park. In the past few years, geotextile sand bags have been used to protect the eastern end of this precinct.

Precinct 3: (Between approximately 520m and 710m east of The Anchorage). Comprising a north-north westerly facing length of foreshore protected by a tipped rock revetment which is too steep and failing extensively. This reach stretches from the eastern end of Conroy Park through to the westernmost groyne (Groyne A), at the tip of Sandy Point, fronting properties between #70 and #48 Sandy Point Road.

Precinct 4: (Between approximately 710m and 810m east of The Anchorage). Comprising a north to north easterly facing length of foreshore revetment between the westernmost groyne, at the tip of Sandy Point (Groyne A), through to the next groyne east (Groyne B). Again there is significant failure, particularly through loss of armour from the crest of the revetment. This precinct comprises the foreshore between #46 and #38 Sandy Point Road.

Precinct 5: (Between approximately 810m and 950m east of The Anchorage). Comprising a variable but heavily protected section of foreshore stretching between Groyne B to Groyne D. This section is the most “at-risk” length of foreshore within the study area. Swell waves tend to approach perpendicularly to the foreshore, maximising runup and overtopping during severe storm events. A significant stormwater outlet runs through the centre of Groyne D. This precinct comprises the foreshore between #36 and #20 Sandy Point Road.

Precinct 6: (Between approximately 950m and 1150m east of The Anchorage). Comprising the foreshore between Groyne D and the easternmost residence on Sandy Point Road (i.e. between addresses #18 and #2). This shoreline section is presently more sheltered than areas to the west, and is afforded some protection by Groyne D, which is acting to both reduce wave heights and trap sand on its eastern side, creating a sandy beach buffer. Even so, there is photographic and field evidence of past damage to structures and overtopping along this length of foreshore, particularly at boat ramps which are “weak points” along the foreshore.

The detailed information presented in Appendices A and B are summarised here for each precinct.

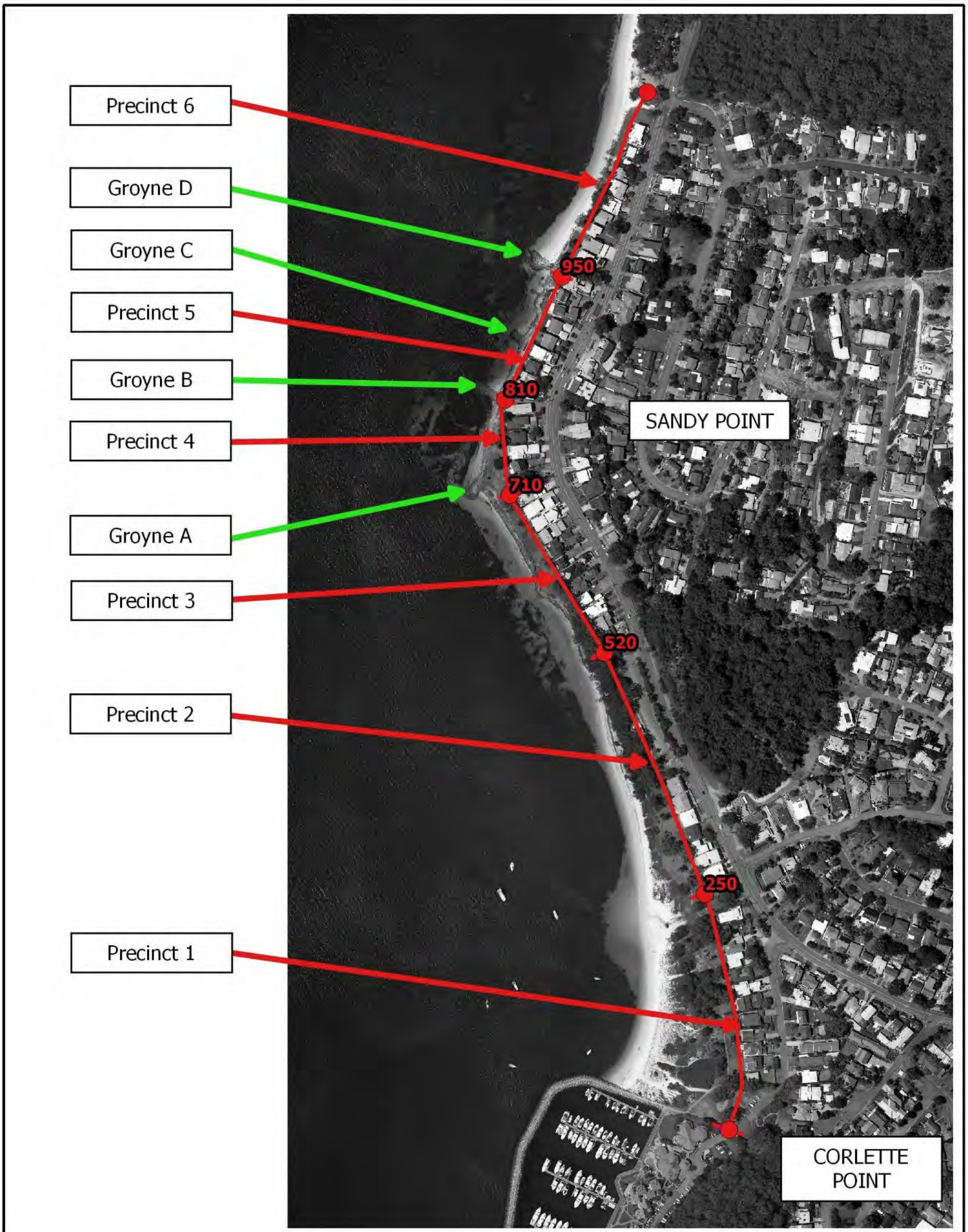

Figure 3 Study Area Precincts

Sandy Point - Conroy Park Foreshore Erosion and Drainage Management Plan

N

Whitehead & Associates
Environmental Consultants

0 100 200 300 m
(Approx Scale)

Revision	A
Drawn	DW
Approved	DW

2.3 Summary of Coastal Processes

2.3.1 Precinct 1

Precinct 1 has seen a substantial accumulation of sand over the last 20 years at rate of around 1,750m^3/year (35,000m^3 total). The construction of “The Anchorage” breakwater in the early 1990s has temporarily blocked the westerly movement of sand and the beach has widened by approximately 60m adjacent to the breakwater. Prior to construction of “The Anchorage” sand would have continued moving westward being transported over the leading edge of the flood tide delta by waves and flood tides and deposited into the deeper estuarine basin of Port Stephens.

The build-up of sand has affected the growth of vegetation in Precinct 1 reducing the area available for seagrass with the shoreward edge of the seagrass retreating over time. However, there has been a commensurate increase in the area occupied by sand dunes and their associated vegetation. Two stormwater outlets adjacent to the Anchorage have been buried by the accumulated sand.

Precinct 1 includes a large stormwater outlet across the middle of Corlette Beach. During high stormwater flows, sand is eroded from the beach face and deposited in the nearshore zone potentially smothering any seagrass that may be growing there.

2.3.2 Precinct 2

Erosion in Precinct 2 is progressing from east to west at the present time, with the most obviously eroding area immediately west of the geotextile sand bag revetment fronting Conroy Park. This erosion has progressively affected the whole of the Sandy Point foreshore from Bagnalls Beach to the west. The erosion is caused by refracted swell waves entering Port Stephens which approach Corlette from the north east. Severe undermining has resulted in the collapse of a number of trees immediately behind the beach along Conroy Park.

At its western end Precinct 2 also contains an inflexion about which the pattern of shoreline evolution changes from receding to accreting. While most of Precinct 2 is eroding, the areas west of the inflexion point, and all of Precinct 1, are presently accumulating sand.

2.3.3 Precinct 3

Precinct 3 extends from the eastern end of Conroy Park through to “Groyne A” at the tip of Sandy Point. Historically, a lobe of sand has existed off the tip of Sandy Point. This has gradually eroded as sand has moved from east to west through the study area over the last 60 years, primarily under the action of swell waves. In the absence of a source of sand from the east of Sandy Point (i.e. from Bagnalls Beach) this sand has not replenished.

Swell waves in Precinct 3 approach the shoreline at a very oblique angle and the resulting erosion has stripped the beach of sand, leaving only a very narrow beach at most tide levels, and the foreshore exposed to wave attack. The overly steep foreshore revetment with a lack of a structural toe and small armour sizes is particularly susceptible to slumping. Storm waves may overtop the foreshore in Precinct 3 on occasion although, as the development is set well back, overtopping is less of an issue than for precincts 4 through 6 (to the east).

2.3.4 Precinct 4

Precinct 4 comprises the foreshore between Groynes A and B. At the western end of the precinct (Groyne A), a small fillet of sand has formed on the eastern side of the groyne due to the dominant east to west littoral transport along this foreshore. Community reports indicate that the location of this fillet may shift to the eastern end, following periods of significant north westerly wind waves, which can also overtop the foreshore protection. In the absence of an ongoing sand supply from the east, there is no significant natural replenishment in this precinct and therefore no wide beach to provide protection from swell waves. When the volume of sand leaving a precinct to the west exceeds the volume entering from the east, the foreshore recedes and the beach is removed. Wave overtopping has caused scouring/slumping of the land surface immediately behind the revetment and also caused the revetment to slump in some sections.

2.3.5 Precinct 5

Precinct 5 includes the foreshore between Groynes B and D. This stretch of foreshore, facing the north east, is presently the most exposed to refracted swell waves and a hydrographic survey undertaken for this study indicates that this may partially be caused by ledges and drop overs in the bathymetry offshore of the precinct. Similar to Precinct 4, a small fillet of sand has built up on the eastern side of Groyne B, under the influence of the dominant east to west littoral transport.

Again, the lack of sand entering the precinct from the east means that no substantial beach is retained here. Groynes B and C are undersized and the foreshore here is particularly exposed to waves. This causes regular overtopping and has resulted in scouring of the land behind the revetment and weakening/failure of sections of the protection works. Smaller, local wind generated waves from the North East and North West are of comparatively minor concern, the major risk being high water levels and ocean swells during storms.

2.3.6 Precinct 6

The western end of Bagnalls Beach is relatively sheltered from swell waves. Groyne D, which is more substantial, has trapped a larger fillet of sand to retain some beach at the western end of Precinct 6, providing some protection, particularly between #10 and #20 Sandy Point Road at the present time. Between #2 and #10 Sandy Point Road, the beach is narrower but, the shoreline is less exposed to these refracted, oblique waves.

Overall, the following combination of factors makes properties within Precinct 6 less exposed to inundation from wave overtopping than Precinct 5:

- presence of a beach;
- more favourable alignment to incoming waves; and
- less focussing of refracted swell energy at this location.

However, the foreshore structures in Precinct 6 are too low to provide the required level of protection from present and future wave inundation. Furthermore, several boat ramps provide points of weakness through which overtopping and inundation of the foreshore can readily occur.

The fillet of sand which has formed to the east of Groyne D has caused a minor reduction in the seagrass area fronting Precinct 6 during recent decades, although the sand here at present is substantially less extensive than it was during the 1950s and 1960s.

2.4 Summary of Drainage Processes

2.4.1 Precinct 1

Within Precinct 1, there are three stormwater outlets (Figure 2) as follows:

- Outlet 5: A pipeline conveyed through the centre of the eastern breakwater of The Anchorage, draining the small catchment comprising the marina resort itself. This outlet presently discharges from the side of the breakwater and, when inspected as part of this study, was partly buried by beach sand limiting performance;

- Outlet 4: A pipeline which drains a small 1.66ha urban catchment comprising the area, generally, to the north of Judith Street and west of the intersection of Corlette Point Rd. and Sandy Pt Road. This pipeline discharges across the beach adjacent to the Anchorage Breakwater to approximately the same location as Outlet 5. At the time of inspection, this outlet was completely buried in beach sand; and
- Outlet 3: The major stormwater crossing of Corlette Beach, which drains areas to the east of Sandy Point Road and west of Conroy Park, including The Peninsula, Corrie Parade and intersecting streets.

Overall, drainage within the residential streets is under designed, in the sense that a 1 in 5 year recurrence interval storm event results in widespread surcharging of the minor stormwater system (pits and pipes). It is estimated that outlets 4 and 5 do not contribute significant pollutants, litter or suspended sediment to the Port, when compared with Outlet 3, which contributes around 10 times more than the other two outlets combined. Management of stormwater in Precinct 1 should focus on Outlet 3, although the intermittent burial of Outlets 4 and 5 by beach sand is not appropriate and may impact overall flood behaviour during storms.

The main concern with Outlet 3 is that it now discharges across a substantial width of beach. Every time a significant storm occurs, sand that has accumulated on the beach seaward of the outlet is scoured from the beach face and spread within the nearshore zone. While this is not of significant concern to the movement of sand and overall foreshore erosion, the large sand delta which has been formed may have otherwise been colonised by seagrasses.

2.4.2 Precinct 5

Within Precinct 5 the second major stormwater outlet (Outlet 2, shown on Figure 2), which discharges through Groyne D is presently fulfilling that role relatively efficiently. Similarly to the western stormwater catchments, the minor stormwater systems draining to Outlet 2 suffer from significant surcharge during a 1 in 5 year recurrence interval storm.

In conjunction with Outlet 1, at the eastern end of the study area, and at the end of Pantowora Street, Outlet 2 is responsible for draining the residential area to the east of Conroy Park, west of Bagnalls Beach and, broadly, to the north of Mulubinda Parade.

In comparison to the main stormwater crossing of Corlette Beach (Precinct 1), this discharge point does not result in the scouring of sand by flowing across a beach. Instead, it discharges directly into Port Stephens from the end of groyne D at around the low tide level. Some sand bypassing of the groyne does occur under waves and currents, but there is no evidence that the outlet has been subject to burial or blockage by sand.

Again, it is estimated that this outlet supplies a similar amount of flow, suspended sediment and pollutants to the coast as Outlet 3 (Precinct 1). When compared to Outlet 5, at the end of Pantowora St., this outlet discharges around an order of magnitude more pollution (and flow) to the coast.

2.4.3 Precinct 6

Outlet 1 crosses the foreshore at the eastern end of the study area, at the end of Pantowora St. While this outlet sits in a low point along Sandy Point Road, it actually plays a secondary role to Outlet 1 in draining the catchment. In effect, Outlet 1 acts as an overflow or relief during very large events. In terms of capturing sediments, pollutants and litter, it is more sensible to target

Outlet 2 for management options, although there are ways in which Outlet 1 could be improved to make the maintenance task here less onerous. Regular maintenance is crucial to ensure efficient operation of this outlet during the largest storm events.

3 Consultation

3.1 Community Questionnaire

3.1.1 Survey Methodology

As a part of this project W&A prepared a questionnaire for PSC for distribution to the Corlette community, seeking local knowledge, historic imagery and also to hear the opinions and concerns of the local residents. Questionnaires were mailed to the residents located on the shoreline and an online survey was made available to the general public. A total of 66 responses were received. The data from these surveys is summarised in the sections below. Examples of the online and mailed surveys are presented in Appendix D.

3.1.2 Respondents

The questionnaire asked if the respondent was an owner-occupier, absentee owner, tenant or a community member from nearby. Of the 64 valid responses, 42 were owner/occupiers, and 15 were non-resident community members.

The survey found that 22 of the respondents had lived in the area between 10-20 years and 17 had lived in the region for more than 20 years. This was followed by 12 residents living in the area for 2-5 years, 8 residents living there for 5-10 years and finally 5 residents had lived there for less than 2 years. Of 63 responses the majority indicated that they use the foreshore and reserves for passive recreation (52) and active recreation (54).

3.1.3 Responses - Changes to the Foreshore

62 respondents reported observed changes to the Sandy Point/Conroy Park shoreline. Shoreline erosion was the most common change observed (55) with respondents voicing particular concern over the loss of land at the eastern end of Corlette Beach. 26 respondents also noted a loss in trees or loss in tree stability due to erosion and storms. 21 respondents reported large sediment build up at the west end of Corlette at The Anchorage and an associated loss of seagrass.

A reduction in small and large fish species was raised as being related to the loss of seagrass. 19 respondents also noted changes in the foreshore region due to the stormwater pipes and outlets. Related issues included were scouring of the beach and sand build up adjacent to The Anchorage, the resulting blocked stormwater pipe and flooding, and odour. 7 residents also noted that the existing seawalls no longer provide suitable protection against large tides, waves and storms. 3 residents also noted that rocks from seawalls had fallen over the years.

52 respondents believe that the changes have become more pronounced in recent years whilst 7 respondents believe they have not.

Many different reasons were provided for the cause of erosion and loss of trees on the shoreline. 5 people believe erosion was caused by The Anchorage and its breakwaters, 8 people believe it is caused by the groynes around Sandy Point, 21 people believe it is caused by natural processes such as storms, winds, tides and waves, 12 people believe that erosion was caused by increased urban development and the associated stormwater run-off and the pipe outlet flows and 3 people believed the erosion has been caused by sea level rise and more intense storms associated with climate change.

13 respondents believe The Anchorage break wall constructed at the western end of Corlette Beach is the reason for sediment build up and reduction of seagrass. A number of alternative reasons were identified by a minority of respondents including (i) natural weather processes; (ii)

groynes; and (iii) increased stormwater flows. Issues with stormwater outlets were associated with (i) the actions of Council, (ii) natural causes (weather); (iii) insufficient structures; and (iv) increased runoff

3.1.4 Management Options

The ranked issues needing to be addressed by the management plan (in order of decreasing importance) were;

1. Foreshore Erosion
2. Stormwater Drainage & Flooding;
3. Loss of Public Access; and
4. Ocean Inundation

The ranked management options, with most favoured first, were:

1. Sand Nourishment; (closely followed by)
2. Rock Revetments;
3. Low Native Vegetation;
4. Increasing Public Access to the Water;
5. Increasing Public Access to the Reserve;
6. More Shade; and
7. Improved Public Safety

Conversely, when asked to identify the management options that they specifically did not want, the following ranking, with least favoured first, were

1. More Public Access; (equal with);
2. Better Access to the water;
3. Rock Revetments;
4. More Shade;
5. Improved Public Safety;
6. Native Vegetation; and
7. Sand Nourishment.

3.1.5 Other

The open comments left the by the respondents varied in nature however reinforce the nature of sections 3.1.2 through to 3.1.4. Many residents left comments placing emphasis on improving public access, safety and defining public and private land better. Residents also placed emphasis on protecting the land from erosion, improving the stormwater outlets and preventing blockage.

3.2 Community Interviews

3.2.1 Purpose of Consultation

Following on from the assessment of the questionnaire results (Section 3.1), interviews were undertaken directly with those residents and community representatives who indicate that they would like to discuss the project face to face. This opportunity was limited to residents directly adjacent to the Sandy Point shoreline or who Council indicate as having a close association with that shoreline.

Previous detailed studies have been undertaken with a view to addressing the issues around the Port Stephens shoreline generally and at Sandy Point in particular. There exists a community perception of the need for active intervention to occur at Sandy Point. Community perceptions are that responses to requests for protection to date have been reactionary, addressing problems after they occur or where public safety may be compromised. Often no Council action is forthcoming. Many longer term residents and some more recent purchasers have undertaken their own works to address the issues of wave inundation, recession and provision of beach access over many years. In the main, these works have been undertaken outside the property boundaries and, at least in part, on the foreshore reserve. Where they have been funded by the residents, there is frequently a sense of “ownership” which includes seawalls, boat ramps and access stairs to the beach. Council has also undertaken significant works over many years to address the issues at various locations within the study area, including the tipping of rock for erosion protection, the construction of rock groynes and the installation of stormwater drainage. In general no evidence of design or formal approvals is available for either private or Council works.

The face to face community consultation has been undertaken by W&A and Coastal Environment for this project. The consultants recognise that the Sandy Point foreshore has a long history of perceived issues and erosion problems. In consulting with the community the objective was specifically to focus on the study area with emphasis on the maintenance of public access along the shoreline, the protection of the existing foreshore (private) development, protection of the foreshore reserves and vegetation thereon, particularly Conroy Park, improving stormwater drainage and the maintenance and potential enhancement of the beach amenity. The purpose of the consultations was to commence a two way dialogue, providing the residents an opportunity to clearly elaborate on the issues they see, the likely causes and their preferred solutions. It also allowed the consultants to discuss the likely feasible options and to obtain additional information relating to the foreshore changes over a long time period. The face to face consultation was undertaken near the commencement of the consultation process, with the intention that contact would continue as the viable management options were developed and evaluated.

The interviews provided an individual opportunity to discuss approaches to management and protection of the area and the viability of undertaking such improvements including advantages, disadvantages, difficulties and costs. In preparing background material for this, we have considered the previous studies, their findings and recommendations. Where practical we have updated those results with more recent information that may be available. The objective was not to revisit the previous studies but to assess the viability of undertaking the management options proposed including practicality, cost and environmental impacts.

One on one interviews were conducted over an extended period of time during June-July 2015 with those residents identified. Interviews were undertaken with residents at their homes on 17th June, 20th June, 23rd June and 16th July 2015. The interviews were undertaken by David

Wainwright (W&A) and Doug Lord (Coastal Environment). An average of 45minutes was allowed for each interview. Where residents were unavailable to interview, phone interviews were undertaken, if required, at the convenience of the residents.

The period of the interviews followed closely after the ANZAC day “super storm” and a following period of elevated ocean levels and high swells which affected the Central Coast, Newcastle and Port Stephens. Those storms had focussed resident interest on the protection issues and provided the opportunity for recent insights into the potential severity and impact of the storms. Residents also provided photo images and video taken during and following those events.

A total of 17 interview requests were followed up, several of which included more than one resident associated with a particular property or strata. One resident could not be contacted and one indicated that he was satisfied with the current protection of his property and did not wish to proceed further with an interview. Three residents were overseas at the time of the interviews and so opted for telephone consultation or later follow up, while another was unavailable and also opted for a telephone discussion. A total of 11 separate face to face interviews were undertaken several of which included more than one party.

The level of response to the initial questionnaire and additional information provided together with the high proportion of responders seeking a further personal consultation, are indicative of the keen local interest in the health and management of the foreshores in the study area. The information acquired during the interviews remains confidential and, given the relatively small size of the sample (compared with the total population of the Corlette area); no statistical analysis of these results was intended or undertaken. The purpose of both the questionnaire and subsequent interviews was to facilitate an understanding by the Council and the consultants of the community issues and preferred solutions.

3.2.1.1 Key Issues from “One on One” Consultation

Recent storms, resulted in overtopping of the existing seawalls, damage to the alongshore access paths and further erosion and loss of trees in Conroy Park in the period immediately prior to the consultation. These storms were foremost in the thinking of residents during the interviews and featured prominently in our discussions.

There was a perception reflected in comments from residents that Council was merely repeating studies that had already been undertaken. Several residents drew attention to the development of the estuary and foreshore management plans and the consultation associated with those which promised improvements to the foreshore but delivered very little in the study area. The purpose of the existing study was clearly explained, the constraints on the area being studied and the limits of what may or may not be achieved were outlined. In particular, the current study was explained to be the next step in addressing the local recommendations already made in the estuary and foreshore management plans. It forms an essential part of the approval and implementation process which Council must address to implement the actions identified in those plans.

There was general agreement amongst all interviewed that the issues relating to the foreshore erosion have worsened over the years. In that regard we were provided with historical photos of the area that confirmed both the increase in the protection works along the central areas of the study area, east of Conroy Park, and the general loss of sandy beach seaward of those protection works. However they also confirmed the existence of protection measures back to the 1960s indicating the problems have existed since the earliest development along the strip and confirming that, at least in part, the present day hazards are exacerbated by the original subdivision and development being too close to the active coastal zone. This problem has been magnified through approval of more development over many years and a recent trend to redevelopment and intensification of that development on foreshore properties.

There was strong support from residents along the foreshore and broader groups within the catchment interviewed as to the importance of Conroy Park as a community resource and access point to the sandy beach west to The Anchorage. There was concern that the increasing protection works along the park, while addressing erosion would result in the loss of the beach and access to the foreshore. There was strong support for the maintenance of tree cover in the reserve both as an important source of shade and also as a stabilising and sheltering buffer from winds and coastal processes. One resident argued the importance of the Coral trees which provide summer shade but permit winter sun into the reserve. Unfortunately, over the course of the consultation period several trees considered a safety hazard were removed from the seaward edge of the reserve. Future management of the reserve and appropriate landscaping and access are a high priority.

A small number of those interviewed identify the loss of sand around Sandy Point with the completion of the Anchorage in the early 1990s and brought our attention to a submission of the Corlette Concerned Citizens Association to the Commission of Inquiry during the approval of that development. They argued that the marina construction has blocked the west to east movement of sand from the marina area along Corlette Beach to Sandy Point under westerly winds. While this effect may operate to a small degree during certain weather conditions, the predominant sand movement along this shoreline is from east to west under swell waves and tidal currents; any impact from blocking the local winds is likely to be minimal, localised and short lived. The erosion problems existed at Sandy Point prior to the marina construction and the beach accretion adjacent to the marina is as predicted in the studies undertaken prior to marina construction.

It was widely recognised amongst the community that a condition of the original approval was the removal of sand accreting on the western side of the marina walls and the placement of that sand at Council's direction for beach nourishment along the beaches on the southern foreshore of Port Stephens. This condition was also intended to limit the losses of sand from the active beach system as, if the beach is allowed to accrete too far, the sand would begin to move around the harbour and over the flood tide delta face into deep water off Corlette Head. A second intent was to prevent the stormwater outfalls adjacent to that wall from being buried and therefore not performing appropriately during storm events.

There was strong support generally for the maintenance and improvement of alongshore public access from Bagnalls Beach to The Anchorage, seaward of existing development. A couple of residents expressed concern with privacy and security arising from such access and this is particularly exacerbated along the eastern end of the study are where the distance between the seaward property boundaries and the existing revetment crest is minimal. There was less support for a cycleway through this narrow access. Within that area there were concerns at the variations in the existing access path including levels, materials, widths and scour. Many of the residents assume responsibility for either constructing the path or maintaining it after storms and there is some degree of "ownership" of the reserve area associated with this. There is a clear recognition that the pathway needs to be improved and be constructed consistently and in accordance with current standards.

Of more concern are the issues relating to the constructed boat launching ramps and access stairs across the walls to the beach area along the foreshores east of Conroy Park to Bagnalls Beach.

The boat ramps and pedestrian accessways (stairs, ramps etc.) are constructed within the public reserve and, in some locations, they have been present for many decades without challenge. This situation has fostered a strong sense of ownership and entitlement for these structures amongst the foreshore residents.

There is broad recognition that pedestrian access to the water needs to be rationalised and probably reduced in number. However this will need to be carefully negotiated with the residents during the implementation phase. Of more concern is the existence of the numerous boat ramps across the walls and servicing individual properties. Only one resident indicated that there was approval for their ramp and, in fact, had paid a permissive occupancy fee at some time in the past. The opinions of residents on these are firmly divided with some property owners expressing a strong desire to retain their ramps which they both use and see as an important attribute to their property value. Others, who generally do not have a ramp, recognise that these are a primary weakness in the foreshore defence, exacerbating wave overtopping during storms.

The existence of boat ramps on adjacent properties increases the extent and frequency of inundation of adjacent properties. It is clear to us that an effective management strategy which has the primary purpose of protecting foreshore development from wave inundation is not compatible with the retention of these boat ramps. Maintaining a low point in any protection works with a smooth ramp that increases wave runup levels will compromise the overall effectiveness of foreshore protection works. This matter will require close consultation with individual property owners as the management options are further developed.

Similarly, there is some sense of ownership of the seawalls constructed along the foreshores east of Conroy Park. Residents have funded and constructed many of these walls and several are satisfied that their works are adequate. Detailed negotiation will be required before these sections of protection can be dismantled, removed or replaced. Where the reserve is wider (immediately east and west of Conroy Park, again many residents have taken a lead role in managing the reserve including gardening and maintaining lawns and this must be recognised in adopting any changes or in formalising future maintenance by Council.

Stormwater drainage was generally identified as an issue with recent experience of water pooling along Sandy Point Road during storms. It was acknowledged that this appeared to be worsening and some residents expressed concern that this would be exacerbated by sea level rise. One resident indicated problems with vehicles driving through the ponded water and generating waves across their property which for the first time posed a risk of inundation of the ground floor from the roadway. This problem is not uncommon during flood events.

3.2.2 Issues beyond the Study Scope

A range of issues were raised by the residents both through the questionnaires and subsequent interviews which are beyond the scope of this study. However, they are listed here for future reference and information. No assessment has been undertaken of these issues and no opinion is offered here as to their veracity. The order of listing does not imply any priority or level of community support.

3.2.2.1 Issues outside the Study Area

The following issues have been raised during consultation. They relate specifically to locations which are outside the scope of the present study but which may affect future management and risks, raise concerns, or be impacted by management measures within the study area.

- Issues relating to the cost; who will pay and timing of implementation of a management strategy were raised by residents;
- Erosion of sediment from the developed areas behind the beaches and increased concentration of stormwater flows to existing outlets;
- The potential impact of movement of the tidal channel and shoals on the foreshores of the study area;
- Increasing depths at the toe of the rock walls and ongoing loss of the sandy beaches;
- Dredging currently undertaken in the Myall River entrance and the potential impact on the sediment movement along the southern foreshore of Port Stephens;
- A small number of those interviewed raised potential changes in management strategy limiting alongshore access at The Anchorage. These include use of the boardwalk for dining and the construction of a concrete function area blocking access to the western rock shelf when functions are in progress.

3.2.2.2 General issues raised

The following issues have been raised during consultation. They relate to more general issues of relevance to the study area and the broader Port Stephens area

- Perception that Council has been slow to address maintenance issues raised following storm damage;
- General reduction in fish stocks through the area;
- Sediment and litter load from stormwater outlets increasing and affecting sea grasses;
- Perceptions of higher and more frequent average water levels and wave heights within the Port and adjacent to Sandy Point;
- Future inundation hazards resulting from climate change and storms;
- Increasing and decreasing areas of seagrass.

4 Summary of Issues, Opportunities and Constraints

4.1 Introduction

This chapter clarifies the underlying problems to be addressed by the Foreshore Erosion and Drainage and Management Plan for the Sandy Point / Conroy Park Area, summarising the key findings of Chapters 2 and 3. As per previous sections of this report the "issues, opportunities and constraints" have been organised on a precinct by precinct basis, summarised in the following sections. These are also presented on Figure 4 (Precincts 1, 2 & 3) and Figure 5 (Precincts 4, 5 & 6).

4.2 Precinct 1

The key issues within Precinct 1 are the ongoing accumulation of sand adjacent to The Anchorage Breakwater, and the presence of stormwater outlets.

The shoreline adjacent to The Anchorage has accreted (widened) by approximately 60m since the early 1990's. At the present time, the accretion is such that two stormwater outlets adjacent to the Breakwater have been buried by sand, rendering them ineffective. The wide beach in this location is viewed as positive for The Anchorage from a tourist perspective. However, the sand that has accumulated here (around 35,000m^3 total within Precinct 1) could also be used beneficially to address erosion within other areas to the east.

The stormwater outlet at around Chainage 250m mobilises a lot of sand from the beach during storm events. That sand is scoured from the beach and deposited in the nearshore zone from which it is gradually reworked onto the shoreline. The deposition of this lobe of sand in the nearshore zone prevents seagrasses from establishing.

There is an opportunity to extend and formalise this stormwater outlet by construction of a groyne through which the stormwater line could pass. This approach has proven effective at Groyne D, at the boundary between Precincts 5 and 6. That stormwater line drains a similar catchment (size and amount of development) to the line draining across Corlette Beach in Precinct 1 and historical aerial photographs show that there is no loss of seagrass at the end of that groyne. A constraint associated with the construction of this groyne relates to the acceptability of such a structure to the community and State Government agencies, and whether it is considered more acceptable than the present, unconstrained discharge across the beach which requires continuous maintenance. Furthermore, as a groyne may present a barrier to pedestrian movement along the beach, it may be desirable to make provisions for access past or over a groyne in this location. Variations on the concept of a groyne as put forward could be considered.

4.3 Precinct 2

The key issue within Precinct 2 is erosion. Erosion is most severe near the eastern end of Conroy Park, but this is becoming more pronounced along the entire length of the foreshore fronting Conroy Park. The shoreline will continue to recede without intervention due to coastal processes in the area and a rising sea level. The geobag walls placed by council recently are unlikely to provide a long term solution to the foreshore recession. To maximise the potential of the park in this area while maintaining the sandy beach amenity, there is an opportunity to nourish the beach, using sand sourced locally, from adjacent to The Anchorage or, alternatively, won by dredging from the leading edge of the flood tide delta (to the north of Corlette Head).

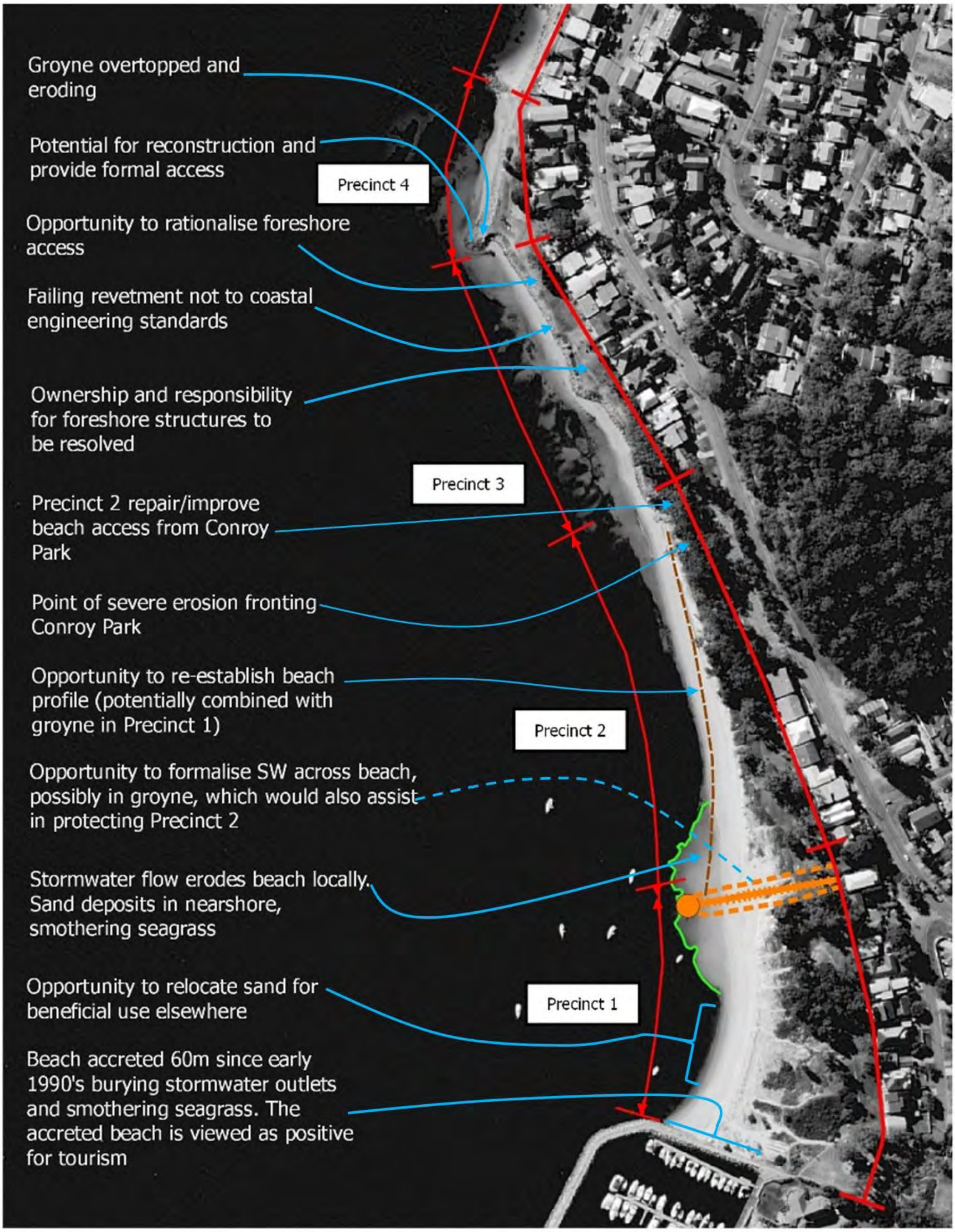

Figure 4: Issues, Opportunities and Constraints: Western Precincts

Sandy Point - Conroy Park Foreshore Erosion and Drainage Management Plan

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Environmental Consultants

0 50 100 150 200 m
(Approx Scale)

N

Revision	A
Drawn	BC
Approved	DW

As the shoreline will continue to recede, linear seawall protection without nourishment will result in progressive loss of the sandy beach and, if the seawall is inadequately designed, eventual loss of that protection as well. Provision of a groyne at the main stormwater outlet in Precinct 1 would act to anchor the beach, causing the beach to accrete on the eastern side of the groyne, in the same manner as has occurred at The Anchorage. The length of that groyne would control the amount of protection provided. There are opportunities to restore and improve access from Conroy Park to the foreshore to enhance access for water based recreation activities in this area, as originally suggested in the Port Stephens foreshore management plan. Extended and/or improved linear protection may be considered for Conroy Park; however, continued access to the preferably sandy foreshore should be an aim for this area.

4.4 Precinct 3

The key issue with Precinct 3 is the ongoing failure of the foreshore protection works. ‘Slumps’ and ‘sinkholes’ are present along the crest, and these present a significant safety issue for the public and result in deterioration and increased risk to the public reserve which exists along the foreshore. Ownership of this foreshore should be clarified with the public to set clear responsibilities for the maintenance and upkeep of the reserve and protection works.

There is an opportunity to reconstruct this revetment to a more acceptable coastal engineering standard. Much of the armour stone is good quality/size and may be re-used. That material of lesser quality/size could be used in a filter layer for the revetment. As the reserve has a significant width between the foreshore and the private property boundaries, there is opportunity to batter back the foreshore slope to a more stable, and safer angle (no steeper than 1V:1.5H) which would enable construction of a more effective and robust revetment.

The ability to retain a broad, sandy beach in this location is constrained by the angle of approach of refracted ocean swell and tidal currents, which tend to transport any sand placed here towards the west. With minimal sand being transported around the tip of Sandy Point (i.e. Groyne “A”), there will continue to be an absence of sandy beach in this area, without intervention (e.g. groyne construction and nourishment).To retain a beach here, a groyne would need to be constructed near the border between Precinct’s 2 and 3 and an appropriate source of nourishment sand identified and secured.

Several foreshore access structures have been built down the face of this revetment. Most of them are unsafe and none comply with current standards for public access ways, raising liability concerns. There is an opportunity to remove unsafe foreshore crossings and to rationalise public foreshore access down the face of the revetment. Due to the height and steepness of this section of foreshore, a final design may need to incorporate a safety railing and accord with relevant standards. Such accessways would be a community rather than private asset.

4.5 Precinct 4

Issues with Precinct 4 are similar to those at Precinct 3, although this precinct is more exposed to refracted swell overtopping and the width of the public reserve is narrower, with that width decreasing with distance east from Precinct 3.

Groyne A is in poor condition, actively eroding and slumping with undersized armour. There is an opportunity to redesign and reconstruct this groyne to a better standard. Lengthening of this groyne will help to shelter the foreshore within Precinct 4 and there is an opportunity to provide pedestrian access out to the end of this structure, with more general community access to the foreshore provided through the easement between #50 and #48 Sandy Point Road.

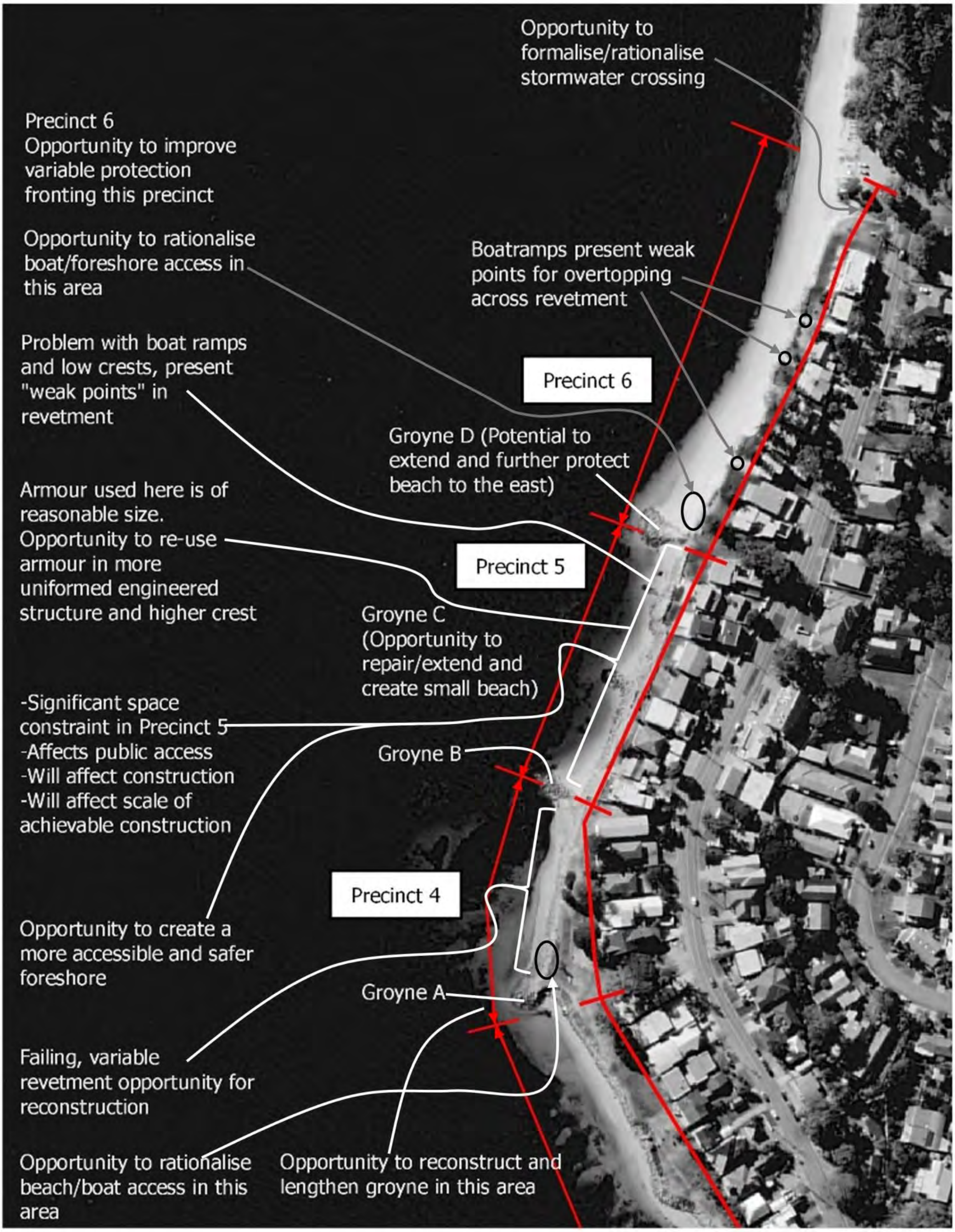

Figure 5: Issues, Opportunities and Constraints: Eastern Precinct

Sandy Point - Conroy Park Foreshore Erosion and Drainage Management Plan

N

Whitehead & Associates
Environmental Consultants

0 50 100 150 m
(Approx Scale)

Revision	A
Drawn	BC
Approved	DW

The armour stone comprising the revetment here is undersized for the prevailing storm waves and generally unsuitable for primary armour in this more exposed location. The revetment is subject to overtopping during severe storms, but the residual width of the foreshore reserve is enough to prevent significant damage to properties behind the foreshore.

Again, there are safety issues associated with overtopping and pedestrian access. At the western end of Precinct 4, the width of the foreshore reserve provides some space where access to the foreshore for launching boats could be provided. This is likely to become an issue within Precinct 5, where existing boat ramps provide gaps in the overall revetment structure, through which overtopping and flooding of the backyards of properties is known to occur.

4.6 Precinct 5

Precinct 5 is the most highly constrained section within the study area. The distance between the foreshore and private properties is next to non-existent, and along this section, it will prove difficult. Issues include:

- Providing public access under all weather conditions;
- Undertaking construction works;
- Need to widen or flatten the foreshore revetment;
- Need to provide more width; it is possible that the foreshore would need to extend further into Port Stephens, to accommodate the revetment and public access requirements. The degree of public access to be provided here needs to be considered carefully from a safety perspective. In addition, some residents expressed concerns about theft from their yards from time to time. The three groynes in this precinct (Particularly Groynes, B & C) could be bolstered, although their ability to retain fillets of sand is uncertain, as the focussing of wave energy in this area would tend to encourage offshore transport of sand during storms. A permanent sandy beach at all tide conditions may not be practically achievable within this precinct. Frequent, artificial sand nourishment may be essential.
- The precinct is more exposed than any other within the study area. Overall, the armour stone used here is substantial and much is likely to be reusable in a properly engineered structure. Such a structure would require a higher crest and, if achievable, a flatter slope to dissipate wave energy and reduce the overtopping threat during storms as sea levels rise. There is an opportunity to remove weak spots in this revetment by reconstructing to a standard and consistent design, and by removing all boat ramps, which encourage runup and flooding of the backshore area. This is a particular problem here as residential backyards exist immediately behind the foreshore and wave overwash is known to impact against houses within this precinct.
- The practicalities of construction in this location need to be considered at the conceptual design stage.

4.7 Precinct 6

At the present time, Precinct 6 is less exposed to refracted ocean swell and overtopping than Precinct 5. Even so, it still experiences overtopping during periods of large ocean swell, although the damage caused by this overtopping is presently less severe than in Precinct 5. This is partly due to the ways in which waves are focussed, and partly because Groyne D has caused a sandy beach to form along much of the length of this foreshore. Even so, given that the eastern basin of Port Stephens including the flood tide delta is continually changing, the degree of exposure may increase in future. Therefore, design of the foreshore works must take that into account.

Again, boat ramps in this area present a point of weakness along this foreshore. Swell waves easily run up these structures and allow water to impact on buildings behind the foreshore. This increases the risk to residents, the public and neighbouring properties. In addition to the issues with wave overtopping, boat ramps also create an impediment to members of the public walking along the foreshore reserve. There is an opportunity to remove these weak points and to rationalise access to the foreshore adjacent to Groyne ‘D’, in the vicinity of the public easement between the foreshore and Sandy Point Road (between residences #20 and #18). At the present time, the stormwater outlet at the eastern end of Precinct 6 discharges from Sandy Point Road, across a channel scoured through the Sandy Beach. Our analysis indicates that this outlet acts primarily as a secondary “relief” outlet for the stormwater catchment which discharges the majority of its flow through Groyne D. There is an opportunity to reconsider how this stormwater might be handled, either by formalising the crossing, or discharging through a groyne, similar to Groyne D, which could carry a pipe across the beach into the waters of Port Stephens. Such a groyne could create some issues with public access to the foreshore and would need further, careful consideration.

5 Identification, Assessment and Shortlisting of Management Schemes

5.1 Methodology

A long list of feasible options was determined for the six precincts and these were assessed using a multi criteria assessment method. The criteria against which the options were assessed for each precinct were:

- **Public Access**: Referring to either an existing level of use by the public for recreation, and whether this is presently difficult, threatened or could be improved or impeded;
- **Public Safety**: Referring to whether a particular option could either improve or negatively affect safety of the public when using the foreshore;
- **Recreation / Boating**: Referring to whether options are likely to improve or detract from recreational amenity of the foreshore;
- **Foreshore Protection From Erosion**: Referring to whether the particular option would significantly improve protection of the foreshore from erosion;
- **Foreshore Protection From Overtopping**: Referring to whether the particular option would significantly improve protection of the foreshore from overtopping;
- **Impact on Coastal Processes**: Referring to whether the option would have a positive or negative impact on broader coastal processes in adjacent precincts;
- **Seagrasses / Ecology**: Referring to whether the option would tend to enhance or detract from nearshore seagrass habitat;
- **Provision of a Sandy Beach**: Referring to whether the option tends to enhance the provision of a sandy beach, which is seen by many in the community as desirable;
- **Enhancement of Dune / Native Vegetation**: Referring to whether the option would tend to create opportunities to create or enhance coastal dunes & vegetation;
- **Management of Stormwater**: Referring to whether the option would tend to improve the handling of stormwater issues, including water quality, the amount of sand scoured from the beach and ease of maintenance;
- **Aesthetics**: Referring to whether the option would tend to improve or detract from the general appearance of the foreshore and associated beaches;
- **Residential Security**: Referring to whether the option would tend to adversely impact the privacy of residents and/or affect the potential for burglary / theft;
- **Adaptability**: Referring to whether the option incorporates the ability to adapt to changing conditions, such as the movement of the flood tide delta affecting wave focussing along the foreshore, or a rise in mean sea level; and
- **Ease of Construction**: Referring to whether the option involves difficult, in-water construction or whether there is limited foreshore access, which would increase the risk of unforeseen costs during construction.

A total of six individuals, including three members of the study team, and three Council staff members were provided with lists of these 14 criteria and asked to grade the importance of those issues for each of the six precincts using the following scale:

- A – Critically Important;
- B - Very Important;
- C – Important;
- D - A Bit Important; and
- E - Not Important / Irrelevant.

Values of A through E were converted to values of 4 through 0 respectively for subsequent calculation. All individuals that took part had been either involved in consultation activities as part of the project, or had experience in management of foreshores and drainage within the study area.

The long list of feasible options are summarised in the following sections. Again, three engineers from W&A and CE were asked to score how well the options performed against each of the 14 criteria. In this instance the following scale was adopted:

- +2 – Addresses issue well;
- +1 – Somewhat addresses issue;
- 0 – Irrelevant / has neutral impact;
- -1 – Has somewhat negative impact; and
- -2 – Makes the situation significantly worse

For each issue/option combination, the average issue importance and option performance scores were multiplied together, considering the responses of all participants. These were then totalled to give an overall score for each of the options. The overall score is representative of the level of benefit that would result from that option. For each precinct the options were subsequently ranked.

The outcomes of the multi-criteria analysis are presented in Appendix E. However, this analysis has some weaknesses, for example:

- Different individuals will interpret the scoring/ranking criteria differently;
- Anomalies will arise from the way individuals interpret (or misinterpret) the different issue/option combinations. However, revisiting and discussing every individual score undermines a key advantage of the method: that individuals are able to exercise their own subjective judgement and preferences relating to the different options, based on a variety of personal experiences; and
- The analysis does not incorporate the compatibility of options between precincts.

For these reasons, the process of selecting final options and formulating the final schemes also involves a degree of oversight. The results were also considered in a high level, qualitative manner to ensure that clearly infeasible options are not short-listed. Any surprising deviation from the expected rankings would be reassessed. In this case, the most highly ranked options coincided with those which were qualitatively considered to be most feasible

Detail on the ranking of each option in the multi criteria analysis, and further consideration of limitations are discussed in Appendix E. Considering all aspects, three final short-listed "schemes", comprising compatible treatments in adjacent precincts are presented in Section 5.2.

5.2 Shortlisted Foreshore/Drainage Management Schemes

Table 1 Summary of Shortlisted Options

Precinct	Scheme 1 Treatments	Scheme 2 Treatments	Scheme 3 Treatments
1	Relocate sand to Precincts 2 and 3.	Retain sand and install twin gross pollutant traps to existing stormwater line.	Retain sand and construct groyne to convey stormwater line across beach. Install twin gross pollutant traps to existing stormwater line.
2	Use Precinct 1 sand to nourish and construct groyne at western end of Conroy Park	Nourish with sand imported from elsewhere.	Nourish with sand imported from elsewhere.
3	Relocate Fence. Remove stairs and ramps. Batter slope back and reconstruct revetment to engineered standard. Nourished using sand from Precinct 1.	Relocate Fence. Remove stairs and ramps. Batter slope back and reconstruct revetment to engineered standard. Repair, bolster and extend Groyne A. Nourishment from imported sand.	Relocate fence. Remove stairs and ramps. Batter slope back and reconstruct revetment to engineered standard. Repair, bolster and extend Groyne 'A'. Enhance existing "headlands" to form pocket beaches and nourish.
4	Rebuild and bolster foreshore revetment (mainly along existing alignment but will require some reclamation).	Rebuild and bolster foreshore revetment (will require some reclamation). Extend and reconstruct Groyne B.	Rebuild and bolster foreshore revetment (will require some reclamation). Extend and reconstruct Groyne B. Nourish beach between Groynes A and B.
5	Remove Boat Ramps, Reconstruct wall, reclaiming where necessary to provide for 2.4m path landward and allowance for crest elevation to accommodate sea level rise.	Provide for "mega" nourishment of beach profile offshore, to the south of and in the vicinity of Precinct 5. Aims to replicate historical beach conditions. Extend Groynes B and C to anchor beaches.	Remove Boat Ramps, Reconstruct wall true to present alignment and provide a robust, suspended walkway around the front of the new revetment.
6	Remove Boat Ramps, reconstruct path and replace with a low revetment with adequate space for future crest heightening as required. Reconstructed revetment along existing alignment. Retain eastern stormwater line as is.	Extend Groyne D and nourish to the south to provide a future source of sand for east to west transport around Sandy Point. Ongoing nourishment would be required. Remove boat ramps and rebuild back beach. Install two pollution traps upstream of Groyne D, Formalise eastern stormwater crossing with shallow dish drain and infiltration trench	Remove Boat Ramps, reconstruct path and replace with a low revetment with allowance for a wave deflector wall to be installed in future. Formalise eastern stormwater crossing with shallow dish drain and infiltration trench.

6 Potential Management Schemes: Detailed Assessment

6.1 Design Parameters

6.1.1 Design Life and Design Standards

A design life of 25 years has been specified by Council. Commonly, shore protection works will need intermittent maintenance to remain serviceable. Examples of this may include periodic renourishment of beaches or topping up of rock revetments following damage by storms. An acceptable maintenance regime needs to be considered as part of the design calculations.

To consider the acceptable risk of damage and/or overtopping of structures, the appropriate level of maintenance, issues associated with access, and the purpose of the structures need to be considered. As a key example, any proposed foreshore rock revetment structure in Precinct 5 would need to minimise overtopping to prevent flooding of the area behind the revetment and to minimise danger to any pedestrians utilising the foreshore reserve. Furthermore, protection of properties behind the foreshore from the impact of waves is important. Overtopping is primarily controlled by setting an appropriate combination of revetment slope and revetment crest elevation.

Similarly, any work in Precinct 2 to create a recreational beach would need primarily to consider the longshore transport rate that arises from changed alignment of the beach and the expected longevity of any nourishment and consequent average time interval between renourishment campaigns. This is affected by the grain size characteristics of any sand used in renourishment (i.e. the “borrow” sand), the final expected planform arrangement of the nourished beach and whether or not structural protection in the form of artificial headlands or groynes are provided to help retain the sand. The performance and maintenance requirements are dependent on the weather. Topping up of nourishment in particular may be required immediately following storm events. These can occur immediately after the nourishment is placed or perhaps not for months or years following initial placement. Renourishment requirements are estimated from average anticipated losses over time, but remain entirely dependent on the conditions that actually occur.

An important consideration in making a decision about appropriate design conditions is the encounter probability. Encounter probability can be calculated using the following equation:

$$P_e = 1 - e^{\frac{-N}{ARI}}$$

$N = \text{Design Life (25 years)}$

$ARI = \text{Recurrance Interval of Event Being Considered (years)}$

$P_e = \text{Probability that the event being considered will occur during the design life}$

The present Australian Standard for Maritime Structures (Standards Australia, 2005) recommends appropriate recurrence intervals for design waves. While the standard explicitly excludes breakwaters, rock armoured walls and groynes, it does provide some context of use. Examining the structures actually covered by the standard indicates that its focus is structures that tend to fail in a more sudden manner rather than “flexible” rock armoured structures which are typically designed to accommodate some level of damage (under the assumption that this will be promptly followed by maintenance). The amount of damage that is considered reasonable during a design event is an important input when sizing armour for flexible rock armoured structures. A more frequent design event could be considered in that context.

Nevertheless, the Australian standard (AS 4997) provides recommendations for structures with a 25 year design life as reproduced in Table 2.

Table 2 Wave Height Recurrence Intervals Recommended by AS4997 (2015)

Function	Average Recurrence Interval For Design Wave Height (yrs.)	Equivalent Encounter Probability (25yr Life)
Structures Presenting a Low Degree of Hazard to Life or Property	50	0.39
Normal Structures	200	0.12
High Property Value or High Risk to People	500	0.05

From Table 2, a decision relating to the consequences of failure needs to be made. Considering the scope of the standard, it is clear that there exist structures with far greater consequences of failure (e.g. community critical infrastructure, high rise apartments adjacent to the shoreline) and it seems unlikely that the structures in the study area would fit into this category. However, the exposure in some areas does pose a significant hazard to life and property. Some structures in the design schemes considered here would fall into the “Normal” category, whereas some would fit into the “Low Degree of Hazard” category.

In the case of a flexible rock revetment structure, it is expected that the design wave height could cause significant, but repairable damage (up to 20%) to the revetment, meaning that up to 20% of the primary armour stones may move from their placement position during the design storm event.

6.1.2 Water Levels

The design “still” water levels have been determined based on research presented in Section 6.3 of Appendix A. A conservative, but reasonable assumption is that the design water level (including a suitably rare “Storm Surge” component) can be combined with an offshore wave of the same recurrence interval. The still water level is primarily of importance in the calculation of overtopping flow rates and volumes. Therefore, in accordance with guidance from the Eurotop Manual (Pullen et al., 2007), a recurrence interval of 50 years is appropriate. Bearing this in mind, the still water level adopted for design of rock armour has been set as follows:

- 1.40m AHD (Table 12 of Appendix A, 50yr ARI water level within Fort Denison);
- + 0.35m (Sea Level Rise, derived from PSC benchmarks, considering a structure life to 2040); and
- +0.13m (Wind Setup).

This gives a design still water level of ~1.9m AHD. We note that this differs from the design still water levels presented by WMA Water (2010), with the differences arising from:

- A lower, up to date, 50yr ARI water level estimate provided during this study by Manly Hydraulics Laboratory, when compared to that utilised during the floodplain management process (1.40m c.f. 1.47m). That earlier analysis was undertaken nearly 20 years ago;
- No allowance for elevation of water levels due to catchment flooding.

The second point is considered reasonable given the dynamics of flow between the western and eastern basin of Port Stephens, which is constrained at Soldiers Point and tend to make water levels in the eastern basin more closely match those of the ocean (including some super elevation due to the tide). In addition, given that this water level is primarily being used for an overtopping calculation, it is important to note that the design swell wave is dependent on a wind approaching from the south east sector and following the swell on its way from offshore to the entrance to Port Stephens. The wind is more or less an offshore wind when considering the southern shoreline of the Port, which tends to cause a set-down of water levels on the southern side of the Port. In this way the inclusion of a positive wind set-up could be viewed as conservative. However, we consider it reasonable to incorporate this degree of conservatism at this conceptual design stage, given our reliance on a numerical wave model that, as yet, has only been validated on the basis of performance across Precinct 5 during the April 2014 storm.

An allowance for wave setup is not required, as the overtopping calculations are based on still water levels which, by definition, do not include wave setup (i.e. when the water is “still” waves are not acting). The overtopping calculations incorporate an intrinsic allowance for wave set up.

6.1.3 Shoreline Wave Conditions

The design waves derived from numerical modelling (Appendix A) were extracted at locations at least 100m offshore of the study site and in depths of at least 7m, offshore of the immediate shoreline around the study site. Those locations are reproduced here in Figure 6.

In order to develop conditions at the immediate shoreline, it is necessary to consider the wave transformation processes that will alter the waves as they traverse the surf zone before they impact upon the foreshore.

To traverse the surf zone, we have utilised relationships put forward by Goda (2000, as recommended in CIRIA, 2007), which account for both the breaking of larger waves, and shoaling as the waves approach the foreshore across the surf zone. Conservatively, the analysis has not considered the effects of refraction across the surf zone, and in calculating armour size, the waves have been assumed to approach the shoreline from a shore normal direction. While this is likely to be reasonable for most precincts, it likely causes a significant difference for swell waves approaching Precinct 3 and the eastern end of Precinct 2. Some relaxation of conditions may be considered in Precinct 3 in particular, although this should be justified at the detailed design stage. The governing design waves are refracted swell waves. Details of the adopted “offshore” wave conditions (from the model) and the calculation used to bring those waves to the immediate foreshore are presented in Appendix F.

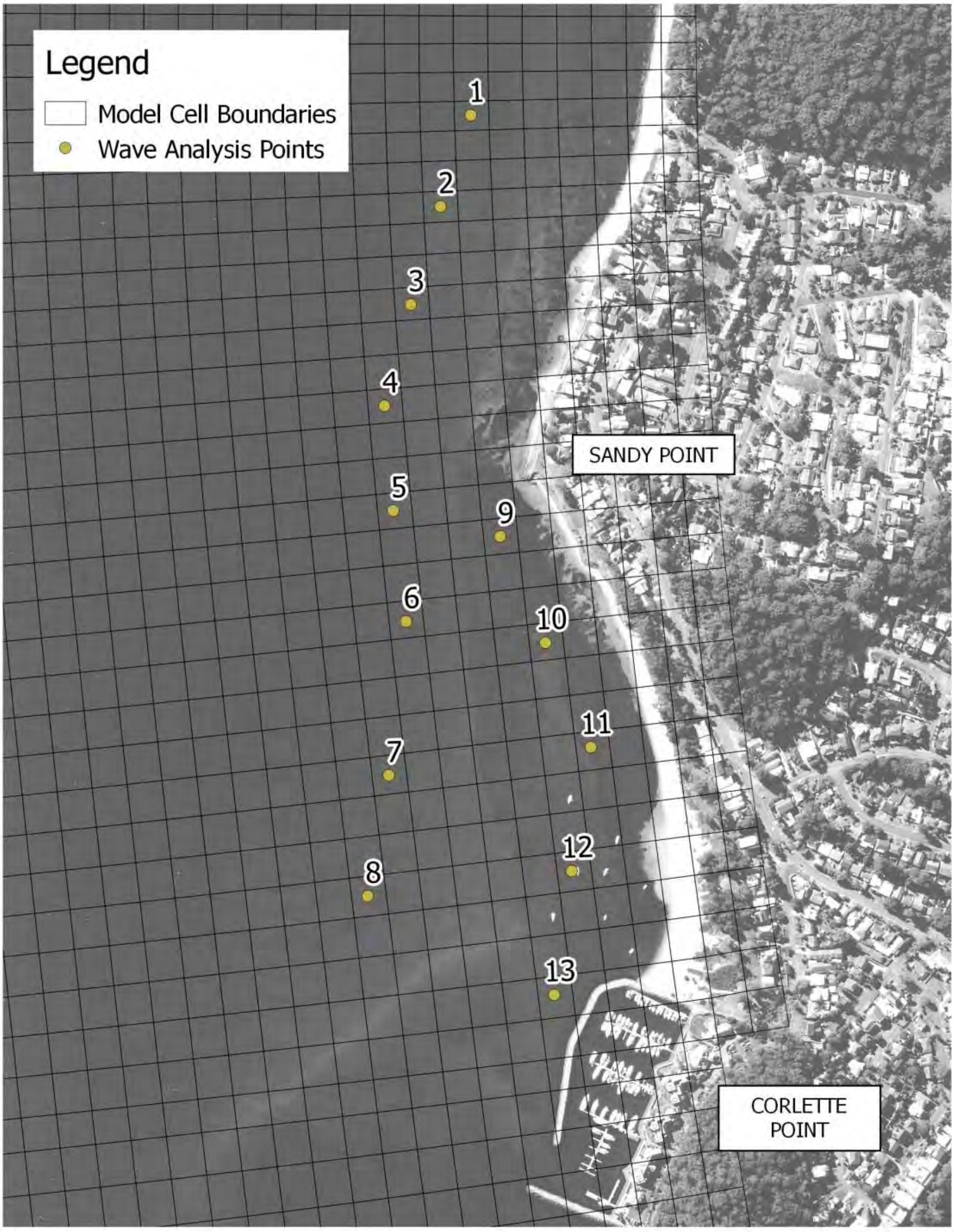

Figure 6 Model Grid near Corlette with Analysis Points

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6.1.4 Overtopping

Overtopping is of key concern, particularly with respect to damage to buildings behind the foreshore (water impact and inundation) and the possible danger to pedestrians that may venture out along the access path behind the beach or into the foreshore reserve during a significant storm. Accepted professional guidance for limits to overtopping are provided in the Eurotop Manual (Pullen et al., 2007). That manual also indicates (Table 3.1 of Pullen et al, 2007) that, for a design life of between 20 and 30 years, protection against a 50 year average recurrence interval event is acceptable. Commensurate with Table 2, such an event would have around a 40% chance of occurring over a 25 year design life.

Values of average overtopping discharge and maximum individual overtopping "event" values of relevance to the study are presented in Table 3.

Table 3 Tolerable Discharge Limits (Pullen et al., 2007)

Description	Mean Discharge (litres/second/metre of seawall)	Maximum Volume of an Individual Overtopping Event (litres/metre)
"Aware" Pedestrian[4]	0.1	20-50
Building Structure Elements	1	-

6.1.5 Toe Scour Conditions

Toe scour is of particular importance to the overall stability of foreshore structures. Historically, studies in the UK have indicated that close to 50% of seawall failures are at least partly attributable to the failure of the toe (CIRIA, 2007). However, the toe can be particularly difficult and costly to construct, which means that design is often finely balanced between construction cost and toe level.

Historical practice along the open coast of NSW has been to adopt a scour level of -1.0m AHD on a sandy beach. -2.0m AHD is adopted for vertical seawalls, to account for the additional scour that can be expected due to the reflective nature of those structures (Nielsen et al., 1992). This was based on available field data for open coast NSW beaches.

Broad guidance in CIRIA, 2007 indicates that scour is of the order of the maximum, incident unbroken wave, when the structure is vertical and highly reflective. That document also indicates that scour depth is related to the magnitude of reflection and is therefore proportional to the "reflection coefficient". For our design purposes, the reflection coefficient has been calculated using the expression:

$$C_r = (0.64 \times \xi_m{}^2)/(8.85 + \xi_m{}^2)$$

This assumes that a two layered armour stone structure is proposed. ξ_m is the surf-similarity parameter relating to the mean wave period, as recommended by CIRIA (2007).

[4] The manual describes this as "*Aware pedestrian, clear view of the sea, not easily upset or frightened, able to tolerate getting wet, wider walkway*." In reality, the foreshore reserve will be accessible to the public. However, we doubt that the reserve would be attractive to normal, rational members of the general public during extreme storm condition. Individuals that are most likely to venture out would be generally aware residents securing items in their front yards, etc.

6.1.6 Rock Armour, Availability and Sizing

Two local quarries were approached to provide details of available rock armour, including density and the testing of parameters relevant for application in a marine environment. Details of parameters of interest to the selection of armour stone were as detailed in Table 4.

Table 4 Rock Size and Density Options

Quarry	Product	Density (kg/m^3)
Boral (Seaham)	400-700mm, Ryolitic Tuff	2560
Boral (Seaham)	700-1200mm, , Ryolitic Tuff	2560
Hunter Quarries (Karuah)	Hornblende, Latite Tuff[5]	2600

Laboratory and Petrographic analyses of stone from both sources was obtained and examined. Either source is considered to be of suitable quality, although the overall grading of the mix and shape of rock sizes would need to be negotiated at a later stage.

6.1.7 Groyne Geometry

The purpose of a groyne is to exert control over the alignment of the shoreline. The following general design principles are summarised from a text by van Rijn (2005) and relate to the use of low groynes to stabilise an existing sandy beach area:

- The crest level near the dune toe should be just below the local beach level;
- The crest level near the tip of the groyne should be slightly higher than the mean low water line and about 1m above the local sea bed to block longshore transport under moderate waves. Within our designs, the crest elevation of groynes has been assumed to slope downwards with distance offshore.
- Overtopping and wash over of sand during storm conditions is acceptable;
- Crest width should be no smaller than 3m to allow the passage of construction equipment;
- Spacing between groynes in a field is around 2 to 4 times the length, with closer spacing where the beach has an oblique angle of wave attack, depending on the length of beach to be stabilised;
- The groynes tend to extend into the surf zone; out to around the mean low water springs tide mark.
- Artificial beaches tend to have generally longer and higher terminal groynes.
- The key areas for considering groynes within this study are Precincts 4, 5 and 6, where 4 groynes already exist, and groynes which feature as part of schemes 1 and 3 near the interface of Precincts 1 and 2.

For the existing groynes, the intention is primarily to bolster and bring existing Groynes A, B and D up to a more engineered standard where possible. A small amount of lengthening could be

[5] Hunter Quarries have advised that they can provide armour stone sizes as required, having previously supplied stone for the breakwaters of the Hunter River. Confirmation of this would be required at detailed design, along with acceptance of the colours available. The material presently quarried from Karuah appears to be darker than the pink rhyodacite that has been previously placed along the study foreshore.

considered to provide some additional stability to the shoreline on the downdrift (western) side by blocking storm waves which may otherwise impact on foreshore properties.

The impact of any groyne extension, or the construction of a long groyne on the stability of the foreshore can be assessed using concept summarised in Hsu et al. (2010). In summary, this method requires the identification of three different aspects:

- The dominant direction of swell wave approach;
- A fixed “updrift” point where wave approach, around which “diffraction” can be considered to occur; and
- A downdrift point where the alignment of the beach is either fixed or in equilibrium.

Utilising this information and a parabolic equation to describe the planform shape of the Bay, the equilibrium alignment of the shoreline can be assessed. Where this method has been applied, the calculations were undertaken using GIS software and the resulting equilibrium shoreline is presented as part of the scheme details provided in Section 6.2.

Further indication of the likely effect of groynes is obtained by assessing the pre-existing geomorphology of the shoreline. At this location, there is a ready illustration of the potential impact in the historical behaviour of the beach following construction of The Anchorage. The eastern breakwater of The Anchorage is effectively a large groyne. Following construction, this breakwater has arrested sand moving along the shoreline from east to west, retaining and stabilising the beach for some 250m to the east. Other examples include short groynes around the eastern side of Sandy Point.

6.1.8 Nourishment Sand

A number of sources for nourishment sand were considered from the area south of Port Stephen’s. General compatibility in terms of colour and grain composition is not considered to be an issue, given that the beaches fronting the foreshore will have a similar marine quartzose sand origin as the surface sands present in the majority of sand quarries in the area.

Generally, coarser sands are considered somewhat desirable, although care is required, as significantly coarser may cause a steepening of the beach profile. Placement of sand as part of beach nourishment can incorporate a degree of “overfill”, which aims to account for the loss of sand from a nourishment project where the borrow sand is finer than the sand which occurs natively in the area being nourished.

The method is empirical, and involves calculation of the phi sorting ratio and phi mean difference between “borrow” and “native” sands:

$$\text{Phi Sorting Ratio} = \frac{\left\{\frac{(\phi_{84}-\phi_{16})}{4}+\frac{(\phi_{95}-\phi_{5})}{6}\right\}_b}{\left\{\frac{(\phi_{84}-\phi_{16})}{4}+\frac{(\phi_{95}-\phi_{5})}{6}\right\}_n}$$

$$\text{Phi Mean Difference} = \frac{\left\{\left[\frac{\phi_{16}+\phi_{50}+\phi_{84}}{3}\right]_b-\left[\frac{\phi_{16}+\phi_{50}+\phi_{84}}{3}\right]_n\right\}}{\left\{\frac{(\phi_{84}-\phi_{16})}{4}+\frac{(\phi_{95}-\phi_{5})}{6}\right\}_n}$$

Where:

$\varphi_s = \log_2 d_s$

$d_s =' \text{ s}'\text{percentile exceedance grain size in } mm$

b, s subscripts refer to 'borrow' and 'native' sand grins respectively

These values are then used with a chart to determine the necessary overfill factor (CERC, 1984). For borrow materials, the particle size distribution published by quarries from around the Port Stephens area, and from sediment sampling undertaken from the leading edge of the flood tide delta (north of Corlette Head) were considered. The sand from the flood tide delta was more compatible with the beach sand (similar size distribution) whereas data from local quarries indicated that the sand was notably coarser. In both cases, an overfill factor of less than 2% was determined from (CERC, 1984).

While the charts from the Shore Protection Manual have been used, some researchers advise that those methods are not very accurate for sands below 0.3mm in size (Van Rijn, 2005). Beach sands from the study area have a mean grain size of around 0.3mm. More sophisticated and/or supplementary methods are presently recommended in the present revision of the United States' Coastal Engineering Manual (US Army Corps of Engineers, 2014). In particular, that manual recommends that nourishment design be based on equilibrium beach profile concepts and an assessment of storm erosion and wave driven longshore transport losses. It is questionable whether the coastal equilibrium beach profile is valid for the study area, given its location well inside the estuary, relative sheltering from highly modified oceanic swell, strong longshore variation and lack of a consistent supply of sediment from the east (Pilkey et al., 1993). Furthermore, the subject shoreline is influenced by dynamics across the flood tide delta of Port Stephens and future behaviour is likely to differ from that of the past.

In designing the nourishment profiles, slopes greater than 1 in 20 have been avoided. In some instances, slightly steeper slopes have been adopted to minimise the coverage of existing seagrass beds. The extent of the profile has been controlled by other concerns, informed by estimates of longshore transport and considerations such as the plan form geometric equilibrium discussed in Section 6.1.7.

Given these concerns, it is important to recognise that beach nourishment design is imprecise. While longevity of 5 or 10 years may be designed for, one significant storm may result in significant removal of the nourished sand. This raises understandable concerns in the community and it is therefore desirable to aim to design for a longer time period if possible.

A management strategy which includes beach nourishment should also include an allowance for regular monitoring, both seasonally and following any significant storm. Monitoring is particularly important to inform and adjust the nourishment requirements as ongoing maintenance is called for in future.

In the case of the subject foreshore, the required volumes of sand have been determined using these considerations, available aerial photography, the digital elevation model developed as part of this study and the results of plan form analyses as required.

6.1.9 Stormwater Drainage Considerations

Outfall 1: Precinct 6

Outfall 1 serves as a relief/surcharge point within the eastern most catchment which drains the area east of Conroy Park. The outlet relieves some of the localised flooding along Sandy Point Road during large storm events. Its removal is not a sensible option.

The main issue with Outfall 1 is backing up of sand into the overflow channel from wave action and tidal surges during large storms events, which blocks off the overland flow path. It is therefore critical that Council regularly clean-out and maintain this overflow channel. Another issue is that, being a surcharge pit, it and the pipe system it serves are always charged (full of stormwater). Therefore, the pit regularly surcharges stormwater into the beach reserve adding to localised erosion problems.

Based on stormwater modelling (Appendix B), the combined 5 Year and 100 year recurrence flows from this outfall only represent 20 percent of the total flow from the overall catchment (Tables 1 & 2). Considering this, and also due to existing pipe invert levels, it would be impractical to retro-fit a gross pollution trap (GPT) to reduce gross pollutants.

Outfall 2: Precinct 5/6

Outfall 2 is one of the major outfalls in the study area, discharging through a pipeline within an existing groyne. It presently works effectively and remains unblocked. Stormwater modelling indicates that the outlet is undersized for the 5 year storm event, with surcharging predicted from pits upstream in Sandy Point Road. Even though it is undersized, it would be impractical and costly at this stage to try and augment the existing piped drainage system.

Outfall 2 carries a considerable amount of suspended sediment and pollutants from the upstream urban areas and the installation of a GPT to address this could be considered.

Outfall 3: Precinct 1

Outfall 3 is the second major outfall, presently discharging across the centre of Corlette Beach. During significant flow events the discharge causes significant erosion and scour of sand from the beach face. Stormwater modelling indicates that the outlet is under-sized for the 5 Year storm event with surcharging and localised flooding evident through the stormwater network upstream of Sandy Point Road.

Like Outfall 2, Outfall 3 carries a considerable amount of suspended sediment and pollutants from the upstream urban areas and the installation of a GPT to address this could be considered.

Outfalls 4 & 5: Precinct 1

Outfalls 4 and 5 have the smallest catchments and contribute the smallest amount of suspended sediment and gross pollutants to the waterway when compared with the other catchments. Outfall 4 was completely buried and Outfall 5 was partially blocked at the time of inspection.

While these outlets are minor, the underperformance of the stormwater system makes it unacceptable that they remain blocked. If the broader management options adopted for the foreshore do not involve the relocation of sand from next to the Anchorage to the foreshores further to the east, regular and vigilant maintenance of these outlets would be required to ensure that they remain clear of sand.

6.1.10 Summary of Design Parameters

For each of the precincts, appropriate design parameters have been calculated and these are tabulated in Appendix F. Those design parameters and the summary considerations provided in Sections 6.1.1 through Sections 6.1.9 have been used to derive the layout, extents, dimensions, armour sizes and costs presented in the remainder of Section 6.

6.2 Presentation of Scheme Design and Costing Details

The important aspects of the different schemes are outlined in tables, followed by figures for Scheme 1 (6.2.1), Scheme 2 (Section 6.2.2) and Scheme 3 (Section 6.2.3). In addition to these descriptions and the associated figures, an artist's impression of each option for Precincts 2 and 5 are presented in Appendix G.

6.2.1 Scheme 1

Table 5 Scheme 1 Details

Scheme 1		
Precinct and Details	**Figures**	**Notes**
Precinct 1: Plan	Figure 7	In this option, sand is moved from the western end of Corlette Beach, to the eastern end (Precincts 2 and 3). The desired beach width was based on conditions from 1992, and it is estimated that around 20,000 to 25,000m^3 of sand would need to be moved to return Precincts 2 and 3 to their 1992 state.
Precinct 1: Profiles	Figure 8 Figure 9	A substantial amount of sand will need to be removed from the delta that has formed in front of the major stormwater crossing of Corlette Beach. This sand will need to be tested for contaminants although, based on its location, is likely to be fairly clean. For costing purposes, it has been assumed that the works would be undertaken by two scrapers assisted by two bulldozers to facilitate loading and spreading of the sand once transported. The designed cut profile aims to create a bench at -1.0m AHD across the beach sloping up at 1 in 10 to meet the existing surface. This leaves the beach with a similar volume to that present during the late 1990's. Over time, the beach will reform, with sand from the bench reworked onshore to form a more natural beach profile. The approach adopted has aimed to acquire the amount of sand needed to nourish precincts 2 and 3 while minimising the loss of existing dune vegetation adjacent to The Anchorage.

Scheme 1		
Precinct and Details	**Figures**	**Notes**
Precinct 2: Plan	Figure 10	Sand has been added to renourish this beach, as per the description provided for Precinct 1. In addition, a groyne is provided at the western end of Conroy Park which aims to hold the beach in place. The groyne is curved to facilitate holding the beach in place. However, even with this groyne, Conroy Park will still tend towards erosion, and periodic renourishment will be required if a sandy beach is to be maintained in this location. Erosion of sand would, however, be less pronounced than in the past. The ongoing maintenance of the geotextile containers will provide a degree of terminal protection to Conroy Park in the event of a significant erosion event. Nourishment activities would normally occur every 5-10 years or more frequently depending on weather conditions.
Precinct 2: Profiles	Figure 11	Sand is to be placed at a slope of no greater than 1 in 10. The aim of this placement activity is to recreate the situation present when the beach was last full of sand, around the middle of the 1990's. This would increase beach width at mid-tide from zero at the present time, to around 30-35 metres when fully nourished.
Precinct 3: Plan	Figure 12	Similarly to Precinct 2, sand nourishment is occurring here to recreate conditions similar to those around the middle of the 1990's. The amount of nourishment in Precincts 2 and 3 is the same for all three schemes. However, the option also includes reconstruction of the foreshore revetment to a proper engineered standard. This means that construction will occur carefully and will not involve the direct dumping of rock onto the eroding face.

Scheme 1		
Precinct and Details	**Figures**	**Notes**
Precinct 3: Profiles	Figure 13 Figure 14	Considering the amount of useful, reasonably sized armour stone on the face of the existing revetment, it has been assumed that cost savings equate to not needing to obtain secondary armour. However, there is effort and cost associated with breaking up and stockpiling existing materials for recycling in the new structure. Once stripped of existing rock armour and debris, the existing slope will be battered back and the slope prepared for construction of the new revetment. Any suitable sand excavated from the embankment can be reused in front of the wall as nourishment material once the revetment has been reconstructed. The revetment face has primary armour stone of 450kg (~700mm diameter) placed at a slope of 1 in 1.5. The revetment toe sits at -1.7m AHD the crest will be set at either 2.65m AHD or at least 1 stone above the reserve ground level. Due to the relative steepness and height of the revetment in this location, a fence is proposed to separate pedestrians from the revetment.
Precinct 4: Plan	Figure 15	For Precinct 4, revetment reconstruction is proposed along the same alignment as exists presently, although some reclamation may be required towards the eastern end.
Precinct 4: Profiles	Figure 16	The revetment proposed has a very similar design to Precinct 3, although the ground elevations in Precinct 4 are generally lower than for Precinct 3. Furthermore, the revetment is now on the eastern side of Sandy Point, meaning that it is more exposed to oceanic swell waves. For this reason, the proposed revetment is at a flatter slope of 1V:2H. Based on the potential for overtopping, the footpath in this precinct needs to be maintained at a level of 2.35m AHD to provide a final barrier against any waves that do manage to run up the front face of the structure and flow between the topmost rows of armour stone.

Scheme 1		
Precinct and Details	**Figures**	**Notes**
Precinct 5: Plan	Figure 17	This revetment has an identical design to that in Precinct 4. However, there are significant construction issues with access to this length of foreshore. This markedly increases the cost of demolition and reconstruction efforts. The plan alignment of the revetment adopted for this option involves some reclamation, up to 10m seaward if the worst affected properties, which are particularly vulnerable at this point in time. By adopting this alignment, we achieve a more consistent, smoother planform without any sharp transitions that might concentrate wave energy and runup. All boat ramps will be demolished. The presence of solid concrete structures throughout Precinct 5 will prove difficult to reuse within the new structure, and it is assumed that half of the materials resulting from demolition of the existing structures will need to be disposed to landfill. A significant cost saving could be made if the demolition materials (bricks, mass concrete etc.) could be reused. In costing, we have assumed that materials amounting to half of the secondary armour will be able to be recycled in the new structure, resulting in some cost saving.
Precinct 5: Profiles	Figure 18	The revetment design is essentially the same as for Precinct 4. However existing ground levels here are typically 2.3m AHD or below. For this reason, there will need to be an allowance for cross drainage, or ground filling in areas where the finished path level is higher than the yards of the adjacent residential properties. The way in which this drainage is provided will be a subject of detailed design.
Precinct 6: Plan	Figure 19	In Precinct 6, the existing foreshore protection is low key compared to Precinct 5. However, the area is still overtopped by ocean swell, a process which is particularly exacerbated by the presence of boat ramps which present a weak point in the existing foreshore protection. The existing beach, which has accreted to the east of Groyne D, provides added protection to the foreshore properties. This beach should be maintained. Scheme 1 proposes that the present, ad-hoc arrangement of foreshore protection works be replaced by a properly engineered structure along the present alignment. The existing stormwater crossing (~ Chainage 1150) is to be retained as is.

