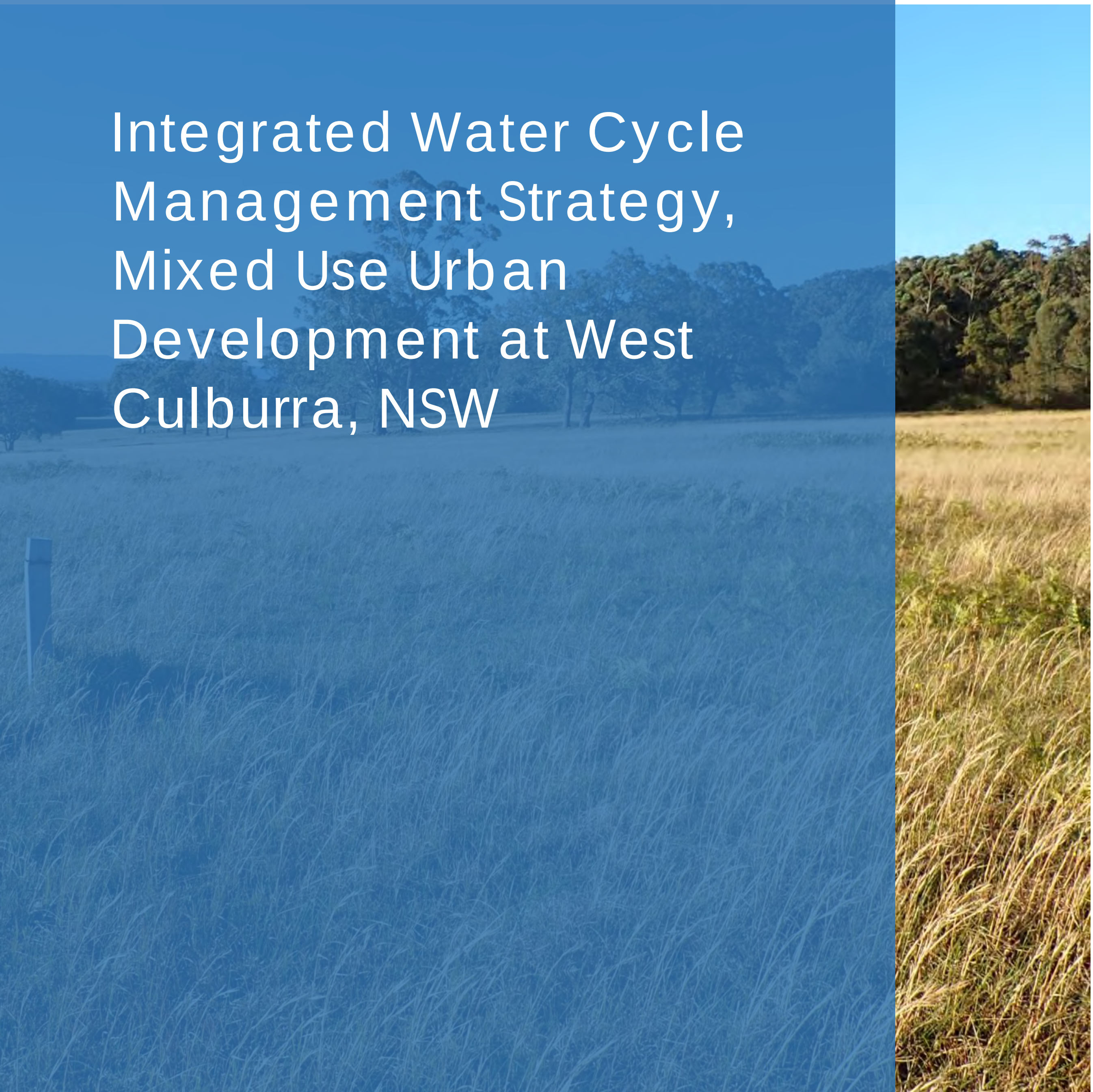
Integrated Water Cycle Management Strategy, Mixed Use Urban Development at West Culburra, NSW



Prepared for Sealark Pty Ltd

Report No: 1203365JR07

17 November 2020

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Project Details

Project Item	Detail
Name	West Culburra Mixed Use Development
Client	Sealark Pty Ltd
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Document	P1203365JR07V06
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Executive Summary

Overview

This report provides an amended Integrated Water Cycle Management Strategy (WCMS) to support a proposed mixed-use urban development (the Proposal) located to the west of the village of Culburra Beach on the NSW South Coast (see location below). The WCMS has been fully revised in response to an amendment of the Proposal footprint, including an internal reconfiguration of the proposed development layout and staging.

Key amendments in this WCMS are:

1. Reduced Development Scale: The WCMS is based on a Concept Plan footprint which has been reduced by approximately 50% from that originally proposed.

2. Further Stormwater System Details: The WCMS is based on a much more detailed proposal layout which provides additional certainty on the location of expected roads, lots and land-uses, and the location and type of all stormwater management infrastructure.

3. Inclusion of Water Sensitive Urban Design: The WCMS has been extended to include some groundwater recharge and stormwater re-use as part of a range of water sensitive urban design (WSUD) stormwater management measures. A large proportion of urban runoff generated will ultimately be directed to one of three large stormwater ponds for collection and re-use over dedicated public parks and sports fields, as well as providing for additional pathogen removal prior to release to the 100 m foreshore environmental buffer area. No new stormwater connections to the Crookhaven River are proposed.

Strategy Objectives

The Concept Plan WCMS has been prepared according to the following objectives and design criteria:

Objective 1 - Provide Riparian Buffers
A 100 m wide best practice vegetated riparian buffer has been implemented serving to protect waterways and the Estuary by filtering, trapping and treating sediment, nutrients, pathogens and other contaminants.

Objective 2 - Implement WSUD Principles
The stormwater management system has been designed on the basis of WSUD principles, including: to manage stormwater at or near its source; to treat stormwater prior to release to the environment; and to integrate stormwater management within the built environment so as to improve amenity and reduce potential environmental impacts.

Objective 3 - Preserve and Protect Wetlands
Stormwater management systems have been designed such that SEPP 14 coastal wetlands are preserved and protected, ensuring that there is no net material ecosystem harm.

Objective 4 - Maintain Oyster Industry Water Quality Criteria
Stormwater management systems have been designed such that they do not compromise the achievement of estuarine water quality objectives for oyster aquaculture.

Objective 5 - Treat Stormwater Prior to Release
All urban runoff is treated prior to release to current best practice standards, including satisfaction of the Neutral or Beneficial Effect (NorBe) test, so as to ensure that receiving waters are not materially impacted.

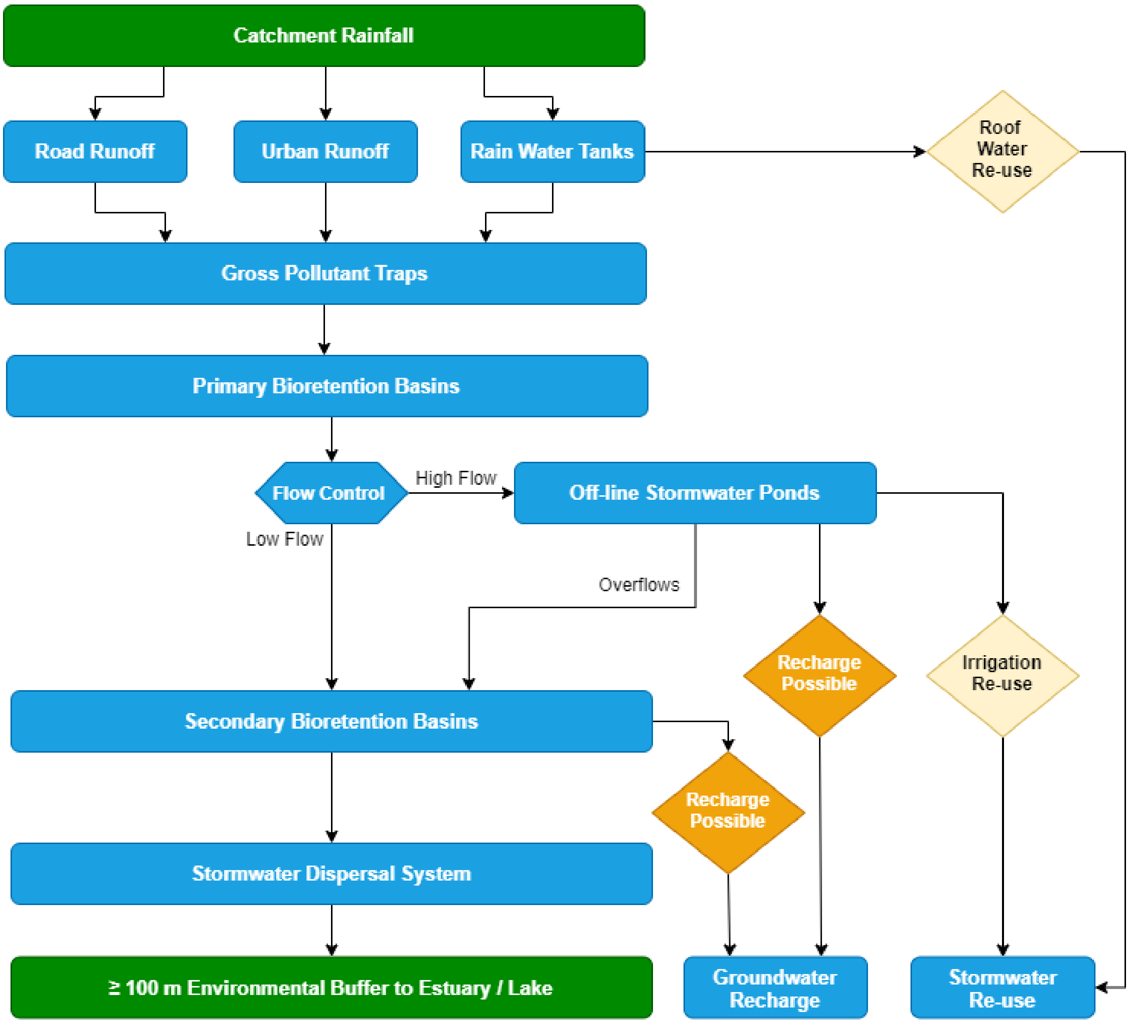
Objective 6 - Encourage Stormwater Re-use
Stormwater capture and re-use within public spaces and other areas within the development area has been incorporated into the Concept Plan.

Objective 7 - Avoid New Piped Stormwater Flows to Estuary
The Concept Plan has been designed so as to not require any direct connections to the Crookhaven River.

Objective 8 - Reticulated Sewer
The development will be serviced by a best practice reticulated sewerage system with appropriate detention, remote monitoring, back-up systems and spill containment measures to prevent dry weather overflows and minimise any wet-weather overflows, thereby controlling and mitigating the impact of any overflows should they occur.

Stormwater Management

The proposed stormwater management system has been designed to include a range of WSUD elements including at source treatment, large scale re-use and groundwater recharge. These general concepts are illustrated in the figure below, which broadly describes the stormwater scheme layout for the majority of the site. Only a small portion of the Proposal area is not serviced by an off-line stormwater pond and a secondary bioretention basin.



Modelling of the stormwater scheme has demonstrated that there will be no material or significant impacts on the downstream environment including the Crookhaven River Estuary or Lake Wollumboola. The following is noted:

1. Pollutant loads to both the Lake Wollumboola catchment and the Crookhaven River estuary will be reduced compared to existing conditions, demonstrating a beneficial impact on receiving waters.

2. Pathogens potentially contained within urban runoff will be subject to treatment prior to release to the 100 m environmental buffer so that pathogen levels to the Crookhaven River estuary will be reduced compared to existing conditions.

3. The Proposal incudes key stormwater management elements that ensure that the hydrological character of overland flows leaving the Proposal area will not be detrimentally altered compared to existing conditions. These elements include: large scale bioretention basins; stormwater detention ponds; large scale

stormwater re-use; stormwater dispersal systems; no new stormwater connections to the Estuary or Lake; and opportunities for groundwater recharge with stormwater. These have contributed to the overall approach to stormwater management representing industry best practice.

Groundwater Management

The impact of the Proposal on local groundwater systems was investigated through the collection and review of extensive physical data and undertaking numerical modelling to simulate developed conditions. Included in the assessment process was an investigation of the benefits and risks associated with recharging stormwater to the groundwater system. The investigation found that development of the Concept Plan would not result in any material groundwater related impacts, and that enabling some groundwater recharge from stormwater treatment measures would reduce overall stormwater flows and not unacceptably impact groundwater. The following is noted:

1. Groundwater flow modelling has demonstrated that groundwater flow regimes and directions are effectively maintained by the Proposal. The predicted groundwater levels, whilst modified somewhat from current conditions due to changes in the distribution in groundwater recharge arising from modifications to vegetation cover and the extent of impervious areas, are not likely to result in any adverse environmental outcomes.

2. Groundwater modelling investigated the potential benefits and risks associated with enabling some recharge of groundwater via a nominal 0.25 mm/hr exfiltration rate at the proposed stormwater treatment measures. Results of those investigations found that some 15 ML/year of stormwater recharge[1] to groundwater can be achieved without any material adverse impact on the groundwater flow regime. Groundwater flow budgets to the Crookhaven River and Lake Wollumboola with a recharge system in place are closely matched to current conditions.

3. On the basis of groundwater contaminant transport modelling undertaken, as well as the comparison between predicted MUSIC exfiltration contaminant concentrations and current groundwater contaminant concentrations, an exfiltration rate of 0.25 mm/hr from stormwater management measures is ecologically sustainable, mitigates some urbanisation effects and will not result in any detrimental harm to the existing groundwater system or downstream receiving environments. On that basis a recharge scheme is recommended.

4. The impact assessment undertaken herein has demonstrated compliance with the NSW Aquifer Interference Policy.

Water Supply

The water supply scheme proposed for the Concept Plan uses a combination of 'at-source' and 'reticulated' services to ensure that an appropriate and sustainable water supply is provided. These include:

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[1] Refer to Section 4.5.3.

1. Reticulated town mains provided by Shoalhaven Water.

2. Rainwater tanks attached to individual dwellings and other commercial or industrial structures.

3. Irrigation water supplied by stormwater harvested from urban runoff.

The water supply scheme has been designed by applying the principles of WSUD so that the demand for reticulated water is appropriately reduced.

Sewage Management

The Concept Plan area will be serviced by a reticulated sewage management scheme owned and operated by Shoalhaven Water in accordance with the recommendations of the Healthy Estuaries Guideline. The sewage management scheme will broadly encompass the following:

1. Reticulated sewer connection will be provided to all urban development areas.

2. The western portion of the Proposal will require a new sewage pumping station (SPS) to be constructed.

3. The eastern portion of the Concept Plan will be configured to drain into the existing Culburra Beach sewer network.

Risks of the sewage management system to Estuary water quality were assessed and the following risk mitigation measures recommended to ensure that maximum protection against overflows reaching and impacting the Crookhaven River Estuary is provided.

1. Implement Best Practice Design and Construction Methods: The sewer would be designed and constructed to current industry standards and in accordance with Shoalhaven Water criteria and obligations.

2. Undertake Integrity Testing During Commissioning: As part of the commissioning process, new sewer lines should be tested for leaks or potential stormwater ingress so as to minimise the potential for future wet-weather ingress.

3. Certification of Construction Works: Certification from appropriate professionals such as engineers, plumbing contractors and surveyors should be provided at each construction stage to confirm that any newly constructed sewer system is free from stormwater cross-connections and has been built in accordance with the relevant plans, standards and codes.

4. 24 Hour Emergency Response Plan: A site-specific emergency response plan will be prepared for any new pumping stations within the Concept Plan area. The response plan will be prepared in consultation with Shoalhaven Water who will own and operate the sewer network.

5. Incorporate System Monitoring: The sewer system will incorporate appropriate alarms and back-to-base telemetry. At a minimum, the following will be provided:

   (a) Live monitoring of SPS water levels and alarms.

(b) Live monitoring of SPS pump flow metering.

(c) Live water level monitoring at key manholes in the Proposal area that will drain directly to the existing Culburra Beach sewer system.

6. Backup Systems: The reticulation system will incorporate various back-up systems and parts to reduce maintenance times required to return any system failures to operating conditions. The following is recommended:

   (a) Alternative power supply to operate sewage pumping station(s) in the event of a local area power failure.

   (b) Duty and stand-by pumping arrangements that have the capacity to accommodate expected wet-weather flows and potential equipment failure.

   (c) Critical spare parts, such as replacement pumps and valves, located at locally so that these can be readily exchanged in the event of a component failure, with the aim of preventing an overflow event occurring.

   (d) Minimum 24-hour average dry-weather flow detention storage to be provided at the sewage pumping station to ensure that sufficient time is provided to repair any breakdowns prior to overflow occurring.

7. No Direct Overflow Point to Estuary: The reticulation system will be designed so that no infrastructure or overflow points are located within the 100 m forested buffer provided as part of the Concept Plan. This will provide an appropriate level of separation between the sewer scheme and the Estuary and will ensure compliance with The Healthy Estuaries Guideline.

8. Direct Overflows to Stormwater Bioretention Basins / Ponds: The sewer reticulation system will be designed so that any potential overflows are capable of being directed to the stormwater bioretention basins / ponds for containment and pathogen treatment and removal in the event of an overflow emergency. In the western portion of the Proposal, the SPS overflow will be configured to be directed to the western pond. In the eastern portion of the Proposal, the sewer will be configured so that redirection from a suitably located manhole can occur.

Construction Staging and Sediment Control

Given the size of the urban land release area proposed, the Concept Plan will be developed in a series of discrete stages including:

1. Nine residential land stages in the western portion of the Proposal.
2. Two Industrial land stages in the central portion of the Proposal.
3. Five Town Centre stages portion in the eastern portion of the Proposal.

Each stage, once completed, will be provided with suitable stormwater management measures to ensure that downstream receiving environments are protected.

During construction of each stage, sediment and erosion control measures will be in place for the duration of construction works. A description of the required measures for each construction stage has been prepared and included in this WCMS. All sediment and erosion control measures will be required to be audited for compliance during their operational phase. This will include at a minimum the following:

1. Certification on Installation: Certification by a suitably qualified engineer that sediment and erosion control structures have been installed in accordance with relevant guidelines such as the Blue Book and any development consent condition requirements.

2. Performance Monitoring: During construction, outflows from all operational sediment ponds should be monitored to ensure compliance with the 'Blue Book'.

3. Post-rainfall Inspections: Following heavy or prolonged rainfall, all sediment and erosion control structures should be inspected, cleaned and repaired as required to ensure on-going compliance.

4. Routine Inspections: In the event that rainfall has not occurred, all sediment and erosion control structures should be inspected, cleaned and repaired on a 3 monthly basis to ensure on-going performance compliance.

5. Record Keeping: A log-book should be kept during the operational phase of all sediment and erosion control measures. The log book should document the date and time of inspection, observations made during the inspection, recommendations for remedial works, and a sign-off for when such works were completed and who completed the works.

Water Quality Monitoring Program

A comprehensive Water Quality Monitoring Program (WQMP) has been prepared to provide a framework through which long-term water quality objectives for the Concept Plan are maintained. The WQMP was prepared on the basis of a water quality risk assessment undertaken in respect of the Proposal and incorporates the following primary elements:

1. An on-going water quality monitoring regime which includes the Estuary, key stormwater treatment devices, the groundwater system and shell fish areas.

2. On-going photographic survey of key environmental receptors including mangrove areas and riparian zones.

3. Interim trigger values and required actions if trigger events occur.

4. Annual reporting requirements.

5. WQMP on-going review requirements.

Conclusions

This WCMS has been prepared in accordance with the principles of ecologically sustainable development (ESD) so as to achieve a NorBE outcome on the environment. The comprehensive suite of risk management and environmental protection measures proposed for stormwater management, groundwater protection, water supply, sewage management and construction management represent current best practice. These water cycle management measures have been developed to ensure that the risk of material harm to the receiving environment is mitigated and sensitive environmental receptors such as SEPP14 wetlands, the Shoalhaven River estuary, including the associated Oyster aquaculture industry, and Lake Wollumboola are appropriately protected.

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1 Introduction

1.1 Overview

This report provides an amended Integrated Water Cycle Management Strategy (WCMS) to support a proposed mixed-use urban development (the Proposal) located to the west of the village of Culburra Beach located on the NSW south coast (see Diagram 1). The report has been produced within the context of appeal proceedings in the NSW Land & Environment Court in matter 28149 of 2019 (the Proceedings). The WCMS has required considerable amendment in response to discussions between the parties during the conciliation process. This has resulted in a large reduction of the Proposal footprint and some internal reconfiguration of the proposed development layout and staging.

Diagram 1: Study area location.

In summary, the key differences between this WCMS and that described in the original application are:

(a) Reduced Development Scale: The WCMS is based on a significantly smaller development footprint which has been reduced by approximately 50% from that originally proposed.

(b) Further Stormwater System Details: The WCMS is based on a much more detailed proposal layout which provides additional certainty on the location of expected roads, lots and land-uses, and the location and type of all stormwater management infrastructure.

(c) Inclusion of Re-use & Pathogen Control: The WCMS has been extended to include some groundwater recharge and stormwater re-use in addition to the provision of a range of water sensitive urban design stormwater management devices. All urban runoff will be directed to one of three stormwater ponds for collection and re-use over dedicated public parks and sports fields, as well as for controlling and removing any pathogens prior to release to the 100 m environmental buffer area.