Scheme 1		
Precinct and Details	**Figures**	**Notes**
Precinct 6: Profiles	Figure 20 Figure 21	The revetment design is similar to that of Precincts 4 and 5, although it incorporates a self-launching toe at -1.0m AHD to minimise the amount of excavation required in the beach which sits relatively high at present. This toe is designed to slump as/if any scour holes develop during a severe storm, thus extending scour protection down to around -2.0m AHD. The footpath is again set at a level of 2.35m AHD and the structure is designed to allow an additional row of armour stone to be added at some time in the future, if required. This may be required as sea levels rise, or if the beach which presently fronts this structure erodes, reducing the amount of protection afforded. In costing, similarly to Precinct 5, we have assumed that materials amounting to half of the secondary armour will be able to be recycled in the new structure, resulting in some materials cost saving. Around half of the demolished structure would require disposal to landfill, with significant savings possible if this building rubble (masonry blocks, bricks, concrete) can be recycled for use elsewhere.

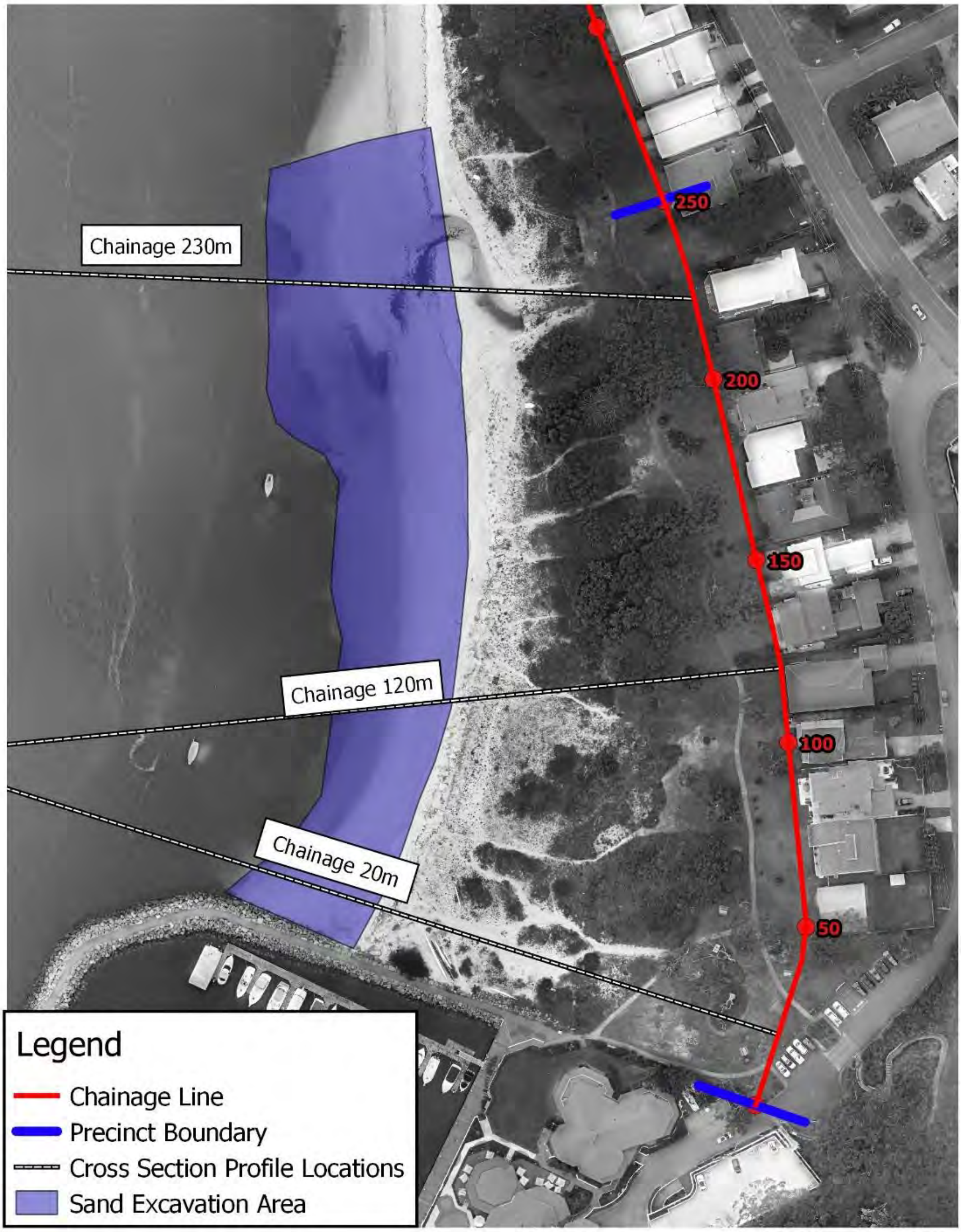

Figure 7 Scheme 1, Precinct 1: Plan

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

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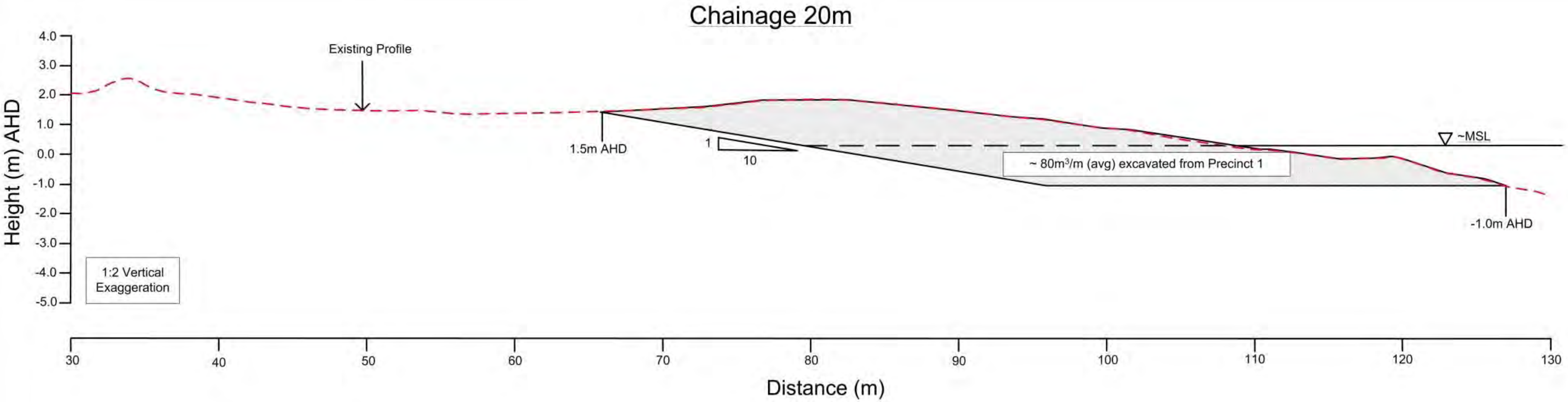
0 20 40 60 80 m

(Approx Scale)

Revision	A
Drawn	BC
Approved	DW



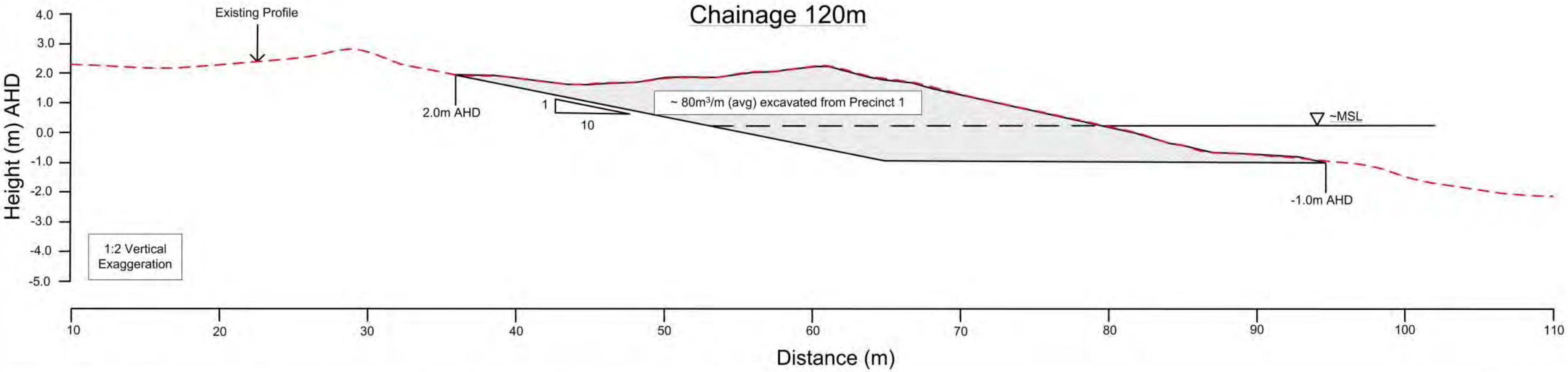


Figure 8 Scheme 1, Precinct 1: Profiles - Chainages 20 and 120m

Sandy Point/Conroy Park Foreshore Erosion and Management Plan

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Cross sections are conceptual, for costing and visualisation purposes only, and are not for construction. Distances along the cross sections are measured in an offshore direction from the main chainage line, which is shown on the corresponding plan.

Revision	A
Drawn	BC
Approved	DW

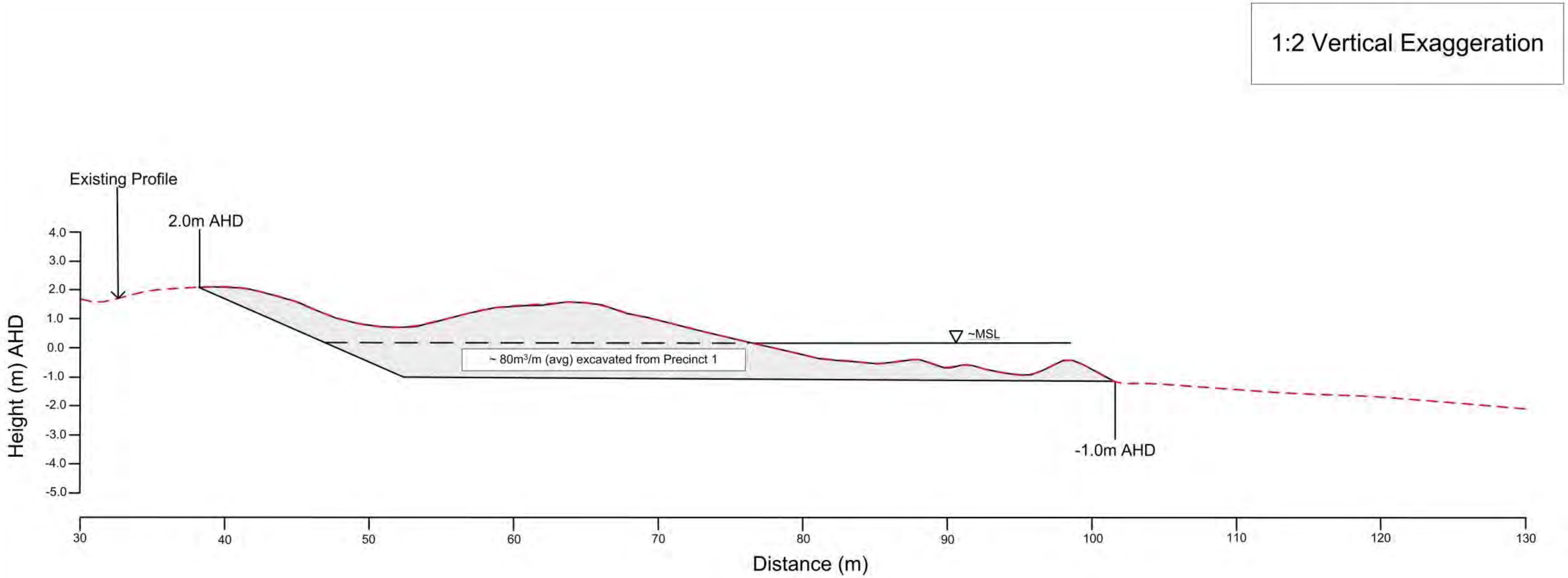

Figure 9 Scheme 1, Precinct 1: Profiles - Chainage 230m

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Approved	DW

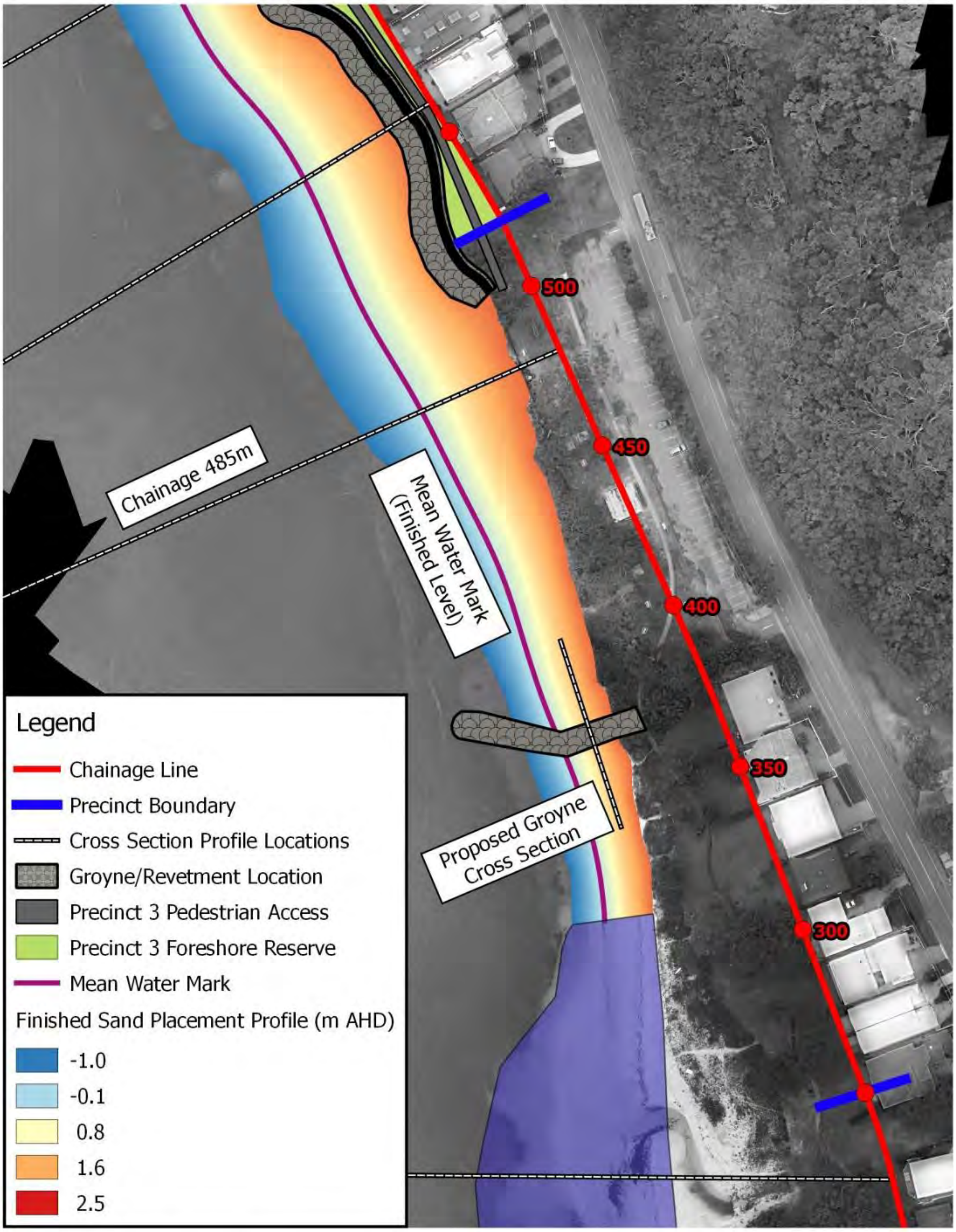

Figure 10 Scheme 1, Precinct 2: Plan

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

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(Approx Scale)

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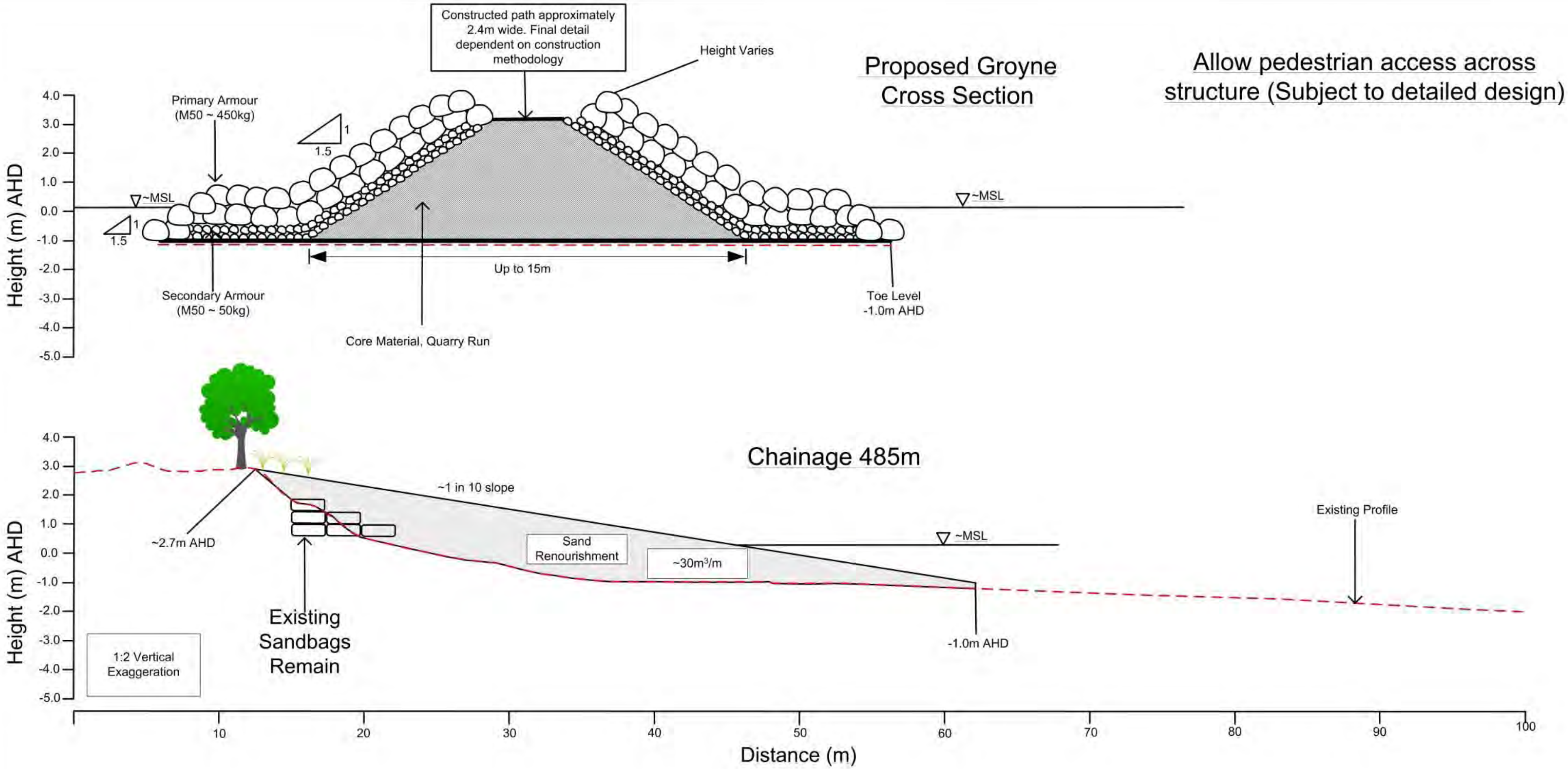

Figure 11 Scheme 1, Precinct 2: Profiles – Chainage 485m and Groyne

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Drawn	BC
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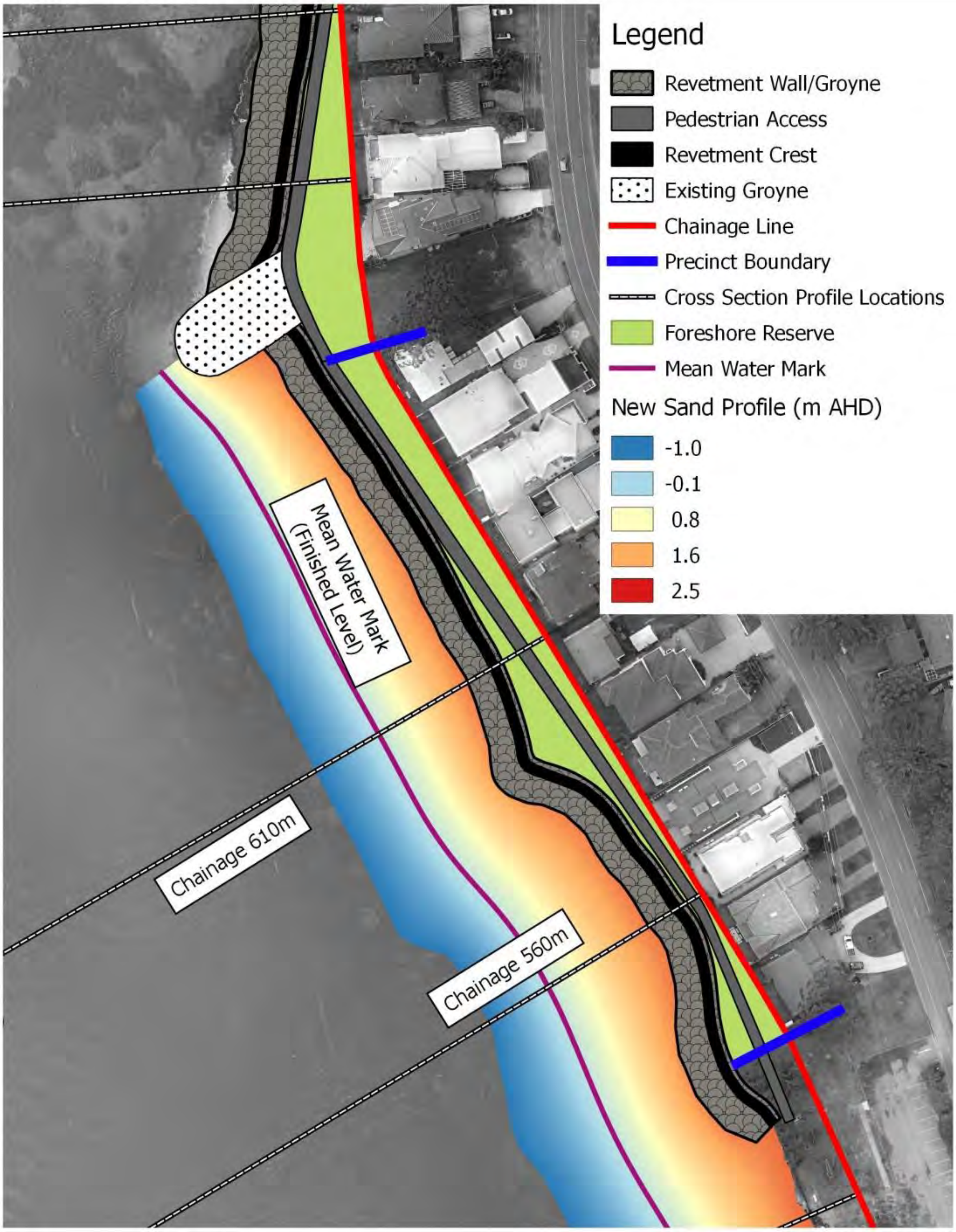

Figure 12 Scheme 1, Precinct 3: Plan

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0 20 40 60 m
(Approx Scale)

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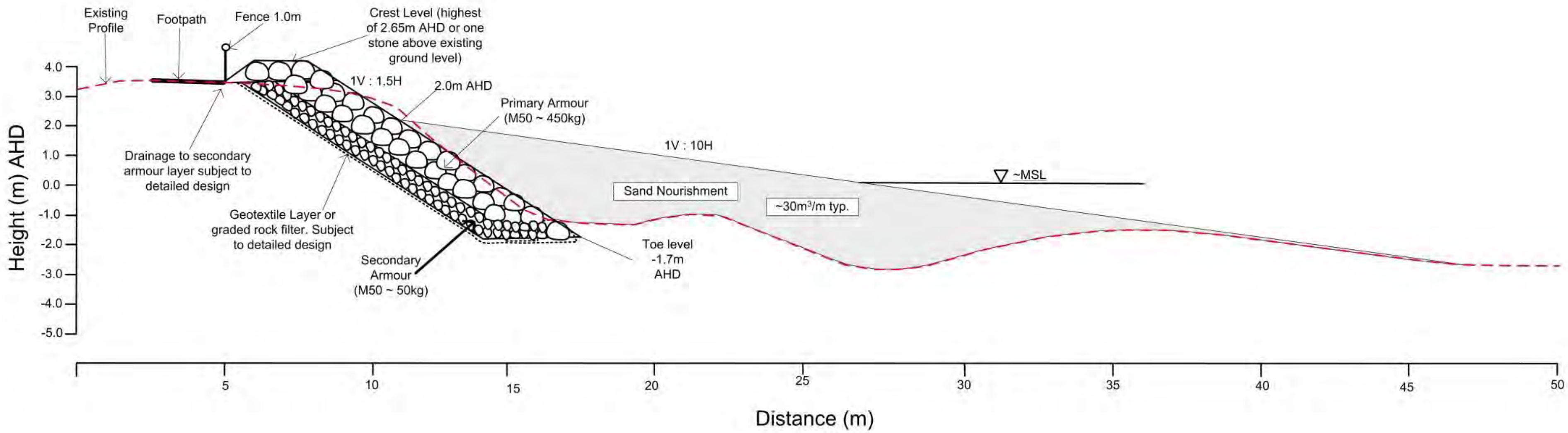

Figure 13 Scheme 1, Precinct 3: Profiles - Chainage 560

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Drawn	BC
Approved	DW

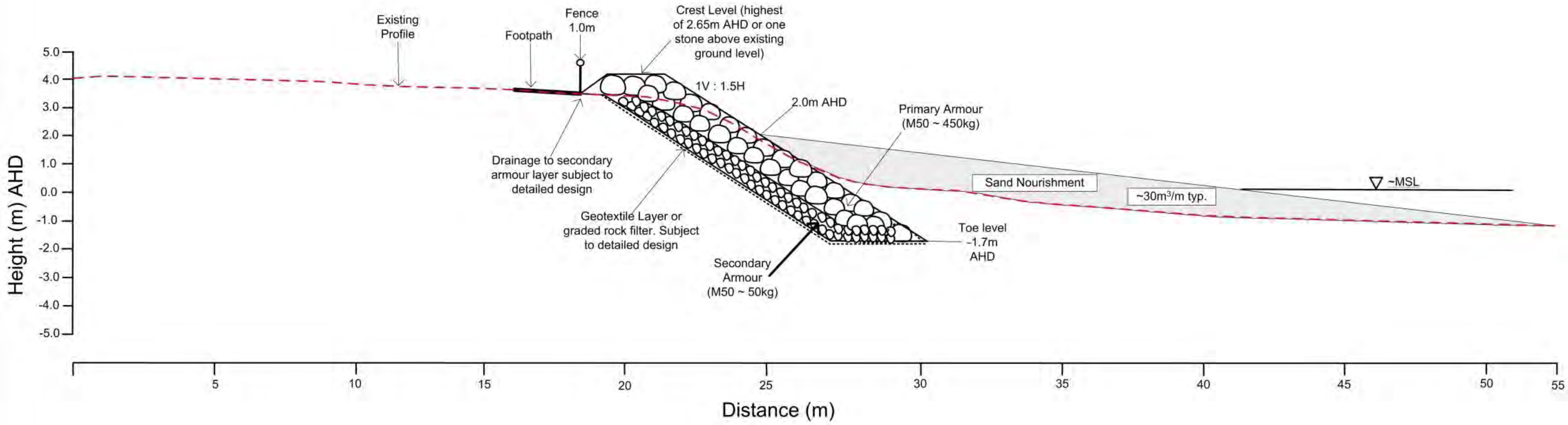

Figure 14 Scheme 1, Precinct 3: Profiles - Chainage 610m

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Approved	DW

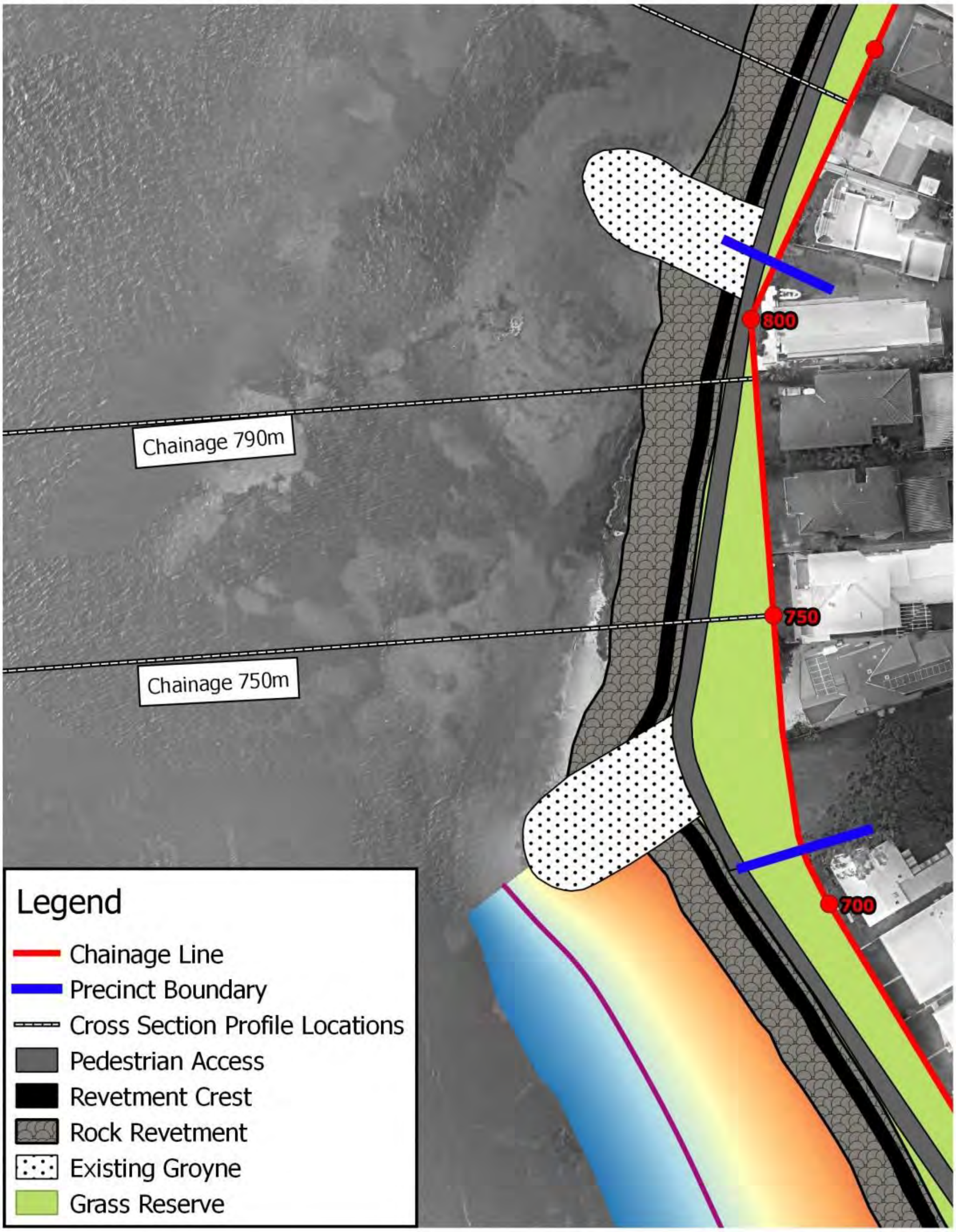

Figure 15 Scheme 1, Precinct 4: Plan

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

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0 10 20 30 40 50 m

(Approx Scale)

Revision	A
Drawn	BC
Approved	DW

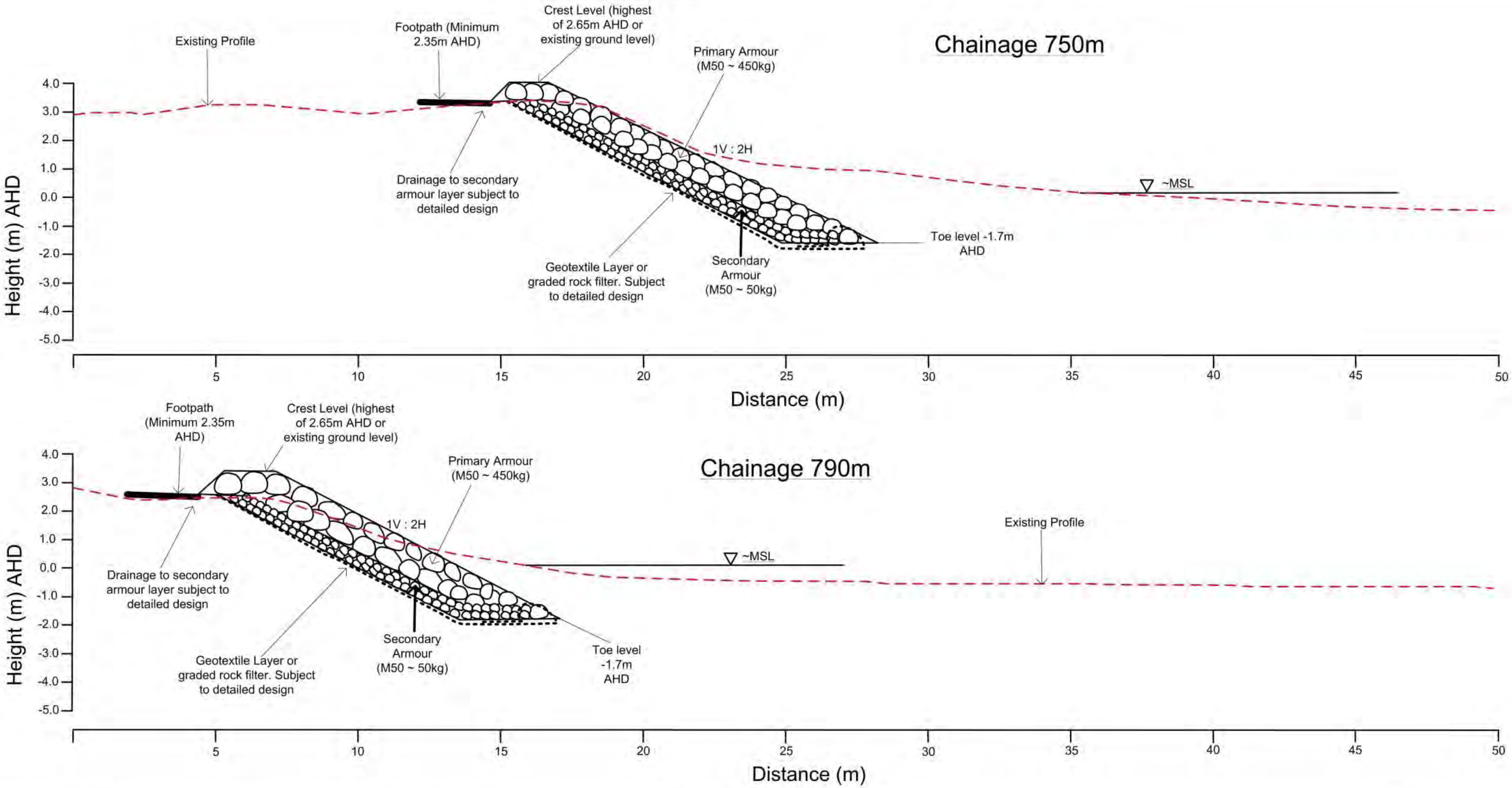

Figure 16 Scheme 1, Precinct 4: Profiles - Chainages 750 and 790m

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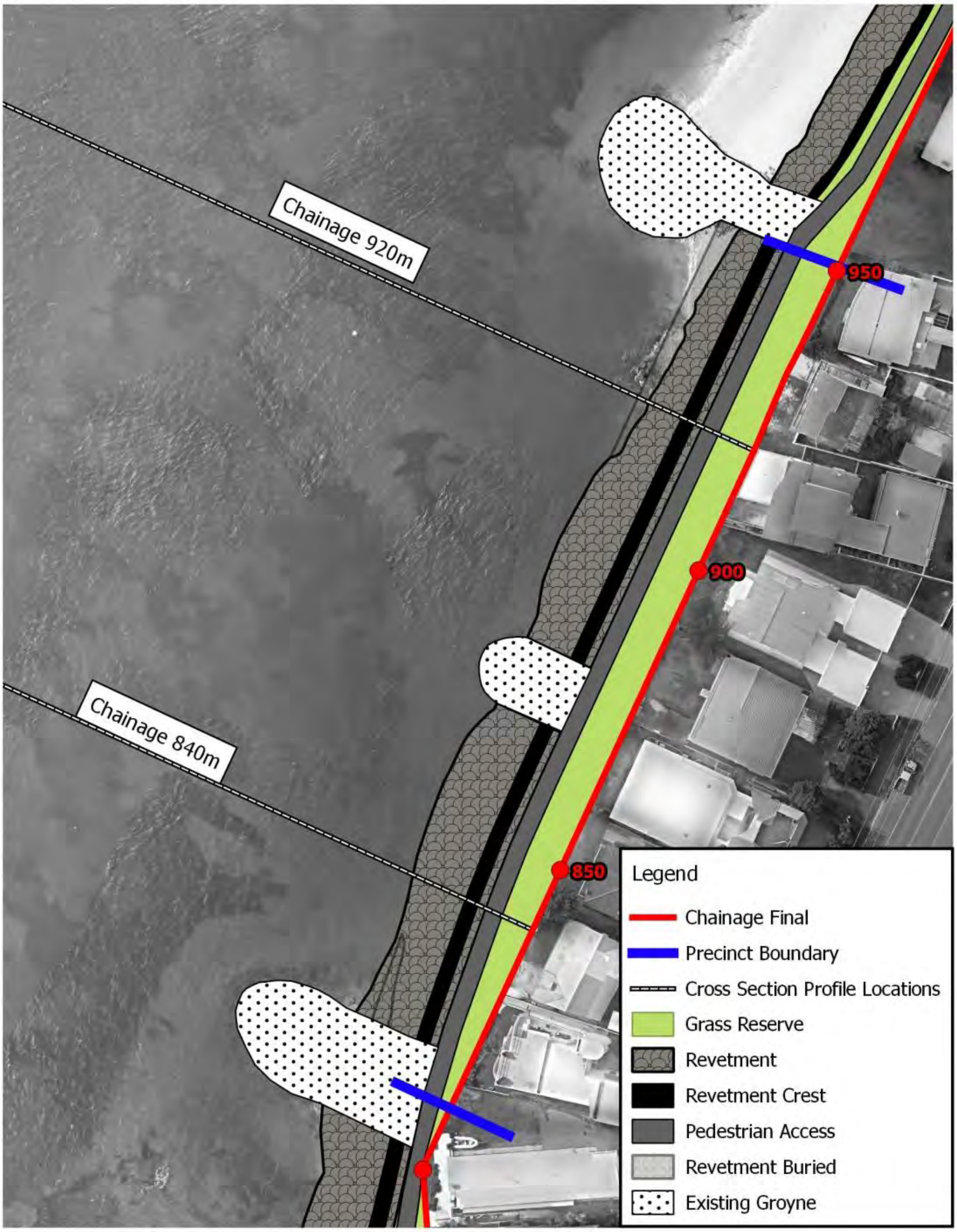

Figure 17 Scheme 1, Precinct 5: Plan

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

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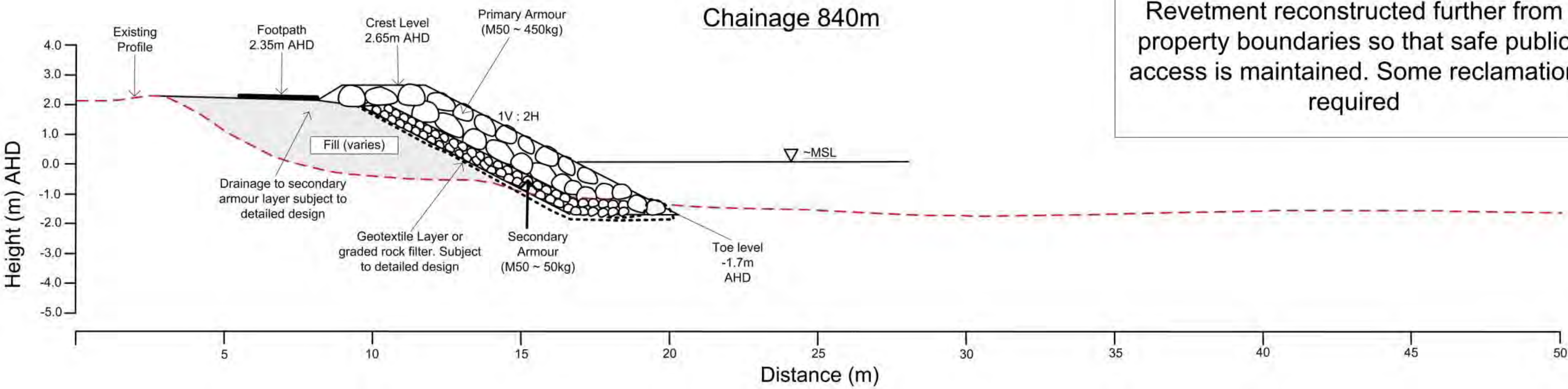
Approved	DW



Revetment reconstructed further from property boundaries so that safe public access is maintained. Some reclamation required

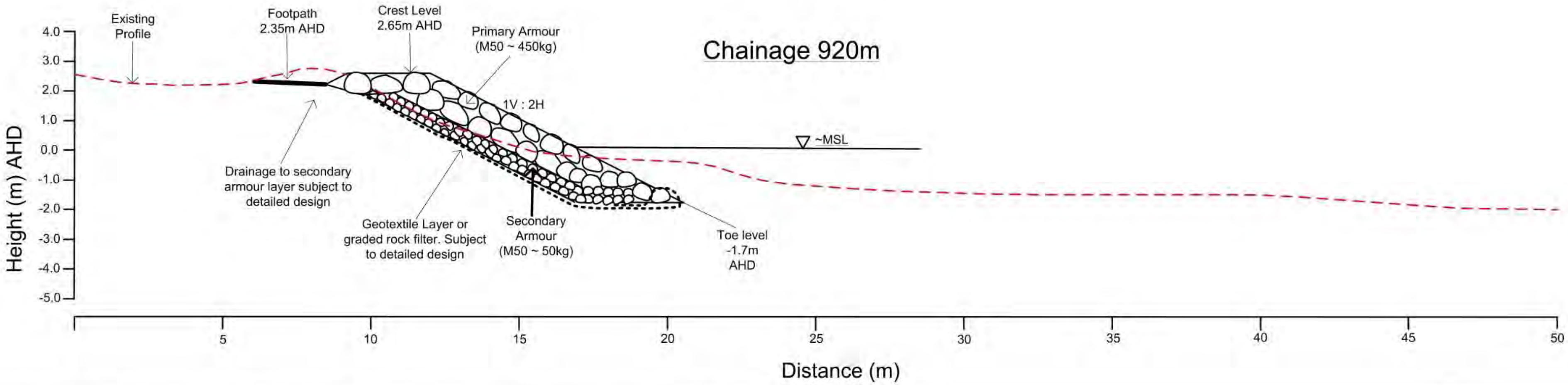


Figure 18 Scheme 1, Precinct 5: Profiles - Chainages 840 and 920m

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Figure 19 Scheme 1, Precinct 6: Plan

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

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Approved	DW

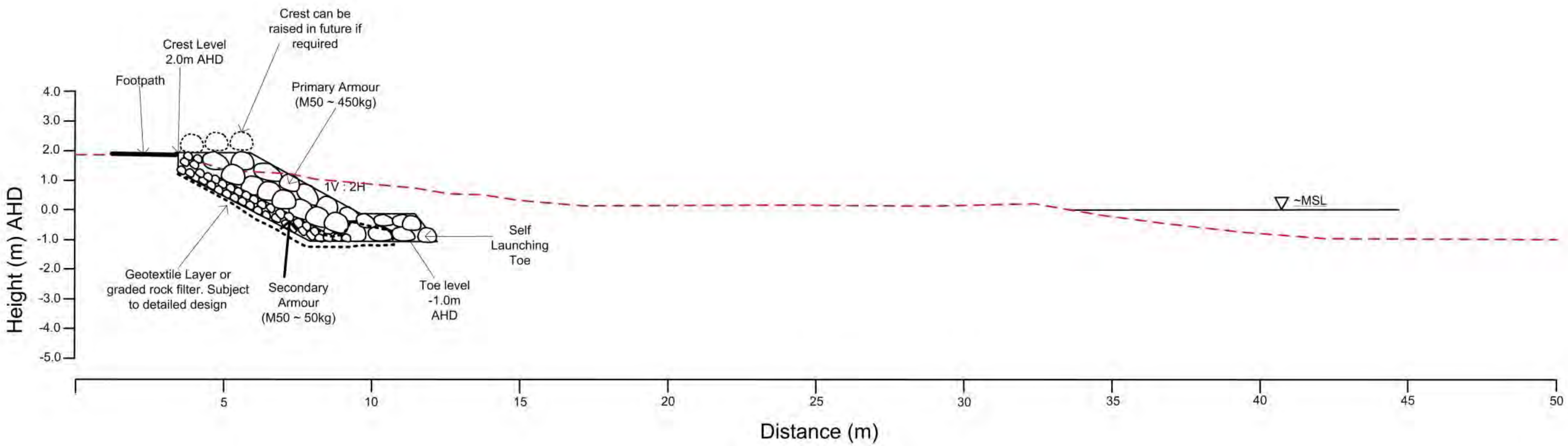

Figure 20 Scheme 1, Precinct 6: Profile – Chainage 1045m

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Scheme 1, Precinct 6, Chainage 1150m, Drainage Cross Section

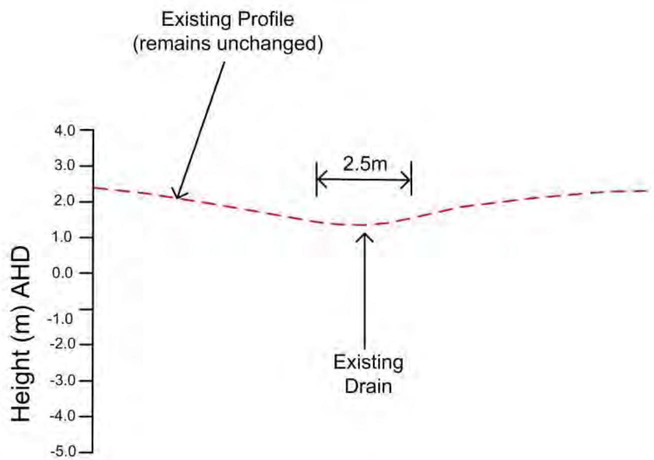

Figure 21 Scheme 1, Precinct 6: Profile 1150m

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Revision	A
Drawn	BC
Approved	DW

6.2.2 Scheme 2

Table 6 Scheme 2 Presentation

Scheme 2		
Precinct and Details	**Figures**	**Notes**
Precinct 1: Plan	Figure 22	Minimal plan changes are proposed for Precinct 1 in Scheme 2. Twin Gross Pollutant Traps would be installed shoreward of the stormwater outlet across Corlette Beach.
Precinct 1: Profiles	Figure 23 Figure 24	There will be no change from the existing situation
Precinct 2: Plan	Figure 25	The beach would be nourished with imported sand, Dredging from the leading edge of the Port Stephens flood tide delta dropover the most economical source, pending permission from state government agencies. The proposed nourishment would increase beach width at mid-tide from zero at the present time, to around 30-35 metres when fully nourished. Nourishment activities would normally occur every 5-10 years or more frequently depending on weather conditions.
Precinct 2: Profiles	Figure 26	Nourished Beach Profiles are identical to those proposed as part of Scheme 1.
Precinct 3: Plan	Figure 27	Similarly to Scheme 1, the revetment is reconstructed and the beach nourished although this time nourished sand would be imported and not taken from the accumulated sand adjacent to “The Anchorage”. The amount of nourishment in Precincts 2 and 3 is the same for all three schemes. In addition to these changes, Groyne ‘A’ would be bolstered, extended and reconfigured to a “fishtail” to encourage the retention of a wider beach adjacent to the foreshore.
Precinct 3: Profiles	Figure 28 Figure 29	It is envisaged that the existing structure at Groyne A will reduce the need to import fill to create the core of the structure by 50%. Otherwise construction and cross section of the groyne is similar to that proposed in Precinct 2 (Scheme 1), with the exception that the side slopes would be at 1V:2H. The flatter slopes are required to accommodate a higher exposure to wave energy in this location.

Scheme 2		
Precinct and Details	**Figures**	**Notes**
Precinct 4: Plan	Figure 30	Similarly to Scheme 1, the revetment is reconstructed with some reclamation. In addition to these changes, groyne 'B' would be bolstered, extended and reconfigured to encourage the retention of a wider beach adjacent to the foreshore.
Precinct 4: Profiles	Figure 31	It is envisaged that the existing structure at groyne B will reduce the need to import fill to create the core of the structure by 50%. Otherwise construction and cross section of the groyne is similar to that proposed for Groyne 'A' (Precinct 3)
Precinct 5: Plan	Figure 32	This option illustrates what would be required to maintain a stable beach in front of Precinct 5. Groyne C is extended (along with Groynes B from Precinct 4 and Groyne D from Precinct 6) to the approximate extent required to provide for a stable beach in each compartment, without the need for a continual infeed of sediment from the east. Periodic nourishment may still be required.
Precinct 5: Profiles	Figure 33	As the beach is currently protected from wave impact and erosion, the revetment is only demolished and reconstructed down to an elevation of 0.5m and reconstructed with the same primary and secondary armour as Scheme 1, providing a clear delineation between the back of the beach and the foreshore reserve. All boat ramps would be demolished and filled in. The groyne cross sections are similar to that for Groyne A; however groynes C and D, as proposed, are longer. The beach is nourished with around 12,500 cubic metres of sand.
Precinct 6: Plan	Figure 34	The existing structures are demolished with non-reusable materials disposed to landfill. Re-useable rock is used to provide delineation between the beach and the foreshore reserve. The beach is nourished offshore to provide an ongoing source of beach sand for longshore transport. Two Gross pollutant traps are proposed upstream of Groyne D and the eastern stormwater crossing is to be formalised by filling and construction of a dish drain with an infiltration trench.

Scheme 2		
Precinct and Details	**Figures**	**Notes**
Precinct 6: Profiles	Figure 35 Figure 36	20,000 cubic metres of sand nourishment is proposed. This will initially bolster the beach fronting Precinct 6 providing protection from storms. However, this will need to be monitored as no enhanced structural protection is proposed. The sandy beach will form the primary defence of this shoreline against the impact of storms. It is expected that sand will progressively move around the coast past precincts 5, 4, 3 and 2 providing "seed" nourishment for the whole study area coastline over coming decades. 20,000 m^3 of sand approximates 10-12 years of the average sand movement rate along Corlette Beach over the past two decades. However, stormier conditions may result in more rapid erosion of Precinct 6 and the sand buffer needs to be maintained.

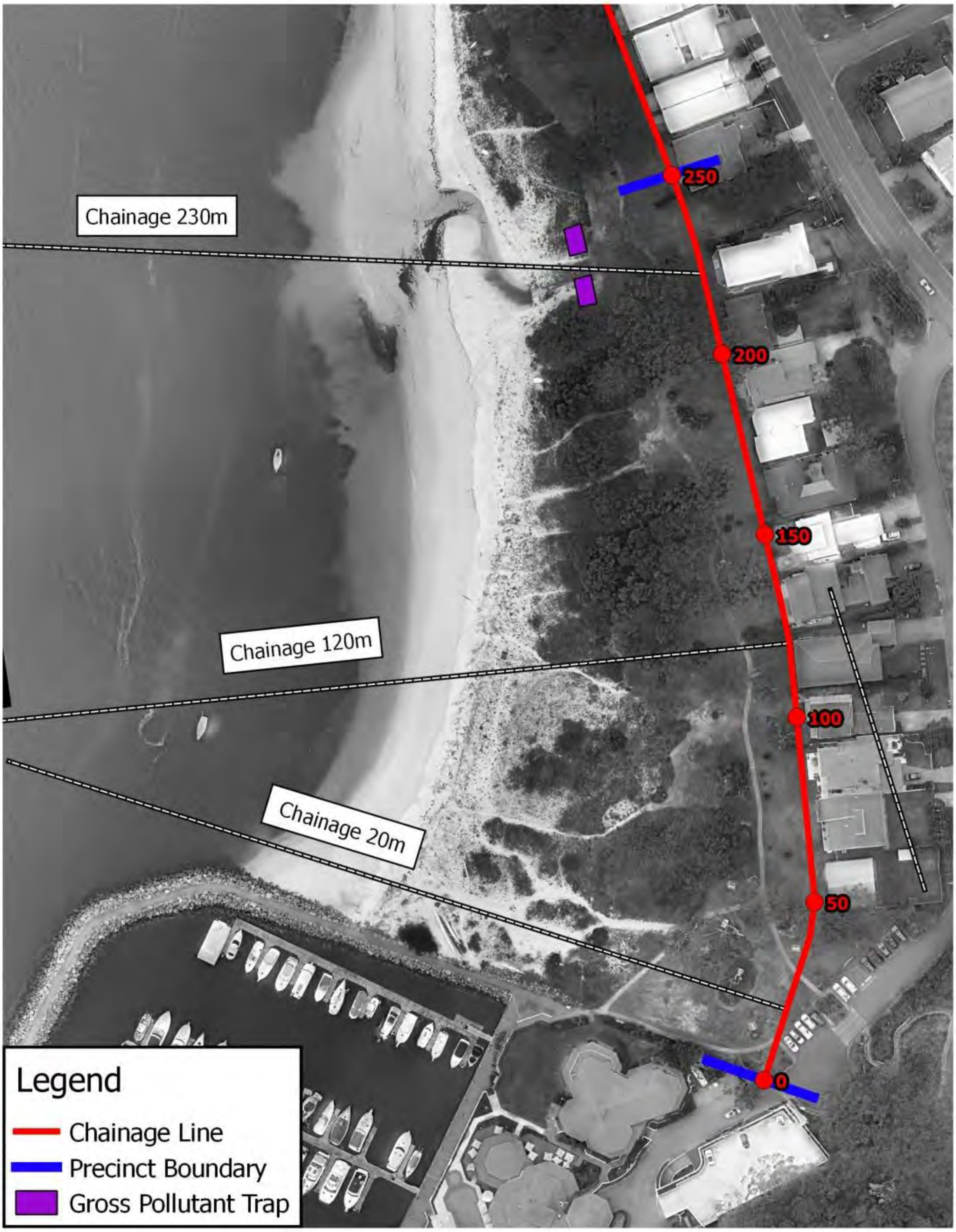


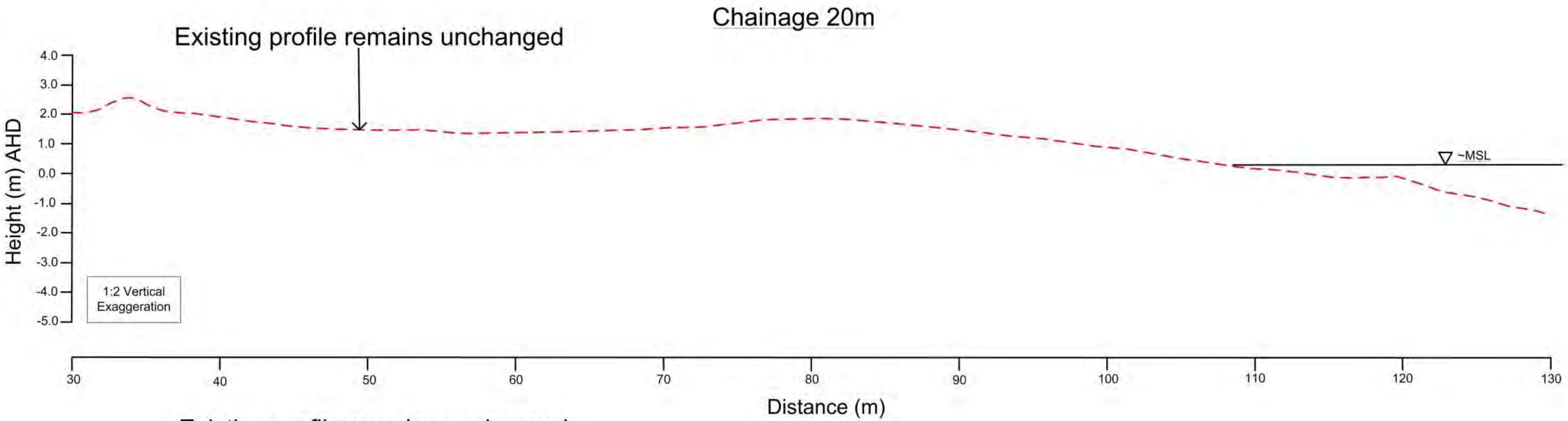
Figure 22 Scheme 2, Precinct 1: Plan

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

Whitehead & Associates
Environmental Consultants

0 20 40 60 80 m
(Approx Scale)

Revision	A
Drawn	BC
Approved	DW



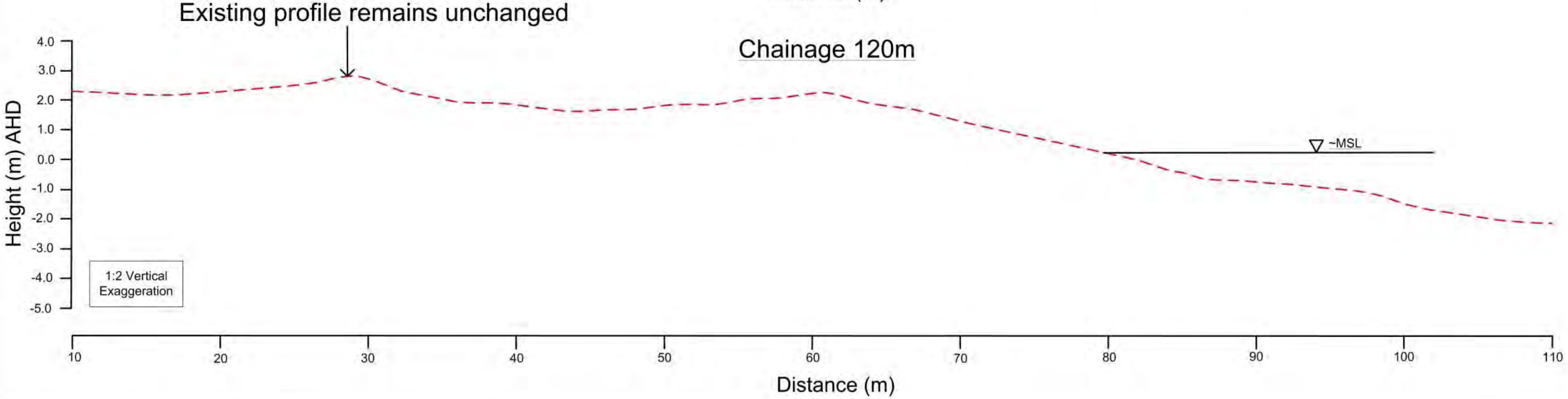


Figure 23 Scheme 2, Precinct 1: Profiles - Chainages 20 and 120m

Sandy Point/Conroy Park Foreshore Erosion and Management Plan

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Environmental Consultants

Cross sections are conceptual, for costing and visualisation purposes only, and are not for construction. Distances along the cross sections are measured in an offshore direction from the main chainage line, which is shown on the corresponding plan.

Revision	A
Drawn	BC
Approved	DW

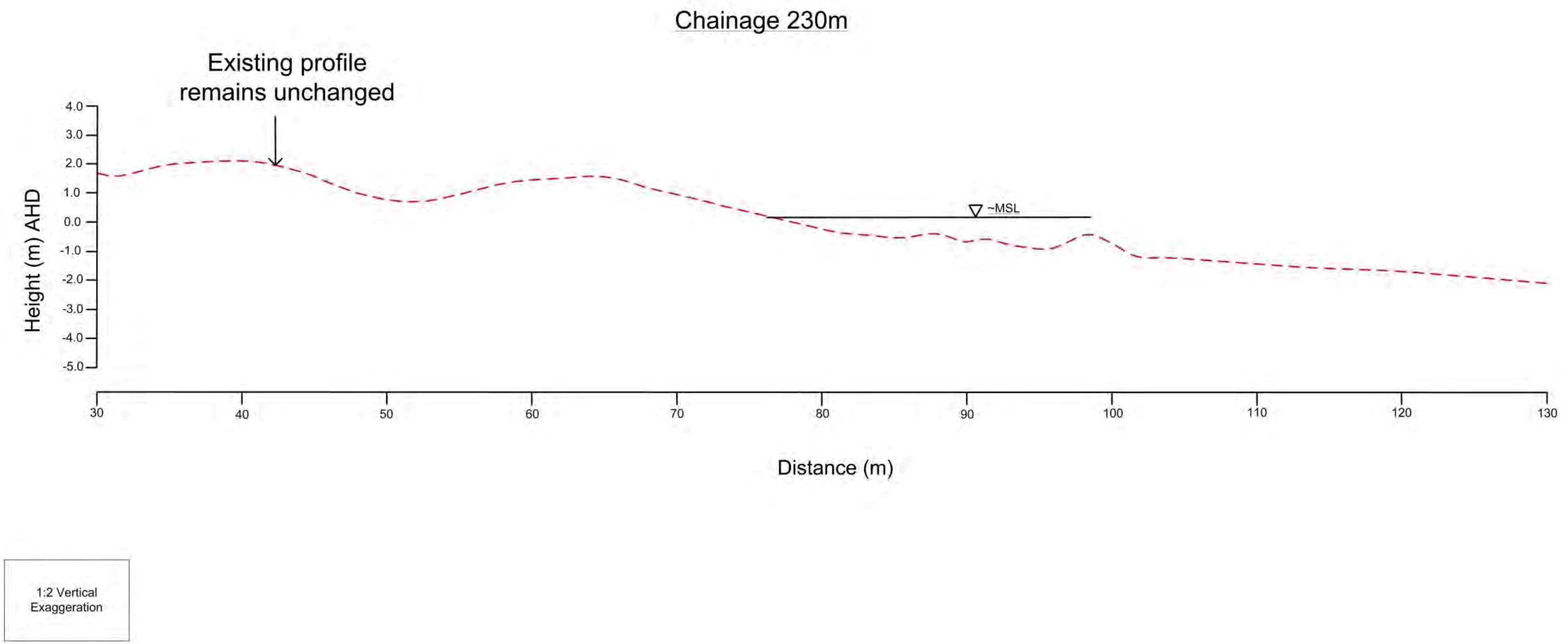

Figure 24 Scheme 2, Precinct 1: Profiles - Chainage 230m

Sandy Point/Conroy Park Foreshore Erosion and Management Plan

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Distances along the cross sections are measured in an offshore direction from the main chainage line, which is shown on the corresponding plan.

Revision	A
Drawn	BC
Approved	DW

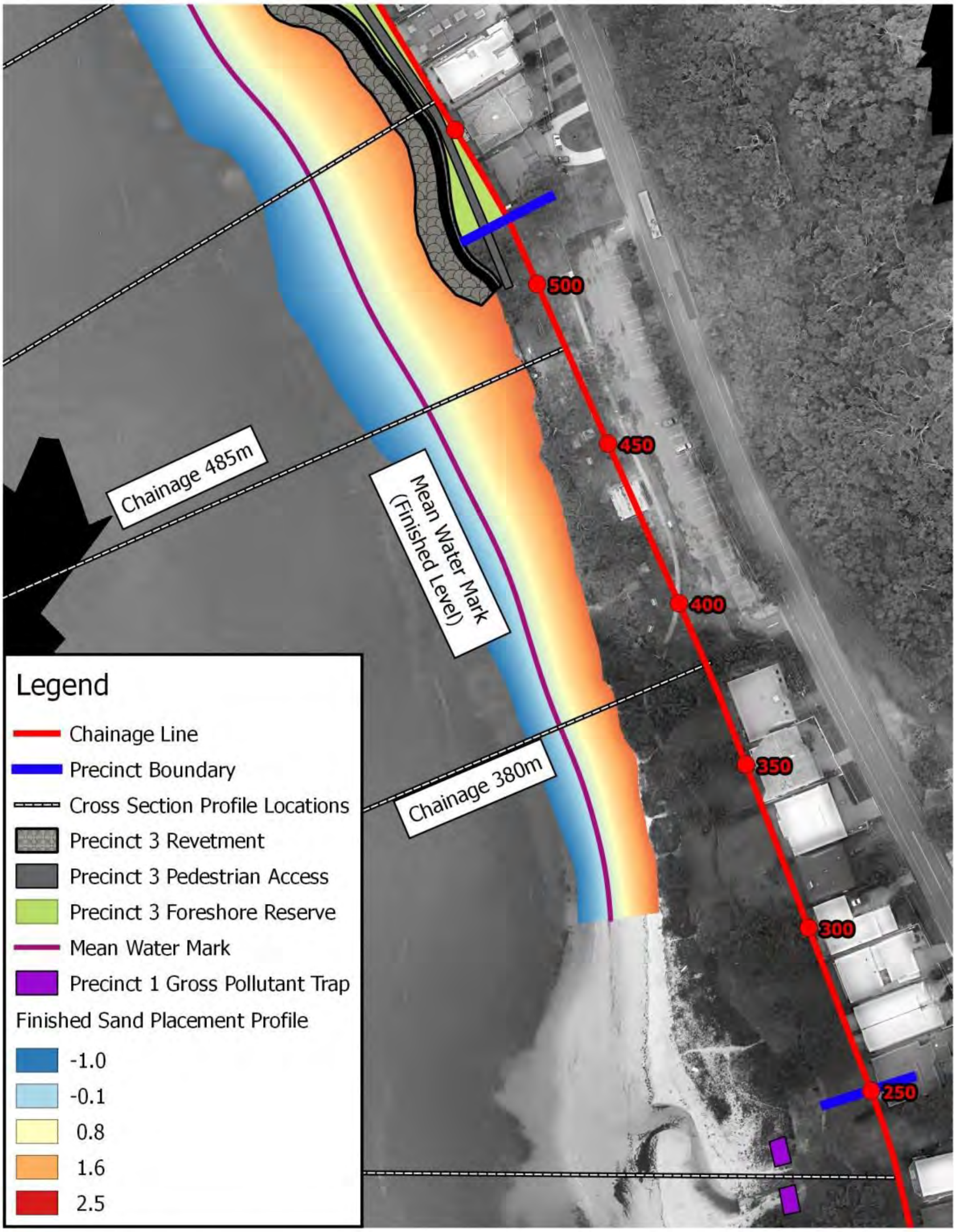

Figure 25 Scheme 2, Precinct 2: Plan

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

Whitehead & Associates
Environmental Consultants

0 20 40 60 80 m
(Approx Scale)

Revision	A
Drawn	BC
Approved	DW

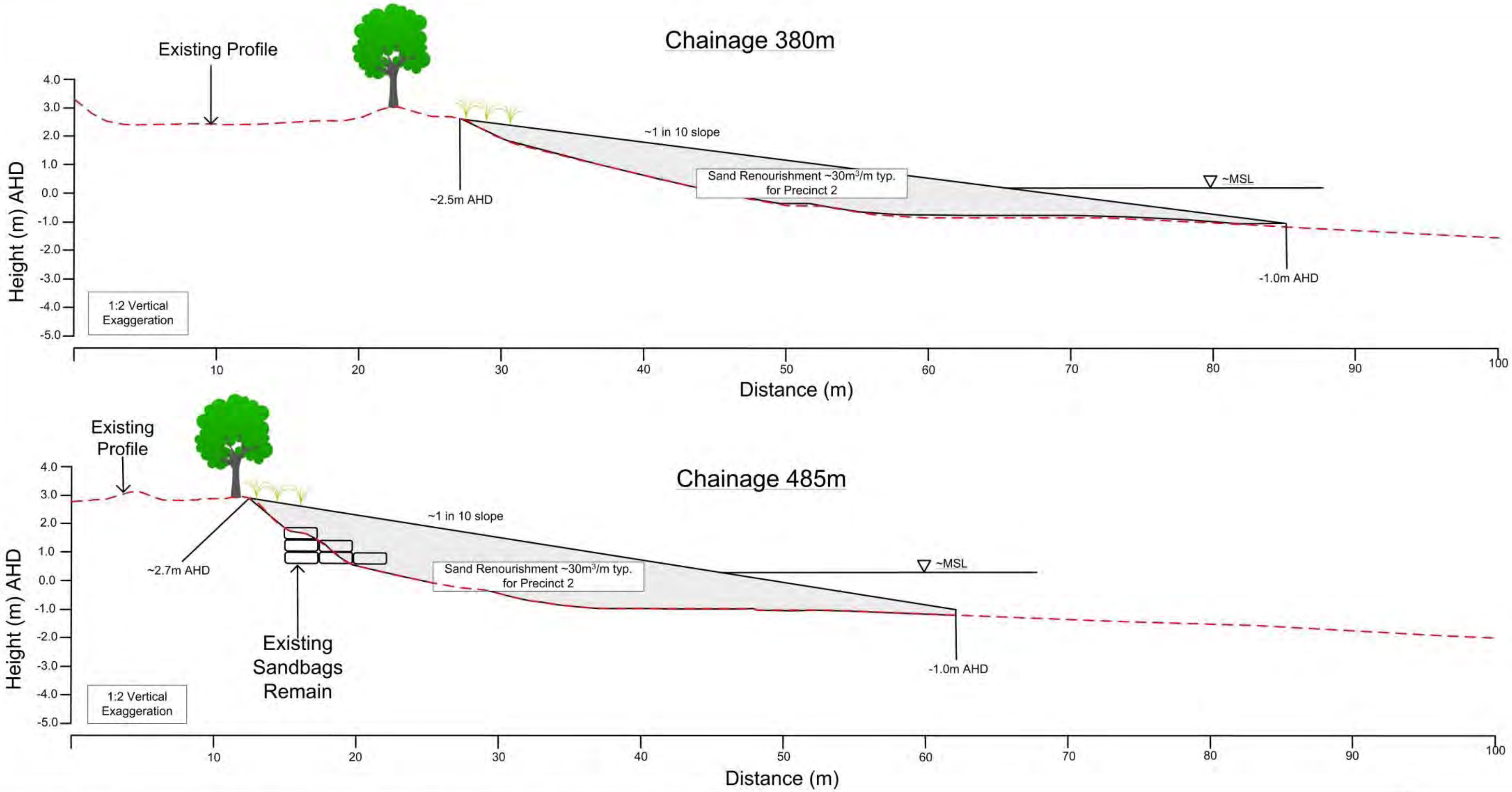

Figure 26 Scheme 2, Precinct 2: Profiles - Chainages 380 and 485m

Sandy Point/Conroy Park Foreshore Erosion and Management Plan

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Revision	A
Drawn	BC
Approved	DW

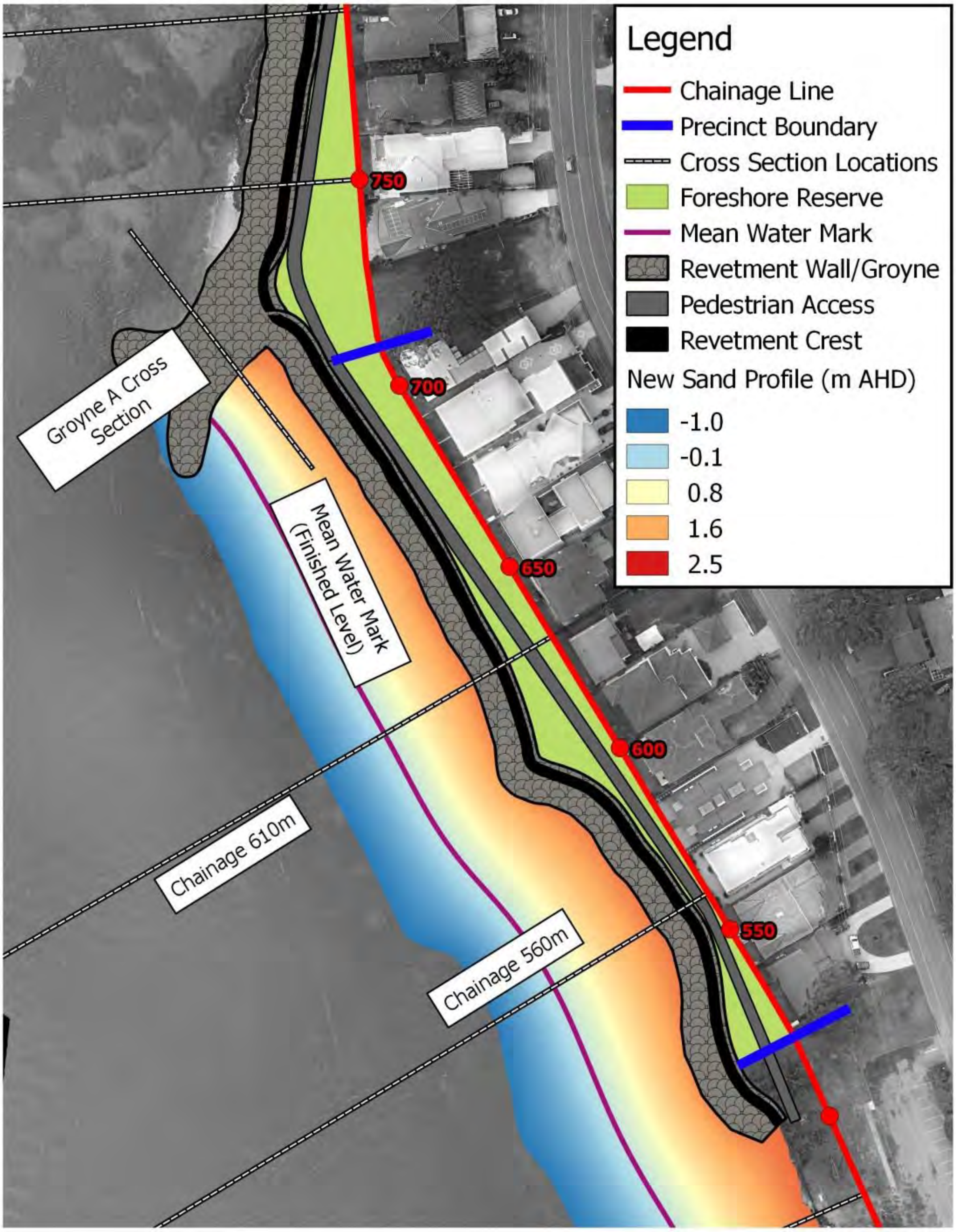

Figure 27 Scheme 2, Precinct 3: Plan

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

Whitehead & Associates
Environmental Consultants

0 20 40 60 m
(Approx Scale)

Revision	A
Drawn	BC
Approved	DW

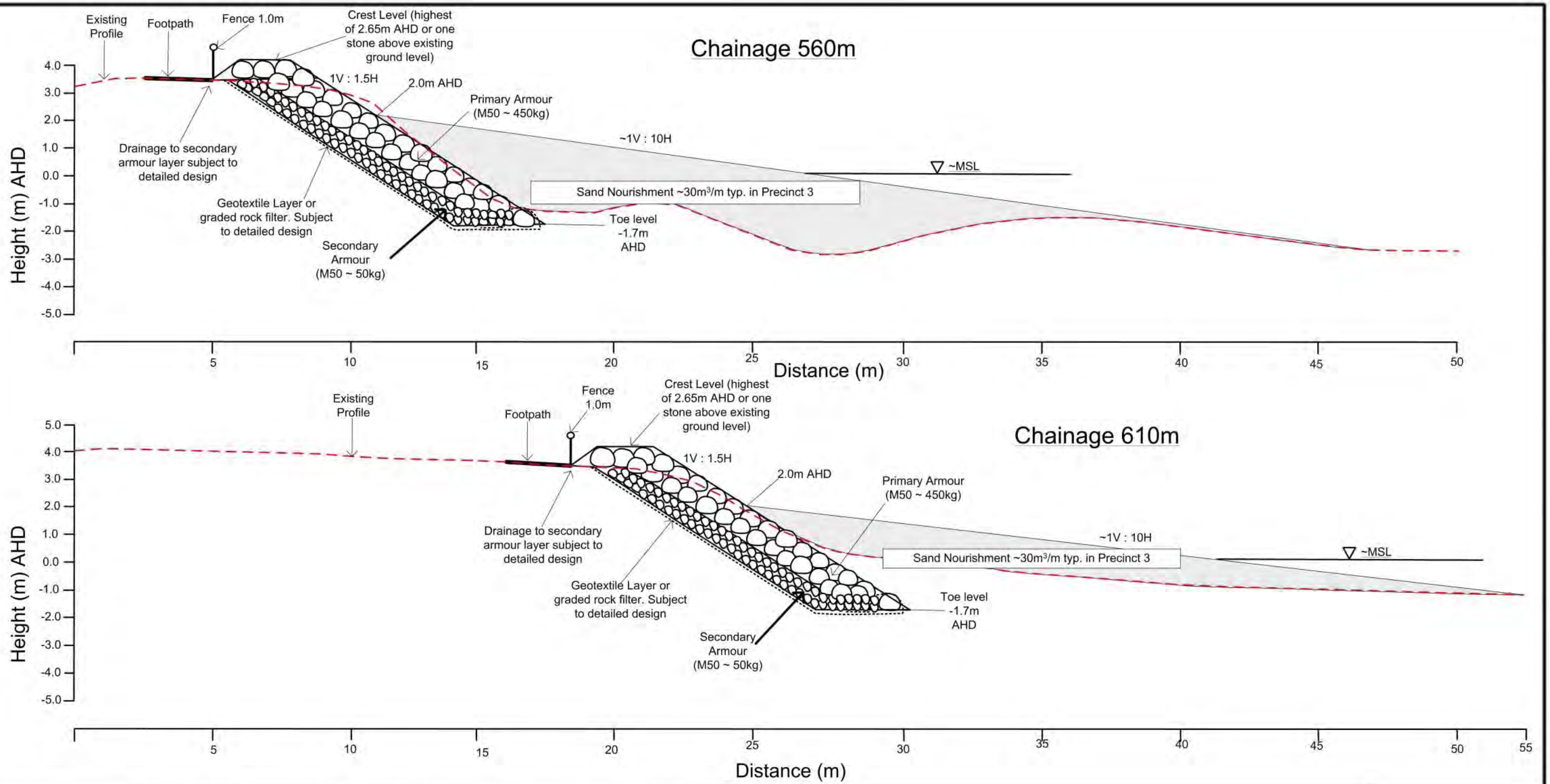

Figure 28 Scheme 2, Precinct 3: Profiles - Chainages 560 and 610m

Sandy Point/Conroy Park Foreshore Erosion and Management Plan

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Revision	A
Drawn	BC
Approved	DW

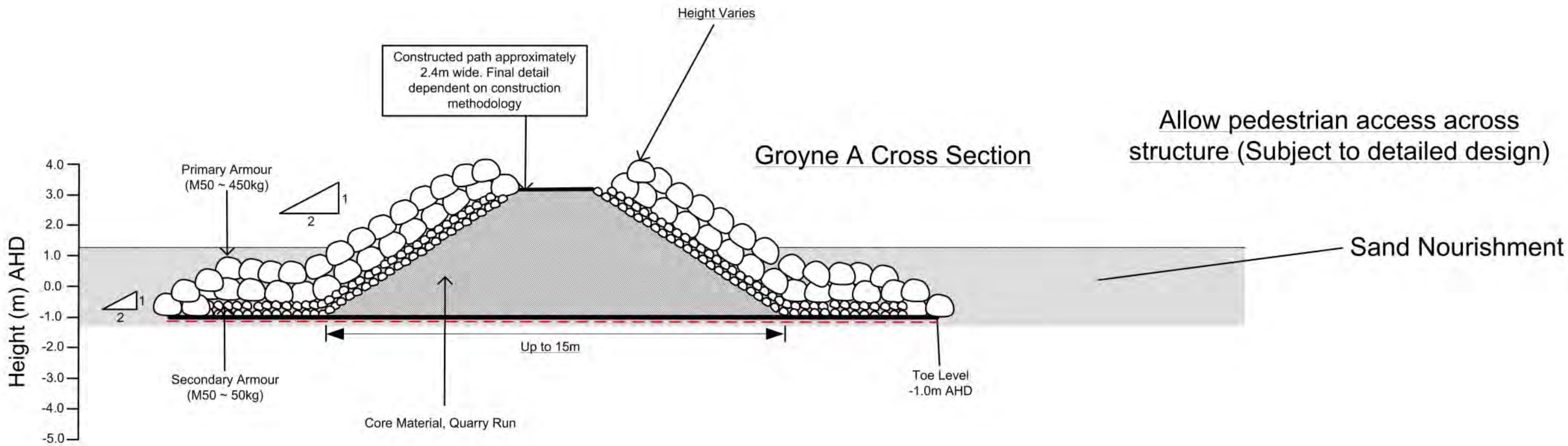

Figure 29 Scheme 2, Precinct 3: Profiles – Groyne A

Sandy Point/Conroy Park Foreshore Erosion and Management Plan

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Revision	A
Drawn	BC
Approved	DW