1.2 The Concept Plan

Since lodgement of the original Concept Plan application several years ago (the Original Concept Plan), there have been several modifications to the development Proposal. These revisions occurred during December 2019 through to September 2020 and have resulted in a large reduction and contraction to the east in the overall footprint of the Original Concept Plan, as well as a reconfiguration of some of the Proposal elements. These revisions have been borne out of on-going discussions between the Applicant and the NSW Department of Planning, Industry and the Environment (the Department).

A copy of the amended Concept Plan (Rev 8) (the Concept Plan), dated 28 September 2020, is provided at Annexure A. In broad terms, the Proposal considered in the Concept Plan considered in this report consists of a staged, mixed-use development situated near the southern side of the Crookhaven River to the west of the existing township of Culburra Beach on the NSW South Coast. In addition to ancillary roads and infrastructure, key development precincts are summarised as follows:

(a) Town Centre Precinct – including mixed use residential and commercial development located near to the existing Culburra Beach township, sports fields, parks and open space.

(b) Industrial Precinct – including development adjacent and near to existing industrial areas.

(c) New Residential Precinct – including residential lots parks and open space.

In terms of development occurring within water catchments, the Concept Plan can be alternatively summarised as being fundamentally occurring within the Crookhaven River catchment as described below:

(a) <u>Draining to Crookhaven River</u> – Approximately 46 ha of urban development comprising of some 40 ha residential / commercial development, 6 ha industrial land and some open space and parkland.

(b) <u>Draining to Lake Wollumboola</u> – Approximately 0.5 ha of urban development comprising of a link road to the western residential land area of the proposed development from Culburra Road, and a new roundabout at the intersection between the proposed link road and Culburra Road.

1.3 **Director General's Requirements**

The Director General's Environmental Assessment Requirements (DGRs) were initially issued on 27 May 2010, outlining the various investigation and reporting requirements for the Proposal. Following an amendment to the proposed Concept Plan, amended DGRs were issued on 5 July 2010.

Key issues identified in the DGRs that are dealt with in this report are outlined below in Table 1.

Table 1: DGRs and responses to issues as contained in this report.

Issue	Element	Description	Sections
4.3	Infrastructure	Contingency measures to ensure sewage infrastructure does not negatively impact on wetland river systems	7
7.1	Water Cycle Management	Prepare an Integrated Water Cycle Management Strategy for the overall development which considers water supply, sewage.	This report
7.2	Water Cycle Management	Address stormwater management based on Water Sensitive Urban Design principles which addresses direct and indirect impacts on quality of surface and groundwater and the surrounding environment (including Lake Wollumboola, the Crookhaven River, riparian areas and the SEPP 14 wetlands), drainage and water quality controls for the catchment, and erosion and sedimentation controls at construction and operational stages. Demonstrate an acceptable level of water quality protection for a range of water quality parameters including turbidity, gross pollutants, nitrogen and phosphorus with respect to water quality and river flow recognising the environmental and food production importance of the receiving waters (eg sea grass bed and oyster aquaculture).Demonstrate consistency with any relevant Statement Joint Intent established by Healthy Rivers Commission, the *NSW Government River Flow Objectives and Water Quality Objectives framework*.	4, 8
7.3	Water Cycle Management	Address potential direct and indirect impacts and relevant mitigation measures on oyster leases and aquaculture in the vicinity of the site.	4.5, 5.6
7.4	Water Cycle Management	Prepare a conceptual design layout plan for the preferred stormwater treatment train showing location, size and key functional elements of each part of the system.	4.2
7.5	Water Cycle Management	Undertake a detailed groundwater assessment that includes (but is not limited to), the current quality of the groundwater, any existing groundwater users, the nature and profile of the groundwater regime under the site (natural flow regime, water table local drainage patterns), interactions between the groundwater and surface water, any hydrologic impacts (including cumulative) which would affect its depth or water quality, result in increased groundwater discharge, impact on the stability of potential acid sulfate soils in the vicinity, or affect groundwater dependent native vegetation. Identify measure for preventing groundwater pollution.	5
7.7	Water Cycle Management	Provide details on any existing surface water and groundwater licences under the *Water Act 1912*, any proposed water extraction (surface or groundwater) including purpose, as well as the function and location of all existing and proposed storage/ponds.	3.1.6, 3.1.6.4, 4.2.4
7.8	Water Cycle Management	Design a long term water quality monitoring program that shall be implemented prior to stage one and last until such time as the dwelling construction phase is complete. The program should include monitoring of the receiving waters of the Crookhaven River and groundwater. The program should be one of adaptive management, used to assess the effectiveness of the water quality controls, by highlighting deficiencies that may exist and enhancements that may be required. The results of the monitoring program should be used to form the basis of the programs for subsequent stages, thereby preventing irreversible impacts to the Crookhaven/Shoalhaven estuary and adjacent wetlands. Provide details of contingency plans in the event of potential adverse impacts and degradation of the Crookhaven/Shoalhaven Estuary and wetlands	9

1.4 Issues in the Proceedings

The issues considered in this report arise out of the Respondent's Statement of Facts and Contentions (the SOFACs) prepared on behalf of the IPC in the Applicant's appeal against the refusal of the Original Concept Plan proposed by the Applicant. The SOFACs contains 6 contentions that relate to the water cycle, these being summarised as follows:

(a) Contention 1: Impact on water quality and quantity in the Crookhaven River.

(b) Contention 2: Impact on water quality and quantity in Lake Wollumboola.

(c) Contention 4: Assessment of impact on Crookhaven River oyster aquaculture.

(d) Contention 7: Consistency with Shoalhaven Local Environmental Plan (SLEP 1985).

(e) Contention 10: Incorporation of sustainability measures.

(f) Contention 14: Details of modelling of water quality and quantity.

Whilst the contentions as particularised in the SOFACs are comprehensive, they can however be summarised as falling into a number of broad issues, these being:

(a) Design of the proposed stormwater management scheme.

(b) Modelling of the proposed stormwater system.

(c) Impacts on the Crookhaven River Estuary.

(d) Impacts on Lake Wollumboola.

(e) Impacts on Oyster Aquaculture.

(f) Construction management.

(g) Ecological sustainability of the Proposal.

(h) Compliance with SLEP 1985.

1.5 Key WCMS Goals

This concept WCMS strategy has been designed to deliver a strategy for the entire development area that provides for long-term ecologically sustainable development and retention and protection of key environmental water features. It is intended to serve as a guidance document for future stages of development that arise out of the Concept Plan and it is expected that any development within the Concept Plan area would need to adhere to the overarching strategy, objectives and concept designs outlined in the WCMS.

Key goals of the strategy are to:

1. Protect and preserve key environmental water features
2. Minimise environmental harm and development impacts
3. Protect industry that is reliant on environmental water assets

1.6 WCMS Implementation

This document provides a concept WCMS that is to be implemented in detail when future staged development applications are lodged within the approved Concept Plan area. At each development stage, the objectives set within this WCMS should be achieved such that the environmental outcomes documented herein are met. For each development stage, the following is likely to be required:

(a) Preparation of a stormwater management plan that is consistent with the WCMS.

(b) Preparation of a soil and water management plan that is consistent with the WCMS.

(c) Preparation of a groundwater management plan that is consistent with the WCMS.

(d) Preparation of an environmental monitoring plan that is consistent with the WCMS.

1.7 Documents Relied Upon

Documents which have been relied upon in preparing this report are outlined below:

(a) Respondent's Statement of Facts and Contentions, filed 24 May 2019 (the SOFACs).

(b) Shoalhaven Local Environmental Plan 1985 (SLEP 1985)

(c) West Culburra Mixed Use Concept Plan, prepared by Allen Price & Scarratts Pty Ltd, Revision 8 dated 28 September 2020 (the Concept Plan).

(d) NSW Oyster Industry Sustainable Aquaculture Strategy, prepared by the NSW Government, dated 2006 (the OISAS).

(e) *Environmental Planning and Assessment Regulation 2000* (NSW) (the EPAR).

(f) State Environmental Planning Policy (State and Regional Development) 2011 (the SEPP SRD).

(g) State Environmental Planning Policy No 62—Sustainable Aquaculture [now repealed] (SEPP 62).

(h) State Environmental Planning Policy No 14—Coastal Wetlands [now repealed] (SEPP 14).

(i) State Environmental Planning Policy (Coastal Management) 2018 (SEPP Coastal Management).

(j) State Environment Planning Policy (Primary Production and Rural Development) 2019 (SEPP PPRD).

(k) Healthy Estuaries for Healthy Oysters Guidelines, NSW Department of Primary Industries, September 2017 (Healthy Estuaries Guideline).

(l) Neutral or Beneficial Effect on Water Quality Assessment Guideline, Sydney Catchment Authority 2015 (NorBE Guideline).

(m) Managing Urban Stormwater: Soils and Construction volume 1 (4th edition), NSW Landcom 2004 (The Blue Book).

(n) NSW Guidelines for Controlled Activities on Waterfront Land Riparian Corridors, NSW Natural Resources Access Regulator, prepared May 2018 (NSW Riparian Corridor Guidelines).

(o) NSW Diffuse Source Water Pollution Strategy, Department of Environment and Climate Change June 2009 (NSW Water Pollution Strategy).

(p) NSW MUSIC Modelling Guidelines, produced by BMT WBM on behalf of NSW Local Land Services Greater Sydney, prepared August 2015 (MUSIC Guideline).

(q) Shoalhaven City Council Development Control Plan 2014, chapter G2: Sustainable Stormwater Management and Erosion / Sediment Control as commenced on 12 February 2020 (SDCP).

(r) Estuarine Processes Modelling Report: Proposed Mixed Use Subdivision, West Culburra, Martens & Associates Pty Ltd, prepared November 2016 reference P1204465JR04V02 (Estuary Process Study).

(s) Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand (2000), Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC Guideline).

(t) Preliminary development staged delivery plans prepared by Allen Price & Scarratts Pty Ltd, dated February 2020 (Development Staging Plans).

(u) Preliminary staged sediment and erosion control plans prepared by Allen Price & Scarratts Pty Ltd, dated March 2020 (Sediment & Erosion Control Plans).

(v) Preliminary engineering plans prepared by Allen Price & Scarratts Pty Ltd, dated March 2020 (Engineering Plans).

1.8 Document Structure

This document is structured as follows:

(a) Section 1 provides a general introduction and overview of the report.

(b) Section 2 considers various guidelines and sets the WCMS objectives.

(c) Section 3 provides an overview of the local environmental setting.

(d) Section 4 outlines the proposed stormwater management scheme and considers impacts of stormwater generated by the development.

(e) Section 5 outlines the proposed groundwater management scheme and considers impact of the development on the groundwater system.

(f) Section 6 outlines the proposed water supply scheme.

(g) Section 7 outlines the proposed sewage management scheme.

(h) Section 8 outlines the requirements for construction staging and management.

(i) Section 9 provides a preliminary water quality monitoring program.

(j) Section 10 provides study conclusions.

1.9 Expert Witness Guidelines

The author has read Part 31 of Division 2 of the *Uniform Civil Procedure Rules 2005*, Schedule 7 of the *Uniform Civil Procedures Rules 2005* and understands his obligations to the Court and agrees to abide by the rules in Part 31 and Schedule 7, as well as the Land and Environment Court expert witness policies. This report has been prepared in accordance with the Expert Witness Guidelines.

2 Guidelines and Strategy Objectives

This section of the report considers various available guidelines that are used to formulate the aims, principles and objectives of the WCMS.

2.1 State Significant Development

Ordinarily for development which is not State Significant Development (SSD), setting aside the requirements of any State Environment Planning Policy, the local Council Development Control Plan (DCP) would define water quality and quantity targets in respect of proposed stormwater management systems. In the case of SSD, traditional DCP controls do not apply.[2]

On that basis, the performance of the Stormwater Proposal should in addition to the relevant State Environment Planning Policies (SEPPs), be assessed against best practice engineering design and environment management principles. The DCP remains however a relevant consideration given Council's involvement in future development applications.

2.2 SEPP 14 and SEPP Coastal Management

Pursuant to SEPP Coastal Management cl 21, the provisions of SEPP 14 continue to apply to the as yet undetermined Proposal, but the provisions of SEPP Coastal Management do not apply.[3]

In respect of SEPP 14, this applies to land mapped as containing a SEPP 14 wetland as defined by the outer edge of the heavy black line on the map.[4] On the basis that part of the Proposal land is near SEPP 14 wetlands, it is acknowledged that the aims of the SEPP are relevant, being:

"*The aim of this policy is to ensure that the coastal wetlands are preserved and protected in the environmental and economic interests of the State*".[5]

SEPP 14 provides no specific stormwater quality or quality objectives. Rather it relevantly requires the consent authority, when considering whether to grant consent, to take into consideration:[6]

> *(a) The environmental effects of the proposed development, including the effect of the proposed development on 'the surface and groundwater characteristics of the site on which the development is proposed to be carried out and of the surrounding area, including salinity and water quality'.*

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2 SEPP SRD cl 11(a).
3 SEPP Coastal Management cl 21(1).
4 SEPP 14 cl 4(1).
5 SEPP 14 cl 2.
6 SEPP 14 cl 7(2).

(b) *'Whether adequate safeguards and rehabilitation measures have been, or will be, made to protect the environment'.*

(c) *'Whether carrying out the development would be consistent with the aim of [the] policy'.*

2.3 SEPP 62 and OISAS

Pursuant to cl 9 of SEPP PPRD,[7] SEPP 62 continues to apply to the Proposal.

Whilst SEPP 62 provides no specific stormwater quality or quantity objectives or control criteria, it does require that a consent authority must consider any comments received from the Director-General of the Department of Primary Industries, including such comments that identify:[8]

(a) *"any adverse effect that the development may have on, or ways in which the development may impede or be incompatible with, any oyster aquaculture development or priority oyster aquaculture area,[9] and*

(b) *any measures to avoid or minimise any such adverse effect, impediment or incompatibility".*

SEPP 62 further provides that 'a consent authority may refuse to grant consent to development':[10]

(a) *if it is satisfied that the development will have an adverse effect on, or impede or be incompatible with:*

(i) *any oyster aquaculture development that is being carried out (whether or not within a priority oyster aquaculture area), or*

(ii) *any oyster aquaculture development that may in the future be carried out within a priority oyster aquaculture area, or*

(b) *if it is not satisfied that appropriate measures will be taken to avoid or minimise any such adverse effect, impediment or incompatibility.*

Pursuant to SEPP 62 cl 15D,[11] a consent authority must take into consideration the NSW Oyster Industry Sustainable Aquaculture Strategy (OISAS). OISAS provides for the following water quality objectives for oyster aquaculture areas in estuaries:[12]

(a) Faecal coliforms — 90th percentile < 43MPN[13] or 21 MF/100 mL

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7 SEPP PPRD cl 9.
8 SEPP 62 cl 15B(2).
9 Development may be incompatible with or impede oyster aquiculture if for example the development will impact on water quality and, consequently, on the health of oysters and of consumers of those oysters.
10 SEPP 62 cl 15C.
11 SEPP 52 cl 15D.
12 OISAS section 3.4 p 23 Table 4.
13 MPN/100 mL is equivalent to CFU/100 mL.

(b) pH	6.75 – 8.75
(c) Salinity	20.0 – 35.0 g/L
(d) Suspended solids	< 75 mg/L
(e) Aluminium	< 10 ug/L
(f) Iron	< 10 ug/L
(g) Other parameters	Refer to ANZECC sections 4.4 and 9.4

2.4 Healthy Estuaries for Healthy Oysters Guideline

The Healthy Estuaries for Healthy Oysters Guideline (Healthy Estuaries Guideline) is a document prepared by the NSW Government with the objective of providing '*councils, state government agencies, private landowners and developers with advice about how to ensure development in close proximity to estuaries is compatible with the requirements of oyster aquaculture*'.[14]

The Healthy Estuaries Guideline was prepared to meet the requirements of Management Action 7 of the NSW Water Pollution Strategy,[15] that being to develop and implement the adoption of best management practice guidelines or standards for specific land uses and industries that include diffuse source water pollution management principles.[16]

Whilst the Healthy Estuaries Guideline was released after the lodgement of this Concept Plan, the document remains one of the few guidelines which provide NSW State Government advice in respect of controlling development on land adjoining or draining to estuaries with oyster aquaculture. The guideline therefore, is relevant to the assessment of the Proposal and its potential impacts.

The Healthy Estuaries Guideline makes reference to what is known as the Neutral or Beneficial Effect assessment (the NorBE Assessment), this being an assessment process applied to highly sensitive drinking water catchments.[17] Whilst the NorBE assessment is referred to, the Healthy Estuaries Guideline does not require or recommend that the NorBE assessment be used. Rather, it is referred to as an assessment methodology that is '*available to provide information to authorities assessing development proposals about minimising the impacts of on the water quality of sensitive receiving bodies such as oyster estuaries*'.[18]

The Sydney Catchment Authority defines the NorBE Assessment in Sydney's drinking water catchments as follows:[19]

> *A neutral or beneficial effect on water quality is satisfied if the development:*

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14 Healthy Estuaries Guideline, Section 1.1 p 1.
15 Healthy Estuaries Guideline, Section 1.1 p 1.
16 NSW Water Pollution Strategy, MA 7, p 24, which committed NSW DPI to lead the development of guidelines for oyster harvest area protection.
17 Healthy Estuaries Guideline, Section 1.3 p 3.
18 Healthy Estuaries Guideline, Section 1.3 p 2.
19 NorBE Guideline, Section 3.1 p 6.

(a) *has no identifiable potential impact on water quality, or*

(b) *will contain any water quality impact on the development site and prevent it from reaching any watercourse, waterbody or drainage depression on the site, or*

(c) *will transfer any water quality impact outside the site where it is treated and disposed of to standards approved by the consent authority.*

The Healthy Estuaries Guideline provides a number of water quality guidelines for oyster aquaculture areas which are aimed at '*protection water quality for safe human consumption and viable production of edible oysters*', these [being identical to those specified in OISAS] including:[20]

(a) Faecal coliforms	90th percentile < 43MPN or 21 MF/100 mL
(b) pH	6.75 – 8.75
(c) Salinity	20.0 – 35.0 g/L
(d) Suspended solids	< 75 mg/L
(e) Aluminium	< 10 ug/L
(f) Iron	< 10 ug/L
(g) Other parameters	Refer to ANZECC sections 4.4 and 9.4

The Healthy Estuaries Guideline is instructive in that it provides recommendations for various mitigation measures that can be applied to ensure that any risks to oyster aquaculture are appropriately managed and controlled. The following guides are particularly relevant to the Proposal.

2.4.1 Reticulated Sewers

The Healthy Estuaries Guideline recommends that reticulated wastewater management systems should be:

(a) *"Designed so that they do not discharge to waterways due to overflows in dry weather and wet weather overflows should be minimised"*.[21]

(b) Envisaged so that *"reticulation systems should incorporate measures such as telemetry, storage, back-up systems and power sources. As well, operators should have emergency response systems in place and ensure that sufficient spare parts are available to ensure that breakdowns can be fixed before overflows occur"*.[22]

(c) Designed with the consideration that sewer overflows can be reduced by a range of mechanisms including: development of a 24-hour emergency response

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20 Healthy Estuaries Guideline, section 1.6 p 5 Table 1.
21 Healthy Estuaries Guideline, section 2.4 p 10.
22 Healthy Estuaries Guideline, section 2.4 p 11.

plan; use of telemetry or dial-up systems to provide early advice of failure; use of back-up pumps and controls; have standby / alternative power available; and ensure that spare parts are readily at hand.[23]

2.4.2 Urban Subdivision

The Healthy Estuaries Guideline recommends that to reduce the risk of subdivision and development adjacent to a waterway or estuarine health and oyster harvest zone:[24]

(a) *Where possible an environmental protection zone adjacent to estuarine foreshores should be established in the Local Environmental Plan*.

(b) *Any new subdivision adjacent to an estuarine waterway should include a minimum 100 m vegetated riparian zone buffer*.

(c) Removal of native riparian vegetation should be avoided where possible. Any planted riparian vegetation associated with subdivision and development should comprise locally appropriate Australian native species.

(d) Subdivision should incorporate Water Sensitive Urban Design with particular emphasis upon stormwater capture and treatment prior to discharge.

(e) Subdivision should utilise a reticulated wastewater management system where possible. The system should be designed and constructed so that overflows into waterways (particularly in proximity to oyster areas) are avoided.

(f) Subdivision and development involving excavation should be avoided in areas with high potential for acid sulfate soils, or an acid sulfate soil management plan should be prepared and implemented if this can't be avoided.

(g) A water quality monitoring program should be designed and implemented to demonstrate that OISAS water quality objectives (refer to Table 1) are met pre- and post-construction.

(h) Plan and implement erosion and sediment control and consider independent auditing of large subdivision sites.

2.4.3 Urban Stormwater

The Healthy Estuaries Guideline recommends that key water sensitive urban design options to control the impact of stormwater on receiving waters include:[25]

(a) Treat stormwater through gross-pollutant traps (GPTs) to capture sediment, sludge and solids.

(b) Constructed wetlands may be used as an additional level of treatment.

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23 Healthy Estuaries Guideline, section 3.3 p 27.
24 Healthy Estuaries Guideline, section 2.5 p 11 – 12.
25 Healthy Estuaries Guideline, section 2.8 p 16.

(c) The effect of the impervious urban landscape can be counteracted using infiltration systems, grass swales instead of gutters, rainwater storage, stormwater storage and re-use systems.

(d) GPTs, constructed wetlands, bioretention systems and other water sensitive urban design devices may also be used to improve runoff from existing urban areas and thereby improve estuarine health.[26]

2.4.4 Construction Erosion and Sediment Control

The risk to aquatic ecosystems and oyster aquaculture can be minimised by:[27]

(a) Designing erosion and sediment control measures in accordance with The Blue Book.

(b) Where erosion and sediment control systems may impact on estuaries and oyster aquaculture areas, these are designed by applying NorBE Assessment principles.

(c) Ensuring that there is a high priority for compliance inspections.

2.4.5 Estuarine Riparian Zones

The following recommendations are made:[28]

(a) Riparian areas be managed to maintain the health of existing native vegetation, encourage recruitment of juvenile trees and shrubs and incorporate weed control.

(b) Areas where little or no vegetation remains, be rehabilitated by replanting or by encouraging natural regeneration.

(c) Stock access to riparian areas be managed, alternative watering points be provided and alternate shade be provided.

(d) Exotic vegetation be replaced with native vegetation.

2.5 NSW Riparian Corridor Guidelines

The NSW Riparian Corridor Guidelines provides key environmental management advice for the protection of NSW waterfront land and is therefore instructive in terms of the Proposal.

Riparian corridors are transitional land between the terrestrial environment, and the river or watercourse or aquatic environment. Riparian corridors perform a range of stormwater management related functions such as:[29]

(a) Providing bed and bank stability and reducing bank and channel erosion.

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26 Healthy Estuaries Guideline, section 3.4 p 28.
27 Healthy Estuaries Guideline, section 2.9 p 17.
28 Healthy Estuaries Guideline, section 3.5 p 29.
29 NSW Riparian Corridor Guidelines, p 4.

(b) Protecting water quality by trapping sediment, nutrients and other contaminants.

(c) Conveying flood flows and controlling the direction of flood flows.

(d) Providing an interface or buffer between developments and waterways.

The NSW Riparian Corridor Guidelines makes the following design recommendations:

(a) The recommended riparian corridor width to any estuary or wetland, as well as any part of a river influenced by tidal waters is an average of 40 m.[30]

(b) The riparian zone width can be reduced by 50 %, that is to a minimum of 20 m, provided that the average recommended width is maintained.[31] Any land gained by reducing the recommended setback can then be used for non-riparian uses including asset protection zones, recreational areas, roads, development lots and infrastructure.

(c) In principle, stormwater should be treated before discharging into a riparian corridor, although stormwater detention structures can be located in the outer 50 % of the riparian zone.[32]

Applications that do not strictly conform to the recommended measures contained within the NSW Riparian Corridor Guidelines are not prohibited, but rather will be subject to a merit assessment.[33]

In summary, the NSW Riparian Corridor Guidelines recommend a default vegetated riparian corridor width of 40 m to an estuary or wetland, although that can be reduced in places to 20 m provided the minimum average width is met. Further the Guidelines do not preclude the application of even smaller riparian corridors.

2.6 NSW MUSIC Modelling Guidelines

The most current NSW stormwater modelling guidelines are provided in the NSW MUSIC Modelling Guidelines which have been prepared by BMT WBM on behalf of NSW Local Land Services (the MUSIC Guideline). The MUSIC Guideline provide guidance on implementing the stormwater model MUSIC (MUSIC Model) for assessing the potential impacts of development on stormwater flow quality and quantity. Whilst the MUSIC Guideline holds no statutory authority, it is generally accepted in NSW as a default standard that is used in conjunction with more detailed information contained within individual Council Development Control Plans and other Council technical or policy documents.

The MUSIC Model is a decision support tool for stormwater management that helps with the planning and conceptual design of stormwater management system.[34] At present the MUSIC Model is the preferred tool for assessing water sensitive design strategies across Australia. The following general commentary is taken from the MUSIC Guideline:

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30 NSW Riparian Corridor Guidelines, p 6.
31 NSW Riparian Corridor Guidelines, p 6.
32 NSW Riparian Corridor Guidelines, p 8.
33 NSW Riparian Corridor Guidelines, p 9.
34 MUSIC Guideline, p 1.

(a) For locations in NSW where load based targets have been established to assess the performance of a stormwater management strategy,[35] the modeller needs to establish the Treatment Train Effectiveness (TTE) by comparing the pollutant load reductions between 'developed-treated' and 'developed-untreated' conditions.[36] Currently in NSW, many authorities define the base scenario as the developed-untreated condition.[37] The 'pre-development' condition, which is typically say forest or rural land, is only modelled when the relevant water quality targets are referenced to a site condition other than the developed-untreated condition.[38]

(b) Given that the hydrology of highly pervious catchments is complex, where possible data should be obtained so as to check the MUSIC Model hydrological predictions.[39] However, this issue is of significantly less importance if the base scenario used to assess TTE is the 'developed-untreated' condition. In addition, soil properties should be determined from geotechnical soil investigations.[40]

(c) Stormwater pollutant parameters should be based on land-use zoning, where the zoning is translated into MUSIC Model 'source nodes'.[41] The MUSIC Guideline recommends that a 'Forest node' is used for Environmental Protection land-use zones, whereas a 'Residential node' is used for land zoned low to medium density residential.[42]

(d) To simplify large areas of interest, it is appropriate to combine areas with similar characteristics.[43] For example in the case of a subdivision, individual lots could be aggregated, or 'lumped', such that the source node used represents a number of lots with similar characteristics.

(e) The MUSIC Guideline states that construction phase sedimentation basins should be sized using the approaches outlined in The Blue Book[44] produced by Landcom in 2004.

(f) In respect of infiltration systems that are proposed to be incorporated into the WCMS, it is important to evaluate the impacts of infiltrating large volumes of stormwater on downslope areas. Infiltration measures should therefore not be adopted to simulate the loss of large loads of stormwater pollutants. It follows therefore where not sufficiently treated, that recharging groundwater with stormwater can contaminate groundwater environments.[45] Where recharge is proposed, impacts on groundwater quality therefore need to be considered and assessed.

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35 Which is the case in the Shoalhaven Local Government area for zones outside of the Sydney drinking water supply catchments, see SDCP, section 5.2.4 p 15-16.

36 MUSIC Guideline, section 7.1 p 62. For example, a 45% Total Nitrogen reduction target means that at least 45 % of the 'developed-untreated' Total Nitrogen load should be removed in the 'developed-treated' condition.

37 MUSIC Guideline, section 5.1 p 14.

38 MUSIC Guideline, section 1.5.2 p 4.

39 MUSIC Guideline, section 1.4 p 2-3.

40 MUSIC Guideline, section 5.1.3 p 18.

41 MUSIC Guideline, section 5.1.4 p 19 – 21.

42 MUSIC Guideline, section 5.1.4 Table 5-8 p 21.

43 MUSIC Guideline, section 6.1.2 p 32.

44 MUSIC Guideline, section 6.5.6 p 44 - 45.

45 MUSIC Guideline, section 6.5.8 p 47 – 48.

2.7 Shoalhaven Council Development Control Plan

Whilst compliance with the Shoalhaven City Council Development Control Plan (SDCP) is not required, that does not mean that the contents of the SDCP should be ignored. Clearly the SDCP has been prepared for a wide range of development types and sizes and has been tailored based on long-term local knowledge and experience, as well as an understanding of the requirements for sustainable waterway and waterbody management. It follows that the SDCP represents best practice engineering design for the local area, and to ignore the SDCP in its entirety would be inadvisable.

The relevance of the SDCP is echoed in the detailed objectives to which the document subscribes, these including to:[46]

(a) *Manage stormwater flow paths and systems to ensure the safety of people and property.*

(b) *Protect and enhance natural watercourses and their associated ecosystems and ecological processes.*

(c) *Maintain, protect and/or rehabilitate modified watercourses and their associated ecosystems and ecological processes towards a natural state.*

(d) *Mitigate the impacts of development on water quality and quantity.*

(e) *Encourage the reuse of stormwater.*

(f) *Integrate water cycle management measures into the landscape and urban design to maximise amenity.*

(g) *Minimise soil erosion and sedimentation resulting from site disturbing activities.*

(h) *Minimise the potential impacts of development and other associated activities on the aesthetic, recreational, cultural and ecological values of receiving water.*

(i) *Ensure the principles of ecologically sustainable development are applied in consideration of economic, social and environmental values in water cycle management.*

(j) *Ensure stormwater systems and infrastructure are designed, installed and maintained so as not to increase the risk to life or safety or people.*

(k) *Provide Green and Golden Bell Frog friendly stormwater detention ponds in areas where Green and Golden Bell Frog are present.*

(l) *Ensure stormwater systems and infrastructure are appropriately designed and installed to minimise the ongoing maintenance costs as much as possible.*

In terms of specific controls that apply to protecting water quality and quantity in downstream receiving environments, the following are noted:

46 SDCP, section 4 p 3-4.

(a) On-site stormwater detention (OSD) may be required but is not a mandatory requirement.[47]

(b) 50 % of any retention volume can contribute towards any OSD volume required for the development, provided the systems are interconnected.[48]

(c) Stormwater use within public open space (irrigation, street cleaning, public amenities) is encouraged.[49]

(d) Erosion and sediment control should be undertaken in accordance with 'The Blue Book'.[50]

(e) Stormwater retention, that being the storing of water for beneficial re-use, should be provided at a rate of 6 to 10 mm (depending on the type of development) x the increase in impervious development area.[51]

(f) For large scale development: post development pollutant loads are to be minimised so as to not unduly impact on the quality of receiving waterways; and to protect stream stability and habitats by providing retention, infiltration and detention to limit development flows.[52] For developments located outside of Sydney's drinking water supply catchments, pollutant load reductions must achieve the following post development average annual load reductions:[53]

(i)	Gross pollutants (up to 4EY event)	Retention of litter > 40 mm Retain sediment > 0.125mm[54]
(ii)	Total suspended solids	80 %[55]
(iii)	Total phosphorus	45 %[56] / 65% for Lake Wollumboola
(iv)	Total nitrogen	45 %

(g) We note that similar pollutant reduction targets have been effectively implemented by many coastal Councils across most of the State, and therefore represent a *de facto* State standard.

(h) The NorBE Assessment methodology is only required for development within Sydney's drinking water supply catchments.[57]

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47 SDCP, section 5.1.4 p 8.
48 SDCP, section 5.1.4 p 10.
49 SDCP, section 5.2.2 p 13.
50 SDCP, section 5.2.1 p 11.
51 SDCP, section 5.2.2 p 12.
52 SDCP, section 5.2.4 p 14.
53 SDCP, section 5.2.4 p 15-16.
54 These criteria differ from a net reduction target of 90% gross pollutant removal expressed in the previous SDCP commenced on 1 July 2015.
55 This criterion has been reduced from the former target of 85 % as expressed in the previous SDCP commenced on 1 July 2015.
56 This criterion has been reduced from the former target of 65 % as expressed in the previous SDCP commenced on 1 July 2015.
57 SDCP, section 5.2.4 p 14.

(i) A core riparian zone of 40 m plus an additional 10 m vegetated buffer, that being a total 50 m riparian buffer, should be provided to sensitive area watercourses. The riparian buffer must be maintained, restored or rehabilitated using appropriate local species with a range of canopy, understorey and groundcover species to enable a healthy and diverse ecosystem.[58]

The following summary observations are made from the SDCP:

(a) The purpose of SDCP Chapter G2 is to provide guidance to applicants about how to implement sustainable stormwater management in the development application process.[59]

(b) The SDCP provides development controls for a wide range of developments, including 'large scale' projects. These controls have been prepared for a wide range of development types and sizes and have been developed from long-term local knowledge and experience, with the aim of delivering sustainable waterway and waterbody management. It is worth observing that the most recent version of the DCP has relaxed the water quality performance criteria for developments draining into coastal rivers and estuaries compared to the targets expressed in DCP between 2015 to 2019.

(c) The SDCP contains best practice environmental and engineering approaches to stormwater management. It is underpinned by the principles of water sensitive urban design (WSUD), providing the detailed design and management requirements necessary for large scale WSUD to be implemented at developments adjoining waterways and estuaries in the Shoalhaven area. Notably because the implementation detailed of WSUD is largely missing in the more generic state-based guidelines already discussed, the principles provided in the SDCP can, and should in our view, be relied upon for the Project.

2.8 Strategy Objectives

In summary, the following objectives and design criteria can be distilled for the integrated water cycle management Proposal in respect of the Concept Plan:

Objective 1 - Provide Riparian Buffers

A vegetated riparian buffer should be implemented because these serve to protect waterways and estuaries by filtering, trapping and treating sediment, nutrients, pathogens and other contaminants. A 100 m vegetated residential development buffer to the estuary is recommended best practice for reducing the risk to estuarine water quality and oyster aquaculture, noting that the NSW Riparian Corridor Guidelines indicate that significantly smaller buffer of an average of 40 m is acceptable.

Objective 2 - Implement WSUD Principles

Stormwater management systems should be designed on the basis of WSUD principles, including: to manage stormwater at or near its source; to treat stormwater prior to release to the environment; and to

58 SDCP, section 5.3.1 p 20 and 22.
59 SDCP, section 1 p 3.

integrate stormwater management within the built environment so as to improve amenity and reduce potential environmental impacts. The measures can include: rainwater tanks and domestic stormwater re-use; roadside swales and bioretention systems; constructed wetlands; bioretention systems; groundwater infiltration schemes; GPTs; and retention and re-use schemes.

Objective 3 - **Preserve and Protect Wetlands**

Stormwater management systems should be designed such that SEPP 14 coastal wetlands are preserved and protected, although there is some scope for minor modification or disturbance provided that there is no net material ecosystem harm.

Objective 4 - **Maintain OISAS Water Quality Criteria**

Stormwater management systems should be designed such that they do not compromise the achievement of estuarine water quality objectives for oyster aquaculture as recommended by OISAS.

Objective 5 - **Treat Stormwater Prior to Release**

Stormwater management systems should treat stormwater prior to release to a waterway or estuary. The pollutant reduction targets provided in the SDCP are reasonable because they represent current best practice and are designed to ensure that waterway and estuarine water quality is sustainably managed. The SDCP pollutant reduction targets are already applied in all areas within the Shoalhaven, as well as many NSW coastal council areas, except in the Sydney drinking water catchments where the NorBE Assessment methodology is applied. This approach is consistent with the MUSIC Guideline. The NorBE Assessment methodology is useful in that it provides a reference framework within which to compare the SDCP pollutant reduction targets. Satisfaction of the NorBe Assessment criteria would therefore provide a further confirmation of the appropriateness of the proposed stormwater management scheme.

Objective 6 - **Encourage Stormwater Re-use**

Where possible, incorporate stormwater capture and detention to provide for re-use within public spaces and other areas within the development area.

Objective 7 - **Avoid New Piped Stormwater Flows to Estuary**

Stormwater management systems should be designed such that new connections to the Crookhaven River estuary are avoided, or if unavoidable, to be significantly minimised.

Objective 8 - **Reticulated Sewer**

The development should be serviced by a best practice reticulated sewerage system with appropriate detention, remote monitoring and back-up systems to prevent dry weather overflows and minimise any wet-weather overflows in accordance with any Shoalhaven Water Environment Protection Licence obligations. The development should provide for the control and mitigation of any overflows in the event that they occur.

3 Local Environment

3.1 The Development Area

3.1.1 Location and Existing Land Use

The study area is located on the northern side of Culburra Road, West Culburra, within the Shoalhaven City Council local government area (LGA). The study area is located on part of Lot 5 and Lot 6 DP 1065111 and covers approximately 65.6 ha.

The study area is bounded by undeveloped vegetated land to the west and south, Crookhaven River to the north and residential lots to the east. Culburra wastewater treatment plant and an existing industrial area separates the study area into a western and an eastern portion. Existing land cover and use within the investigation area includes forested areas, frequently with limited understorey development (see Diagram 2), active and semi-inactive internal dirt roads (see Diagram 3 and Diagram 4), and a number of areas which have been previously cleared, are presently highly disturbed and impacted by historical cattle access with vegetation in various stages of re-establishment (see for example Diagram 5).

Diagram 2: Example of forested areas within the site with limited understorey.

Diagram 3: Example of active dirt road within the site.

Diagram 4: Example of semi-inactive dirt road and cleared area within the site.

Diagram 5: Example of cleared area within the site.

3.1.2 Climate

Monthly climate statistics for the nearby Nowra Ran Air station (BOM station 068072) are provided in Table 2. Data indicate that the Site experiences a temperate coastal climate with mean daily maximum temperatures ranging between say 17 and 28 degrees.

In terms of rainfall, higher monthly falls tend to occur in late summer and early autumn, but can also occur during winter as extra-tropical lows form off the NSW eastern seaboard. The number of rainy days in any given month is generally uniform, varying between say 8 – 13 days per months, with more frequent rain concurring with higher monthly rainfall totals. Similarly months where heavier rainfalls of > 25 mm/day are more likely occur in February, March and June.

In terms of evapotranspiration, summer rates of around 100 – 110 mm/month are considerably higher than rates during winter and early spring which are typically in the order of 20 mm/month, or some 20 % of summer rates. Rainfall surplus over evapotranspiration is not achieved during the months of October to January, although is likely to vary somewhat between years with temperature and vegetation cover type.

Table 2: Site climate data summary (BOM station 068072).

Month	Mean Maximum Temp (°C)	Mean Rainfall (mm)	Mean Rainy Days	Mean Rainy Days >= 25 mm/day	Mean Monthly ET (mm)[1]
January	27.8	64.2	11.0	0.8	113
February	26.5	145.9	11.8	1.6	84
March	25.3	112.0	12.9	1.1	72
April	22.9	62.9	11.7	0.4	36
May	19.8	47.0	9.1	0.6	21
June	16.9	116.9	12.1	1.2	22
July	16.7	55.6	9.1	0.6	21
August	18.2	65.6	7.9	0.5	20
September	21.1	41.8	8.7	0.2	34
October	23.2	63.5	9.6	0.6	69
November	24.9	72.9	11.6	0.5	94
December	26.3	73.4	10.1	0.7	102
Annual	22.5	871.9	125.6	8.8	688

[1] ET Data sourced from national mapping prepared by BOM.[61]

3.1.3 Topography and Landform

Topography within the Concept Plan area is generally undulating with slopes typically gentle ranging between say 3-8 %, although locally slopes may be slightly steeper or flatter than this range. Topographic contours for the Concept Plan area, as well as the Crookhaven River catchment can be seen at Map 2 and Map 3.

Most of the Concept Plan area is orientated towards the north, forming part of the catchment to the Crookhaven River. A small portion of the Concept Plan is orientated towards the south, forming part of the upper catchment of Lake Wollumboola. This part of the Concept Plan only includes a new roundabout on the existing Culburra road, as well as a link road from the proposed roundabout to new urban land within the Concept Plan area.

3.1.4 Geology

Within the study area, there are two geologies identified by the Wollongong 1:250,000 Geological Map. These can be seen in Map 8 and comprise of the following:

(a) At low elevations, generally land below 10 mAHD, geological units typically include Quaternary deposits (Qal) comprising: alluvium, gravel, swamp deposits and sand dunes.

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[61] Bureau of Meteorology, Average annual and monthly evapotranspiration, http://www.bom.gov.au/jsp/ncc/climate_averages/evapotranspiration/index.jsp.

(b) At higher elevations, generally land above 10 mAHD, local geology is dominated by the Wandrawandian Siltstone formation (Psw), comprising of pebbly siltstones and to poorly sorted pebbly lithic sandstone.

3.1.5 Soil Landscapes

Local soil landscapes are documented in the Kiama 1:100,000 Soil Landscape Sheet,[62] with an extract containing the Concept Plan area provided in Map 9. Three soil landscapes occur within the local area:

(a) *Seven Mile (sm) soil landscape* – this occurring at low elevations of generally < 10 mAHD and comprising of a series of dune ridges and swales, swamps and lagoons on Quarternary marine sands.

(b) *Mangrove Creek (mc) soil landscape* – this occurring at low elevations of generally < 10 mAHD along foreshore areas, and comprising of vegetated tidal flats in estuarine areas on Holocene sediments.

(c) *Greenwell Point (gp) soil landscape* – this occurring at higher elevations, typically in association with the Wandrawandian Siltstone formation, and comprising of structured silty to sandy loams overlying sandy clays grading to medium clays at depth.

3.1.6 Surface Water Systems

3.1.6.1 Surface Water Catchments

The Concept Plan area falls into two catchments

(a) *Crookhaven River Catchment* – the Concept Plan area is almost exclusively contained within this catchment. Drainage consists of two broad sub-catchments separated by land owned by Council which contains the Culburra sewage treatment works. The western development area drains to a part of the Crookhaven River estuary known as Billys Island. The eastern part of the development area drains to a part of the Crookhaven River estuary known as Curleys Bay.