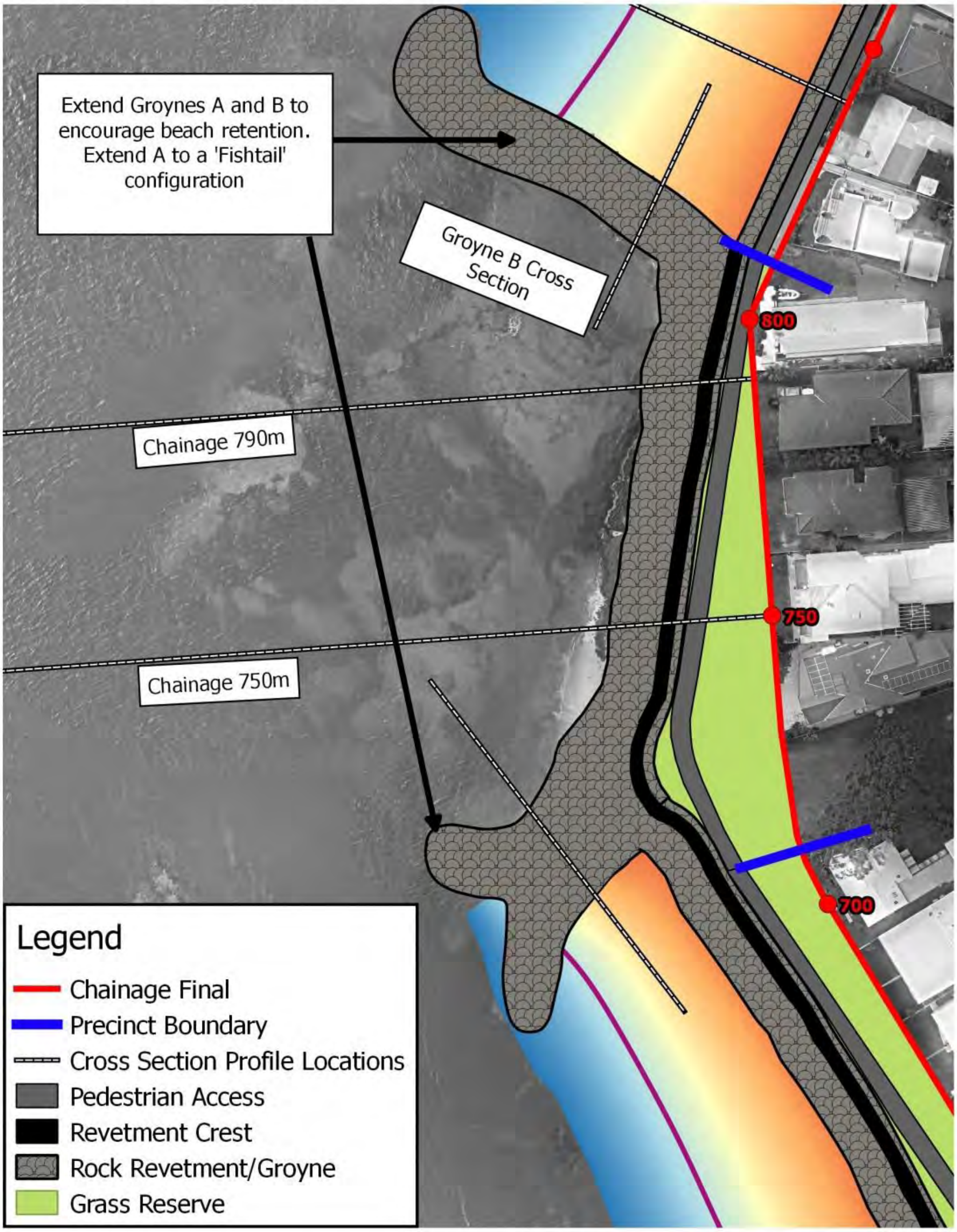

Figure 30 Scheme 2, Precinct 4: Plan

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

N

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Environmental Consultants

0 10 20 30 40 50 m

(Approx Scale)

Revision	A
Drawn	BC
Approved	DW

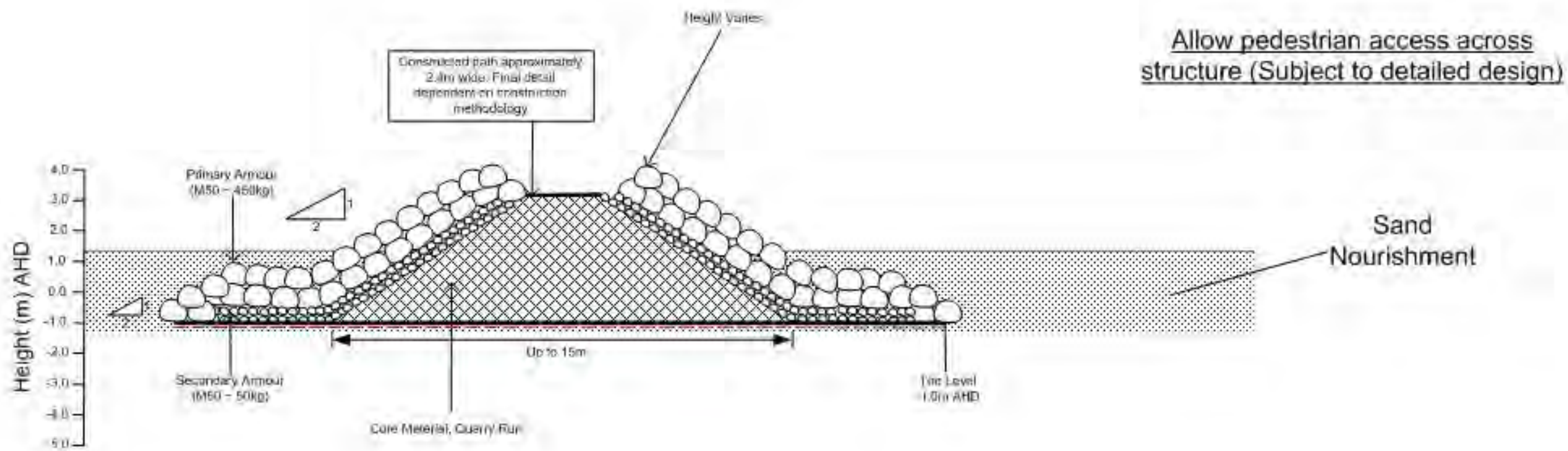

Figure 31 Scheme 2, Precinct 4: Cross Section – Groyne B

Sandy Point/Conroy Park Foreshore Erosion and Management Plan

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		Drawn	BC
		Approved	DW

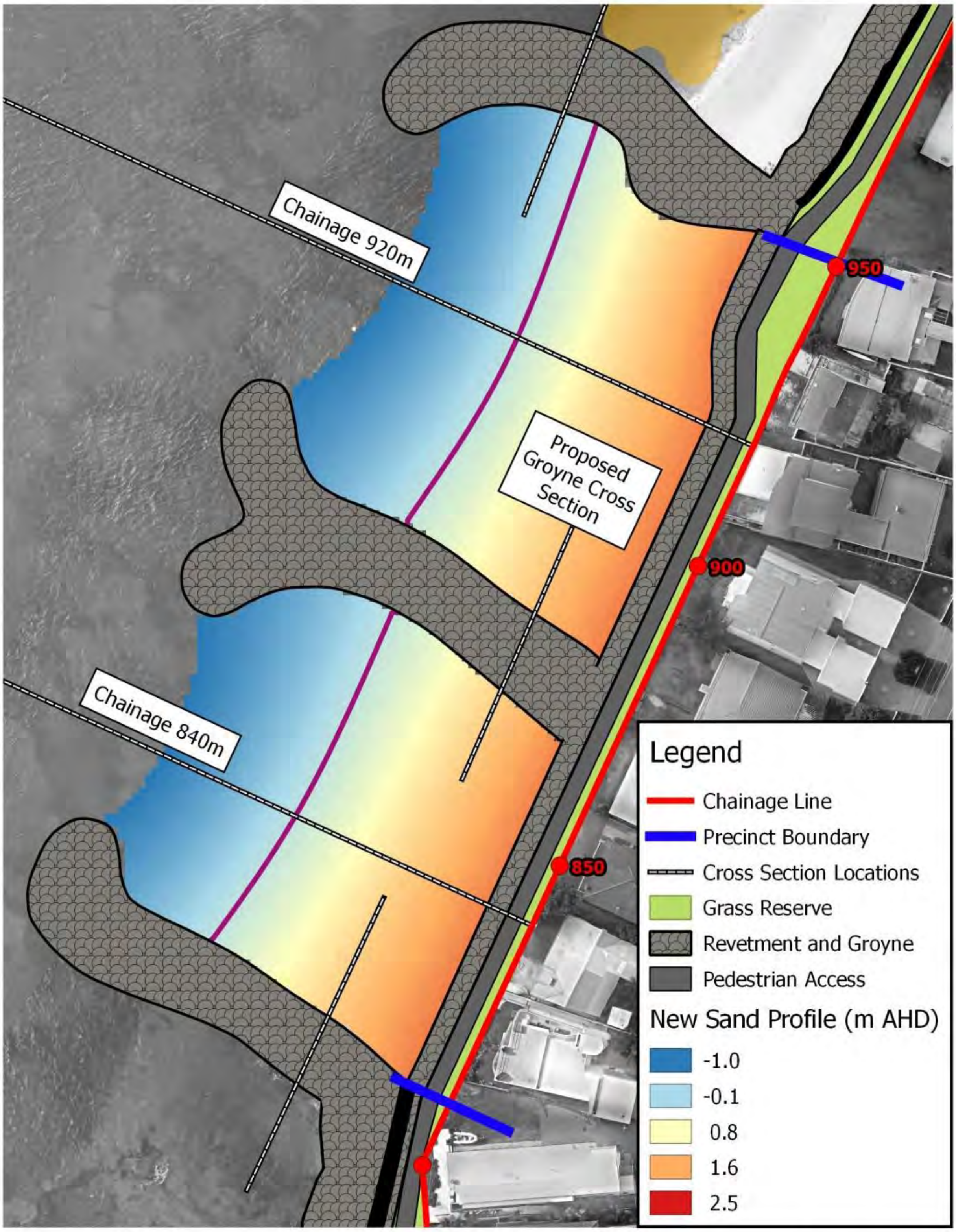

Figure 32 Scheme 2, Precinct 5: Plan

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

N

Whitehead & Associates
Environmental Consultants

0 10 20 30 40 50 m

(Approx Scale)

Revision	A
Drawn	BC
Approved	DW

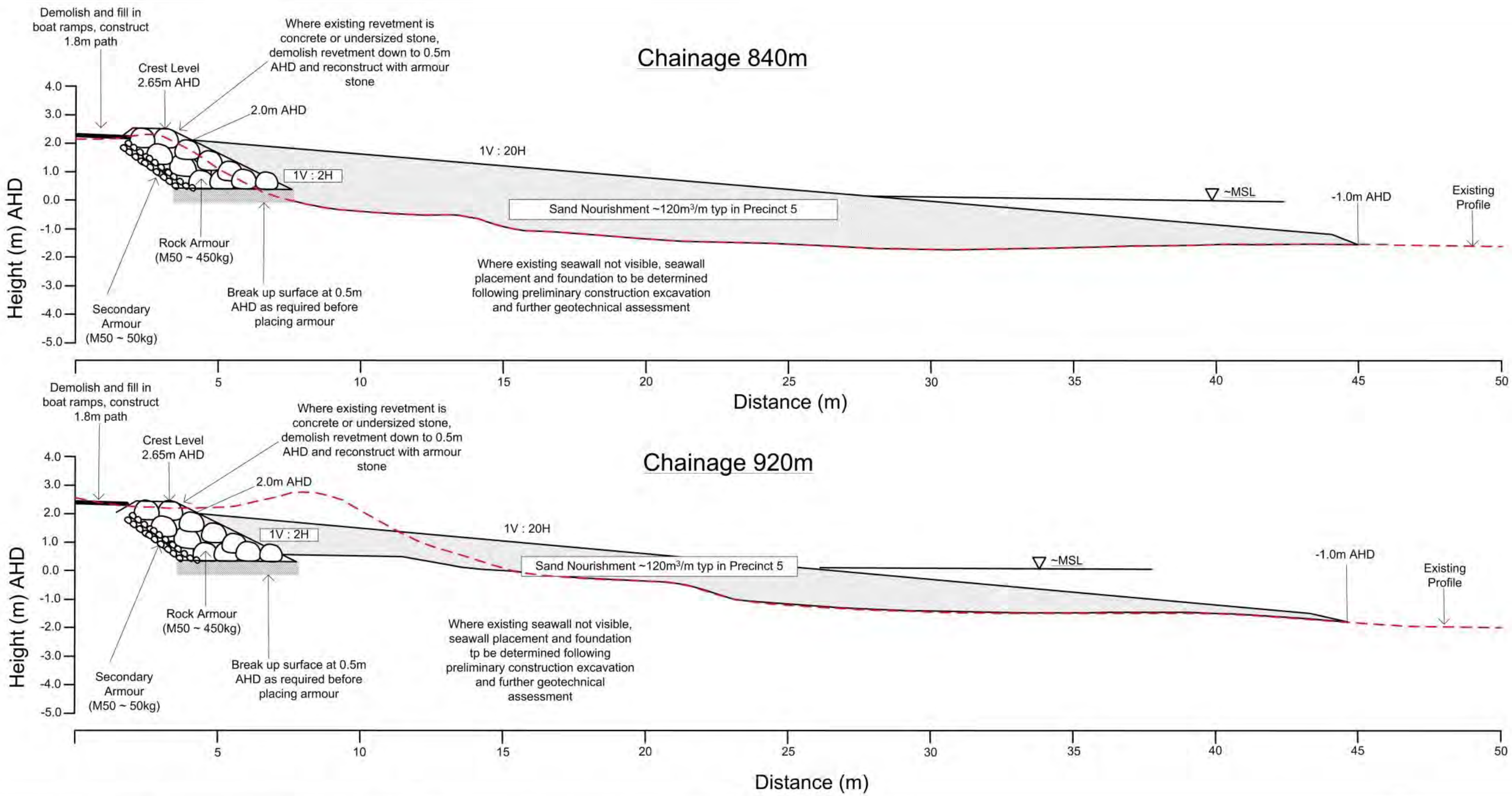

Figure 33(a) Scheme 2, Precinct 5: Profiles - Chainages 840 and 920m

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Revision	A
Drawn	BC
Approved	DW

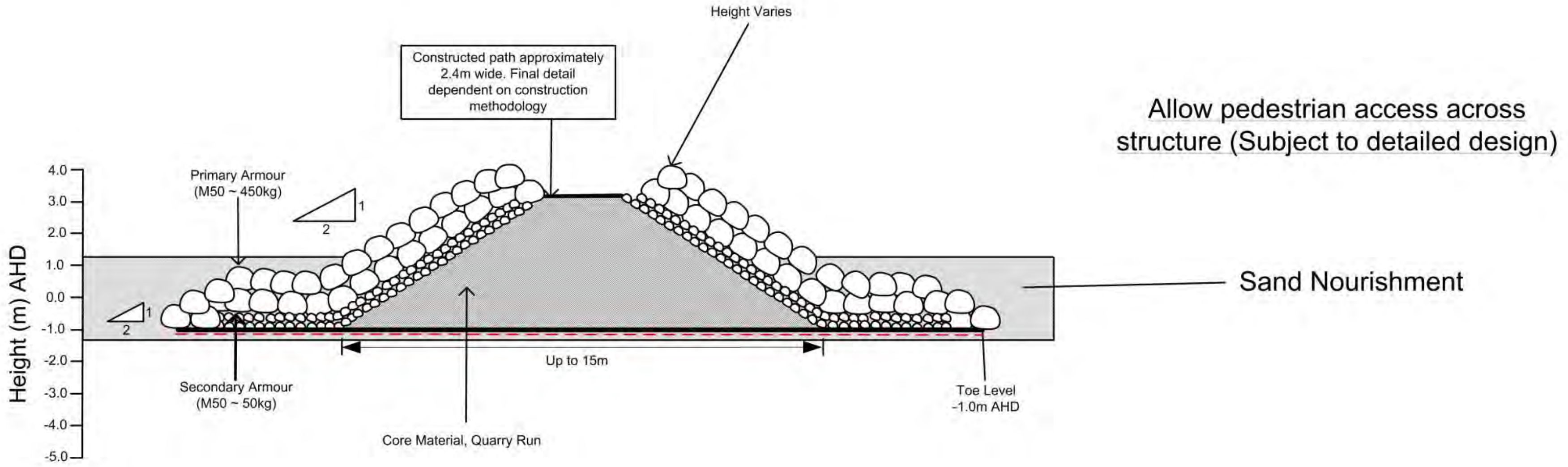

Figure 33(b) Scheme 2, Precinct 5: Cross Section – Proposed Groyne

Sandy Point/Conroy Park Foreshore Erosion and Management Plan

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Revision	A
Drawn	BC
Approved	DW

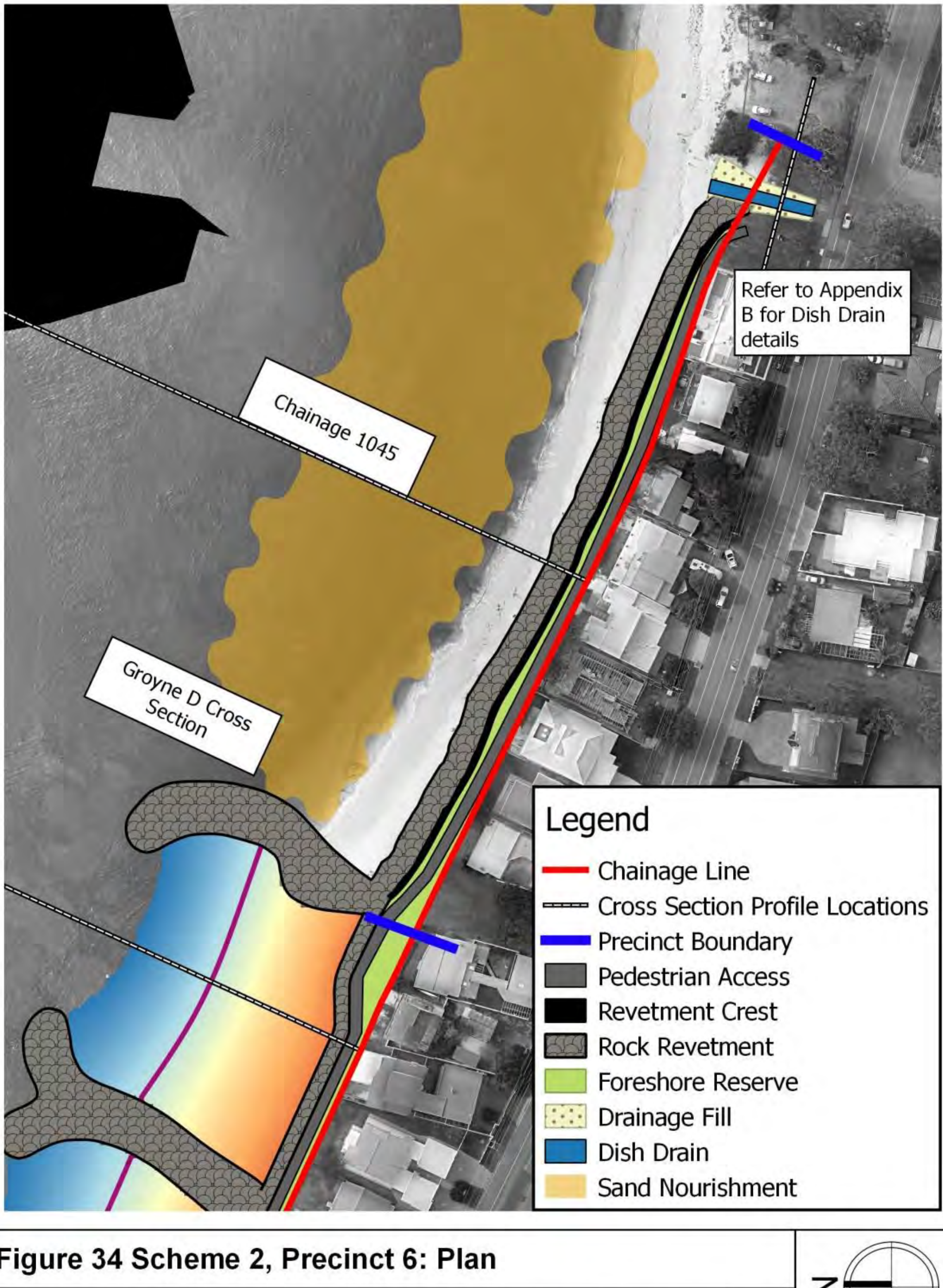

Figure 34 Scheme 2, Precinct 6: Plan

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

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Environmental Consultants

Revision	A
Drawn	BC
Approved	DW

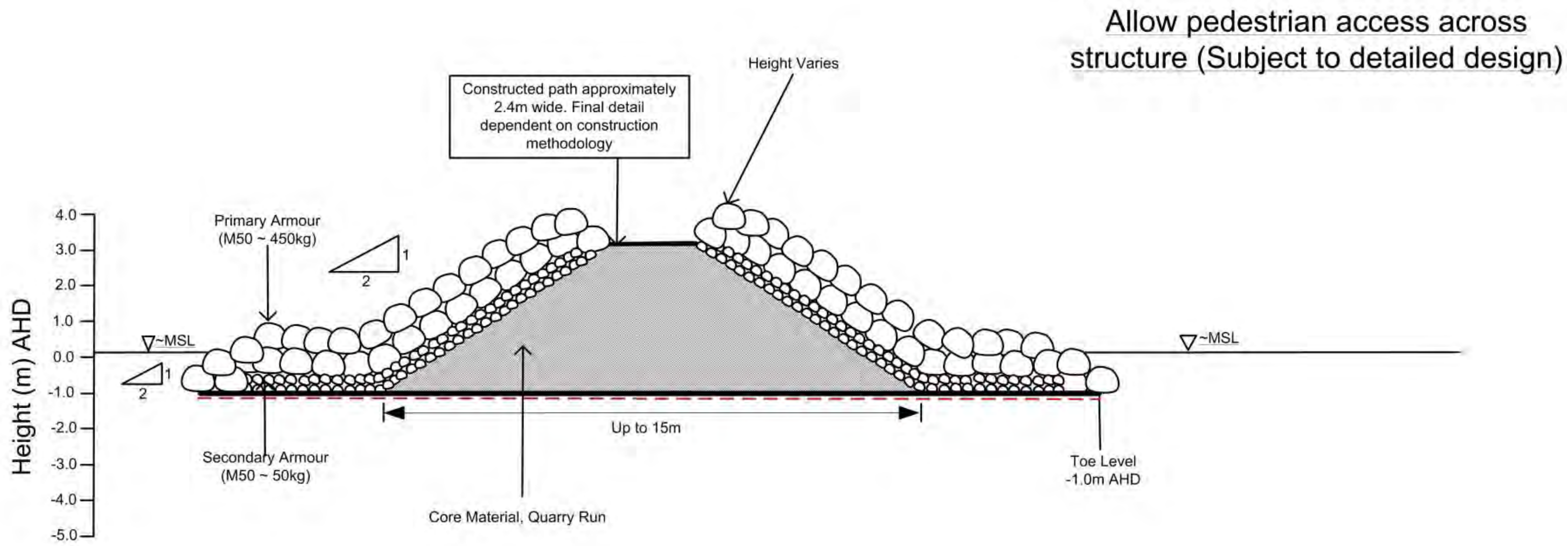

Figure 35 Scheme 2, Precinct 6: Profiles – Groyne D

Sandy Point/Conroy Park Foreshore Erosion and Management Plan

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Revision	A
Drawn	BC
Approved	DW

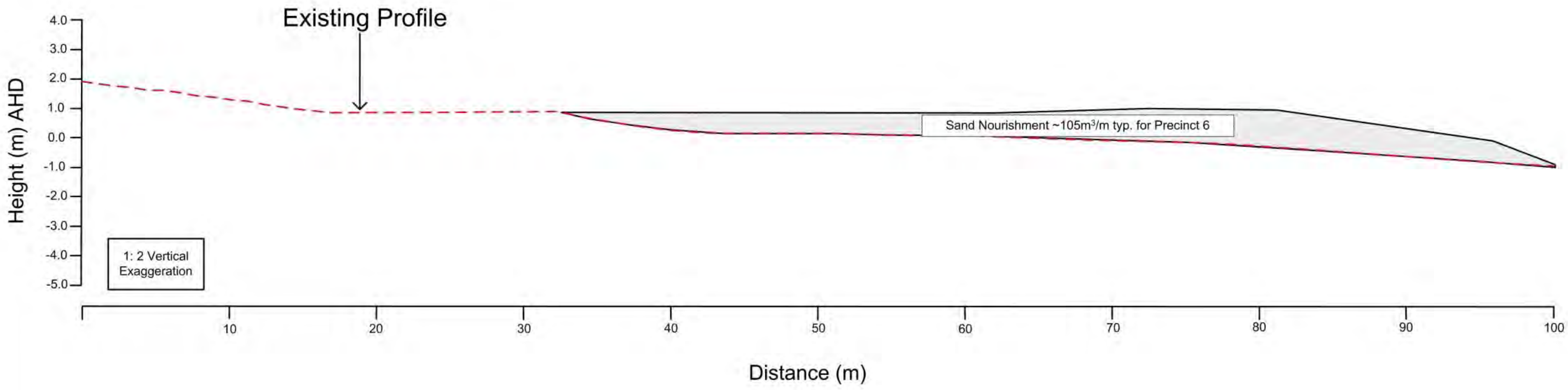

Figure 36 Scheme 2, Precinct 6: Profile 1045m

Sandy Point/Conroy Park Foreshore Erosion and Management Plan

Whitehead & Associates Environmental Consultants	Cross sections are conceptual, for costing and visualisation purposes only, and are not for construction. Distances along the cross sections are measured in an offshore direction from the main chainage line, which is shown on the corresponding plan.	Revision	A
		Drawn	BC
		Approved	DW

6.2.3 Scheme 3

Table 7 Scheme 3 Presentation

Scheme 3		
Precinct and Details	**Figures**	**Notes**
Precinct 1: Plan	Figure 37	Sand is retained within Precinct 1. A 60m groyne is constructed across the beach in the vicinity of the existing stormwater discharge. This groyne serves two purposes, to convey the stormwater line from the back beach area to deeper water, so that stormwater flows are less likely to scour sand from the beach and to help maintain beach width along the eastern end of Corlette Beach (fronting Conroy Park). However, this groyne will not be sufficient to completely stabilise the beach fronting Conroy Park and periodic maintenance of the beach sand to the east would be required. Two gross pollutant traps are included in this option.
Precinct 1: Profiles	Figure 38 Figure 39	The beach profiles remain as they are. However, construction of the groyne will cause some re-alignment of the beach. In the absence of the stormwater outfalls next to The Anchorage being extended, periodic maintenance to ensure they remain clear would be required.
Precinct 2: Plan	Figure 40	Here the desired beach profile is achieved through importing sand. Comparison of costs between dredging the flood tide delta and trucking sand in from a local quarry indicates that dredging is around 3 times as cost effective. However, there is uncertainty as to whether such dredging would be allowed. Dredging is physically achievable, and was previously undertaken to form the platform for The Anchorage in the early 1990's. The proposed nourishment would increase beach width at mid-tide from zero at the present time, to around 30-35 metres when fully nourished. Nourishment activities would normally occur every 5-10 years or more frequently depending on weather conditions.
Precinct 2: Profiles	Figure 41	The desired beach profiles are identical to those for the other two schemes.

Scheme 3

Precinct and Details	Figures	Notes
Precinct 3: Plan	Figure 42	This Precinct 3 option is similar to that for Scheme 2, with addition of two artificial headlands, or "fishtail groynes" which would aim to retain two pocket beaches. The groynes extend to the existing seagrass edge to avoid the smothering of seagrasses during construction. The fishtail ends act to help anchor the beach on both the upstream and downstream sides of the structure. It is expected that some additional habitat suitable for seagrass could be created within the bays. However, with the existing seagrass constraint adopted, it is unlikely that the headlands/groynes (as shown) will completely stabilise the beaches. Period renourishment would still be required.
Precinct 3: Profiles	Figure 43 Figure 44	Sand nourishment profiles would be identical to those for the other two schemes. The groyne and headland cross section is similar to that provided in Precinct 1, except that the side slopes are set at 1 in 2, to account for the additional wave exposure in this location.
Precinct 4: Plan	Figure 45	Precinct 4 is effectively the same as for Scheme 2, except that nourishment sand is placed between Groynes A and B.
Precinct 4: Profiles	Figure 46	The nourished profile extends from 2.0m AHD down to -1.0m AHD at a placement slope of around 1 in 10.
Precinct 5: Plan	Figure 47	The option for Precinct 5 is most similar to that proposed for Scheme 1, except that reclamation is minimised and the revetment follows the existing alignment reasonably closely. Instead of having a footpath behind the crest, a piered footbridge is carried around the front of the revetment.
Precinct 5: Profiles	Figure 48	The profiles are very similar to those for Scheme 1, with the exception that filling is minimised and a footbridge is provided around the front of the structure. All boat ramps would need to be demolished.
Precinct 6: Plan	Figure 49	This option for precinct 6 is very similar to that for Scheme 1, with existing revetment and boat ramps demolished and reconstructed on (almost) the existing alignment to an engineered standard. The eastern stormwater crossing is to be formalised by filling and construction of a dish drain with an infiltration trench.

Scheme 3		
Precinct and Details	**Figures**	**Notes**
Precinct 6: Profiles	Figure 50	Provision is made for installation of a wave deflecting barrier in future (as opposed to raising the revetment). The difference is minor in upfront capital expenditure, but affects the location of the public access way and visual impact of the option in future.

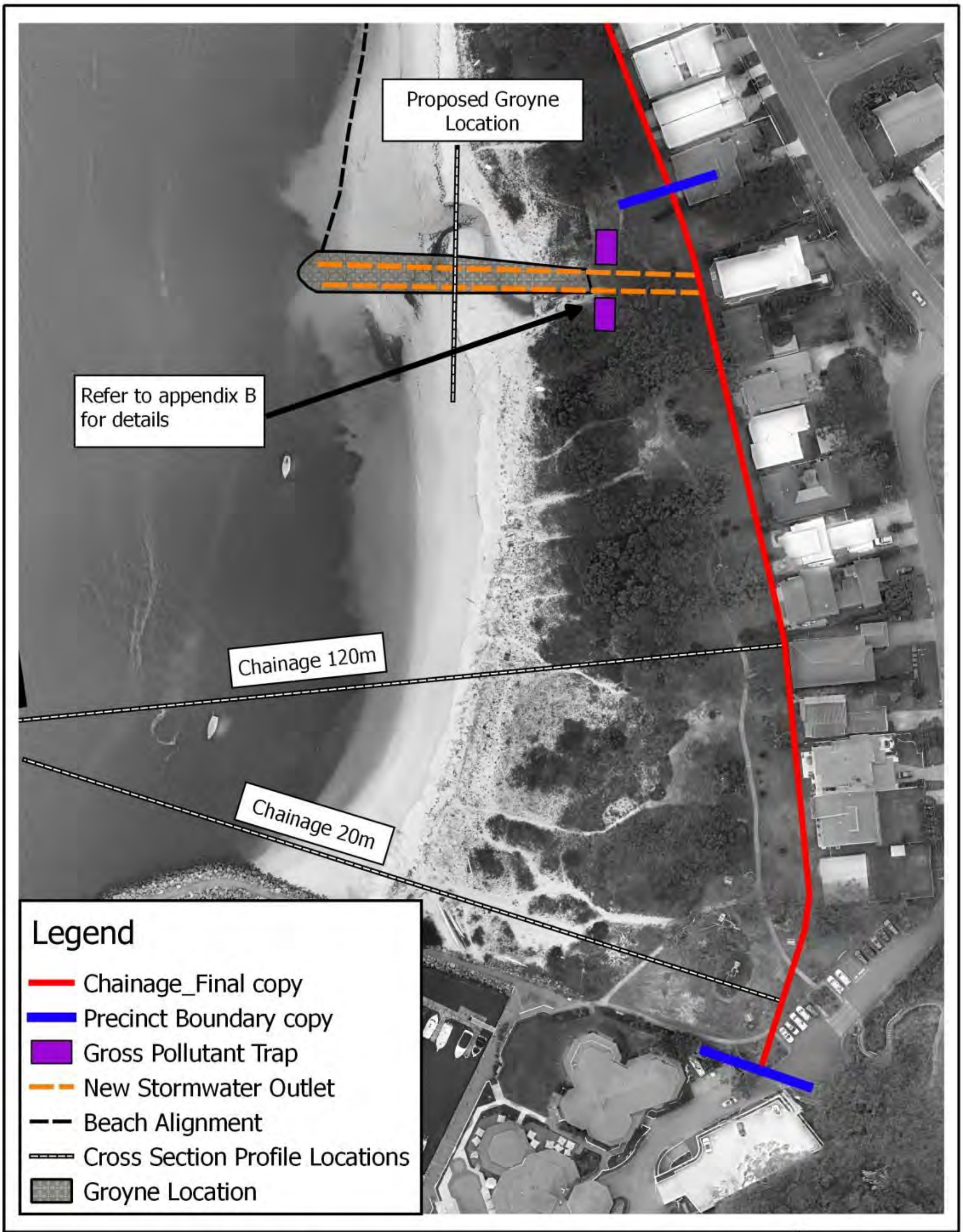

Figure 37 Scheme 3, Precinct 1: Plan

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

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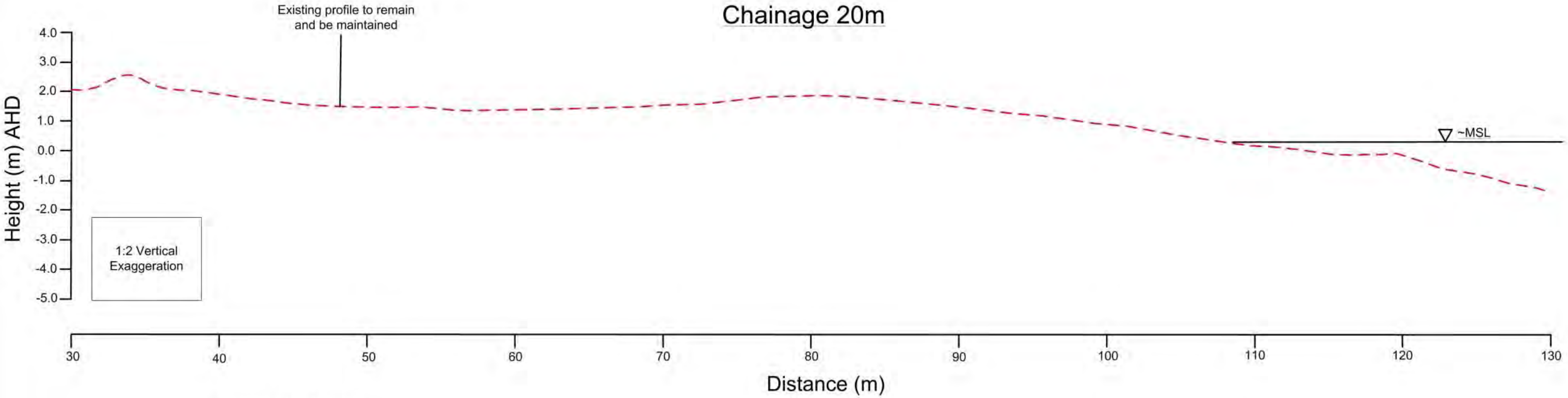
Revision	A
Drawn	BC
Approved	DW



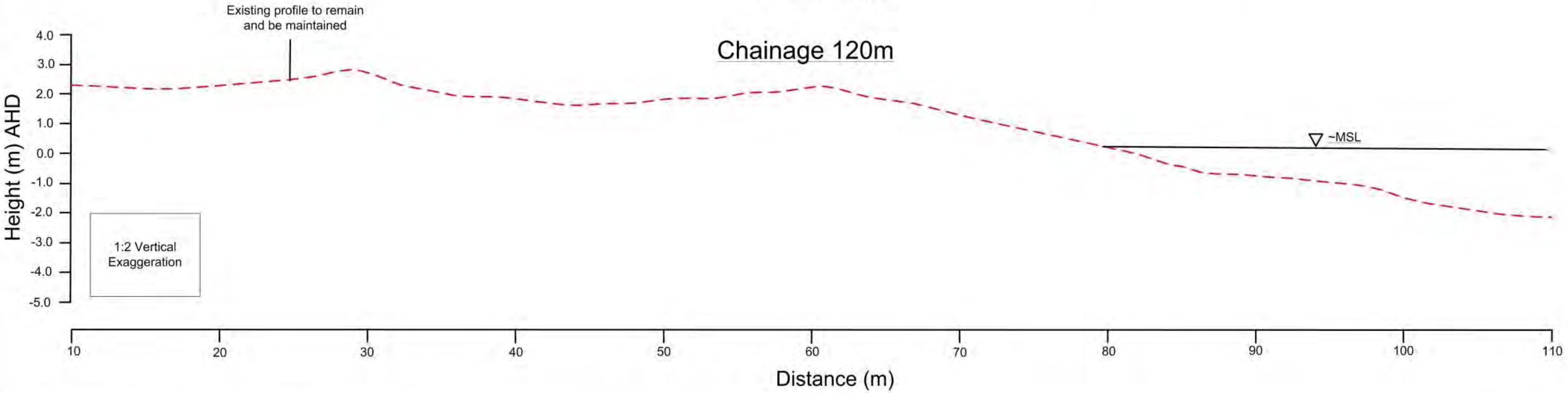


Figure 38 Scheme 3, Precinct 1: Profiles - Chainages 20 and 120m

Sandy Point/Conroy Park Foreshore Erosion and Management Plan

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Revision	A
Drawn	BC
Approved	DW

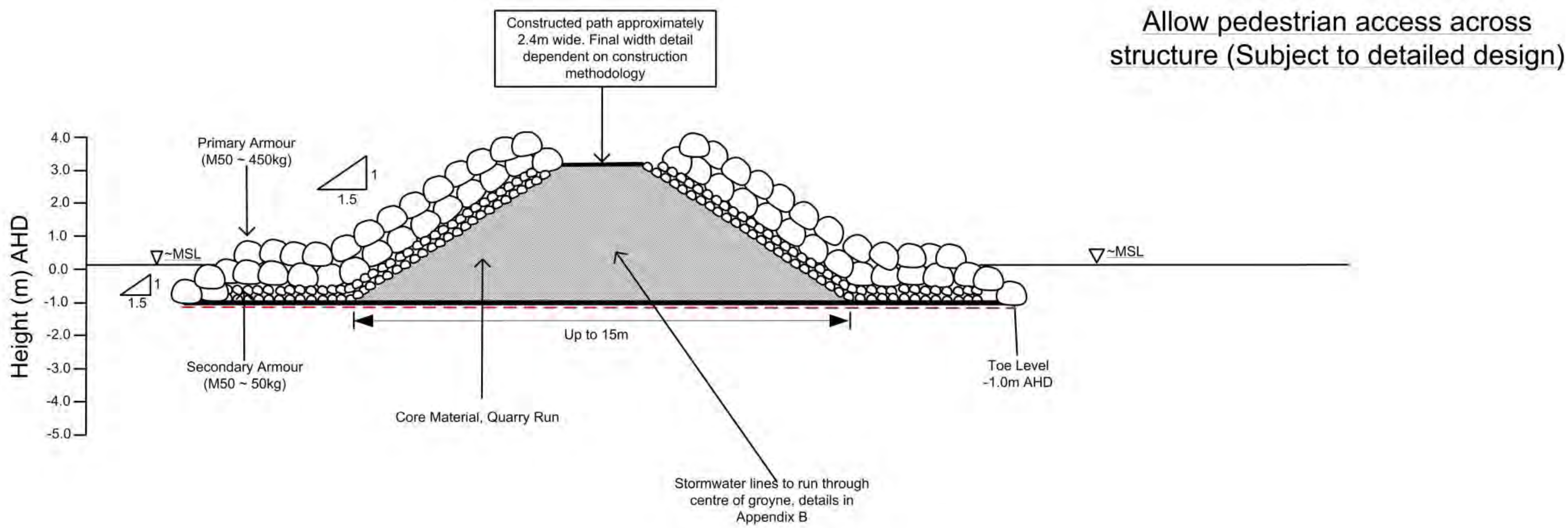

Figure 39 Scheme 3, Precinct 1: Proposed Groyne Cross Section

Sandy Point/Conroy Park Foreshore Erosion and Management Plan

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Revision	A
Drawn	BC
Approved	DW

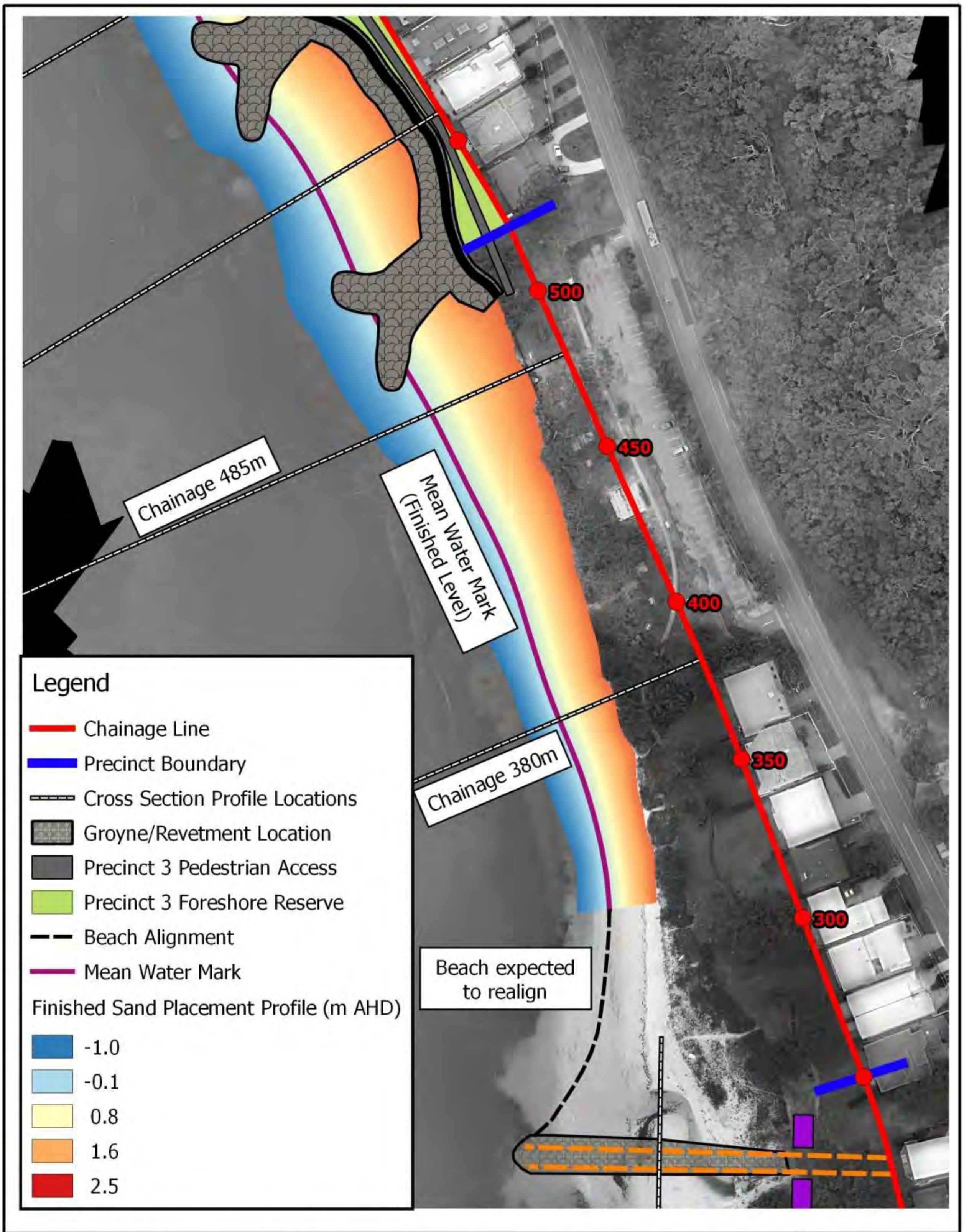

Figure 40 Scheme 3, Precinct 2: Plan

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

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Revision	A
Drawn	BC
Approved	DW

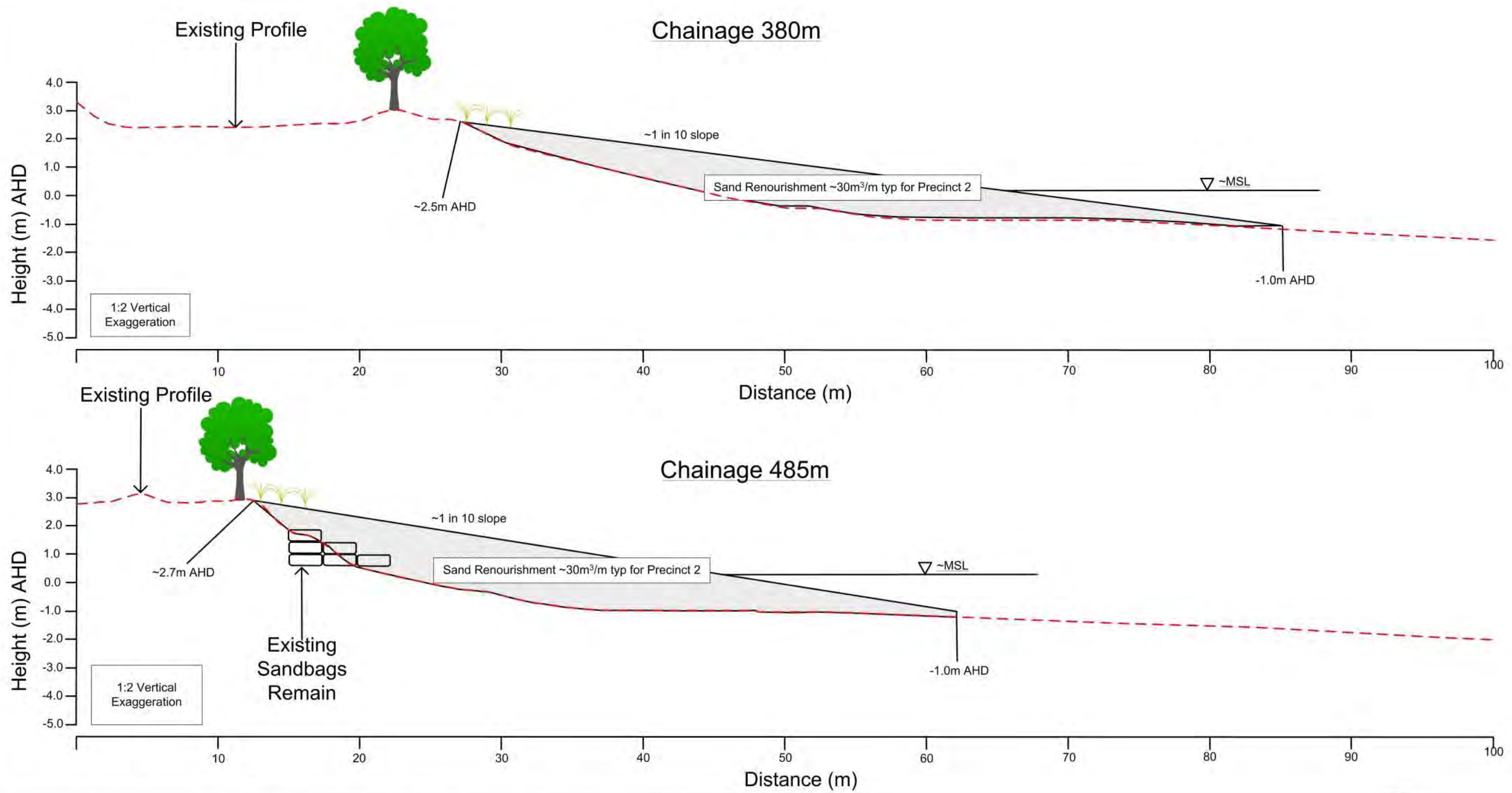

Figure 41 Scheme 3, Precinct 2: Profiles – Chainages 380 and 485

Sandy Point/Conroy Park Foreshore Erosion and Management Plan

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Revision	A
Drawn	BC
Approved	DW

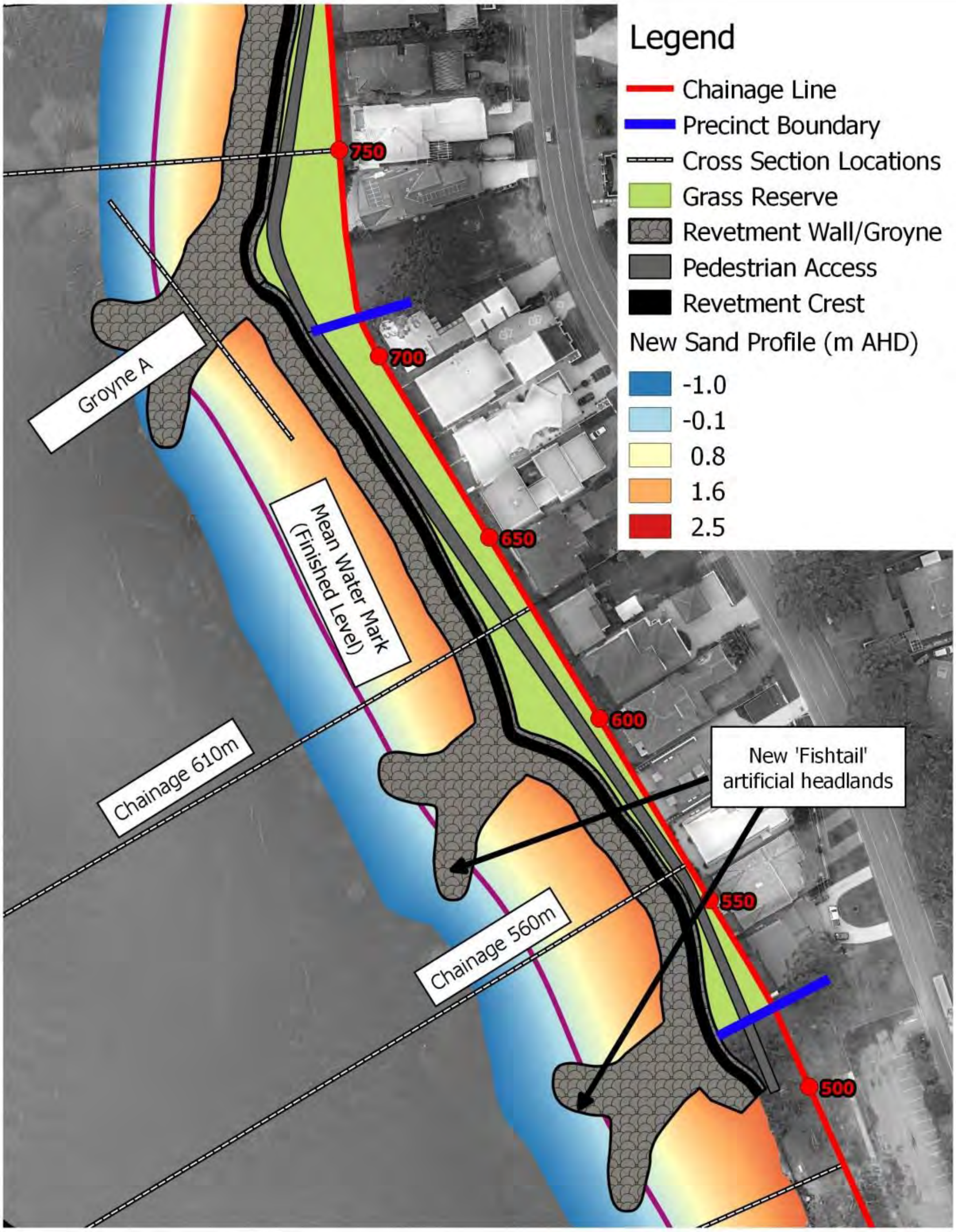

Figure 42 Scheme 3, Precinct 3: Plan

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

N

Whitehead & Associates
Environmental Consultants

0 20 40 60 m
(Approx Scale)

Revision	A
Drawn	BC
Approved	DW

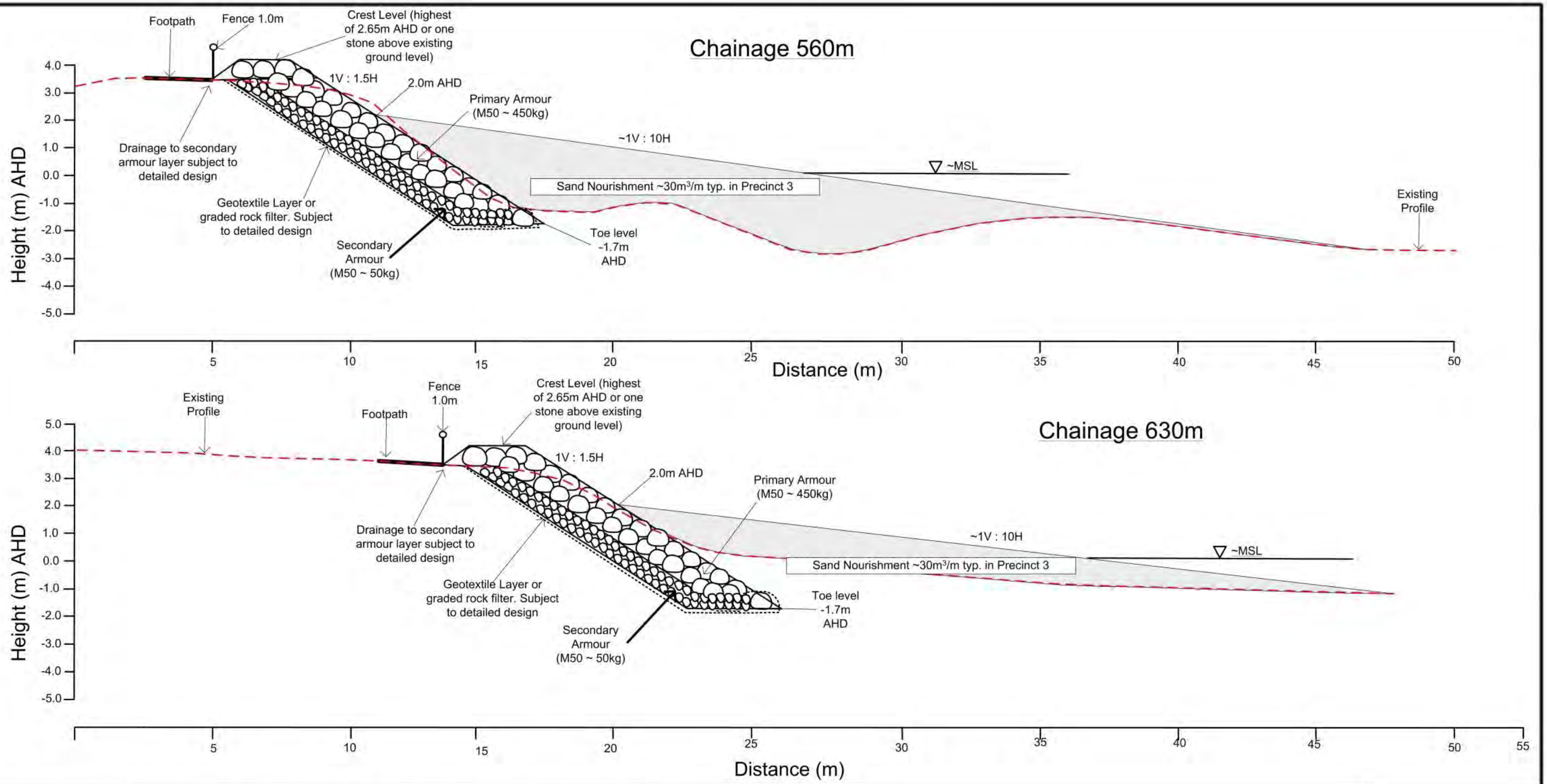

Figure 43 Scheme 3, Precinct 3: Profiles - Chainages 560 and 630m

Sandy Point/Conroy Park Foreshore Erosion and Management Plan

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Revision	A
Drawn	BC
Approved	DW

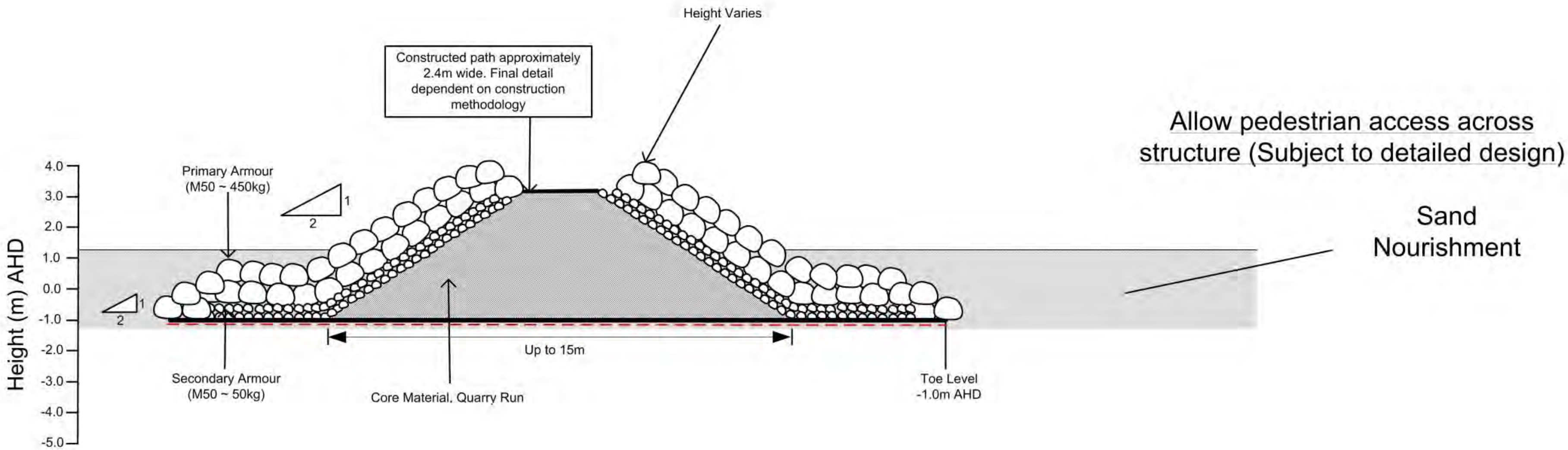

Figure 44 Scheme 3, Precinct 3: Cross Section – Groyne A

Sandy Point/Conroy Park Foreshore Erosion and Management Plan

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Approved	DW

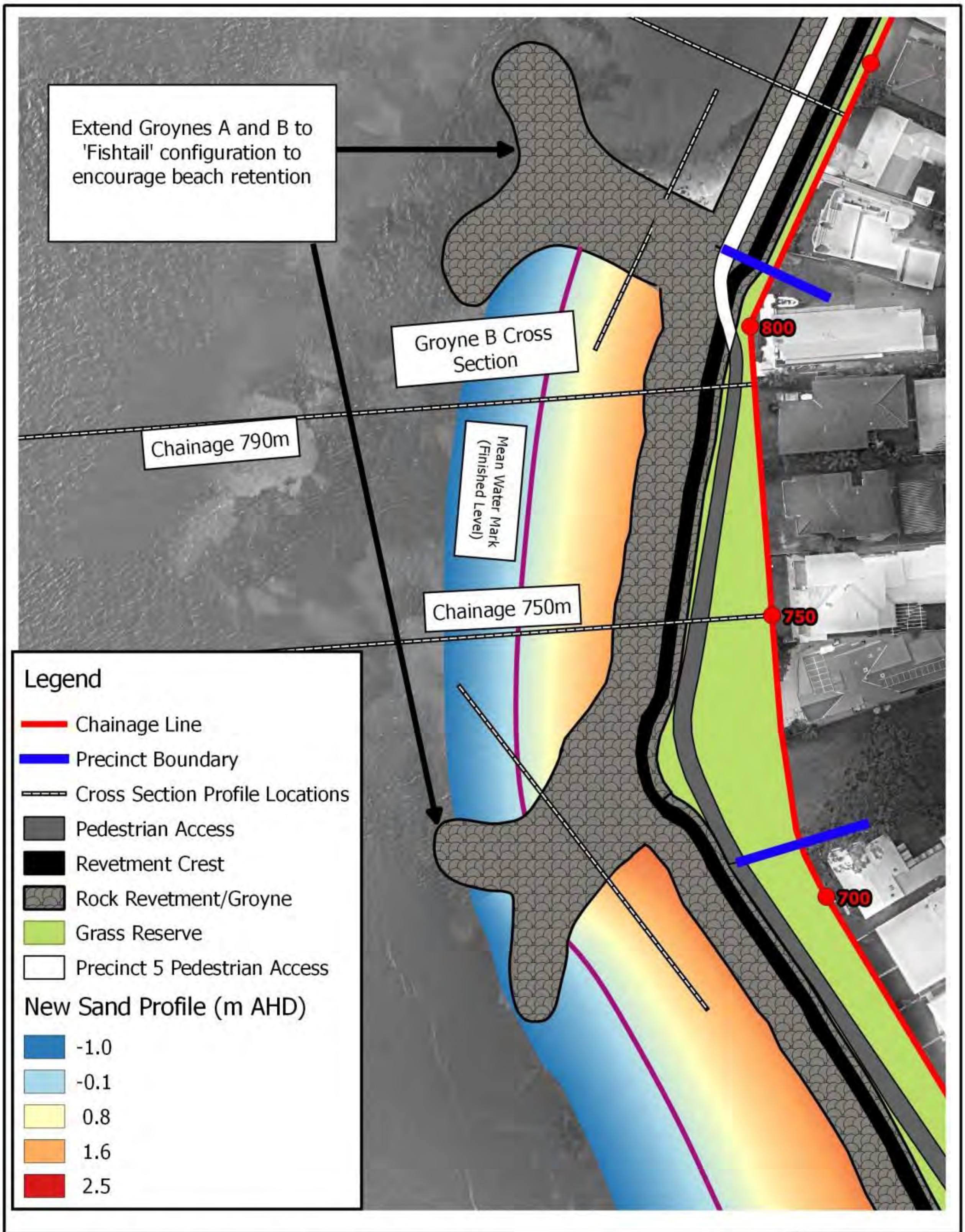

Figure 45 Scheme 3, Precinct 4: Plan

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

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Revision	A
Drawn	BC
Approved	DW

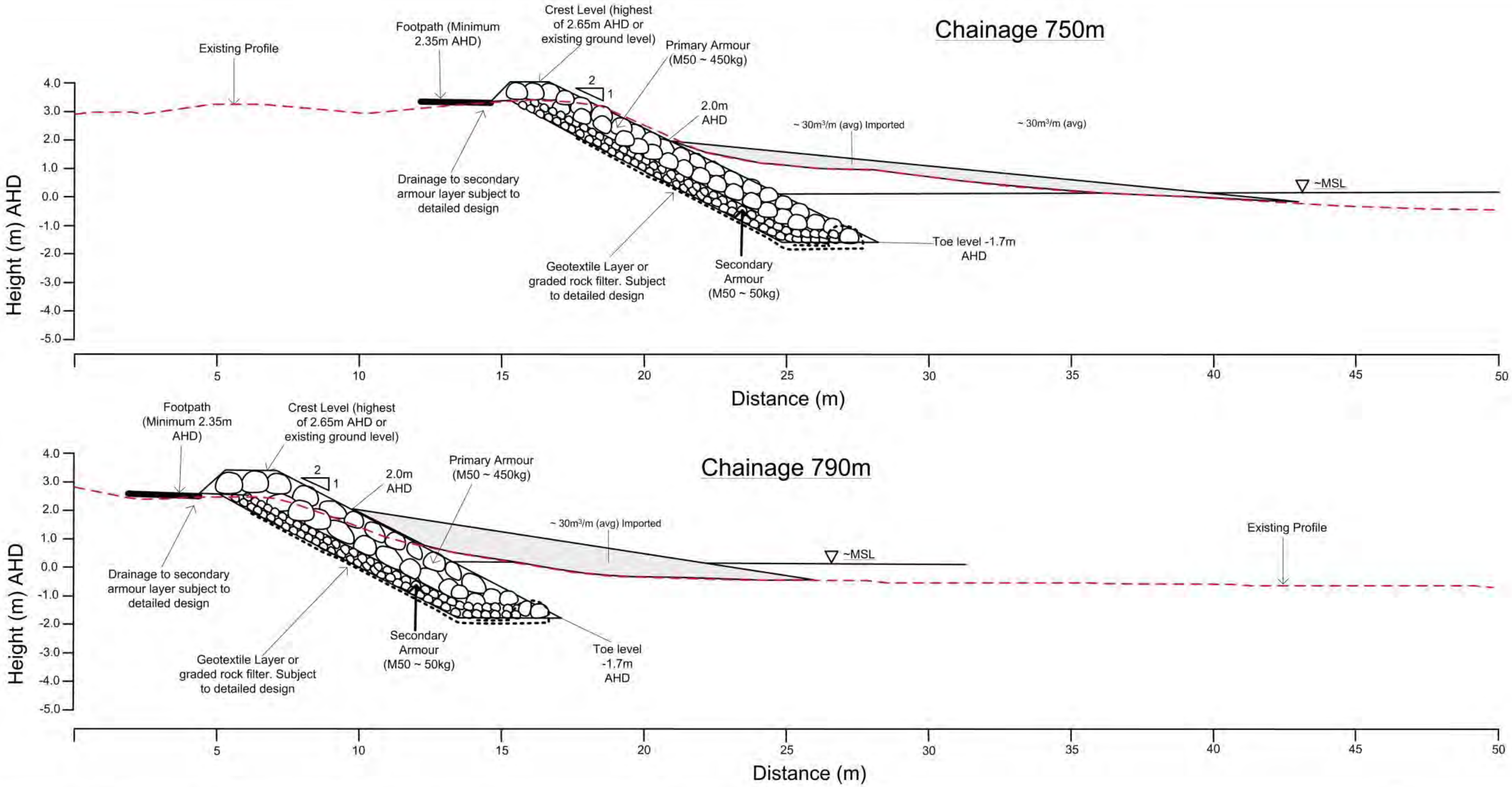

Figure 46 Scheme 3, Precinct 4: Profiles - Chainages 750 and 790m

Sandy Point/Conroy Park Foreshore Erosion and Management Plan

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Drawn	BC
Approved	DW

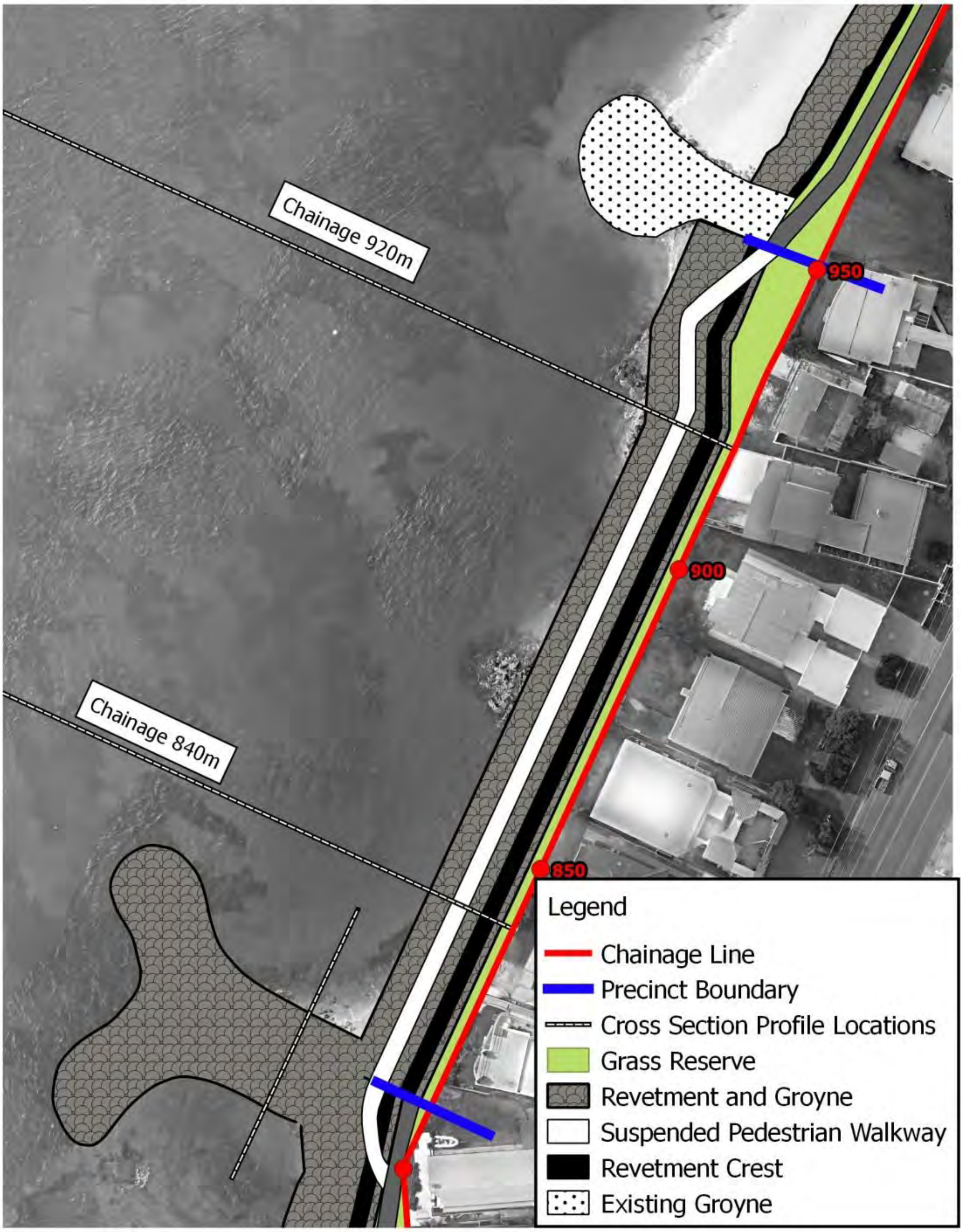


Figure 47 Scheme 3, Precinct 5: Plan

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

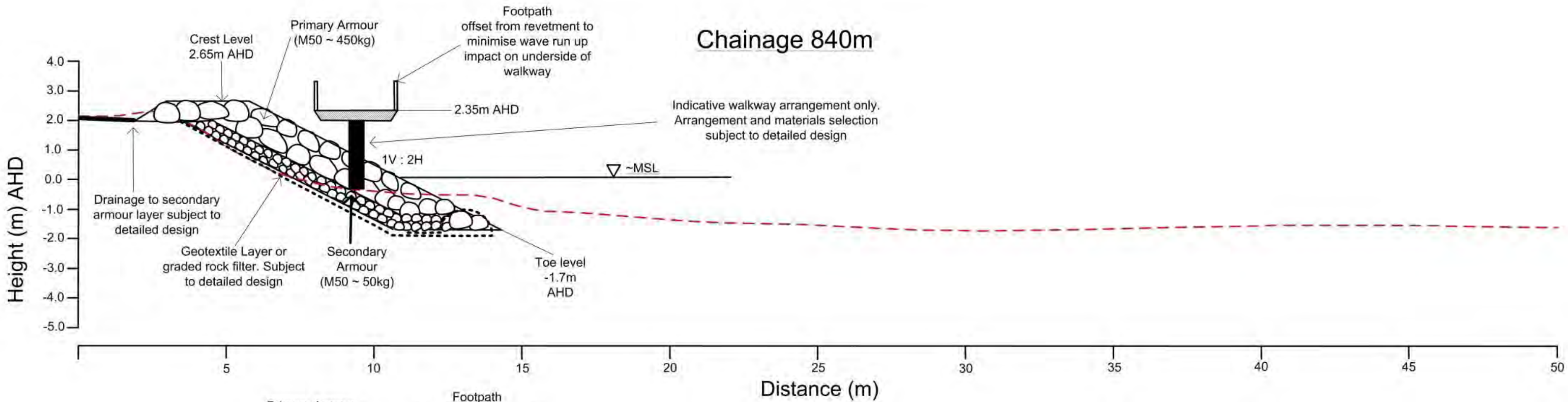
N

Whitehead & Associates
Environmental Consultants

0 10 20 30 40 50 m

(Approx Scale)

Revision	A
Drawn	BC
Approved	DW



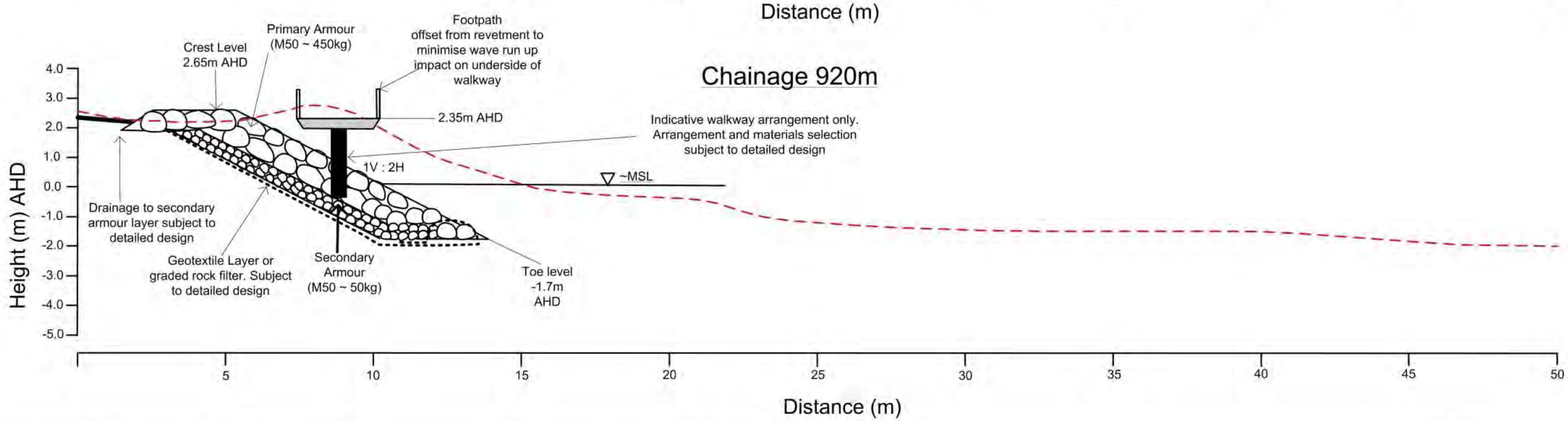


Figure 48 Scheme 3, Precinct 5: Profiles - Chainages 840 and 920m

Sandy Point/Conroy Park Foreshore Erosion and Management Plan

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Approved	DW

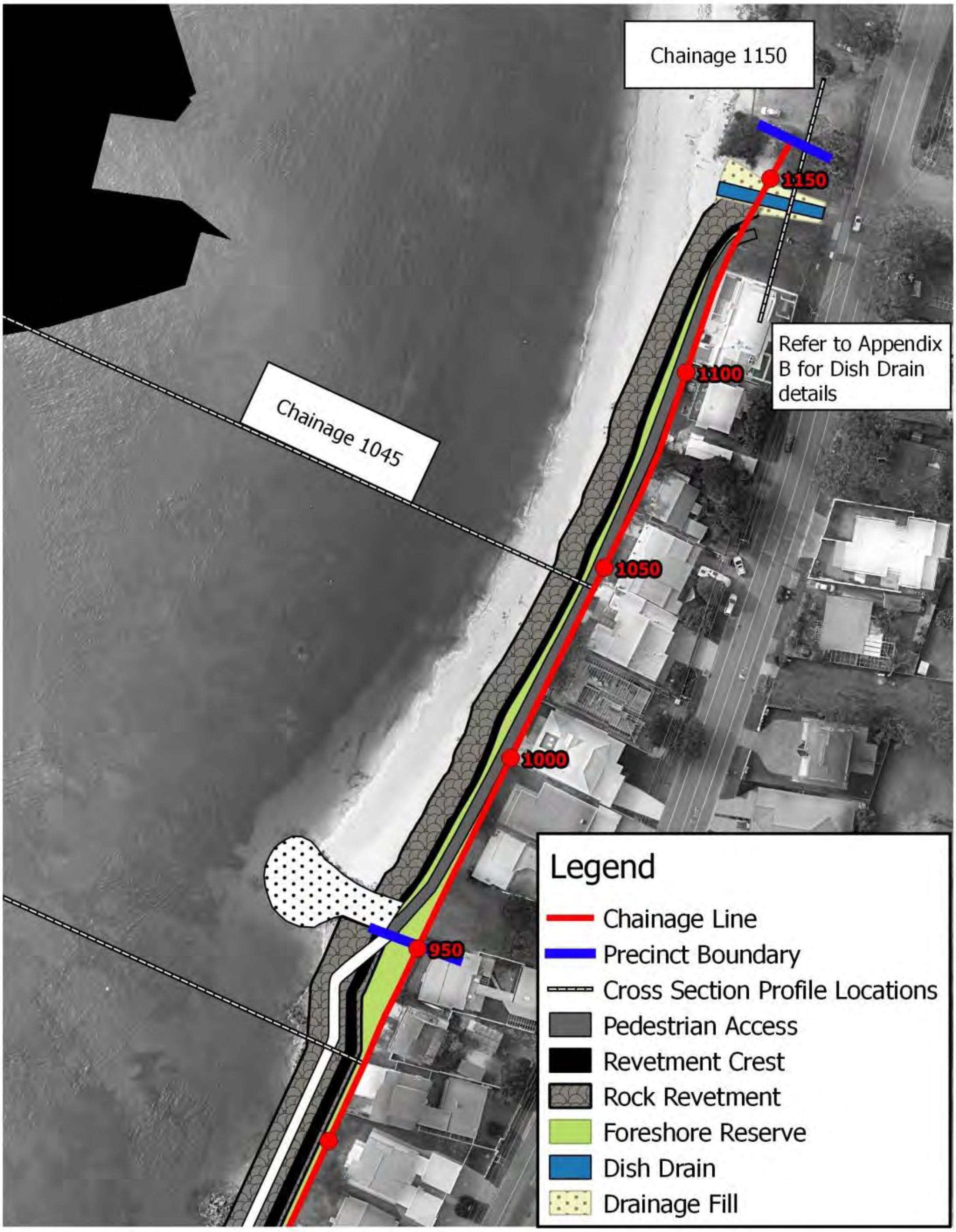

Figure 49 Scheme 3, Precinct 6: Plan

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

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Revision	A
Drawn	BC
Approved	DW

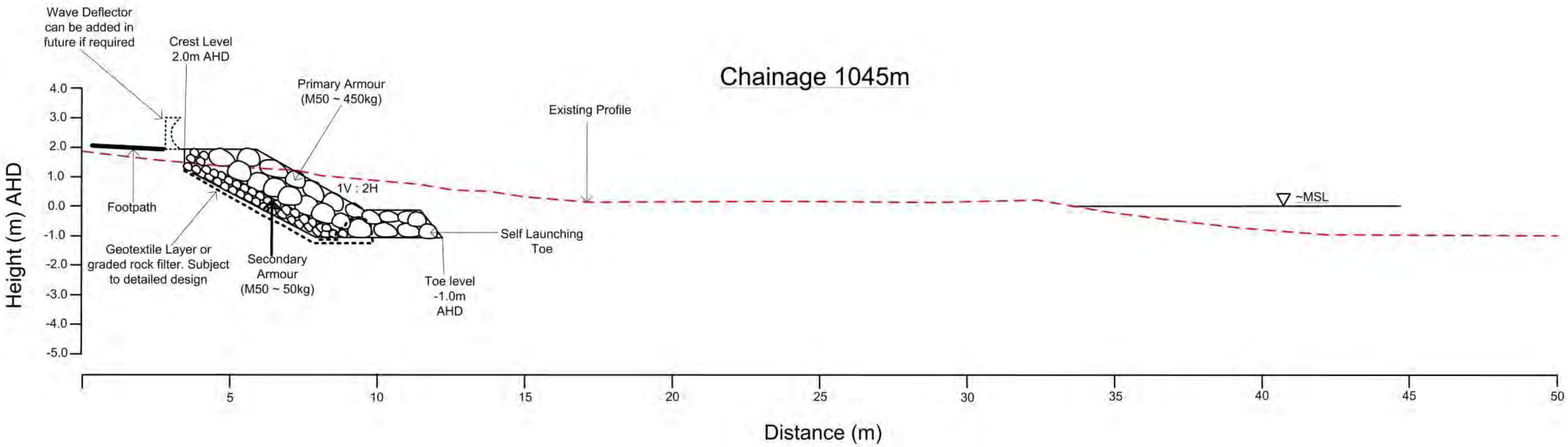

Figure 50 Scheme 3, Precinct 6: Profile at Chainage 1045m

Sandy Point/Conroy Park Foreshore Erosion and Management Plan

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Drawn	BC
Approved	DW

6.3 Cost Estimates for Presented Options

Cost estimates for the conceptual designs have been prepared. Details are provided in Appendix H, but a summary is provided in Table 8. The base estimated values have been adjusted upwards by a contingency amount of 20% and for inflation to place the estimates at the end of 2015. The methods used to estimate quantities are based on conceptual cross sections and modifications at detailed design stage, and changes to the economic situation prior to construction means that these estimates must be considered as preliminary, but reasonably indicative. The cost for additional investigation, detailed design and environmental impact assessment activities has not been included in these estimates, although a common rule of thumb would place these activities at somewhere around 10% of the capital cost.

Table 8 Preliminary Cost Estimates.
(Annualised Maintenance Cost Estimate in Brackets)

Location	Scheme 1	Scheme 2	Scheme 3
Precinct 1	$0.085M ($8,500)	$0.38M ($11,000)	$1.3M ($6,300)
Precinct 2	$0.51M ($500)	$0.26M ($21,000)	$0.26M ($21,000)
Precinct 3	$1.1M ($1,100)	$1.65M ($9,000)	$2.7M ($10,000)
Precinct 4	$0.43M ($430)	$0.91M ($1,000)	$0.94M ($4,300)
Precinct 5	1.3M ($1300)	$2.23M ($9,500)	$1.53M ($1,500)
Precinct 6	0.81M ($850)	$0.85M ($31,000)	$0.82M ($800)

7 Recommended Management Plan for Sandy Point / Conroy Park

7.1 Study Exhibition

The preceding chapters of this report were placed on public exhibition. Initially, the exhibition period was to be from 16th September to 15th October, 2015. Following requests from the community, this was extended by 3 weeks, and closed on 6th November. The community were invited to make formal, written submissions to Council during the exhibition period.