(b) *Lake Wollumboola Catchment* – the Concept Plan does not include any substantive development in the catchment draining to the Lake. The only portions of the Concept Plan that drain to the Lake Wollumboola Catchment include the proposed roundabout on Culburra Road, and the short link road that will come from the northern side of the proposed roundabout and will be used to access the western portion of the Concept Plan area. These areas drain to a small northern Lake catchment at a point around 1.2 km from the Lake.

3.1.6.2 Watercourses and Drainage

Whilst the Crookhaven River lies to the north of the Concept Plan area, there are no identified watercourses actually located within the Concept Plan area.

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62 Hazelton, P.A. (1992) Soil Landscapes of the Kiama 1:100,000 sheet, NSW Department of Conservation and Land Management.

Existing site drainage consists of broad overland flow paths, as well as some areas where due to the arrangement of convex topography, overland flows converge to form more concentrated overland flow paths. Surface runoff is therefore rainfall driven, occurring either during heavy and extended rainfall, or perhaps during lighter rainfall when soils are temporarily saturated from antecedent heavy or prolonged rainfall.

3.1.6.3 Surface Water Quality

There are no formal surface water monitoring locations within the Concept Plan area, either operated by Council or any other government authority. This is not unexpected or unusual given the relatively small size of the local drainage catchments and the lack of any identified watercourses within the Concept Plan area. To the west and east of the Concept Plan area, topography is not dissimilar from that observed on the proposed development site, and for that reason no watercourses can be found in these areas.

In order to develop an understanding of the quality of local surface water currently discharging into the Crookhaven River estuary, a number of sampling locations were established in the local area, these being shown on Map 7. In total, 10 monitoring sites, locations A to J, were established so as to cover urban, agricultural and vegetated or 'forested' land cover types. Monitoring was undertaken between 29 November 2018 to 14 July 2020, however the number of sampling events was significantly restricted due to the low rainfall during much of this period and the difficulty in obtaining sufficient representative water sample volumes. Locations E and F were not able to be sampled due to insufficient surface water being collected at these locations.

Sampling location details are provided in Table 3. A summary of the surface water quality data collected is provided in Table 4, with laboratory data provided at Annexure M.

Table 3: Surface water sampling location details.

Sample Location	Representative Catchment Type	Number of Observations
A	Forest[1]	6
B	Forest	6
C	Urban	6
D	Urban	6
E	N/A	0
F	N/A	0
G	Agricultural	7
H	Urban	3
I	Forest	3
J	Forest	2

[1] The 'Forest' sampling sites included areas where various vegetation covers dominated.

Table 4: Surface water sampling data summary (average values) for catchment type.

Parameter	Urban	Agricultural	Forest
TSS (mg/L)	12.9	26.8	20.3
TP (mg/L)	0.089	0.058	0.046
TN (mg/L)	1.769	1.900	1.247
Salinity (μS/cm)	1,543	1,854	342
Salinity (mg/L calculated)	988	1,186	219
Iron (mg/L)	1.086	4.757	1.505
Aluminium (mg/L)	0.809	2.380	2.418
Copper (mg/L)	0.010	0.005	0.003
Faecal Coliforms (CFU/100ml)	7,050	2,253	2,829

In respect of the monitored surface water quality data, the following general observations are made:

(a) It is worth noting that whilst there were three urban catchment sites and four forested catchment sites, there was only one catchment which could be categorised as agricultural.

(b) Whilst urban areas tended to have higher phosphorus concentrations, nitrogen concentrations were broadly similar between catchments.

(c) Higher salinity levels were observed in the urban and agricultural areas. These are attributed to the site's coastal location and propensity for salt deposition and wash off from areas with less vegetative cover.

(d) Iron and aluminium levels in urban runoff were typically lower than that observed in runoff sourced from forested areas. However, copper levels were slightly elevated in urban areas, although not significantly above the levels observed in the agricultural catchment.

(e) Faecal Coliform levels were highest in urban runoff compared to agricultural and forest runoff. Interestingly though, forest runoff maintained elevated Faecal Coliform levels, higher than those observed in the agricultural catchment, indicating that local wildlife materially contributes to bacteriological levels within surface runoff entering the Crookhaven River estuary.

3.1.6.4 Surface Water Access Licences

We have undertaken a search of the water access licenses (WALs) register administered by the Natural Resources Access Regulator (NRAR) pursuant to the *Water Management Act 2000*. The following search results were found:

(a) Lot 5 DP 1065111 No records found (the Concept Plan area)

(b) Lot 6 DP 1065111 No records found (the Concept Plan area)

(c) Lot 1 DP 631825 No records found (Council sewage works land)

(d) Lot 2 DP 836137 No records found (nearby industrial land)

(e) Lot 6 DP 880627 No records found (nearby industrial land)

(f) SP 70423 No records found (nearby industrial land)

(g) SP 39522 No records found (nearby industrial land)

(h) Lot 1 DP 226779 No records found (nearby industrial land)

(i) Lot 12 DP 788445 No records found (residential land to the south)

(j) Lot 4 DP 631825 No records found (residential land to the south)

(k) Lot 6 DP 825697 No records found (residential land to the south)

On this basis we conclude that there are no active WALs within the Concept Plan area and that there are no significant nearby licenced water users that would be affected by the Proposal.

3.1.7 Groundwater Systems

3.1.7.1 Overview

Within the Concept Plan and surrounding areas, groundwater systems can be described as generally unconfined low yielding, low permeability and poor quality[63] due to local geology and small catchments with relatively low recharge capacity. Groundwater levels typically mimic surface topography, with shallower groundwater being found near the estuary, becoming deeper within distance inland.

3.1.7.2 Groundwater Licences

There are currently no groundwater bores within the Concept Plan area or within 250 m of the Concept Plan which are licenced for water abstraction purposes. Existing groundwater users are therefore not expected to be affected by the Proposal.

3.2 The Crookhaven River and Estuary

3.2.1 Catchment and Estuarine Characteristics

The Crookhaven River and its catchment flow generally from the west to the east, draining into the lower Crookhaven River estuary (the Estuary). In addition to incoming flows from the Shoalhaven River and the Ocean, contributing catchment area to the Estuary is more than 70 km^2, whilst the Estuary maintains a surface area in the order of 2.5 – 3.0 km^2 depending on where this is assessed (see Map 2).

The Crookhaven River floodplain represents much of the total contributing catchment area, this being defined by low relief flat alluvial plains located centrally and within the northern portions of the catchment. Higher elevations occur along the southern and eastern portions of the catchment (Map 3).

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63 See Section 5.4.8.

A variety of land-uses occur within the catchment as follows (see Map 4):

(a) Agricultural activities dominate the expansive floodplain areas in the northern portion of the catchment, occupying approximately 30 % of the entire catchment area.

(b) Urban areas are primarily consolidated in the western upper reaches of the catchment, occupying approximately some 7 % of the total catchment area. Rural-residential land-uses are more scattered and located east of the main urban areas, occupying a further 5 % of the total catchment area.

(c) Forested areas are primarily located within the steeper southern portions of the catchment, occupying some 40 % of the catchment.

(d) The balance 18-20% of the catchment is comprised of ancillary land uses, other vegetation and open water.

It is worth observing that the drainage regime within low lying agricultural portions of the floodplain have been substantially altered through an extensive network of constructed drains. These drains extend for many kilometres across the floodplain and have served to permanently lower local water tables, thereby drying soil profiles and providing for increased soil moisture retention. It is unnecessary and beyond the scope of this report to provide further analysis in respect of the artificial drainage network, suffice to say that this has caused a historical modification to the natural drainage regime and thus hydrology of the Estuary.

An important aspect of the Crookhaven River drainage system is that the southern arm of the River is controlled by a major flood gate located under Culburra Road (see Map 1 for location). The flood gate functions to contain freshwater flows in the southern arm of the catchment until such times that the flood gates are open, thereby releasing considerable freshwater 'flushes' through the Estuary. When the flood gates are closed, the effective tidal prism is reduced, thereby improving salt water cycling through the Estuary.

Previous hydrodynamic modelling of the Estuary has indicated that the Estuary is well flushed with salt water due the close proximity of the Crookhaven River heads. Water within the lower Estuary is near fully flushed with oceanic water on say a 1-2 day basis.[64] Spring tides range between a low of -0.547 mAHD and a high of 0.483, with a mean Spring inter-tidal range of 1.03 m.[65]

A number of SEPP 14 wetlands have been mapped to occur within the Estuary (see Map 5), with some of these adjoining the northern boundary of the Concept Plan area. It is noted that the Proposal includes a 100 m vegetated setback to these wetlands, this exceeding the 40 m setback recommended in the NSW Riparian Corridor Guidelines.

64 Estuary Process Study.
65 Estuary Process Study, p 18.

3.2.2 Estuarine Water Quality

3.2.2.1 Council Routine Monitoring

The Crookhaven River and Shoalhaven River estuaries have been the subject of a relatively extensive water quality monitoring program undertaken by Shoalhaven City Council. That data is publicly available through the Aqua Data website.[66] We have reviewed these data for a number of locations within both estuaries, with the monitoring locations considered being shown in Map 7 and more detailed monitoring summaries at each location provided at Annexure N.

Water quality data for estuary monitoring sites is summarised in Table 5. The following commentary is offered:

(a) Median nutrient levels are within levels expected for a south eastern Australian lowland river and estuary system. Nutrient levels in the Crookhaven are slightly higher than those found in the Shoalhaven.

(b) Very limited Aluminium water quality data were available, including only six samples collected in 1992. Whilst the available data suggest elevated aluminium levels, our view given the very limited testing regime is that these data are unreliable.

(c) Faecal Coliform levels in the estuary are generally low and within acceptable criteria. Several 'spike' levels were noted in the available data set.

Table 5: Median river water quality data.[1]

Location	TN (mg/L)	TP (mg/L)	TSS (mg/L)	Aluminium (mg/L)	Faecal Coliforms (CFU/100mL)
Entire Estuary	0.280	0.030	33	0.45	16
Crookhaven River	0.425	0.035	na	0.47	5
Shoalhaven River	0.250	0.030	33	0.20	20

1. Lower Shoalhaven and Crookhaven River systems, based on Shoalhaven City Council monitoring data.

3.2.2.2 MA Water Quality Sampling

To supplement Council's water quality monitoring data, further sampling was undertaken at five locations within the Crookhaven Estuary between 3 October 2019 and 19 March 2020. Sampling locations are provided in Map 7, with a summary of results provided in Table 6 and laboratory reports provided at Annexure O.

Table 6: Median water quality data for recent Crookhaven River sampling.[1]

Location	TN (mg/L)	TP (mg/L)	TSS (mg/L)	Aluminium (mg/L)	Faecal Coliforms (CFU/100mL)
Crookhaven River	0.300	0.008	na	< 0.010	5

1. Based on sampling undertaken between October 2019 and March 2020.

66 https://shoalhaven.nsw.gov.au/Environment/Aqua-Data.

3.2.2.3 Comparison of Water Quality Datasets

Estuarine water quality data collected during late 2019 and early 2020 are generally comparable to that found in Council's long-term monitoring of the Estuary. Significantly, median aluminium levels are much lower than results obtained by Council during the limited sampling in 1992, with levels typically <10 ug/L in accordance with the OISAS guidelines.

At Diagram 6, Diagram 7, Diagram 8 and Diagram 9, observed TN, TP, Aluminium and Faecal Coliforms surface water concentrations are compared to Council's long-term monitoring data. Each comparison plot includes minimum, maximum, interquartile, median and mean (shown as 'x') of the observed data. We note that the surface water data was collected over a relatively brief period whereas the Council data represents a significantly larger data set. Notwithstanding this, the following is observed:

(a) Total nitrogen (TN) interquartile ranges for all surface runoff types are higher than those found in the estuary. This indicates that processes such as assimilation and tidal cycling and mixing are very effective in reducing nitrogen loads received from the catchment. Higher absolute maximum observation concentrations found in Council's data reflect 'spikes' found in the long-term monitoring.

(b) Total phosphorus (TP) interquartile ranges for urban runoff types are higher than for other land cover types and the Estuary, this not being unexpected given that there are multiple possible phosphate sources within urban areas. Higher absolute maximum observation concentrations found in Council's estuarine data reflect 'spikes' found in the long-term monitoring that are likely associated with larger catchment runoff events.

(c) Aluminium interquartile ranges are highest in runoff from agricultural and forested areas, with urban areas being similar to levels found in the Estuary. This indicates that urban runoff is unlikely to materially affect estuarine aluminium levels. We reiterate that the estuarine aluminium levels plotted are not considered reliable.

(d) Whilst no Iron water quality data were available for the Estuary, we expect that Iron concentrations in surface runoff would be in similar proportions to those found for aluminium. Urban runoff would therefore not likely impact on Iron levels within the Estuary.

(e) Catchment surface runoff Faecal Coliform interquartile ranges are significantly higher than those reported for the Estuary, this reflecting the sanitising effect of a large body of salt water. Higher 'spike' levels were however evident in Council's monitoring data which fall in the range of surface runoff. It is worth noting that the observations for forest runoff are not too dissimilar from that found in urban runoff, indicating that wildlife may contribute significantly to pathogen loads to the Estuary.

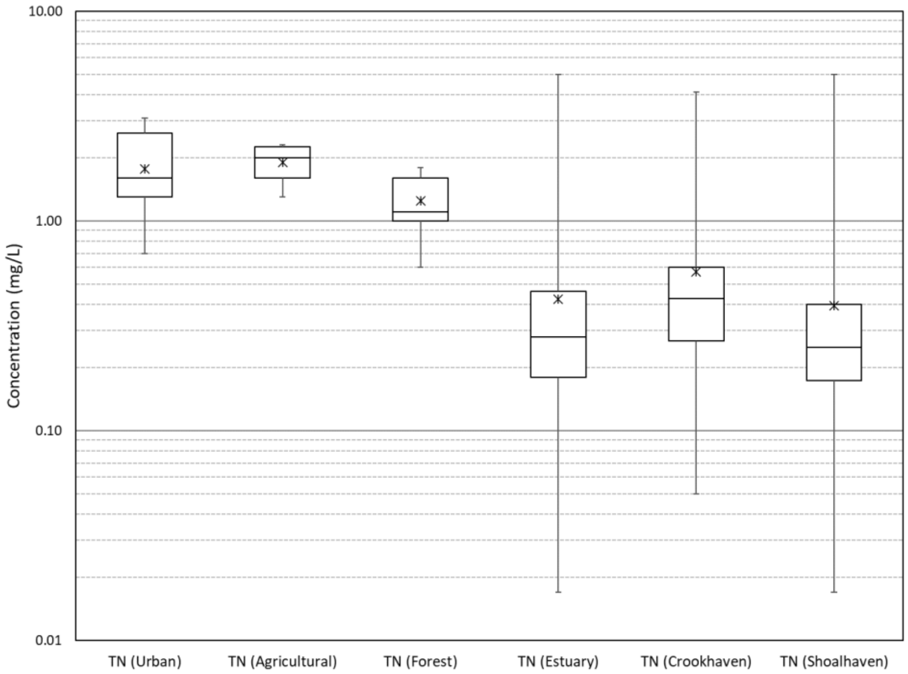

Diagram 6: Total nitrogen (TN) box-whisker comparisons between observed surface runoff and estuary concentrations.

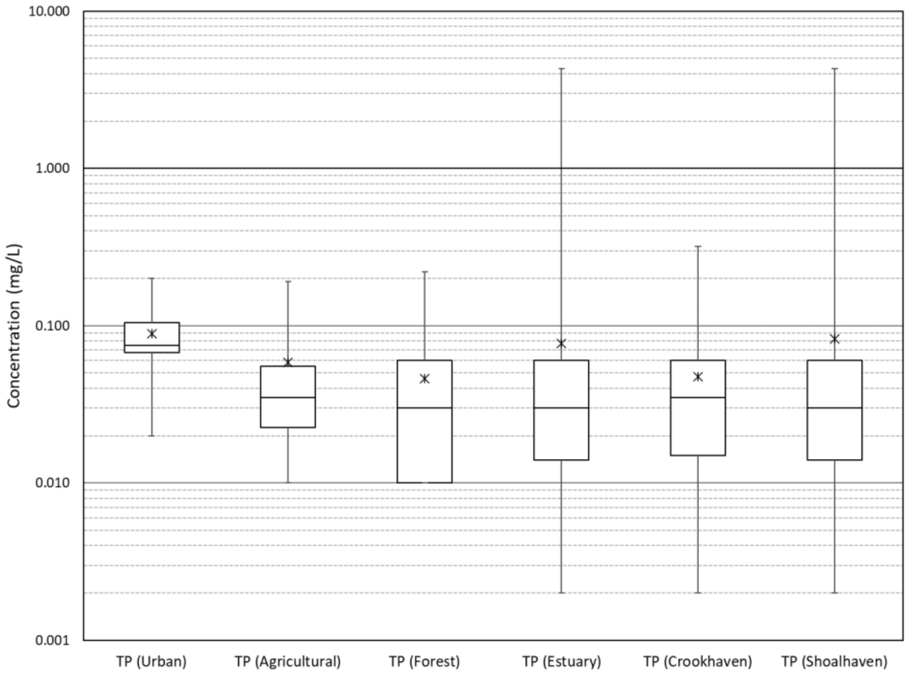

Diagram 7: Total phosphorus (TP) box-whisker plots of observed surface runoff and estuary concentrations.

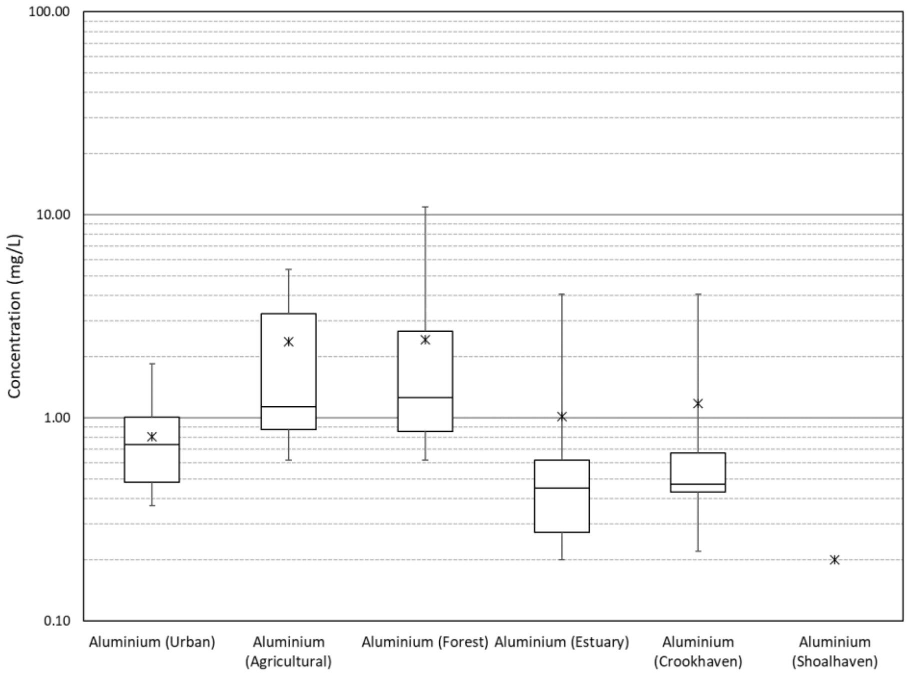

Diagram 8: Aluminium box-whisker plots of observed surface runoff and estuary concentrations.

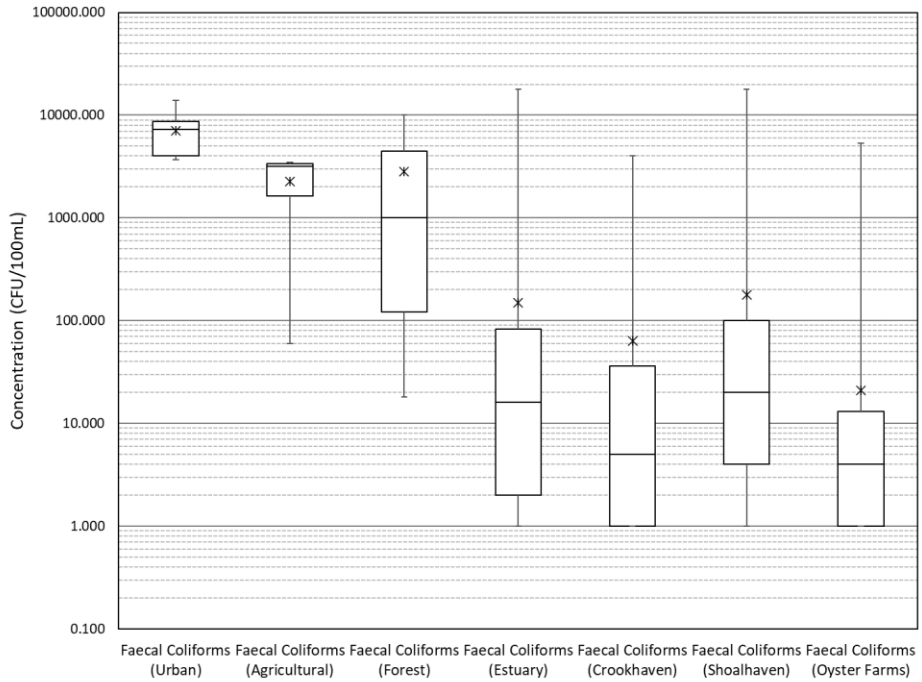

Diagram 9: Faecal Coliform (FC) box-whisker plots of observed surface runoff and estuary concentrations.