A public meeting was held at Corlette Hall in the evening of 23rd September. The meeting was well attended, by an estimated 60 community members. At the meeting, a presentation was made on the exhibited report and management options being considered, including a discussion of background processes and coastal engineering aspects of the design concepts. Following the presentation, questions were invited from the floor and answered by study team members and Council staff. Similarly, at the close of formal proceedings, attendees were free to clarify any remaining issues in a less formal, face to face manner.

7.2 Outcomes of Public Exhibition

The written submissions were collated and reviewed by Council staff. This was necessary, as many of the issues raised by the community dealt with administrative and/or legal issues relating to the implementation of different options. Specific comments on the technical content of the exhibited report were referred through to the study team.

A summary report discussing the community feedback has been prepared by Council staff. An early draft of the summary report was reviewed by the study team and contains our response to issues raised on the contents of the exhibited report. Necessary changes have been made to preceding chapters and appendices to this report, although none of the changes impact significantly on the findings of the report.

While reviewing the public exhibition outcomes, we have discussed preferred strategies with Council staff. The desires of the community, likely funding constraints and other practicalities have been considered in selecting the preferred strategy for each precinct outlined below.

7.3 Discussion of Preferred Strategy by Precinct

7.3.1 Precincts 1 and 2.

The preferred option involved removing sand from Precinct 1, including sand offshore of the main stormwater outlet, and relocating it to Conroy Park. The final intended beach plan alignment would be achieved by removing around half of the beach width that has accumulated adjacent to the Anchorage since its construction in the early 1990’s.

Since the construction of The Anchorage, as predicted a wide beach accreted adjacent to the eastern breakwater. While conditions of consent for that development allowed for the periodic removal of sand from this area, it is clear that there is strong support from the public in retaining the beach amenity that has formed there.

However, the volume of sand accretion in this area is now affecting the operation of stormwater outlets adjacent to the eastern breakwater and if not addressed may result in increasing siltation within the harbour entrance.

A balanced approach which seeks to relocate around half of this sand is prudent. This will both clear the stormwater lines adjacent to the breakwall and retain some of the beach width that has accreted there. However, this will have the following impact on the original design intent for nourishment works fronting Conroy Park:

- Around 10,000 – 15,000 m^3 of sand would need to be moved (instead of 20,000 - 25,000m^3)
- The designed nourished dry beach width at mid-tide would reduce from around 30-35m (at present) to around 15-20 metres adjacent to The Anchorage harbour wall following sand removal;
- The expected frequency of re-nourishment required in front of Conroy Park would approximately double (i.e. from around once every 7 to 10 years, to around once every 3 to 5 years, although the expected volume requiring relocation would be approximately halved; and

There would be less of a buffer for the beach at Conroy Park to withstand extreme storms, increasing the likelihood of full erosion of the beach (i.e. back to its present location) during stormy conditions. Terminal protection for Conroy Park Reserve will be provided by the ongoing maintenance, and extension if necessary, of existing geotextile containers along its length. If combined with sand nourishment this option is provides the desired aesthetic and amenity outcome.There is a significant positive benefit arising from placing smaller nourishment volumes more frequently. The placement of a larger volume of sand on existing seagrass beds would directly smother the present landward margins of the seagrass. We expect that any direct loss of seagrass would be offset eventually by the colonisation of areas deepened by the removal of sand from next to The Anchorage and from the deposition fan immediately offshore of stormwater Outlet 3.

Detailed design will need to consider how placement of the smaller volume could be optimised both from a practical point of view and to minimise direct seagrass loss. For example, placing the bulk of the sand in front of Precinct 3 at a steeper slope may be advantageous, providing maximum benefit to Conroy Park over the medium term while reducing direct impacts on nearby seagrass beds.

The carriage of the stormwater line (Outlet 3) across Corlette Beach and construction of gross pollutant traps is recommended. However, there is a desire to minimise the scale of the construction to avoid impacts on seagrasses and to reduce costs and visual impact. The primary purpose of any groyne would be for conveyance of stormwater while preventing the wash out of sand from the beach face into the nearshore zone. To do this the groyne has to extend to a suitable depth.

We recommend that design and construction of this outlet extension be delayed for a number of years while initial nourishment activities are undertaken, and the response of the beach is monitored to verify the expected behaviour and optimise subsequent design. We recommend that beach survey be undertaken on a 3 monthly basis, with particular focus on the area near the outlet to determine the active water depth in this location. The depth to which the groyne should be extended may then be determined

A secondary benefit arising from the construction of the groyne would be the retention of sand at a location closer to Conroy Park. While it is not expected that the groyne would markedly affect present day erosion rates in front of Conroy Park, sand relocation activities would, at least in part, access sand from the groyne location eastwards to Conroy Park.

Depending on the length of the groyne finally determined, it is possible that circulation patterns and beach alignment between the groyne and The Anchorage would be modified. Eventually, this is likely to evolve into a Beach shape similar to that at present, although some enhanced erosion on the down drift side of the groyne would be expected. Some minor nourishment to rectify this erosion, as required, may be desirable. We expect that the east to west transport of seagrass wrack would continue in a manner similar to that with the present beach alignment adjacent to the Anchorage and that the frequency of seagrass wrack accumulation along this beach would not change significantly.

7.3.2 Precinct 3

The treatment outlined under Scheme 1 is recommended, including nourishment using sand from adjacent to the Anchorage (see preceding section), battering back of the foreshore and construction of a foreshore revetment to coastal engineering standards along with a shared pathway.

It appears likely that construction/upgrade of the revetment may be delayed, due to the cost associated with it. However, public safety in this area has been highlighted previously, and we recommend that an appropriate fence and signage be constructed to separate pedestrian activity away from the crest of the foreshore, which is steep, high and prone to collapse in some areas. Minor repairs (maintenance) may be considered from time to time before a properly engineered solution can be implemented.

7.3.3 Precinct 4

The treatment under Scheme 1 is recommended, involving revetment reconstruction. Briefly, this would involve the construction of a new revetment along the present alignment, with the exception of the eastern end, where some reclamation may be required to allow the space needed for construction of a shared pathway.

Existing foreshore access points are to be consolidated, and the construction of public stair accesses across the revetment to the beach should be considered as part of investigations and consultation undertaken with the community during the detailed design stage.

7.3.4 Precinct 5

The treatment under Scheme 1 is recommended, namely the reconstruction of a robust revetment with some realignment. This will require reclamation in some areas. All unauthorised access ways and boat ramps should be removed from this area to ensure integrity of the revetment, minimising overtopping by waves and inundation/damage to properties. No work is proposed for the existing groynes, and twin gross pollutant traps are recommended for Outlet 2. Public space seaward of the development in this area is at a premium, and the width of pathway provided will affect the costs associated with any reclamation works. The design here allows for a 2.4m wide path, although paths of 2.5m or wider may be considered more appropriate if a shared pathway is to be provided.

7.3.5 Precinct 6

The treatment under Scheme 1 is recommended. This involves removal of unauthorised boat ramps and access points, and consolidation of foreshore access. A low revetment crest is proposed, with capacity to be raised in future to accommodate sea level rise. No work is proposed to the existing groyne. However, this strategy differs from Scheme 1 in that an infiltration trench at Outlet 1 is to be considered further, and could potentially be implemented separately to the remainder of works proposed for this precinct.

It appears likely that Precinct 6 works will have the lowest priority, based on existing conditions. However, existing unauthorised access ways and boat ramps do hinder the movement of less able pedestrians through this area. Temporary works to demolish those structures and fill the depressions formed by boat ramp construction could be considered as a preliminary measure, although this would involve extra costs. The existing structures could be broken up and stockpiled for re-use as secondary armour in a temporary structure. The low points along the foreshore could then be filled and compacted with clean, imported fill. Primary armour of the size recommended for the final structure could then be used to line the seaward face to fill the gaps in the revetment. The reserve could then be grassed. This temporary approach would have the following benefits:

- Primary and secondary armour could be reused in the final structure, once it is constructed;
- The foreshore would remain accessible and would provide better service than at present; and
- The area would become more accessible and safer for the general public.

This preliminary work would not be wasted, as most of it is required for implementation of the preferred strategy. However, the foreshore would still not provide the full protection of a properly engineered structure and monitoring is recommended to assess performance and the need for ongoing repairs/maintenance.

7.4 Implementation

The recommended time frame for completion and expected costs for detailed design (including detailed design, contract preparation and administration) and construction are outlined in Table 9. Nourishment in front of Conroy Park is prioritised first due to the benefit in protecting the park and relatively low costs. Priorities 2 and 3, dealing with Precincts 5 and 3 respectively, are also considered critical with regards to public safety and the protection of property.

Table 9 Recommended Staging and Expected Costs[6]

<table>
<tr><th>Priority</th><th>Works</th><th>Design Timing</th><th>Detailed Design Costs</th><th>Construction Timing</th><th>Construction Costs</th><th>Maintenance Cost (/annum)</th></tr>
<tr><td>1</td><td>Precinct 1 & 2 (Nourishment)</td><td>Complete</td><td>$15,000</td><td>Mid 2018-19</td><td>$0.06M</td><td>$10,000</td></tr>
<tr><td colspan="7">Description: Move sand from Precinct 1 (around 15,000m^3) and place in front of Precincts 2 (and 3). Restores beach width fronting Conroy Park and allows proper operation of Outlets 4 and 5 (adjacent to The Anchorage). Maintenance of geotextile sand bags.</td></tr>
<tr><td>2</td><td>Precinct 5</td><td>2019</td><td>$110,000[7]</td><td>2019-2020</td><td>$1.65M</td><td>$1,500</td></tr>
<tr><td colspan="7">Description: Construct robust revetment with some realignment to enable construction of a shared pathway. Install twin gross pollutant traps to Outlet 2. Determine foreshore access requirements in consultation with community.</td></tr>
<tr><td>3</td><td>Precinct 3 (Pedestrian Management)</td><td>2019</td><td>$5,000</td><td>2019</td><td>$0.06M</td><td>$5,000</td></tr>
<tr><td colspan="7">Description: Construct pathway and fence to divert pedestrians from the steep foreshore. Monitoring and maintenance required until full option is adopted (see below).</td></tr>
<tr><td>4</td><td>Precinct 4</td><td>2020</td><td>$50,000</td><td>2021</td><td>$0.43M</td><td>$1,000</td></tr>
<tr><td colspan="7">Description: Demolish foreshore protection and reconstruct revetment. Some reclamation required at eastern end (adjacent to Precinct 5). Consolidate foreshore accesses in consultation with community.</td></tr>
<tr><td>5</td><td>Precinct 1 (Stormwater)</td><td>2021</td><td>$30,000</td><td>2022 (or later)</td><td>$1.35M</td><td>$1,500</td></tr>
<tr><td colspan="7">Description: Construct Twin Gross Pollutant Traps and extend the stormwater line in the form of a groyne across Corlette Beach Construction to minimise the scale of the groyne wherever possible.</td></tr>
<tr><td>6</td><td>Precinct 3 (Revetment)</td><td>2023</td><td>$100,000</td><td>2024 (or later)</td><td>$1.00M</td><td>$1,000</td></tr>
<tr><td colspan="7">Description: Demolish existing structures, batter back foreshore and construct new revetment. Note that path and fencing will have been constructed as part of Priority 3.</td></tr>
<tr><td>7</td><td>Precinct 6[8]</td><td>As Required</td><td>$50,000</td><td>As Required</td><td>$0.83M</td><td>$1,000</td></tr>
<tr><td colspan="7">Description: Demolish existing structures and construct continuous revetment with appropriate pedestrian crossings. Construct dish drain and infiltration trench to outlet 1. Note that the dish drain is relatively cheap and could be constructed as a separable piece of work.</td></tr>
</table>

[6] Costs are approximate and based on the detailed estimates provided for the three schemes exhibited. Costs exclude GST but include a contingency of 20%. Costs relevant to late 2015/early 2016 and an allowance for inflation needs to be applied to future costs. All works are subject to the identification of a suitable funding source.

[7] This figures includes an allowance to complete a distributional and cost benefit analysis for all proposed rock revetment works under priority 2, 4, 6 and 7.

[8] Note that preliminary works to remove existing weak points (boat ramps, foreshore crossings) from this precinct could be undertaken initially, possibly in conjunction with the Precinct 5 construction. Refer to text.

Table 10 Implementation Details

Sand Nourishment			
Priority	**1**	**Comments**	**Actions for Implementation**
Land Ownership	Crown Land	To restores beach width and amenity fronting Conroy Park and allows proper operation of Outlets 4 and 5 (adjacent to the Anchorage).	Generation of detailed design. Surveyof the MHWM. Environmental assessment & relevant approvals. Explore long-term funding arrangements with the Anchorage Marina Complex leaseholders. Community Engagement Program. Establish a monitoring program. Maintenance program for sand nourishment and geotextile sand bags..
Lead Agency[9]	Port Stephens Council		
Stakeholders	Dept of Industry – Lands & Forestry, Dept of Primary Industries - Fisheries, Port Stephens – Great Lakes Marine Parks, Anchorage complex, community		
Community Engagement	Focus on rational, timing, expected impact and monitoring regime		
Revetment works			
Priority	**2, 4, 6 & 7**	**Comments**	**Actions for Implementation**
Land Ownership	Port Stephens Council & Crown Land	A similar implementation process will be followed for all revetment works. Implementation can be staged but design must be considered collectively It is recognised that there are public and private benefits to the proposed works. The degree of benefit varies depending on the precinct. Unauthorised structures in their current form reduce the integrity and effectiveness of the existing rock revetment.	Cost benefit and distributional analysis for all proposed rock revetment work Generation of detailed engineering designs including investigation of public access options Management of unauthorised structures. Community engagement program. Survey of the MHWM Environmental assessment Relevant approvals.
Lead Agency	Port Stephens Council		
Stakeholders	Dept of Industry – Lands & Forestry, Dept of Primary Industries - Fisheries, Port Stephens – Great Lakes Marine Parks, community & foreshore residents.		
Community Engagement	Design Stage – feedback on public access, & aesthetics Implementation – Information provision on timing and expected impacts.		

[9] Lead Agency refers to the group responsible for project management of the action.

Precinct 3 – Pedestrian Management			
Priority	**3**	**Comments**	**Actions for Implementation**
Land Ownership	Port Stephens Council	The focus of this work is access and signage. If structural works are required to the wall relevant approvals must be obtained.	Regular safety inspections of the area. Community engagement.
Lead Agency	Port Stephens Council		
Stakeholders	Community & foreshore residents		
Community Engagement	Provision of information regarding details of works.		
Precinct 1 - Stormwater			
Priority	**5**	**Comments**	**Actions for Implementation**
Land Ownership	Port Stephens Council & Crown Land	The behaviour of the beach in response to the sand nourishment program will be a leading factor in the refinement of the design of this structure.	Monitor beach behaviour post implementation of the sand nourishment program. Review concept design in light of monitoring results. Community and agency consultation. Detailed design Environmental assessment & relevant approvals
Lead Agency	Port Stephens Council		
Stakeholders	Dept of Industry – Lands & Forestry, Dept of Primary Industries - Fisheries, Port Stephens – Great Lakes Marine Parks, community.		
Community Engagement	Anchorage, surrounding residents & general community.		

7.4.1 Relevant Legislation and Approvals

Assessment of relevant legislation covering the potential impacts of the proposed activities and the permissibility of the actions will be made at the project management stage of all works. This will include but not be limited to *Environmental Planning and Assessment Act 1979, National Parks and Wildlife Act 1974, Threatened Species Conservation Act 1995, Fisheries Management Act 1994, NSW Heritage Act 1977, Noxious Weeds Act 1993, Water Management Act 2000, Marine Estate Management Act 2014* and the *Environmental Protection Biodiversity Conservation Act 1999.* This will also include an assessment of Aboriginal heritage and consideration of the *Native Title Act 1993* and the *Aboriginal Land Rights Act 1983*.

Crown Lands Act 1989

It will be necessary to clarify the position of the MHWM prior to any works proceeding as land ownership arrangements will underpin planning and approval pathways. Where proposed works, either in whole or in part, are located below the MHWM and within the Crown waterway (see Figure 2a), authorisation will required under the *Crown Land Management Act 2016*. If proposed works are to be located in Crown land / waterway, then development applications lodged under the Environmental Planning and Assessment Act 1979 may require land owner's consent from the department. In addition, an authorisation under Crown Land legislation will be required, should the development be approved. This authorisation may be in ther form of an easement or licence. Approvals will be subject to a range of considerations including potential impacts on the environment and coastal processes, beach amenity and public access. An appropriate approval pathway will be explored at the project management stage of implementation. Forward planning is required early in the project to determine the available options, whether there are any implications under the Native Title legislation and the *Aboriginal Land Rights Act 1983*, and allow for administration and processing.

Adequate lead time (at least six months) is required for the Department of Industry – Lands & Water o assess and issue authorisation (licence) works on Crown land. As per correspondence dated July 2018 this Department is not to be considered a potential funding partner for the actions in this CZMP.

7.4.2 Funding

The cost of coastal protection is extensive with the estimated total cost of the preferred works being in excess of $5,000,000. This is beyond the capacity for Council it fund itself. There is both public and private benefit to protecting this section of foreshore. The community consultation indicated that the loss of public access is one of the top three areas of concern for the community, indicating the high degree of public ownership and value placed on protecting the public access to the foreshore. However the significant private benefit of the works cannot be disregarded. Council should explore a beneficiary pays model. A distributional and cost benefit analysis will be undertaken for each of the priority actions to refine funding options. Internal funding of works will be prioritised within Councils Capital Works budget.

Council is eligible to seek funding under the NSW Coastal and Estuary Management Grant Programs, administered by the Office of Environmental and Heritage, for any actions listed in a certified Coastal Zone Management Plan or Program. A number of activities are eligible outside of certified plans which are listed by OEH. Council will investigate funding under all relevant government programs available. Given the long-term timeframe of this Plan it possible current government and non-government funding opportunities will change and new ones will become available.

Further investigation is recommended into the enforcement of the condition consent on the original approval for the Anchorage development regarding the transfer the sand accreting on the eastern side of the marina breakwall.

7.4.3 Community Engagement

Ongoing community engagement should continue through the detailed design and implementation phases of this plan. Information should be circulated prior to the implementation of the sand nourishment to manage community expectations; this should include design rational, implementation timing and expected behaviour of the surrounding beach.

Extensive community consultation will be required through the detailed design of each stage of the rock revetment. Primary points of concern previously raised by the community were foreshore and pedestrian access, safety, privacy and aesthetics.

A separate engagement program will be needed targetting foreshore residents in line with the cost benefit analyse of the works and to address the management unauthorised foreshore structures.

7.4.4 Monitoring

Integrated and specialized monitoring programs will need to be developed along with the detailed design for each action. This will include but not be limited too

- photos;
- detailed survey of the back beach and beach face out to at least the low tide mark;
- monitoring the impacts on seagrass and;
- monitoring of costs and maintenance activities.

Initial monitoring should occur monthly, following each significant storm or following any reports of significant changes.

The results of beach surveys will help refine the ongoing nourishment program and the inform the further investigation and detailed design of the carriage of the stormwater line (Outlet 3) across the beach

8 References

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Appendix A Coastal Processes Study

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Sandy Point/Conroy Park Coastal Process Study

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Disclaimer

The information contained in this report is based on independent research undertaken by David Wainwright of Whitehead & Associates Environmental Consultants Pty Ltd (W&A) and Doug Lord of Coastal Environment Pty. Ltd. To our knowledge, it does not contain any false, misleading or incomplete information. Recommendations are based on an appraisal of the site conditions subject to the limited scope and resources available for this project, and follow relevant industry standards. The conclusions made in this report are based on the information gained and the assumptions as outlined. The coastal environment is inherently variable, and the conclusions in this report have a limited lifespan.

Copyright Note

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1 Introduction

This report presents the findings of a coastal processes assessment that was undertaken as part of the Sandy Point / Conroy Park Foreshore Erosion and Drainage Management Plan. It forms Appendix A of the main study report. For a more detailed description of the site locality and purpose of the overall study, readers are referred to the Introduction of that report.

The primary purpose of this assessment is to provide background information on coastal processes, so that informed decisions can be made when designing and evaluating management strategies for the foreshore extending across Sandy Point, westwards to the Anchorage at Corlette, along the southern foreshore of Port Stephens.

The key aims of the Coastal Processes study were to:

1. Identify long term morphology at the site;
2. Calculate longshore transport rates;
3. Determine design water levels and tidal variation at the site;
4. Determine appropriate design current velocities; and
5. Determine nearshore wave conditions for design.

The Coastal Processes Study includes the following:

- Chapter 2: A detailed examination of available background reports;
- Chapter 3: An assessment of existing foreshore structures;
- Chapter 4: Review and analysis of available hydrosurvey and aerial photography;
- Chapter 5: Presentation of a Numerical Model of the Port;
- Chapter 6: Discussion of Design Conditions
- Chapter 7: Summary of Report Findings with reference to the key objectives

2 Background Information

2.1 Introduction

Numerous background studies were sourced and reviewed to determine the baseline understanding of the site. These included:

- *Port Stephens Marina, Corlette. Coastal Processes* (Geomarine Pty. Ltd., 1988)*;*
- *The Anchorage, Corlette, Port Stephens. Environmental Impact Statement* (Gutteridge, Haskins and Davey, 1989);
- A Natural Flushing System for Artificial Harbours; a Case Study of The Anchorage, Port Stephens, Corlette, N.S.W (Nielsen and McCowan, 1994);
- *Port Stephens Flood Study - Stage 2. Design Water Levels and Wave Climate ;*
- *Port Stephens Flood Study - Stage 3. Foreshore Flooding* (Manly Hydraulics Laboratory, 1998)*;*
- *Port Stephens / Myall Lakes Estuary Processes Study* (Manly Hydraulics Laboratory, 1999)*;*
- *Port Stephens and Myall Lakes Estuary Management Plan* (Umwelt (Australia) Pty. Limited, 2000)
- *Port Stephens Foreshore (Floodplain) Management Study* (Webb, McKeown & Associates Pty. Ltd, 2002a);
- *Port Stephens Foreshore (Floodplain) Management Plan* (Webb, McKeown & Associates Pty. Ltd, 2002b);
- *Living on the Edge. A Foreshore Management Plan for Port Stephens* (Umwelt, 2009)*;*
- *Port Stephens Design Flood Levels. Climate Change Review* (WMA Water, 2010);
- *Unique soft coral habitat in a temperate estuary: significance to biodiversity and marine park management* (Poulos, 2011)
- *Review of Studies on Estuarine Morphology and Sediment Movement Conducted in Port Stephens Estuary* (University of Sydney, n.d.)
- *Assessment and Decision Frameworks for Seawall Structures* (Coastal Environment, 2013);

The discussion provided in the remaining sections of this chapter is based upon our review of these documents.

2.2 Geomorphology

2.2.1 Broad Scale Geomorphology

Port Stephens can be broadly separated into two basins, to the east and west of Soldiers Point. The western basin is infilling with fluvial sediments from the Karuah River. In comparison, the eastern basin is affected by marine processes. The ocean entrance, which stretches 1.25 kilometres between Yacaaba Headland on the northern side and Mt Tomaree to the south enables the penetration of swell waves and ocean tides into the eastern basin.

Bathymetry in the eastern basin is dominated by the large flood tide delta, which is slowly moving westwards into the Port. At the present time, the leading edge of the flood tide delta stretches (approximately) along a north-south alignment between Corlette and Pindimar. The wave and climate environment of the study site is governed by the bed elevations, typically less than 10m, across the flood tide delta and the ongoing changes to its channels which convey tides in and out of the Port.

The present form of the Port has evolved during the past 1.8 million years, including the Ice age of the *Pleistocene Epoch*. Ice Ages comprise glacial periods (cooler earth, lower sea levels) and interglacial periods (warmer earth, higher sea levels). The present *Holocene Epoch* stretches from around 10,000 years b.p and contains the tail end of the last period of post glacial sea level rise, which ceased around 6,000 years ago.

The movement of the flood tide delta into Port Stephens is a continuation of ongoing change that was triggered by that rise in sea level, which started some 20,000 years ago, when sea levels were some 120 to 130m below their present level. With this rise, the shoreline gradually moved across the continental shelf, reworking sand westwards, and ultimately (when the ocean reached the present level) forming a series of sandy dune ridges which are evident both to the north and south of Port Stephens. The barriers comprise unconsolidated quartz sands, present as the “Stockton” soil group, comprising beach sands which were deposited to both infill the space between volcanic hills (such as Corlette Head) and fringe the flood tide delta along Corlette and Bagnalls Beaches. These are the same sands which stretch southwards from the study site towards the sand dunes of the Stockton Bight. The sands which fringe Port Stephens are being continually reworked by ongoing change within the flood tide delta, and the resulting modifications to waves and tides within the entrance to Port Stephens.

Within the flood tide delta, the sand is up to 20 to 25m thick, overlying the relict channel of the Karuah River, which used to flow, some 70 to 140m north of the study site, on its way eastwards to the ocean. With the sea level rising up until 6000 years ago, this channel was drowned by the ocean, leading to Port Stephens’ classification as a “drowned river valley” type estuary. Bedrock is shallower at the shorelines of the study area, given the proximity of volcanic hills behind Sandy Point and at Corlette Head. Bedrock dips from south to north.

Simplistically, the flood tide delta can be considered as comprising a relatively flat stoss ‘ramp’ side stretching from the entrance and into the Port, and a much steeper leeward face (or dropover’) where the delta meets the deeper waters of the estuarine basin (i.e. between Corlette and Pindimar). Frolich (2007) argued that, under the action of waves and tides, sediment is presently eroding from the ramp side and being carried over the dropover, lowering the ramp and causing related recession of the beaches which fringe the eastern basin. The estuary processes study for Port Stephens (Manly Hydraulics Laboratory, 1999) also noted that there has been an historical tendency for the recession of sandy shorelines in the Port.

While useful in a very broad sense, there are particular, location specific aspects that need to be considered when looking at implementing foreshore management options with an expected design life span of 25 years.

For example, Geomarine (1988), considered that destruction of “Myall Point” may have been of particular relevance to evolution of the Corlette shoreline. Myall Point was a long sand spit which formed along the eastern edge of the entrance to the Lower Myall River during the 1800's and was subsequently destroy by a severe coastal storm in the late 1920's. Geomarine raised the possibility that the shoals which formed from the redistributed remains of that spit may have altered the patterns of swell wave focussing within the Eastern Basin, with energy particularly focussing on Sandy Point and causing its subsequent erosion. A more detailed examination of the changes in shoals over the last 50 years is presented in Frolich (2007) showing that shoals are continuing to evolve in a complex manner in near vicinity of Myall Point.

2.2.2 Impacts in the Study Area

Corlette Beach, to the west of Sandy Point is around 750m long, stretching between Sandy Point and Corlette Head. Sand movement along Corlette Beach, and within the study area, is overwhelmingly dominated by east to west sand transport. This occurs as a result of tides in the deeper channels, and the impact of refracted oceanic swell waves against the shoreline. Sand which is transported from east to west is ultimately carried over the flood tide delta dropover, settling out in the deep estuarine basin which continues to infill with marine sands. Geomarine (1988) highlighted that there exist no processes to resuspend this sand once it has been carried over the dropover. Temporary reversals of the sand drift direction along Corlette Beach will occur during period of strong westerly winds, however net shoreline transport is dominated by westwards drift (University of Sydney, n.d.). While locally generated wind waves may reverse sand movement along the study foreshores from time to time, these waves do not contain the required energy to reactivate sand lost over the dropover.

Prior to the construction of the Anchorage Marina, Geomarine (1988) estimated that some 28,500m^3 of sand had accumulated on the beach adjacent to the shoreline fronting Corlette Head over 27 years, turning what was once a rocky foreshore into a sandy beach. By examining historical aerial photographs, Geomarine considered that some of this this sand (~6,900) had eroded from the eastern end of Corlette Beach and from a large sand lobe which had previously formed offshore of Sandy Point. This lobe had gradually diminished in size over preceding decades. In other words, the sand which was offshore of Sandy Point in the 1950's had moved westwards, covering a previously rocky shoreline at Corlette Head by the late 1980's. Applying a multiplier of 3 to account for sand below the waterline, Geomarine estimated that an average 3,000m^3/yr of littoral transport, noting that it seemed to have slowed between 1977 and 1986. It was expected that this rate would slow to around 1,000m^3/yr with time.

Construction of the Anchorage Marina in the early 1990's has sheltered the western end of Corlette Beach from waves but, given the overall east to west transport direction, this is unlikely to have had any significant effect on erosion patterns along this Beach. To the east of Sandy Point, Bagnalls Beach is also subject to east to west littoral transport. However, by virtue of its location and alignment, it is less exposed to the penetration of oceanic swell.

Erosion in the study area has been recognised as a problem ever since residential construction began along the foreshore, which was subdivided in 1945. Geomarine (1988) considered it likely that groynes were constructed along the eastern side of Sandy Point following severe storms in July and October, 1959. Furthermore, significant erosion occurred at Sandy Point as a result of the 1974 'Sygna' storm (Webb, McKeown & Associates Pty. Ltd, 2002a).

There is a strong perception within the community that the erosion has accelerated since the 1950's with some considering it to be a result of the construction of marinas along the southern shorelines of the Port, including the Anchorage and d'Albora's Marina at Nelson Bay. However, the lack of reliable reports from before the 1950's makes it very difficult to provide an objective assessment of foreshore variability before this time. To attribute ongoing erosion to foreshore developments, or the destruction of Myall Point, or some other immediately definable and specific cause is likely to only tell a small part of the ongoing story of underlying changes to the flood tide delta. What is necessary for the present project is to recognise that there is a problem with erosion impacting on the foreshores of the study area, and that a resilient, adaptable design is required to provide the flexibility for future uncertainty.

Hydrosurvey and aerial photography, which are reviewed in Section 4 of this report, help to provide a picture of change since the 1950's. It is clear that the foreshore of Sandy Point, which was once "sandy", is now far less sandy and completely armoured by a variety of rock and concrete structures. The pattern of erosion has also progressed from east to west, beginning with structures along the eastern side of Sandy Point, progressing to more recently (last 10 years) additional constructed rock work along the western side of Sandy Point, and stretching to the even more recent (last few years) construction of a "temporary" geotextile sand bag structure fronting the eastern end of Conroy Park. That sand bag structure is now being outflanked by erosion on its western side, continuing the ongoing east to west progression of erosion and recently the addition of further bags to the wall. This pattern is entirely consistent with the well-recognised coastal engineering principle of "downdrift" erosion commensurate with a dominant east to west transport direction.

The east to west transport is also reflected by the behaviour of the present western end of Corlette Beach, adjacent to the Anchorage Marina. Construction of the marina breakwater has interrupted the east to west littoral transport, and sand has accumulated on the updrift (eastern) side of the Marina. This behaviour was predicted as part of the Anchorage Marina EIS (Geomarine Pty. Ltd., 1988), with an estimate of 3,000m^3/yr accumulation provided. Subsequent conditions of consent placed on the development required that a beach nourishment operation would be implemented …

> *"whenever the high water mark against the eastern wall progrades 60m seaward of its present location, or significant subaerial bypassing of the eastern breakwater under waves and current action occurs"*

… and that the sand would be moved to a location along the southern shores of Port Stephens, as directed by Council. The relocation of sand has an important practical purpose, to prevent two stormwater outlets adjacent to, and through the breakwater from being buried by sand. During a site inspection in May, 2015, the study team noted that both of these stormwater outlets were non-functional, due to the build-up of sand. In 2007, Short reported that the beach had accreted some 50m seaward of the original location (Short, 2007).

The subsequent foreshore management plan for Port Stephens also recommended that the accumulated sand could be used to nourish the beach at the eastern end of Corlette Beach to address erosion, highlighting that the earthmoving operation would be relatively simple. Such remedial work would need to be repeated from time to time.

In addition to changes to the immediate foreshore resulting from construction, the leading edge of the prograding flood tide delta was dredged (~170,000m^3) to fill the marina area and to provide a founding bench for the rock breakwaters and thus eliminate the need for excessive and expensive rock work. In addition, some nearshore dredging (~30,000m^3) was required to deepen the Marina area adjacent to the foreshore.

Evidence for the westward movement of sediment offshore of the site was also examined by Geomarine (1988), considering a long record of depths recorded at a nearby sewage outfall which has now been decommissioned. By observing the changes in depth with time, it was calculated that bedforms were moving eastwards at one wavelength (40m) every four years. A sand transport rate of up to 10m^3/m/yr was estimated in the deepest (~ 7-8m) part of the tidal channel offshore of the site. A commensurate growth of the dropover at 0.5 to 1.0m/yr towards the west was also estimated. In the tidal channels, sediments are coarse and very well sorted, reflecting a high energy sediment transporting environment. Closer to shore, sediments are fine to medium grained. Along with the presence of healthy seagrasses, this indicates that current driven transport in the nearshore area is probably limited to the immediate face of the foreshore. At this location, waves impacting the shoreline act to (i) stir up sediments; and (ii) drive a longshore current which transports those suspended sediments. We note that swell waves tend to approach the most severely eroding section of Corlette Beach at an angle of around 45 degrees, which is an optimal condition for beach sediment transport.

2.3 Waves

2.3.1 Swell Waves

Waves are probably the most important physical process affecting the shoreline within the study area. The wave environment includes two key components:

- Ocean swell entering Port Stephens and refracted to impact on the study shoreline;
- Locally generated wind waves, with the largest waves coming from the north-west.

Swell wave heights of over 3.0m can be expected in the immediate entrance of Port Stephens, but are generally less than 0.5m inside the Port (Webb, McKeown & Associates Pty. Ltd, 2002a). That study also indicated that maximum swells and seas of around 1m each could reach Corlette Beach.

Geomarine (1988) noted that swell waves are responsible for most of the movement of sand along the Corlette Beach shoreline, and estimated that swell wave heights along the foreshore could be as much as 10% of those measured offshore, but also indicated that, because of wave direction effects, 10% was at the upper end of the likely range. The direction of swells arriving at the shoreline is considered to be almost constant, as these long period waves adjust towards the alignment of the shoreline as they propagate from the entrance across the flood tide delta. At Bagnalls Beach and along the eastern side of Sandy Point, the swell waves are almost parallel to the present shoreline alignment, which is not conducive to the generation of a longshore current. However, at the eastern end of Conroy Park, swells presently approach from an angle of 45 degrees which is the most efficient direction for generating longshore drift.

Within the Port Stephens Flood Study Stage 2 report (Manly Hydraulics Laboratory, 1997) it was assumed that waves within the study area were approximately 0.04 times the offshore wave heights. This factor was determined from 2 years of wave records at Nelson Bay, with the factor determined for Nelson Bay applied directly to the Bagnalls Beach / Sandy Point / Conroy Park Area. The resulting design waves are presented in Table 1.

Table 1 Swell Wave Climate in the Study Site (from Manly Hydraulics Laboratory, 1997)

Recurrence	Height (m)
Extreme	0.5
1% AEP	0.4
2% AEP	0.4
5% AEP	0.3

However, the patterns of refraction modelled during the present study and other evidence, including data from a storm in April, 2015, indicate that the degree of exposure along the eastern side of Sandy Point may be more pronounced than that at Nelson Bay.

The estuary processes study (Manly Hydraulics Laboratory, 1999) assumed that water depths and shoaling patterns will remain unaffected by a slow rise in mean sea level, arguing that shoal development would match the slow increase in mean sea level. In effect, this would mean that design swell waves won't change significantly as a result of future sea-level rise. This could be seen as non-conservative, particularly given some morphological evidence indicating that the flood tide delta is flattening with time (Frolich, 2007). A brief analysis undertaken by SMEC as background to the foreshore management study (Umwelt, 2009), adopted a design swell wave height of 2.6m for Sandy Point. However, subsequent discussions with the author of that report indicate that this was a simple adoption of the "depth limited" wave that could physically occur at the site. Given the modelling undertaken as part of this study, we consider that this wave height is an overestimate for design purposes.

2.3.2 Wind Waves

As part of the Port Stephens Flood Study (Manly Hydraulics Laboratory, 1997) wind generated wave heights were also estimated utilising a model based on methods outlined in the Shore Protection Manual (CERC, 1984). However, that report indicated that the CERC method requires "10-minute average maximum gust speeds", a term which seems self-contradictory. The CERC method actually specified averaged wind speeds. Furthermore, the extreme wind speeds presented from the Williamtown record seem abnormally high in the Port Stephens Flood Study, and it seems likely that gust wind speeds may have been erroneously applied.

Previous researchers (Geomarine Pty. Ltd., 1988; Manly Hydraulics Laboratory, 1997) have found that the Williamtown wind record is suitable for analysing wind conditions at Port Stephens. For this study the Williamtown record has been considered a reasonable proxy for conditions across Port Stephens.

2.4 Water Surface Elevations

2.4.1 Ocean Water Levels

The tidal elevations within Port Stephens are close to the tidal levels in the ocean. Accordingly ocean water levels tend to control the "still" water level within Port Stephens. Based on an analysis of historical water levels at Sydney, Stage 2 of the Port Stephens Flood Study (Manly Hydraulics Laboratory, 1997) presented the design offshore water levels reproduced in Table 2

Table 2 Design Offshore Water Levels for Sydney (Manly Hydraulics Laboratory, 1997)

AEP	Ocean Water Level (m AHD)
5%	1.43
2%	1.47
1%	1.50

2.4.2 Still Water Levels inside the Port

In addition to the ocean values, wind setup was modelled across the Port for the 100yr ARI for various starting water levels and wind durations. At the study site, wind setup was most pronounced for an easterly wind, with maximum values of 0.12 and 0.13 modelled at Sandy Point and Corlette Head, respectively, for a 2.5 hour duration wind and starting water level of 1.5m AHD. These values were added to derive the combined still water levels (Storm Tide + Flood Runoff + Wind Setup) reproduced in Table 3.

Table 3 Design Still Water Levels for the Study Site (in mAHD Manly Hydraulics Laboratory, 1997)

AEP	Sandy Point	Corlette Head
5%	1.58	1.60
2%	1.62	1.65
1%	1.67	1.69
Extreme	1.70	1.72

In applying these still water levels, Manly Hydraulics Laboratory advised that any subsequent flood planning level (FPL) should include an allowance for freeboard and wave breaking processes against the foreshore. Wave breaking and runup is discussed in Section 2.4.4.

For direct comparison, the corresponding design water level components used in the design of the Anchorage Marina incorporated:

- 1.0m AHD (maximum high tide)

- Storm Surge + 0.5m
- Local Wind Setup + 0.3m;

Resulting in a value of 1.8m AHD, where the difference between this elevation and those presented in Table 3 resulting from the higher estimate of wind set up, derived without the assistance of a numerical model, from the Anchorage EIS.

The estuary processes study argued that wave setup within Port Stephens is not significant. This is consistent with research that has been undertaken since the design of the Anchorage Marina (Dunn et al., 2000; Hanslow and Nielsen, 1992).

2.4.3 Impact of Climate Change

A gradual increase in mean sea level in the ocean will result in a similar increase to mean water level inside Port Stephens. Flood planning levels inside Port Stephens were adjusted by WMA Water to include the present Port Stephens Council allowances for sea-level rise (WMA Water, 2010). This incorporated an allowance of 40cm by 2050 and 90cm by 2100, above 1990 levels, directly added to the design still water levels. They reported the design still water levels for different recurrence interval events as replicated in Table 4.

Table 4 Design Still Water Levels including Sea-level Rise (WMA Water, 2010)[1].

Site	5% AEP (2050)	1% AEP (2050)	Extreme (2050)	5% AEP (2100)	1% AEP (2100)	Extreme (2100)
Sandy Point	2.0	2.1	2.1	2.5	2.6	2.6
Corlette Point	2.0	2.1	2.1	2.5	2.6	2.6

In summary, WMA Water recommended a Flood Planning Level (corresponding to a 1% AEP event) of 2.5m AHD throughout the Estuary, but increasing by 0.4 (to 2.9m AHD) by 2050, and by 0.9 (to 3.4m AHD) by 2100. These FPL's do not include an allowance for wave runup or freeboard.

2.4.4 Wave Runup

Waves impact and run-up the foreshore, and it is the elevation and volume of runup that will affect the design of foreshore structures. In the Anchorage Marina EIS (Geomarine Pty. Ltd., 1988), a design crest height of 2.7m AHD was specified for the breakwaters. The floodplain management study (Webb, McKeown & Associates Pty. Ltd, 2002a) adopted the underlying work of the previous flood studies, and presented design runup levels for sites around Port Stephens. These are replicated in Table 5 and it can be seen that the reported 1% runup level for Sandy Point is lower than the corresponding 5% level, which is counterintuitive.

[1] Rounded to nearest 0.1m in WMA report

Table 5 Design Runup Levels (Manly Hydraulics Laboratory, 1998; in m AHD, without Sea Level Rise)

Site	5% AEP	1% AEP	Extreme
Sandy Point	2.4	2.3	2.9[2]
Corlette Point	2.2	2.3	2.9[2]

Taking a closer look at the foreshore flooding document from which these figures are taken (Manly Hydraulics Laboratory, 1998), we note that the maximum of the following two options was adopted for each site:

- 1% and 5% AEP water level to be combined with the 1% and 5% AEP swell waves (from east to south-west quadrant) plus the 1yr ARI wind waves (from the east counter clockwise to the south west) to estimate 1% and 5% AEP foreshore flood levels; or
- 1yr ARI water level (1.26m) combined with the 1% and 5% AEP wind waves from the worst direction to estimate the 1% AEP and 5% AEP foreshore flood levels.

However, The MHL (1998) study recommends that detailed investigation is probably justified in the eastern basin to address the aspect of wave overtopping. Presently, standard design methods aim to control overtopping volumes, beyond setting crest elevations based on estimated run up levels (Pullen et al., 2007). The impacts are mainly restricted to immediate foreshore areas (~ within 50m of the waterline) however large overtopping volumes can cause a safety issue for the public. This safety issue needs to be appropriately considered in design and in particular where public access or development is close to the crest.

2.5 Currents

Available current and flow data is sparse. A tidal gauging on 29th-30th September 1993, captured a time series of discharge values along a line to the north of Soldiers Point, indicating a total tidal prism of around $110 \times 10^6 m^3$.

Tidal currents were measured by Geomarine (1988) in the vicinity of the (then proposed) Anchorage Marina and estimated that the maximum tidal velocity near the proposed entrance would be around 1.1m/s (depth averaged) or slightly higher after the harbour walls were constructed.

Geomarine also estimated nearshore wind driven currents along Corlette Beach, utilising the results of limited numerical modelling undertaken by PWD in 1987. The assumed relationship for wind driven currents was that the current velocity would be 1/20th of the wind velocity, at a distance 100m from shore. Tidal currents are much stronger than wind driven currents in the vicinity of the study area.

2.6 Ecology

The ecology of the study area was examined as part of the Anchorage Marina EIS (Gutteridge, Haskins and Davey, 1989). The ecological study considered two

[2] The foreshore is overtopped for the extreme events

nearshore areas within the study site, “Area 8” located to the east of the Marina, and “Area 9” to the east of Sandy Point.

At this time, the inshore area had three species of seagrass *Zostera Capricornii, Posidonia Australis* and *Halophila Ovalis.* The presence of well-established seagrasses in the nearshore indicates that sediment transport had ceased at the time of the survey. The seagrasses supported a considerable population of epiphytic algae and many species of invertebrates and fish.

These seagrass beds stretch eastwards along Bagnalls Beach along with patches of the soft coral *Dendronephthya australis* which is restricted to the southern shoreline of Port Stephens (Poulos, 2011). Poulos identified a patch of *D.australis* offshore of Sandy Point, in the vicinity of a steep section of bathymetry immediately to the north of Sandy Point. The soft coral depends on a habitat with strong currents and low wave energy to efficiently feed. However, its presence here also seems to indicate that there is some hard feature such as a rock outcrop or reef which fixes this steep bathymetry, enabling strong currents without carrying the sandy substrate away.

2.7 Practicalities, Planning Constraints, Potential Solutions and Community Aspects

While the immediate foreshore of the study area was subdivided in 1945, the local area surrounding Corlette tripled in population between 1986 and 1996. The Foreshore Management Plan for Port Stephens identified that Conroy Park has potential to be utilised to a much greater extent, particularly for boat based activities, if suitably rehabilitated.

While the study area is within the “General Use Zone” it is still within the bounds of the Port Stephens Marine Park. The area below Mean High Water Mark is owned by the Crown and any works undertaken at the foreshore would likely require land owners consent under the *Crown Lands Act,* 1989.

A number of documents have taken aim at the state of the foreshore surrounding Sandy Point. Problems raised include:

- The seawalls and groynes have not been constructed in accordance with sound coastal engineering principles;
- Armour sizes are inadequate;
- The discontinuous state of the structures leads to concentrations of wave energy and, potentially, unravelling of the structures;
- Vertical sections act to reflect wave energy and induce nearshore scour with the potential for undermining and collapse;
- Access along the surface of the seawall is uneven and dangerous due to the varied types of structures present;
- The height of the seawall around Sandy Point is such that a safety rail would be required;
- Groynes are not large enough to be effective and their impact may actually be detrimental; and
- Placement of rock has been haphazard and is unsightly

The foreshore management plan (Umwelt, 2012) is particularly emphatic on this point stating

> *"Urgent attention is required to rehabilitate the erosion protection works at Sandy Point. This foreshore is used regularly by the public for walking exercise and it would appear that, given the dilapidated nature of the structures and the haphazard construction of the footpath, with uneven surfaces and no guard rails, there is a serious accident waiting to happen there."*

Residents do like rock or concrete protection along their foreshore. While other options such as offshore breakwaters, revegetation, dune reconstruction and beach nourishment could be considered, these are less likely to be acceptable to the community.

Recommendations provided by others in previous documents, and relating to the rehabilitation of the seawalls include:

- Converting vertical seawalls to a sloped revetment of 30 degrees (2H:1V) and don't allow new structures steeper than this to be constructed;
- Remove the Groynes and, potentially recycle this rock for reconstruction of the foreshore revetments;
- Survey the nearshore area to determine levels;
- Rehabilitate the eastern end of Corlette Beach through the construction of a suitable revetment buried in sand sourced from adjacent to the Marina Breakwater; and
- Ensure that crest levels prevent significant overtopping.

There are issues associated with the large scale removal of unauthorised structures including (Umwelt (Australia) Pty. Limited, 2000)

- The costs involved in demolition and reconstruction of a natural foreshore profile;
- Issues associated with identifying the authority responsible for funding and undertaking the work; and
- Objections from individual landowners that see removal as placing their property at risk, particularly when entire foreshore lengths would need to be reconstructed for the works to be effective.

3 Assessment of Foreshore Structures

3.1 Foreshore Structure Inspection and Database

The shoreline of the study area extends approximately 1.1 km from the eastern wall of the Anchorage to the western end of Bagnalls Beach. In the following discussion, chainages are measured in distance east of the Anchorage Breakwater. The western 400m from the centre of Conroy Park to The Anchorage is unprotected and comprises a flat beach and nearshore backed by a low sandy dunes or an erosion escarpment exposing the pre-existing back beach sediments. The western most 250 metres from just east of the stormwater outlet to the Anchorage breakwater has, since the harbour construction, accreted by approximately 60 metres seaward against the wall. A broad, flat dune and beach has built up as the sand moving alongshore from east to west is trapped against the eastern breakwater.

From chainage 250m to chainage 470m (the eastern end of Conroy Park), the beach is realigning and continuing to recede. This has resulted in the loss of mature coral trees and some significant eucalypts along the seaward margin of the park. From about chainage 380m to 470m protection of the eroded bank has been recently undertaken by PSC using geotextile containers, the most recent of these placed in July 2015, in accordance with the NSW Government guidelines for emergency protection works. This work was constructed in an attempt to limit the foreshore recession and overtopping during storms and to protect the remaining significant vegetation in the reserve. Overtopping and erosion at the western end of the first section of this geotextile revetment resulted in scour and undermining and loss of a large eucalypt in the April 2015 storms. The geotextile revetment has been subsequently extended further to the west to try and retain some Coral Trees.

The assessment of the seawalls fronting the properties between Conroy Park and the stormwater drain at the western end of Bagnalls Beach were undertaken over two days in May 2015. The inspections were undertaken by qualified and experienced coastal engineering staff from Whitehead & Associates and Coastal Environment Pty Ltd and utilised the reporting procedures suggested for inspection of seawalls in SCCG 2013 (Appendix B, page 26, “Seawall Preliminary Assessment Form”). The inspections were visual only and included no subsurface investigation or material testing to determine material sizes and composition. In most instances the toe level of existing works was not readily visible or discernible.

For all locations, no design information was available although some residents indicated sections of the walls were constructed based on “engineering advice”. Similarly, for Council constructed sections, no detailed information was available on construction dates, material quantities or concept designs. The details of the wall that could be ascertained were recorded on individual record sheets on a property by property basis and the visible seawall photographed. This more detailed information has been provided separately (digital format) to Council for inclusion within their asset management system.

The following general observations relating to the constructed protection works are relevant:

- The first protection structures around Sandy Point were initially installed in the 1950s and 1960s to protect against perceived recession of the shoreline at that time;
- Construction has continued and been extended along the beach until the present;
- The orientation of the shoreline protected varies through 45^0 with consequent variation in the wave exposure of sections of the foreshore experienced during storm events;
- The walls and groynes constructed are located outside the property boundaries on the crown reserve or the beach and seabed;
- Some walls were constructed by Council, while the majority were initially constructed by individual residents or groups of residents. Some resident constructed walls may have been topped up with rock supplied and placed by Council at a later date;
- Construction materials and techniques are varied and provide differing levels of protection to storm erosion and overtopping from property to property. Materials used include timber sleeper walls (earliest protection), tipped rubble walls (varying sizes and slopes), concrete cubes, mass concrete, brick and geotextile containers;
- Many of the wall sections are showing signs of progressive failure, including: slumping of the rubble walls to a more stable slope (undersize armour stone); loss of armour; and scour holes behind the crest from overtopping;
- Crest levels vary along the wall and at virtually all locations adjacent to Sandy Point, may be overtopped during significant storm events;
- Pedestrian access along the public reserves is varied and depends on the location and width of remaining reserve. The access path may comprise grass, paving, concrete or rubble. The path height and width varies and requires pedestrians to negotiate stairs and boat ramps at different locations; and
- Many properties have individual boat ramps and/or stairs to the beach, constructed on the reserve outside of the property boundaries;

The construction of the existing walls and in particular the lack of design details, the absence of an appropriate toe to limit scour and undermining and the complete absence of any filter layer underlying the armour units, means that it is not possible to certify the adequacy of any section of the existing ad-hoc seawalls as meeting appropriate design standards. While some sections of the revetment are more substantial than others, are exposed to lower wave conditions or are located well seaward of existing residential development, the majority of the protection works are showing signs of failure during storms. Higher crest levels are required and, at present, the protection works are susceptible to scour and piping failures from wave overtopping. The associated dangers of the seawalls, boat ramps, access stairs and pedestrian thoroughfare raises questions of public liability both resulting from storm damage and accident.

There are four key areas of concern in relation to protection of the foreshore at the current location

- Erosion/recession of the shoreline. This has been evident since the mid-20th century when residents along the Sandy Point foreshore commenced construction of protection works to maintain a permanent back beach area, providing a buffer between development and the beach. These works have effectively held the location of this shoreline at the cost of the sandy beach. With the beach experiencing recession and alongshore sand movement through the area, the erosion has translated downdrift and (to the west), over time necessitating extension along the shore of protection works. Without intervention and with a scenario of increasing sea level rise, this trend to foreshore recession will continue for the foreseeable future.
- Loss of the shallow nearshore and sandy beach areas as the nearshore beach profile continues to erode and the protection structures become more prominent. With continuing hardening of the foreshore extending from the western end of the study area, it is likely that the sandy beaches will continue to disappear. Those beaches will re-establish and/or be exposed less frequently over time, unless an integrated management strategy is adopted to address this problem. The existing rock groynes serve this purpose to a limited extent.
- The shoreline recession and loss of the reserve has resulted in a narrow buffer of public land between the private residential boundaries and the seawall crest at Sandy Point. This has compromised the public access along the foreshore and in some locations the access is limited to the crest of the seawall or hard apron, constructed on public land by residents and Council.
- As the beach disappears, the wave impacts are magnified with waves breaking onto what is in some locations a vertical seawall, with resulting, significant wave overtopping. The variable seawall crest levels are in the main too low for the current conditions and this is exacerbated by the construction of boat ramps at many locations along the foreshore on the public reserve. These low points reduce the revetment crest level at these locations and funnel water over the seawall, increasing the inundation of the public reserve and private property. This overtopping has in recent events (April 2015) resulted in scour and piping failures through the walls, loss of armour units from the seawall face and crest, and a risk to the public using the now compromised alongshore access path. In the absence of upgrading of the seawall and with the scenario of increasing ocean levels this situation will continue to deteriorate. More frequent and more severe storm inundation from the Port will occur over time.

3.2 Study Area “Precincts”

For ease of discussion the study area has been divided into six separate precincts on the basis of orientation, exposure to coastal processes and the nature of existing protection works. This facilitates a general discussion of the nature of the hazards, the effectiveness of existing protection works and possible future management strategies. The extent of all six precincts is illustrated in Figure 1.

Figure 1: Study Area Precincts

Sandy Point / Conroy Park Coastal Processes Study

Whitehead & Associates
Environmental Consultants

0 100 200 300 m (Approx Scale)

N

Revision	A
Drawn	DW
Approved	DW

3.2.1 Precinct One – The Anchorage eastern wall (chainage. 00m) to the east side of the Corlette Point Park stormwater outfall (chainage. 250m).

This section of the beach has accreted following the construction of the eastern harbour wall at the Anchorage in the early 1990s with the trapping of sand which moves naturally along the Sandy Point - Corlette shoreline from east to west under the influence of waves and currents. The accretion forms a triangular fillet with the maximum increase in beach width of approximately 60m against the eastern wall at the present time. The sand accretion is currently covering the stormwater outlets adjacent to the harbour wall which discharge stormwater from the development and the catchment immediately to the south. If allowed to accrete to the extent that it begins to bypasses the harbour wall, sand will then move westward around the harbour and over the face of the flood tide shoal into deeper water off Corlette Head. It is then effectively lost from the beach system.

The amount of accretion over the past two decades decreases with distance east. At the stormwater outlet across Corlette Point Park the accretions is now well seaward of the constructed headwall at the back of the beach. The water discharges across the beach, scouring a narrow channel following rainfall. The headwall is currently around 25m from the high water mark. The sand build-up decreases further to around 0m approximately 75m east of the stormwater outlet (adjacent to #78 Sandy Point Road and the erosion of the foreshore and realignment of the beach dominate from that location to the east.

No foreshore protection works are required to maintain development and crown land within this precinct. The major issues relate to the stormwater drainage outlets (3 of) which are affected by sedimentation. The sand build up also provides an opportunity to source sand on a regular basis which may be transferred to other locations along the southern Port Stephens foreshores east of this location. The original design and approval of for The Anchorage predicted this sand accretion and beach realignment and envisaged the relocation of this sand to address the possible impacts on the stormwater system and to prevent the “loss” of a valuable sand reserve from the active beach system.

Figure 2 Western end of Precinct 1. Sand accretion against the Anchorage marina wall is burying stormwater outlets. *Photo Source:* D Lord, 8th May 2015

Figure 3 Eastern end of Precinct 1. Sand accretion extends to the west of the stormwater drain across Corlette Point Park. *Photo Source:* D Lord, 8th May 2015

3.2.2 Precinct Two - East of the stormwater outfall (chainage. 250) to the western end of rock protection works at the eastern end of Conroy Park (chainage. 520m)

The foreshore between chainage 250 and 470 at the Western end of Conroy Park has remained largely unprotected and fronts the public reserve, providing a sandy beach amenity along the entire length. In recent years the erosion of this foreshore has increased with the high water mark at the base of the escarpment and no usable beach width at high tides. No residential assets are immediately at risk with all development west of Conroy Park set well back from the escarpment. The closest dwelling west of Conroy Park is more than 30m landward of the escarpment crest.

Recently, the major concern has been the erosion of vegetation through Conroy Park with the loss of eucalypts along the shoreline and coral trees which are valued for their summer shade in the reserve. Access to the Beach directly from the park has been comprised although pedestrian access from Conroy Park to Corlette Point Park along the waterfront reserve remains. Council has undertaken emergency foreshore protection through two campaigns, installing geotextile containers as permitted by the current NSW Government guidelines for emergency beach management. These have provided limited protection but do relocate the increased erosion to the western end of the completed wall section (end wall effects). This is evident at Conroy Park where erosion continued to the west of rock protection works prior to the installation of the geotextile bag protection. Again an increase in erosion was evident at the western, unprotected end of the geotextile bags.

Figure 4 Western end of Precinct 2 where accretion of the beach finishes east of the stormwater outlet and erosion of the back beach commences through to Conroy Park. ***Photo Source:*** **D Lord, 8th May 2015**

Figure 5 Looking west along precinct 2 from Conroy Park. A sandy beach remains at mid to low tides and is a popular walking area between Conroy Park and the Anchorage.
***Photo Source:* D Lord, 8th May 2015**

In the absence of management works, the erosion to the west of the protection works will continue, requiring extension of the protection to the west through this precinct. Ultimately this will affect access and reduce the sandy beach amenity. There will be a hard line, delineating the back beach (protected) area and the narrowing sandy beach. While residential assets are not at risk in this precinct, a higher priority is the retention of natural vegetation with easy access to a sandy foreshore for recreation. This may require some additional protection possibly coupled with some structural works to retain sand on the beach. Initial and ongoing artificial placement of sand either along the precinct foreshores or further to the east, may help to mimic the situation from previous decades, when there was a sand supply from the east and through the study area.

Figure 6 Precinct 2 eastern end. Geotextile containers have been employed for emergency beach protection along the eastern end of Conroy Park. Increased erosion west of the end of the protection is evident. Additional containers have been placed to extend the wall since this photo. There is little sandy beach width remaining at this location and no beach at mid to high tides. Access to the beach from the park has been affected.
***Photo Source:* D Lord, 8th May 2015**

3.2.3 Precinct Three – From the eastern end of the geo-container protection in Conroy Park (chainage. 520m) to the most western rock groyne (chainage. 710m)

This precinct includes the shoreline from the east end of Conroy Park (adjacent to #70 Sandy Point Road) to the rock groyne adjacent to the reserve immediately west of #46 Sandy point Road at the tip of Sandy Point. The shoreline within this precinct is relatively straight and faces NNE. It is more protected from ocean swells passing through the entrance to Port Stephens than the area further to the east, but has exposure to winter westerly wind waves. The foreshore is mostly protected by tipped rock walls which have not been designed and which vary in their current state of repair and effectiveness. The 12 dwellings behind this foreshore are set back between 13m (western end) and 25m (at #60 Sandy Point Road). The average setback is around 20m. The reserve seaward of the properties is wide and accessible with lawns and some planting maintained by the residents.

Figure 7 Precinct 3 eastern end Conroy Park. Rock protection has been placed along this section of the foreshore to the western most groyne. *Photo Source:* D Lord, 8th May 2015

Figure 8 Precinct 3 looking east to the western groyne. Various access stairs of differing design cross the revetment. The wall is generally steep, with some slumping and loss of armour near the crest, exposing the erodible bank behind. Armour stone size is variable. The western groyne and Port Stephens entrance are at the top of the photo. *Photo Source:* D Lord, 8th May 2015

Figure 9 Precinct 3 looking west from the western groyne to Conroy Park.
***Photo Source:* D Lord, 8th May 2015**

Slumping and some overtopping of these walls are evident. Residential development along this precinct is not immediately at risk. The sandy beach has effectively been replaced by a rock wall extending into the water at most stages of the tide. Patches of sandy beach may appear at lower tides and from time to time depending on weather conditions. Upgrading of the revetment along this section should consider the reinstatement of some sandy beach amenity as appropriate.

3.2.4 Precinct Four - From the western rock groyne (chainage. 710m) to the next rock groyne (chainage. 810m)

The coastal alignment changes through 45^0 at the tip of Sandy Point with the 90m shoreline of Precinct 4 facing ENE towards the entrance of the Port between the rock groyne at #46 Sandy Point Road and the next rock groyne at #38 Sandy Point Road. A small fillet of sand has accreted on the eastern side of this groyne.

The reserve seaward of the properties narrows from west to east with the set back of residences changing from 20m to 10m landward of the seawall crest. This section of the shoreline is vulnerable to wave attack and overtopping with the rock walls generally under designed and the beach all but eroded away. There is a small fillet of sand on the eastern side at the base of the western groyne, indicating the dominant east to west alongshore transport direction and the potential effectiveness of shore normal structures in maintaining a, small sandy beach area. Along the remainder of the precinct the sandy beach is only exposed on the lower tides, if at all.

While this shoreline is less exposed to the ocean swells than precinct five (to the east), there is a need to reconsider the effectiveness of the existing protection which is generally undersized and failing.

Figure 10 Precinct 4 looking east along the revetment face from the western groyne to the next groyne east. Rock armour sizes along this section are variable with significant slumping and loss of armour near the crest, exposing the erodible bank behind. The accreted sand fillet is visible in the lower left hand corner of the photo
***Photo Source:* D Lord, 8th May 2015**

Figure 11 Eastern end of Precinct 4. A boat ramp is located west of the groyne. Rock armour has been grouted to form a smooth wall. The rock groyne has slumped and is too short and low to anchor the beach or provide significant protection. A concrete apron can be seen beyond the groyne in Precinct 5. *Photo Source:* D Lord, 8th May 2015

3.2.5 Precinct Five- From the second most western groyne (chainage. 810m) to the eastern most groyne (chainage. 950m)

Precinct 5 is the most exposed, at risk and vulnerable section of coastline with development close behind a variety of ad-hoc protection works. This precinct includes the foreshore between the second most westerly groyne and the eastern groyne, a length of approximately 150m. There are 9 residences along this precinct from #36 to #20 Sandy Point Road. There is a small but ineffective (height and length) groyne between #28 and #30 Sandy Point Road. The setback from the seaward face of the dwellings varies from about 5m to 12m with little width remaining of the original public reserve.

This limited setback has compromised the alongshore access which is integrated into the seawall crest across some properties and varies in height, width and construction. Following the April 2015 storms the access alongshore through this precinct was unusable in some locations, with damage to the path surface, scour holes and dislodged rocks resulting in sections being taped off to restrict access, pending repair. This section is the most at risk with regular damage to the revetment, and extensive overtopping of the varied protection structures. The effect of wave overtopping is notably exacerbated by boat ramps, with low crest levels and poor drainage from behind the wall also causing issues.

Figure 12 Western end of Precinct 5. A vertical concrete block wall has been constructed in the centre but this precinct is predominantly tipped rock. Little or no sandy beach remains, even at low tide. The public access through Precinct 5 is compromised and wave overtopping during storms is resulting in damage and inundation of property landward of the wall.
***Photo Source:* D Lord, 8th May 2015**

Figure 13 Much of the rock wall along Precinct 5 comprises substantial sized stone at a flatter slope. This is the most exposed section of the study area receiving ocean swells entering the Port during storms. At the time of inspection damage to the wall including loss of armour from the face and crest was observed. Scour holes under slabs and through the wall from overtopping was evident at a number of locations. The alongshore access was closed (SES tapes) along several sections. *Photo Source:* D Lord, 8th May 2015

Figure 14 Eastern end of Precinct 5. Sections of the wall have undersized armour, grouted stones and various access stairs and ramps across them. Precinct 5 is the most exposed section of the foreshore and the protection provided is poor for the level of exposure.
***Photo Source:* D Wainwright, 12th May 2015**

3.2.6 Precinct Six – from the eastern most groyne (chainage. 950m) to the western stormwater overflow on Bagnalls Beach (chainage. 1160m)

Precinct six extends from the eastern most groyne adjacent to #20 Sandy Point Road to the western side of the stormwater outlet at the western end of Bagnalls Beach (adjacent to #2 Sandy Point Road). A stormwater line crosses a vacant drainage reserve between #18 and #20 Sandy Point Road. The line runs inside and along the spine of the rock groyne which now serves a double purpose, both providing protection to the Beach to the east and discharging stormwater offshore. The stormwater outlet at the east end of Precinct 6 is also connected to this stormwater line also, with that stormwater outlet conveying excess flows primarily during high rainfall events.

Precinct 6 is more sheltered than areas to the west but is still subject to wave erosion and overtopping as evidenced by the existence of substantial sections of revetment of varying design along the foreshore. The groyne is effectively retaining sand to the east and a sandy beach area fronts the seawall along this precinct under most conditions. Even so, the presence of boat ramps along this precinct allows waves to easily run up and inundate the area behind the foreshore.

Figure 15 Precinct 6. Located to the east of the eastern most groyne, this section just west of Bagnalls Beach is more sheltered than areas westward (Precinct 5) with generally lower protection structures and a build-up of sand on the eastern side of the groyne. The groyne was lengthened and upgraded to carry the stormwater outlet beyond the beach. The type and standard of back beach protection is variable. Overtopping is experienced right along this precinct although much of the development is set further back from the shoreline. *Photo Source:* D Wainwright, 12th May 2015

Figure 16 Precinct 6. Some larger rock has been placed along sections of this precinct and a sandy beach remains seaward of this protection work.
***Photo Source:* D Wainwright, 12th May 2015**

3.3 Discussion of Protection Issues

The area west of Conroy Park to Corlette Point Park is fully developed with residential properties (houses and units) along Sandy Point Road. Similarly, the road frontage along Sandy Point Road and landward of the reserve along the foreshore east of Conroy Park to the stormwater drain at the western end of Bagnalls Beach is fully developed. Much of the development immediately adjacent to Sandy Point, and particularly to the east, is dependent on the protection provided by the ad-hoc seawalls constructed and bolstered since homes were constructed here. These structures are mostly under designed. The proximity and value of the residential properties make any option other than the continued protection of the foreshore at or around its present location seem unlikely.

However, the existing works are in need of substantial upgrading to bring the standard of protection to best practice, reduce overtopping and inundation during storm events and to formalise a consistent and accessible public access both along and to the shoreline.

The ownership of much of the shared infrastructure on the public reserve and the consequent responsibility for its maintenance and continued performance are at present unclear. Similarly, potential issues including damage to properties and dwellings, accident and injury to the public, and exacerbation of erosion or inundation on adjacent properties are all areas of continuing uncertainty.

Where properties are close to the seawall crest and the public reserve is narrowest (from the tip of Sandy Point to the east), there is a range of issues that will need to be considered in the design and alignment of any protection works proposed. This includes:

- The current practice of privately constructed boat ramps across the reserve and seawall with lower seawall crests. These compromise the integrity of any protection which can be provided but are highly valued by some property owners.
- The retention of the sandy beach at the base of the seawall. As the walls increase in size, the frequency and extent of the sandy beach area is decreasing. To the east of the eastern groyne, the wave energy is lower and the retained beach and access to that beach is highly valued. At other locations to the west around Sandy Point to Conroy Park, the sandy beach is mainly lost with a steep seawall to the waterline at high tide. At times and in some locations pockets of sandy beach do form, are exposed at low tides, and are valued. Enhancement of the sandy beach amenity could form part of the development of an adequate protection strategy.
- The potential removal and reconstruction of sections of seawall, built by residents at their expense, to bring them up to a current design standard. This may be resisted where residents have undertaken recent works or where they believe the existing protection works are adequate.
- The potential loss of individual access to the shoreline via constructed paths and stairways, often at each property and which do not conform to current design codes for access.

4 Analysis of Historical Aerial Photography and Hydrosurvey

4.1 Aerial Photography

Council and the Office of Environment and Heritage (OEH) provided W&A with multiple aerial photographs of the Corlette/Sandy Point region for our desktop investigation. The aerial photographs, spanning a period from 1953 to 2012, were provided in digital format. The scans were georeferenced and orthorectified for analysis in the geographical information software system "QGIS".

Orthorectification involves removing the distortion effects of aerial photography from camera tilt and terrain effects. Orthorectification allows for features to be in their true position and allows for more accurate measurement of distances, angles and area. The accuracy of the two processes varied for each photograph due to resolution and a lack of land marks in the older historical photos to georeference to the 2012 satellite image. Despite these issues a reasonable degree of accuracy was achieved. The plan accuracy varied between 0-10 pixels which approximates to ±5.0 metres for the older aerial photographs. Accuracy within more recent aerial photography is within 2.0m,

Following georeferencing (bringing photographs into a common mapping coordinate system), the aerial photographs were used to map and analyse changes to the extent of the following features:

- Seagrass, noting that the limit of seagrasses will not generally grow within the intertidal range (i.e. above ~ -1.0m AHD). When clear and dense seagrass beds are present, the extent of seagrasses is a reasonable proxy for the -1.0m AHD contour;
- A foredune is present along the western end of Corlette Beach, where the dune system has been accreting since construction of the Anchorage Marina. A reasonable proxy for the seaward edge of the foredune is the presence of primary grasses or "light" vegetation. Similarly, the landward edge of the foredune could be interpreted by the presence of denser vegetation or a nominated contour level.
- The presence of "hard" structures has also been mapped from the aerial photographs. This information has helped to ascertain the timing and progression of construction along the shoreline.

The mapped seagrass, vegetation and structural extents along with the corresponding aerial photographs are presented in Appendix A. A description of each photograph is presented in Table 6. Care needs to be taken in interpreting the mapping undertaken here. In particular, the interpreted extents can be affected by the clarity of water, stage of the tide and pixel resolution and reflection off the water surface. In some cases, the resolution is not adequate for clearly locating any structures that may have been present.

Table 6 Aerial Photographs Considered in this Assessment

Year	Original Scale/Resolution	Quality	Useable
1951	1:33,000 Approx.	Beach clearly defined, seagrass not clearly defined	No
1952	1:31,000 Approx.	Beach clearly defined, seagrass not clearly defined	No
1959	1:16,000 Approx.	Beach clearly defined, seagrass not clearly defined	Yes
1963	1:34,000 Approx.	Seagrass, light and dense vegetation reasonably defined, structure extents poorly defined	Yes
1965	1:16,000 Approx.	Seagrass and light vegetation poorly defined, dense vegetation and structure extent reasonably defined.	Yes
1968	1:21,000 Approx.	Seagrass, dense vegetation and structure extent reasonably defined, light vegetation poorly defined.	Yes
1976	1:16,000 Approx.	Seagrass, dense vegetation and structure extent reasonably defined, light vegetation poorly defined.	Yes
1979	1:42,000 Approx.	Seagrass and light and dense vegetation reasonably defined, structure extent poorly defined.	Yes
1986	1:8000 Approx.	High reflection off ocean, seagrass not clearly defined, light and dense vegetation and structure extent well defined.	Yes
1992	1:16000 Approx.	Seagrass, vegetation and structure extents highly defined.	Yes
1996	1:8000 Approx.	Seagrass, vegetation and structure extents highly defined.	Yes
1998	1 pixel: 1m	Seagrass, vegetation and structure extents highly defined.	Yes

Year	Original Scale/Resolution	Quality	Useable
1999	1:8000 Approx.	Seagrass, vegetation and structure extents highly defined.	Yes
2003	1 pixel: 1m	Seagrass, vegetation and structure extents highly defined.	Yes
2005	1:10000 Approx.	Seagrass moderate to highly defined, vegetation and structure extents highly defined.	Yes
2007	1 pixel: 1m	Seagrass, vegetation and structure extents highly defined.	Yes
2012	1 pixel: 1m	Seagrass, vegetation and structure extents highly defined.	Yes

While all of the visible features have been mapped and presented in Appendix A, we have extracted key features from a few years to demonstrate the underlying trends of shoreline evolution since the 1960's.

Figure 17 presents the landward extent of seagrass beds from 1963, 1992 and 2012. The figure indicates that erosion of the eastern end of Corlette Beach, and Accretion of the western end has been ongoing since the 1960's. Of particular interest is the presence of a point about which the beach appears to have "pivoted" around 250m to the east of the present day Marina Breakwater. To the east of that point, Corlette Beach has eroded, and to the west, it has accreted. The key finding from this analysis is that this process has been occurring since *before the Anchorage Marina was constructed*. We do not believe that construction of the Marina has contributed in any significant way to the erosion of eastern end of Corlette Beach. Furthermore, the pattern of less sand being present in the nearshore zone continues around Sandy Point, and indicates that ongoing erosion is largely a function of less sand being available from an *updrift* direction (i.e. Bagnalls Beach or the flood tide shoal).

Figure 18 indicates the approximate dates at which different foreshore protection works have been constructed. Over time, the nature, configuration and alignment of different elements of the constructed works have changed, in response to storms or ongoing erosion. However, it is clear that there were minimal structures present during the 1950's, with the progressive construction of foreshore works occurring from the early 1960's onwards. It appears that settlement of the area during the late 1940's and 1950's, following subdivision in 1945 occurred when the beach was particularly wide as a result of a pulse of sand moving from east to west around Sandy Point. However, in the late 1950's through to the 1970's, coastal storms resulted in a dramatic re-alignment of the shoreline around Sandy Point, as sand which was present in large lobes offshore of the site were progressively moved in a westerly direction, leaving the shoreline relatively denuded of sand and with a comparatively narrower beach.

Figure 17: Movement of Landward Edge of Seagrass Beds Over Time

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

N

Whitehead & Associates Environmental Consultants

0 50 100 150 200 m

(Approx Scale)

Revision	A
Drawn	BC
Approved	DW

*From shoreline alignment appears structures were here from 1963, however they become more prominent with time.
**Progressive construction tended to be from east to west.

Figure 18: Approximate Construction Dates for Foreshore Structures

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

N

Whitehead & Associates
Environmental Consultants

0 50 100 150 m

(Approx Scale)

Revision	A
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As this shoreline adjustment took place, a variety of structures were built to address ongoing erosion. This began on the eastern side of Sandy Point, and progressed westwards. This pattern of foreshore protection is entirely consistent with an east to west longshore drift, noting that "edge effects" of coastal protection structures tend to result in increased erosion of a beach on the downdrift side of the structure. This east to west progression of the erosion continues today, with the most recent construction of sand filled geotextile revetments fronting Conroy Park (June 2015).

The evolution of an alternative proxy measurement for foreshore alignment is presented in Figure 19. In that figure, the "light" vegetation, which approximates the seaward location of the foredune along the western end of Corlette Beach, has been mapped for 1979, 1992 and 2012. Similarly to Figure 17, Figure 19 indicates that progradation of the Beach had begun in this location prior to the construction of the Anchorage. Similarly, there is an apparent point about which the beach has pivoted or "rotated" around 250m to the east of the Anchorage breakwater.

4.2 Hydrosurvey

4.2.1 Data Sources

Four hydrosurvey data sets were obtained and examined for this study, and these are described below.

1969 Hydrosurvey

The 1969 hydrosurvey was prepared by the NSW Department of Public Works and covers the area to the east of Soldiers Point. The final product comprises a set of 65 detailed sheets (44 outside the Port and 21 inside the Port). These are accompanied by two 1:12000 scale compilation sheets. The less detailed compilation sheets were the only ones available for the present study. The 1969 survey formed the basis for much of chart *AUS209*, published by the Australian Hydrographic Service. The contours on AUS209 were digitised and used as a basis for the 1969 Digital Elevation Model (DEM) developed during this study. To the west of Soldiers Point, contours on this chart date from 1920 (Admiralty Chart 1070).

2007 Hydrosurvey

The 2007 hydrographic survey dates from October and November of that year with the outputs comprising an index sheet and 12 detailed sheets covering the area from just outside the entrance to Port Stephens, westwards to include Salamander Bay. Survey lines were spaced at 50m typically, but relaxed to 100m to the west of Corlette Point. This survey is far more detailed than the 1969 survey. In generating the 2007 DEM, the point data file (x, y, z) coordinates were imported to GIS and these were used in place of the 1969 information where the more up to date information was available.

2011 Multi-beam Echo sounding

OEH undertook limited multi-beam echo sounding along the southern side of Port Stephens during 2011. This survey did not provide broad coverage of the Port, but is useful in that it provided a high resolution of soundings through the deepest parts of the southern tidal channel of the Port. From this survey, bedform patterns are discernible, and it is clear that sediment transport is to the west within this channel, consistent with the findings of previous researchers.

Figure 19: Change in Dune Vegetation Extent over Time

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

N

Whitehead & Associates
Environmental Consultants

0 50 100 150 200 m

(Approx Scale)

Revision	A
Drawn	BC
Approved	DW

2015 Hydrosurvey (This Study)

As part of the present study, hydrosurvey was undertaken by McGlashan and Crisp Pty. Ltd., offshore of the study area. Shore normal transects, spaced at 20m were surveyed to distances of between 600 and 700 metres offshore. This survey was combined with a high accuracy UAV (drone) survey of ground elevations onshore at the study site to derive a continuous DEM of the transition between onshore and underwater elevations at the site. The resulting survey plans and CAD files were provided to Council as a deliverable for the overall project and will form a suitable basis for detailed design.

DEMs derived from all four data sources were generated using a multi-level B-spline interpolation algorithm from within the geographical information systems software environment QGIS. These models are presented in Appendix B.

4.2.2 Comparisons and Interpretation

Based on the 2015 hydrosurvey (Figure 20), bed elevations offshore of the site vary from 0 at the shoreline, down to elevations of around -10.0m AHD some 400 – 500 metres offshore. The nearshore variation of elevation changes has a different character on the east and western sides of Sandy Point.

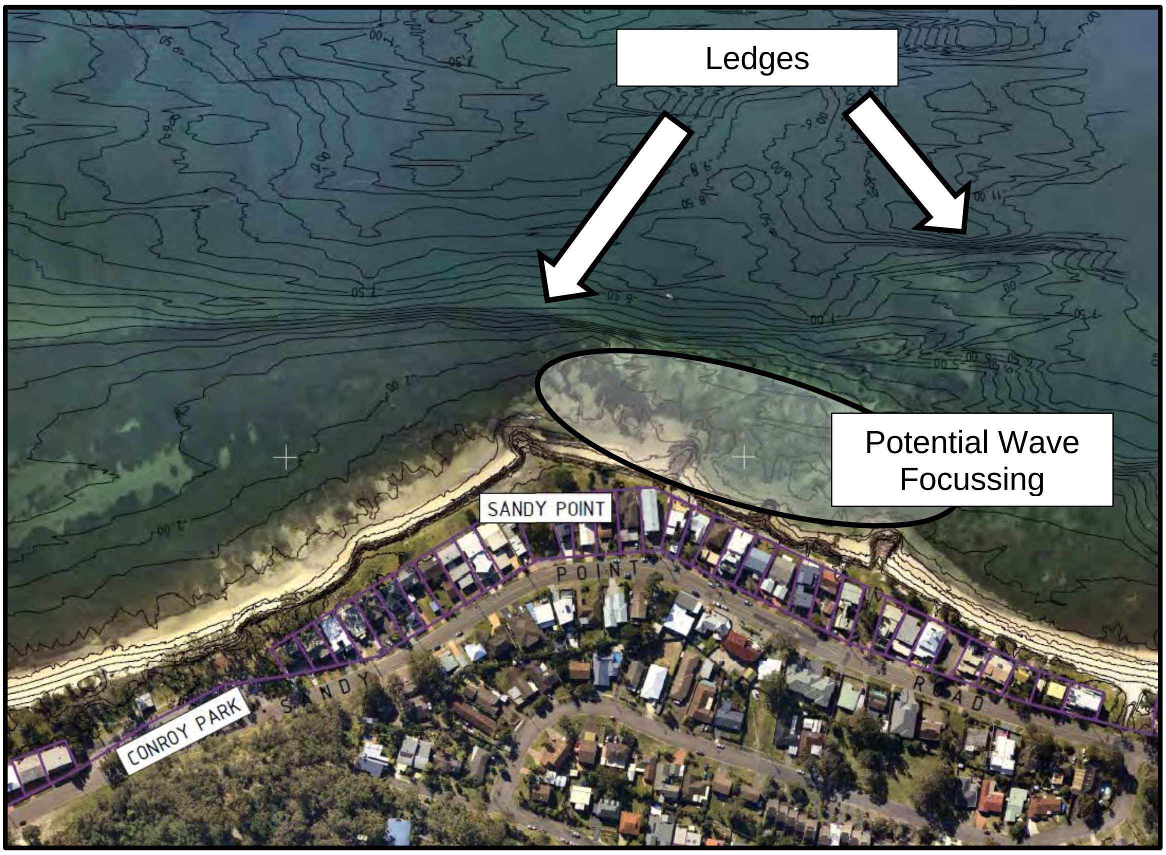

Figure 20 Extract from 2015 Survey Offshore of Sandy Point

Offshore from the eastern side of Sandy Point the bathymetry contains a number of ledges and drop overs which effect steep localised falls of 3-5 metres in the bathymetry. Based on the patterns of seagrass present in these areas, it appears likely that these features cause localised wave focussing and scouring of seagrasses to the east of Sandy Point. Conversely, to the west of Sandy Point, seagrass patches are denser and broader. This appears to result from Sandy Point providing a sheltering effect on the nearshore zone offshore from Conroy Park, by sheltering from wave energy, and by deflecting currents to ensure that the main channel flows, typically, more than 100m to the north of Corlette Beach.

Two comparisons between different dates of data were made. Firstly, a long term, broad scale comparison was made between 1969 and 2007. Noting that detailed sounding information was not available, and to avoid a second stage of interpolation, measured differences were calculated along the contour lines of the 1969 survey. A surface was then interpolated between those differences. The resulting difference map is provided as Figure 21, noting that areas of accretion are presented as positive values, and areas of erosion as negative values.

Figure 21 shows a few readily explainable features, such as dredging offshore of the Anchorage Marina where the spoil was used to fill the platform on which the Marina was constructed. Furthermore there are a number of areas where tidal channels have been actively depositing sand over the leading edge of the flood tide delta. Immediately offshore from Sandy Point, the analysis indicates an accumulation of sand, particularly around the point and western shorelines. This seems counter intuitive, given that most evidence points towards overall erosion of the beach in this area. However, beaches with higher energy tend to flatten out and it is possible that more sand could be present in the nearshore area, while the immediate foreshore is receding. Furthermore, the differences in detail between the 1969 and 2007 hydrosurveys could be causing some bias in interpolation throughout this area. Another confounding factor is the ongoing patterns of lobes of sand moving around Sandy Point during the second half of the 20th century. The exact configuration of the immediate foreshore shoals in 1969 is not clear from the survey plans. This apparent accretion is less than 1.0m and may just reflect the accuracy of the comparison available given the paucity of data in the earlier survey.

Nevertheless, the offshore pattern is governed by lowering of the tidal channels, and apparent accretion upon some shoaled areas. Offshore of Conroy Beach, the bed elevations have remained relatively stable. This is reflected by the healthy seagrasses that have flourished in this area. Slow, ongoing changes in the bed elevations offshore of the study site will have a governing impact on the foreshores over time. Any continued deepening or southward movement of the channel will increase the likelihood of erosion of the Sandy Point foreshores.

Secondly a more recent and localised analysis of elevation changes was made by subtracting the 2007 elevations model from the 2015 elevations model. The calculation was limited by the extent of the 2015 hydrosurvey. The resulting difference map is provided as Figure 22. Figure 22 indicates that any significant recent changes offshore of the study site show, almost uniformly, erosion. These include erosion adjacent to the foreshores of Sandy Point and Conroy Park, and further offshore, in the tidal channel. The pattern is consistent with the “lowering” of the ramp side of the flood tide delta, and transport of those sand westwards, likely depositing on the prograding face of the flood tide delta immediately to the north of Corlette Headland. We expect that the bed may continue to lower offshore of the study site in coming decades.

However, the present rate of lowering is unlikely to significantly affect the way in which currents and waves will impact the study shoreline over the 25 year design life for which foreshore protection measures are to be considered.

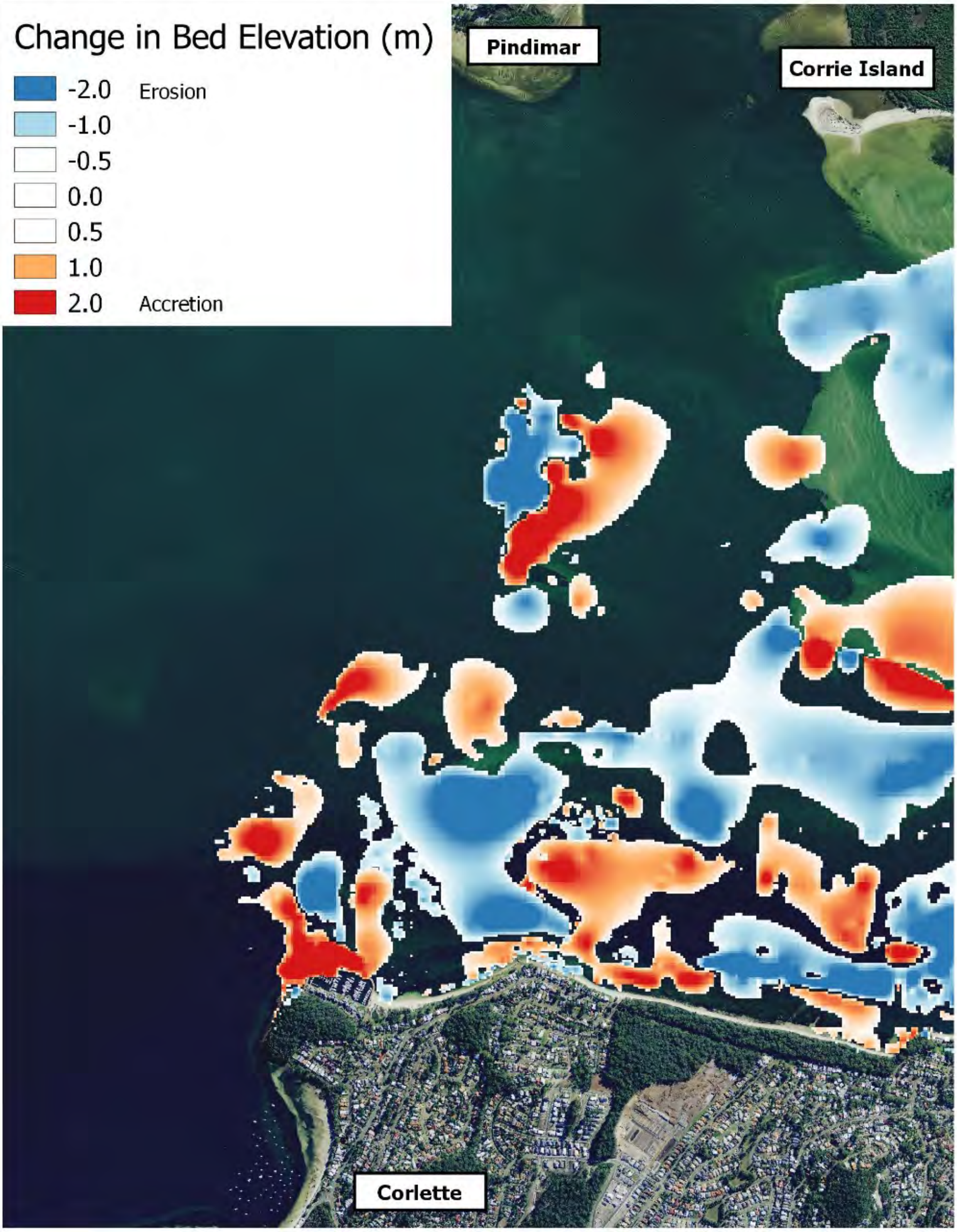

Figure 21: Change in Bed Elevations, 1969 to 2007

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

Whitehead & Associates
Environmental Consultants

0 250 500 750 1000 1250 m
(Approx Scale)

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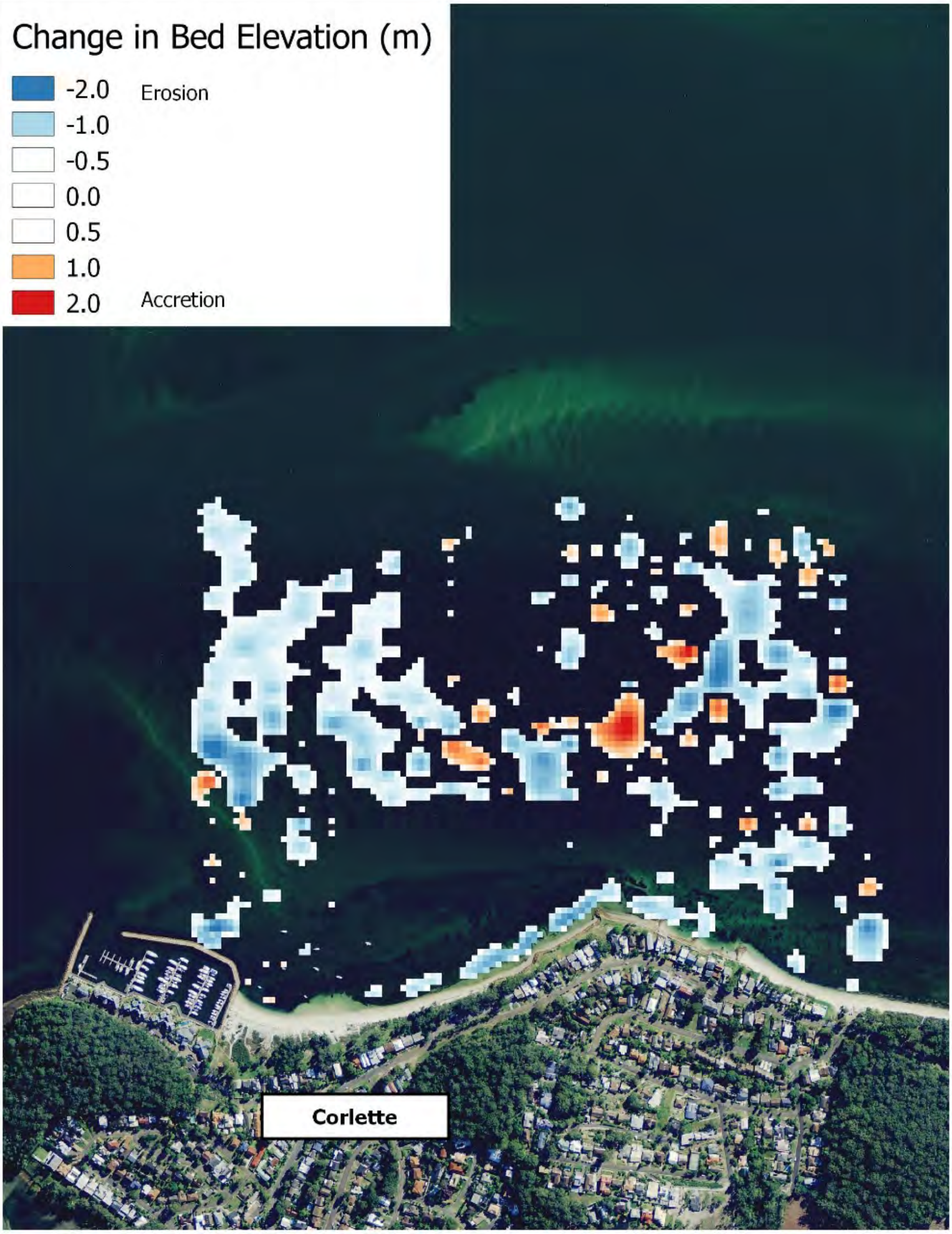

Figure 22: Change in Bed Elevations, 2007 to 2015

Sandy Point/Conroy Park Foreshore Erosion and Drainage Management Plan

Whitehead & Associates
Environmental Consultants

0 100 200 300 400 500 m
(Approx Scale)

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Revision	A
Drawn	BC
Approved	DW

4.3 Estimation of Sand Transport Rates

It is clear from the aerial photographs that sand has accumulated against the eastern breakwater of The Anchorage since its construction in the early 1990's. We have estimated the amount of sand that has accumulated since construction and, by extension, have estimated an average annualised sediment transport rate along the beach over the past two decades.

From Figure 17 a pivot point about which the beach has apparently "rotated" can be identified around 250m east of the breakwater. To the west of this point, the beach has accreted, and to the east of this point, the beach has eroded. The rate of sand accumulation to the west of the pivot point has been estimated, and this used to estimate the average annual sand transport rate between 1992 and 2012.

Eight shore normal cross sections (~30m spacing) were established along the length of beach over which accretion has occurred during the past 2 decades. The shape of the present beach profile was estimated from a combination of the 2007 hydrosurvey and onshore lidar data provided by Port Stephens Council for the purpose of this project. The distance which the profile has moved seaward over this time was estimated based on the extent of the seagrass. Furthermore, based on the 2007 hydrosurvey, the profile was noted to flatten out at around -4.0m AHD. Accordingly, only volumes of accretion above -4.0m AHD were considered. Assuming that the overall profile has maintained a similar shape, which is reasonable given that the overall swell wave climate has not changed, profiles along each of the cross-sections for both 1992 and 2012 were determined. An example of the result for Cross-Section 1 (closest to the Anchorage Marina) is presented in Figure 23. By 2012, the profile adjacent to the Marina Breakwater had moved an estimated 50m northwards from its location in 1992.

The difference in area between the two profiles in Figure 23 illustrates the cross-sectional of accretion that has occurred adjacent to the breakwater. This area was calculated for each of the eight cross-sections, and then multiplied by the distance between the cross-sections to estimate the value of accretion to the west of the pivot point in the beach. The change in area at each cross-section, and total volume of accretion are presented in Table 7. Using these figures, around 33,800m^3 of sand is estimated to have accumulated along the western section of Corlette Beach between 1992 and 2012.

This equates to around 1700m^3 per year of sand passing the pivot point of Corlette Beach and agrees broadly with the estimates of Geomarine (1988) who indicated an average 3,000m^3/yr of littoral transport historically, but with an expectation that the rate would reduce to around 1,000m^3/yr with time. This sand comes from either sand transport around Sandy Point and/or erosion of the shoreline and near shore profile from Sandy point to the area of accretion at The Anchorage. The volume estimate provides a sound basis for considering sand placement and beach nourishment options.

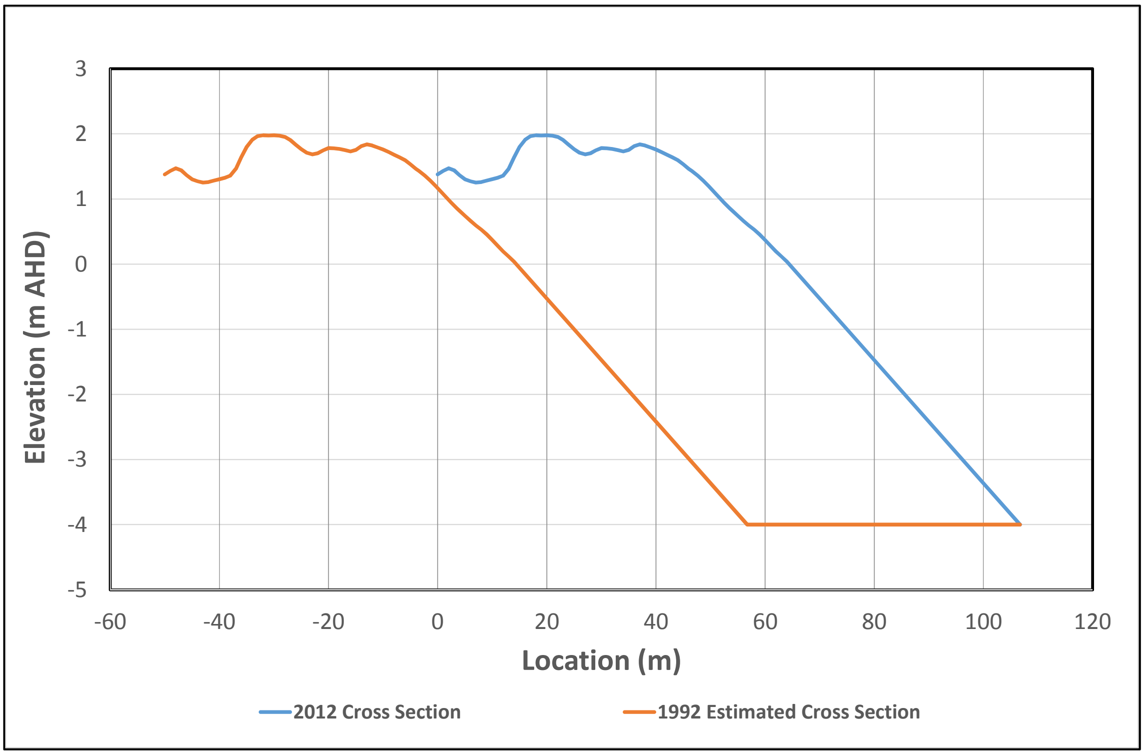

Figure 23 Example of Derived Cross Section Profiles for Transport Analysis

Table 7 Cross Section Areas and Total Volume

Distance East from Breakwater (m)	Change in Area (m^3/m)
16	282
48	203
80	189
112	158
144	244
176	70
208	45
240	13
Volume of Accumulation	33,800

5 Numerical Modelling

5.1 Introduction

A numerical model was built based on the Delft3d open source modelling software. That software is capable of simulating two dimensional (depth averaged) and three dimensional flow, sediment transport and morphology, waves, water quality and ecology. The wave component within the Delft3d modelling suite is provided via a link to the widely applied SWAN spectral wave model.

For this particular application, the model has been used in 2-dimensional (depth averaged) mode with the interactions between waves and wind as follows:

- Wind has been applied across the water surface of the hydrodynamic model to generate wave driven currents;
- Wind is applied to the water surface of the wave model to simulate the generation and growth of waves by wind across Port Stephens and in the open ocean;
- An ocean boundary is adopted for the application of ocean tides, which raise and lower the ocean water level and drive tides in and out of Port Stephens, generating currents and altering water levels inside the Port in accordance with the bathymetry used as input to the model;
- The same ocean boundary is adopted for the input of oceanic swell wave conditions, representative of depth conditions where waves are recorded offshore of NSW. The SWAN model propagates these offshore waves in through the mouth of Port Stephens, were they are altered primarily by the effects of shoaling, friction, refraction and diffraction, before they reach the study shoreline at a greatly reduced height and changed direction, but with relatively minor changes to the wave period;
- The wave model is used to calculate forces that act to both set-up water levels at the shoreline, and drive longshore currents.

The model bathymetry utilised for this study comprises the completed "2015" bathymetry as discussed in Section 4.2.1.

5.2 Configuration

The present open source version of Delft 3d undertakes its calculations on a curvilinear grid, comprising two sets of orthogonally intersecting lines (m & n lines) that bend slowly in space. These lines form approximately rectangular cells that vary slowly in size in the m and n directions. Orthogonality (lines intersecting at right angles) and smoothness (rate of change of size between adjacent cells) need to be kept within reasonable bounds to build a successful model.

The model built for this project extends over the entire surface of Port Stephens, and extends into the ocean to the 100m contour Figure 24. At this depth, it is reasonable to input waves as measured by the wave recorder network maintained offshore of NSW. The model covers large portions of the tributaries of Port Stephens, including Tilligerry Creek and the lower reaches of the Lower Myall and Karuah Rivers, although those areas are not targeted specifically for analysis at this time and the resolution there is less than around the study area. The model could be readily adapted for other locations in the future.

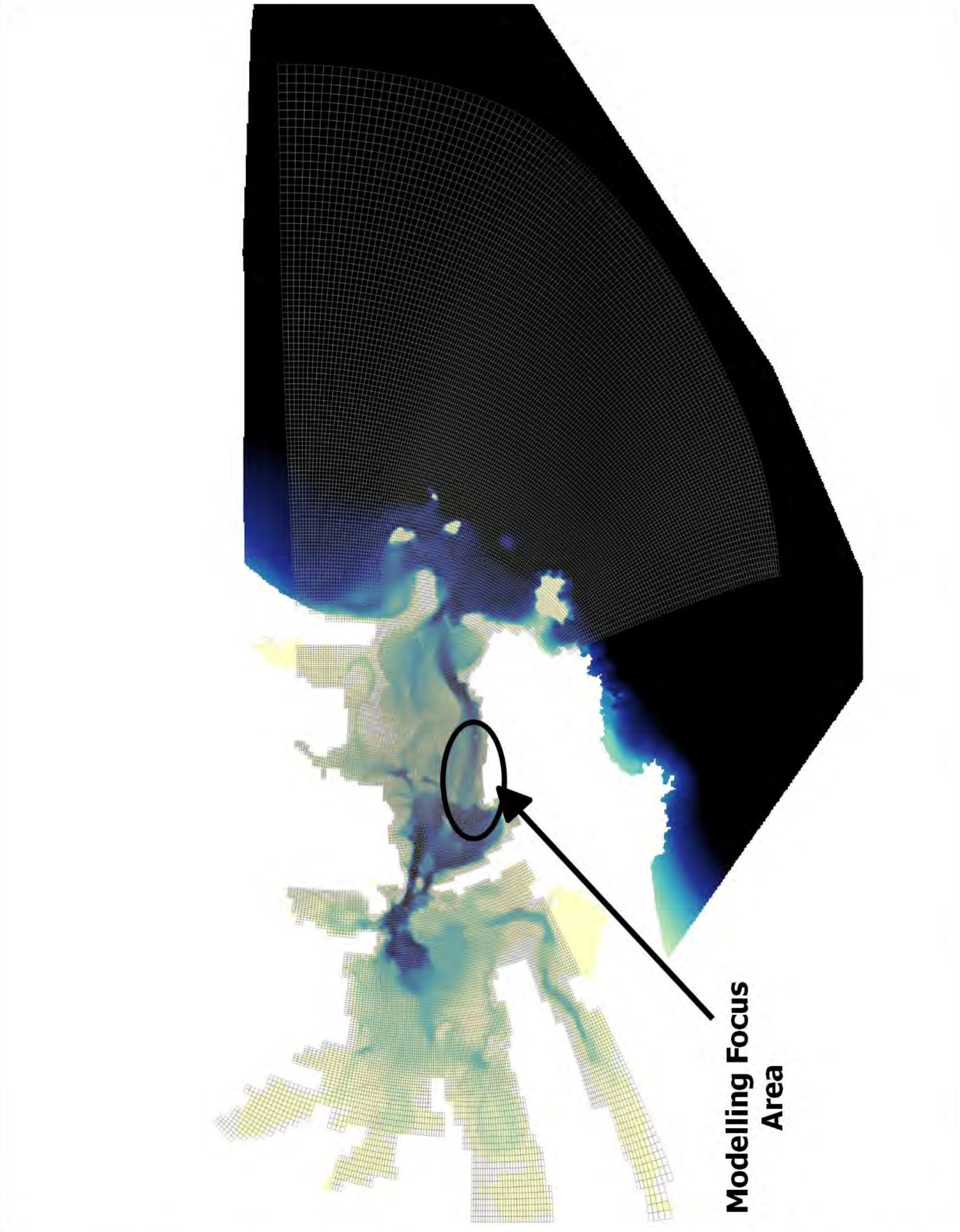

Figure 24: Model Extent and Configuration

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N

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0 2.5 5 7.5 10 12.5 km
(Approx Scale)

Revision	A
Drawn	DW
Approved	DW

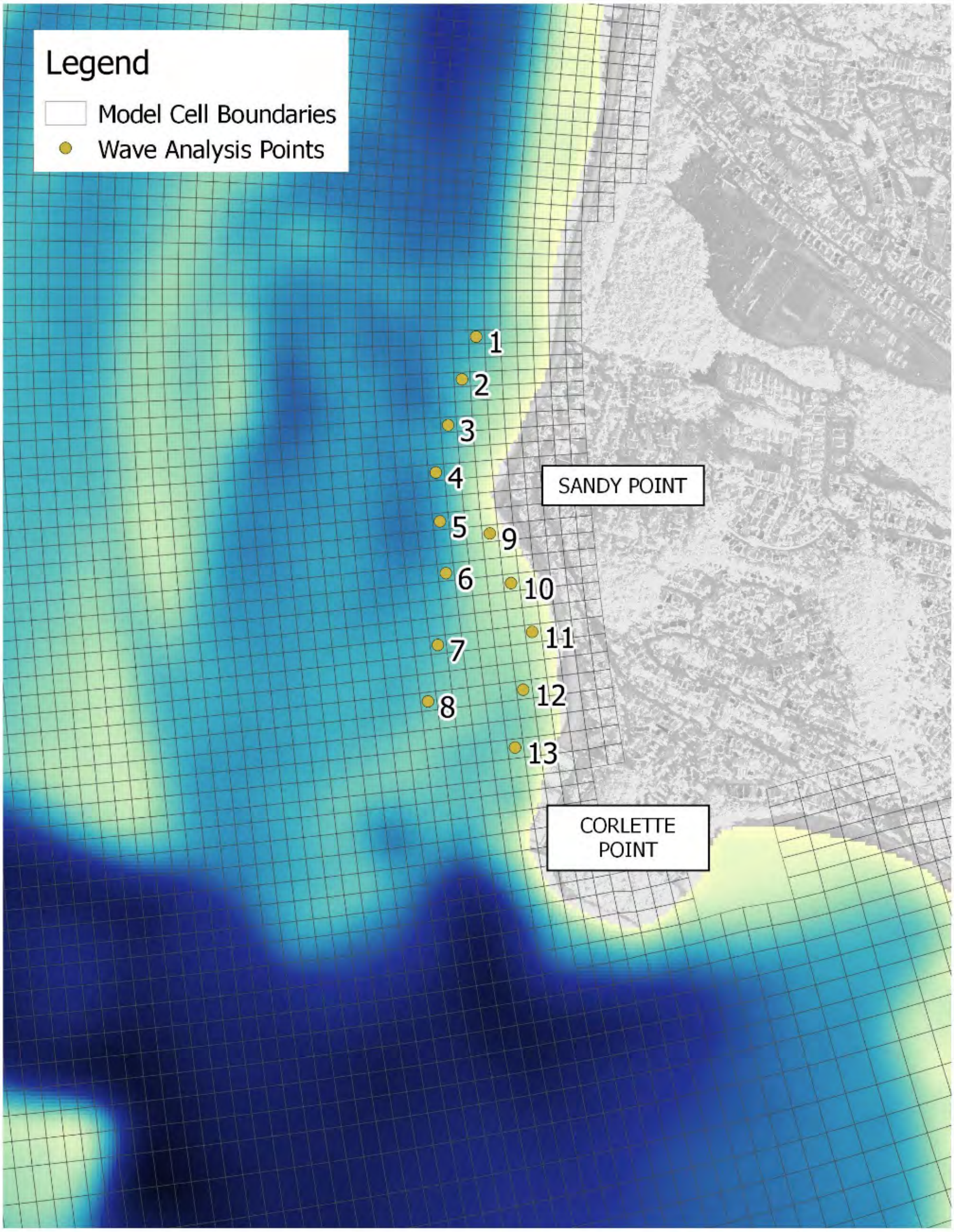

Figure 25: Model Grid Near Corlette and Wave Analysis Points

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0 200 400 600 800 m
(Approx Scale)

Revision	A
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The fringes of the model domain, where cells are coloured white in Figure 24 are included to ensure a reasonable representation of water storage at elevated water levels, particularly in conjunction with projected sea level rise. Lidar data, provided by Port Stephens Council were utilised to determine low lying ground elevations in those areas. The largest grid cells, along the ocean boundary of the model, have sides of up to 400m long. Around the study area the grid cells are finer, with side lengths of around 40 to 50m (Figure 25). Figure 25 also shows locations where results have been extracted from the wave model to help assess appropriate design conditions for any foreshore management options, as detailed in Section 6

5.3 Calibration

Before using the model, it is necessary to be comfortable with its ability to replicate real world conditions. Classically, any model should go through a two-step process involving:

- Calibration, where the model parameters are adjusted within reasonable bounds such that the model predicts field measurements over a given period of time; and
- Validation, where a second set of independent measurements is used to test the parameters arising from the model calibration.

In practice, there is some iteration between these processes resulting from the paucity of reliable data, particularly during significant storm events. We are unaware of any detailed and recent measurements in the near vicinity of the study site. Therefore, limited information was available to complete the two step process.

Initially, we have tested model performance against the recent, April, 2015 storm, being representative of the present configuration of the flood tide delta, and conditions that are experienced during an extreme storm, which is of most interest to the present study. Wave and tide data were obtained from Manly Hydraulics Laboratory, which manages tide and wave collection instruments in NSW on behalf of the Office of Environment and Heritage. Wind data were obtained from the Bureau of Meteorology for the Williamtown recorder. The Tomaree “ocean” tide gauge record was applied at the ocean boundary, as were the wave conditions from the Sydney recorder. Wind was applied uniformly across the surface of the model.

There was only one other tide gauge data set available inside the Port Stephens entrance, at Mallabula to the west of Soldiers Point. The following parameter values were adopted to achieve the “best fit” to the modelled water levels as follows:

- Manning Roughness of 0.017 (uniform across model domain), which is at the low end but within an acceptable range;
- Horizontal eddy viscosity of 100m^2/s, which is at the higher end of the recommended range;
- Subgrid scale turbulence was modelled using the standard large eddy simulation formulation and parameters as recommended in the modelling documentation; and
- Standard wind drag coefficients were adopted.

A time step of 0.05 minutes was adopted to achieve stability. A comparison of the resulting modelled and measured tide levels at the Mallabula gauge site is provided in Figure 26 covering a range of tidal cycles over 9 days.

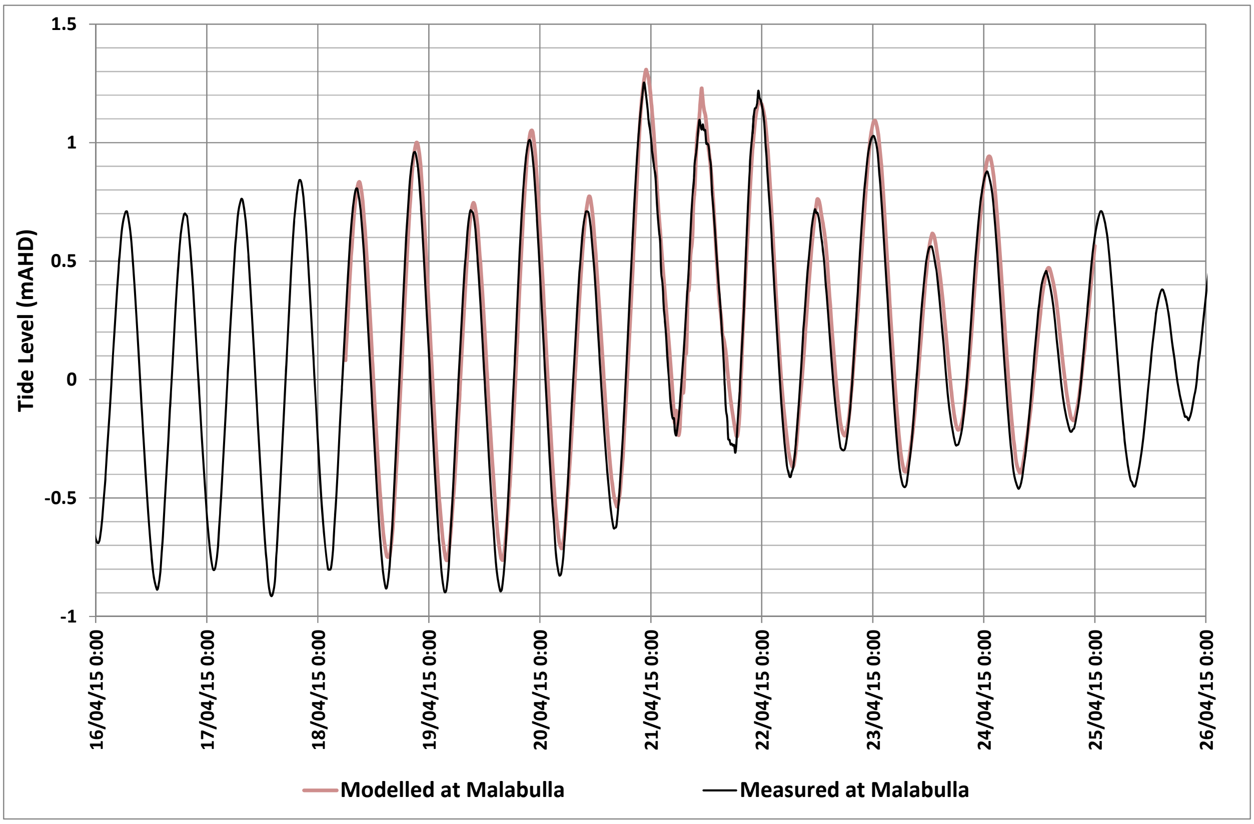

Figure 26 Modelled and Measured Tides at Mallabula Gauge, April 2015 Storm

A close look at the results indicates the following:

- The modelled values tend to be around 5cm higher than the measured values at both the tidal peaks and troughs; and
- The modelled high and low tides tend to occur slightly later than the corresponding measured high and low tides.

This type of mismatch, although reasonably minor, could normally be adjusted by lowering the friction coefficients within the model. However, as discussed above, the adopted coefficient is reasonably low already, and further downward adjustment is not prudent. It appears most likely that the application of the Tomaree Tide gauge, which actually sits inside the entrance to Port Stephens, as the ocean boundary, would account for much of this mismatch. It is likely that the ocean tide has been transformed by the time it propagates to the Tomaree gauge location.

Even so, the performance of the model is reasonable for storm conditions, considering the purpose to which it is to be applied in this study (deriving design conditions for conceptual design). Future users of the model would need to judge the sufficiency of the model for their particular purpose before application.

We are unaware of any robust wave measurements undertaken in the vicinity of the study area. Following the April 2015 storm and the community consultation undertaken as part of the overall project, we were provided with videos captured by the community during various storm events. In particular, one video captured around 27s of footage at around 11am on 21st April, showing waves breaking across the foreshore of No. 36 Sandy Point Road. Stills from that video are reproduced here as Figure 27. Importantly this video was captured very close to the time at which a record wind speed of over 25m/s was measured at Williamtown, with the wind approaching from a bearing of 150 degrees.

It is difficult to estimate a representative wave height from the video, although it appears that the actual wave height offshore at the time would be of the order of 1m, but probably less. As shown by the bottom left frame in Figure 27, the wave approaches from slightly east of shore normal, breaking across the eastern end of the foreshore fronting No. 36 first before peeling westwards along the structure. This corresponds to a wave approaching from almost north east.

The model prediction at 11am on 21st April is shown in Figure 28. That figure demonstrates wave heights around 0.8m offshore of the site, and waves approaching from east which are shore normal, as witnessed on site. This provides confidence that the modelled wave heights are reasonable, and that the model is capable of predicting extreme design wave conditions, including the influence of very strong winds.

As waves approach the foreshore they increase rapidly in height. This process is not accurately replicated by the SWAN wave model and neither is wave breaking. For this reason, the apparent decrease in wave height close to shore in Figure 28 is not matched by the actual waves which shoal and break. In considering waves at the foreshore for design, separate methods are needed to take this into account during the design process.

Current speed data are sparse. Nielsen & McGowan (1994), undertook modelling of the flushing pipes at the Anchorage Marina, and collected some current velocity data near the entrance to the Marina, indicating that peak ebb and flood current speeds were both around 0.4m/s. However, limited information is provided within that paper to discern the type of tide being considered, although there is some evidence that a tide range of around 1.6-1.7m was applied, some 10% larger than the mean spring tide at this site.

To test the model, a tide ranging from -0.75 to 0.9m was used in the model, and the current patterns and speeds that developed with such a tide were examined. For that simulation, winds and waves were not included. Figure 29 shows the predicted flood tide currents offshore of the study site. Notably, the current “streamlines” contract around Sandy Point and Corlette Head, causing faster flows in these areas, whereas tidal currents inshore adjacent to Corlette Beach are relatively static. While the 50m grid size of the model is insufficient to replicate exact current patterns around the Anchorage Marina, it can be seen that the model predicts currents in the vicinity of 0.3 to 0.4m/s near the entrance to the Marina, with currents up to 0.6m/s or more with distance offshore. A very approximate rule of thumb would suggest that currents of 0.25m/s are capable of entraining and transporting sand size coastal sediments in NSW. The corresponding figure for ebb tide currents (Figure 30) indicates a very similar pattern to the flood tide currents, albeit in the reversed direction. If anything, the current speeds on ebb tides are marginally slower than those on the Flood Tide.

The model does a reasonable job of predicting currents in this area, possibly tending towards a slight under prediction of velocities.

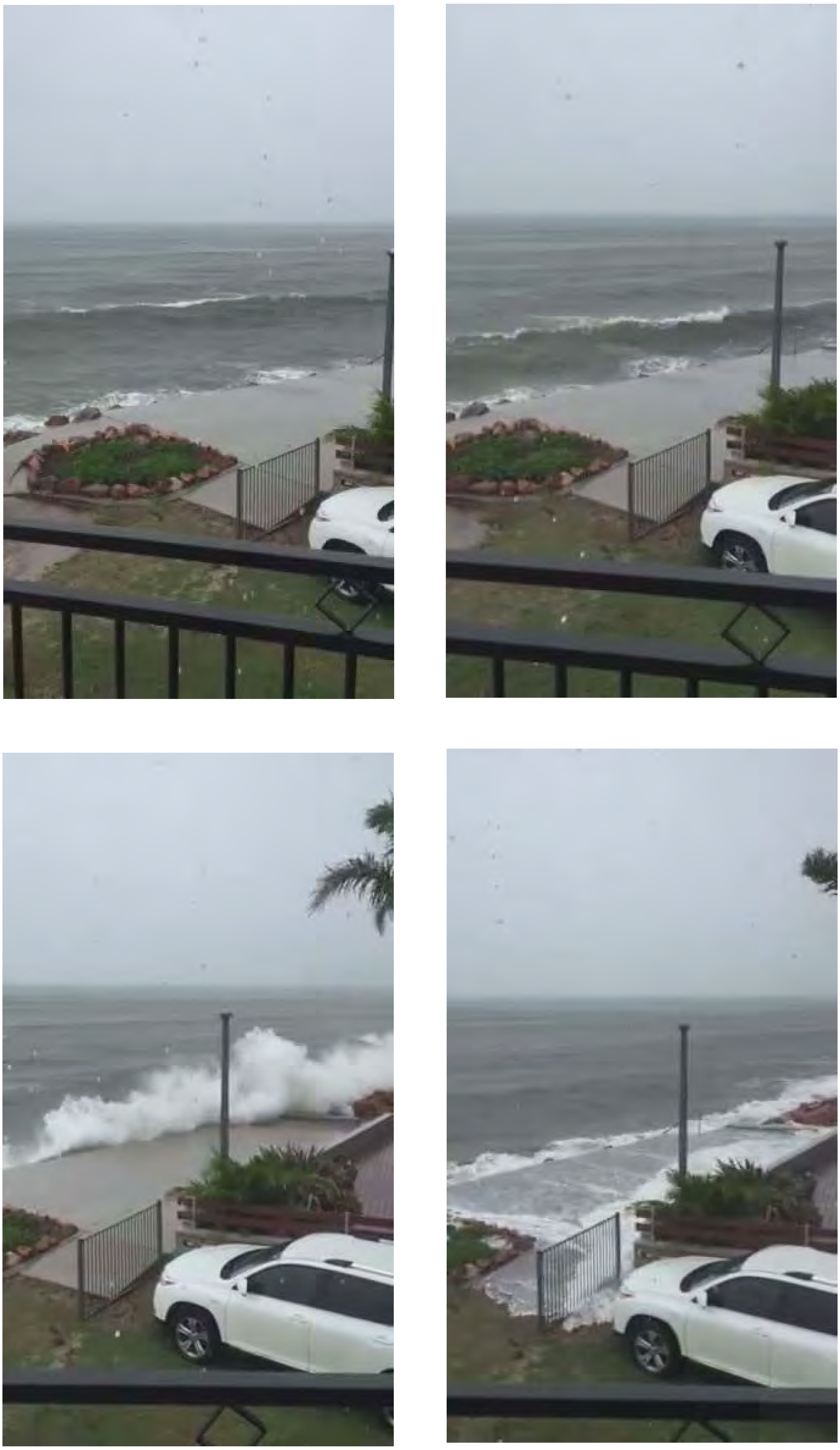

Figure 27 Stills from Video of Foreshore Overtopping, 21st April, 2015.
(Top Left: Approaching, Top Right: Breaking, Bottom Left: Impact, Bottom Right: Backwash)

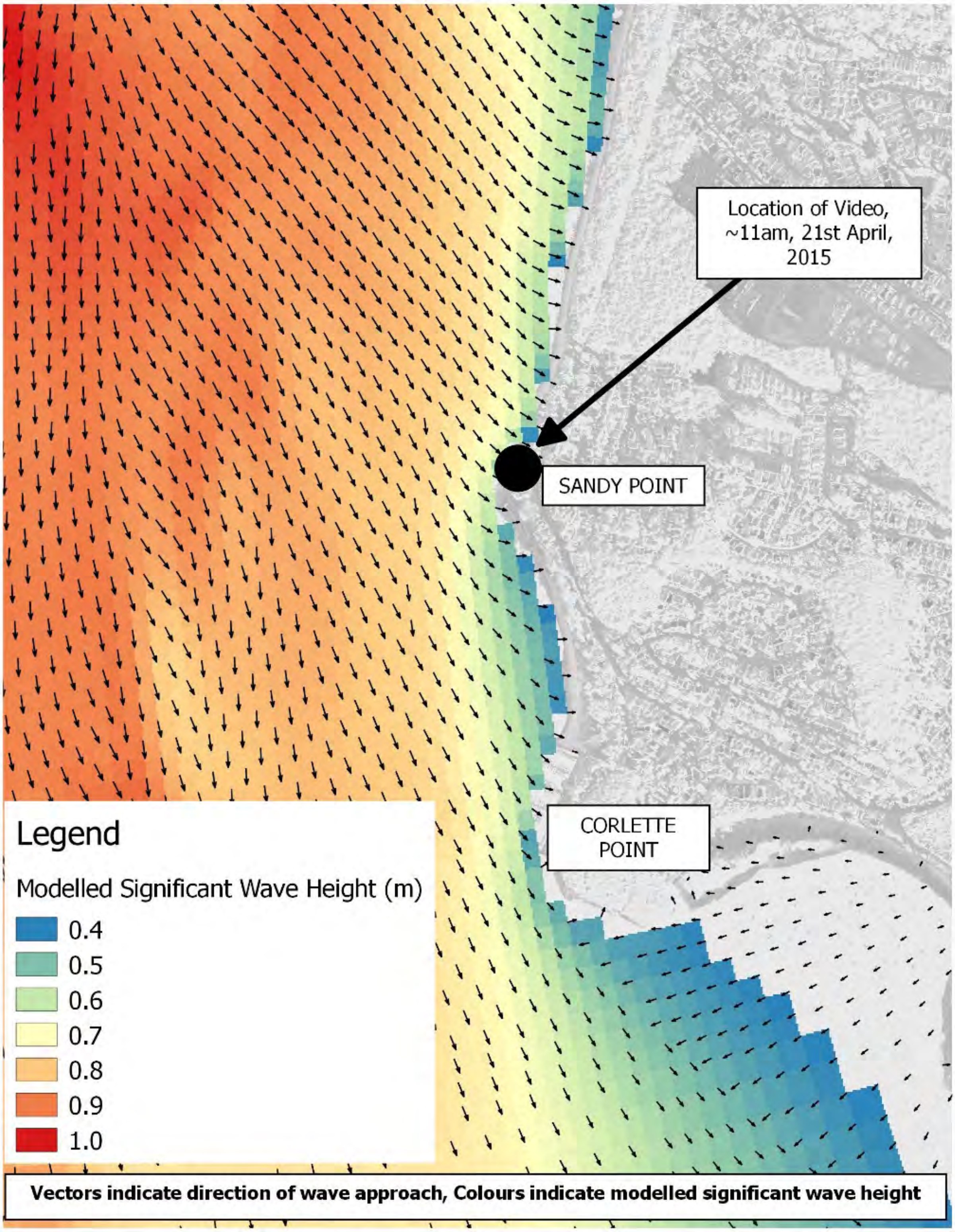

Figure 28 Modelled Wave Conditions 21st April, 2015, 11am

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Drawn	DW
Approved	DW

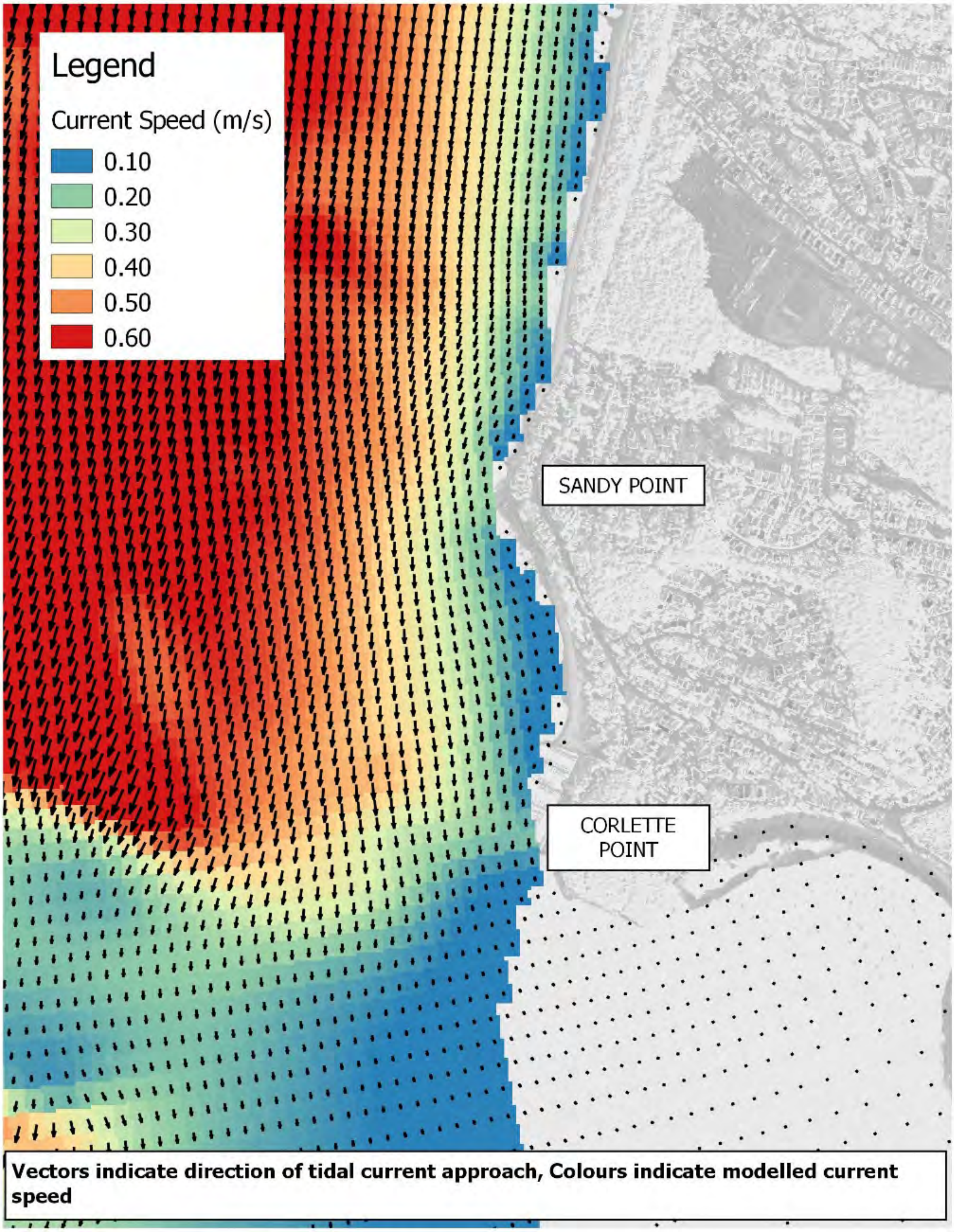

Figure 29: Modelled Peak "Flood" Currents

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Environmental Consultants

0 200 400 600 800 m
(Approx Scale)

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Approved	DW

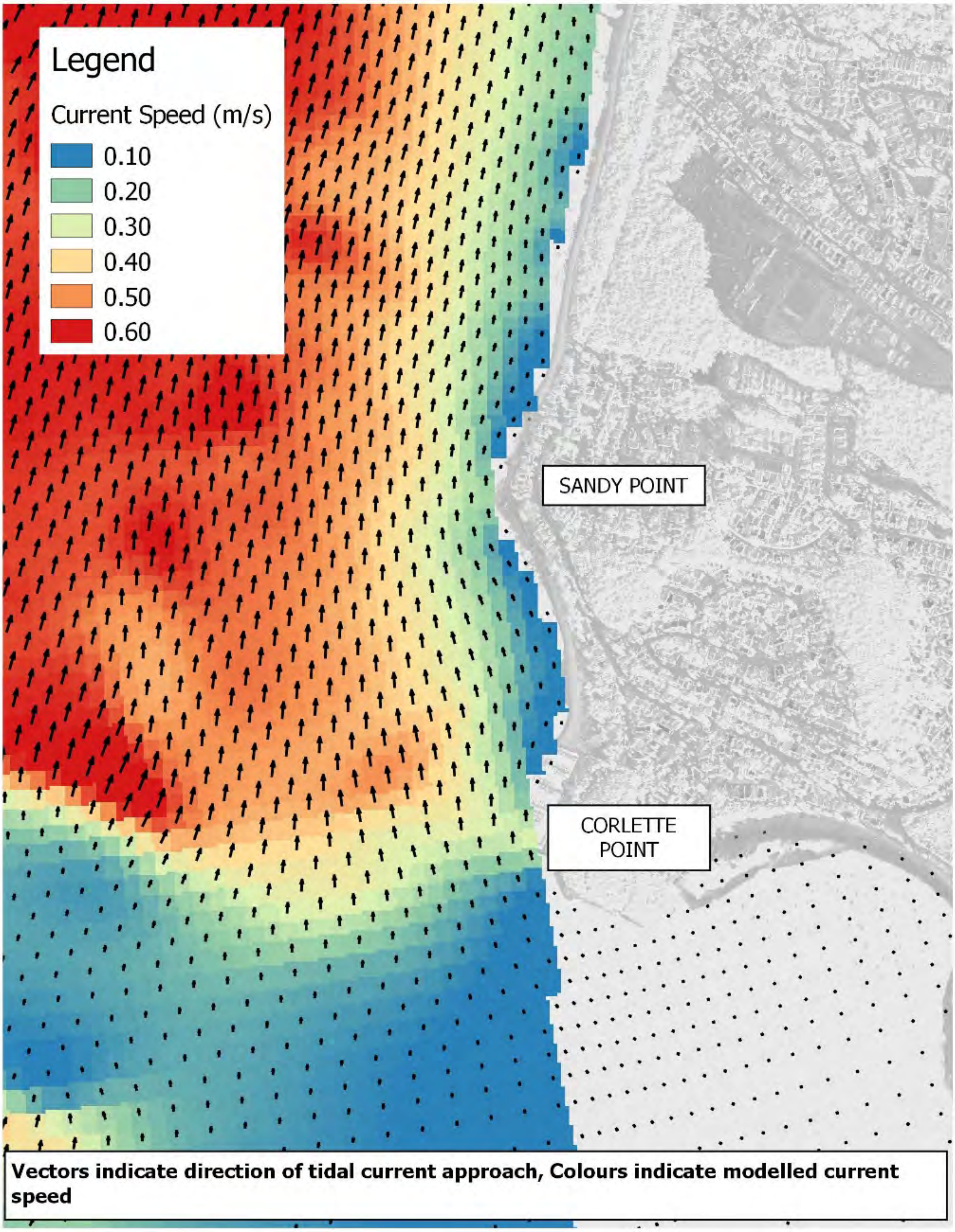

Figure 30: Modelled Peak "Ebb" Currents

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Environmental Consultants

0 200 400 600 800 m
(Approx Scale)

Revision	A
Drawn	DW
Approved	DW

6 Design Conditions

6.1 Offshore Waves and Water Levels

6.1.1 Offshore Waves

Design “storm” conditions typically comprise both an elevated water level and the action of high waves. Shand et al. (2012) undertook a Joint Probability Assessment of these parameters for available records along the NSW coast. From the Crowdy Head and Sydney records, they present Wave Buoy Extreme values as shown in Table 8.

Table 8 Estimated Extreme Offshore Significant Wave Heights (m)

Probability	Sydney[3]	Crowdy Head[4]
10% (P=0.1)	2.55	2.48
1% (P=0.01)	4.19	2.94
1yr ARI (P~0.0001)	5.9	5.4
10yr ARI (P~0.00001)	7.5	7.0
100yr ARI (P~0.000001)	9.0	8.5

Table 8 illustrates a long recognised feature of the NSW wave climate: that the central NSW coast, around Sydney tends to have a more severe, stormier wave climate than the coast to the north (e.g. Crowdy Head) or south. While the average of both sites could be taken to approximate conditions offshore of Port Stephens, a slightly conservative approach is to adopt the more severe, Sydney conditions and this is the approach taken herein. In terms of the actual waves experienced at the Sandy Point / Conroy Park site, the wave heights are greatly reduced, as shoaling, refraction and friction losses affect waves as they propagate into Port Stephens towards Corlette.

With respect to wave direction Callaghan et al. (2008) studied 30 years of coastal storms at Sydney. They found that there was a tendency for extreme storms to have waves approaching from between 150 and 170˚ (i.e. from south of south east), with less extreme storms clustering around 175˚. They were, however, unable to determine a robust relationship between storm wave height and direction. For the present study, waves between 130 degrees and 180 degrees were investigated in setting the design storm wave heights inside the Port, noting that the offshore direction and period of the wave are very important determinants of the degree of focussing and refraction once waves propagate inside the entrance to Port Stephens.

Callaghan et al. (2008) also presented a statistically derived expression for the “expected” or most likely value for the period associated with a particular storm wave height. Adopting that expression, and the extreme Sydney Wave Heights from Table 8, appropriate periods for the design waves were derived.

[3]Directional Record between 1989 and 2009 Analysed
[4]Non Directional Record between 1985 and 2010 Analysed

Table 9 Expected Wave Period for Adopted Design Offshore Wave Heights

Probability	H_s(m)	T_p(s)
1yr ARI	5.9	10.7
10yr ARI	7.5	11.5
100yr ARI	9.0	12.3

6.1.2 Offshore Water Levels

Astronomical tide levels have been reported by Manly Hydraulics Laboratory (2012). The tidal planes for the closest ocean tide gauge at Tomaree are presented in Table 10. These values are based on an annual average covering 20 years of data between 1990 and 2010.

Table 10 Annual Averaged Tidal Planes (Tomaree)

Tidal Plane	Level (m AHD)
Higher High Water Springs Solstices	0.976
Mean High Water Springs	0.601
Mean High Water	0.474
Mean High Water Neaps	0.348
Mean Sea Level	-0.038
Mean Low Water Neaps	-0.423
Mean Low Water	-0.55
Mean Low Water Springs	-0.677
Indian Springs Low Water	-0.945

The joint probability analysis of Shand et al. (2012) concluded that, in the absence of sufficient data to enable a more comprehensive analysis at a particular site, complete dependence of offshore significant wave heights and tidal residual[5] should be assumed. While many smaller storms do not show any real dependence, Shand et al. noted that there does appear to be a correlation near the extremes, with the largest measured tidal residuals corresponding to the largest measured wave heights.

Bearing this in mind, the extreme values of tidal residuals described in Shand et al. (2012) are presented in Table 11

[5]The tidal residual is the amount by which the offshore water level exceeds the predicted astronomical tide.

Table 11 Estimated Extreme Tidal Residuals (m)

Probability	Fort Denison[6]	Sydney[7]	Port Macquarie (Offshore)[8]
1yr ARI (P~0.0001)	0.36	0.31	0.37
10yr ARI (P~0.00001)	0.44	0.38	0.48
100yr ARI (P~0.000001)	0.61	0.47	0.61

Due to the apparent anomalies between Fort Denison and Sydney, which should be statistically similar, Manly Hydraulics Laboratory (MHL) was contacted to discuss this issue. MHL was in the process of updating water level analyses, including water levels during storms, along the NSW coast. Draft outputs from that report (MHL 2236) were provided to us by Ben Modra from MHL.

Charts showing total water levels for different recurrence intervals were provided for both the Tomaree Gauge and Fort Denison. Values were extracted from these charts and are presented in Table 12. It was noted that present analysis shows more consistency between the two Gauges in Sydney Harbour

Table 12 Ocean Water Levels for Various Recurrence Intervals

Recurrence Interval (yrs.)	Fort Denison (Sydney Harbour) Water Level (m AHD)	Tomaree (Port Stephens) Water Level (m AHD)
5	1.3	1.28
20	1.36	1.31
50	1.40	1.35
100	1.42	1.37

Herein, considering the slight tidal amplification present in Port Stephens, and the much longer record available for Fort Denison, the analysis for the Fort Denison Gauge data is considered an appropriate basis for foreshore protection design.

At the present time, PSC has adopted an allowance for sea level rise in line with the benchmark values adopted by the NSW government in 2009, and subsequently withdrawn in 2011. Local Councils have been advised to investigate and make their own decision regarding the projections that they should adopt, and many local councils in NSW have retained the original benchmark values. The values comprise a 0.4m rise in mean sea level between 1990 and 2050 with a further 0.5m by 2100. Of importance to the present study is that a 25 year planning time frame was set by Council (i.e. designed to be serviceable until 2040). Interpolating the 40/90 values via a second order polynomial, results in applying a rise of close to 32cm between 1990 and 2040. However, to make this meaningful for design, it needs to be adjusted to be relative to AHD. Wainwright et al. (2014) presented analysis of the Fort Denison tidal record and estimated that mean sea level was around 3cm above AHD in 1990. Accordingly, we estimate that an appropriate allowance for mean sea level in 2040 will be 35cm AHD and advise that this should be used for design.

[6]Record between 1914 and 2011
[7]Record between 1987 and 2011
[8]Record between 1984 and 2011

6.2 Nearshore Water Levels

Astronomical tide levels have been reported by Manly Hydraulics Laboratory (2012). The tidal gauge at Mallabula, to the west of Soldiers Point and some 9km west of Sandy Point was commissioned in 1992. Manly Hydraulics Laboratory reported annually averaged tidal planes as presented in Table 13.

Table 13 Annual Averaged Tidal Planes (Mallabula)

Tidal Plane	Level (m AHD)
Higher High Water Springs Solstices	1.08
Mean High Water Springs	0.69
Mean High Water	0.588
Mean High Water Neaps	0.443
Mean Sea Level	0.009
Mean Low Water Neaps	-0.431
Mean Low Water	-0.57
Mean Low Water Springs	-0.709
Indian Springs Low Water	-0.995

A comparison of these tidal planes indicates that there is a small amplification of the tides, with the tidal ranges at Mallabula higher than those at Tomaree. Furthermore, the mean sea level at Mallabula is higher than at Tomaree, indicating a slight "pumping" up of the tide. Overall, at the high tide levels of importance to designing foreshore management strategies, there is a difference of around 10cm. Most of the bathymetric features which would contribute to these modifications exist downstream (i.e. east) of the site. Therefore, it is reasonable to adopt the tidal planes at Mallabula as an underlying basis for design water levels. Similarly, adding 0.1m to the still water levels presented in Table 12 will include an allowance for the tidal amplification effects that are felt at the site.

It can be reasonably assumed that mean water level, and all tidal planes within the Port will rise by a similar amount to those in the open ocean, as a result of climate change driven sea level rise. Utilising Council's adopted values, Mean Sea Levels are projected to be around 0.35m AHD in 2040, which is the timeframe for planning required by Port Stephens Council for this project.

6.3 Nearshore Waves

6.3.1 Introduction

The design wave climate near the shoreline of Sandy Point and Conroy Park comprises two notably different types of waves:

- Modified ocean swell which propagates through the entrance to Port Stephens and is significantly refracted and affected by frictional losses before approaching the study shoreline. These waves tend to have a low height in the vicinity of Corlette, even during extreme events, but shoal (rear up) significantly as they approach the shoreline. The degree to which they shoal is affected by the wave period, with longer period waves shoaling to a greater extent; and

- Waves generated by winds acting locally over the surface of Port Stephens. The shoreline is exposed to wind waves approaching from the west, north and east. Southerly winds will generate offshore waves at the site. While these locally generated waves can be quite high, they have short periods and are not subject to shoaling to the same extent as refracted oceanic swell.

In order to obtain design wave conditions close to the shoreline, both types of waves have been simulated using the numerical model described in Section 5, with details of those simulations provided in the following two sections. Model results were extracted for the 13 locations shown on Figure 25 to ascertain whether there was a difference in nearshore design wave heights at different locations.

6.3.2 Swell Waves

Swell wave simulations were executed for the conditions presented in the 1, 10 and 100yr recurrence interval conditions presented in Table 8. In addition to these three recurrence intervals, intermediate wave heights and periods were also simulated. In all cases, a following wind was also applied to the model. By applying this wind to the surface of the model, additional wave height growth between the offshore location (where waves are recorded, and the statistics are based) and the inside of Port Stephens is represented. Testing showed that this following wind could contribute significantly to the refracted swell wave heights simulated inside the Port and, based on our model testing of the April 2015 storm, must be included to get reasonable results. The wind speed was selected to match the direction and recurrence interval of the swell wave simulated at the model boundary. This is appropriate, as a commensurately strong wind is required to generate a wave of a given recurrence interval. In summary, there were 5 base wave conditions considered as presented in Table 14. Note that 3 different directions were considered, between 130 and 180 degrees based on the findings of Callaghan et al. (2008). While the wave height used was the same, the wind speed was varied based on the extreme analysis undertaken of the Williamtown wind record.

Table 14 Swell Wave Conditions Modelled

ARI	Hs	Tp	Wind Speed (From 130 degrees)	Wind Speed (From 155 degrees)	Wind Speed (From 180 degrees)
1	5.9	10.7	13 0	13.4	15.1
Intermediate	6.7	11.1	14.5	14.9	15.7
10	7.5	11.5	16.0	16.3	16.3
Intermediate	8.25	11.9	18.0	18.6	16.5
100	9.0	12.3	20.1	20.8	16.7

In total, there were 15 different conditions simulated, and these were executed for an extreme (and unrealistic) 12.5 hour tidal cycle varying between -0.95 and 1.60m AHD. The tide signal was constructed by adding a 0.6m surge on top of a tide varying between ISLW and HHWSS in the ocean. The surge rose and fell completely in sync with the tide. The purpose of this synthesised water level was twofold:

- To investigate swell wave propagation over a wide range of water levels; and

- To investigate an extreme current condition and how that might affect focussing of wave energy due to wave-current interaction, which is built into the model.

Following completion of the simulation, the maximum wave height resulting from the 12.5hr of each tidal cycle was analysed to find the maximum wave height at each of the 13 locations considered and this was the nearshore design wave condition adopted at that location for each of the modelled conditions from Table 14.

A full summary of the outputs for all 13 sites is tabulated in Appendix C. The results indicate that swell waves at the site are highest when waves approach from a more easterly direction (i.e. 130 degrees). Along the eastern side of Sandy Point, the 100 year swell wave condition is around 0.8m, whereas for a 1yr ARI the wave heights are around 0.6m. Waves approach from between 75 and 80 degrees at this location. At point 8, the wave results are not fully representative of the swell condition, and there are anomalous results present due to the generation of wind waves from inside Salamander Bay. Otherwise, along the western side of Sandy Point, the swell wave heights are smaller ranging from around 0.4m for a 1yr ARI up to 0.7m for a 100yr ARI Event. Waves to the west of Sandy Point approach from between 45 and 55 degrees.

In comparison, MHL (1997) predicted design swell waves of around 0.4m for a 100yr ARI event and 0.5m for an extreme event. One possible reason for this was the reliance on pure swell conditions input to the boundary of the model. We have found that wind on coastal waters can significantly increase wave heights from between the depths where 'offshore' waves are typically measured in New South Wales and the coastline. Testing of our model without the following wind indicated that similar design values to those presented by MHL were obtained.

6.3.3 Wind Waves

Local wind waves have been tested in the model, with extreme wind conditions determined from the Williamtown wind record. Previous studies have highlighted an excellent correlation between the record at Williamtown, and temporary wind records collected during studies at Jimmy's Beach (Geomarine, 1988; MHL, 1997). Accordingly it is reasonable to apply the record at Williamtown for this purpose. The Williamtown Recorder has an elevation of 9m. It is standard to adjust the wind to match an equivalent wind at 10m height. The adjustment from 9m to 10m elevation results in an increase in wind speed of 1.5%.

Using the data record provided by BoM for Williamtown, all records were grouped into 16 bins equally spaced around the compass and then a statistical fit to the generalised extreme value distribution undertaken using the maximum likelihood method.

Overall, the fit was good for most directions of interest, although there were anomalies for winds from North to East. Technically, the derived shape parameter for the distribution in these directions (ξ) returned positive values in a number of instances. This appears physically implausible for winds being generated from one 'type' of meteorological system. The presence of significant large outliers in a number of these N⇨E directional bins suggests that there may be more than two types of meteorological systems generating winds from this quadrant, one of which results in the most extreme of events.

Regardless, the positive value of ξ results in higher wind speeds at the higher recurrence intervals, and the values from the analysis have been adopted as moderately conservative.

Table 15 Extreme Wind Analysis Results

Direction	ARI (years)					
	10	20	25	30	50	100
W	18.6	19.3	19.6	19.7	20.2	20.7
WNW	21.6	22.5	22.7	22.9	23.4	24.0
NW	18.7	19.6	19.9	20.1	20.6	21.3
NNW	15.2	16.4	16.7	17.0	17.7	18.4
N	12.9	15.2	16.0	16.7	18.7	21.8
NNE	11.1	12.3	12.7	13.0	13.9	15.2
NE	11.9	12.8	13.1	13.4	14.1	15.2
ENE	12.9	13.6	13.8	13.9	14.4	15.0
E	14.1	15.3	15.7	16.0	17.0	18.4

A simulation was executed with these wind speeds from each of the directions being considered. The simulation was continued over a full range of tidal elevations, utilising the tidal boundary described in Section 6.4 to examine the impact of water levels on the generation of these local waves. Outputs were derived at the same locations as described in Section 6.3.2. The maximum wave simulated at each location over the entire tidal cycle was selected for design, and the results are tabulated in Appendix C.

The results show that wind waves from West North West are the largest for almost every location and recurrence interval considered, except for the rarest events at Point 2, where a North Westerly wave is the largest. Design waves vary between 0.6 and 0.8m for all locations and recurrence intervals.

The maximum height waves approach from a direction that will impact almost normal to the western side of Sandy Point. However, along the eastern side (Output Points 1 through 4) a northerly wave, which approaches in a more shore normal direction, may be more appropriate for designing against wind waves. Wind waves are unlikely to refract significantly to impact on the eastern side of Sandy Point.

The wind waves modelled here are significantly smaller than those presented in the part 2 of the Port Stephens Flood Study (MHL, 1997), which estimated wind waves of over 2.0m for the 100yr ARI event. As noted in Section 2.3.2, we consider this to have been most likely caused by an overestimate of the design wind speeds particularly from the North West and west, which the present study has shown to be the critical direction for wind waves.

6.3.4 Use of Modelled Waves in Design

The waves presented in the preceding two sections have been extracted at locations at least 100m and in depths of at least 7m, offshore of the immediate shoreline around the study site. In order to develop conditions at the immediate shoreline, it is necessary to consider the wave transformation processes that will alter the waves as they traverse the surf zone and impact upon the foreshore. The complex wave breaking and surf zone dynamics are not well replicated by the numerical model. The design of foreshore treatments, such as revetments and sea walls, needs to consider the way in which these waves interact with the structures. The more detailed propagation of these waves and their interaction with the shoreline is to be considered during the design of foreshore treatments as part of the design of management options during latter stages of this study.

6.4 Current Velocities

Current circulation patterns and peak velocities have been investigated using the numerical model. A repeating, theoretical tide, representing the largest oceanic astronomical tidal range was applied as the ocean boundary condition, with no wind or waves applied and the maximum depth averaged ebb and flood current speeds calculated in the vicinity of the study site. These are presented in Figure 31 and Figure 32 for flood and ebb tide currents respectively.

Figure 19 demonstrates that the current speeds are increase with distance offshore, reaching 0.6m/s approximately 300m north of Corlette in the centre of the east-west aligned tidal channel. Currents are comparatively slower around Corlette Point. This is related to the offshore bathymetry at Corlette. As the flood tide flows around Sandy Point, it diverges off Sandy Point and follows the line of a steep shelf which carries it away from Corlette Beach, as indicated by Figure 19. As the tidal flows continue west past Corlette Head, the depth averaged speed decreases due to the sudden increase in depth at the tidal dropover.

Similarly, the Ebb tide in Figure 20 moves fastest approximately 300m offshore from Corlette and is slowest around Corlette Point. The Ebb tide current drains Salamander Bay resulting in a convergence of flow and acceleration around Corlette Point, which again acts to divert tidal currents from Corlette Beach. Accordingly, tidal currents tend to be faster around the northern tip of Sandy Point, but slower along Corlette Beach.

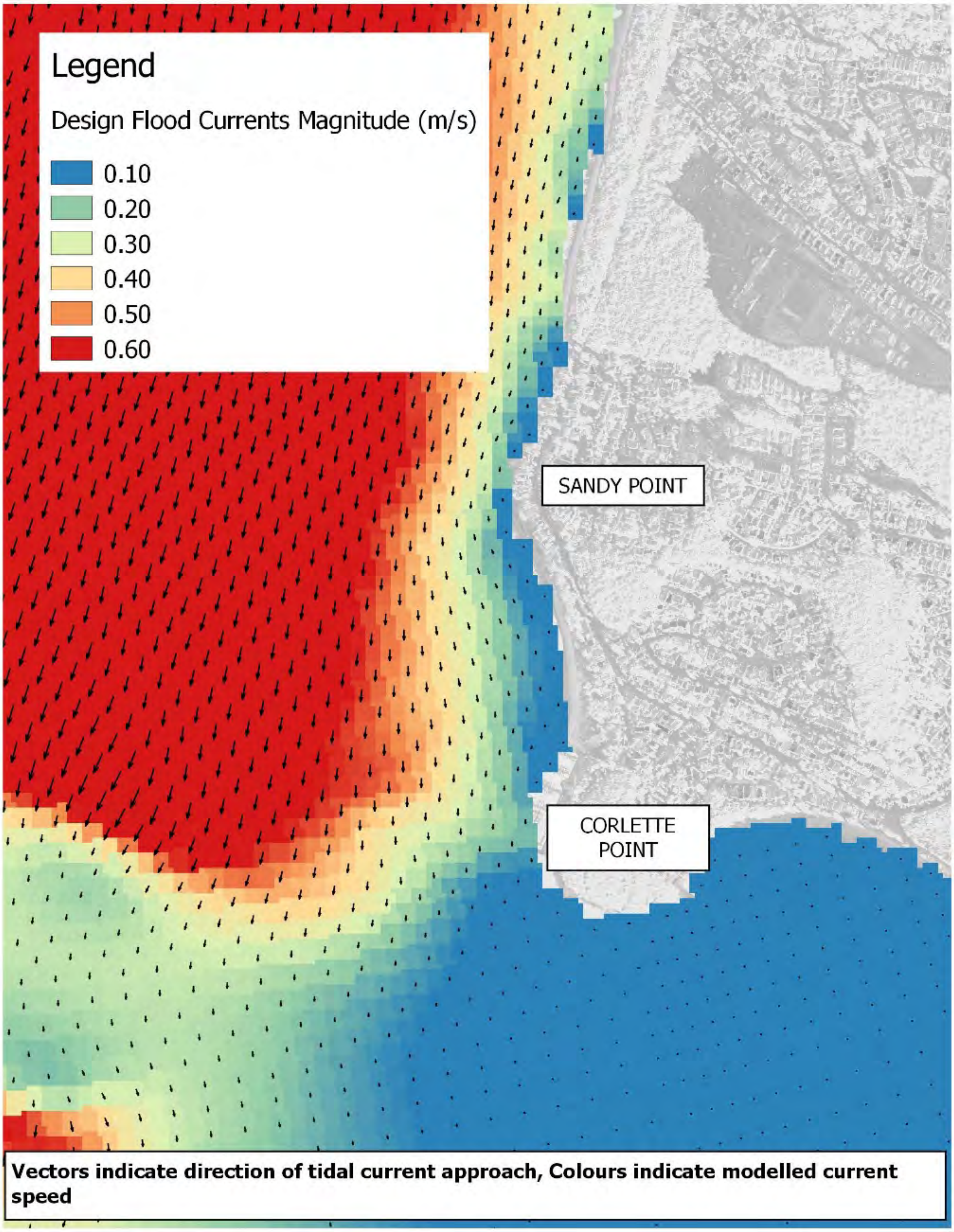

Figure 31: Design Flood Tide Currents

Sandy Point / Conroy Park Coastal Processes Study

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0 200 400 600 800 m
(Approx Scale)

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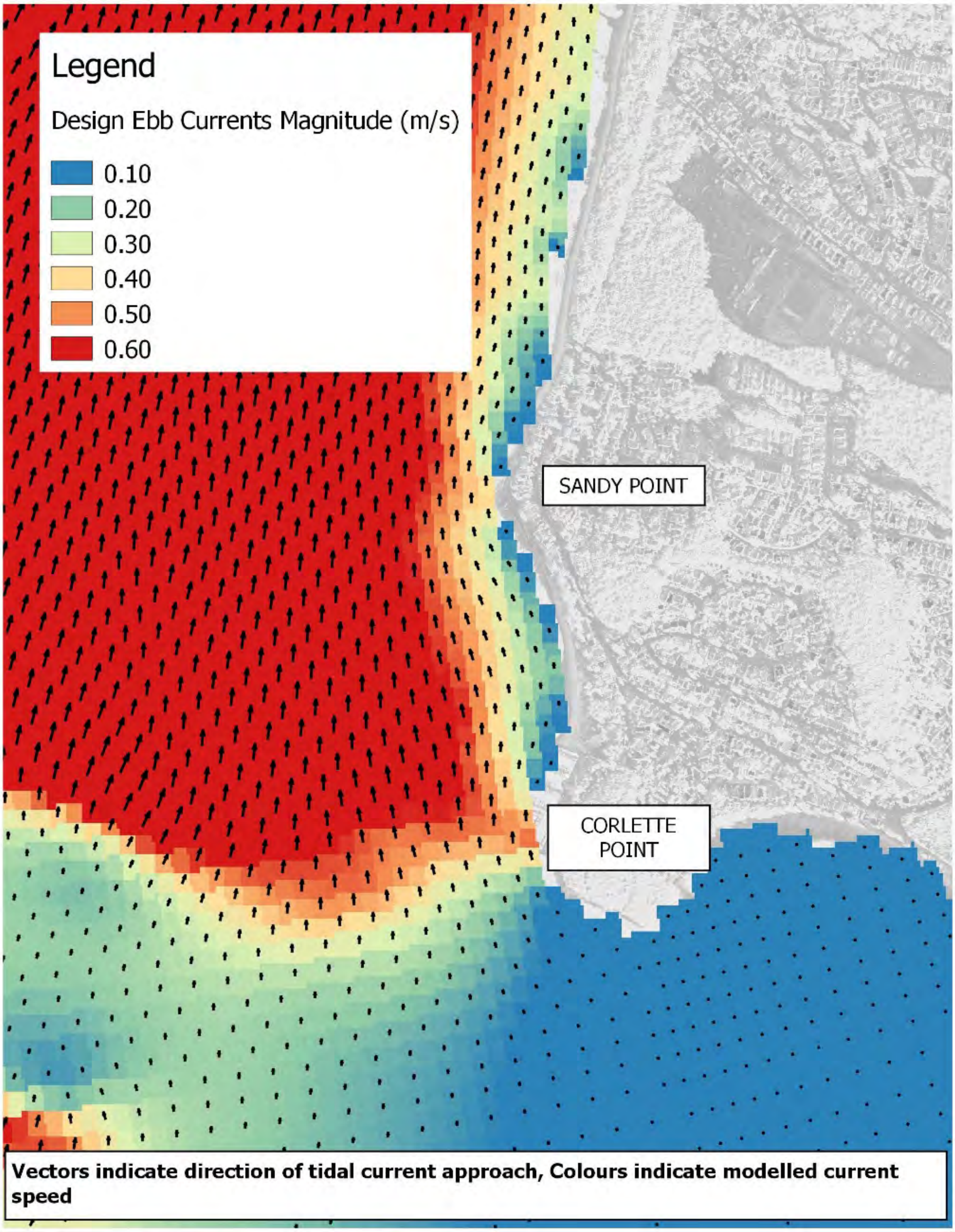

Figure 32: Design Ebb Tide Currents

Sandy Point / Conroy Park Coastal Processes Study

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0 200 400 600 800 m
(Approx Scale)

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7 Summary

This Coastal Processes report was prepared to inform the development of appropriate management strategies for the Sandy Point / Conroy Park Foreshores within Corlette, to the south of Port Stephens.

Firstly, the report examined the geomorphological context of the study area and found that the foreshore, along with most foreshores in the lower (eastern) basin of Port Stephens, is strongly influenced by behaviour across the estuarine flood tide delta. The flood tide delta is a large sand body which defines bathymetry in the lower basin and is slowly moving into the Estuary, at estimated rates of between 0.5 and 1.0m per year. The present, prograding (leading) face of the delta exists approximately between Corlette Head and Pindimar.

The study foreshore, extending from the western end of Bagnalls Beach, has suffered from intermittent and presently ongoing erosion since the area was first settled in the late 1940's and 1950's. At the time that subdivision occurred, a large sandy lobe existed offshore of Sandy Point, providing a wide sandy beach and obviously affecting the naming of the point. Within a decade of initial settlement, however, this lobe had eroded to such an extent that foreshore erosion was becoming a problem to residents. Initial settlement of the point was undertaken without a clear understanding of the variability or processes acting along this length of foreshore. The original sand lobe was clearly not a permanent feature, and Sandy Point is located on a receding shoreline. The historical siting of development within coastal areas that have subsequently proven to be “at-risk” is not uncommon along the NSW coast, but it means that there are now a number of complex management issues to be addressed.

Historically, the foreshore has been subject to intermittent periods of erosion, when no sandy beach was present, and periods when plenty of sand was present. This has been caused by the intermittent transport of pulses of sand from east to west along the foreshore. In the past two decades, the situation has tended more towards a lack of sandy foreshore, with the exception of the western end of Corlette Beach, adjacent to “The Anchorage” marina, where sand has been accumulating.

Since the late 1950’s, the need to protect the foreshore has been clear, with protective structures appearing along the eastern side of Sandy Point from the early 1960's. Over time, the extent and magnitude of protective works has increased, with the protected length of foreshore extending westwards as time passed. This is consistent with an ongoing east to west sediment transport along the shoreline, forced by ocean swell which enters the Port and is refracted across the flood tide delta to impact on the study shorelines.

At the present time, the most westward of this sequence of structures is a sand filled geotextile sand bag wall fronting the eastern end of Conroy Park. Erosion will continue to the west of this structure with time unless appropriate management actions are taken to arrest it. To the west of geotextile sand bag wall, Corlette Beach has shown a pattern of erosion over the past 20 years, although that eroded sand is accreting on the beach adjacent to “The Anchorage” marina. This results in an apparent “pivot” point about which the beach has rotated, with that point located around 250m to the east of “The Anchorage”. The beach is presently adjusting to be “in equilibrium” with the incoming swell wave direction and, if allowed to continue, will likely erode the majority of Conroy Park, the adjacent car park and road. The rate at which this is occurring would slow with time and, if allowed to continue, such extensive erosion would likely take many decades. Even so, erosion of Conroy Park is a contemporary problem, with the previous sandy beach having been lost and foreshore vegetation being progressively undermined and lost to wave action. The area fronting Conroy Park is referred to as “Precinct 2” in our study, and is one of the key areas of concern for ongoing management.

A group of around 9 residences on the eastern side of Sandy Point are highly exposed to overtopping of the foreshore by refracted ocean swell waves. This appears to have been the case for a number of decades, and may be influenced by the focussing of wave energy by ledges in the nearshore bathymetry, where those ledges may result from the underwater outcropping of underlying geology. Foreshore structures in this area, while substantial, do not meet the standard of engineering that is normally applied in professional coastal engineering practice in NSW at the present time.

Anecdotally, we understand that some of these structures are presently overtopped several times per year, although this would vary from property to property, as the nature and effectiveness of the foreshore protection varies substantially. The nature of some of these structures presents an impediment to foreshore access by the public, given that a public reserve exists between the shoreline and the properties which the structures aim to protect. The area fronting this group of residences is referred to as “Precinct 5” in our study, and is also key area of concern for ongoing management.

Elsewhere, the structures are less substantial, but also have significant problems with design, the most notable being over-steepness, lack of filter, insufficient crest elevations and lack of a structural toe. Perhaps of more concern is the presence of numerous boat ramps along the foreshore which present a significant weakness for foreshore protection and allow the runup of waves and inundation of the foreshore reserve and residential yards during moderate wave conditions. During numerous site inspections undertaken during this study, we have noted the deposition of sand on the landward side of removable barriers installed in an attempt to prevent boat ramp runup reaching residential buildings. These measures are apparently only effective to a small degree and it is highly doubtful that they would prove effective during relatively frequent storms.

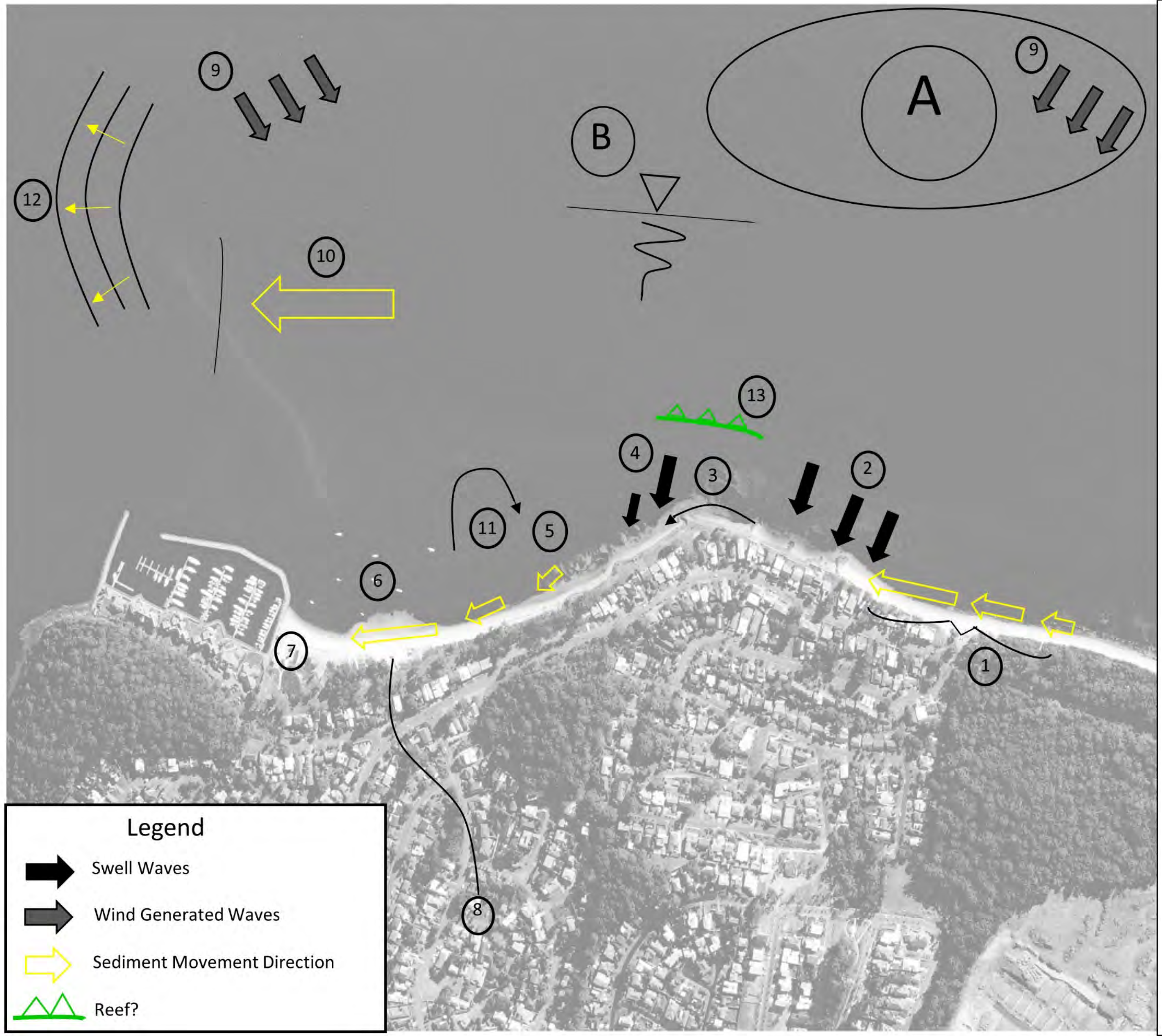
The analysis of aerial photography and hydrosurvey data as part of this study has validated the findings of previous investigations, namely that:

- Sand movement is from east to west;
- There is less sand offshore of Sandy Point than there used to be in the past, with no imminent respite expected from this as a result of natural processes;
- Erosion will continue at the western end of structures lining this length of foreshore without some intervention; and
- Sand will continue to move and accumulate adjacent to the breakwater of the Anchorage Marina at rates of between 1000 and 2000 m^3/yr on average.