3.2.3 Water Quality Commentary

It is worth observing that a significant proportion of the water received into the Estuary is sourced from the Shoalhaven River. This means that to some extent the quality of water in the Estuary is a function of water quality in the Shoalhaven River. Factors that affect water quality in the Shoalhaven River are complex, but can be summarised as: runoff during rainfall events; overflows from sewage pumping stations within the catchment; fresh water releases from Tallowa Dam;[67] and water releases from the Crookhaven River flood gate located on the southern arm of the River under Culburra Road (see Map 2 for location).

Under existing conditions, approximately 205 ha of residential land drains directly into the Estuary. This is comprised of a number of significant residential areas including:

(a) Some 65 ha draining from Greenwell Point.

(b) Some 40 ha draining from Orient Point.

(c) Some 100 ha draining from Culburra Beach.

Significantly, no formal stormwater treatment infrastructure has been installed within any of the villages in order to improve the quality of stormwater discharging into the Estuary. In some places limited historically constructed grass swales are used for road side drainage, however, these ultimately generally discharge to open drains or piped systems and then to the Estuary without any control of sediment, dissolved pollutants or gross pollutants.

The following further commentary is provided in respect of existing water quality in the Estuary:

(a) Median nutrient concentrations are typically at or below ANZECC Guideline trigger levels for lowland rivers and estuaries, although these levels are variable and are exceeded at times indicating that nutrient stressed conditions can occur within the Estuary. Notably the ANZECC Guidelines do not provide trigger levels for wetlands. Further, OISAS contains no recommendations in respect of desirable nutrient concentrations for Oyster growing areas.

(b) Typical salinity levels within the Estuary range between 25 – 30 g/L, somewhat below full sea water conditions,[68] but well within the range recommended by OISAS. However, salinity levels fluctuate considerably due to the influx of fresh water both from the Crookhaven River catchment, but also from the Shoalhaven River system. Estuary salinity levels can fall below the lower bound of 20 g/L required for optimal growth due to extended and heavy catchment rainfall-runoff events. Such events are however natural phenomena and part of the inherent environmental variability of the Estuary ecosystem.

(c) Based on Council's long-term water quality monitoring in the Estuary, median faecal coliform levels are very low, and fall generally in the range of < 30 CFU/100 mL, below the upper OISAS recommended levels. However, at infrequent times faecal coliforms have spiked between 500 to > 5,000 CFU/100 mL, indicating that the Estuary at times will be closed from Oyster production.

(d) There are limited water sampling data available for either aluminium or iron levels with the Estuary as these elements do not form part of Council's routine River and

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67 Tallowa Dam is located on the Shoalhaven River approximately 70 km upstream of the Estuary.

68 Estuary Process Study.

Estuary water quality monitoring program. It can be taken from this that Aluminium and Iron levels are not a present water quality concern for the Estuary.

3.2.4 Local Oyster Industry

3.2.4.1 Production Overview

The oyster industry in the Estuary cultivates Sydney Rock Oysters (*Saccostrea glomerate*) and Pacific Oysters (*Crassostrea gigas*). In the 2018/19 financial year, the Estuary produced some 263,539 dozen of Sydney Rock Oysters and 3,592 dozen of Pacific Oysters. Together the worth at the farm gate is $2,288,352, which is approximately 4% of NSW oyster industry.[69]

To reduce the level of certain pathogenic organisms that may lead to food safety concerns, most oysters require depuration before sale. A depuration plant provides a controlled environment in which oysters spend the final 36 hours before sale in high quality water, allowing any possible contaminants to be removed by purging.[70] Oysters which can be harvested from areas with exceptional water quality are classified as 'Approved' under Australian Shellfish Quality Assurance Program (ASQAP) do not require depuration.[71]

3.2.4.2 Management Framework of Harvest Areas

The NSW Department of Primary Industries identifies areas within NSW estuaries where oyster aquaculture is suitable with consideration of navigation, conservation, heritage, public health safety, fishing and recreational activities.[72]

The NSW Food Authority is responsible for licencing the oyster aquaculture industry, classifying harvest areas, specifying and enforcing harvest area management plans. Each plan is based on food safety and local environmental risk factors of the harvest area. [73]

A total of 108.6 ha of the estuary is presently designated as suitable for oyster aquaculture and is classified into three harvest areas. Locations of harvest areas and current oyster leases are shown on Map 6.

Current triggers for closure of harvest areas in the Estuary are summarised in Table 7. To reopen a harvest area, water and shellfish samples are analysed in a laboratory after rainfall has ceased and salinity has recovered. Formal instructions of closure and reopening of the harvest area are issued by the NSW Food Authority (2018 data).

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69 Aquaculture Production Report 2018-2019, NSW Department of Primary Industries.
70 https://www.dpi.nsw.gov.au/fishing/aquaculture/publications/oysters/oyster-industry-in-nsw
71 The Australian Shellfish Quality Assurance Program Operations Manual, Australian Shellfish Quality Assurance Advisory Committee, 2019
72 NSW Oyster Industry Sustainable Aquaculture Strategy 2016, NSW Department of Primary Industries.
73 https://www.foodauthority.nsw.gov.au/industry/shellfish

Table 7: Closure triggers for harvest areas in Crookhaven River estuary.

Harvest Area	Direct Harvest	Harvest and Depuration	Closed [3]
Goodnight Island	Rainfall[1] < 40mm in 48 hrs AND Rainfall < 60mm in 7 days AND Salinity[2] > 26 ppt	Rainfall in 48 hrs between 40 and 50mm AND Salinity > 22 ppt	Rainfall > 50mm in 48hrs OR Salinity < 19ppt
Curleys Bay	Not allowed	Rainfall < 40mm in 48hrs AND Salinity > 22 ppt	Rainfall > 40mm in 48hrs OR Salinity < 22 ppt
Crookhaven River	Not allowed	Rainfall < 40mm in 48hrs AND Salinity > 19 ppt	Rainfall > 40mm in 48hrs OR Salinity < 19ppt

[1] Rainfall is measured at BOM Greenwell Point (568180).

[2] Salinity is measured at designated water sampling sites.

[3] Closure is confirmed by lab results of faecal coliform in water sample and E-coli in shellfish sample.

3.2.4.3 Operating History

Recorded harvest area closures are summarised in Table 8. On average Curleys Bay and Crookhaven River harvest areas are closed for over 5 months per year. By contrast, each year the Goodnight Island harvest area experiences 3 months of closure and 1 month of mandatory depuration since the commencement of direct harvest. Causes and length of closure are shown in Diagram 10. The majority of closures are caused by rainfall exceeding the trigger level.

Table 8: Summary of closure days by harvest area (2010-2019).[74]

Harvest Area	Goodnight Island		Curleys Bay	Crookhaven River
Year	Days of closure	Days required depuration[1]	Days of closure	Days of closure
2010	86	-	141	188
2011	70	-	150	177
2012	59	-	93	131
2013	136	-	198	193
2014	103	-	195	126
2015	108	0	184	185
2016	114	1	295	195
2017	100	87	250	217
2018	51	18	51	58
2019	53	46	76	70
Average	88	30	163	154

[1] Days required depurations are counted since September 2015 when reclassification of Goodnight Island Harvest Area allow the direct harvest and sale of shellfish.

74 Zone status history, NSW Food Authority, 2020.

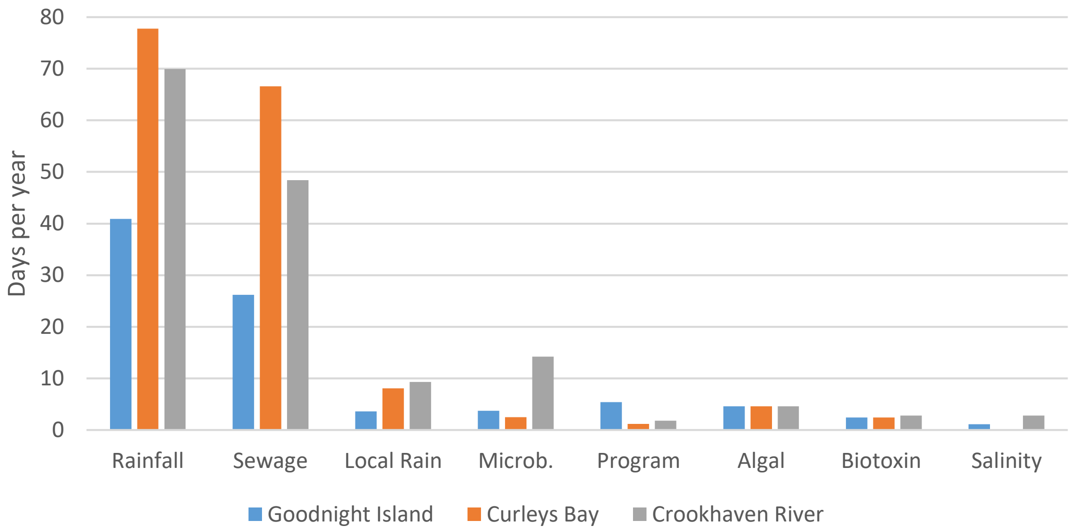

Diagram 10: Summary of Estuary oyster harvest area closures.

3.3 Lake Wollumboola

3.3.1 Catchment and Lake Characteristics

Lake Wollumboola is a shallow depth Intermittently Closed and Open Lake or Lagoon (ICOLL) that lies south of the Crookhaven River Estuary. Catchment area draining to the Lake is approximately 30-40 km^2, with flows arriving generally from the west and south. The Lake maintains a surface area in the order of 5-6 km^2, being almost double the size of the Crookhaven River Estuary. Estuary volume has been estimated at 4,979.3 ML. [75]

A number of east draining watercourses flow to Lake Wollumboola, the primary of these being Coonemia Creek which drain much of the western portion of the catchment. Closer to the Lake, Irrayadda and Wollong Creek drain central and northern portions of the catchment. In addition to these named watercourses, a number of minor unnamed watercourses flow into the Lake around its perimeter.

A variety of land-uses occur within the Lake's catchment including:

(a) In the order of 1-1.5 km^2 of land, or approximately 4.5% has been cleared or partly cleared for agricultural uses, much of this being located closer to the Lake.

(b) In the order of 1 km^2 of urban land, or approximately 3.5 %, within the Culburra Beach village to the north drains directly to the Lake.

(c) There is a Council operated waste depot, covering approximately 1 ha, situated within the catchment.

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75 Lake Wollumboola Estuary – Estuary Ecosystem Heal Report Card 2010-2011, Shoalhaven City Council, https://www.shoalhaven.nsw.gov.au/soe/Region/Indicator%20Results%2012/Estuary%20Health%20Report%20Card%20Wollumboola.htm.

(d) There are numerous sealed and unsealed roads within the Lake's catchment. Major roads within the catchment include Culburra Road and Coonemia Road, both of which are sealed major local transport routes.

(e) The balance of the catchment is largely vegetated.

It is worth observing that due to the naturally intermittently closed nature of the Lakes entrance, water levels within the Lake may fluctuate significantly throughout the year. During periods of heavy and extended rainfall, when the Lake's entrance is closed, incoming surface runoff can cause Lake water levels to rise considerably above mean sea level.

A number of SEPP 14 wetlands have been mapped to occur within the Lake (see Map 5), although these are located at a considerable distance of many hundreds of metres from the Project site, well in excess of the 40 m setback recommended in the NSW Riparian Corridor Guidelines.

3.3.2 Water Quality

There is considerable natural variation in water quality within the Lake in response to varying lake water levels,[76] as well as varying entrance conditions which control the proportion of saltwater contained in the Lake.

A variety of water sources contribute to water quality within the Lake including:

(a) Urban runoff from Culburra Beach is presently discharged directly into the Lake without any material stormwater treatment.

(b) A limited volume of unmanaged agricultural runoff supplies the Lake.

(c) Untreated runoff from a number of roads within the catchment also discharges to the Lake.

Existing water quality in the Lake has been monitored for a number of years by Shoalhaven City Council[77] with the following noted:

(a) Nutrient levels can vary considerably. Between 2008-2012, total phosphorus levels ranged up to around 0.07 mg/L, but were generally less than 0.03 mg/L. Nitrogen levels were typically over 0.5 mg/L, although levels as high as 2.5 mg/L have been recorded.

(b) Faecal coliform levels were highly variable, although generally less than 150 CFU/100 mL, this being the threshold for swimming.[78] On two monitoring occasions faecal coliforms reached between 30 – 400 CFU/100 mL.

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[76] Lake Wollumboola Estuary – Estuary Ecosystem Heal Report Card 2010-2011, Shoalhaven City Council, https://www.shoalhaven.nsw.gov.au/soe/Region/Indicator%20Results%2012/Estuary%20Health%20Report%20Card%20Wollumboola.htm.

[77] https://www.shoalhaven.nsw.gov.au/soe/Region/Indicator%20Results%2012/Surfacewaterqualitylakewoolumboola%2012.htm.

[78] ANZECC Guideline Table 5.2.2, p 5 - 3.

4 Stormwater Management Plan

4.1 Overview

The stormwater management proposal for the Concept Plan uses a combination of 'at-source' and 'end-of-line' controls to ensure the adopted objectives are satisfied. The industry standard water quality modelling software package (MUSIC) was used to analyse the performance of the proposed stormwater treatment train. Modelling was undertaken generally in accordance with the NSW MUSIC Modelling Guidelines (2015). In order to better represent site parameters, calibration of the MUSIC model was undertaken based on site soil data (soil calibration) and recharge rates obtained from the groundwater model (groundwater calibration).

The general arrangement of the stormwater management scheme is shown in Diagram 11, noting that small parts of the site are not serviced by the stormwater ponds and a secondary bioretention basin.

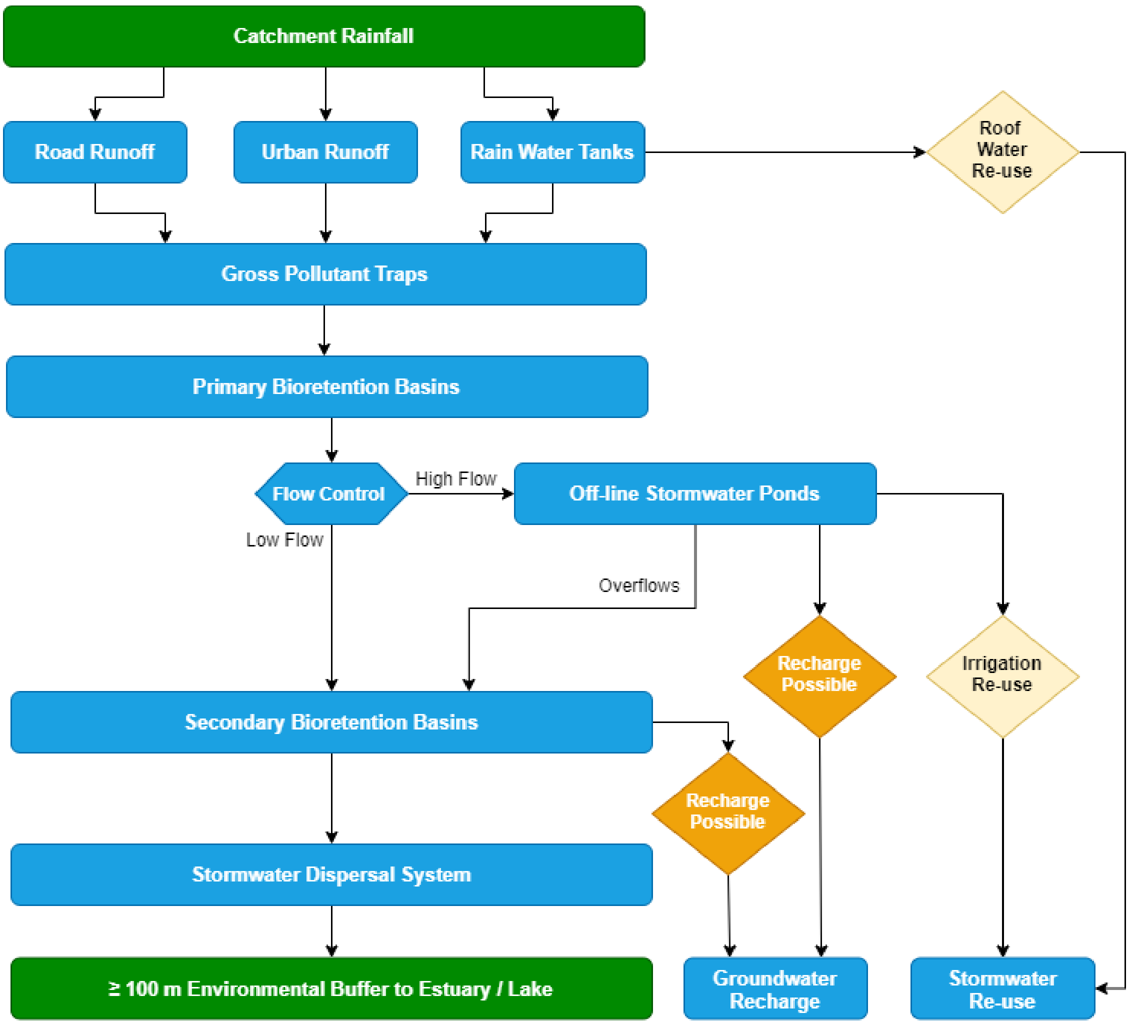

Diagram 11: Stormwater management scheme for the Concept Plan.

Notable elements include the following:

(a) Implementation of WSUD devices such as rainwater tanks and gross pollutant traps throughout the catchment to reduce runoff volumes and treat water quality.

(b) Construction of primary and secondary bioretention basins to treat stormwater runoff through filtration, evapotranspiration and detention.

(c) Higher flows are diverted to stormwater ponds which provide for management and reduction of stormwater flows released to the Estuary buffer area, storage of stormwater for irrigation of local parks and sports fields, and retention of stormwater to assist in pathogen deactivation and control.

(d) A stormwater dispersal system so that flows released from the bioretention basins are spread as broad overland flow rather than concentrated flows.

4.2 Stormwater System Elements

The following sections provide descriptions of each of the elements of the stormwater management system.

4.2.1 Rainwater Tanks

Rainwater capture and re-use from roof runoff has been incorporated into the Concept Plan proposal. Assumptions used for modelling purposes are provided in Table 9.

Table 9: Rainwater tank assumptions used in MUSIC modelling.

Type	Provision	End Use(s)	Equivalent Tenement[1]
Residential /commercial development	5 KL tank / lot	Toilet flushing, laundry and outdoor irrigation	1 ET / dwelling
Industrial development	15 KL tank / lot	Toilet flushing, internal industrial uses and outdoor irrigation	15 ET / gross ha

1. 1 ET = 200 kL/year.

Internal water use, being uses such as toilet and laundry, was assumed to be 44% of the total water demand,[79] this equating to 0.265 kL/day/ET. External water usage demands assumed the following:[80]

(a) 55.115 kL/yr/dwelling for individual dwellings.

(b) 32.12 kL/yr/lot for multi-residential dwellings / mixed use lots.

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79 Refer to NSW Department of Water and Energy (DWE) (2008) '*NSW Guidelines for Greywater Reuse in Sewered, Single Household Residential Premises*'.

80 Refer to the MUSIC Guidelines.

4.2.2 Gross Pollutant Traps (GPTs)

Seven Gross Pollutant Traps (GPT, HumeGard or equivalent) have been included in the stormwater treatment train, to be located upstream of stormwater treatment structures. System specification, sizing, and removal efficiency of the GPTs are provided by the manufacturer.[81] Refer to Table 10 for locations and Annexure G for further details.

Table 10: GPT treatment measures included in MUSIC modelling.

GPT ID	Location
1	Upstream of Primary Biobasin 1
2	Upstream of Primary Biobasin 2
3	Upstream of Primary Biobasin 3
4	Upstream of Pond 3
5	Upstream of Pond 2
6	Upstream of Primary Biobasin 6
7	Upstream of Secondary Biobasin E

4.2.3 Bioretention Basins

Bioretention basins (Biobasins) provide a key water quality management element in the stormwater management strategy. Several primary and secondary Biobasins have been proposed at various locations within the Concept Plan area.

Stormwater runoff from the proposed development will be conveyed by way of a pit and pipe network to primary Biobasins located typically within proposed road reserves. Secondary Biobasins have been incorporated within proposed parkland areas to provide supplementary treatment prior to dispersal. They provide significant stormwater treatment through media filtration, detention and some biological uptake of nutrients.

The preference is to allow secondary Biobasins to be semi-permeable (with a nominal exfiltration rate of 0.25 mm/hr), to enable some potential groundwater recharge of stormwater within the Concept Plan area subject to groundwater impact considerations. Whilst this is however not essential to the stormwater management scheme, it in our view represents good practice and is consistent with WSUD principles. The Biobasin located within the Lake Wollumboola catchment is however proposed to maintain a fully impermeable liner given the more sensitive nature of the catchment.

A summary of the proposed Biobasins is provided in Table 11 with full details provided in Annexure G.

81 Refer to HumeGard® GPT Technical manual Issue 5 (2020).

Table 11: Biobasin treatment measures included in MUSIC modelling.