Also notable, is the slow lowering of the bed offshore of the study site. This is consistent with expected ongoing processes associated with the flood tidal delta in Port Stephens. While we expect this to continue, the incremental impact on waves and currents and the immediate nearshore bathymetry of the study site is expected to be minimal over the design time frame established for this project (25 years).

A numerical model was developed as part of the study, and used to estimate design conditions. While the model appears to reasonably replicate real world conditions, and provides results that are broadly consistent with previous studies in the area, we note that insufficient data exist to validate the model. We consider that deployment of wave/current meters in the vicinity of the site would be a useful exercise prior to detailed design, to enable proper validation of the model and to give more confidence in the design values simulated by the model.

A conceptual model summarising the coastal processes surrounding the site has been prepared. This model is presented as Figure 33



A. Long Term changes to the Flood Tide Delta of Port Stephens cause ongoing change to wave refraction and current patterns. These affect patterns of erosion and deposition within the study area.
B. The water levels in the Port here are largely governed by ocean water levels (and tides). A rise in mean sea level will result in an equivalent rise in ocean water levels during storms.

1. Eastern Bagnalls Beach is relatively sheltered from ocean swell waves, however, exposure increases with distance westwards.
2. At western Bagnalls Beach refracted swell waves approach perpendicular to the beach resulting in a small amount of east to west longshore drift. Waves are particularly focussed on the eastern end of Sandy Point. Groynes do act to trap some sand, but they are sub-optimal.
3. A lobe of sand which existed at Sandy Point has diminished over the past 60 years, driven by swell wave induced east to west sediment transport, this has resulted in the exposure of residential properties to quite severe wave conditions. We cannot reliably say that this sand will be replenished from the East in future. Properties here are now subject to significant threats. Structures in this area are variable and not to an acceptable coastal engineering standard. Overtopping is severe for relatively frequent storms
4. Around the western side of Sandy Point, waves are more oblique, becoming increasingly optimal at the eastern end of Conroy Park driving erosion at that location.
5. The eastern 1/3rd of Corlette Beach, fronting Conroy Park is subject to an increasing sediment transport rate with distance westward. Therefore, erosion is present in front of Conroy Park at the present time, and expected to become more severe over the coming decades.
6. The western 2/3rds of Corlette Beach are now accreting, due to the interruption of sand by the Anchorage Marina breakwater. Sand has accumulated at an average rate of around ~1,000 m^3/year since construction. This is as predicted. Due to this point and point (5), Corlette Beach is seen to be rotating to be more aligned with incoming swell waves (and minimise transport). It is not in equilibrium with the present swell environment.
7. Sand has accreted to the point where stormwater outlets are now buried adjacent to the Anchorage. This will exacerbate stormwater flooding upstream.
8. This major stormwater outlet, erodes sand from the beach face, depositing in the nearshore. The process is not of significant concern, and any pollutants carried here do not seem to be affecting seagrasses (with the exception of smothering). The sand deposited in the nearshore is still part of the littoral transport, as the long period swell waves are strong enough to move the sand.
9. Wind generated waves from the NW and NE are of minor concern. They don't contribute as much to sand movement as swell waves, but can cause some nuisance overtopping of foreshores, and fretting of already destabilised eroding shorelines, such as at Conroy Park.
10. Offshore, the tidal channel is slowly deepening. It transports sand at 10m^3/m/year.
11. Wind driven circulations offshore of Corlette Beach have only minor impacts on sand transport .
12. Tidal Delta "Drop Over" is accreting in this location at a rate of 0.5-1.0m/year.
13. Apparent reef (persistent steep bathymetry) in this area concentrates currents around Sandy Point, also contributes to east to west movement of sand.

Figure 33: Conceptual Coastal Processes Model

Sandy Point / Conroy Park Coastal Processes Study

Whitehead & Associates
Environmental Consultants

Revision	A
Drawn	BC
Approved	DW

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Appendix B Drainage Processes Study

Stormwater Drainage and Water Quality Assessment

for Sandy Point/Conroy Park Foreshore

Prepared by: Jason Armstrong & Mark Passfield

SEEC Reference: 15000047-SWMP-04

1st April 2016

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Document Certification

This report has been developed based on agreed requirements as understood by SEEC at the time of investigation. It applies only to a specific task on the nominated lands. Other interpretations should not be made, including changes in scale or application to other projects.
Any recommendations contained in this report are based on an honest appraisal of the opportunities and constraints that existed at the site at the time of investigation, subject to the limited scope and resources available. Within the confines of the above statements and to the best of my knowledge, this report does not contain any incomplete or misleading information.

Jason Armstrong & Mark Passfield
SEEC
1st April 2016

Issue	Author	Change Notes	Authorised	Date
01	JA, MP	Draft Issue	M.P	29th June 2015
02	JA, MP	Final Draft	M.P	25th August 2015
03	JA, MP	Revised Draft	M.P	28th January 2016
04	JA, MP	Final Issue	M.P	1st April 2016

TABLE OF CONTENTS

1 Introduction

SEEC has been commissioned by Whitehead and Associates on behalf of Port Stephens Council to provide this Stormwater Drainage and Water Quality Assessment.

This study has been prepared in accordance with the guidelines and recommendations set out in ***Australian Rainfall & Runoff (1998***) and ***Port Stephens Council Infrastructure Specification (2006).***

This assessment outlines the procedures used to determine storm flows for the 5 year *'minor'* and 100 year *'major'* ARI storm events throughout each catchment contributing flows to the five existing drainage outfalls located along the Sandy Point to Conroy Park foreshore. It also estimates mean annual flow volumes and sediment and pollutant loads from the total catchment at each of the five outfall locations.

This assessment is based on a desktop study of upstream catchment areas. The accuracy of this assessment is controlled by the level of detail obtainable from the desktop study and a visual site inspection. Any results, assumptions or conclusions provided within this report are suitable only for the purpose of assessing the five outfalls and should not be used for any other reason.

2 Project Description

This assessment is part of a project to undertake an Erosion and Drainage Management Plan of the Sandy Point to Conroy Park Foreshore Area. It will be used as input into a management plan for the holistic sustainable management and protection of the foreshore, its homes, Conroy Park Beach and the immediate aquatic environment. Council's objectives for the study area are to balance the public access and recreational amenity needs of the community with the environmental values of the area and the protection of private assets.

3 Site Description

3.1 Location and General Topographic Situation

The study area is located within the township of Corlette (Figure 1). Corlette is located along the southern foreshore of Port Stephens. The terrain within the catchments of the study area ranges from moderately to very steep, but the foreshore area itself is almost flat.

Figure 1 – Site Location & Catchment Plan

3.2 Catchment Area Description

The study area contains three main catchments areas (Figure 1) that are described as follows:

3.2.1 *Catchment CA1*

This catchment has an area of 29 Ha with the majority of this catchment consisting of approximately 85% urban land with some small areas of approximately 4 Ha made up of steep terrain and parkland that are undeveloped. Grades range from 2 – 5% slope within the foreshore area and rise to between 15 – 25% heading back towards the escarpment.

3.2.2 *Catchment CA2*

This catchment is similar to catchment CA1 and has an area of 29.4 Ha. The majority of this catchment consists of approximately 87% urban land with some small areas of approximately 3.8 Ha made up of steep terrain and parkland that are undeveloped. Grades are also similar to catchment CA1 and range from 2 – 5% slope within the foreshore area and rise to between 15 – 25% heading back towards the escarpment.

3.2.3 *Catchment CA3*

This is the smallest catchment and has an area of 4.3 Ha located mainly around the foreshore area. Approximately 77% of the catchment is urban with the remaining areas consisting of foreshore reserve area and a steeper undeveloped reserve located to the west. This has similar grades to catchment CA1 & CA2, relatively flat with grades ranging from 2 – 8% along the foreshore and with grades of 15 – 30% grade at the steeper sections.

3.3 Existing Stormwater Discharge Locations

There are five main stormwater discharge locations located within the study area. These are shown on Figure 1 as Outfalls 1 to 5. A description of each is given below.

3.3.1 *Outfall 1*

Outfall 1 is located within catchment CA1. It consists of a surcharge pit and overland flow path across the beach reserve (Photo 1). It is located at a lowpoint within Sandy Point Road and serves as a relief point during localised flooding of Sandy Point Road during large storm events. The surcharge path requires regular maintenance for it to work effectively and it had recently been cleaned out prior to our inspection.

Photo 1 – Looking south towards surcharge pit at Outfall 1 location.

3.3.2 *Outfall 2*

This is a major discharge point located within catchment CA1. It consists of two, 1200mm diameter reinforced concrete pipes under a rock groyne wall (Photo 2).

Photo 2 - Outfall 2 Looking north

3.3.3 *Outfall 3*

Outfall 3 is located within catchment CA2. It is a major discharge point consisting of three 1200mm diameter concrete pipes discharging directly onto Corlette Beach (Photo 3). The pit immediately upstream of the outlet contains a surcharge outlet, surcharging larger flows during major storms into an existing concrete apron.

Photo 3 – Outfall 3 Looking South East

3.3.4 *Outfalls 4 & 5*

Both of these outfalls are located next 'The Anchorage' Marina and within catchment CA3. Outlet 4 is a 600mm diameter reinforced concrete pipe and was completely blocked during the site inspection (Photo 4).

Outfall 5 is a 375mm reinforced concrete pipe located under the eastern breakwater of the marina. This was partial blocked during our site inspection (Photo 5) and was missing a flap valve.

Photo 4 – Outfall 4, completely blocked.

Photo 5 – Outfall 5, partially blocked with flap valve removed.

4 Hydrological Modelling

4.1 Design Parameters

A hydrological model of the study area was developed using *DRAINS* urban stormwater drainage modelling software. *DRAINS* uses the *ILSAX* hydrological model. The design data used to develop the model was taken from the following information.

4.1.1 *ILSAX Model Data*

The following parameters were used within the ILSAX model.

Parameter	Value
Impervious Area Depression Storage (mm)	1
Supplementary Area Depression Storage (mm)	1
Pervious Area Depression Storage (mm)	5
Soil Type	2 (Moderate Infiltration Rate)
AMC (Antecedent Moisture Condition)	3

4.1.2 *Rainfall Data*

The Intensity Frequency Duration (IFD) rainfall data for the site was produced from the 'Bureau of Meteorology's Rainfall IFD Data System' which is based on data presented in Australian Rainfall and Runoff (1987) Book 2 for Corlette (Appendix 1). This information was input into the *DRAINS* model.

4.1.3 *GIS Data*

GIS information supplied by Port Stephens Council was imported into *Autocad Civil 3D.* This data included existing contour levels (0.5m intervals), lot boundaries and existing stormwater drainage pits and pipe locations and sizes. Pit depths at the start, major intersection points and at the ends were checked during a site inspection of the study area.

A three-dimensional model of each of the pipe networks was developed to represent the existing drainage infrastructure using *Advanced Road Design,* which is an add-on application for *Civil 3D*. There are four stormwater drainage pipe networks:

(i) **Network 1** in Catchment CA1 contains drainage Outfalls 1 and 2;
(ii) **Network 2** in Catchment CA2 contains Outfall 3;
(iii) **Network 3** in Catchment CA3 contains Outfall 4; and
(iv) **Network 4** in Catchment CA3 contains Outfall 5.

4.1.4 *Sub-Catchment Areas*

Each of the catchments described in Section 3.2 were broken down into sub-catchment areas to each of the existing stormwater pits using Autocad. The areas, slope lengths and grades were exported into the *DRAINS* model using the *Advanced Road Design* software. Impervious area within the urbans areas of the catchment was set at 60% in accordance with Port Stephens Council's *Handbook for Drainage Criteria Section D5.06* for Zone 2a – normal residential zoned land.

4.1.5 *Pit Blockage Factors*

Pit blockage factors of 50% for sag pits and 20% for pits on-grade were specified in the DRAINS model in accordance with Council's *Infrastructure Design Specification – D5 Stormwater Drainage Table D5.2.* Note that outlets 4 and 5 where completed blocked with sand at the time of inspection.

4.1.6 *Overland Flow Paths*

Overland flow paths from surcharging pits were modelled using a typical roadway cross-section for surcharge paths along roads and with a generic cross-section for surcharge paths along property easements. Slope lengths were taken directly from the DTM during the software transfer process from *Civil 3D* into *DRAINS.*

4.2 Stormwater Modelling Results

4.2.1 *Resultant Flows at Outfalls*

The resultant flows from the *DRAINS* modeling for the peak (worst case) 5-year and 100-year ARI storm events at each of the stormwater outfalls previously described in Section 3.3 are shown below in Tables 1 and 2. They show the total flows for each catchment broken into pipes flow and overland flow along the surcharge path, including the storm duration.

Table 1 - 5 Year ARI (Minor System) Results

Outfall No.	5 Year ARI –Pipe (m^3/s)	Pipe Flow Peak Storm Duration (mins)	5 Year ARI Overland Flow (m^3/s)	Overland Flow Peak Storm Duration (mins)	Total Flowrate (m^3/s)	Max. Velocity (m/s)
1	0.328	25	0	25	0.328	0.328
2	3.28	25	0.405	60	3.685	3.26
3	4.2	60	0.007	60	4.207	3.27
4	0.096	60	0	60	0.096	1.32
5	0.114	25	0	25	0.114	2.17

Table 2 - 100 Year ARI (Major System) Results

Outfall No.	100 Year ARI –Pipe (m^3/s)	Pipe Flow Peak Storm Duration (mins)	100 Year ARI Overland Flow (m^3/s)	Overland Flow Peak Storm Duration (mins)	Total Flowrate (m^3/s)	Max. Velocity (m/s)
1	0.641	60	0.679	120	1.32	0.59
2	4.19	60	1.12	60	5.31	3.48
3	5.52	45	0.193	90	5.713	3.44
4	0.321	60	0.02	60	0.341	1.81
5	0.231	20	0.134	25	0.365	2.50

4.2.2 *Stormwater Pipe Capacity*

Overland (surcharge) flow quantities and their locations are shown in Appendices 2 to 5 and referenced on Drawing 15000047_P01_SWMP01 (Appendix 6). These are the numbers shown in red and are shown for both the 5 year and 100 year ARI storm events in m^3/s. There are numerous pits that surcharge during a 5-year storm event which shows the existing piped stormwater system is significantly under-sized when compared to current Council and Australian Standards. These locations have also been identified on drawing 15000047_P01_SWMP01 (Appendix 6).

5 Stormwater Quality Modelling

5.1 Introduction

The estimated sediment and pollutant loads are modelled using MUSIC (Model for Urban Stormwater Improvement Conceptualisation), developed by eWater. The model is appropriately set up using inputs as in Tables 3, 4 and 5. Statistics are produced in MUSIC for the following parameters:

- Flow (ML/yr)
- TSS - Total Suspended Solids (kg/yr)
- TP - Total Phosphorus (kg/yr)
- TN - Total Nitrogen (kg/yr)
- Gross Pollutants (kg/yr)

5.2 Climate Data

Creation of a MUSIC catchment file requires an associated meteorological data file. In this case data provided by Port Stephens Council via *MUSIC LINK* has been used. The data file used was the *"default catchment, sandy soils, Williamtown RAAF"*. Rainfall and evapotranspiration statistics are in Table 3 and a time-series graph is in Figure 2.

Table 3 - Rainfall and PET statistics

Meteorological Data Statistics

	Rainfall/6 Minutes	Evapo-Transpiration
mean	0.012	3.817
median	0.000	3.270
maximum	10.570	5.870
minimum	0.000	1.770
10 percentile	0.000	1.770
90 percentile	0.000	5.840

	Rainfall	Evapo-Transpiration
mean annual	1013	1394

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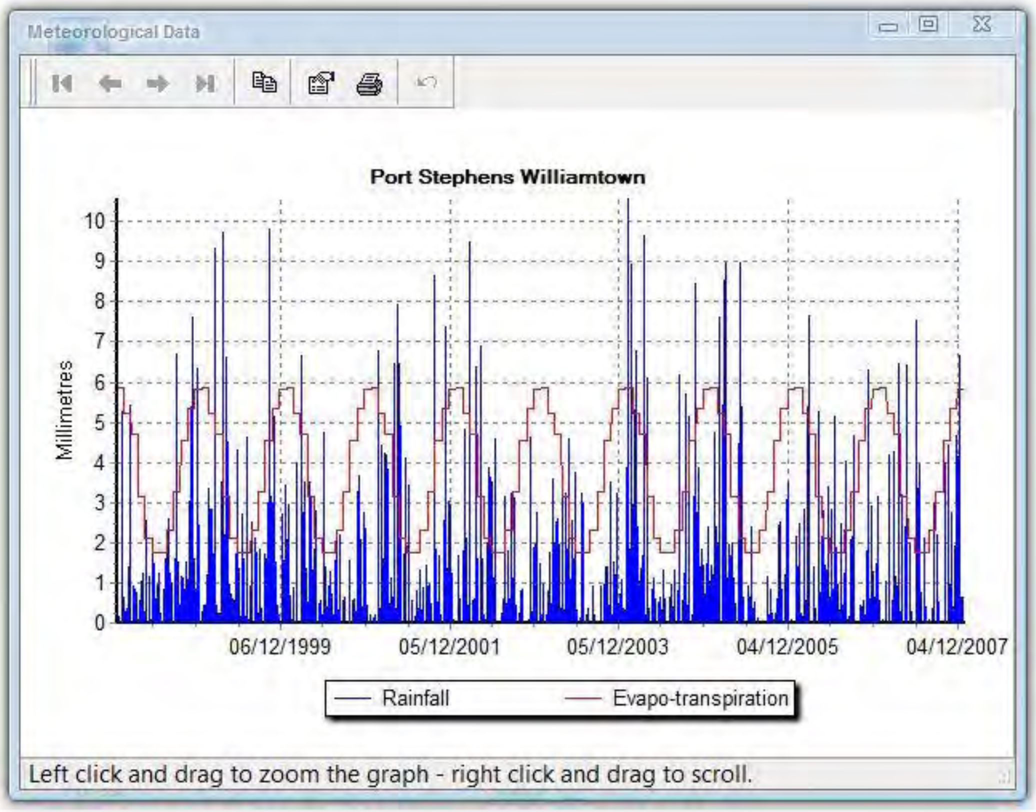


Figure 2 - Rainfall and PET Time Series Graph

5.2.1 Node Parameters

Table 4 presents the storm flow concentration parameters for the MUSIC model. They are derived from SMCMA (2010).

Table 4 - Storm flow concentration parameters used in MUSIC

	TSS mean (log mean)	TSS std dev (log std dev)	TP mean (log mean)	TP std dev (log std dev)	TN mean (log mean)	TN std dev (log std dev)
Urban Land	141 (2.15)	2.09 (0.32)	0.251 (-0.6)	1.78 (0.25)	2 (0.3)	1.55 (0.19)
Forest	39.8 (1.6)	1.58 (0.2)	0.08 (-1.1)	1.66 (0.22)	0.89 (-0.05)	1.74 (0.24)

The pervious area parameters for both pre and post modelling are given in Table 5. They are based on the method described in Section 3.6.3 of SMCMA (2010), see also Section 5.2.2.

Table 5 - Pervious area parameters used in MUSIC

Parameter	Value
Soil storage capacity	170
Initial storage	30
Field capacity	70
Infiltration capacity coefficient	210
Infiltration capacity exponent	4.7
Groundwater initial depth	10
Daily recharge rate	50
Daily base flow rate	5
Daily deep seepage rate	0

5.2.2 Catchment Hydrology Check

To check the model's hydrological calibration the outflow from a calibration node with 55% *effective* imperviousness[1] was checked against the Annual Runoff Fraction (Figure 3). The model's annual rainfall is 1,013 mm so the annual runoff fraction should be about 0.6 which equals 6.08 ML/ha/yr. The calibration node's actual runoff is 6.02 ML/y which is within 1%.

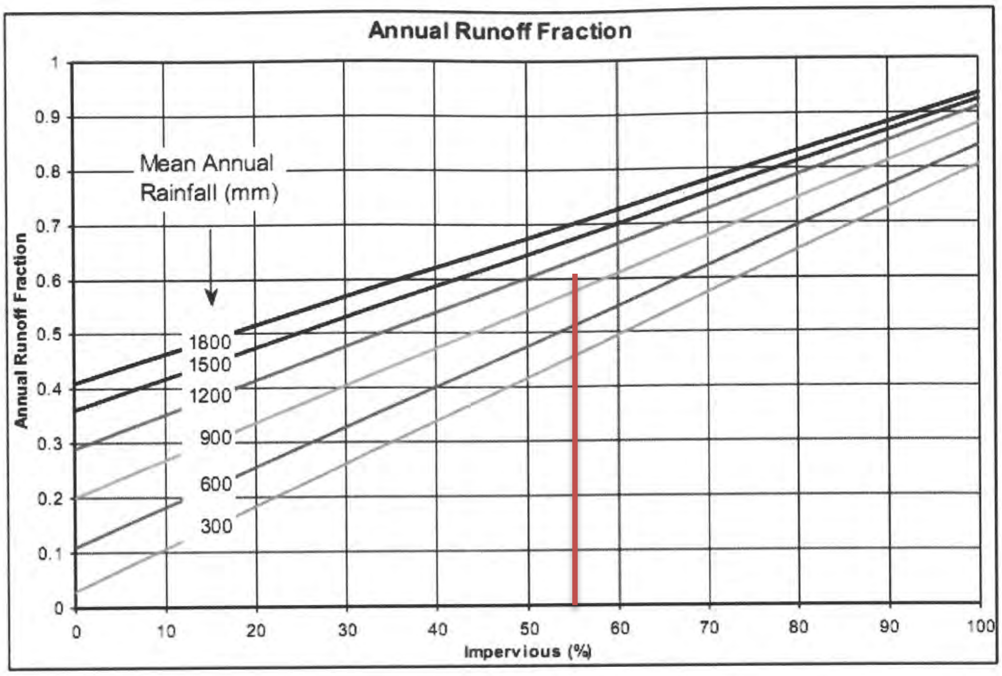


Figure 3 - Annual Runoff Fraction

1 Reference: Table 3-3 in SMCMA, 2010. Effective imperviousness is different to actual imperviousness as it only accounts for impervious surfaces that are directly connected to the stormwater system

5.3 Model Input

The MUSIC model is divided into the five piped-networks as detailed in Section 3.3. Table 6 gives the breakup of each catchment which are divided into urbanised land and reserves (modelled with a forest source node).

Table 6 – Catchment Areas

	Catchment Area	Forest (ha) (100% pervious)	Urban (ha) (55% impervious)
Outlet 1	3.24	3	0.24
Outlet 2	25.29	-	25.29
Outlet 3	27.5	3	24.5
Outlet 4	1.66	-	1.66
Outlet 5	1.29	0.79	0.5
Totals	59.11	8.11	51

The MUSIC model schematic is shown in Figure 4.

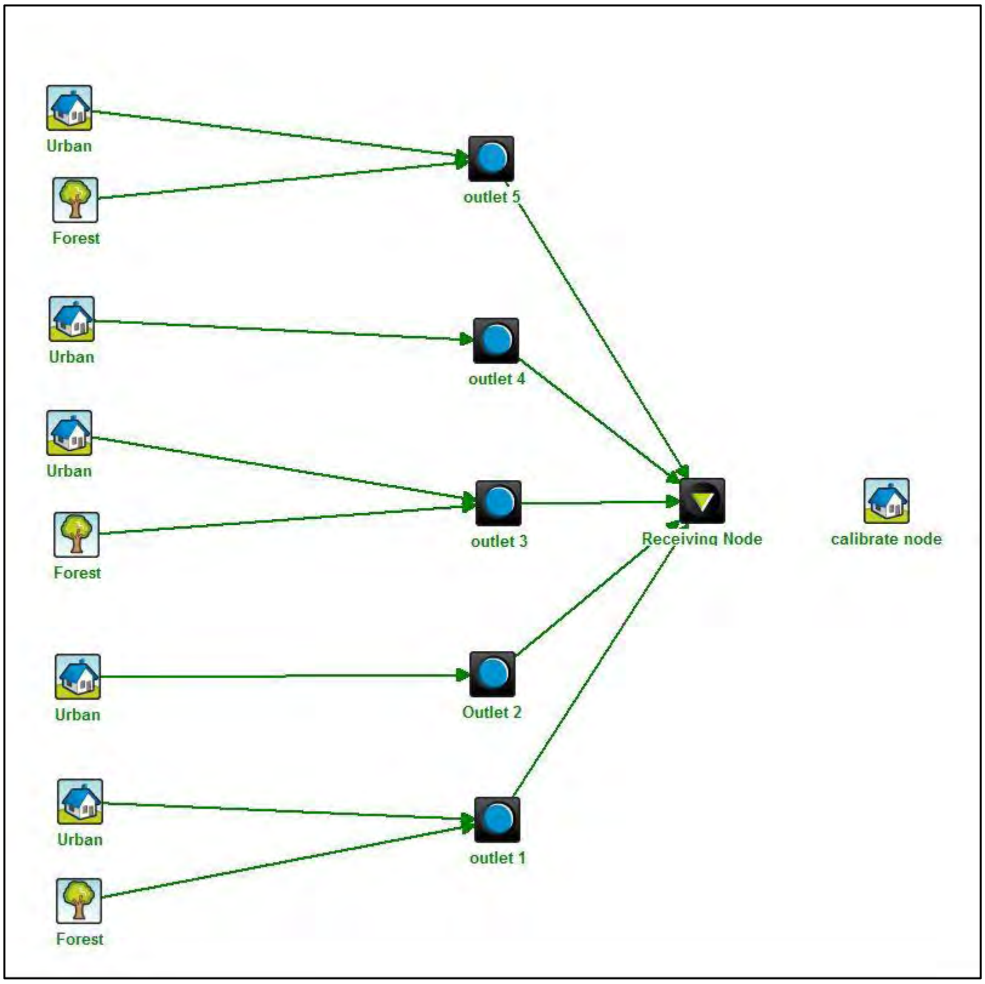


Figure 4 – MUSIC Model Schematic

5.4 MUSIC Results

The results of the modelling are given on Table 7.

Table 7 – Estimated Mean Annual Flow and Pollutant Loads

	Outlet 1	Outlet 2	Outlet 3	Outlet 4	Outlet 5	Total
Mean Annual Flow (ML/y)	11.6	152	158	10	5.7	337.3 ML/y
Total Suspended Solids (kg)	332	23800	24300	1630	511	50573 kg/y
Total Phosphorous (kg)	2.97	271	270	18.4	5.6	567.97 kg/y
Total Nitrogen (kg)	10.7	314	313	20.8	8.2	666.7 kg/y
Gross Pollutants (kg)	41.4	4360	4230	286	86.3	9003.7 kg/y

6 Stormwater Outfall Management

Part of this assessment is to determine which stormwater outfalls would benefit from upgrading works to help reduce the amount of erosion that is occurring along the foreshore and, in turn, help reduce maintenance costs in the long term. The outfalls that would benefit from some engineering works are discussed below.

6.1 Outfall 1 – Catchment CA1

6.1.1 *Design Considerations*

Outfall 1 as described in Section 3.3.1 is part of Network 1 as identified within the *DRAINS* model. As previously discussed it serves as a relief/surcharge point within catchment CA1 to relieve some of the localised flooding along Sandy Point Road during large storm events; therefore its removal would not be an option.

The main issue with Outfall 1 is backing up of sand into the overflow channel from wave action and tidal surges during large storms events, which blocks off the overland flow path. It is therefore critical that Council regularly clean-out and maintain this overflow channel. Another issue is that, being a surcharge pit, it and the pipe system it serves are always charged (full of stormwater). Therefore, the pit regularly surcharges stormwater into the beach reserve adding to erosion problems.

Based on the resultant flows from the *DRAINS* analysis, the combined 5 Year and 100 Year flows from this outfall only represent 20 percent of the total flow from catchment CA1 (Tables 1 & 2). Considering this, and also due to existing pipe invert levels, it would be impractical to retro-fit a gross pollution trap (GPT) to reduce gross pollutants. However, two practical options for upgrading this outfall are discussed in the following.

6.1.2 *Design Options*

(i) Option 1 – Fill in and regrade the existing overflow channel. Construct a rock lined swale drain from the surcharge outlet down to the beach front. Topsoil and revegetate either side of newly lined swale drain. Refer to drawing 15000047_P01_SK01 in Appendix 7 for details.

(ii) Option 2 – As for option 1 above with the addition of a rock-filled filtration trench located under the swale drain. Weep holes would then be installed through the outlet wall of the surcharge pit into the filtration trench to help reduce the water level in the upstream piped drainage system. A sump and trash screen would also have to be installed around the weep holes to help reduce the chance of blockage. Refer to drawing 15000047_P01_SK02 (Appendix 7) for details.

6.2 Outfall 2 – Catchment CA1

6.2.1 *Design Considerations*

This is one of two major outfalls within the foreshore. As previous described in section 3.3.2 it is located under an existing groyne and discharges directly into Port Stephens. It is currently working effectively and was unblocked during the time of inspection and did not seem to be contributing to any local erosion. The *DRAINS* analysis shows this outlet to be under sized for the 5 Year storm event (Tables 1 & 2) with surcharging of the system evident upstream in Sandy Point Road. Although being undersized, it would be impractical and costly at this stage to try and augment the existing piped drainage system.

Being the major discharge point from catchment CA1, Outfall 2 carries a considerable amount of suspended sediment and pollutants from the upstream urban areas. This is summarised in Table 7. An option to resolve this is discussed below.

6.2.2 *Gross Pollution Trap*

This outlet would benefit from retro-fitting two Gross Pollutant Traps (GPTs) upstream of the outlet within the existing Council reserve. Twin Humeguard HG40B GPTs (one for each 1200mm diameter outlet) were modelled in MUSIC with the predicted pollutant reductions shown in Table 8. The Humeguard was chosen due to its efficiency working in high tailwater conditions. Refer to drawing 1500047_P01_SK03 (Appendix 7) for details.

Table 8 – Outfall 2 - Mean Annual Pollutant Load Reductions

Mean Annual Loads - Generic GPT

	Inflow	Outflow	% Reduction
Flow (ML/yr)	152	152	0.0
Total Suspended Solids (kg/yr)	24.2E3	14.4E3	40.6
Total Phosphorus (kg/yr)	278	218	21.5
Total Nitrogen (kg/yr)	316	281	11.3
Gross Pollutants (kg/yr)	4.36E3	476	89.1

6.3 Outfall 3 – Catchment CA2

6.3.1 *Design Considerations*

This is the second major outfall and is located in the centre of Corlette Beach. The outfall discharges across a substantial width of beach causing significant erosion and loss of sand from the beach front. The *DRAINS* analysis shows that outlet is under-sized for the 5 Year storm event (Tables 1 & 2) with surcharging of the system and localised flooding evident upstream in Sandy Point Road.

Like Outfall 2, Outfall 3 carries a considerable amount of suspended sediment and pollutants from the upstream urban areas within catchment CA3. This is summarised in Table 7. Two practical options for upgrading this outfall are discussed in the following.

6.3.2 *Design Options*

(i) Option 1 – Install two GPTs upstream of the outlet within the existing Council reserve. These would also need to be twin Humeguard HG40B GPTs as discussed for Outfall 2. The GPTs would need to be arranged differently to those at Outfall 2. This is due to there being three 1200mm diameter pipes at Outfall 3. Therefore, each outside pipe would be connected to a Humeguard via a new junction pit and the central outlet would need to be raised to act as an overflow weir during large storm events. The two GPTs were modelled in MUSIC with the predicted pollutant reductions shown in Table 9 below. Refer to drawing 1500047_P01_SK04 (Appendix 7) for details.

Table 9 - Outfall 3 - Mean Annual Pollutant Load Reductions

Mean Annual Loads - Generic GPT

	Inflow	Outflow	% Reduction
Flow (ML/yr)	158	158	0.0
Total Suspended Solids (kg/yr)	24.3E3	14.4E3	40.9
Total Phosphorus (kg/yr)	270	212	21.6
Total Nitrogen (kg/yr)	312	277	11.2
Gross Pollutants (kg/yr)	4.23E3	458	89.2

(ii) Option 2 – Install Humeguard GPTs as for Option 1 but also extend the three 1200mm diameter concretes pipes a minimum of 80m into the bay of Port Stephens. A 3 metre wide rock groyne would then be constructed over the newly extended pipe line. Refer to drawing 1500047_P01_SK05 (Appendix 7) for details.

6.4 Outfalls 4 & 5 – Catchment CA3

Outfalls 4 and 5 as described in Section 3.3.4 have the smallest catchments and contribute the least amount of suspended sediment and gross pollutants compared with the other catchments.

Outfall 4 was completely buried and Outfall 5 was partially blocked at the time of inspection. In the absence of any works to extend these outlets, a regular maintenance effort will be required to prevent burial by beach sand as it accretes against the breakwater.

7 Conclusion

The existing stormwater pipe network is significantly undersized throughout the catchments. There is little that can be done to relieve this without the costly exercise of augmenting the entire piped drainage system downstream of the problem areas. However, Council should ensure overland flow paths through properties are clearly defined and clear of obstructions such as vegetation or illegal structures.

The estimated total mass of sediment exported from the five outlets is 50.73 tonnes per annum, with Outfalls 2 and 3 accounting for approximately 47% each. The remaining three outlets have minor sediment loads. Retro-fitting of GPTs at Outfalls 2 and 3 would achieve significant reductions in suspended sediments and gross pollutants into the bay as discussed in Sections 6.2 and 6.3.

8 References

Engineers Australia (1998). *Australian Rainfall and Runoff, A Guide to Flood Estimation, Volume 1 and Volume 2.*

Port Stephens Council (2006). *Infrastructure Specification – Design Specification Series Part 1.*

Port Stephens Council. Topographic details (0.5 meter contours).

SMCMA (2010). *Draft NSW MUSIC Modelling Guidelines. Sydney Metropolitan Catchment Management Authority.* (MUSIC Modeling Reference).

Watercom Pty Ltd *DRAINS Version 2015.07.*

9 Appendices

9.1 Appendix 1 – Rainfall Intensity Frequency Duration Information

Intensity-Frequency-Duration Table

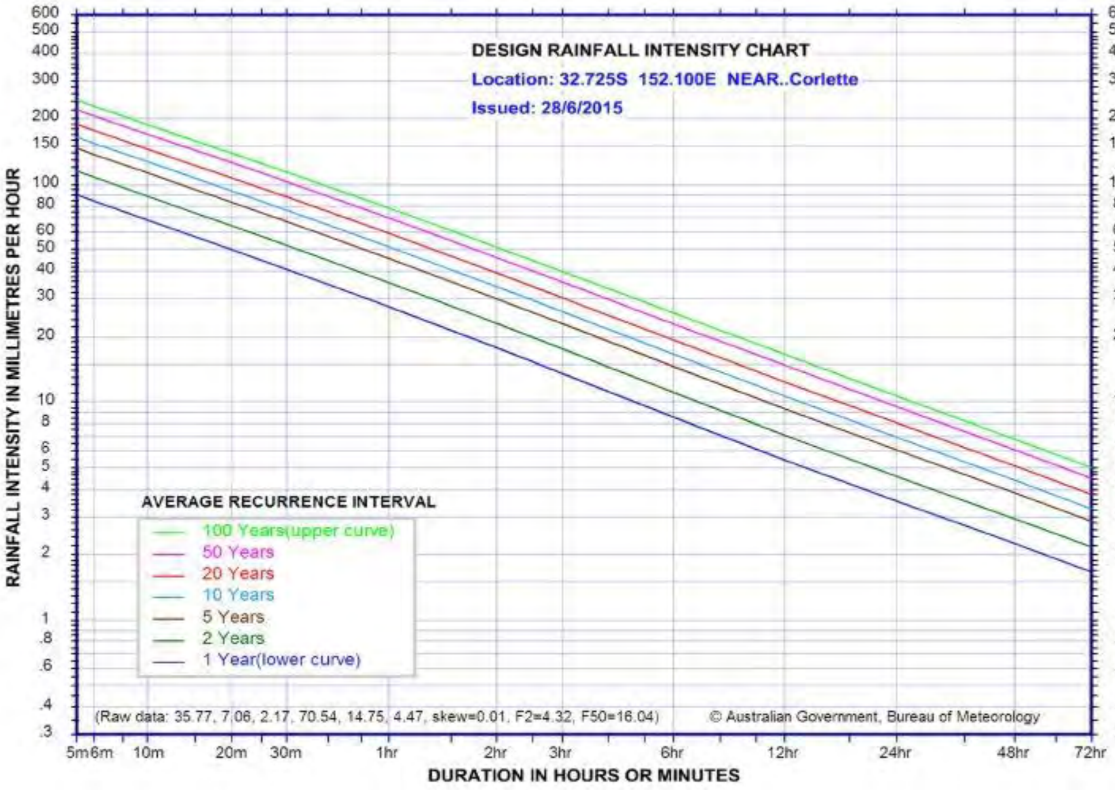
Location: 32.725S 152.100E NEAR.. Corlette Issued: 28/6/2015

Rainfall intensity in mm/h for various durations and Average Recurrence Interval

Average Recurrence Interval

Duration	1 YEAR	2 YEARS	5 YEARS	10 YEARS	20 YEARS	50 YEARS	100 YEARS
5Mins	89.7	115	147	165	189	220	244
6Mins	83.9	108	137	154	177	206	228
10Mins	68.6	88.2	113	127	145	170	188
20Mins	50.2	64.6	82.8	93.3	107	126	139
30Mins	40.8	52.6	67.5	76.2	87.7	103	114
1Hr	27.5	35.5	45.8	51.8	59.8	70.2	78.1
2Hrs	17.8	23.0	29.8	33.9	39.2	46.1	51.4
3Hrs	13.6	17.6	23.0	26.1	30.2	35.7	39.9
6Hrs	8.55	11.1	14.6	16.6	19.3	22.9	25.7
12Hrs	5.43	7.07	9.33	10.7	12.4	14.8	16.6
24Hrs	3.52	4.57	6.04	6.91	8.05	9.55	10.7
48Hrs	2.25	2.92	3.84	4.39	5.10	6.04	6.77
72Hrs	1.67	2.17	2.85	3.25	3.78	4.48	5.02

(Raw data: 35.77, 7.06, 2.17, 70.54, 14.75, 4.47, skew=0.01, F2=4.32, F50=16.04)