Biobasin ID	Primary or Secondary	Base Area (m^2)	Area Serviced
1	Primary	250	Residential
2	Primary	300	Residential
3	Primary	250	Residential
6	Primary	500	Residential, commercial, industrial
7	Primary	840	Access road and roundabout that drains into Lake Wollumboola
A	Secondary	6,000	Residential
B	Secondary	3,000	Residential, commercial, industrial, park, carpark
C	Secondary	2,000	Industrial, park
D	Secondary	250	Industrial

4.2.4 Stormwater Ponds

Three offline stormwater ponds (Ponds) have been integrated into the stormwater management strategy. In sub-catchments serviced by ponds, stormwater generated by the development within the Crookhaven River catchment portion of the Concept Plan (with exception of Lot 301 and 302) will be conveyed to flow control structures upslope the ponds. Flow control will divert high flows to the pond and low flows to a bioretention basin. The ponds have been included in the stormwater scheme for a number of key purposes:

(a) Increased Hydraulic Retention Time - To provide for increased hydraulic retention time within the stormwater system so as to reduce pathogens potentially contained within urban runoff.

(b) Stormwater Re-use - To enable urban runoff to be efficiently captured so that it can be beneficially re-used for irrigation purposes within parks and sports fields incorporated into the Concept Plan.

(c) Stormwater Retention and Detention - To enable urban runoff to be retained and detained so as to reduce the frequency of stormwater flow generation and reduce the rate of stormwater release.

Preliminary specifications for ponds are provided in Table 12 with full details provided in Annexure G.

Table 12: Preliminary specification of ponds.

Pond ID	Minimum Inflow Threshold (L/s)	Minimum Surface Area (m^2)	Extended Detention Depth (m)	Permanent Pool Volume (m^3)
1	20	3,500	2	10,500
2	10	2,500	2	7,500
3	10	1,000	2	3,000

4.2.5 Re-use via Landscape Irrigation

Significant parks and open space land are proposed as part of the Concept Plan, this including:

(a) A 2.5 ha sporting fields area adjoining proposed mixed-use urban areas in the eastern part of the Concept Plan area.

(b) A 1.0 ha and a 0.13 ha open parkland area located along the northern boundary of the western residential portion of the Concept Plan area.

(c) A 1.7 ha open parkland area located between the western residential and industrial areas.

(d) A 0.7 ha open parkland area located between the eastern industrial area and the medium density lots.

These areas will be irrigated by stormwater captured in the Ponds. In order to estimate a reasonable irrigation demand rate, a literature review was undertaken for a range of similar end uses. As part of this process, Shoalhaven Council was contacted for their advice in respect of likely irrigation rates for parks or sports fields that are irrigated by Council. Results of these investigations are provided in Table 13 and Table 14, with a copy of the advice provided by Shoalhaven Council replicated in Annexure F.

Table 13: Review of landscape and sporting field irrigation rates.

Source	Irrigation Rate (ML/ha/year)	Comment
SA Water (2015)[82]	6.1 - 11.0	Base irrigation requirement for good quality growth of a variety of turf types.
NSW DEC (2006)[83]	3 - 8	Typical rates depending on local climate, vegetation type and type of irrigation system used.
NSW Agriculture (2001)[84]	8.5	Estimated irrigation requirement for turf.
NSW Agriculture (2001)[85]	6.5	Estimated irrigation requirement for perennial pasture.
Horticulture Innovation Australia (2016)[86]	6 - 8	Typical rates required for reasonable turf growth.
Connellan (2013)[87]	5 - 10	Typical rates based on season and sprinkler efficiency.

82 SA Water (2015) *Code of Practice, Irrigated Public Open Space*, p 64.
83 NSW Department of Environment and Conservation (2006) *Managing Urban Stormwater: Harvesting and Re-use*, p 7.
84 NSW Department of Agriculture (2001) *Sydney-South Coast Region Irrigation Profile*, p 46.
85 NSW Department of Agriculture (2001) *Sydney-South Coast Region Irrigation Profile*, p 46.
86 Horticulture Innovation Australia (2016) *Planning or Expanding a Turf Farm*, p 2.
87 Connellan, G (2013) *Water Use Efficiency for Irrigated Turf and Landscape*, p 12.

Table 14: Shoalhaven Council irrigation rates for Ray Abood Oval, Cambewarra.

Type of Year	Irrigation Volume (ML/year)	Irrigation Rate (ML/ha/year)
Dry Year	13.9	11.1
Average Year	10.6	8.5
Wet Year	9.8	7.8

[1] See Annexure F.

We note that the irrigation demand rates reviewed have typically been assessed on the basis of balancing resulting crop quality against the cost of supplying irrigation water, where increased irrigation rates invariably result in improved vegetation growth. In terms of the Concept Plan and the proposed configuration of the stormwater management scheme, no limitation need be placed on the volume of stormwater irrigated as there will be no material cost implications in sourcing water for irrigation.

On the basis of the above data therefore, it would be reasonable to adopt an irrigation rate for the sports field and parkland areas of say 8 ML/ha/year, or perhaps even 10 ML/ha/year. However, for conservative modelling purposes, a rate of 7 ML/ha has been adopted.

4.2.6 Stormwater Dispersal System

Within parts of the Concept Plan draining to the Crookhaven River, treated stormwater that is released from the Biobasins will be dispersed such that concentrated stormwater outflows will not occur. Dispersal systems will include a combination of broad Biobasin overflow weirs and shallow depth vegetated swales constructed parallel to land contours. Flows will thus be evenly dispersed as non-concentrated shallow overland flow during rainfall-runoff periods into the 100 m vegetated buffer to the Crookhaven River.

4.3 Performance Targets

The adopted performance targets for the stormwater management system are outlined below:

(a) Pollutant Load Reductions: Achieve the minimum pollutant removal targets required under Shoalhaven Council's DCP Chapter G2 for stormwater released into Shoalhaven river and estuarine systems.

(b) Maintain Hydrology: Reduce or control stormwater flows so that they maintain or mimic as best as possible existing hydrological systems.

(c) Pathogen Reductions: Achieve appropriate reductions of pathogens potentially contained within urban runoff generated by the Proposal.

(d) NorBE: Achieve a neutral or beneficial impact on the Estuary and Lake Wollumboola.

(e) Avoid Estuarine and Lake Impacts: Establish that any material or significant impacts on the Estuary or Lake are avoided.

4.4 Stormwater Model Development

4.4.1 Purpose

A stormwater model was developed to simulate stormwater flow volumes and quality generated by the development so as to evaluate the performance targets of the proposed stormwater management system in controlling and managing urban runoff generated in the Concept Plan area. The MUSIC model software developed by Cooperative Research Centre (CRC) for Catchment Hydrology (version 6.3) was used given its industry wide acceptance.

4.4.2 Approach

The MUSIC model was developed using the following general approach:

(a) Stormwater catchments to be simulated were determined based on the Concept Plan layout, site topography and the concept stormwater plan.

(b) Soil and groundwater properties were adjusted and calibrated where possible to reflect site observations and data.

(c) Other model data and set-up requirements were obtained generally from the MUSIC Guideline.

4.4.3 Set-up and Calibration

The following sections outline the MUSIC model set-up and calibration process.

4.4.3.1 Catchments

Three MUSIC model catchment plans were developed:

(a) Catchments under existing conditions based on current land-use zones (Existing - Land Zoning, see Map 13).

(b) Catchments under existing conditions based on land surface cover type (Existing– Land Cover, including current land cover and a conservative alternative which assumes all vegetated areas are assumed to be pristine forest, see Map 14)

(c) Catchments under developed conditions (Developed, see Map 15).

Each catchment was further divided into various further sub-categories to distinguish roads, roofs and other activities.

4.4.3.2 Land-use Zones

Land-use zones were obtained from the Shoalhaven Local Environmental Plan 2014 (SLEP 2014), and where that plan contained deferred matters, from the Shoalhaven Local Environmental Plan 1985 (SLEP 1985).

Existing land-use zones applicable to this WCMS, including approximate aerial coverages, comprise broadly of the following:

(a) Local Centre (B2), which provides for a range of retail, business, entertainment and community uses.

(b) General Industrial (IN1) and Industrial (General) (4(a)), which provides for a wide range of industrial and warehouse land uses.

(c) Infrastructure (SP2), which provides for infrastructure and related uses. Within the Concept Plan area this consists primarily of road corridors.

(d) Environmental Conservation (E2), which seeks to protect, manage and restore areas of high ecological, scientific, cultural or aesthetic values.

(e) Residential (2(c)), this being under SLEP 1985 and provides for new residential areas with a range of housing types with provision for urban facilities to serve the local community.

4.4.3.3 Soil Properties

Soil properties adopted for the MUSIC model were developed based on various historical geotechnical investigations within the Concept Plan area. Whilst not all historical investigations covered all the relevant soil property information, sufficient information was available to form a good understanding of typical soil profile horizon configuration and textural classifications. Soil profile log sheets are reproduced at Annexure D, with historical soil test locations provided at Map 11.

On the basis of these data, whilst there was some variability in soil profiles across the Concept Plan area, those areas where urbanisation is proposed contained a reasonably similar dominant soil profile which consisted typically of 0.25 m of sandy loam overlaying 0.25 m of medium clay. Assuming that the effective depth for hydrologic modelling purposes is 0.5 m, as suggested in the MUSIC Guideline, the depth weighted average of each rainfall-runoff properties could then be determined. Adopted rainfall-runoff properties were then obtained from recommended values provided in the MUSIC Guideline, with these summarised in Table 15.

Table 15: Adopted depth weighted soil rainfall-runoff parameters.

Property	Adopted Value
Soil Storage Capacity (mm)	96
Initial Storage (% of capacity)	25
Field Capacity (mm)	70
Infiltration Capacity Coefficient "a" (mm/d)	193
Infiltration Capacity Exponent "b"	2.7
Initial Depth (mm)	10
Daily Recharge Rate (%)	35
Daily Baseflow Rate (%)	28
Daily Deep Seepage (%)	0

We note that default the Daily Recharge Rate (DDR) obtained was further modified for each land cover type to accord with observed groundwater recharge rates (see Section 4.4.3.5) as part of the MUSIC calibration process.

4.4.3.4 Climate Data

The eWater climate file for the Nowra RAN Air Station was adopted for the purposes of MUSIC model development. A 6 minute time step was utilised, including all data for the years 1965 – 1973. Mean annual rainfall for this period is 927 mm/year, this being higher by 6 % than the long-term mean annual rainfall for that station of 871.9 mm/year (see Table 2). Annual rainfall for each year of simulation is summarised in Table 16, which shows that the period includes appropriate low rainfall (464 mm/year in 1968) and high rainfall (1,468 mm/year in 1969) years. Average monthly evapotranspiration data was obtained from Shoalhaven City Council.[88]

Table 16: eWater climate file summary for Nowra RAN Air Station.

Year	Annual Rainfall Total (mm/year)
1965	673
1966	1,024
1967	879
1968	464
1969	1,468
1970	814
1971	1,141
1972	809
1973	1,068

[1.] For years 1965 – 1973

4.4.3.5 Hydrologic Calibration

The MUSIC Guideline recommends that where possible, calibration of pervious area soil rainfall-runoff parameters is considered, particularly when modelling catchments which contain large proportions of pervious ground area. The preferred method for adjusting rainfall-runoff parameters is to compare MUSIC model predictions to available stream flow data for the catchment, or in the absence of local data, compare to nearby catchments. This approach is not practical for the Concept Plan area because there are no available watercourses [gauged or ungauged] either within the Concept Plan area or in nearby similar sized catchments.

The MUSIC Guideline provides an alternative approach in situations where groundwater recharge rates are available. In those circumstances, the Daily Recharge Rate (DDR), which represents the percentage of the soil moisture store released to groundwater, can be adjusted to match observed groundwater recharge rates.[89] In the case of this study,

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88 Shoalhaven City Council DCP (2014) Chapter G2 - Supporting Document 1: Sustainable Stormwater Technical Guidelines.

89 MUSIC Guideline p 25.

adequate groundwater data were available to enable recharge rates from various land-uses to be determined.[90] These data are provided in Table 38.

The calibration process consisted of the following:

(a) Groundwater recharge rates (in mm/year) were obtained for available land-uses occurring within the existing conditions groundwater model domain. In the case of urban areas, as the recharge rate represented net aerial recharge over all surfaces including pervious and impervious, these were factored up to a unit rate for pervious surfaces only.

(b) Recharge rates were converted to target annual recharge volumes (in ML/year) based on MUSIC model catchment areas. In the case of urban areas, these were factored down to a unit rate which reflected the adopted percentage impervious area expected in the proposed urban areas.

(c) MUSIC was run iteratively in order that the DDR value could be adjusted so that predicted groundwater recharge rates matched those derived from the groundwater investigations.

The calibrated daily recharge rate is provided in Table 17.

Table 17: Calibrated daily recharge rate (DDR as %) for different land uses.

Rainfall-Runoff Parameter	Forest	Agricultural	Urban
Daily Recharge Rate (%)	20	92	39

4.4.3.6 Irrigation Demand Rates

On the basis of the adopted irrigation rate of 7 ML/ha/year (see Section 4.2.5), irrigation demand volumes were determined for each terminal pond, with these being summarised in Table 18. We note that beyond the nominated irrigation areas, there are several other open space or parkland areas that could require irrigation in the future.

Table 18: Adopted irrigation demand volumes.

Pond ID	Nominated Irrigation Area (ha)	Irrigation Demand (ML/year)
Pond 1 (west)	1.13 (parkland)	7.94
Pond 2 (east)	3.54 (sports grounds)	24.8
Pond 3 (middle)	1.49 (parkland)	10.4

4.4.3.7 Effective Impervious Area

The MUSIC model requires for each water catchment simulated, an estimate of the effective impervious area (EIA) as a percentage of the entire catchment. EIA represents the impervious area that contributes to surface runoff observed at the outlet during days where the daily rainfall exceeds the rainfall threshold. It is essentially the proportion of

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90 Based on observed groundwater levels, measured *in-situ* hydraulic conductivity, incident rainfall and evapotranspiration.

total impervious surfaces that are linked by a continuous series of impervious surfaces.[91] For large urban development proposals over presently undeveloped land, the MUSIC Guideline provides guidance for converting expected total impervious areas (TIA) to EIA.[92]

The methodology adopted to determine EIA for sub-catchments modelled in MUSIC consisted of the following, with the adopted parameters summarised in Table 19.

(a) Utilise the design TIA for each proposed development type (e.g. residential, industrial, medium density *etc*) from the SDCP.

(b) Obtain typical average roof areas for a range of development types and lot sizes based on aerial photography analysis of existing nearby local developments.

(c) Determine typical average lot sizes based on the Concept Plan layout.

(d) Determine for each proposed sub-catchment type, calculate effective impervious areas for land which is not classified as roof or road.

Table 19: Factors used to determine EIA percentages.

	Residential Lot	Medium Density/ Integrated Housing Lot	Mixed Residential/ Commercial Lot	Industrial Lot
Typical Lot area (m^2)	550	350	900	2,000
% Total Impervious Area[1]	80%	80%	85%	80%
EIA factor[2]	60%	80%	80%	90%
Roof Area (m^2)[3]	250	200	540	1,000

1. Based on SDCP.
2. MUSIC Guideline Table 5-3.
3. Based on analysis of aerial imagery of local developments.

4.4.3.8 Exfiltration Rates

It is generally accepted that care must be taken when infiltrating stormwater into the groundwater system, that there is a risk of groundwater pollution occurring if stormwater is of a significantly poor quality compare with the local groundwater system. For this reason, it is usually desirable not to simulate the loss of large loads of stormwater pollutants through infiltration means.[93] Notwithstanding this, the risk of groundwater pollution needs to be balanced against the benefits that may be gained through implementing a groundwater recharge system as part of an overall WSUD approach to the stormwater management system.

The MUSIC model enables groundwater recharge from stormwater treatment systems through the adopted exfiltration rates. In order to investigate the ability of surface soils to accommodate stormwater, five constant head well permeameter tests for saturated hydraulic conductivity (K_{sat}) were undertaken at various locations within the Concept

91 MUSIC Guideline p 15.
92 MUSIC Guideline Table 5-3, p 17.
93 MUSIC Guideline p 47.

Plan Area. The permeameter provides a more reliable estimate of K_{sat} than that obtained via falling head tests at depths approximately 300 mm below the natural ground surface.

Results of these investigations are provided in Table 20, with test locations shown at Map 12 and test results provided in Annexure I. Average K_{sat} was found to be 21.3 mm/hr. This is higher than the previously reported mean K_{sat} of 1.5 mm/hr in the deeper clay units. On this basis, an exfiltration rate of 0.25 mm/hr was adopted for investigation purposes. The rate was taken to be sufficiently conservative against the background of historical K_{sat} testing, but also sufficiently low to preclude the release of large quantities of stormwater pollutants into the groundwater system, noting that the projected stormwater contaminant concentrations are not dissimilar to those found in groundwater below the Concept Plan area (refer to Table 35).

The effect of adopting a 0.25 mm/hr exfiltration rate was investigated for each modelling scenario considered in this report, and compared to a baseline assumption of a lined system (i.e. 0 mm/hr exfiltration). The exception to this was runoff draining to the Lake Wollumboola catchment, where no MUSIC model scenarios considered exfiltration from stormwater treatment systems.

Table 20: Constant head permeability (K_{sat}) testing results.

Test Location / ID	Saturated Hydraulic Conductivity (K_{sat}, mm/hr)
BH501	18.8
BH502	5.4
BH503	55.0
BH504	20.0
BH505	7.1
Average	21.3

4.4.4 Model Scenarios

The MUSIC modelling scenarios considered in this report are summarised in Table 21. The models used for TTE analysis, that is pollutant load reduction assessments, include D-UT, D-T1 and DT2. Models used for consideration of NorBE criteria include PD-LU, PD-LC1 and PD-LC2.

Table 21: MUSIC modelling scenarios considered in this report.

Model Type	Description	Purpose
D-UT	Developed – untreated	To determine runoff volumes and pollutant loads during developed conditions without any stormwater treatment measures in place.
D-T1	Developed – treated (no exfiltration)	To determine the stormwater volume reductions and pollutant load reductions provided by the stormwater treatment measures, with all measures lined.
D-T2	Developed – treated (with exfiltration)	To determine the stormwater volume reductions and pollutant load reductions provided by the stormwater treatment measures, with measures draining to the Crookhaven River partially permeable.
PD-LU	Pre-development – land use zoning	To determine runoff volumes and pollutant loads adopting EMCs based on land-use zoning as recommended in the MUSIC Guideline.[94] Used for NorBE analysis.
PD-LC1	Pre-development – current land cover	To determine runoff volumes and pollutant loads adopting EMCs based on current land-cover observed from aerial imagery and site inspections. This scenario has incorporated the unsealed road, revegetated / cleared land in the undeveloped area. Used for NorBE analysis.
PD-LC2	Pre-development – forest land cover	To determine runoff volumes and pollutant loads adopting EMCs based on the assumption that all non-agricultural vegetated areas are assumed to be pristine forest. Used for NorBE analysis.

4.5 Performance Assessment

4.5.1 Overview

Performance of the stormwater management system was assessed against each of the performance targets discussed at Section 4.3. This included the following

(a) <u>Pollutant Load Reductions</u>: Determined by comparing the developed-untreated MUSIC modelled pollutant loads to developed-treated MUSIC modelled pollutant loads (gross pollutants, nutrients and suspended sediment) and assessing whether removal targets were achieved.

(b) <u>Comparison to Existing Conditions</u>: Whether in terms of annual pollutant loads, a NorBE outcome would likely arise from the development was determined by comparing the pre-development conditions in stormwater from the site reaching the Estuary and Lake Wollumboola and considering this in the context of the NorBE criteria.

(c) <u>Mimic Hydrology</u>: Whether there would be a material change in the hydrology within the 100 m forested buffer zone or the Estuary was assessed by considering changes to total stormwater flow volumes and flow frequencies arising from the Proposal.

(d) <u>Pathogen Reductions</u>: Whether appropriate reductions of pathogens potentially contained within urban runoff were achieved was assessed by considering the

94 MUSIC Guideline, section 5.1.4 Table 5-8 p 21.

effective of stormwater retention within the terminal ponds prior to release to the receiving environment.

(e) Estuary and Lake Impacts: By considering potential pollutant loads to the Estuary and Lake, assess whether material or significant impacts are likely.

4.5.2 Pollutant Load Reductions

Modelled pollutant loads and load reductions are summarised in Table 22 for catchments draining to the Crookhaven River Estuary, and in Table 23 for catchments draining to Lake Wollumboola. In both cases, developed-untreated conditions are shown (MUSIC model type D-UT). Results for the developed-treated Crookhaven River catchments include scenarios with no allowance for exfiltration from stormwater treatment systems (MUSIC model type D-T1) and scenarios with some allowance for exfiltration from stormwater treatment systems (MUSIC model type D-T2). Results for the Lake Wollumboola catchment only cover the scenario where exfiltration is excluded (MUSIC model type D-T1).

The following comments are provided in respect of catchments draining to the Crookhaven River:

(a) Pollutant removal targets are achieved across all pollutants including gross pollutants, TSS, TP and TN. Indeed the load reductions are very high compared to the requirements as specified in SDCP Chapter G2.

(b) The loss of pollutants to groundwater where some exfiltration is provided is very small, being in the order of 12-13 % of the annual TN and TP load.

The following comments are provided in respect of catchments draining to Lake Wollumboola:

(a) Pollutant removal targets are achieved across all pollutants including gross pollutants, TSS, TP and TN.

(b) The loss of pollutants to groundwater through the base of stormwater treatment structures does not occur because these are modelled as being impermeable (i.e. no exfiltration).

In summary, pollutant load reduction targets are achieved by the proposed stormwater management system.

Table 22: Pollutant loads and load reductions for Crookhaven River catchments.

Pollutant	Exfiltration Criteria (mm/hr)	Developed-Untreated (kg/year) (D-UT)	Developed-Treated (kg/year) (D-T1/D-T2)[1]	Load Reduction (%)	Target Achieved (Y/N)
Gross Pollutants	0	4,890	0	100	Y
	0.25		0	100	Y
TSS	0	27,100	416	98%	Y
	0.25		376	99%	Y
TP	0	58.6	7.96	86%	Y
	0.25		6.92	88%	Y
TN	0	455	74.7	84%	Y
	0.25		65.4	86%	Y

1. Upper value is MUSIC model type D-T1 and lower value is MUSIC model type D-T2.

Table 23: Pollutant loads and load reductions for Lake Wollumboola catchments.

Pollutant	Exfiltration Criteria (mm/hr)	Developed-Untreated (kg/year) (D-UT)	Developed-treated (kg/year) (D-T1)	Load Reduction (%)	Target Achieved (Y/N)
Gross Pollutants	0	191	0	100	Y
TSS	0	2540	200	92	Y
TP	0	4.67	1.32	72	Y
TN	0	24.5	12.4	49	Y

4.5.3 Stormwater Flow Regime

Changes to the hydrology of surface flows generated within the Concept Plan area catchments draining to the Crookhaven River were evaluated by examining average annual stormwater flows predicted by the MUSIC model under various model scenarios, with results summarised in Table 24. The following observations are made:

(a) Under pre-development conditions, depending on how these are modelled, annual stormwater volumes generated within the Concept Plan area are around 92-95 ML/year.

(b) With the full development in place and no exfiltration assumed to occur within stormwater treatment structures, annual stormwater flow volumes are increased by around 21 ML/year.

(c) If stormwater treatment structures are designed to be partially permeable such that some groundwater recharge is permitted, then annual stormwater flows are decreased in the order of 15 ML/year, bringing the developed conditions flow volumes significantly closer to pre-development conditions. Whilst not necessary, this is a preferred outcome because surface water hydrology within the 100 m buffer is more closely matched to existing conditions.

Table 24: Average annual stormwater flow volumes (ML/year) to the Crookhaven River.

Pre-development – land use zoning (PD-LU)	Pre-development – current land cover (PD-LC1)	Pre-development – forest land cover (PD-LC2)	Developed – treated (no exfiltration) (D-T1)	Developed – treated (with exfiltration) (D-T2)
95.9	92.2	92.2	116	101

Further to the above analysis, the frequency of average daily flow rates emanating from Concept Plan catchments draining to the Crookhaven River was also investigated under various MUSIC model scenarios. Results of the frequency analysis are provided in Table 25, which highlights the range of flows which represent around 95% of all stormwater flows. Cumulative flow frequencies are plotted in Diagram 12. The following observations are made:

(a) Under pre-development conditions, for slightly more than 50% of the time no overland flow is generated from the site, with 95% of flows being < say 865 m^3/d. This is not unexpected given the soil types found in the Concept Plan area.

(b) Under developed-untreated conditions, that is without the stormwater treatment measures in place, notably the stormwater ponds and the landscape irrigation scheme, average daily flow rates are increased, with higher flows > 0.01 m^3/s being more common. The 95th percentile flow rate is increased to ≤ 0.03 m^3/s.

(c) Under developed-treated conditions, flow frequency distributions more closely mimic flows currently experienced within the Concept Plan area. In the scenario where no exfiltration is assumed to occur from the stormwater treatment structures, flow reductions arise primarily out of the stormwater re-use scheme. In the scenario where some exfiltration is assumed to occur from the stormwater treatment structures, the hydrologic regime begins to resemble more closely the current hydrologic regime.

(d) It is worth observing that due to the proposed stormwater capture and re-use scheme, there will likely be some minor reduction in the frequency of lower flow rate stormwater flows.

(e) The concepts described above can be more clearly seen in the cumulative flow frequency plot provided at Diagram 12. In particular, this shows the benefit of implementing the proposed stormwater treatment measures, including stormwater capture and re-use, on overall flow rate distributions.

Further to the above, it is noted that stormwater released from the ponds will be returned to bioretention basins and then spread and dispersed so as to further mimic existing hydrology (refer to Section 4.2.6).

Table 25: Distribution of stormwater flows to the Crookhaven River.

Average Daily Flow Rate (m³/s)	Pre-development – land use zoning (PD-LU)	Pre-development current land cover (PD-LC1)	Pre-development – forest land cover (PD-LC2)	Developed – untreated (D-UT)	Developed – treated (no exfiltration) (D-T1)	Developed – treated (with exfiltration) (D-T2)
0	53.1%	54.7%	54.5%	51.9%	28.0%	61.5%
0.01	42.0%	41.4%	41.7%	35.6%	66.2%	33.5%
0.02	2.6%	2.3%	2.2%	5.9%	2.7%	2.3%
0.03	1.0%	0.2%	0.2%	1.8%	0.6%	0.7%
0.04	0.2%	0.2%	0.2%	1.3%	0.5%	0.5%
0.05	0.1%	0.1%	0.1%	0.9%	0.5%	0.4%
0.06	0.1%	0.1%	0.1%	0.5%	0.3%	0.1%
0.07	0.0%	0.1%	0.1%	0.3%	0.1%	0.1%
0.08	0.1%	0.1%	0.1%	0.2%	0.1%	0.1%
0.09	0.1%	0.1%	0.1%	0.2%	0.1%	0.0%
0.10	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%
> 0.10	0.7%	0.8%	0.8%	1.3%	0.8%	0.7%

1. Bolded and shaded cells represent approximately 95% of all stormwater flows.

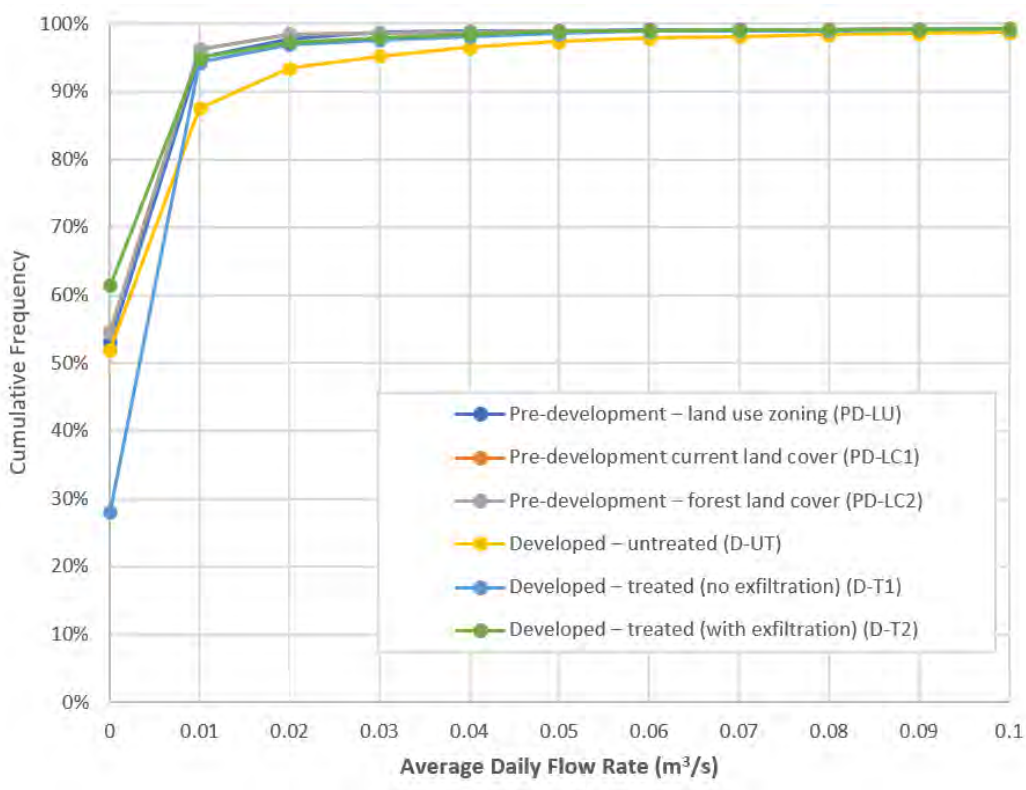

Diagram 12: Cumulative frequency of average daily flow rates under various MUSIC model scenarios.

4.5.4 Pathogen Control

It is generally accepted that stormwater can potentially contain elevated pathogen concentrations, typically reported by indicator organisms such as *Escherichia coli* (*E. coli*) or more generally as Faecal Coliforms. Based on the local catchment runoff monitoring undertaken, median urban runoff Faecal Coliform concentrations are around 7,000 CFU/100 mls, as compared to agricultural and forest runoff concentrations which range between say 2,200 and 3,000 CFU/100 mls.

In terms of control of faecal pathogens potentially contained within urban runoff, this is achieved by the proposed stormwater management system through two primary pathways:

1. Removal within bioretention basins.

2. Removal within the stormwater ponds.

In respect of the bioretention basins, these have been demonstrated to be an effective method of removing pathogens,[95] with micro-organism removal occurring through a variety of processes such as straining or filtration, adsorption, inactivation due to temperature and moisture, predation and competition.[96] Log reductions of 1-2 are likely for typical stormwater inflows containing fine sediment.[97] For the purpose of this assessment, a log reduction of 1 is adopted for a bioretention basin which receives all flows, and a slightly higher log reduction of 1.5 is adopted for a bioretention basin where higher flows are first diverted to the stormwater ponds for additional detention and treatment before being returned to the bioretention basin. These basins in sequence can therefore expect a net log 2.5 log reduction.

In terms of pathogen removal within the stormwater ponds, microbial die-off can be modelled using a first order kinetic decay equation as follows:

$$C_t = C_o e^{-kt} \qquad (1)$$

Where:

C_t = Pathogen concentration at time = t (days)

C_o = Initial pathogen concentration

k = Rate constant (day-1)

t = Time elapsed (days)

The rate constant k is related to the pathogen half-life as follows:

$$t_{0.5} = \frac{0.693}{k} \qquad (2)$$

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95 Emily Payne, Belinda Hatt, Ana Deletic, Meredith Dobbie, David McCarthy and Gayani Chandrasena (2015) *Adoption Guidelines for Stormwater Biofiltration Systems*, CRC for Water Sensitive Uses p 101.

96 Chandasena, K. K. G. I., Deletic, A., Ellerton, J. and McCarthy, D.T. (2011) *Removal of Escherichia coli in Stormwater Biofilters*, 12th International Conference on Urban Drainage, Porto Alegre/Brazil, p 1.

97 Chandasena, K. K. G. I., Deletic, A., Ellerton, J. and McCarthy, D.T. (2011) *Removal of Escherichia coli in Stormwater Biofilters*, 12th International Conference on Urban Drainage, Porto Alegre/Brazil, p 6.

Where:

$t_{0.5}$ = Pathogen half-life (days)

In respect of a suitable value for $t_{0.5}$, the NSW Sydney Catchment Authority has adopted a design pathogen half-life of 1.2 days for assessing Faecal Coliform releases into the receiving environment.[98] This value is not dissimilar to other values reported in the literature,[99] and on that basis the Sydney Catchment Authority approach is considered reasonable, and a rate constant of 0.578 is adopted for this assessment.

In order to investigate the capacity of the stormwater ponds to reduce pathogen concentrations, hydraulic properties for each pond were obtained from the developed-treated case (DT-1) MUSIC model. Results are provided in Table 26 and indicate that hydraulic retention times (HRTs) are typically around 30 – 50 days for much of the year. HRTs of 30 days are achieved for 90 % of the time, and a HRT of 7 days is achieved by each pond for at least 97.5% of the time, or around 356 days of the year.

Table 26: Terminal stormwater pond hydraulic properties.[1]

Flow Element	Pond 1	HRT (days)	Pond 2	HRT (days)	Pond 3	HRT (days)
Permanent pool volume (m^3)	10,500	-	7,500	-	3,000	-
Flow-weighted daily mean (m^3/day)	219	48	91	82	41	73
All data average daily flow (m^3/day)	219	48	91	82	41	73
90th percentile flow (m^3/day)	306	34	164	46	76	40
95th percentile flow (m^3/day)	721	15	317	24	154	19
97.5th percentile flow (m^3/day)	1599	7	551	14	296	10

1. As extracted from the D-T1 MUSIC model, including daily flow statistics and associated hydraulic retention times (HRT in days)

Applying Equations (1) and (2), a log 1 reduction occurs if HRT = 4 days, a log 1.5 reduction occurs if HRT = 6 days, a log 1.75 reduction occurs if HRT = 7 days, a log 2 reduction occurs if HRT = 8 days, a log 2.25 reduction occurs if HRT = 9 days, and log a 2.5 reduction occurs if HRT = 10 days. On this basis, each stormwater ponds will in isolation achieve a log 1.75 to > 2.5 reduction for at least 97.5% of the year.

98 See WaterNSW (2015) *Wastewater Effluent Model*, as described in WaterNSW (2015) Neutral or Beneficial Effect on Water Quality Assessment Tool, Consultants and Consultant Administrators; and Martens & Associates (2011) *Technical Update of the Development Assessment Module (DAM) – Final Report*, prepared on behalf of the Sydney Catchment Authority.

99 See for example: Vinten, A.J. A, Douglas, D. R, Lewis D. R., Aitken, M. N and Fenlon (2004) Relative risk of Surface Water Pollution by C. coli Derived from Faeces of Grazing Animals Compared to Slurry Application, *Soil Use and Management* 20, 13 – 22, at p 19 who reported a half-life of 1.2 days for *E. coli* at 15^{o} temperature; Sobratee, N. , Mohee, R., Driver, M.F. and Mudhoo, A. (2007) Survival Kinetics of Faecal Bacterial Indicators in Spent Broiler Litter Composting, *Journal of Applied Microbiology* 104 (2008) 204–214, at p 209 report a half-life of 1.4 days for Faecal Coliforms; Kimberly, L. A., Whitlock, J. E. and Harwood, V. J (2005) Persistence and Differential Survival of Fecal Indicator Bacteria in Subtropical Waters and Sediments, *Applied Environmental Microbiology* 71(6) 3041 – 3048, report half-life as low as 0.3 days for Faecal Coliforms in freshwater; Blaustein, R. A., Pachepsky, Y., Hill, R. L., Shelton, D. R. and Whelan, G. (2013) *Escherichia coli* Survival in Waters: Temperature Dependence, *Water Research* 47(2), 569–578, reported in a review of various data sources, an average *E. coli* half-life of around 0.75 days for non-saline river water at 20^{o}.

In terms of target water quality, the following is noted:

1. A log reduction of around 0.4 is required to treat urban stormwater to existing 'forest' conditions of 3,000 CFU/100 mls. Similarly, a log reduction of around 0.6 would be required to achieve the existing 'agricultural' runoff conditions of around 2,200 CFU/100 mL. All proposed stormwater discharge points will achieve water quality below these thresholds because all stormwater will be treated by bioretention systems which deliver at least a log 1 pathogen reduction. This outcome satisfies the NorBE test.

2. A log reduction of 1.75 is required to achieve faecal coliform levels in stormwater suitable for primary contact, including recreational bathing and swimming of < 150 CFU/100 mL.[100] Given that the majority of urban stormwater generated by the proposal will be subject to a combination of bioretention and pond detention, the proposal is expected to achieve this standard.[101] We note that this would represent a significant improvement in water quality compared to the pathogen quality of water currently discharging into the Crookhaven River estuary.

3. If the OISAS estuarine water quality standard were adopted for catchment inflows to the Crookhaven River estuary, then a log reduction of around 2.25 would be required to achieve a faecal coliform level 43 CFU/100 mL. Significantly, the OISAS guideline recommends that this criterion is achieved within saline estuarine waters[102] for 90% of the time for the purpose of oyster aquaculture, thus accepting that there will be exceedances due to catchment land-use and runoff processes.

   We do not recommend this criterion as the relevant target for urban stormwater water quality as it goes well beyond the NorBE standard. However, we expect that given the majority of urban stormwater generated by the proposal will be subject to a combination of bioretention and pond detention, and also that much of the urban footprint will be serviced by two bioretention treatment phases, that urban stormwater released from the site would likely achieve this standard for at least 90% of the time. We note that this represents a significant water quality improvement compared to the pathogen quality of water currently discharging into the Crookhaven River estuary.

The analysis demonstrates that the stormwater treatment train will be capable of treating pathogens to at least background 'pre-development' levels at all times, but for most of the time to a considerably higher standard than that found in current runoff entering the Estuary. The proposed stormwater treatment train therefore provides an important and effective barrier to pathogens potentially contained in urban runoff being released into the Estuary.

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100 ANZECC Guideline Table 5.2.2, p 5 - 3.

101 Bioretention basins achieve at least log 1 reduction + all stormwater ponds achieve a log 1.75 reduction for 97.5% of the time.

102 Noting that saline waters have strong disinfectant properties.

4.5.5 Comparisons to Existing Conditions

One of the WCMS performance targets was to seek to achieve a NorBE outcome in respect of the Proposal, this being satisfied where the development has no identifiable potential impact on water quality.[104]

A broad and somewhat crude means by which the NorBE criteria can be considered is by comparing gross pollutant, nutrient and suspended sediment loads generated by the development with those generated under pre-development conditions. It important to note that these are not the sole factors which relate to the NorBE criteria, but one of a suite of considerations including for example flow regime, pathogens and other pollutants.

As noted in Section 2.6, the MUSIC Guideline recommends that stormwater pollutant parameters should be based on land-use zoning, where the zoning is translated into MUSIC Model 'source nodes'.[105] This is encapsulated in the MUSIC model type PD-LU. Notwithstanding this, we also have undertaken to assess pollutant loads under pre-development conditions based on land cover within the study area, this being encapsulated in models PD-LC1 and PD-LC2.

Comparisons of developed-treated and pre-development conditions are provided at Table 27 for catchments draining to the Crookhaven River. The following observations are made:

(a) Gross pollutant and suspended sediment load generation rates in the developed scenario are lower than pre-development conditions irrespective of whether pre-development conditions are based on land-use zoning or land-use cover.

(b) Nutrient load generation rates in the developed scenario are lower than pre-development conditions irrespective of whether pre-development conditions are based on land-use zoning or land-use cover.

(c) If in addition to the above we note that with the stormwater dispersal system in place, stormwater in the developed scenario will be released over a total interface length of > 500-600 m. Therefore at least around 5 ha of forested buffer will receive treated stormwater discharged from the Concept Plan development prior to reaching the Crookhaven River. Nutrient uptake rates published by the Sydney Catchment Authority for good quality woodland in its NorBE guidelines recommend rates of 25 kg/ha/year TP and 90 kg/ha/year TN.[106] We therefore expect that a further significant proportion of nutrients contained within treated stormwater released from the development would be removed prior to entering the Estuary.

(d) No water quality impacts on the Crookhaven River are therefore expected.

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104 NorBE Guideline, Section 3.1 p 6.

105 MUSIC Guideline, section 5.1.4 p 19 – 21.

106 WaterNSW (2015) *Neutral or Beneficial Effect on Water Quality Assessment Tool, Consultants and Consultant Administrators* p 50.

Comparisons of developed-treated and pre-development conditions are provided at Table 28 for catchments draining to Lake Wollumboola. The following observations are made:

(a) Gross pollutant and suspended sediment load generation rates in the developed scenario are lower than pre-development conditions irrespective of whether pre-development conditions are based on land-use zoning or land-use cover.

(b) Nutrient load generation rates in the developed scenario are lower than pre-development conditions irrespective of whether pre-development conditions are based on land-use zoning or land-use cover.

(c) No water quality impacts on Lake Wollumboola are therefore expected.

In summary, the following can be said of the comparisons between gross-pollutant, nutrient and suspended sediment loads generated by the development compared to pre-development conditions:

(a) In respect of gross pollutants and suspended sediment, irrespective of the modelling method adopted, loads generated by the development are reduced compared to pre-development conditions.

(b) Nutrient loads are not expected to increase to either the Crookhaven River Estuary or to Lake Wollumboola as loads will be sufficiently reduced within the proposed stormwater management measures to provide that no material increases to receiving waters will occur.

(c) On this basis, NorBE criteria will be met by the Proposal.

Table 27: Pollutant loads comparisons for Crookhaven River catchment.

Pollutant	Exfiltration Criteria (mm/hr)	Developed-treated (kg/year) (D-T1/D-T2)[1]	Pre-development – land use zoning (kg/year) (PD-LU)	Difference (kg/year)[2]	Pre-development – current land cover (kg/year) (PD-LC1)	Difference (kg/year)[2]	Pre-development – forest land cover (kg/year) (PD-LC2)	Difference (kg/year)[2]
Gross Pollutants	0	0	35.5	-35.50	33.3	-33.30	33.3	-33.30
	0.25							
TSS	0	416	11,400	-10984	6,270	-5854	3,780	-3364
	0.25	376		-11024		-5894		-3404
TP	0	7.96	23	-15.04	10.9	-2.94	9.52	-1.56
	0.25	6.92		-16.08		-3.98		-2.60
TN	0	74.7	177	-102.3	93.5	-18.8	87	-12.3
	0.25	65.4		-111.6		-28.1		-21.6

1. Lower value is MUSIC model type D-T1 and upper value is MUSIC model type D-T2.
2. Difference is the difference between the Concept Plan load compared to pre-development conditions.