9.2 Appendix 2 – *DRAINS* Results for Network 1

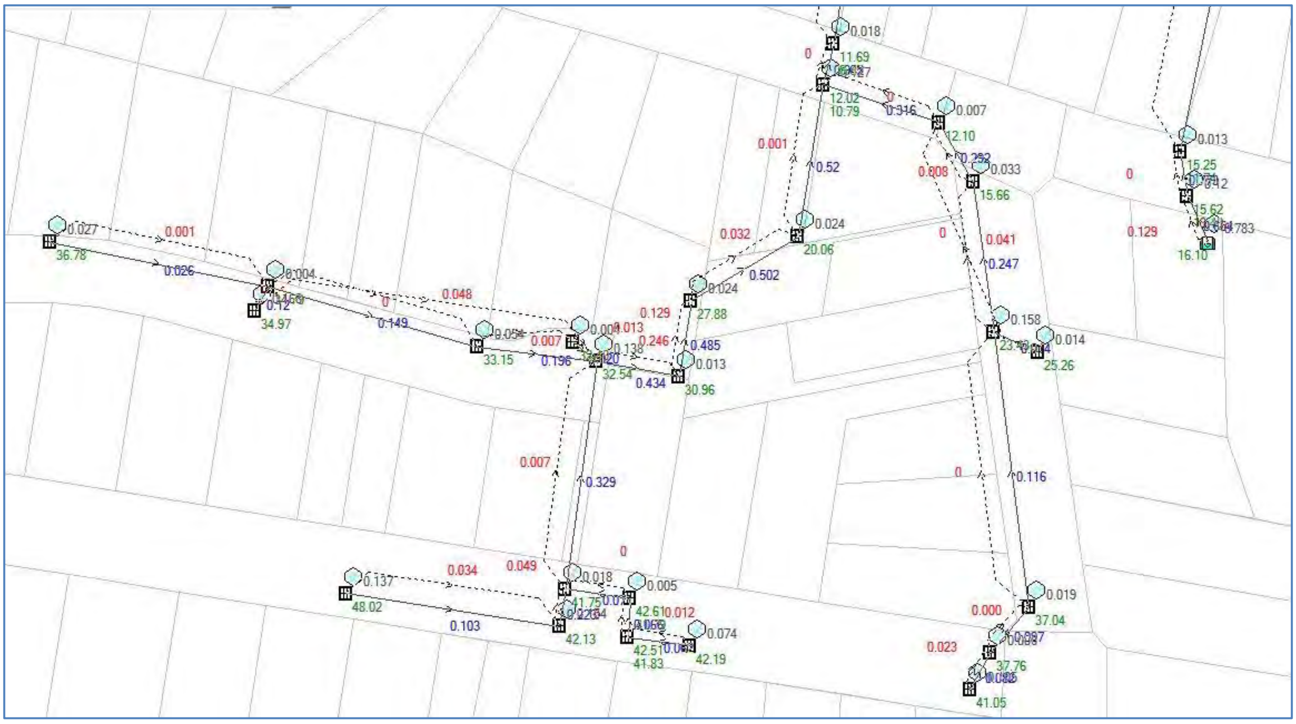


Figure 5 – Network 1 – 5 year Overland Flow Results – Detail 1

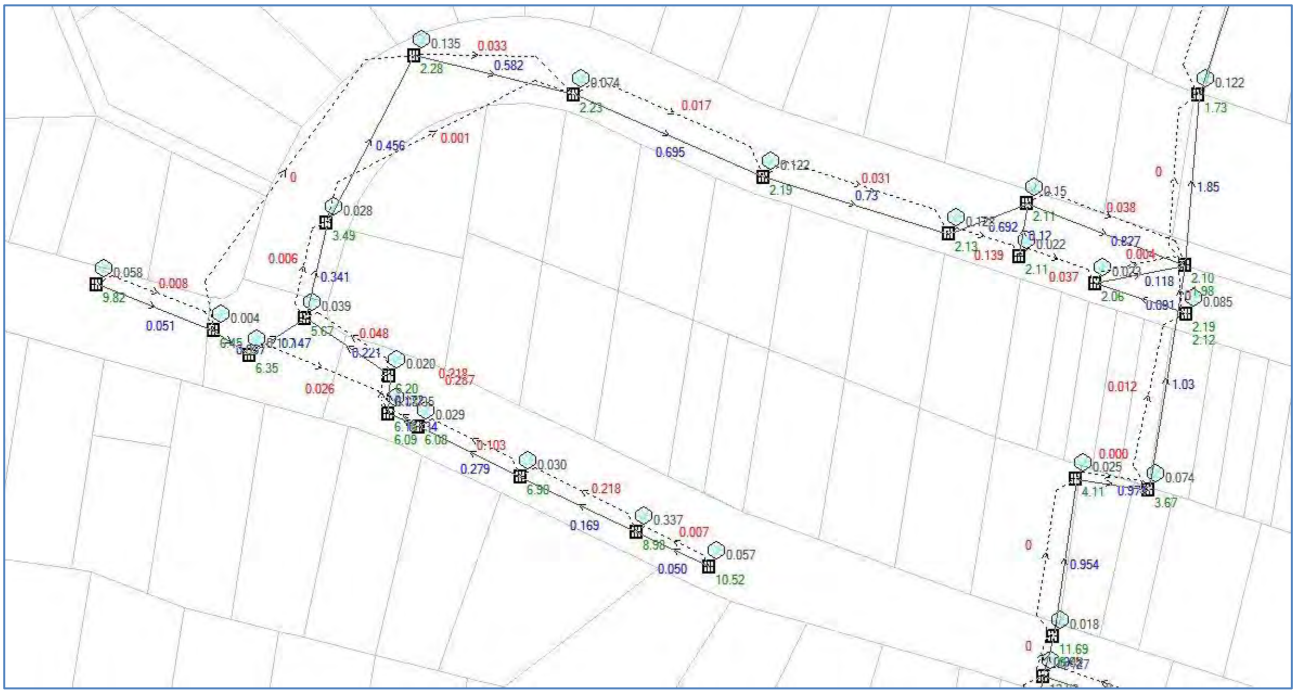


Figure 6 - Network 1 – 5 year Overland Flow Results – Detail 2

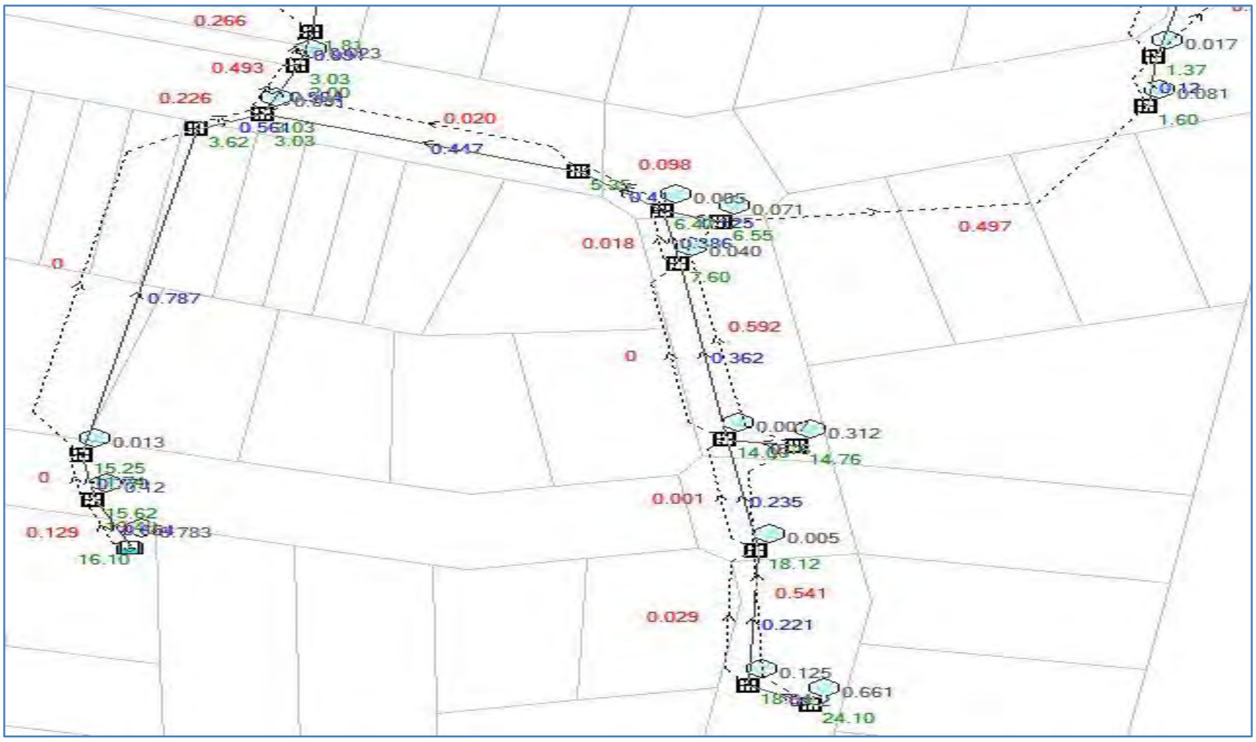


Figure 7 - Network 1 – 5 year Overland Flow Results – Detail 3

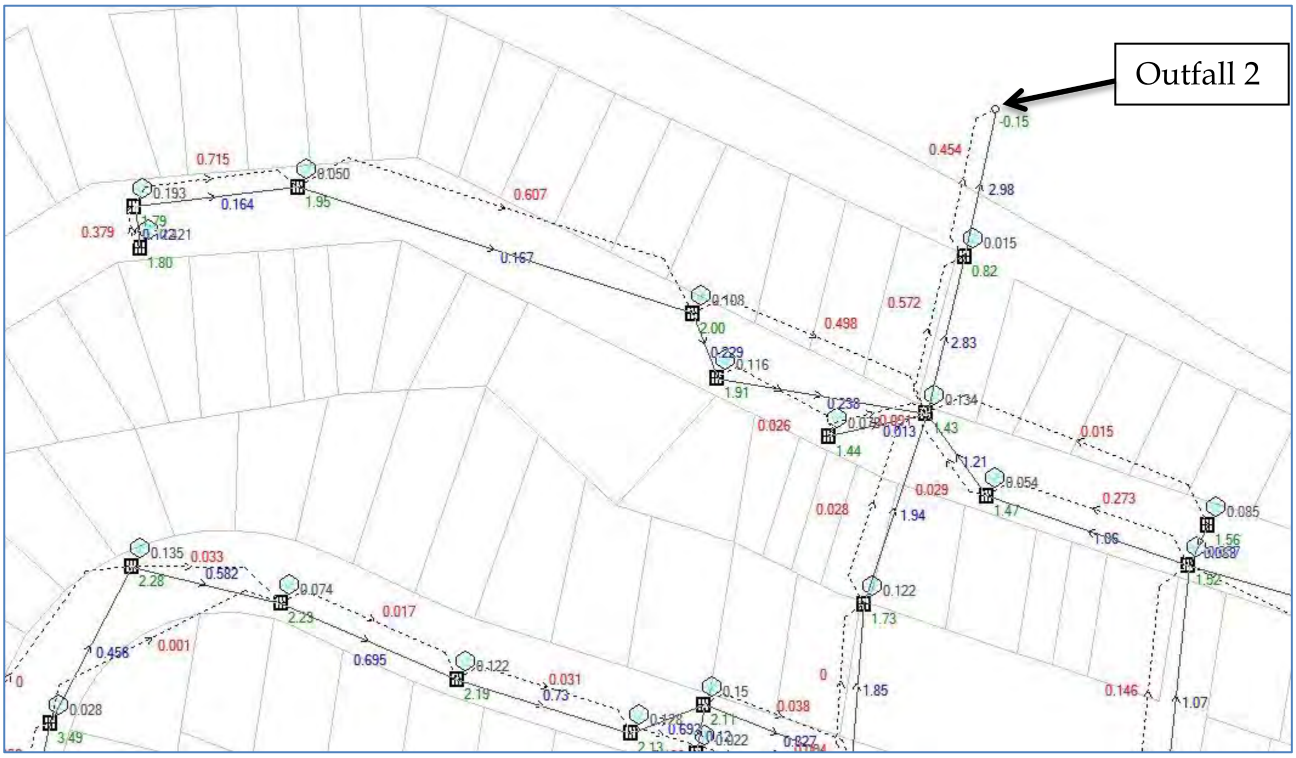


Figure 8 - Network 1 – 5 year Overland Flow Results – Detail 4

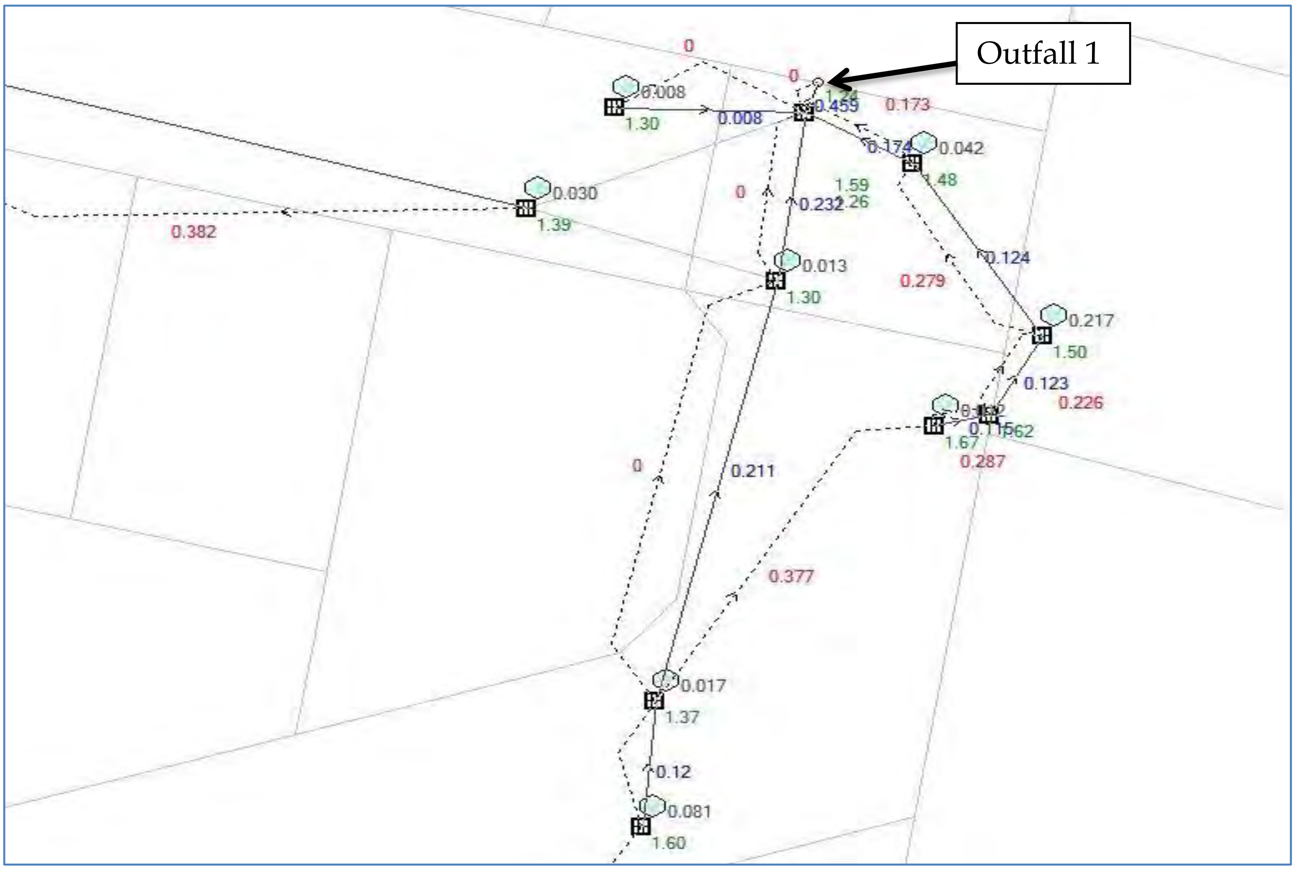


Figure 9 - Network 1 – 5 year Overland Flow Results – Detail 5

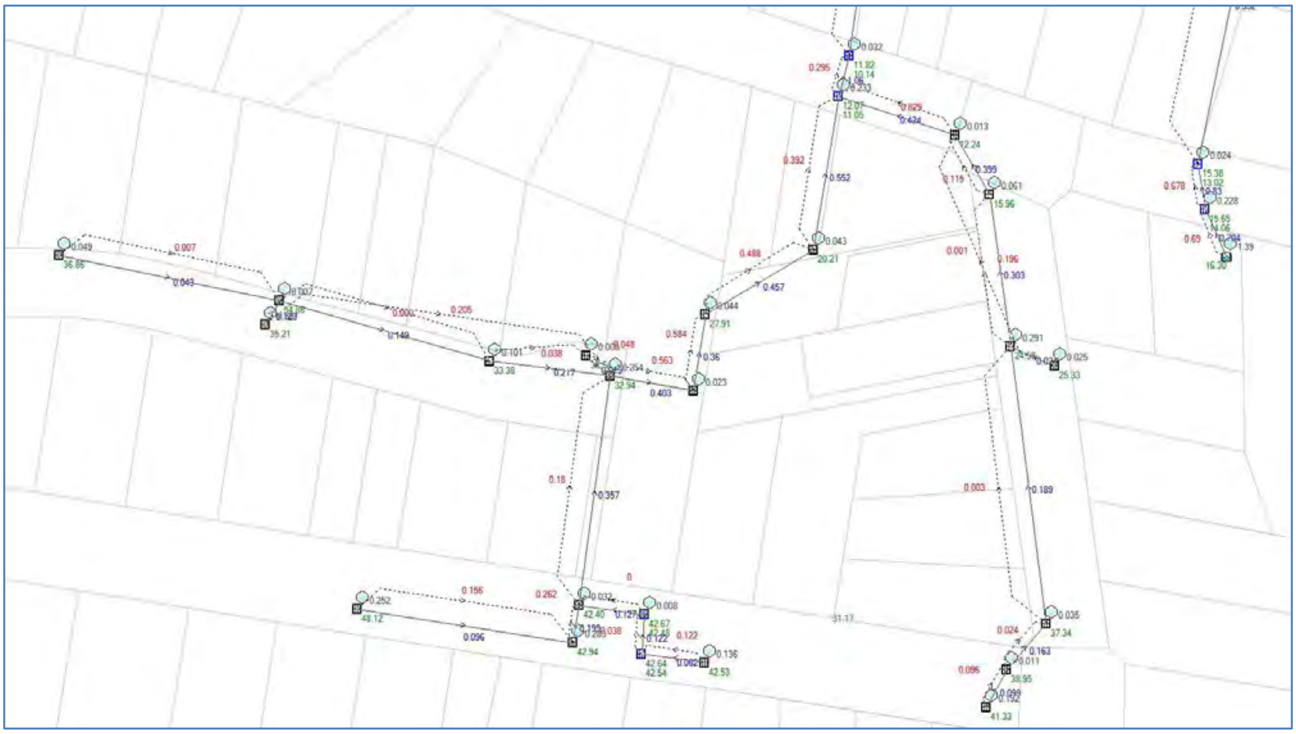


Figure 10 – Network 1 – 100 year Overland Flow Results – Detail 1

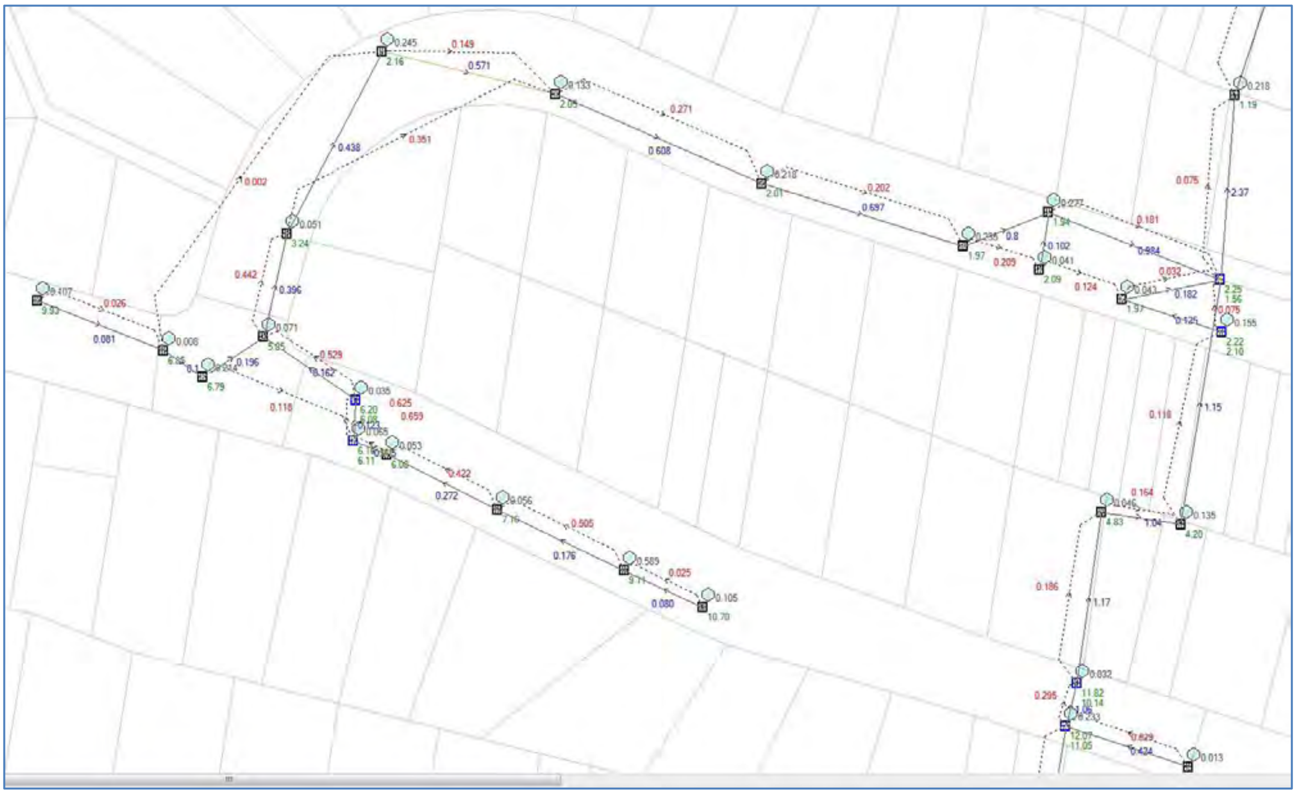


Figure 11 – Network 1 – 100 year Overland Flow Results – Detail 2

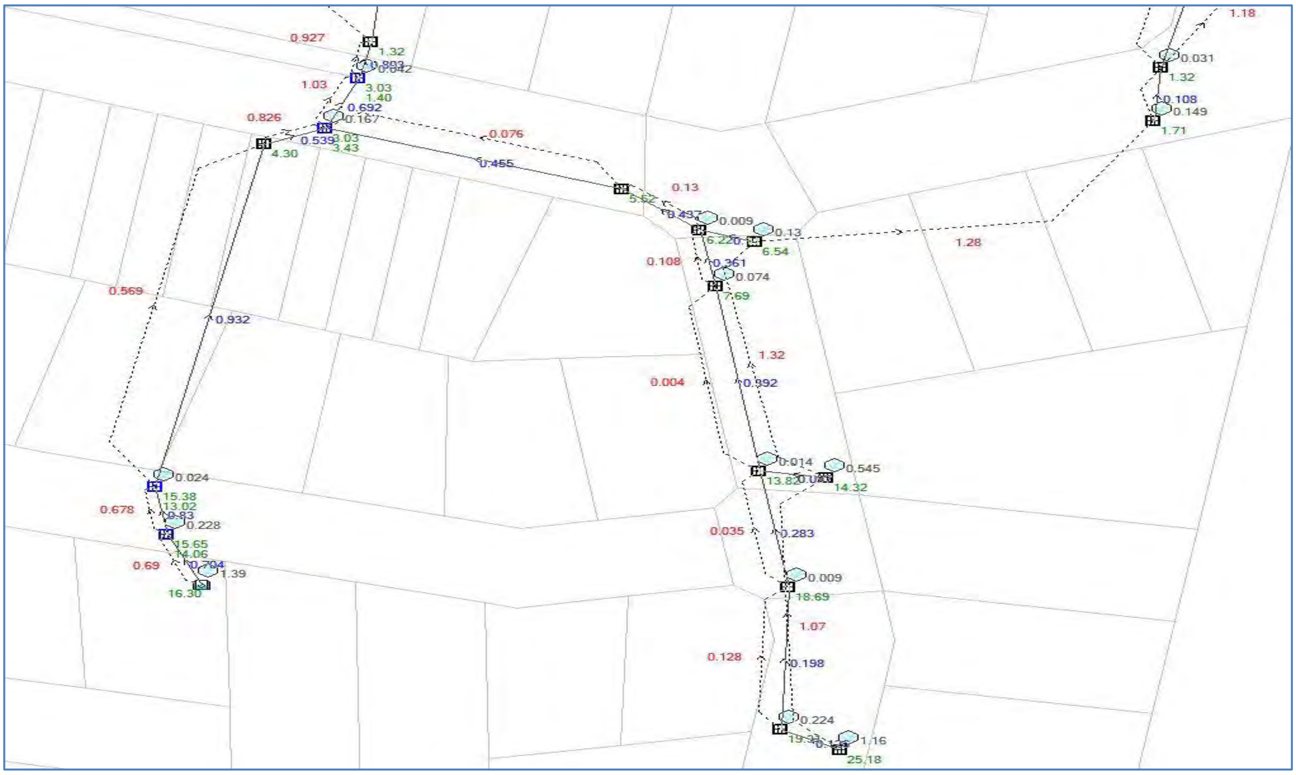


Figure 12 – Network 1 – 100 year Overland Flow Results – Detail 3

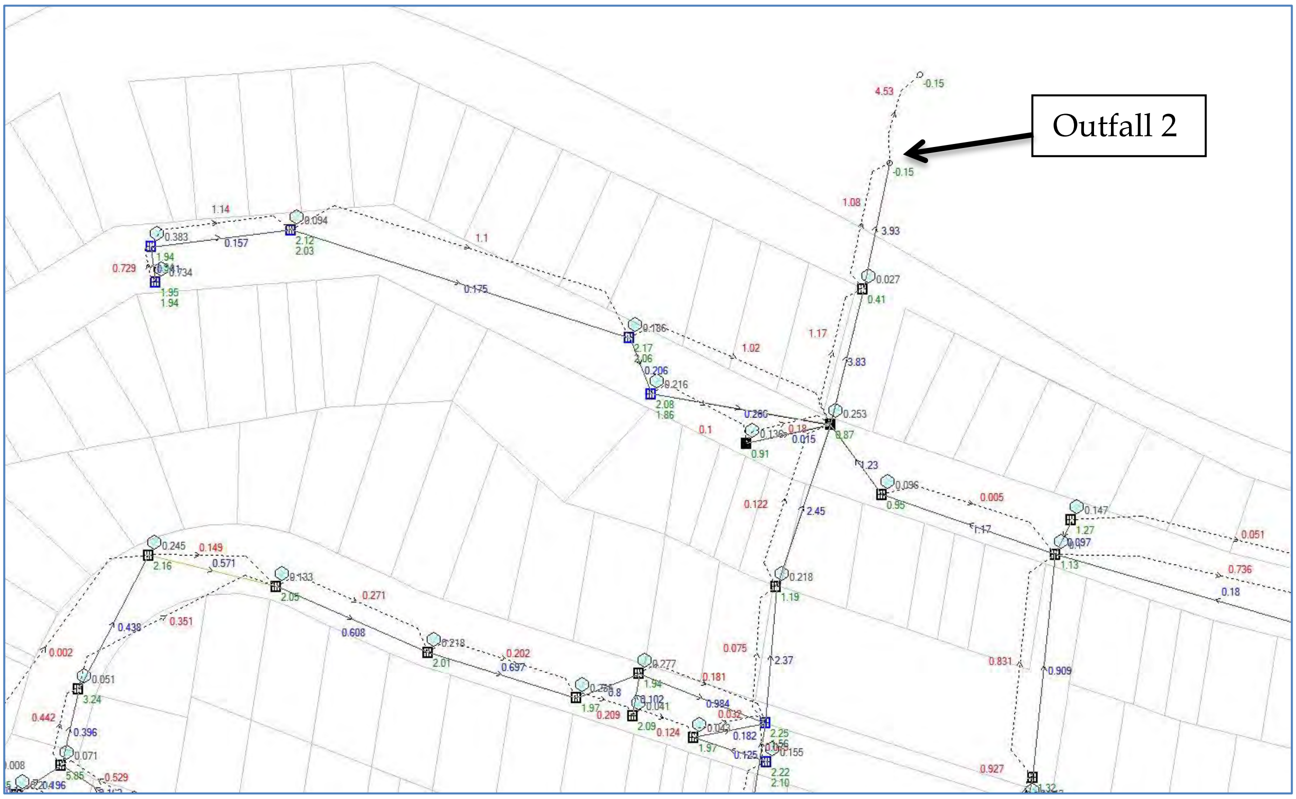


Figure 13 – Network 1 – 100 year Overland Flow Results – Detail 4

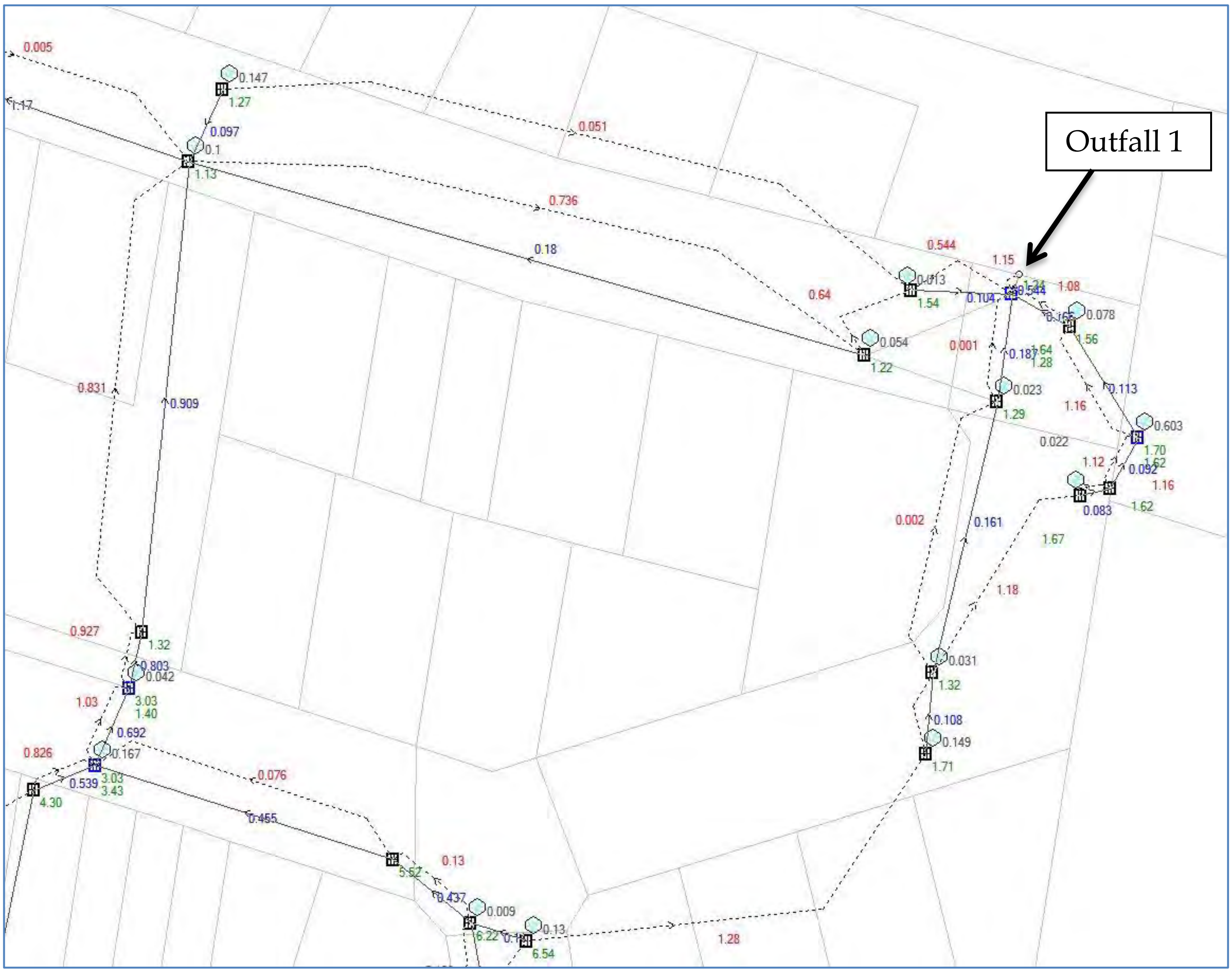


Figure 14 – Network 1 – 100 year – Overland Flow Results – Detail 5

9.3 Appendix 3 - *DRAINS* Results for Network 2

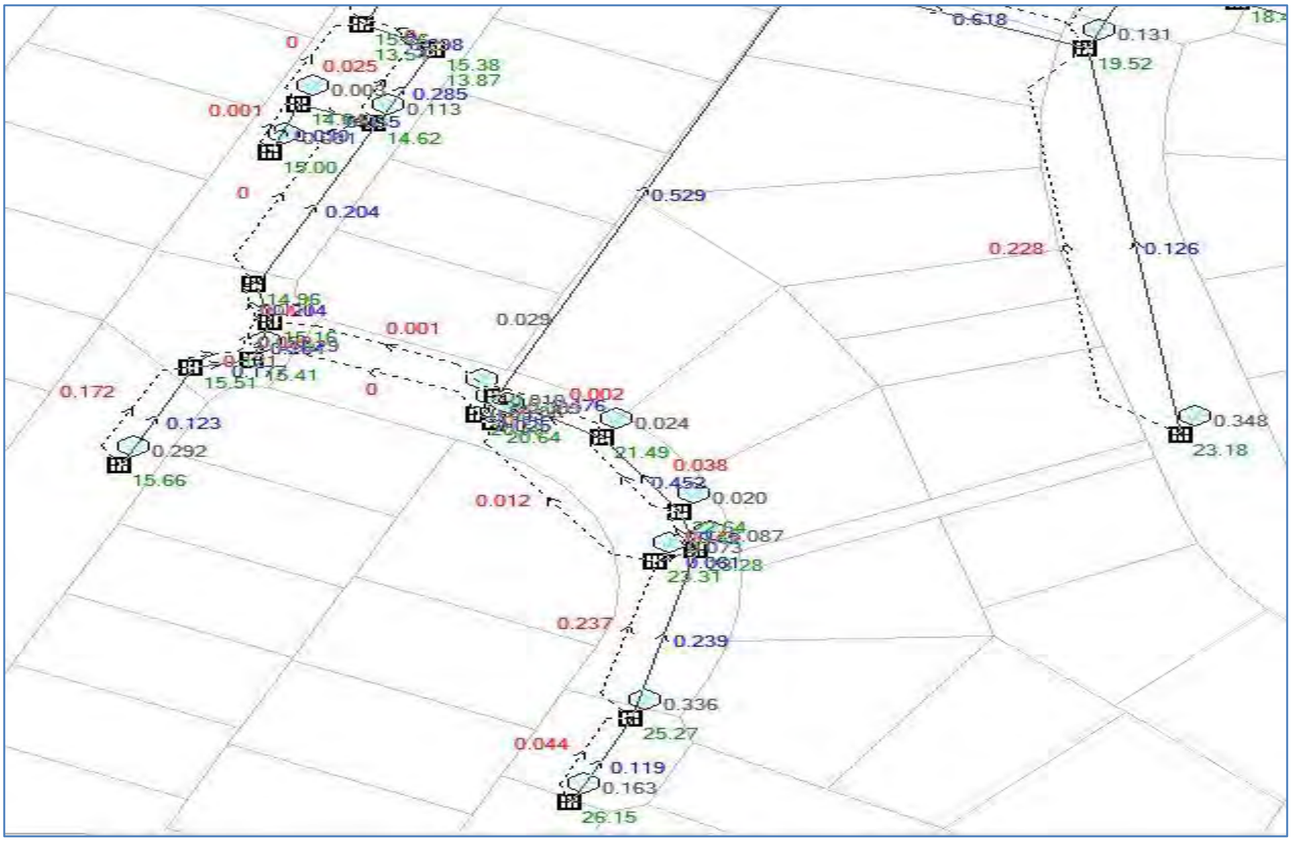


Figure 15 - Network 2 – 5 year Overland Flow Results – Detail 1

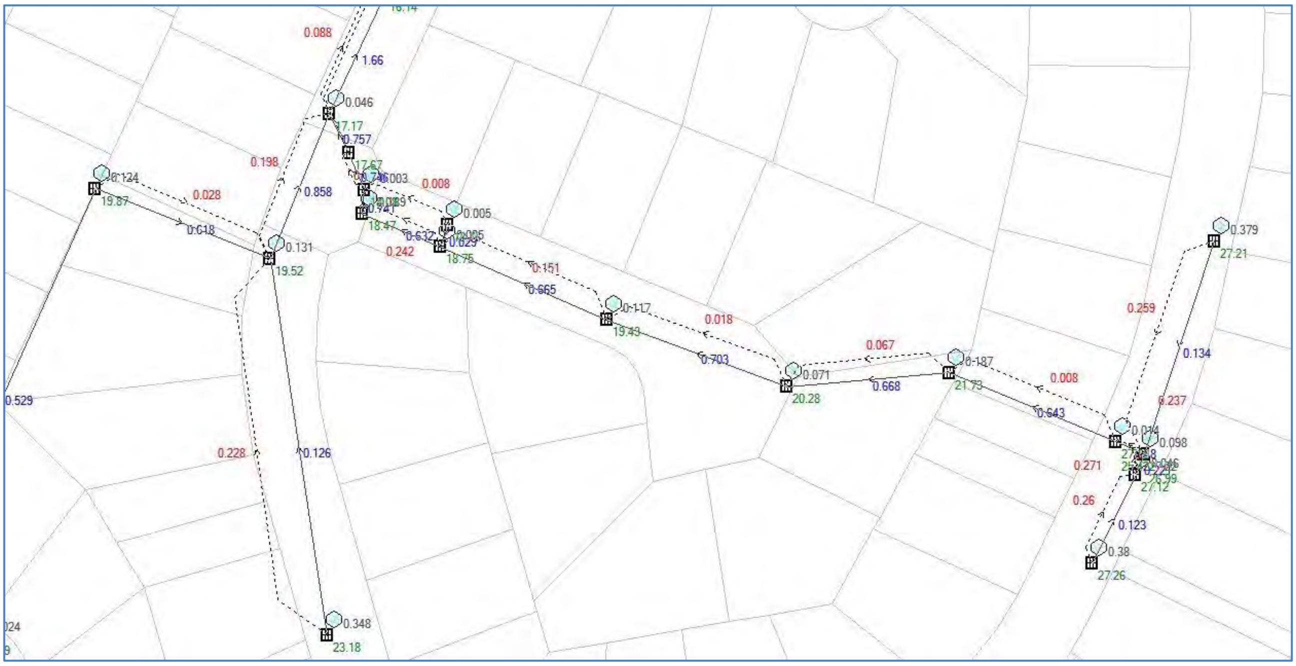


Figure 16 - Network 2 – 5 year Overland Flow Results – Detail 2

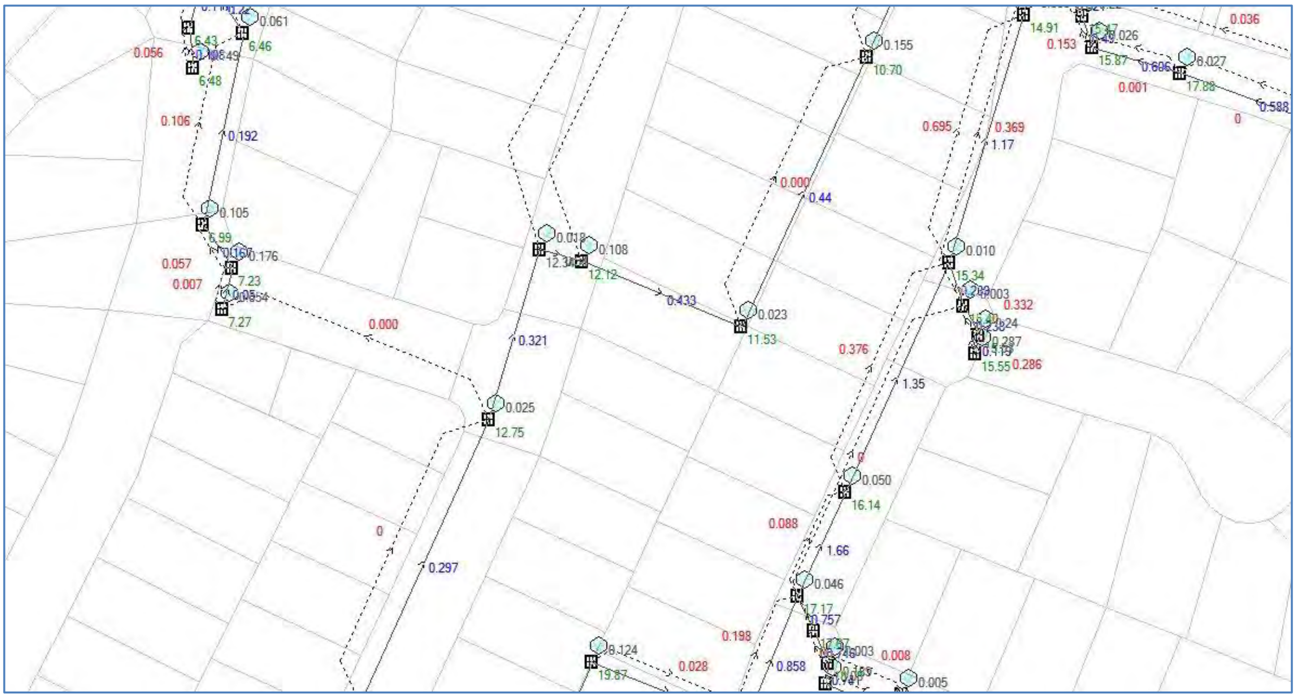


Figure 17 - Network 2 – 5 year Overland Flow Results – Detail 3

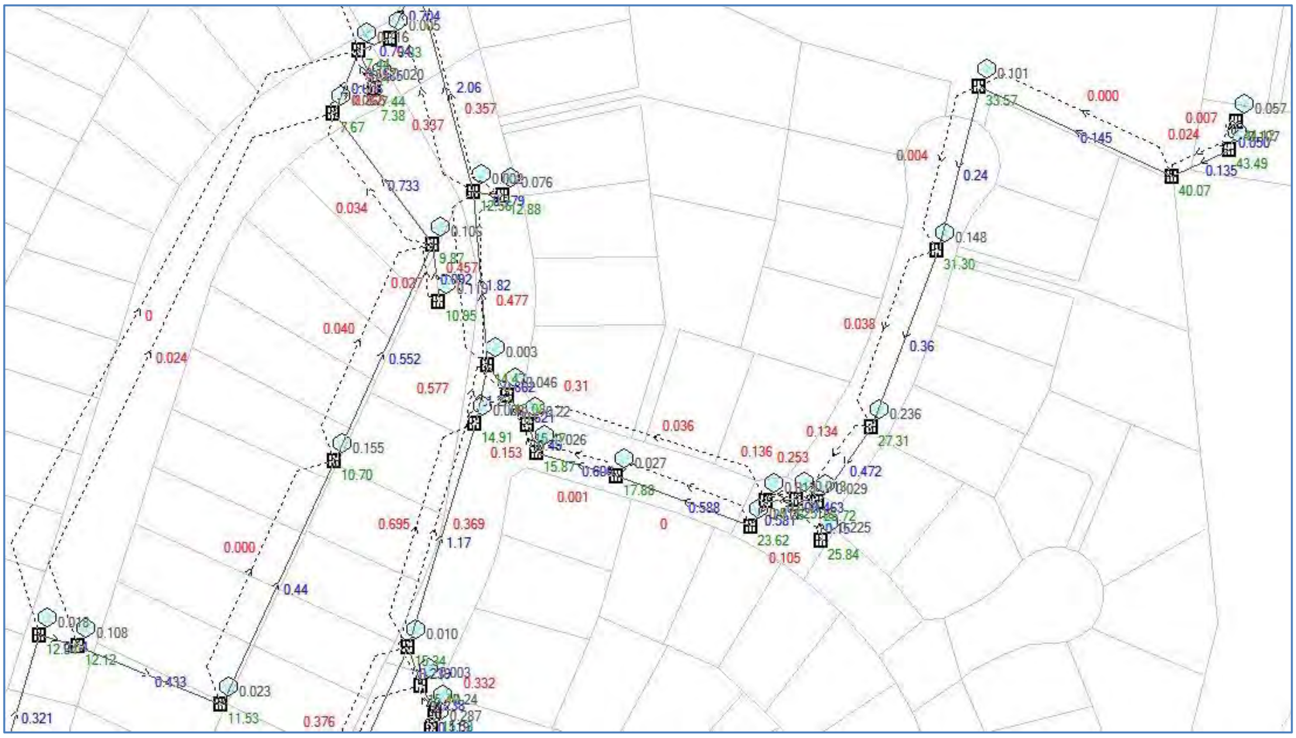


Figure 18 - Network 2 – 5 year Overland Flow Results – Detail 4

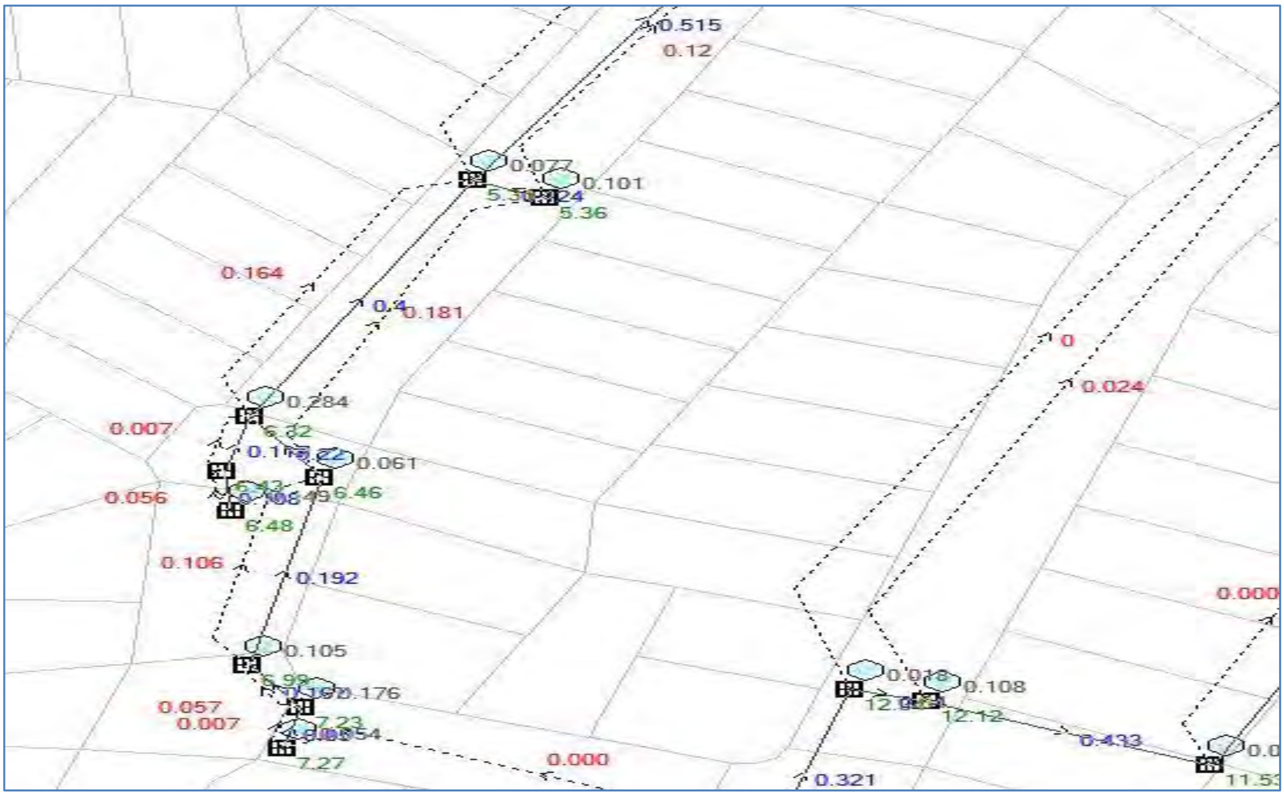


Figure 19 - Network 2 – 5 year Overland Flow Results – Detail 5

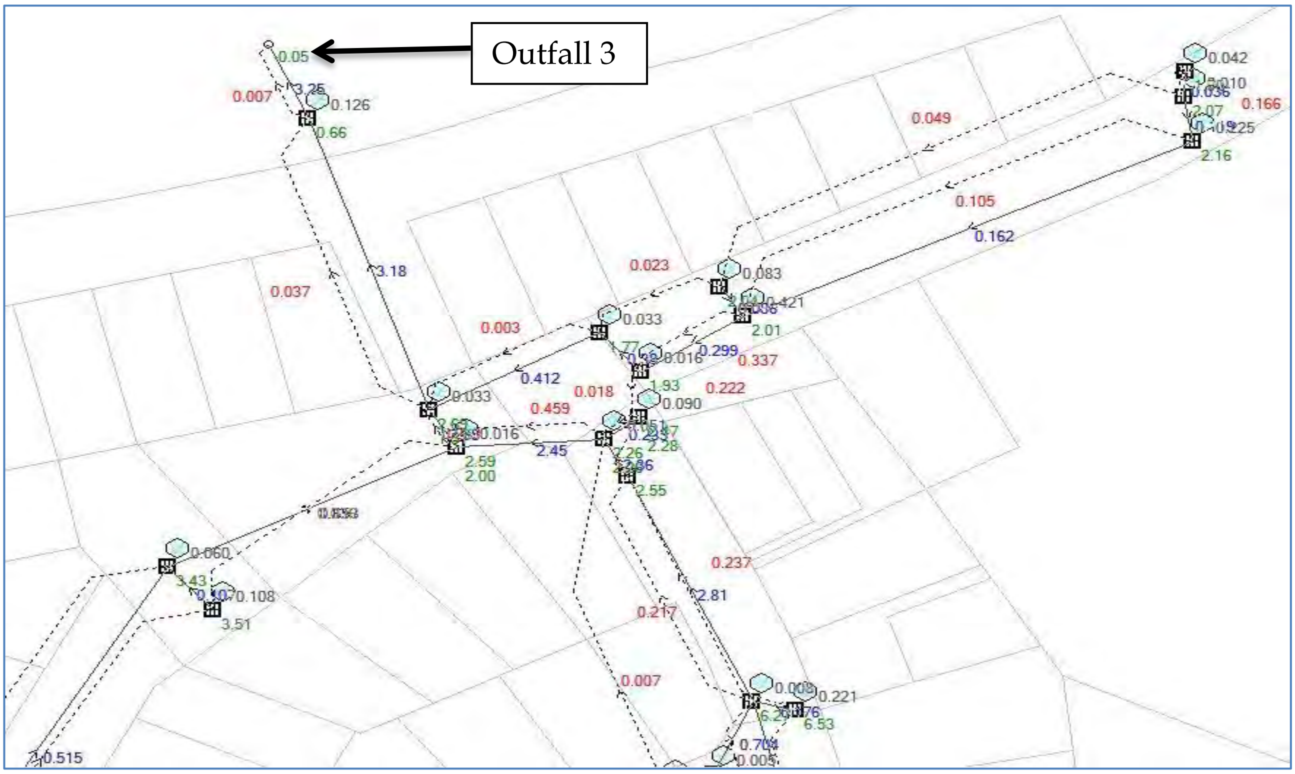


Figure 20 - Network 2 – 5 year Overland Flow Results – Detail 6

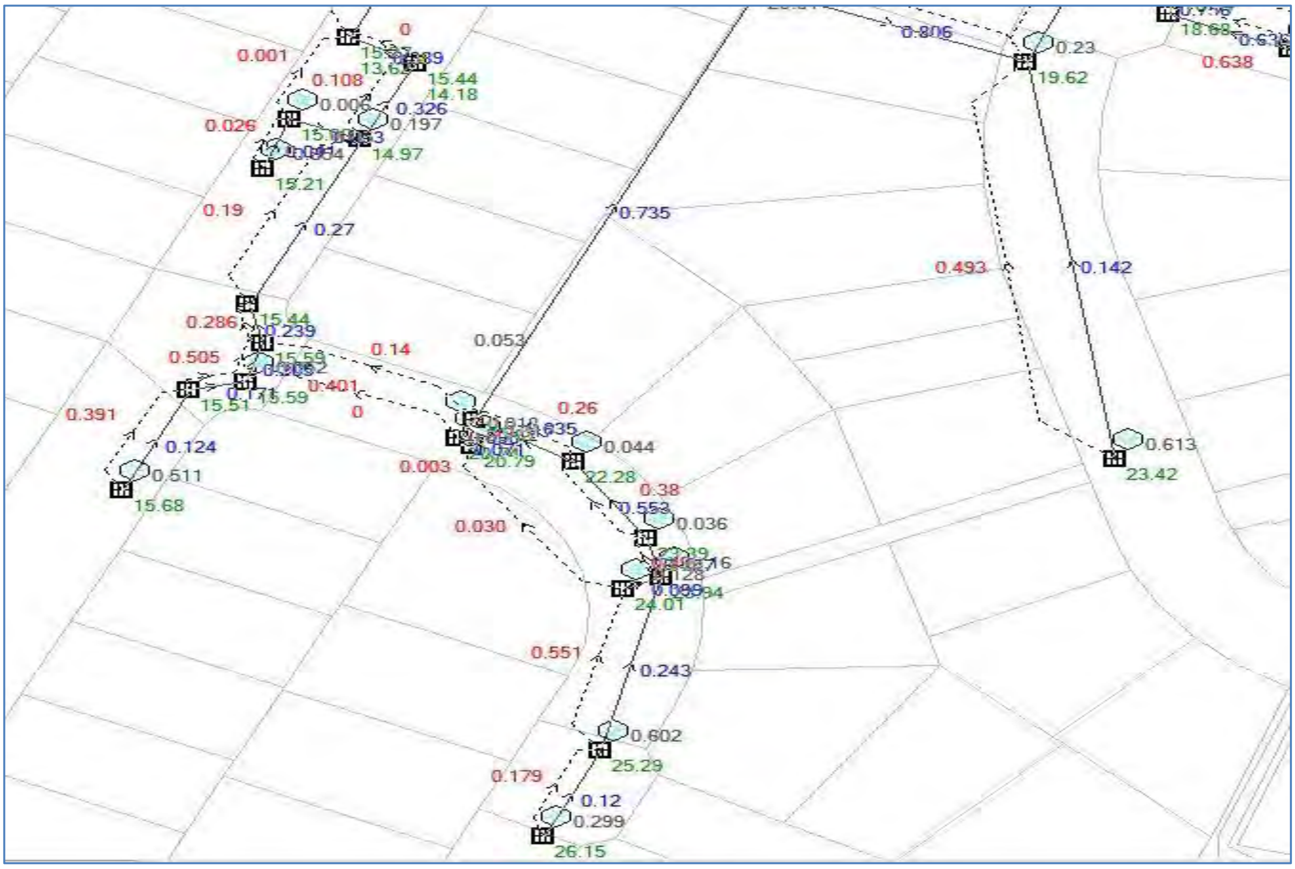


Figure 21 - Network 2 – 100 year Overland Flow Results – Detail 1

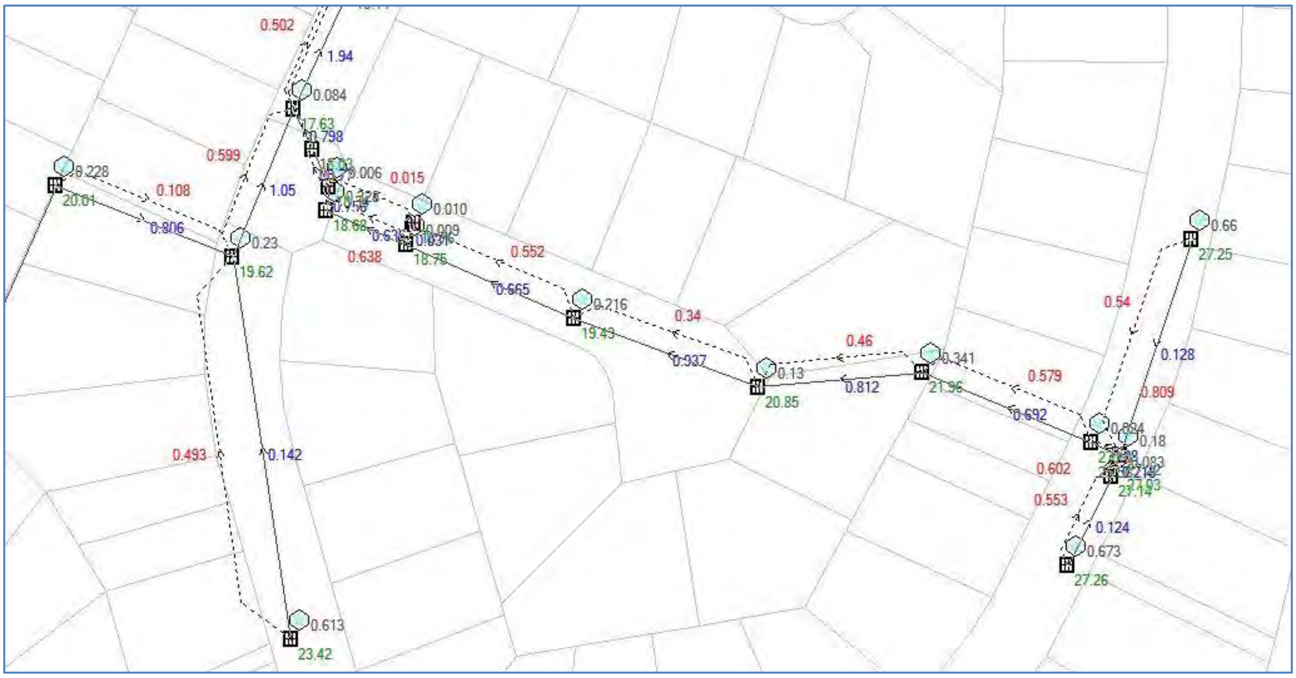


Figure 22 - Network 2 – 100 year Overland Flow Results – Detail 2

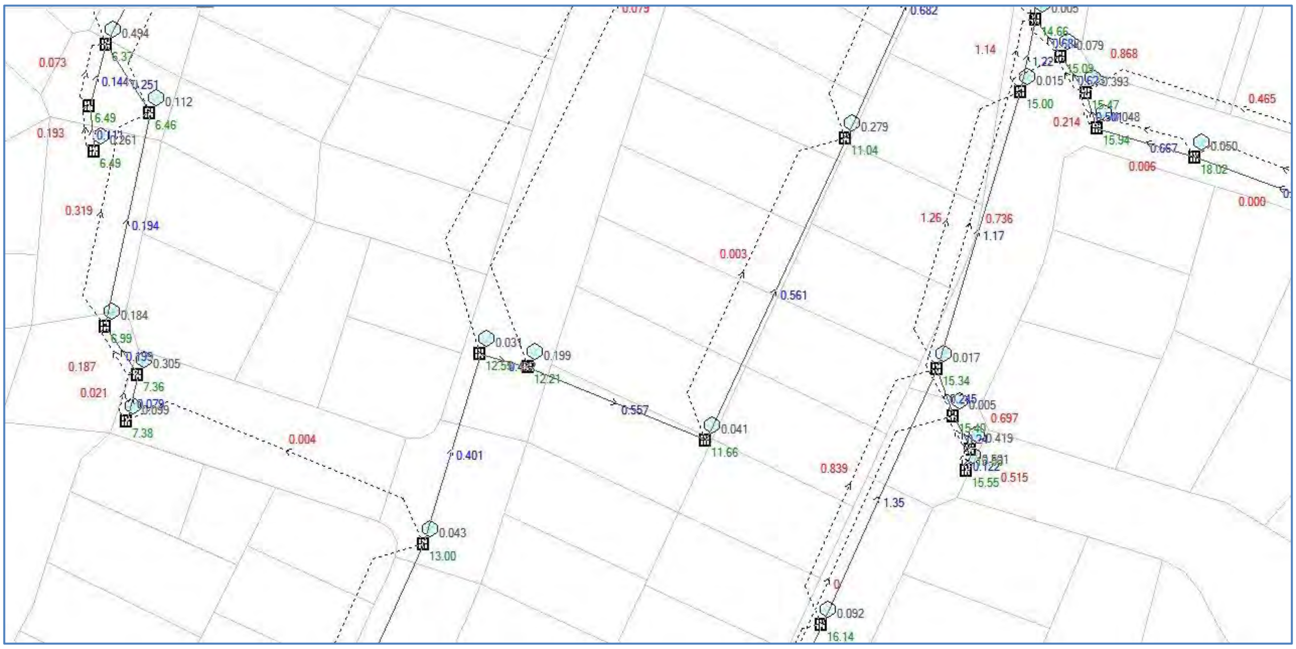


Figure 23 – Network 2 – 100 year Overland Flow Results – Detail 3

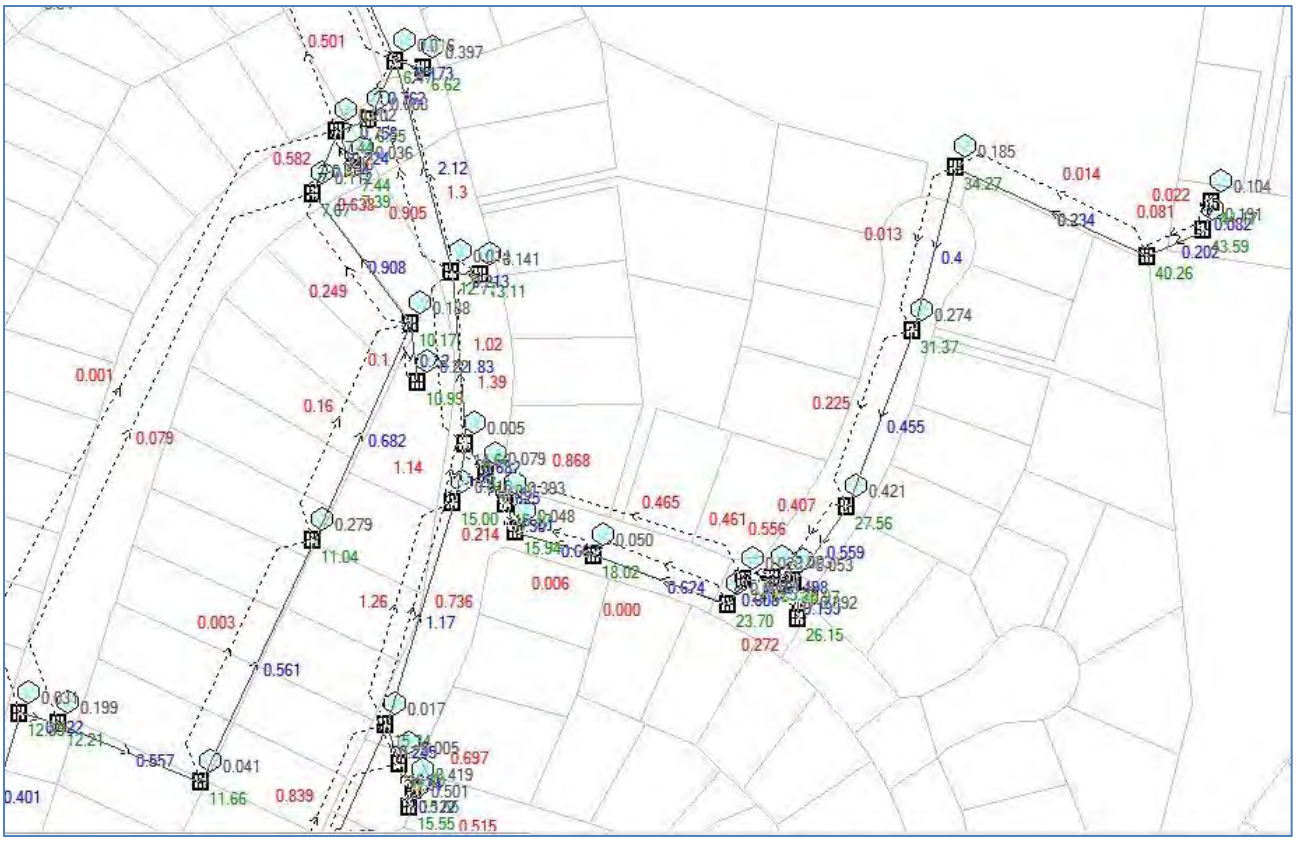


Figure 24 - Network 2 – 100 year Overland Flow Results – Detail 4

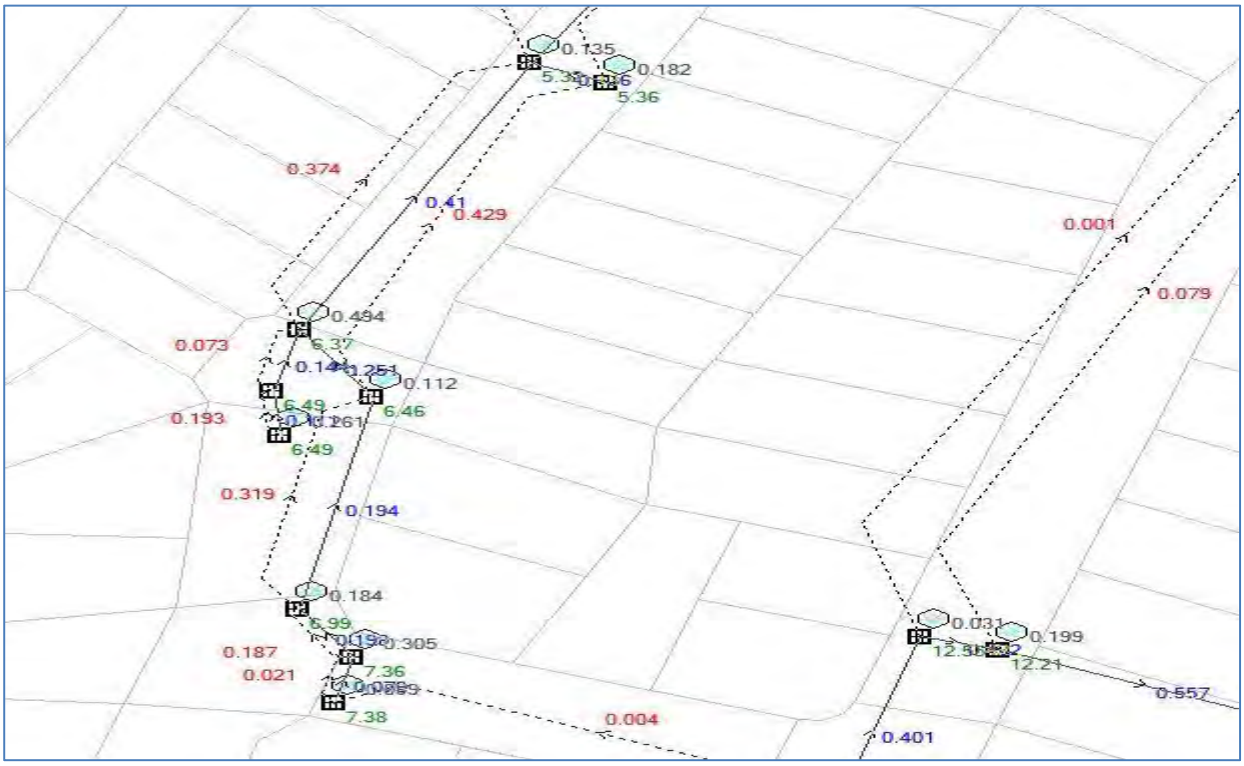


Figure 25 - Network 2 – 100 year Overland Flow Results – Detail 5

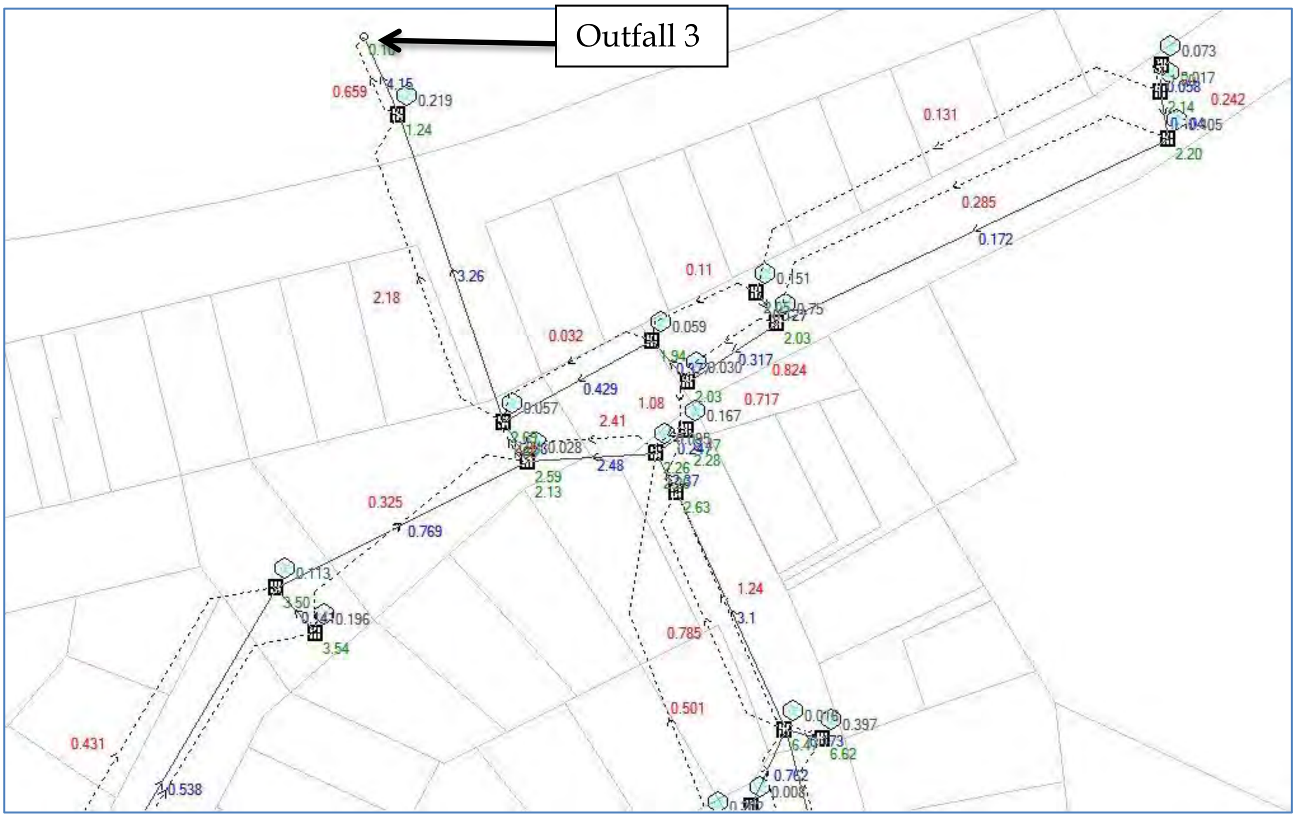


Figure 26 - Network 2 – 100 year Overland Flow Results – Detail 6

9.4 Appendix 4 - *DRAINS* Results for Network 3

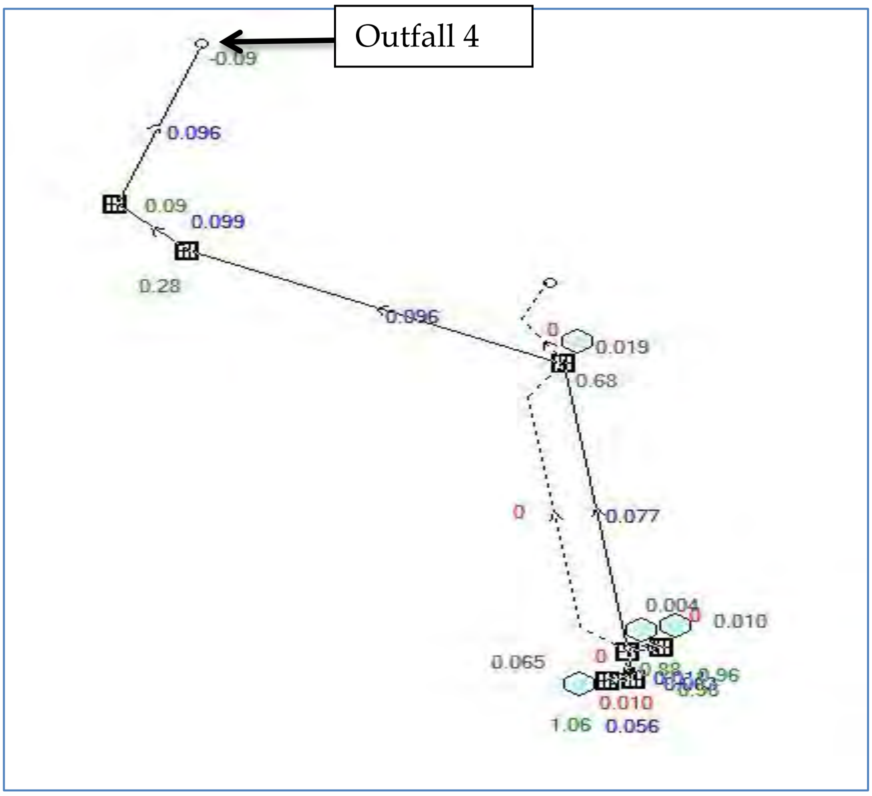


Figure 27 - Network 3 – 5 year Overland Flow Results

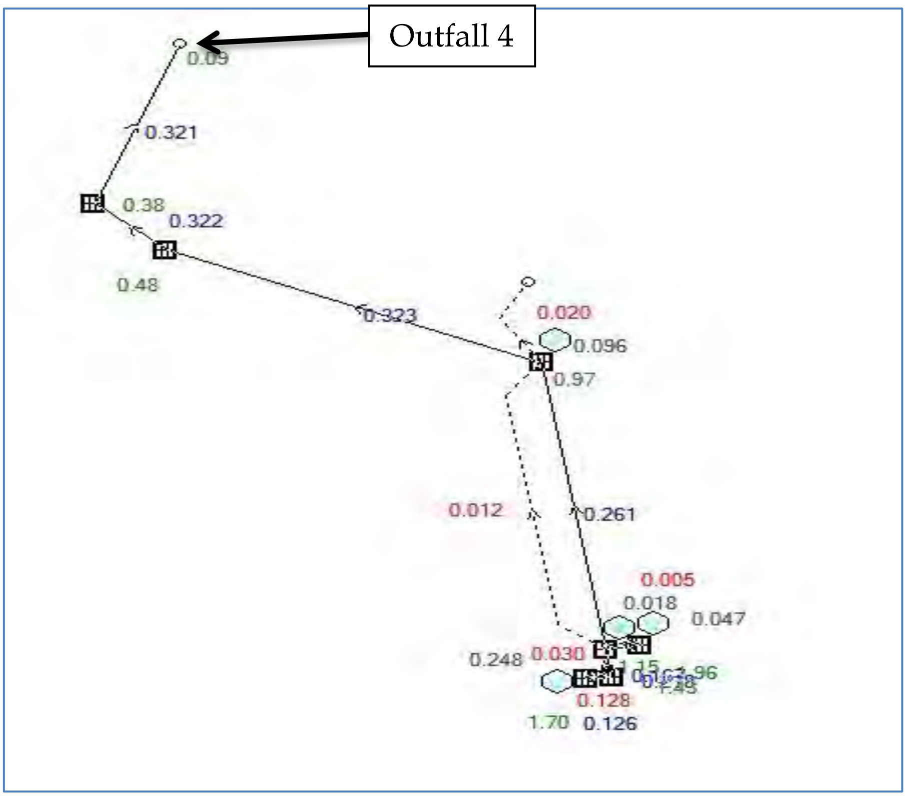


Figure 28 - Network 3 – 100 year Overland Flow Results

9.5 Appendix 5 - *DRAINS* Results for Network 4

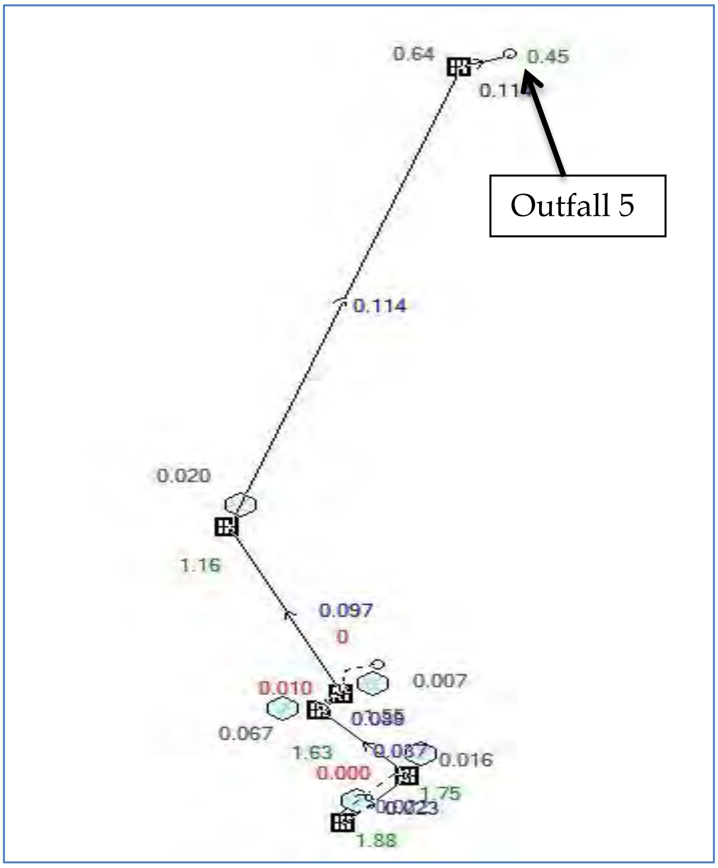


Figure 29 - Network 4 – 5 year Overland Flow Results

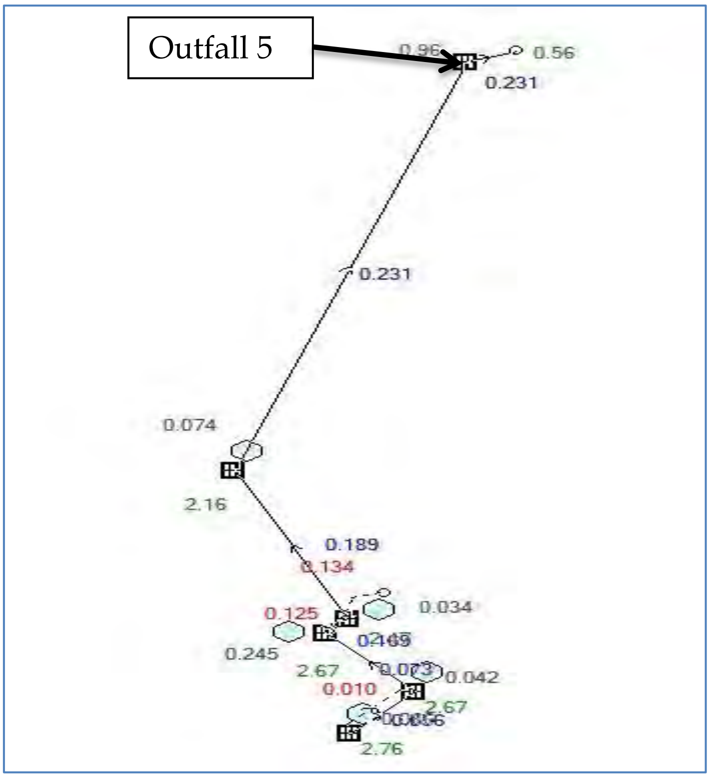
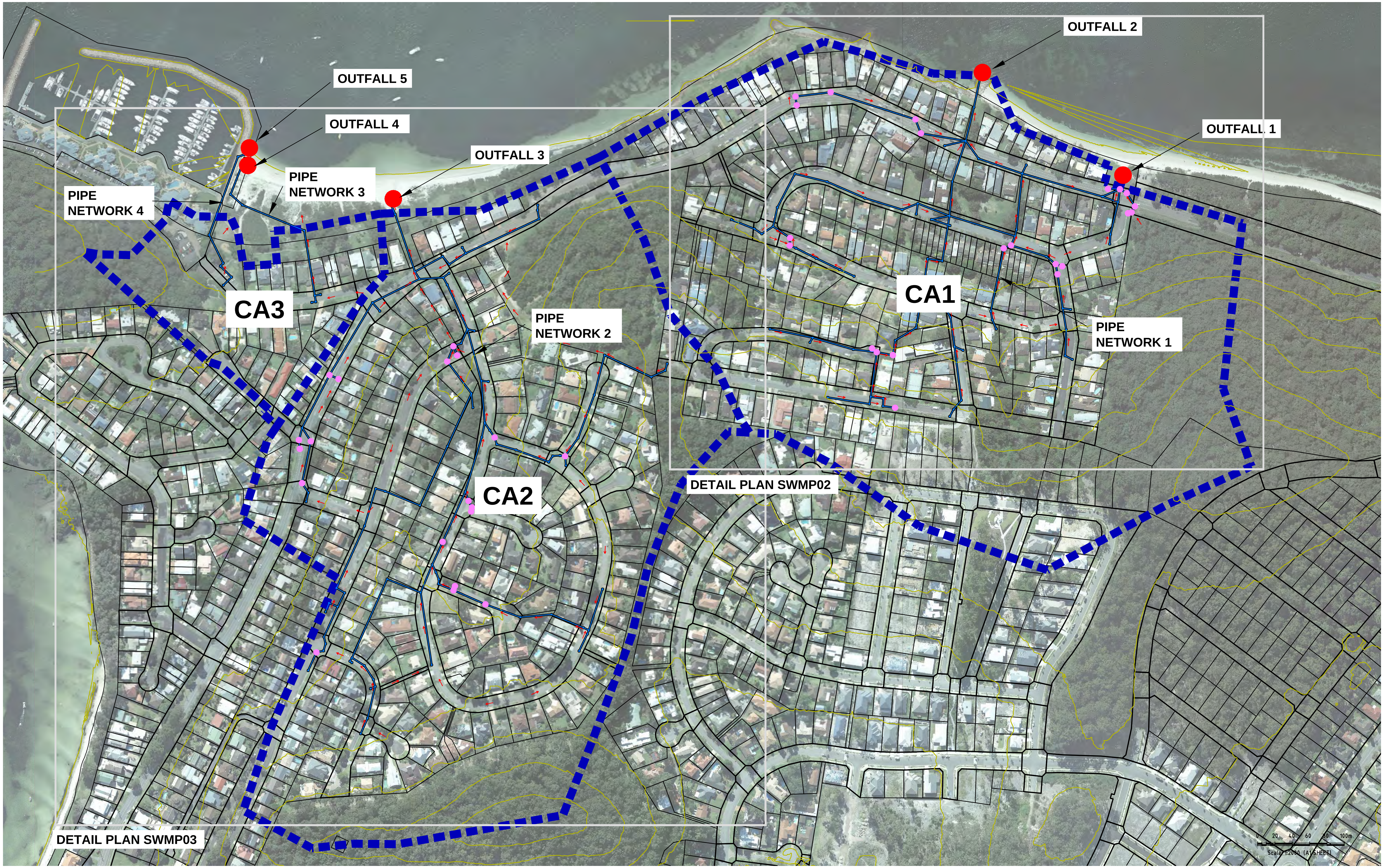


Figure 30 - Network 4 – 100 year Overland Flow Results

9.6 Appendix 6 – Plan of Study Area Showing Pipe Networks – 15000047_P01_SWMP01

9.7 Appendix 7 – Concept Design Plans



REV	DATE	DES.	DRN.	APP.	REVISION DETAILS
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B	28/01/16	J.A.	A.J.B.	J.M.A.	DRAFT ISSUE FOR CONSULTATION
A	28/08/15	J.A.	N.L.	J.M.A.	DRAFT ISSUE

DRAWING STATUS

DESIGN BY	J.A.
DRAWN BY	N.L.
FINAL APPROVAL	J.M.A.
SCALE: (on A1 Original)	1:2000

DRAFT

North

CLIENT

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PROJECT TITLE

EROSION AND DRAINAGE MANAGEMENT PLAN FOR SANDY POINT/CONROY PARK CORLETTE

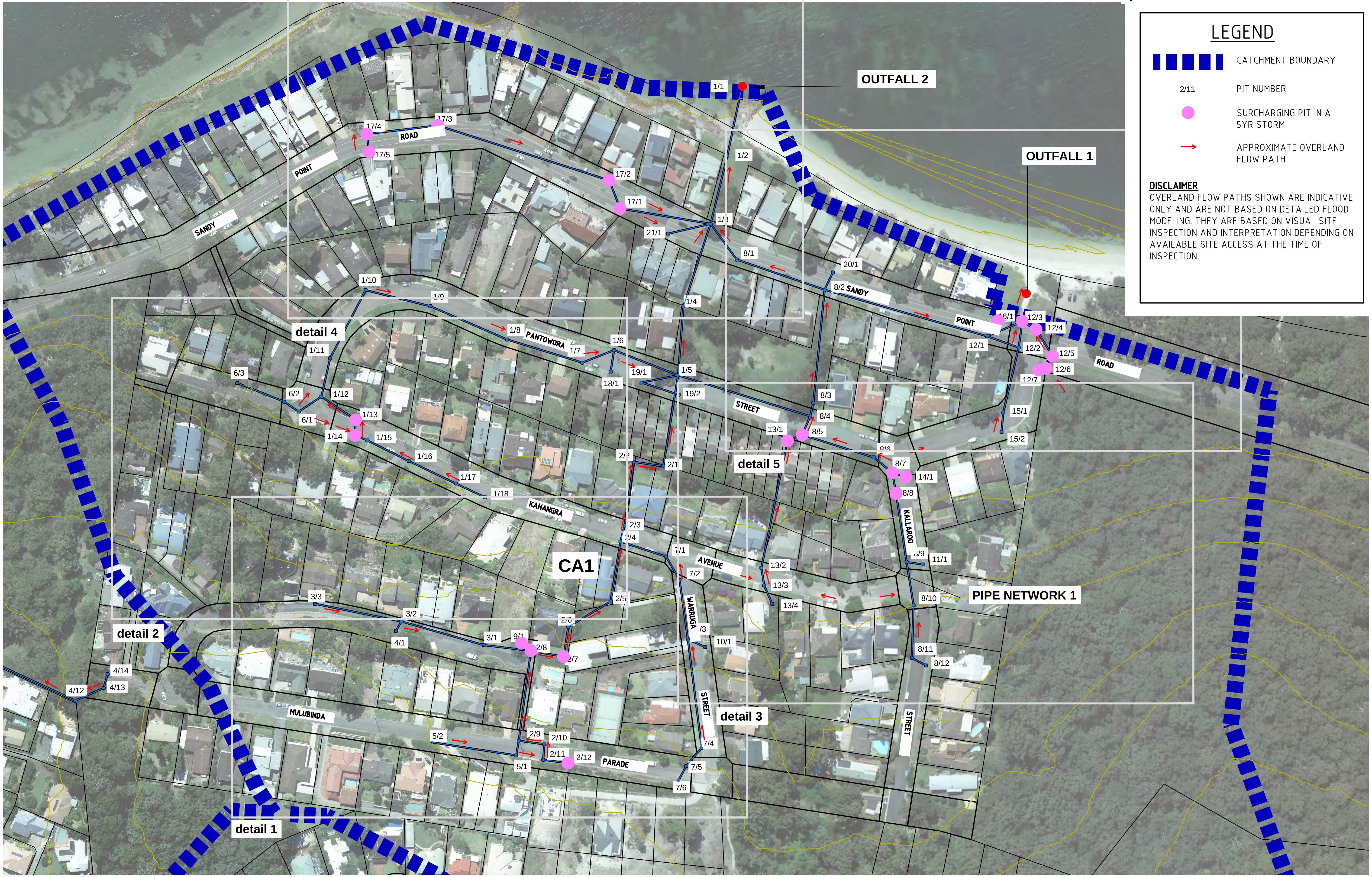
DRAWING TITLE

OVERALL STUDY AREA PLAN SHOWING CATCHMENT AREAS

PROJECT NO.	SUB-PR NO.	DRAWING NO.	REV
15000047	P01	SWMP01	00

Plot Date: Friday, 1 April 2016 11:37:03 AM

CAD File Name: I:\15000047 Sandy Point_Conroy Park Foreshore Erosion and Drainage Management Plan\Drawings\15000047_P01_C_REV 00.dwg



LEGEND

- CATCHMENT BOUNDARY
- 2/11 — PIT NUMBER
- SURCHARGING PIT IN A 5YR STORM
- APPROXIMATE OVERLAND FLOW PATH

DISCLAIMER

OVERLAND FLOW PATHS SHOWN ARE INDICATIVE ONLY AND ARE NOT BASED ON DETAILED FLOOD MODELING. THEY ARE BASED ON VISUAL SITE INSPECTION AND INTERPRETATION DEPENDING ON AVAILABLE SITE ACCESS AT THE TIME OF INSPECTION.

REV	DATE	DES.	DRN.	APP.	REVISION DETAILS
00	01/04/16	J.A	A.J.B	J.M.A	FINAL ISSUE
B	28/01/16	J.A.	A.J.B.	J.M.A.	DRAFT ISSUE FOR CONSULTATION
A	28/08/15	J.A.	N.L.	J.M.A.	DRAFT ISSUE

DRAWING STATUS	
DESIGN BY	J.A.
DRAWN BY	N.L.
FINAL APPROVAL	J.M.A.
SCALE: (on A1 Original)	AS SHOWN

DRAFT

North

CLIENT: PORT STEPHENS COUNCIL

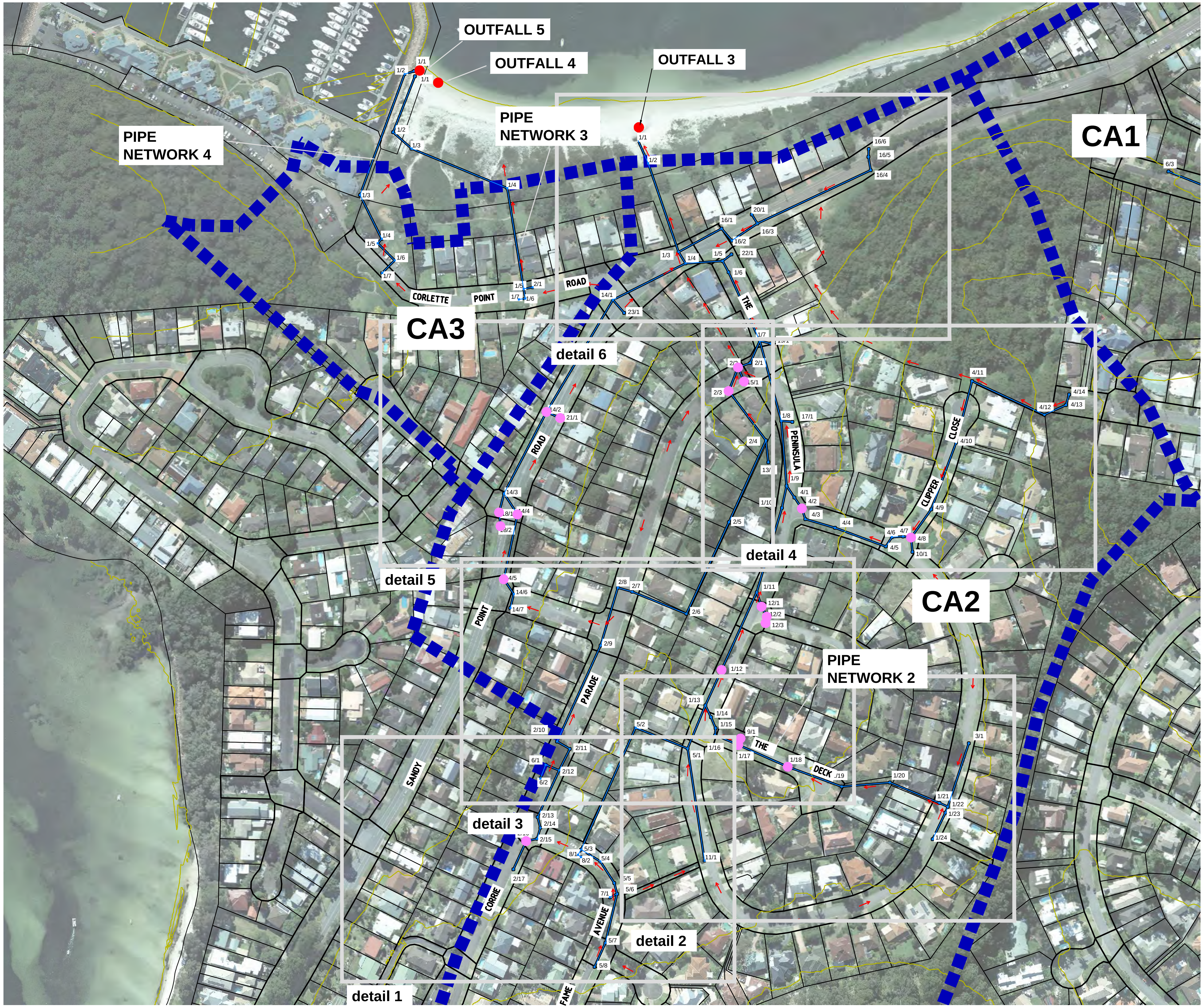
SEEC
Suites 7 & 8, 68-70 Station Street
PO Box 1098, Bowral NSW 2576.
(t) 02 4862 1633
(f) 02 4862 3088
email: reception@seec.com.au
WWW.SEEC.COM.AU

PROJECT TITLE: EROSION AND DRAINAGE MANAGEMENT PLAN FOR SANDY POINT/CONROY PARK CORLETTE

DRAWING TITLE: DETAIL PLAN CATCHMENT CA1 PIPE NETWORK 1

PROJECT NO.	SUB-PR NO.	DRAWING NO.	REV
15000047	P01	SWMP02	00

Plot Date: Friday, 1 April 2016 11:37:12 AM   CAD File Name: I:\15000047 Sandy Point_Conroy Park Foreshore Erosion and Drainage Management Plan\Drawings\15000047_P01_C_REV 00.dwg



LEGEND

- CATCHMENT BOUNDARY
- 2/11 — PIT NUMBER
- SURCHARGING PIT IN A 5YR STORM
- APPROXIMATE OVERLAND FLOW PATH

DISCLAIMER

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0 15 30 45 60 75m

Scale: 1:1500 (A1 SHEET)

REV	DATE	DES.	DRN.	APP.	REVISION DETAILS
00	01/04/16	J.A	A.J.B	J.M.A	FINAL ISSUE
B	28/01/16	J.A.	A.J.B.	J.M.A.	DRAFT ISSUE FOR CONSULTATION
A	28/08/15	J.A.	N.L.	J.M.A.	DRAFT ISSUE

DRAWING STATUS

DESIGN BY	J.A.
DRAWN BY	N.L.
FINAL APPROVAL	J.M.A.
SCALE: (on A1 Original)	1:1500

DRAFT

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PROJECT TITLE: EROSION AND DRAINAGE MANAGEMENT PLAN FOR SANDY POINT/CONROY PARK CORLETTE

DRAWING TITLE: DETAIL PLAN CATCHMENTS CA2 & CA3 PIPES NETWORKS 2, 3 & 4

PROJECT NO.	SUB-PR NO.	DRAWING NO.	REV
15000047	P01	SWMP03	00

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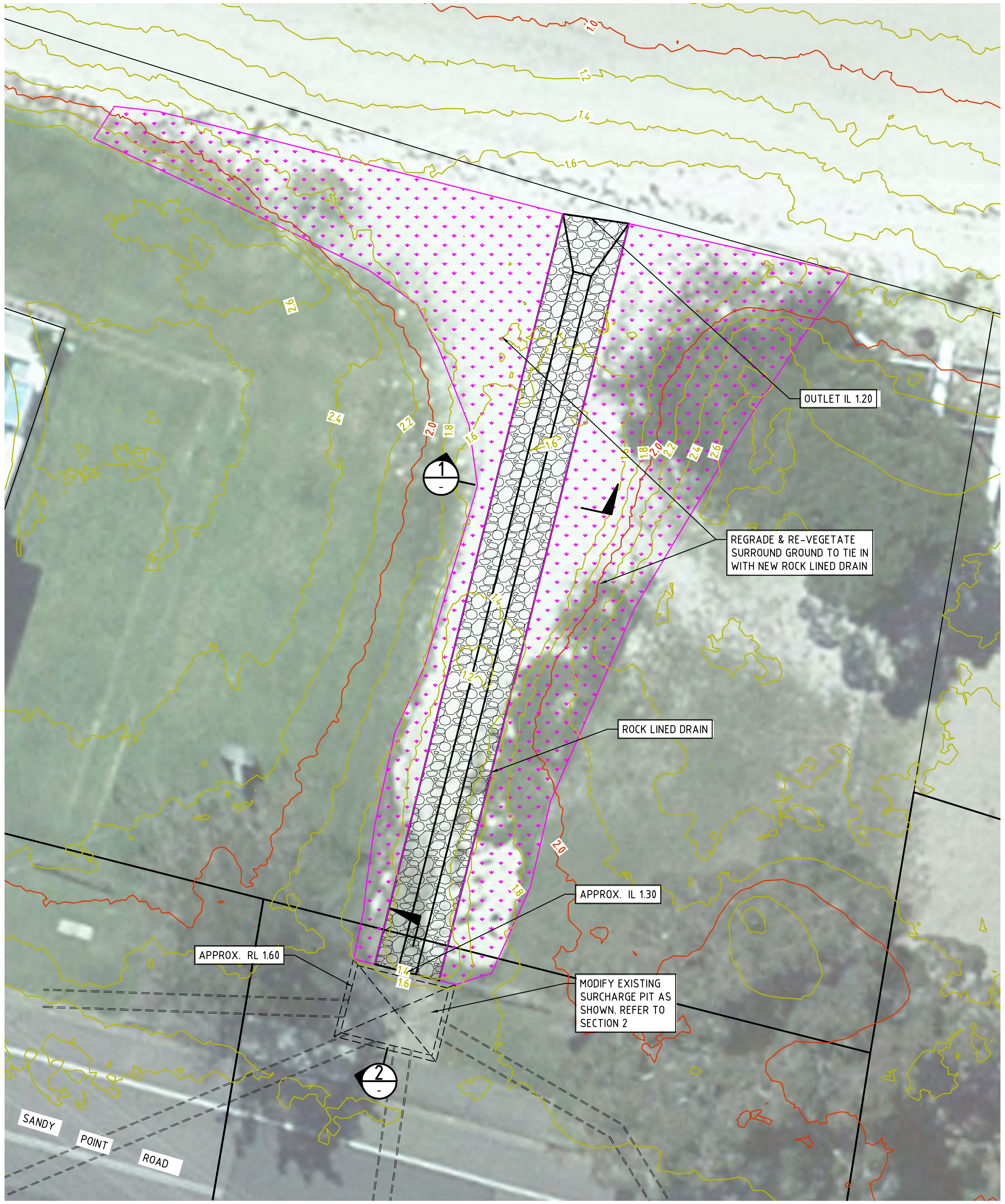
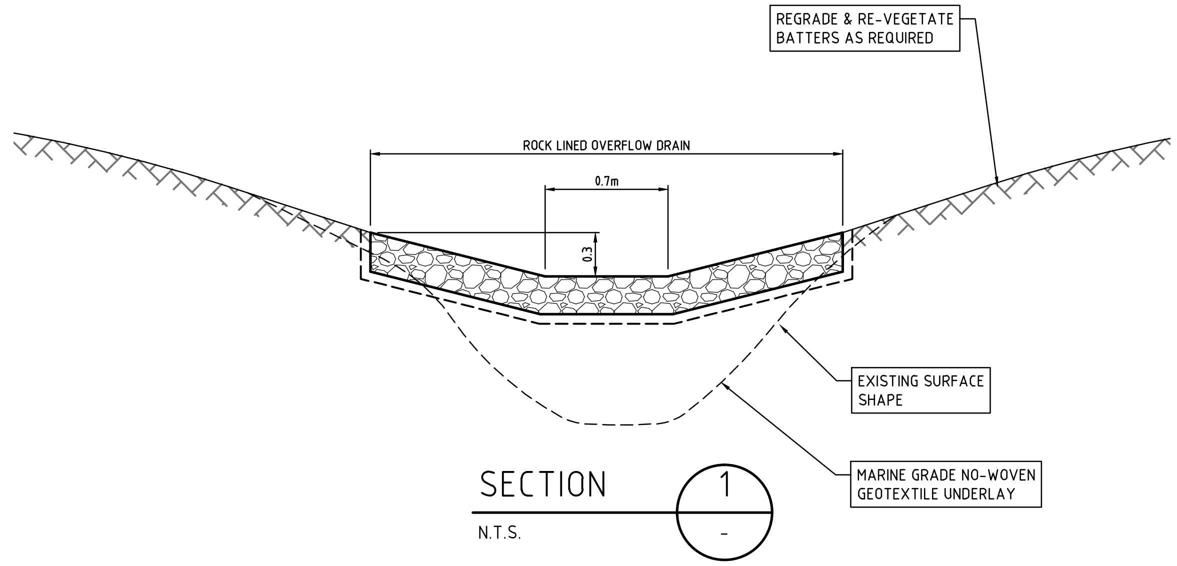
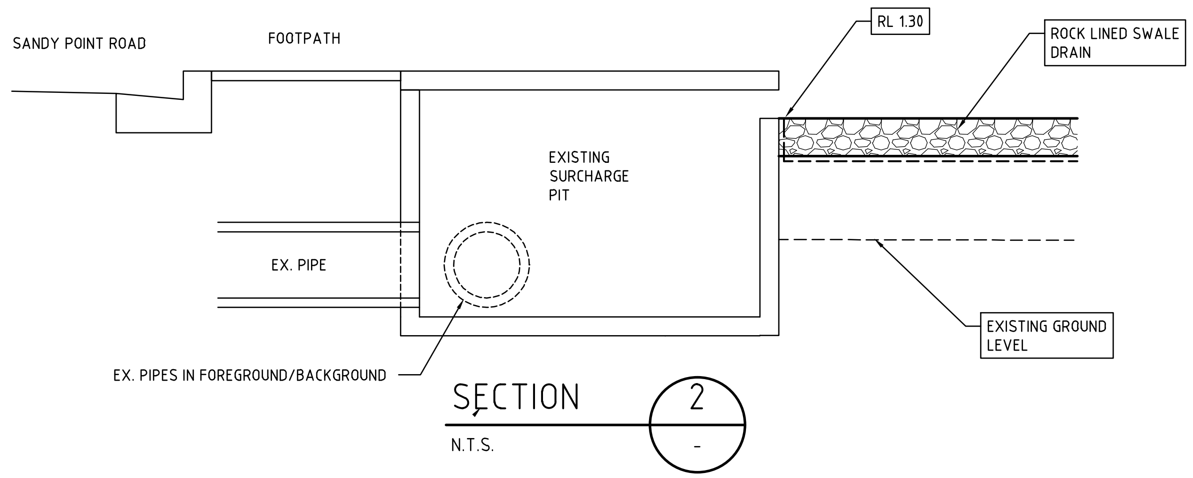


OUTFALL 1 DETAIL PLAN

0 1 2 3 4 5m
Scale: 1:100 (A1 SHEET)



TYPICAL SECTION THROUGH ROCK LINED DRAIN



TYPICAL SECTION THROUGH EXISTING SURCHARGE PIT

0 0.2 0.4 0.6 0.8 1.0m
Scale: 1:20 (A1 SHEET)

REV	DATE	DES.	DRN.	APP.	REVISION DETAILS
00	01/04/16	J.M.A	M.R	J.A	FINAL ISSUE
A	25/08/15	J.M.A.	N.L.	J.A.	DRAFT

DRAWING STATUS	
DESIGN BY	J.A.
DRAWN BY	N.L.
FINAL APPROVAL	J.M.A.
SCALE: (on A1 Original)	AS SHOWN

FINAL

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PROJECT TITLE
EROSION AND DRAINAGE MANAGEMENT PLAN FOR SANDY POINT/CONROY PARK CORLETTE

DRAWING TITLE
OUTFALL 1 CONCEPT DESIGN OPTION 1

PROJECT NO.	SUB-PR NO.	DRAWING NO.	REV
15000047	P01	SK01	00

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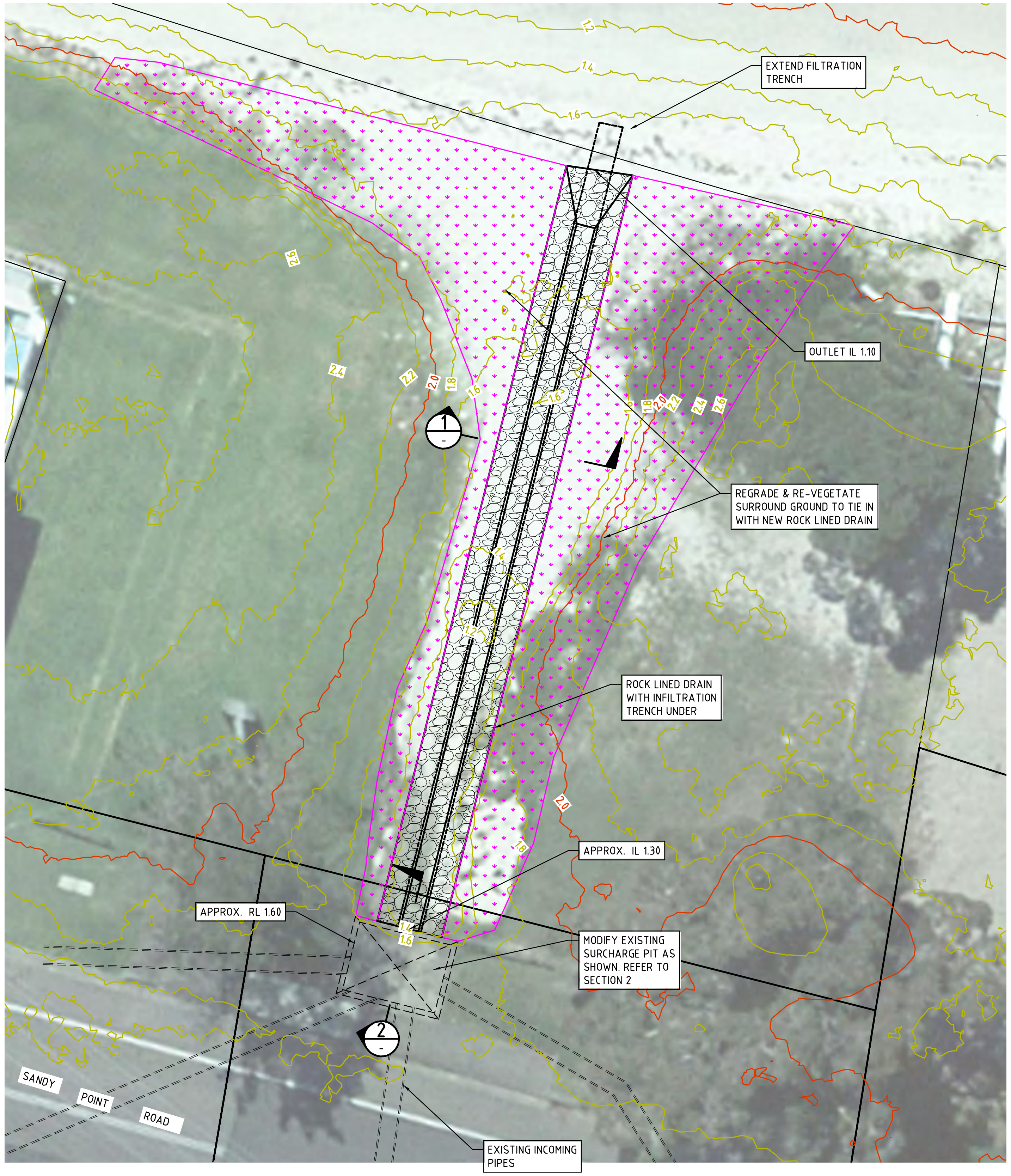
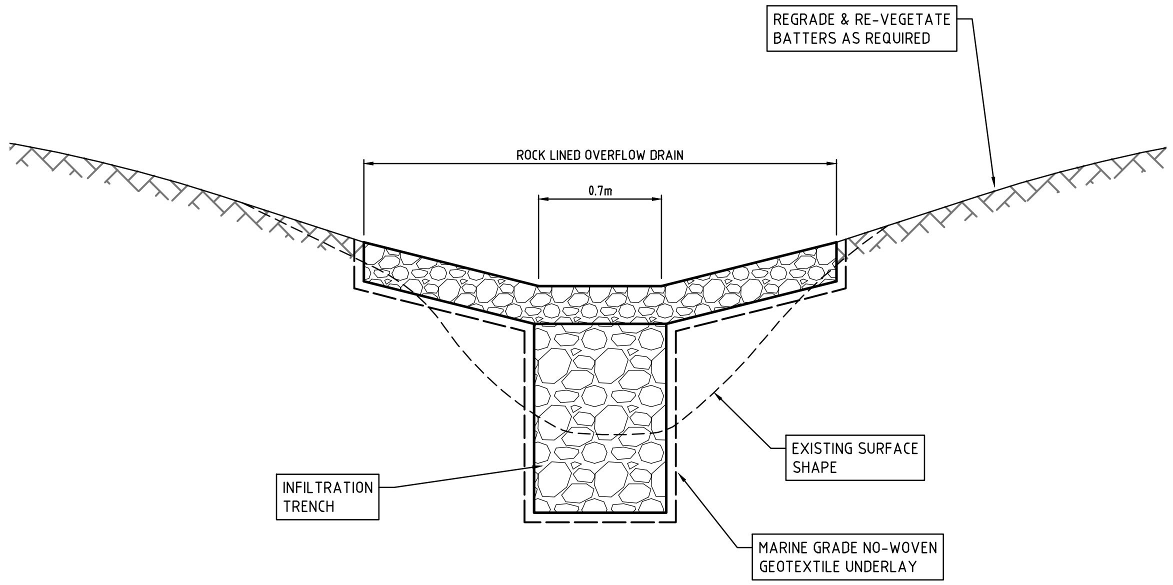


OUTFALL 1 DETAIL PLAN

0 1 2 3 4 5m

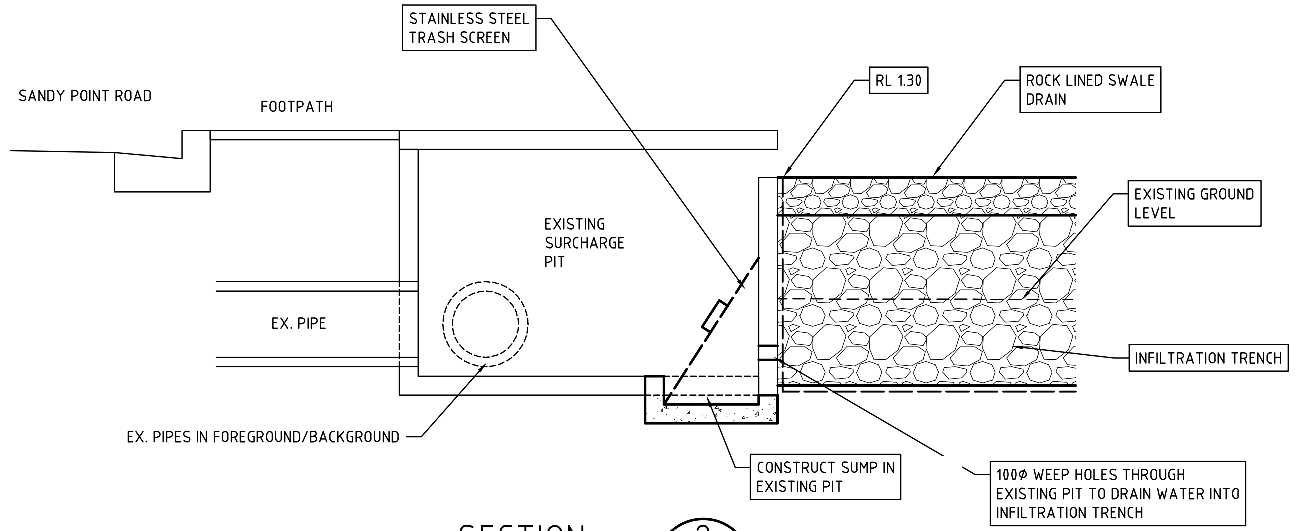
Scale: 1:100 (A1 SHEET)



SECTION 1 -

1:20

TYPICAL SECTION THROUGH ROCK LINED DRAIN



SECTION 2 -

1:20

TYPICAL SECTION THROUGH EXISTING SURCHARGE PIT

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Scale: 1:20 (A1 SHEET)

REV	DATE	DES.	DRN.	APP.	REVISION DETAILS
00	01/04/16	J.M.A	M.R	J.A	FINAL ISSUE
A	25/08/15	J.M.A.	N.L.	J.A.	DRAFT

DRAWING STATUS

DESIGN BY	J.A.
DRAWN BY	N.L.
FINAL APPROVAL	J.M.A.
SCALE: (on A1 Original)	AS SHOWN

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PROJECT TITLE: EROSION AND DRAINAGE MANAGEMENT PLAN FOR SANDY POINT/CONROY PARK CORLETTE

DRAWING TITLE: OUTFALL 1 CONCEPT DESIGN OPTION 2

PROJECT NO.	SUB-PR NO.	DRAWING NO.	REV
15000047	P01	SK02	00

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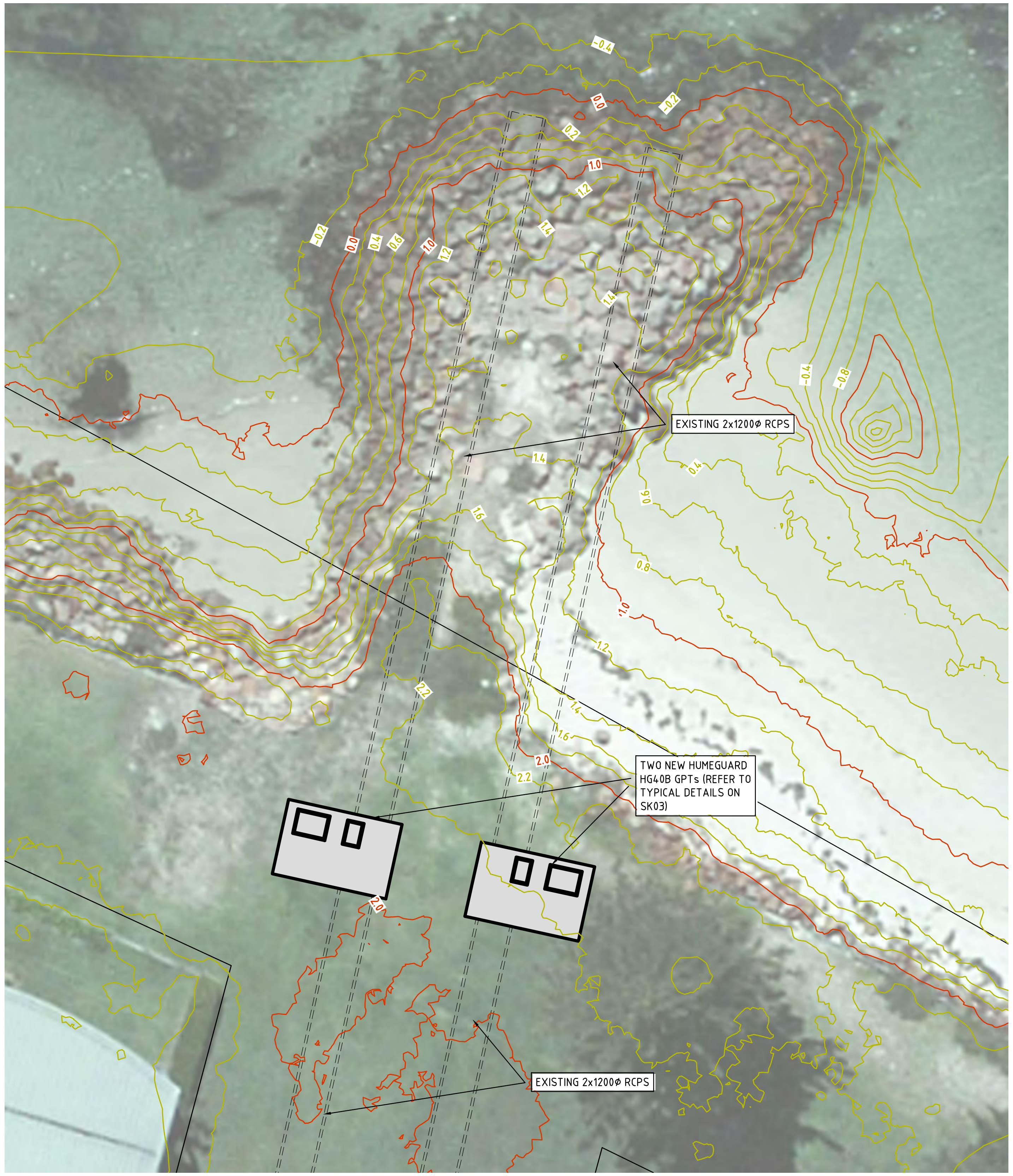
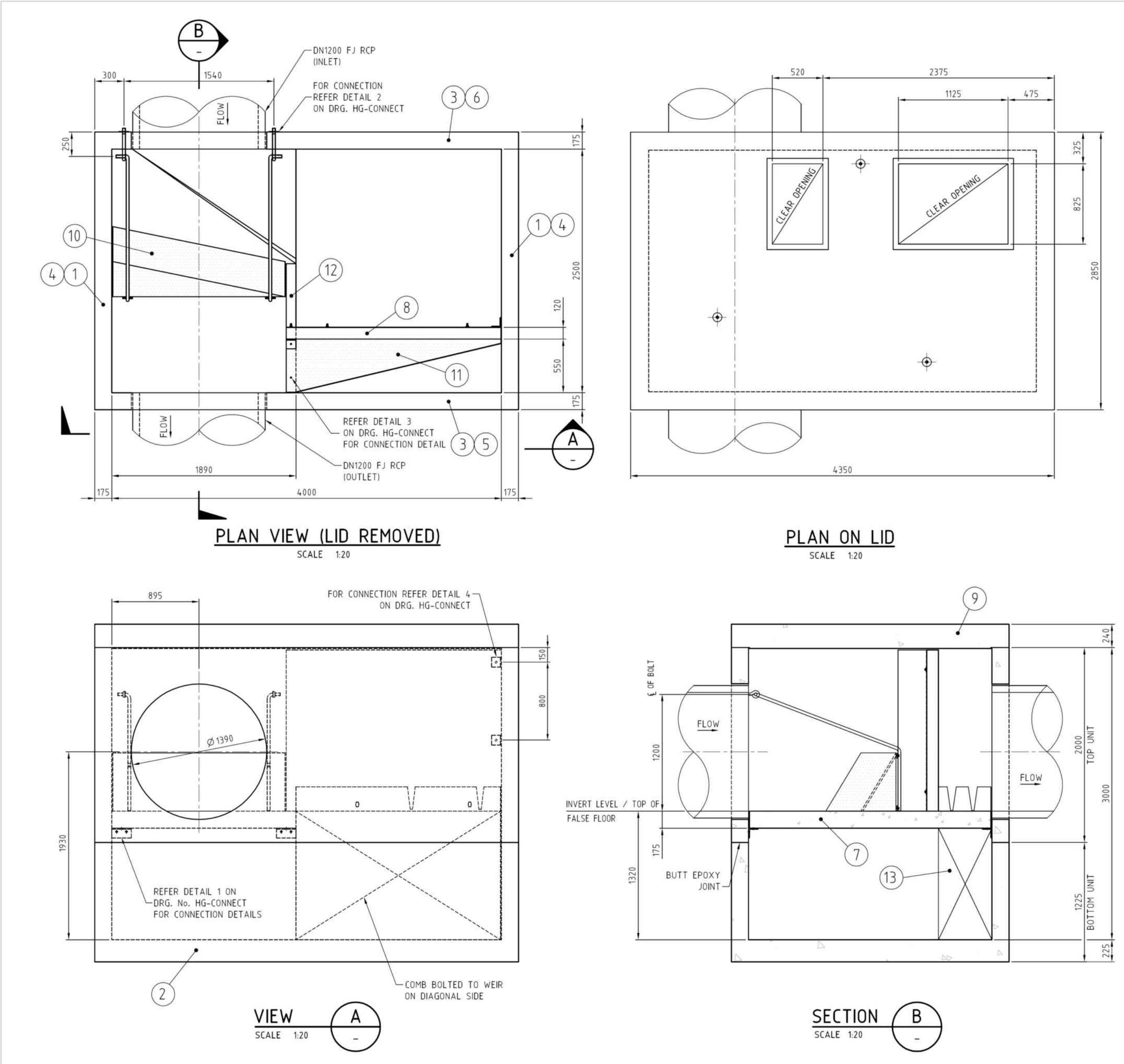


OUTFALL 2 DETAIL PLAN

Scale: 1:100 (A1 SHEET)



TYPICAL DETAIL OF HUMEGUARD HG40B/L

NOT TO SCALE

REV	DATE	DES.	DRN.	APP.	REVISION DETAILS
00	01/04/16	J.M.A	M.R	J.A	FINAL ISSUE
A	25/08/15	J.M.A.	N.L.	J.A.	DRAFT

DRAWING STATUS	
DESIGN BY	J.A.
DRAWN BY	N.L.
FINAL APPROVAL	J.M.A.
SCALE: (on A1 Original)	AS SHOWN
FINAL	

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PROJECT TITLE: EROSION AND DRAINAGE MANAGEMENT PLAN FOR SANDY POINT/CONROY PARK CORLETTE

DRAWING TITLE: OUTFALL 2 CONCEPT DESIGN

PROJECT NO.	SUB-PR NO.	DRAWING NO.	REV
15000047	P01	SK03	00

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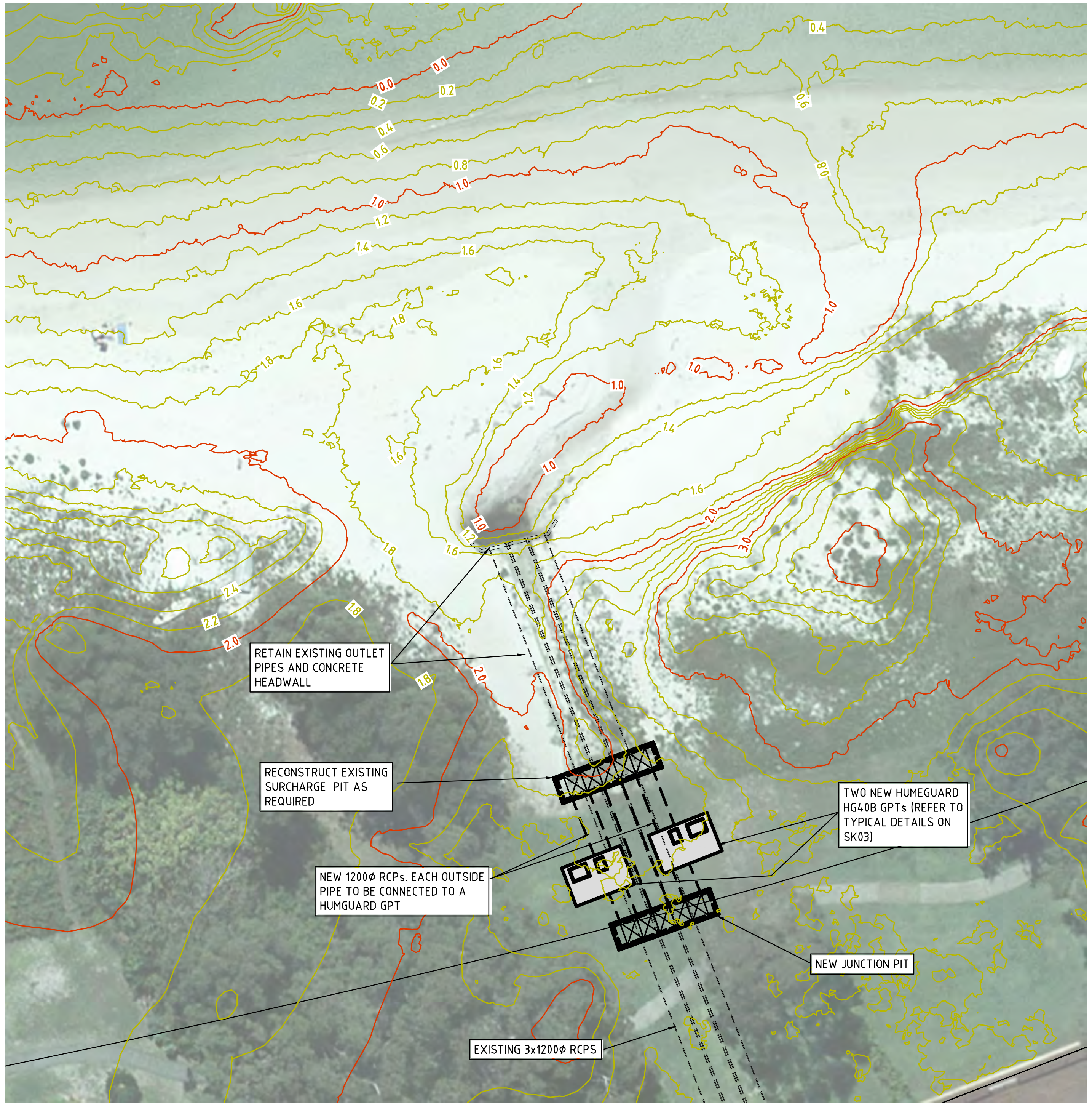

OUTFALL 3 DETAIL PLAN

0 2 4 6 8 10m

Scale: 1:200 (A1 SHEET)

REV	DATE	DES.	DRN.	APP.	REVISION DETAILS
00	01/04/16	J.M.A	M.R	J.A	FINAL ISSUE
A	25/08/15	J.M.A.	N.L.	J.A.	DRAFT

DRAWING STATUS	
DESIGN BY	J.A.
DRAWN BY	N.L.
FINAL APPROVAL	J.M.A.
SCALE: (on A1 Original)	AS SHOWN
FINAL	

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PROJECT TITLE

EROSION AND DRAINAGE MANAGEMENT PLAN FOR SANDY POINT/CONROY PARK CORLETTE

DRAWING TITLE

OUTFALL 3 CONCEPT DESIGN OPTION 1

PROJECT NO.	SUB-PR NO.	DRAWING NO.	REV
15000047	P01	SK04	00

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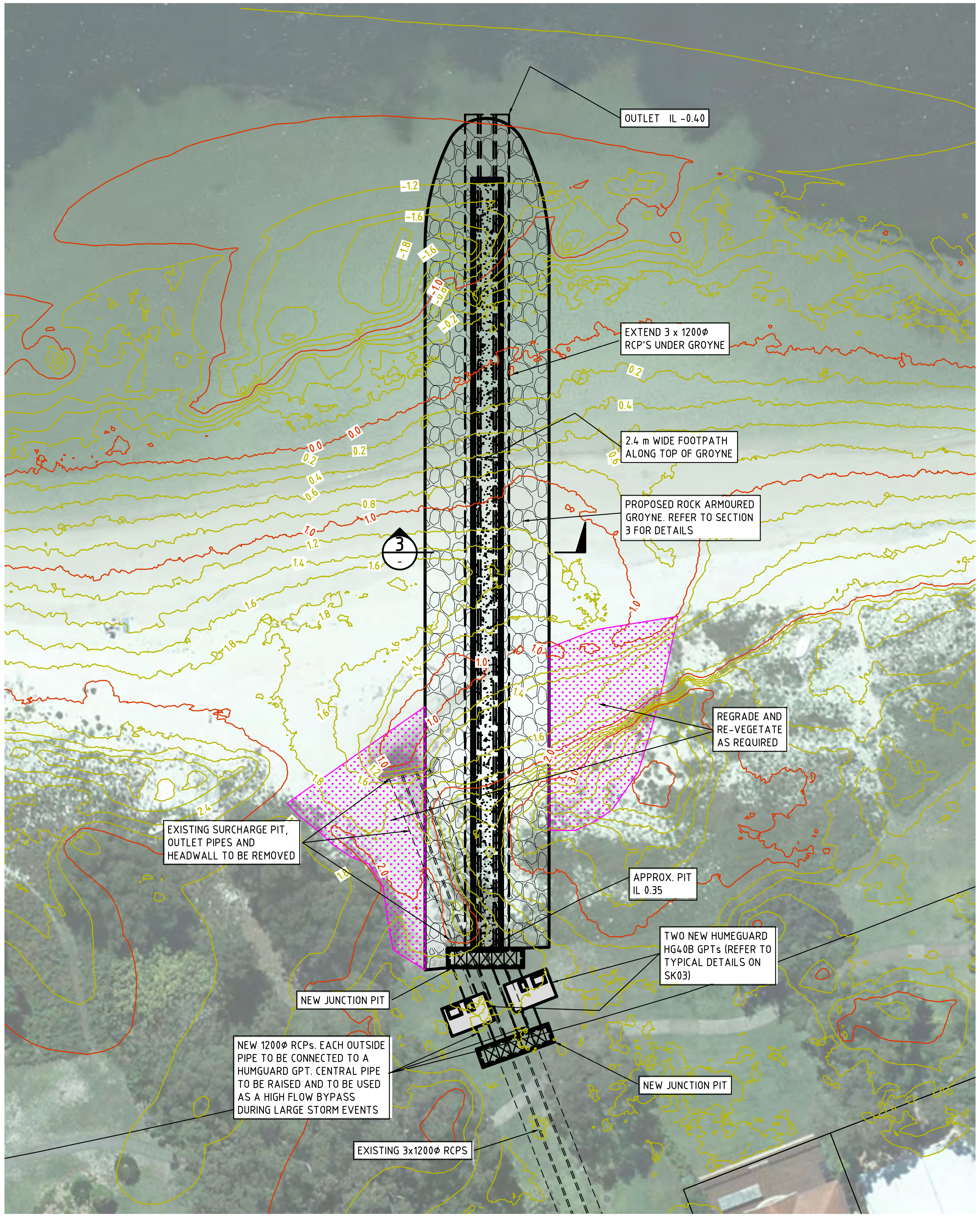
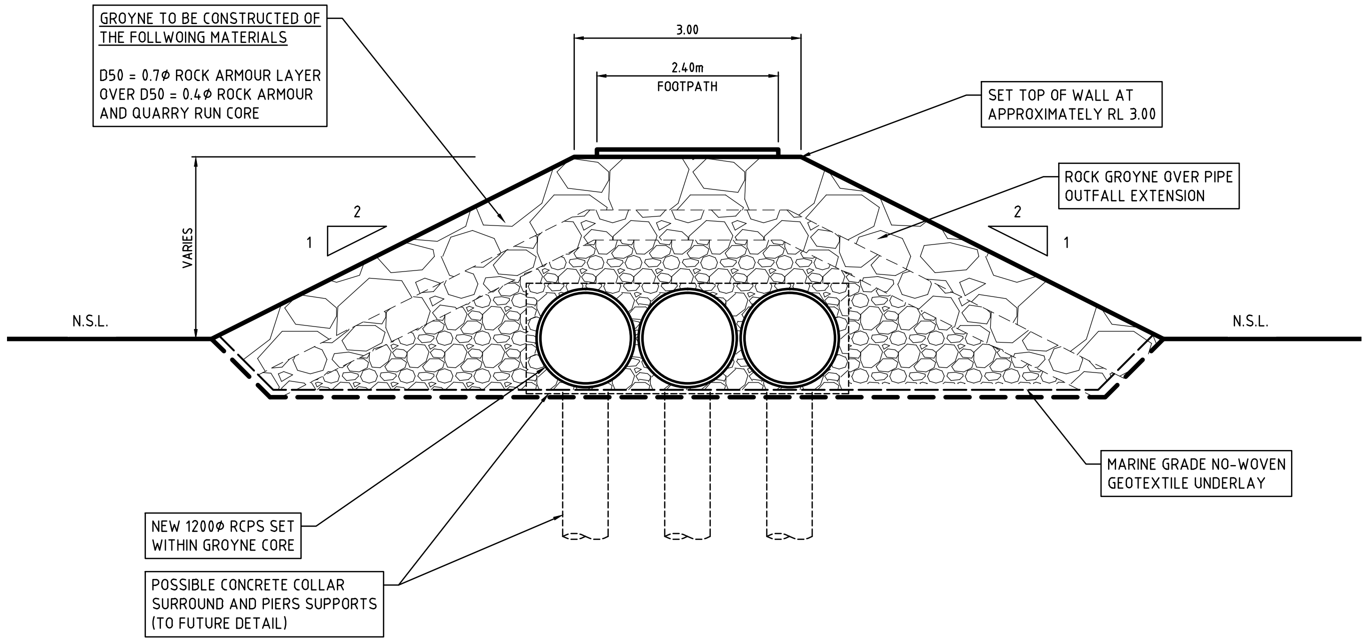


OUTFALL 3 DETAIL PLAN

0 2.5 5 7.5 10 12.5m

Scale: 1:250 (A1 SHEET)



SECTION 3 / -

1:50

TYPICAL SECTION THROUGH GROYNE

0 0.5 1 1.5 2 2.5m

Scale: 1:50 (A1 SHEET)

REV	DATE	DES.	DRN.	APP.	REVISION DETAILS
00	01/04/16	J.M.A.	M.R	J.A	FINAL ISSUE
A	25/08/15	J.M.A.	N.L.	J.A.	DRAFT ISSUE

DRAWING STATUS	
DESIGN BY	J.A.
DRAWN BY	N.L.
FINAL APPROVAL	J.M.A.
SCALE: (on A1 Original)	AS SHOWN

FINAL

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PROJECT TITLE

EROSION AND DRAINAGE MANAGEMENT PLAN FOR SANDY POINT/CONROY PARK CORLETTE

DRAWING TITLE

OUTFALL 3 CONCEPT DESIGN OPTION 2

PROJECT NO.	SUB-PR NO.	DRAWING NO.	REV
15000047	P01	SK05	00

Plot Date: Friday, 1 April 2016 11:14:53 AM CAD File Name: I:\15000047 Sandy Point_Conroy Park Foreshore Erosion and Drainage Management Plan\Drawings\15000047_P01_SK_REV 00.dwg

Appendix C Summary of Collected Ground and Hydro Survey Data

Background

As part of the "Sandy Point / Conroy Park Foreshore Erosion and Drainage Management Plan, a full survey of the foreshore and nearshore area was undertaken. The final survey plans are attached here, although a number of digital products were also provided to Port Stephens Council for future use as required. These digital products are detailed in Table C1.

Table C 1 Description of Digital Survey Data Provided to Council

File Name	Description
conpk_150524_points.laz	Compressed point cloud (laser scan) file format of photogrammetrically derived UAV survey data. The point cloud includes all 3d points for around 1 block back from the foreshore. Prepared by Propeller Aerobotics.
con_model.dxf conpk_half_model.dxf conpk_quarter_model.dxf	AutoCAD text file formats of triangulated ground surface covering the same area as the point cloud. Objects such as houses and trees have been removed to provide a digital elevation model of the study area. The files are large and different resolutions are provided for convenience. Prepared by Propeller Aerobotics.
150707_PRT_STEPHENS.dwg	AutoCAD version of final survey plan derived from the ground models prepared by Propeller Aerobotics and hydrographic survey undertaken by McGlashan and Crisp.
150707_PRT_STEPHENS_EAST.pdf 150707_PRT_STEPHENS_WEST.pdf 150707_PRT_STEPHENS_COMPLETE.pdf	.pdf plots of three views from the corresponding .dwg file covering the eastern end, western end and complete study area respectively. These figures are presented in the following pages
conpk_150524_ortho_Georefenced.tif	Very high resolution stitched vertical image of the study area derived from the drone survey. Geotiff format referenced to MGA 56.

LGA PORT STEPHENS Locality		Drawn F.H.	LEVEL BOOK	McGLASHAN & CRISP Pty Ltd CONSULTING SURVEYORS 117 VICTORIA STREET, TAREE 2430. Ph:02 65521566. DX 7009 EMAIL: admin@mcglashancrisp.com.au	FILE No. F993	JOB No.	CLIENT PORT STEPHENS COUNCIL
DATUM MGA/AHD	AZIMUTH MGA	Checked J.C.					
		Date 03/07/2015	COMPUTER FILE		No. IN SET	SHEET No.	PROJECT SURVEY OF CORLETTE
		Scale 1/3000 @A2					

TITLE

PLAN SHOWING HYDROGRAPHIC & TOPOGRAPHIC CONTOURS BETWEEN SANDY POINT AND ANCHORAGE RESORT

NOTES:
CONTOUR INTERVAL 0.5 M
PHOTO UNDERLAY DATING TO AUGUST 2014 AND FIXED TO BEST FIT
DATUM TO AHD ORIGIN SSM8265 RL 2.331
TOPOGRAPHIC CONTOURS DERIVED BY PHOTOGRAMETRY
HYDROGRAPHIC CONTOURS DERIVED FROM SOUNDINGS

LGA	PORT STEPHENS
Locality	
DATUM	MGA/AHD
AZIMUTH	MGA
Drawn	F.H.
Checked	J.C.
Date	07/07/2015
Scale	1/1000 @A2
LEVEL BOOK	
COMPUTER FILE	
FILE No.	F993
JOB No.	
No. IN SET	
SHEET No.	
CLIENT	PORT STEPHENS COUNCIL
PROJECT	SURVEY OF CORLETTE
TITLE	PLAN SHOWING HYDROGRAPHIC & TOPOGRAPHIC CONTOURS EAST OF SANDY POINT

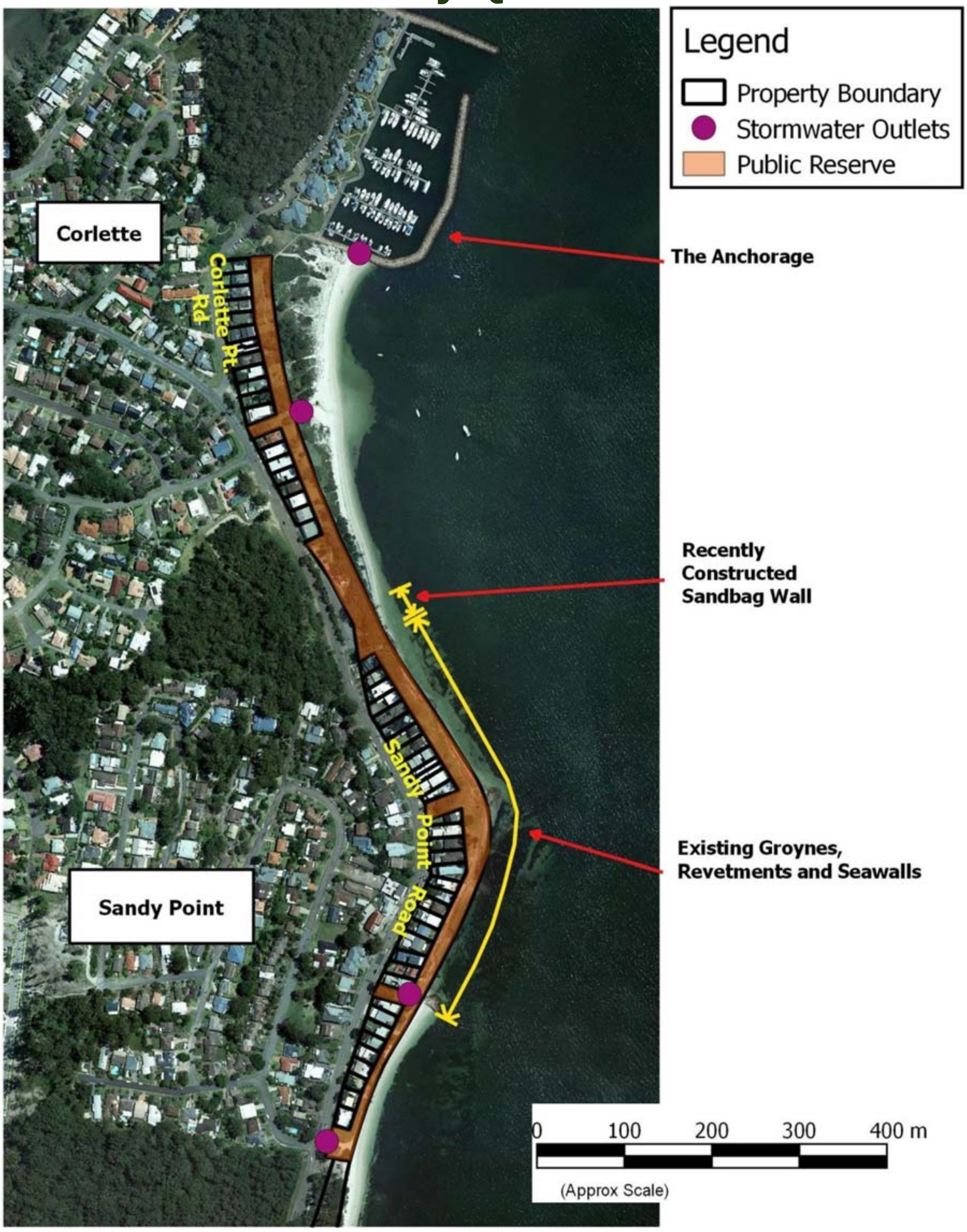
McGLASHAN & CRISP Pty Ltd
CONSULTING SURVEYORS
117 VICTORIA STREET, TAREE 2430. Ph:02 65521566. DX 7009
EMAIL: admin@mcglashancrisp.com.au

NOTES:
CONTOUR INTERVAL 0.5 M
PHOTO UNDERLAY DATING TO AUGUST 2014 AND FIXED TO BEST FIT
DATUM TO AHD ORIGIN SSM8265 RL 2.331
TOPOGRAPHIC CONTOURS DERIVED BY PHOTOGRAMETRY
HYDROGRAPHIC CONTOURS DERIVED FROM SOUNDINGS

LGA: PORT STEPHENS	Drawn: F.H.	LEVEL BOOK	McGLASHAN & CRISP Pty Ltd	FILE No.: F993	JOB No.	CLIENT: PORT STEPHENS COUNCIL	TITLE: PLAN SHOWING HYDROGRAPHIC & TOPOGRAPHIC CONTOURS EAST OF THE ANCHORAGE RESORT
Locality	Checked: J.C.		CONSULTING SURVEYORS				
DATUM: MGA/AHD	AZIMUTH: MGA	Date: 07/07/2015	COMPUTER FILE	117 VICTORIA STREET, TAREE 2430. Ph:02 65521566. DX 7009	No. IN SET	SHEET No.	PROJECT: SURVEY OF CORLETTE	
		Scale: 1/1000 @A2		EMAIL: admin@mcglashancrisp.com.au				

Appendix D Community Questionnaire

Sandy Point - Conroy Park
Foreshore Erosion & Drainage Management Plan
Community Questionnaire



Address for returning questionnaires:
Philippa Hill
Coast and Estuaries Officer
Port Stephens Council
PO Box 42, Raymond Terrace, NSW 2324

Alternatively, responses can be emailed to philippa.hill@portstephens.nsw.gov.au

Background

Foreshore erosion at Sandy Point and along the Conroy Park shoreline (east of the Anchorage) has been evident for a number of decades. Various protection measures have been constructed over time and recently, Council has further addressed the problem by extending the protection westwards in front of Conroy Park (using geotextile 'sand bags') in accordance with NSW Government policy. Further interim works are currently being investigated to protect trees at the western end of the sand bags. Private residential property along this foreshore is separated from the waterway by a public reserve, to enable continuous public access along the foreshore. Continuing foreshore erosion, wave overtopping during storms, reduction in public access along the foreshore and flooding and scour at stormwater outlets all remain as issues.

Port Stephens Council has commissioned a study to examine the causes for the erosion, evaluate the effectiveness of existing structures and to evaluate possible options to address these ongoing issues.

As part of the study, we are seeking input from the local community to better understand these issues and to develop and assess options that would match broad community expectations. The information collected from the community will be combined with information contained in previous studies and further investigations to be undertaken as part of this study. This questionnaire has been prepared for residents in and around the Sandy Point and Conroy Park foreshores to get feedback from the local community. However, it can be completed by anyone with an interest in this stretch of foreshore.

In addition to the questionnaire, a limited number of follow up interviews will be conducted and there is an option at the end of this questionnaire for owner/residents with beach front properties, to indicate whether you would like to be interviewed.

A reply paid envelope has been provided for your convenience. Please return completed questionnaires to the address on the first page by 22 of May so that your answers can be considered during the study. It is not necessary to answer all questions, but any information will be helpful. Names and addresses will not be made public but responses may be published in full.

Who Are You?

1. What is your current residential address?

____

2. Are you a permanent resident in the foreshore study area?

- ☐ Owner and Occupier
- ☐ Absentee Owner
- ☐ Tenant
- ☐ No, but I'm an interested community member

3. How long have you lived near Sandy Point?

- ☐ < 2 years
- ☐ 2 – 5 years
- ☐ 5 - 10 years
- ☐ 10 – 20 years
- ☐ >20 years (please tell us how long): ____________________

4. How do you use the beaches and waterway between Sandy Point and the Anchorage? (Select more than one if appropriate)

- ☐ Passive Recreation (e.g. walking, shore line fishing, photography)
- ☐ Active recreation (e.g. boating/sailing, swimming, canoe/paddle board/kite, boat fishing)
- ☐ Other (Please describe) ____________________

What else do you value about the foreshore?

Changes to the Foreshores

5. In the time that you have lived here, what changes have you seen along the Sandy Point/Conroy Park shoreline and beaches? i.e. erosion, recession, changes in water depth, vegetation, seagrass, drainage issues (e.g. beach erosion, flooding) etc.

6. Do you have any further information (such as historical photographs, reports or documents) which you can provide to the study team?

☐ Yes ☐ No

____

____

____

If yes, please return copies of this information with your response. Alternatively a study team member can contact you to discuss further - Please provide your telephone number). We are particularly interested in historical photographs you may have of the foreshore and its use/change. Photos of interest should be of known locations and with the approximate year known. **Do not enclose original photos** with your response (copies, not to be returned are OK) Alternatively, you may indicate whether you have photos which you think may be relevant and which you would like to show us.

7. Do you think the changes have become more pronounced in recent years, or are they slowing down?

____

____

____

8. What do you think has caused any identified changes to the foreshores?

____

____

____

9. What would you identify as the main issues which need to be addressed through a management plan for the beaches and shoreline in the area? (ranking)

☐ Foreshore erosion and recession

☐ Ocean inundation

☐ Loss of public access

☐ Stormwater drainage and flooding

☐ Other: ____

Please expand and note specific locations if applicable (next page):

Management Options

10. What would you like to see in the future management of the foreshore? (please rank)

- ☐ Rock revetment (sloping rock wall)
- ☐ Sand nourishment
- ☐ More native low vegetation
- ☐ More shade
- ☐ More public access through the reserve
- ☐ Better public access to the water
- ☐ Improved public safety
- ☐ Other, please expand below….

What do you NOT want to see on the foreshore? (please rank)

- ☐ Rock revetment (sloping rock wall)
- ☐ Sand nourishment
- ☐ More native low vegetation
- ☐ More shade
- ☐ More public access through the reserve
- ☐ Better public access to the water
- ☐ Improved public safety
- ☐ Other, please expand below….

11. What do you think would be the benefits of your preferred options from Question 10?

- ______________________________
- ______________________________
- ______________________________
- ______________________________
- ______________________________

Further Contact

12. If you are a waterfront owner/ resident in the area, would you like to take part in a follow up interview?

☐ Yes ☐ No

If yes, can you please provide your name, telephone number so that a member of our study team can contact you?

Name: ______________________ **Phone Number:** ______________

Please use the following lines if you wish to expand on any answers provided above.

____

____

____

____

____

____

____

____

Appendix E Multi Criteria Analysis Results

Methodology

A long list of feasible options was determined for the six precincts and these were assessed using a multi criteria assessment method. The criteria against which the options were assessed for each precinct were:

- **Public Access**: Referring to either an existing level of use by the public for recreation, and whether this is presently difficult, threatened or could be improved or impeded;
- **Public Safety**: Referring to whether a particular option could either improve or negatively affect safety of the public when using the foreshore;
- **Recreation / Boating**: Referring to whether options are likely to improve or detract from recreational amenity of the foreshore;
- **Foreshore Protection From Erosion**: Referring to whether the particular option would significantly improve protection of the foreshore from erosion;
- **Foreshore Protection From Overtopping**: Referring to whether the particular option would significantly improve protection of the foreshore from overtopping;
- **Impact on Coastal Processes**: Referring to whether the option would have a positive or negative impact on broader coastal processes in adjacent precincts;
- **Seagrasses / Ecology**: Referring to whether the option would tend to enhance or detract from nearshore seagrass habitat;
- **Provision of a Sandy Beach**: Referring to whether the option tends to enhance the provision of a sandy beach, which is seen by many in the community as desirable;
- **Enhancement of Dune / Native Vegetation**: Referring to whether the option would tend to create opportunities to create or enhance coastal dunes & vegetation;
- **Management of Stormwater**: Referring to whether the option would tend to improve the handling of stormwater issues, including water quality, the amount of sand scoured from the beach and ease of maintenance;
- **Aesthetics**: Referring to whether the option would tend to improve or detract from the general appearance of the foreshore and associated beaches;
- **Residential Security**: Referring to whether the option would tend to adversely impact the privacy of residents and/or affect the potential for burglary / theft;
- **Adaptability**: Referring to whether the option incorporates the ability to adapt to changing conditions, such as the movement of the flood tide delta affecting wave focussing along the foreshore, or a rise in mean sea level; and
- **Ease of Construction**: Referring to whether the option involves difficult, in-water construction or whether there is limited foreshore access, which would increase the risk of unforeseen costs during construction.

A total of six individuals, including three members of the study team, and three Council staff members were provided with lists of these 14 criteria and asked to grade the importance of those issues for each of the six precincts using the following scale:

- A – Critically Important;

- B - Very Important;
- C – Important;
- D - A Bit Important; and
- E - Not Important / Irrelevant.

Values of A through E were converted to values of 4 through 0 respectively for subsequent calculation. All individuals that took part had been either involved in consultation activities as part of the project, or had experience in management of foreshores and drainage within the study area.

The long list of feasible options are summarised in the following sections. Again, three engineers from W&A and CE were asked to score how well the options performed against each of the 14 criteria. In this instance the following scale was adopted:

- -2 – Addresses issue well;
- -1 – Somewhat addresses issue;
- 0 – Irrelevant / has neutral impact;
- +1 – Has somewhat negative impact; and
- +2 – Makes the situation significantly worse

For each issue/option combination, the average issue importance and option performance scores were multiplied together, considering the responses of all participants. These were then totalled to give an overall score for each of the options. The overall score is representative of the level of benefit that would result from that option. For each precinct the options were subsequently ranked.

The outcomes of the multi-criteria analysis are presented below. However, this analysis has some weaknesses, for example:

Different individuals will interpret the scoring/ranking criteria differently; and

The analysis does not incorporate the compatibility of options between precincts.

The ranking of each option in the multi criteria analysis, and further consideration of limitations are discussed below, along with a “ball park” estimate of costs. Considering all aspects, three final short-listed “schemes”, comprising compatible treatments in adjacent precincts is then provided.

Precinct 1 Options

Option 1: Do nothing. This was the highest scoring option for Precinct 1, with the majority of benefits seen to accrue from the continued provision of a sandy beach and the aesthetics at the western end of Corlette Beach. Particular problems will arise from continued accumulation of sand at the stormwater outlets adjacent to the breakwater.

<u>Benefit Score (Rank)</u>: 12.1 (1/5)

Option 2: Removal of sand. Sand has accumulated in this area since breakwater construction and the sand here could be used for beneficial purposes elsewhere. However, removal of the sand will impact on the aesthetics, public access and would potentially cause loss of dune vegetation.

Benefit Score (Rank): -1.33 (3/5)

Option 3:Construct groyne to convey stormwater. This would prevent sand from the beach face being jetted into the nearshore zone and smothering seagrasses during stormwater runoff events. While it would likely be excellent at addressing stormwater issues, it would have negative impacts on aesthetics, public access and safety.

Benefit Score (Rank):-2.56 (4/5)

Option 4: Option 3 + Option 2. This option has the combined impacts of options 2 and 3, and given that both of those options have an assessed negative benefit score, this option is the most poorly scoring of all options considered for Precinct 1.

Benefit Score (Rank):-4.67 (5/5)

Option 5: No sand removal; extend stormwater lines adjacent to The Anchorage. This is similar to the Option 1, although the interaction of the stormwater extension with beach access, safety and continued widening of the beach has resulted in it having a comparatively lower benefit score. Even so, this option should be considered.

Benefit Score (Rank):7.39 (2/5)

Precinct 2 Options

Option 1: Do nothing. Doing nothing will cause the foreshore to have continued problems with overtopping and erosion, retaining a situation that has issues with public safety, lacks a sandy beach and is suboptimal for recreation and aesthetics.

Benefit Score (Rank): -24.10 (10/10)

Option 2: Nourish with sand from next to Anchorage. While this option has a negative impact on Precinct 1, it is beneficial for Precinct 2 and is ranked second for this Precinct. This option vastly improves on the do nothing option in relation to public access, public safety, foreshore protection, overtopping and aesthetics.

Benefit Score (Rank): 29.24 (1/10)

Option 3: Nourish with sand from edge of delta dropover. This option scores similarly to Option 2, with the exception that it is better for coastal processes along the entire length of Corlette Beach (i.e. not taking from one end to provide sand to the other).

Benefit Score (Rank): 25.99(4/10)

Option 4: Nourishment plus construction of groyne at S/W outlet in Precinct 1. Again, scores similarly to Options 2 and 3, with the exception that the groyne improves the handling of stormwater and the stability of the Beach in Precinct 2. There is, however, a negative aesthetic impact. While this option scores well for this precinct, construction of a groyne is less favourable for Precinct 1.

Benefit Score (Rank): 29.23 (2/10)

Option 5: Progressive construction of a rock revetment, as required. This option will protect the foreshore from erosion and overtopping, but will not achieve the benefits obtained for recreation and dune/native vegetation that would arise from having a sandy beach.

Benefit Score (Rank): 5.38 (7/10)

Option 6: Progressive construction of a geotextile sandbag wall. This option was considered aesthetically poor without sand nourishment and does not provide significantly better long term protection from erosion and overtopping over time. Again, it will not achieve the benefits of having a sandy beach.

Benefit Score (Rank): -9.88 (9/10)

Option 7: Progressive rock revetment and construction of groyne at S/W outlet in Precinct 1. Similar benefits to option 5, with the exception that stormwater is managed better and the groyne acts to stabilise the beach to a larger extent within Precinct 2.

Benefit Score (Rank): 12.47 (5/10)

Option 8: Offshore breakwater: There have been difficulties in achieving effective outcomes using offshore breakwaters, multipurpose or surfing reefs in Australia and around the world. Particularly in a situation such as Corlette Beach, with oblique waves and a strongly bimodal wave climate, we doubt that this would be an effective solution.

Benefit Score (Rank): - 7.33 (8/10)

Option 9: Groyne at western end of Conroy Park, with more groynes constructed as required: This would retain a beach of some width, would presumable eventually improve stormwater handling in Precinct 1, although progressive downdrift erosion would continue. While a properly designed groyne field would provide effective protection from erosion and overtopping, a broad sandy beach such as that which was present in the past is unlikely to be achieved and the aesthetics of the area would continue to be compromised.

Benefit Score (Rank): 5.90 (6/10)

Option 10: Option 9 + Nourishment: This would drastically improve Option 9, by providing a sandy beach, with its attendant benefits along this foreshore.

Benefit Score (Rank): 27.41 (3/10)

Precinct 3 Options

Option 1: Do nothing. The do nothing option is seen as problematic for public safety and overtopping. Furthermore, the existing structure is failing to adequately protect the foreshore from erosion and the overall foreshore interface is unsightly. This option ranks most poorly of the 9 considered for Precinct 3.

Benefit Score (Rank): -4.64 (9/9)

Option 2: Relocate fence away from crest, fill gaps in revetment and repair obvious failures. This option comprises an aesthetic treatment of the revetment structure and measures to improve public safety which is an issue due to the high, steep nature of the revetment. It does not address the issues associated with erosion of this foreshore.

Benefit Score (Rank): -3.17 (8/9)

Option 3: Remove stairs, ramps and revetment crossings and rationalise public access. This option includes additional steps to remove unsafe access points across the revetment and is good from the point of view of public access and safety. Even so, it does not address foreshore erosion adequately.

Benefit Score (Rank): 11.80 (6/9)

Option 4: Options 2 & 3 plus batter back foreshore and reconstruct revetment. This option achieves the positive outcomes of the previous two options, while making a considered effort towards eliminating problems with foreshore erosion. It does not, however, provide a sandy beach at the foreshore.

Benefit Score (Rank): 21.73 (3/9)

Option 5: Options 2 & 3 plus construct revetment seaward to avoid loss of public reserve: Within Precinct 3, the foreshore reserve is wide, meaning that the additional costs associated with reclaiming part of the foreshore to accommodate a reconstructed revetment is not warranted. It provides similar protection to Option 4, but would be more difficult to construct.

Benefit Score (Rank): 17.03 (4/9)

Option 6: Options 2 & 3 plus bolster and extend Groyne A. This provides some additional protection from overtopping, and is beneficial to the retention of sand in Precinct 4. It does not provide the level of protection from overtopping and erosion provided by options 4 and 5.

Benefit Score (Rank): 12.87 (5/9)

Option 7: Option 6 plus batter back and reconstruct revetment. This combines the benefits of Options 4 and 6, resulting in an outcome which is ranked second in terms of benefits for Precinct 3.

Benefit Score (Rank): 22.94 (2/9)

Option 8: Repair, bolster and extend Groyne A plus nourishment. This option is less favourable than, say, options 4,5 or 7, as it does not provide the level of protection from erosion as those other options, and does not robustly address safety issues.

Benefit Score (Rank): 9.08 (7/9)

Option 9: Options 4 & 8, plus construction of two artificial headlands. The two 'artificial headlands' considered here are rhythmic protrusions that have formed in this length of foreshore as the shoreline has historically adjusted to the prevailing wave climate. One is located on the eastern end of Conroy Park and the other midway between Groyne A and Conroy Park. Bolstering these, by building them out slightly further will result in more definite pocket beaches that could be nourished. However, these would require nourishment on a fairly regular basis. In terms of benefits, this is the most favourable option, but also one of the most expensive ones.

Benefit Score (Rank): 34.76 (1/9)

Precinct 4 Options

Option 1: Do Nothing. This option is problematic from foreshore erosion, overtopping and coastal processes points of view. The foreshore is also unsightly and there are issues with public safety, residential security and public access.

Benefit Score (Rank): -15.80 (6/6)

Option 2: Rebuild and bolster foreshore revetment (limited scope for battering back, some reclamation will be required). Bolstering the foreshore revetment will provide better protection from erosion and overtopping whilst also improving public access and safety in the area. Construction would be somewhat difficult making this option less favourable than the first ranked Option 5.

Benefit Score (Rank): 11.16 (3/6)

Option 3: Groyne A, extend and reconstruct. This option is not favourable due to the difficulty in construction and relatively low level of protection it provides from overtopping.

Benefit Score (Rank): -4.73 (5/6)

Option 4: Groyne B, extend and reconstruct. This option is also not favourable for similar reasons to Option 3.

Benefit Score (Rank): -4.21 (4/6)

Option 5: Options [2] + [3] + [4]. Option 5 scored the highest due to its positive impact on public access, public safety, the protection it provides from erosion and overtopping and its provision of a sandy beach. Even though this option scored the highest overall, it would require substantial construction effort.

Benefit Score (Rank): 22.39 (1/6)

Option 6: [5] + Nourish Beach. Option 6, while scoring reasonably was seen to result in the potential smothering of seagrass beds and having a possible negative effect on residential security by encouraging higher usage of the foreshore in a residential area.

Benefit Score (Rank):13.60 (2/6)

Precinct 5 Options

Option 1: Do Nothing. This option is problematic for public access and safety and scores poorly against foreshore protection from erosion and overtopping. This option is also poor for recreation purposes, lack of a sandy beach and residential security.

Benefit Score (Rank): -24.22 (8/8)

Option 2: Remove boat ramps, reconstruct and raise walls in present location, replacing with uniform rock revetment. This option achieves good protection of the foreshore from erosion and overtopping and is positive for public safety. The difficulty of construction and lack of adaptability cause this option to rank poorly.

Benefit Score (Rank): 3.96 (6/8)

Option 3: [2] + Reclamation to provide for 2.4m path landward of crest + allowance to adapt (raise) crest by 0.35m. This option would have a positive impact on public access and safety while also providing protection to the foreshore from erosion and overtopping. The option is seen to improve the visual appearance of the precinct. The adaptability of the works were also seen as a positive. However, this option would be difficult to build.

Benefit Score (Rank): 23.93 (2/8)

Option 4: [2] + Provision for robust pathway around front of revetment. Option 4 scored similarly to option 3, however it was seen to have a greater positive impact on residential security and aesthetics. This option would pose significant construction challenges.

Benefit Score (Rank): 24.27 (1/8)

Option 5: Extend groynes “D” and (”B”) and nourish beach between these two groynes. Creating a sandy beach approximately 120m long in front of the revetment increases protection from erosion and overtopping, improves the aesthetics of the area and would positively impact overall coastal processes. This option does not improve public access and safety and will also be difficult to construct.

Benefit Score (Rank): 0.51 (7/8)

Option 6: Extend groynes “D” and (”B”), construct enclosing revetment with reclamation of enclosed area. This option achieves positive outcomes for public access and safety and foreshore protection from erosion and overtopping. The difficulty of construction is problematic for this option.

Benefit Score (Rank): 17.97 (3/8)

Option 7: “Mega” nourishment, in vicinity of groynes “C”, “D” and offshore. With monitoring and possible adoption of a structural solution in future. Providing a sandy beach in front of the precinct provides protection from erosion and overtopping and also has a positive impact on coastal processes. The sandy beach is also aesthetically pleasing and positive for recreation. Construction would be difficult. Encouraging public use of the foreshore may cause issues for residential security.

Benefit Score (Rank): 15.19 (4/8)

Option 8: [2] + Extend groyne D. Option 8 had similar positives to Option 7, however the additional works on the groyne increases public safety (protection from overtopping) and accessibility (widening of beach). Due to construction difficulty, this option scored lower than Option 7.

Benefit Score (Rank): 7.53 (5/8)

Precinct 6 Options

Option 1: Do Nothing. Option 1 scored the lowest for Precinct 6. The only positive for this option was that the existing sandy beach is seen as positive. Taking no action in this precinct will not improve foreshore protection nor address the issues associated with public safety.

Benefit Score (Rank): -4.61 (8/8)

Option 2: Remove boat ramps and replace with low wall, adaptable if required in future. Replacing boat ramps with a low wall will protect the backshore from inundation therefore improving public safety. A uniform, properly engineered structure would improve protection from erosion and overtopping. This option is also seen to improve the aesthetics of Precinct 6.

Benefit Score (Rank): 16.70 (2/8)

Option 3: [2] except build wave deflector wall along edge of pathway. Option 3 was deemed to have the same positive impacts as Option 2 although it was not as visually appealing as 2.

Benefit Score (Rank): 16.02 (3/8)

Option 4: Extend groyne "D" and provide ongoing nourishment. By extending the groyne and providing ongoing nourishment a wider, more consistent sandy beach would be provided

Benefit Score (Rank): 23.92 (1/8)

Option 5: Formalise stormwater by raising bed to elevation of outlet and providing an infiltration trench. This is the second best ranked of the stormwater outlet options. It will reduce the amount of sand scoured from the beach during runoff events and improve aesthetics of the area. It is also relatively easy to construct.

Benefit Score (Rank): 11.69 (5/8)

Option 6: Replace stormwater channel with GPT and infiltration trench on present alignment. This is similar to Option 5, with added benefits relating to the prevention of litter entering the waterway and expected slightly less scouring of sand from the beach. It will pose some difficulties for construction.

Benefit Score (Rank):6.31 (6/8)

Option 7: Carry stormwater pipe across beach on low groyne with crossing for pedestrians. This is the least favoured of the stormwater management options, primarily because of its impact on aesthetics and the visual and pedestrian barrier it would create across the western end of Bagnalls Beach.

Benefit Score (Rank):-0.98 (7/8)

Option 8: Disconnect the eastern stormwater line. Considering that the stormwater line acts primarily as a relief outlet during storms, this line could potentially be disconnected. This would somewhat remove the discontinuity in the beach, and improve aesthetics, concentrating flow through the main stormwater line which exist through Groyne D. This would require additional modelling and consideration of the capacity of the adjacent stormwater system, and some provision for overland flow would need to be made here to account for this sitting in a topographic sag point.

Benefit Score (Rank):13.48 (4/8)

Appendix F Tabulated Design Parameters

Summary of Structural Design Conditiosn

Precinct	Design Wave Conditions Per Precinct (1) 50yr Hs	50yr Hmax	50yr Tp	100yr Hs	100yr Hmax	100yr Tp	200yr Hs	200yr Hmax	200yr Tp
1&2	1.18	1.57	12.1	1.23	1.63	12.3	1.29	1.70	12.5
3	1.18	1.66	12.1	1.29	1.72	12.3	1.34	1.82	12.5
4,5 & 6	1.22	1.73	12.1	1.32	1.78	12.3	1.38	1.86	12.5

(1) Waves offshore of site estimated using Delft 3d, Brought to Foreshore using Goda (2000) relationships.

Armour Sizing - Hudsons Equation (as presented in CIRIA, 2007)

Precinct	Rock Density (2)	Water Density	Kd	Slope (1 in X)	Relative Buoyancy	Zero Damage Condition – 50 yr Event Sd	Hs (m)	Dn50 (m)	M50 (kg)	Ds50 (m)	20% Damage Condition 200 yr Event Sd	Hs	Dn50	M50	Ds50
1&2	2560	1025	4	1.5	1.497561	2	1.18	0.56	447	0.69	14	1.29	0.45	240	0.56
3	2560	1025	4	1.5	1.497561	2	1.18	0.56	441	0.69	14	1.34	0.47	271	0.59
4,5 & 6	2560	1025	4	2	1.497561	2	1.22	0.52	366	0.65	14	1.38	0.44	221	0.55

(2) Based on Rock Density provided by Boral Quarries at Seaham

Overtopping – Average Discharge (Eurotop Manual, 2007)

Precinct	Offshore Wave, 50 yrs (m)	Degrees from Normal Approach	Still Water Level (50 yrs + SLR)	Runup Crest Level (m AHD)	Rc (m)	gammaf	gammab	RHS	LHS Denom	q (l/s/m)
1&2	1.18	0	1.88	2.3	0.42	0.4	1	0.03	4.02	0.10
3	1.18	0	1.88	2.3	0.42	0.4	1	0.03	3.99	0.10
4,5 & 6	1.22	0	1.88	2.35	0.47	0.4	1	0.02	4.20	0.09

Overtopping Maximum Volume for Single Wave (Eurotop Manual, 2007)

Precinct	Crest Level	Ac	Dn	Pov	Storm Duration Peak (s)	Tz	Nw	Now	a	Allowable Volume (l/m)	P (allowable)	No. Waves Exceeding	Vmax
1&2	2.65	0.77	0.56	0.14	14400	6.9	2088	291	4.33	50	0.9981	0.6	43.8
3	2.65	0.77	0.56	0.14	14400	6.9	2088	288	4.30	50	0.9981	0.5	43.4
4,5 & 6	2.65	0.77	0.56	0.16	14400	6.9	2088	402	2.74	50	0.9999	0.1	29.9

Scour Depth (CIRIA, 2007)

Precinct	Structure Slope	Design Wave Height (200yr Hs)	Design Wave Height (200yr Hmax)	Tm	Fictitious Offshore Steepness	Surf Similarity (based on mean wave)	Breaker Type	Reflection Coefficient	Scour Depth
Precincts 1&2	0.67	1.29	1.70	7.13	0.02	5.24	Surging	0.48	0.82
Precinct 3	0.67	1.34	1.82	7.13	0.02	5.13	Surging	0.48	0.87
Precincts 4 to 6	0.50	1.38	1.86	7.13	0.02	3.79	Surging	0.40	0.74

Appendix G 3d Visualisation of Management Options

Whitehead & Associates Environmental Consultants

Sandy Point / Conroy Park Foreshore Erosion and Drainage Management Plan

Precinct 2: Scheme 1

PORT STEPHENS COUNCIL

Whitehead & Associates Environmental Consultants

NSW GOVERNMENT Office of Environment & Heritage

LIGHTBOX

Sandy Point / Conroy Park Foreshore Erosion and Drainage Management Plan

Precinct 5:Existing Condition

Whitehead & Associates
Environmental Consultants

Office of Environment & Heritage

Sandy Point / Conroy Park Foreshore Erosion and Drainage Management Plan
Precinct 5: Scheme 1

Whitehead & Associates Environmental Consultants

Office of Environment & Heritage

Sandy Point / Conroy Park Foreshore Erosion and Drainage Management Plan

Precinct 5: Scheme 2

PORT STEPHENS COUNCIL
Whitehead & Associates Environmental Consultants
NSW GOVERNMENT Office of Environment & Heritage
LIGHTBOX

Sandy Point / Conroy Park Foreshore Erosion and Drainage Management Plan
Precinct 5: Scheme 3

Appendix H Cost Estimates

Summary of Cost Estimates and Application of Contingencies and Inflation: Scheme 1 (Exclusive of GST)

Description	Base Cost	Contingency	Inflation[2]	Total	Adopt	Annual Maintenance (Structural)	Annual Maintenance (Nourishment)
Precinct 1: Relocate Sand[1]	$ 67,840.00	$ 13,568.00	$ 3,392.00	$ 84,800.00	85K		$ 8,480.00
Precinct 2: Construct Groyne (Western end, Conroy Park)	$ 407,658.29	$ 81,531.66	$ 20,382.91	$ 509,572.86	0.51M	$ 509.57	
Precinct 3: Demolish and Reconstruct Revetment, Make Safe	$ 849,873.87	$ 169,974.77	$ 42,493.69	$ 1,062,342.34	1.1M	$ 1,062.34	
Precinct 4: Rebuild Foreshore Revetment (Some Reclamation)	$ 341,156.76	$ 68,231.35	$ 17,057.84	$ 426,445.95	0.43M	$ 426.45	
Precinct 5: Demolish and Rebuild, including Reclamation	$ 1,026,481.17	$ 205,296.23	$ 51,324.06	$ 1,283,101.47	1.3M	$ 1,283.10	
Precinct 6: Demolish and Rebuild, (Minor Reclamation)	$ 645,480.97	$ 129,096.19	$ 32,274.05	$ 806,851.21	0.81M	$ 806.85	

[1]The relocated sand is used to nourish Precincts 2 and 3. The total cost for this operation is included under costs for Precinct 1

[2]Base Cost relates to estimates relevatn to the end of 2014. A 5% inflation rate has been applied in accordance with Rawlinson's Quarterly update to their *Australian Construction Handbook* from July, 2015. That places the resulting

Cost Estimate: Scheme 1, Precinct 1

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, insall sediment curtain/environmental controls.	1	Item	2000	2000	
1.2	Remove and clean up at end of work	1	Item	2000	2000	
Subtotal						$ 4,000.00
2	**Sand Excavation and Placement (7 day Operation)**					
2.1	Scraper Hire (2 of)	112	hours	300	33600	
2.2	Dozer Hire (2 of)	112	hours	270	30240	
Subtotal						$ 63,840.00
Total						**$ 67,840.00**

Cost Estimate: Scheme 1, Precinct 2

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, install sediment curtain/environmental controls. Establish Stockpile	1	Item	5000	5000	
1.2	Remove and clean up at end of work	1	Item	5000	5000	
Subtotal						$ 10,000.00
2	**Groyne Construction**					
2.1	Acquire and Place Core (Above MSL)	445	T	50	22250	
2.2	Acquire and Place Secondary Armour (Above MSL)	180	T	75	13500	
2.3	Acquire and Place Primary Armour (Above MSL)	1123	T	140	157191	
2.4	Acquire and Place Core (Below MSL)	970	T	70	67900	
2.5	Acquire and Place Secondary Armour (Below MSL)	500	T	85	42500	
2.6	Acquire and Place Primary Armour (Below MSL)	502	T	180	90317	
2.7	Construct Path (40m Long)	40	m	100	4000	
Subtotal						$ 397,658.29
Total						**$ 407,658.29**

Cost Estimate: Scheme 1, Precinct 3

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, install sediment curtain/environmental controls. Establish Stockpile	1	Item	5000	5000	
1.2	Remove and clean up at end of work	1	Item	5000	5000	
Subtotal						$10,000.00
2	**Demolition**					
	(Costs of Demolition Assumed Offset by gains from not having to acquire Secondary Armour)					
Subtotal						$0.00
3	**Excavation**					
3.1	Batter Back and Prepare Slope.	5200	cu.m	5	26000	
Subtotal						$26,000.00
4	**Revetment Construction**					
4.1	Geotextile	2600	sq.m	10	26000	
4.2	Place Secondary Armour (Above MSL)	1360	T	65	88407	
4.3	Acquire and Place Primary Armour (Above MSL)	3406	T	100	340594	
4.4	Place Secondary Armour (Below MSL)	1251	T	70	87543	
4.5	Acquire and Place Primary Armour (Below MSL)	1903	T	120	228331	
4.6	Construct Path	200	m	100	20000	
4.7	Construct Fence	200	m	115	23000	
Subtotal						$ 813,873.87
Total						**$ 849,873.87**

Cost Estimate: Scheme 1, Precinct 4

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, install sediment curtain/environmental controls. Establish Stockpile	1	Item	5000	5000	
1.2	Remove and clean up at end of work	1	Item	5000	5000	
Subtotal						$10,000.00
2	**Demolition**					
	(Costs of Demolition Assumed Offset by gains from not having to acquire Secondary Armour)					
Subtotal						$0.00
3	**Excavation**					
	Batter Back and Prepare Slope.	1800	cu.m	5	9000	
Subtotal						$9,000.00
4	**Revetment Construction**					
4.1	Geotextile	900	sq.m	10	9000	
4.2	Place Secondary Armour (Above MSL)	413	T	65	26866	
4.3	Acquire and Place Primary Armour (Above MSL)	1105	T	100	110452	
4.4	Place Secondary Armour (Below MSL)	563	T	70	39394	
4.5	Acquire and Place Primary Armour (Below MSL)	1062	T	120	127444	
4.6	Construct Path	90	m	100	9000	
Subtotal						$ 322,156.76
Total						**$ 341,156.76**

Cost Estimate: Scheme 1, Precinct 5

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, install sediment curtain/environmental controls. Establish Stockpile	1	Item	5000	5000	
1.2	Remove and clean up at end of work	1	Item	5000	5000	
Subtotal						$10,000.00
2	**Demolition, Stockpiling and Disposal**					
2.1	Demolish Existing Structures and Stockpile Reuseables	450	cu.m	20	9000	
2.2	Dispose of Non-reuseable materials to Landfill	596	T	285	169931	
Subtotal						$178,931.25
3	**Revetment Construction**					
3.1	Core (Above MSL)	2494	T	60	149625	
3.2	Place Secondary Armour (Above MSL)	689	T	47.5	32722	
3.3	Acquire and Place Primary Armour (Above MSL)	1310	T	140	183378	
3.4	Place Core (Below MSL)	1247	T	70	87281	
3.5	Place Secondary Armour (Below MSL)	938	T	57.5	53932	
3.6	Acquire and Place Primary Armour (Below MSL)	1770	T	180	318611	
3.7	Construct Path	120	m	100	12000	
Subtotal						$ 837,549.92
Total						**$ 1,026,481.17**

Cost Estimate: Scheme 1, Precinct 6

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, install sediment curtain/environmental controls. Establish Stockpile	1	Item	5000	5000	
1.2	Remove and clean up at end of work	1	Item	5000	5000	
Subtotal						$10,000.00
2	**Demolition, Stockpiling and Disposal**					
2.1	Demolish Existing Structures and Stockpile Reuseables	405	cu.m	10	4050	
2.2	Dispose of Non-reuseable materials to Landfill	537	T	285	152938	
Subtotal						$156,988.13
3	**Excavation**					
	Batter Back and Prepare Slope.	2160	cu.m	5	10800	
Subtotal						$10,800.00
4	**Revetment Construction**					
4.1	Geotextile	1080	sq.m	10	10800	
4.2	Place Secondary Armour (Above MSL)	532	T	37.5	19965	
4.3	Acquire and Place Primary Armour (Above MSL)	1182	T	100	118239	
4.4	Place Secondary Armour (Below MSL)	824	T	42.5	35005	
4.5	Acquire and Place Primary Armour (Below MSL)	2214	T	120	265684	
4.6	Construct Path	180	m	100	18000	
Subtotal						$467,692.85
Total						**$ 645,480.97**

Summary of Cost Estimates and Application of Contingencies and Inflation: Scheme 2 (Exclusive of GST)

Description	Base Cost	Contingency	Inflation[1]	Total	Adopt	Annual Maintenance (Structural)	Annual Maintenance (Nourishment/Sand Clearing)
Precinct 1: Install Twin Gross Pollutant Traps. Maintenance clearing of sand from outlets 4 and 5 required	$ 304,000.00	$ 60,800.00	$ 15,200.00	$ 380,000.00	0.38M	$ 6,000.00	$ 5,000.00
Precinct 2: Nourish with imported sand	$ 210,000.00	$ 42,000.00	$ 10,500.00	$ 262,500.00	0.26M		$ 21,000.00
Precinct 3: Demolish and reconstruct revetment, Make safe. Reconstruct and extend groyne A. Nourish with imported Sand	$ 1,296,561.15	$ 259,312.23	$ 64,828.06	$ 1,620,701.43	1.65M	$ 1,545.70	$ 7,500.00
Precinct 4: Rebuild foreshore revetment (Some reclamation). Reconstruct and extend groyne B	$ 727,844.04	$ 145,568.81	$ 36,392.20	$ 909,805.04	0.91M	$ 909.81	
Precinct 5: Demolish upper part of Revetment (down to 0.5m AHD). Reconstruct upper part of revetment to engineering standard.	$ 1,782,450.27	$ 356,490.05	$ 89,122.51	$ 2,228,062.83	2.23M	$ 2,153.06	$ 7,500.00
Precinct 6: Demolish and remove ramps. Stormwater outlet channel filled and shallow dish drain with infiltration trench provided. Reconstruct line of stone between back of beach and foreshore reserve. 'Mega' nourishment of beach.	$ 676,384.13	$ 135,276.83	$ 33,819.21	$ 845,480.16	0.85M	$ 6,595.48	$ 25,000.00

[1]Base Cost relates to estimates relevant to the end of 2014. A 5% inflation rate has been applied in accordance with Rawlinson's Quarterly update to their *Australian Construction Handbook* from July, 2015. That places the resulting estimates as current at the end of 2015.

Cost Estimate: Scheme 2, Precinct 1

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, insall sediment curtain/environmental controls.	1	Item	2000	2000	
1.2	Remove and clean up at end of work	1	Item	2000	2000	
Subtotal						$ 4,000.00
2	**Stormwater**					
2.1	Gross Pollutant Traps	2	Item	150000	300000	
Subtotal						$ 300,000.00
Total						**$ 304,000.00**

Cost Estimate: Scheme 2, Precinct 2

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, install sediment curtain/environmental controls. Establish Stockpile	1	Item	5000	5000	
1.2	Remove and clean up at end of work	1	Item	5000	5000	
1.3	Mobilise / Demobilise Dredging Plant	1	Item	60000	60000	
Subtotal						$ 70,000.00
2	**Nourishment**					
2.1	Dredge and Pump Ashore (Cutter Suction)	14000	cu.m	6.5	91000	
2.2	Spread to Design Profile	14000	cu.m	3.5	49000	
Subtotal						$ 140,000.00
Total						**$ 210,000.00**

Alternative 2: Import from Local Quarry

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, install sediment curtain/environmental controls. Establish Stockpile	1	Item	5000	5000	
1.2	Remove and clean up at end of work	1	Item	5000	5000	
Subtotal						$ 10,000.00
2	**Nourishment**					
2.1	Sand Delivery to Site	14000	cu.m	40.25	563500	
2.2	Spread to Design Profile	14000	cu.m	3.5	49000	
Subtotal						$ 612,500.00
Total						**$ 622,500.00**

Based on these figures, Trucking Sand from a local quarry is much more expensive than Dredge Nourishment, which is substantially more expensive than moving sand from next to The Anchorage

Cost Estimate: Scheme 2, Precinct 3

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, install sediment curtain/environmental controls. Establish Stockpile	1	Item	5000	5000	
1.2	Remove and clean up at end of work	1	Item	5000	5000	
Subtotal						$10,000.00
2	**Demolition**					
	(Costs of Demolition Assumed Offset by gains from not having to acquire Secondary Armour for revetment)					
Subtotal						$0.00
3	**Excavation**					
	Batter Back and Prepare Slope.	5200	cu.m	5	26000	
Subtotal						$26,000.00
4	**Revetment Construction**					
4.1	Geotextile	2600	sq.m	10	26000	
4.2	Place Secondary Armour (Above MSL)	1360	T	65	88407	
4.3	Acquire and Place Primary Armour (Above MSL)	3406	T	100	340594	
4.4	Place Secondary Armour (Below MSL)	1251	T	70	87543	
4.5	Acquire and Place Primary Armour (Below MSL)	1903	T	120	228331	
4.6	Construct Path	200	m	100	20000	
4.7	Construct Fence	200	m	115	23000	
Subtotal						$813,873.87
5	**Bolster Groyne 'A'**					
5.1	Acquire and Place Core (Above MSL)	222	T	60	13338	
5.2	Acquire and Place Secondary Armour (Above MSL)	222	T	75	16678	
5.3	Acquire and Place Primary Armour (Above MSL)	1336	T	140	186995	
5.4	Acquire and Place Core (Below MSL)	485	T	70	33915	
5.5	Acquire and Place Secondary Armour (Below MSL)	535	T	85	45444	
5.6	Acquire and Place Primary Armour (Below MSL)	502	T	180	90317	
Subtotal						$386,687.28
6	**Nourishment**					
6.1	Dredge and Pump Ashore	6000	cu.m	6.5	39000	
6.2	Spread to Design Profile	6000	cu.m	3.5	21000	
	(Note: Establishment Disestablishment Costs are included in Precinct 2)					
Subtotal						$60,000.00
Total						**$ 1,296,561.15**

Cost Estimate: Scheme 2, Precinct 4

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, install sediment curtain/environmental controls. Establish Stockpile	1	Item	5000	5000	
1.2	Remove and clean up at end of work	1	Item	5000	5000	
Subtotal						$10,000.00
2	**Demolition**					
	(Costs of Demolition Assumed Offset by gains from not having to acquire Secondary Armour)					
Subtotal						$0.00
3	**Excavation**					
	Batter Back and Prepare Slope.	1800	cu.m	5	9000	
Subtotal						$9,000.00
4	**Revetment Construction**					
4.1	Geotextile	900	sq.m	10	9000	
4.2	Place Secondary Armour (Above MSL)	413	T	65	26866	
4.3	Acquire and Place Primary Armour (Above MSL)	1105	T	100	110452	
4.4	Place Secondary Armour (Below MSL)	563	T	70	39394	
4.5	Acquire and Place Primary Armour (Below MSL)	1062	T	120	127444	
4.6	Construct Path	90	m	100	9000	
Subtotal						$322,157
5	**Bolster Groyne 'B'**					
5.1	Acquire and Place Core (Above MSL)	222	T	60	13338	
5.2	Acquire and Place Secondary Armour (Above MSL)	222	T	75	16678	
5.3	Acquire and Place Primary Armour (Above MSL)	1336	T	140	186995	
5.4	Acquire and Place Core (Below MSL)	485	T	70	33915	
5.5	Acquire and Place Secondary Armour (Below MSL)	535	T	85	45444	
5.6	Acquire and Place Primary Armour (Below MSL)	502	T	180	90317	
Subtotal						$386,687.28
Total						**$ 727,844.04**

Cost Estimate: Scheme 2, Precinct 5

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, install sediment curtain/environmental controls. Establish Stockpile	1	Item	10000	10000	
1.2	Remove and clean up at end of work	1	Item	10000	10000	
Subtotal						$20,000.00
2	**Demolition, Stockpiling and Disposal**					
2.1	Demolish Existing Structures and Stockpile Reuseables	450	cu.m	20	9000	
2.2	Dispose of Non-reuseable materials to Landfill	447	T	285	127448	
Subtotal						$136,448.44
3	**Revetment Construction**					
3.1	Geotextile	1500	sq.m	10	15000	
3.2	Place Secondary Armour (Above MSL)	411	T	47.5	19513	
3.3	Acquire and Place Primary Armour (Above MSL)	1328	T	140	185856	
3.4	Construct Path	120	m	100	12000	
Subtotal						$232,369.15
4	**Reconstruct and Extend Groyne D**					
4.1	Acquire and Place Core (Above MSL)	595	T	60	35716	
4.2	Acquire and Place Secondary Armour (Above MSL)	254	T	75	19061	
4.3	Acquire and Place Primary Armour (Above MSL)	1526	T	140	213709	
4.4	Acquire and Place Core (Below MSL)	315	T	70	22045	
4.5	Acquire and Place Secondary Armour (Below MSL)	611	T	85	51936	
4.6	Acquire and Place Primary Armour (Below MSL)	573	T	180	103219	
Subtotal						$445,685.84
5	**Complete Rebuild of Groyne C**					
5.1	Acquire and Place Core (Above MSL)	902	T	80	72124	
5.2	Acquire and Place Secondary Armour (Above MSL)	318	T	95	30180	
5.3	Acquire and Place Primary Armour (Above MSL)	1908	T	220	419785	
5.4	Acquire and Place Core (Below MSL)	630	T	100	62985	
5.5	Acquire and Place Secondary Armour (Below MSL)	764	T	115	87833	
5.6	Acquire and Place Primary Armour (Below MSL)	717	T	300	215040	
Subtotal						$887,946.83
6	**Nourish**					
6.1	Dredge and Pump Ashore	12500	cu.m	6.5	39000	
6.2	Spread to Design Profile	12500	cu.m	3.5	21000	
	(Note: Establishment Disestablishment Costs are included in Precinct 2)					
Subtotal						$60,000.00
Total						**$1,782,450.27**

Cost Estimate: Scheme 2, Precinct 6

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, install sediment curtain/environmental controls. Establish Stockpile	1	Item	5000	5000	
1.2	Remove and clean up at end of work	1	Item	5000	5000	
Subtotal						$10,000.00
2	**Demolition, Stockpiling and Disposal**					
2.1	Demolish Existing Structures and Replace Reuseable material	405	cu.m	10	4050	
2.2	Dispose of Non-reuseable materials to Landfill	537	T	285	152938	
Subtotal						$156,988.13
3	**Nourishment**					
3.1	Dredge and Pump Ashore	20000	cu.m	6.5	130000	
3.2	Reshape	20000	cu.m	3.5	70000	
Subtotal						200000
4	**Construction of Drain with Infiltration Trench**					
4.1	Grade and place Geotextile	171	sq.m	10	1710	
4.2	Place Rock Fill	106.02	T	50	5301	
4.3	Lay Turf and maintain for nominal period	159	sq.m	15	2385	
Subtotal						$ 9,396.00
5	**Gross Pollutant Traps**					
5.1	Install two Gross Pollutant Traps upstream of Groyne D	2	Items	150000	300000	
Subtotal						$ 300,000.00
Total						**$ 676,384.13**

Summary of Cost Estimates and Application of Contingencies and Inflation: Scheme 3 (Exclusive of GST)

Description	Base Cost	Contingency	Inflation[1]	Total	Adopt	Annual Maintenance (Structural)	Annual Maintenance (Nourishment/Sand Clearing)
Precinct 1: Retain Sand. Construct groyne across beach to convey stormwater line. Install Twin Gross Pollutant Traps in foreshore reserve. Maintenance clearing of sand from outlets 4 and 5 required.	$ 1,044,772.32	$ 208,954.46	$ 52,238.62	$ 1,305,965.40	1.3M	$ 1,305.97	$ 5,000.00
Precinct 2: Nourish with imported sand	$ 210,000.00	$ 42,000.00	$ 10,500.00	$ 262,500.00	0.26M		$ 21,000.00
Precinct 3: Demolish and reconstruct revetment, Make safe. Reconstruct and extend Groyne A. Enhance existing "Headlands"	$ 2,164,441.70	$ 432,888.34	$ 108,222.09	$ 2,705,552.13	2.7M	$ 2,630.55	$ 7,500.00
Precinct 4: Rebuild foreshore revetment (Some reclamation). Extend groyne B and nourish between groynes A and B	$ 754,844.04	$ 150,968.81	$ 37,742.20	$ 943,555.04	0.94M	$ 909.81	$ 3,375.00
Precinct 5: Demolish and rebuild, including reclamation. All boat ramps demolished. Pedestrian access around front of new revetment.	$ 1,221,154.92	$ 244,230.98	$ 61,057.75	$ 1,526,443.65	1.55M	$ 1,526.44	
Precinct 6: Demolish and rebuild, (minor reclamation). All boat ramps removed. Allow for construction of wave deflector wall in future. Stormwater outlet channel filled and shallow dish drain with infiltration trench provided	$ 654,876.97	$ 130,975.39	$ 32,743.85	$ 818,596.21	0.82M	$ 818.60	

[1]Base Cost relates to estimates relevent to the end of 2014. A 5% inflation rate has been applied in accordance with Rawlinson's Quarterly update to their *Australian Construction Handbook* from July, 2015. That places the resulting estimates as current at the end of 2015.

Cost Estimate: Scheme 3, Precinct 1

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, insall sediment curtain/environmental controls.	1	Item	5000	5000	
1.2	Remove and clean up at end of work	1	Item	5000	5000	
Subtotal						$ 10,000.00
2	**Groyne Construction**					
2.1	Acquire and Place Core (Above MSL)	445	T	60	26676	
2.2	Acquire and Place Secondary Armour (Above MSL)	179	T	75	13446	
2.3	Acquire and Place Primary Armour (Above MSL)	1123	T	140	157191	
2.4	Acquire and Place Core (Below MSL)	969	T	70	67830	
2.5	Acquire and Place Secondary Armour (Below MSL)	497	T	75	37312	
2.6	Acquire and Place Primary Armour (Below MSL)	502	T	180	90317	
Subtotal						$ 392,772.32
3	**Stormwater Extension**					
3.1	Screw Piers	60	Item	900	54000	
3.2	Stormwater Lines	180	m	1600	288000	
3.3	Gross Pollutant Traps	2	Item	150000	300000	
Subtotal						$ 642,000.00
Total						**$ 1,044,772.32**

Cost Estimate: Scheme 3, Precinct 2

Alternative 1: Dredging

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, install sediment curtain/environmental controls. Establish Stockpile	1	Item	5000	5000	
1.2	Remove and clean up at end of work	1	Item	5000	5000	
1.3	Mobilise / Demobilise Dredging Plant	1	Item	60000	60000	
Subtotal						$ 70,000.00
2	**Nourishment**					
2.1	Dredge and Pump Ashore (Cutter Suction)	14000	cu.m	6.5	91000	
2.2	Spread to Design Profile	14000	cu.m	3.5	49000	
Subtotal						$ 140,000.00
Total						**$ 210,000.00**

Alternative 2: Import from Local Quarry

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, install sediment curtain/environmental controls. Establish Stockpile	1	Item	5000	5000	
1.2	Remove and clean up at end of work	1	Item	5000	5000	
Subtotal						$ 10,000.00
2	**Nourishment**					
2.1	Sand Delivery to Site	14000	cu.m	40.25	563500	
2.2	Spread to Design Profile	14000	cu.m	3.5	49000	
Subtotal						$ 612,500.00
Total						**$ 622,500.00**

Based on these figures, Trucking Sand from a local quarry is much more expensive than Dredging, which is substantially more expensive than acquiring sand from adjacent to The Anchorage

Cost Estimate: Scheme 3, Precinct 3

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, install sediment curtain/environmental controls. Establish Stockpile	1	Item	5000	5000	
1.2	Remove and clean up at end of work	1	Item	5000	5000	
Subtotal						$10,000.00
2	**Demolition**					
	(Costs of Demolition Assumed Offset by gains from not having to acquire Secondary Armour for revetment)					
Subtotal						$0.00
3	**Excavation**					
	Batter Back and Prepare Slope.	5200	cu.m	5	26000	
Subtotal						$26,000.00
4	**Revetment Construction**					
4.1	Geotextile	2600	sq.m	10	26000	
4.2	Place Secondary Armour (Above MSL)	1360	T	65	88407	
4.3	Acquire and Place Primary Armour (Above MSL)	3406	T	100	340594	
4.4	Place Secondary Armour (Below MSL)	1251	T	70	87543	
4.5	Acquire and Place Primary Armour (Below MSL)	1903	T	120	228331	
4.6	Construct Path	200	m	100	20000	
4.7	Construct Fence	200	m	115	23000	
Subtotal						$813,873.87
5	**Bolster Groyne 'A'**					
5.1	Acquire and Place Core (Above MSL)	222	T	60	13338	
5.2	Acquire and Place Secondary Armour (Above MSL)	222	T	75	16678	
5.3	Acquire and Place Primary Armour (Above MSL)	1336	T	140	186995	
5.4	Acquire and Place Core (Below MSL)	485	T	70	33915	
5.5	Acquire and Place Secondary Armour (Below MSL)	535	T	85	45444	
5.6	Acquire and Place Primary Armour (Below MSL)	502	T	180	90317	
Subtotal						$386,687.28
5	**Two New Fishtail Headlands**					
5.1	Acquire and Place Core (Above MSL)	889	T	60	53352	
5.2	Acquire and Place Secondary Armour (Above MSL)	445	T	75	33357	
5.3	Acquire and Place Primary Armour (Above MSL)	2671	T	140	373990	
5.4	Acquire and Place Core (Below MSL)	1938	T	70	135660	
5.5	Acquire and Place Secondary Armour (Below MSL)	1069	T	85	90888	
5.6	Acquire and Place Primary Armour (Below MSL)	1004	T	180	180634	
Subtotal						$867,880.56
6	**Nourishment**					
6.1	Dredge and Pump Ashore	6000	cu.m	6.5	39000	
6.2	Spread to Design Profile	6000	cu.m	3.5	21000	
	(Note: Establishment Disestablishment Costs are included in Precinct 2)					
Subtotal						$60,000.00
Total						**$ 2,164,441.70**

Cost Estimate: Scheme 3, Precinct 4

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, install sediment curtain/environmental controls. Establish Stockpile	1	Item	5000	5000	
1.2	Remove and clean up at end of work	1	Item	5000	5000	
Subtotal						$10,000.00
2	**Demolition**					
	(Costs of Demolition Assumed Offset by gains from not having to acquire Secondary Armour)					
Subtotal						$0.00
3	**Excavation**					
	Batter Back and Prepare Slope.	1800	cu.m	5	9000	
Subtotal						$9,000.00
4	**Revetment Construction**					
4.1	Geotextile	900	sq.m	10	9000	
4.2	Place Secondary Armour (Above MSL)	413	T	65	26866	
4.3	Acquire and Place Primary Armour (Above MSL)	1105	T	100	110452	
4.4	Place Secondary Armour (Below MSL)	563	T	70	39394	
4.5	Acquire and Place Primary Armour (Below MSL)	1062	T	120	127444	
4.6	Construct Path	90	m	100	9000	
Subtotal						$322,157
5	**Bolster Groyne 'B'**					
5.1	Acquire and Place Core (Above MSL)	222	T	60	13338	
5.2	Acquire and Place Secondary Armour (Above MSL)	222	T	75	16678	
5.3	Acquire and Place Primary Armour (Above MSL)	1336	T	140	186995	
5.4	Acquire and Place Core (Below MSL)	485	T	70	33915	
5.5	Acquire and Place Secondary Armour (Below MSL)	535	T	85	45444	
5.6	Acquire and Place Primary Armour (Below MSL)	502	T	180	90317	
Subtotal						$386,687.28
6	**Nourishment**					
	Dredge and Pump Ashore	2700	cu.m	6.5	17550	
	Spread to Design Profile	2700	cu.m	3.5	9450	
	(Note: Establishment Disestablishment Costs are included in Precinct 2)					
Subtotal						$ 27,000.00
Total						**$ 754,844.04**

Cost Estimate: Scheme 3, Precinct 5

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, install sediment curtain/environmental controls. Establish Stockpile	1	Item	5000	5000	
1.2	Remove and clean up at end of work	1	Item	5000	5000	
Subtotal						$10,000.00
2	**Demolition, Stockpiling and Disposal**					
2.1	Demolish Existing Structures and Stockpile Reuseables	450	cu.m	20	9000	
2.2	Dispose of Non-reuseable materials to Landfill	596	T	285	169931	
Subtotal						$178,931.25
3	**Revetment Construction**					
3.1	Geotextile	1500	sq.m	10	15000	
3.2	Place Secondary Armour (Above MSL)	689	T	47.5	32722	
3.3	Acquire and Place Primary Armour (Above MSL)	1310	T	140	183378	
3.4	Place Core (Below MSL)	0	T	70	0	
3.5	Place Secondary Armour (Below MSL)	938	T	57.5	53932	
3.6	Acquire and Place Primary Armour (Below MSL)	1770	T	180	318611	
Subtotal						$603,643.67
4	**Footbridge**					
4.1	Piers	45	Item	1500	67500	
4.2	Deck, Ballustrade, Rails etc.	408	sq.m	885	361080	
Subtotal						$428,580.00
Total						**$1,221,154.92**

Cost Estimate: Scheme 3, Precinct 6

Item No.	Item Description	Qty	Unit	Rate ($)	Capital Cost	Sub-Total
1	**Site Establishment/Disestablishment**					
1.1	Erect regulatory signs, setup, plant hire, install sediment curtain/environmental controls. Establish Stockpile	1	Item	5000	5000	
1.2	Remove and clean up at end of work	1	Item	5000	5000	
Subtotal						$10,000.00
2	**Demolition, Stockpiling and Disposal**					
2.1	Demolish Existing Structures and Stockpile Reuseables	405	cu.m	10	4050	
2.2	Dispose of Non-reuseable materials to Landfill	537	T	285	152938	
Subtotal						$156,988.13
3	**Excavation**					
	Batter Back and Prepare Slope.	2160	cu.m	5	10800	
Subtotal						$10,800.00
4	**Revetment Construction**					
4.1	Geotextile	1080	sq.m	10	10800	
4.2	Place Secondary Armour (Above MSL)	532	T	37.5	19965	
4.3	Acquire and Place Primary Armour (Above MSL)	1182	T	100	118239	
4.4	Place Secondary Armour (Below MSL)	824	T	42.5	35005	
4.5	Acquire and Place Primary Armour (Below MSL)	2214	T	120	265684	
4.6	Construct Path	180	m	100	18000	
Subtotal						$467,692.85
5	**Construction of Drain with Infiltration Trench**					
5.1	Grade and place Geotextile	171	sq.m	10	1710	
5.2	Place Rock Fill	106.02	T	50	5301	
5.3	Lay Turf and maintain for nominal period	159	sq.m	15	2385	
Subtotal						$9,396.00
Total						**$ 654,876.97**

Appendix I Certification Comments & Alterations

The *Sandy Point / Conroy Park Foreshore Erosion & Drainage Management Plan 2016* was submitted for certification as an Coastal Zone Management Plan (CZMP) under the *NSW Coastal Protection Act 1979* on the 21st of October 2016. Feedback was supplied from Dept of Industry – Lands and Forestry (DoI) on the 29 August 2017; and the Office of Environment & Heritage and the NSW Coastal Panel 26 September 2017. The primary concerns raised included land ownership, approval pathways and the level of detail provided for implementation. Council provided a response in March 2018 and were provided with a second round of comments in July 2018 which were subsequently addressed. A summary of the comments and Council's response is summarised in the Table below. All revision were undertaken by Port Stephens Council.

Alternations in response to the NSW Coastal Panel comments

Comment	Response
The Plan was considered to be an options study with no definitive concluded strategy for the 6 precinct areas under consideration.	Existing Tables E3 & 9 represent the recommended strategy for each precinct area including prioritisation and costings. Section 4, 5 and 6 represent the options study component of the document. Section 7 outlines the preferred or recommended actions for each precinct. Table 10 – *Implementation Table* has been added to provide additional detail for implementation. The plan was endorsed by Port Stephens Council on the 12 April 2016. This included endorsement of the actions outlined in Table E3 and 9. These actions will be progressed as funding becomes available. Section 7.4.2 has been added to outline potential funding sources Section 2.1 was added to outline how the plan satisfies Coastal Zone Management Planning Requirements

Alterations in response to DoI – Lands & Forestry Comments

	Comment	Suggested Action	Response
1	***General Comment Land Ownership*** CZMP lacks information on public ownership and management arrangements in the coastal zone. This information underpins the management actions as it enables the identification of the appropriate organisation / agency etc responsible for implementation of actions.	Consider including a section at the beginning of the document that details relevant public land management, and Reserve Trust management arrangements for public coastal land. Acknowledge and /cross reference to relevant Plans of Management (where appropriate)	• Figure 3a added to outline land ownership. Including identification that *Crown waterway is below the MHWM* (mean high water mark). • Action added to Table 10 to survey MHWM. • Section 7.4.1 *Relevant Legislation and Approvals* has been added. This includes an outline of the approval process for works on crownland. Wording provided by Department. • Text in section 2 has been added regarding management plans of relevance to this document

	Comment	Suggested Action	Response
	Identification of relevant Plans of Management for public lands is recommended to promote a consistent, integrated and 'whole of government' approach to coastal zone management (Coastal Management Principle 2).		such as Foreshores and Parks Plans of Management
2	***Aboriginal & Land Claims & Native Title*** It is unclear if the CZMP has considered *Native Title Act 1993* (Cth) and *Aboriginal Land Rights Act 1983* (NSW) considerations / obligations.	Incorporate these considerations if and where relevant	Section 7.4.1 *Relevant Legislation and Approvals* has been added. This includes consideration of Aboriginal Heritage and native title as part of the approval process.
3	***Crown land authorisations*** Where works are proposed on Crown land, not under Council Trust management, an appropriate authorisation from DoI Lands & Forestry will be required prior to works commencing. Note that adequate lead time (at least six months) is required for the Department to assess and issue authorisation (licence) works on Crown land.	The CZMP needs to clearly identify if and where works are proposed on Crown Land and where authorisations would be required from the department	• Figure 3a added to outline land ownership. • Section 7.4.1 *Relevant Legislation and Approvals* has been added. This includes an outline of the approval process for works on crownland.
4	**Table E3 and 9** It is assumed that these tables serve as the 'Implementation Schedule' for the CZMP. It is noted that these tables do not comply with the requirements of the Guidelines for Preparing Coastal Zone Management Plans (OEH, 2013), for example the responsible agency for each action is not nominated against each action.	Ensure that the tables comply with the OEH Guidelines and Clarify that Council is to be the lead agency for each of the actions in the tables.	• Existing Table 9 includes recommended staging and expected cost of the works • Table 10 has been added to provide implementation details including clarification of land ownership, lead agency, stakeholders, comments and actions for implementation. • Section 7.4.2 has been added to outline potential funding sources • Section 7.4.4 has been added to provide detail on monitoring. • Section 7.4.3 has been added to outline ongoing community engagement. Specific detail regarding

	Comment	Suggested Action	Response
		• Clarify the intent of the term Lead Agency. • Link Table 9 & 10 regarding the staging of the Cost Benefit and distributional Analysis. • It would be prudent for Council to consider the risks associated with seeking the certification of a plan which appears to be largely unfunded.	community engagement has also been added to Table 10. • Footnote added to Table 10 • Footnote added to Table 9 outlining that the cost benefit work and the distributional analysis for all rock revetment work will be undertaken at the design stage of priority 2. This is also reflected in the 'Actions for Implementation' in Table 10. • Noted and discussed with Office of Environment & Heritage.
5	**Table E3 and 9 – Priority Actions 1, 2, 4, 5, 6, 7** Land status and management arrangements relevant to these actions needs to be clarified, refer comment #1 and #3. This may include establishing the location of the mean high water mark to determine Council owned / managed and Crown land (below MHWM) at some locations.	• Further information is required concerning the location of the works, land status, impacts on crownland / Crown land management principles. • Notwithstanding this, it is highly likely that some treatments (eg the building of revetments, GPTs may be sites, in part, on Crown land. As a result, land ownership and / or authorisation of the proposed works by way of Crown tenures/s is likely to be required in order to formalise the occupation of Crown land and define ongoing maintenance responsibilities. Alternatively Council could accept Trust management of the site to streamline approval processes and ongoing maintenance of works.	• Table 10 has been added to provide implementation details including land ownership, lead agency, stakeholders, comments and actions for implementation. • Figure 3a added to outline land ownership. • Action added to Table 10 to survey mean high water mark. • Section 7.4.1 *Relevant Legislation and Approvals* has been added. This includes an outline of the approval process for works on crownland.
6	**Table E3 and 9 – Priority 1 Precinct 1 & 2 (Nourishment)** Proposed dredging and nourishment treatments (where nourishment is to occur below MHWM) are likely to require authorisation, with approvals/licences also required for	• Further information is required concerning the location of the works, land status, impacts on Crown land / Crown land management principles. • Noting land ownership will require clarification of the MHWM. • The term 'explore long term funding options'	• Figure 3a added to outline land ownership. • Action added to Table 10 to survey MHWM. • Wording changed within Table 10 to 'Anchorage Marina Complex leaseholders'.

	Comment	Suggested Action	Response
	these actions	should be clarified, that these investigation are being held with the leaseholder of the Anchorage Marina Complex. • For clarification the department is not to be considered a potential funding partner for this action.	• Text added to section 7.4.1 to clarify the Departments funding position
7	**Table E3 and 9 – Priority 3 Precinct 3 (Make Safe)**	• This action is supported, noting that where works are proposed on Crown land, not under Council Trust management, an appropriate authorisation from DoI Lands & Forestry will be required prior to the works commencing. • Note that adequate lead time (at least 6 months) is required for the Department to assess and issue authorisation (licence) works on Crown Land. • It is noted that 'The focus of this work is access and signage'. If high public safety risks are present, then it may be prudent for Council to elevat this action to the highest priority and provide clarity concerning funding.	• Section 7.4.1 added outlining the approval process for works on crownland. • Figure 3a added to outline land ownership. • Noted • Wording charged for Priority 3 in table E3 and 9 from "Make Safe" to *Pedestrian Management* to better reflect the intent of the action. Works in relation to high public safety risk are undertaken immediately regardless of the location.
8	**Table 10 – Priority Action 2, 4, 6 & 7**	• The department is not to be considered a potential funding partner for this action. • Funding arrangement are yet to be determined	• Section 7.4.1 *Relevant Legislation and Approvals* has been added. This includes an outline of the approval process for works on crownland and clarification of the Departments funding position. • Section 7.4.2 has been added to outline potential funding sources
9	**Priority Action 5 - Stormwater**	• It is recommended that monitoring (with a link to the proposed 'Monitoring of Priority Action 1') is listed as the first 'Action for Implementation against this action in Table 10.	• Wording changed for Priority 5 in table E3 and 9 to clarify that the stormwater outlet will be enclosed in a groyne. • Action added to Table 10 to 'Monitor beach behaviour post sand nourishment'. • Action has been added to Table 10 to *'Monitor beach behaviour post implementation of the sand nourishment program'*