Table 28: Pollutant loads comparisons for Lake Wollumboola catchment.

Pollutant	Exfiltration Criteria (mm/hr)	Developed-treated (kg/year) (D-T1/D-T2)[1]	Pre-development – land use zoning (kg/year) (PD-LU)	Difference (kg/year)[2]	Pre-development – current land cover (kg/year) (PD-LC1)	Difference (kg/year)[2]	Pre-development – forest land cover (kg/year) (PD-LC2)	Difference (kg/year)[2]
Gross Pollutants	0	0	162	-162	124	-124	124	-124
TSS	0	202	2,370	-2,168	2,020	-1,818	1,880	-1,678
TP	0	1.31	4.51	-3.20	3.64	-2.33	3.52	-2.21
TN	0	12.3	35.3	-23.0	21.0	-8.7	21.5	-9.2

1. Lower value is MUSIC model type D-T1 and upper value is MUSIC model type D-T2.
2. Difference is the difference between the Concept Plan load compared to pre-development conditions.

4.5.6 Estuary and Lake Impacts

The following sections summarise the assessment of potential Proposal impacts on the Crookhaven River Estuary and Lake Wollumboola.

4.5.6.1 Gross Pollutants and Sediment

The proposed stormwater management system forming part of the Concept Plan effectively removes all gross pollutants potentially generated by urban areas (refer to Table 22 and Table 23) and will not result in any increase in suspended sediment loads released to the 100 m vegetated riparian buffer, nor ultimately to the Estuary (see Table 27). No impacts on the Estuary, nor the Lake, in respect of gross pollutants or suspended sediment is therefore anticipated.

4.5.6.2 Salinity

The surface water sampling regime undertaken as a part of this investigation observed that runoff from urban areas, whilst still falling within the classification of fresh water, maintained higher salinity levels than those observed in runoff from forested or agricultural catchments. No material modification to Estuary salinity levels is therefore expected and no impacts on Oyster aquaculture lease areas are anticipated.[107]

4.5.6.3 Nutrients

Based on the MUSIC modelling undertaken herein, nutrient loads will not increase either to the Crookhaven River Estuary or to Lake Wollumboola as loads will be sufficiently reduced within the proposed stormwater management measures to provide that no increases to receiving waters will occur.

107 Refer to Section 3.1.6.3.

4.5.6.4 Pathogens

Based on the analysis provided at Section 4.5.4, pathogens potentially contained within urban runoff generated by the Proposal will be appropriately reduced prior to being released into the 100 m vegetated buffer to the Estuary, after which further pathogen removal will occur as there will be no direct stormwater connection to the Estuary. No impacts on the Oyster aquaculture industry within the Crookhaven River are therefore anticipated.

In respect of the Lake Wollumboola catchment, no residential, commercial or industrial areas are included as part of the Concept Plan draining into this catchment. The small volume of road runoff generated in the catchment will be fully treated after being passed through a bioretention basin prior to being released in the upper portion of the catchment. No pathogen related impacts are anticipated.

4.5.6.5 Metals

In order to consider the potential impact of dissolved metals potentially contained in urban runoff, simple annual mass budgets delivered from the Proposal area to the Estuary have been assessed based on catchment surface sampling undertaken as part of this investigation.[109] For the sake of simplicity and convenience, it has been assumed that the pre-development concentrations are those data reported for forest catchments, and post-development concentrations are those data reported for urban catchments. We note that this approach is highly conservative because it does not account for the high level of suspended particulate matter removal (> 98%). Metals entrained within stormwater are typically associated with fine particulate matter and moderate to high levels of removal would therefore be anticipated within stormwater treatment structures such as bioretention basins.[110]

Table 29: Iron and Aluminium production estimates from the development area.[1]

Parameter	Pre-development – land use zoning (PD-LU)	Pre-development – current land cover (PD-LC1)	Pre-development – forest land cover (PD-LC2)	Developed – treated (no exfiltration) (D-T1)	Developed – treated (with exfiltration) (D-T2)
Iron (kg/year)	145	140	140	120	110
Aluminium (kg/year)	232	223	223	89	82

1. Production load estimates are for the Crookhaven River and are preliminary only, based on very limited data. For Developed conditions, no removal was assumed within stormwater treatment devices.

Results of this broad analysis are provided in Table 29. The following comments are provided:

109 Refer to 3.1.6.3, Table 4.

110 See for example Glass, C. and Bissouma, S. (2005) Evaluation of a parking lot bioretention cell for removal of stormwater pollutants, *WIT Transactions on Ecology and the Environment* Vol 81, 73, where heavy metal removal rates of up to 80 % were observed for a bioretention filter.

(a) Following development, based on the available surface water sampling, Aluminium loads to the estuary are likely to decrease as there is less contact between surface runoff and aluminium rich clay within the catchment.

(b) Following development, based on the available surface water sampling, Iron loads to the estuary are likely to decrease as there is less contact between surface runoff and aluminium rich clay within the catchment.

4.6 Summary Observations and Comments

The following summary comments are made in respect of the Stormwater Management Plan and associated investigations documented herein:

(a) The inclusion of additional WSUD elements not contained within previous iterations of the Concept Plan, including terminal ponds, stormwater dispersal systems and no new stormwater connections to the Estuary or Lake, large scale stormwater re-use and opportunities for groundwater recharge with stormwater, have contributed to the overall approach to stormwater management representing best industry best practice.

(b) The proposed stormwater treatment measures have been demonstrated to be effective in removing or reducing water borne contaminants to acceptable levels. Pollutant load reduction targets are achieved, the potential for pathogen impacts is mitigated, and the NorBE water quality criteria are satisfied because the development will have no identifiable potential impact on water quality.[111]

111 In accordance with the NorBE definition provided in the NorBE Guideline, Section 3.1 p 6.

5 Groundwater Management

5.1 Overview

Groundwater forms an integral part of the water cycle within and near to the Concept Plan area. The local groundwater system is predominantly recharged by direct rainfall infiltrating into the soil and it therefore follows that changes to the surface arrangement of vegetation type and extent of impervious areas may affect upon the flow regime, distribution or quality of local groundwater. Ultimately groundwater generated within the Concept Plan area discharges to the Shoalhaven River or to Lake Wollumboola and understanding the potential impacts of the Proposal on groundwater systems is therefore relevant.

This groundwater assessment has included:

(a) Collecting field data and reviewing other available information in order that the local groundwater environment could be properly described

(b) Developing a numerical groundwater model for the local area that is calibrated to the available physical data.

(c) Assessing potential changes to the groundwater regime arising out of the Proposal from urban cycle elements such as changes to recharge rates and the potential connection between stormwater generated by the Proposal and groundwater quality.

5.2 Other Groundwater Investigations

The following studies are relevant to groundwater and have been reviewed for this assessment:

(a) *West Culburra groundwater assessment, Interim monitoring report* (Dec 2017 to Dec 2018), HGEO Pty Ltd (2019), hereafter referred to as 'the HGEO report'.

(b) *Groundwater Assessment: Lot 61 DP755971 an part of Lot 6 DP1065111, Culburra Road, West Culburra, NSW, P1002842JR03V01*, Martens and Associates (2011).

(c) *Water Cycle Management Report – Mixed Use Subdivision: West Culburra, NSW, P1203365JR01V07*, Martens and Associates (2016).

5.3 Performance Targets

The adopted performance targets for groundwater management are outlined below:

(a) Maintain Flow Regimes: Seek to maintain where possible groundwater flow regimes so as to minimise potential changes in groundwater discharged to receiving waters.

(b) Avoid Groundwater Contamination: Where groundwater recharge from stormwater management systems occurs, this should not lead to contamination of groundwater such that groundwater dependent ecosystems or groundwater users are detrimentally affected.

(c) Sustainable Management: Modifications to the groundwater regime should not result in long-term changes to ecological systems.

5.4 Groundwater Model Development

5.4.1 Purpose

A groundwater model was developed to simulate groundwater flow volumes and quality arising out of the development so as to evaluate the groundwater management performance targets. The MODFLOW model was adopted using the GMS 10.4.1 (2018) graphical user interface to model the hydrogeological conditions given its industry wide acceptance. A MT3DMS pollutant transport model was then developed to model groundwater quality changes arising from potential stormwater recharge to groundwater.

5.4.2 Approach

The groundwater model was developed using the following general approach:

(a) Relevant geo-spatial data were collated, including for example: LIDAR topography; aerial imagery; groundwater level and quality data; rainfall and evapotranspiration data; geology and soil data; and hydraulic conductivity test data.

(b) These data were used to develop a conceptual model of the hydrogeological system which was then constructed in GMS. The MODFLOW model grid construction utilised the observed ground and rock surface elevations as the top elevations of model layers 1 and 2 respectively.

(c) An existing conditions model was developed using the collected data for the model inputs including hydraulic conductivity of various zones, constant head boundaries at Crookhaven River and Lake Wollumboola, and an evapotranspiration rate over the model. The aerial imagery was used to classify areas according to land-use and vegetation to assign recharge rates and evapotranspiration extinction depths. Average groundwater levels based on long-term monitoring were used as calibration targets to measure the accuracy of the model results. Recharge rates were adjusted until a suitable level of calibration was achieved.

(d) From the calibrated existing conditions model, a post-development model was constructed by modifying the recharge and evapotranspiration zones to reflect the proposed development. Groundwater level and regime changes resulting from this regime change were then able to be quantified.

(e) The post development MODFLOW model was used to build a MT3DMS pollutant transport model to model the transport of total nitrogen (TN), total phosphorous (TP) and Faecal Coliforms (FC) above the baseline conditions.

5.4.3 Regional Geology and Soils

Borehole data from the multiple site investigations by MA and others generally show that the soil profile consists of a layer of topsoil overlying clay, silty clay, and sandy clay. The underlying siltstone formation is variably weathered at the rock/soil interface. Table 30 summarises the depth to bedrock[112] at relevant boreholes. Site monitoring well locations are shown in Map 18. Monitoring well logs are provided in Annexure E.

Table 30: Borehole (BH) depths to moderately weathered bedrock.

Borehole ID	BH Elevation (mAHD)[2]	Rock Depth (mbgl)[1]	Rock Elev. (mAHD)	Borehole ID	BH Elevation (mAHD)[1]	Rock Depth (mbgl)[1]	Rock Elev. (mAHD)
BH1	5.87	2.60	3.27	MB402A	20.29	5.00	15.29
BH2	26.16	5.50	20.66	MB403A	8.04	6.00	2.04
BH3	16.42	5.50	10.92	MB404	35.09	6.00	29.09
BH4	9.64	5.50	4.14	MB405A	2.15	7.00	-4.85
BH5	7.97	5.50	2.47	MB406	22.99	1.00	21.99
BH7	13.24	1.60	11.64	MB407A	17.34	3.00	14.34
BH8	18.19	1.90	16.29	MB407B	17.15	3.00	14.15
BH8	18.19	1.90	16.29	MB407B	17.15	3.00	14.15
BH11	8.57	1.80	6.77	MB408A	9.98	8.00	1.98
BH13	9.00	1.70	7.30	MB409	13.82	7.00	6.82
BH18	19.83	2.00	17.83	MB410A	1.61	9.00	-7.39
BH19	9.13	2.50	6.63	MB411A	10.13	1.00	9.13
BH101	17.52	0.70	16.82	MB412A	2.64	10.00	-7.36
BH103	14.82	1.10	13.72	TP9	26.31	2.00	24.31
BH104	3.42	6.60	-3.18	TP10	19.26	2.00	17.26
BH105	8.45	5.50	2.95	TP12	16.66	2.20	14.46
BH202	5.85	6.00	-0.15	TP14	18.11	1.00	17.11
MB401A	2.22	7.00	-4.78	TP21	5.28	2.60	2.68

1. Depth to rock taken as the depth to moderately weathered siltstone.
2. Some elevations surveyed. Where survey data unavailable, LIDAR data was used.

5.4.4 Existing Licenced Groundwater Users

According to the Bureau of Meteorology's (BoM) 'Australian Groundwater Explorer' (2020) website there are 6 registered boreholes in the Culburra Beach township. Registered bore locations are shown in Map 19 and available data are summarised in Table 31. None of the registered bores have available water level data. Of the registered bores, the three that are closest to the proposed development, are monitoring bores which appear to be for the Metro Service Station on Fairlands Street. Of the three remaining bores, one is abandoned and the other two were drilled more than 50 years ago and can be assumed abandoned. Regardless, these three supply bores are all within

[112] Taken as the depth to moderately weathered siltstone formation.

200 m of the coast and are not expected to be influenced by minor changes in the groundwater regime in the Concept Plan area.

Table 31: Registered boreholes in Culburra Beach township.

Bore ID	Bore Depth (m)	Drilled Date	Purpose	Status
GW018579	16.1	1/09/1961	Irrigation	Unknown
GW027461	18.8	1/08/1967	Water Supply	Unknown
GW106001	36	13/07/2004	Water Supply	Abandoned
GW115038	8.5	19/08/2014	Monitoring	Functional
GW115039	9	19/08/2014	Monitoring	Functional
GW115040	9	20/08/2014	Monitoring	Functional

5.4.5 Ocean and Lake Levels

The long-term ocean and lake levels are required in order to define constant head boundaries along the appropriate edges of the MODFLOW model.

Manly Hydraulics Laboratory (MHL) operates a tidal gauge at Crookhaven Heads (station number 215408), approximately 2.75 km north of site, where the river meets the Pacific Ocean. Harmonic analysis of data from 1990-2010[113] shows that the mean sea level is typically between -0.01 and 0.05 mAHD with the long-term average mean sea level equal to 0.03 mAHD.

MHL also operates a water level gauge in Lake Wollumboola (station number 215454), approximately 2.0 km south-east of site. MA acquired data from the gauge from January 2017 to February 2020 which shows that the long-term average water level over that time was equal to 0.33 mAHD. The long-term average water level data for Crookhaven River and Lake Wollumboola is summarised in Table 32.

Table 32: Crookhaven River and Lake Wollumboola water levels.

	Monitoring Start Date	Monitoring End Date	Long-Term Average Level (mAHD)
Crookhaven River	1991	2010	0.03
Lake Wollumboola	01/01/2017	17/02/2020	0.33

5.4.6 Groundwater Level Observations

Time series plots of groundwater levels for monitored bores and daily rainfall are provided in Annexure C, Figure 2 to Figure 6. To different degrees, almost all boreholes show a downward trend in groundwater levels which is accelerated in the period of September 2019 to January 2020 inclusive, where very little rainfall was received. The general downward trend is indicative of drier than usual conditions which is supported by the monthly cumulative residual rainfall plot. During periods of wet weather (notably February 2020) some bores show a much greater groundwater level response than

113 NSW Office of Environment and Heritage, 2012.

others, which is likely due to differing degrees of connectivity to surface hydrology and / or differing lags between rainfall events and groundwater level responses.

Statistical summaries of groundwater levels recorded by data loggers are provided in Table 33.

Table 33: Statistical summary of monitoring well water levels.

Bore I.D.	Ground Level (mAHD)	Monitoring Period		Groundwater Levels				
		Start	End	Min. (mAHD)	Median (mAHD)	Mean (mAHD)	Max (mAHD)	Range (m)
BH01	5.87	19/09/2019	19/02/2020	1.59	4.29	4.34	5.73	4.14
BH02	26.08	19/09/2019	19/02/2020	18.99	21.88	22.13	25.63	6.64
BH06	4.86	1/10/2019	19/02/2020	1.03	3.27	3.31	4.26	3.23
MB401A	2.43	27/11/2017	26/02/2020	-0.45	0.27	0.21	0.64	1.09
MB401B	2.63	27/11/2017	26/02/2020	-0.37	0.33	0.31	0.79	1.17
MB402A	20.23	27/11/2017	26/02/2020	2.36	3.31	3.30	4.21	1.86
MB402B	6.78	19/12/2017	26/02/2020	0.50	1.40	1.66	3.01	2.51
MB403A	8.64	28/11/2017	26/02/2020	6.29	7.21	7.16	8.05	1.75
MB403B	8.44	28/11/2017	21/08/2019	5.98	6.87	6.86	7.84	1.86
MB404	35.15	28/11/2017	26/02/2020	25.90	27.91	27.95	31.49	5.59
MB405A	2.07	19/12/2017	19/02/2020	0.07	0.63	0.61	1.13	1.06
MB405B	2.18	19/12/2017	26/02/2020	-0.01	0.74	0.77	1.95	1.96
MB406	22.87	27/11/2017	26/02/2020	9.61	10.07	10.03	10.23	0.62
MB407A	17.25	27/11/2017	26/02/2020	3.28	8.25	8.45	17.02	13.74
MB407B	17.12	30/06/2018	26/02/2020	9.88	9.90	9.96	15.18	5.30
MB408A	9.89	28/11/2017	26/02/2020	0.23	0.84	0.91	1.76	1.52
MB408B	9.78	24/11/2017	5/02/2020	3.28	3.28	3.29	3.73	0.45
MB409	13.58	27/11/2017	26/02/2020	3.92	4.35	4.40	5.02	1.10
MB410A	1.45	28/11/2017	26/02/2020	0.87	1.15	1.15	1.45	0.58
MB410B	1.51	24/11/2017	26/02/2020	0.35	0.83	0.85	1.41	1.07
MB411A	10.24	27/11/2017	26/02/2020	4.25	4.69	4.72	6.50	2.24
MB411B	10.39	27/11/2017	25/02/2020	4.22	5.57	5.57	9.05	4.82
MB412A	2.58	19/12/2017	26/02/2020	0.24	0.81	0.85	1.43	1.19
MB412B	2.54	19/12/2017	26/02/2020	0.19	0.89	0.96	1.83	1.64

No regional groundwater data was available to be utilised in this assessment.

5.4.7 Hydraulic Conductivity

Hydraulic conductivity (K_{sat}) testing has been undertaken over several site visits in the last decade in West Culburra. Additional constant head permeameter testing was also conducted in early 2020. The calculation sheets for all testing are provided in Annexure H and Annexure I, with results summarised in Table 34.

Table 34: Result from site saturated hydraulic conductivity testing.

Testing Regime	Bore ID	Result (m/day)	Average (m/day)
2010 Rising Head Slug Tests (Siltstone)[1]	BH1	0.057	0.036
	BH1a	0.035	
	BH2	0.043	
	BH6	0.007	
2014 Falling Head Permeability Tests (Lower Subsoil)[1]	TP302	0.013	0.035
	TP303	0.002	
	TP304	0.052	
	TP305	0.027	
	TP306	0.056	
	TP307	0.079	
	TP309	0.019	
2020 Constant Head Permeability Tests (Upper Subsoil)[2]	BH501	0.452	0.511
	BH502	0.129	
	BH503	1.321	
	BH504	0.481	
	BH505	0.170	

1. Previously reported in Water Cycle Management Report – Mixed Use Subdivision: West Culburra, NSW, P1203365JR01V07 (MA, 2016). Annexure H for slug tests and Annexure I for falling head tests.
2. See Annexure I.

5.4.8 Groundwater Quality

For this assessment, groundwater quality testing on the site was conducted at 5 monitoring wells on six separate occasions between September 2019 and March 2020. Previously, groundwater quality was investigated in 2010 by MA on one occasion across three monitoring bores (previously reported in P1002842JR03V01), and by HGeo in 2017-2018 across their monitoring bore network (21 bores, reported in the HGeo report).

Groundwater quality data for the whole site is summarised in Table 35. Graphs of average acidity (pH), electrical conductivity (EC), total dissolved solids (TDS), total nitrogen (TN), total phosphorous (TP), and Faecal Coliforms (FC) for the current monitoring period are provided in Annexure C, Figure 7 to Figure 12 respectively. Full results for these parameters are provided in Annexure K.

Table 35: Summary of all site groundwater quality results.

	pH	EC	TDS	TN	TP	FC [1]
Units	pH Units	µS/cm	mg/L	mg/L	mg/L	CFU/100 mL
PQL [2]	N/A	1	5	0.1	0.05	1
Minimum	4.21	170	150	0.10	0.01	1
25th Percentile	6.10	2,335	1,400	0.21	0.05	10
Median	6.73	3,950	2,470	0.43	0.10	20
Mean	6.55	7,184	4,769	1.26	0.35	312
75th Percentile	7.20	11,550	6,780	0.91	0.30	20
Maximum	7.88	22,700	19,800	31.10	3.05	5,400

1. Where the value of FC was reported as being less than a value, the maximum value was taken for the purposes of this summary (e.g. a reported value of <10 CFU/100 mL was taken as 10 CFU/100 mL).
2. PQL = practical quantification limit. For the purposes of this summary, any results below the PQL were taken as the PQL.

5.4.9 Groundwater Dependent Ecosystems (GDEs)

We understand from the project ecologist, Mr Paul Anink, that there are no GDEs downslope of the proposed development, on the fringes of the Crookhaven River.

The Water Sharing Plan (WSP) for the Clyde River Unregulated and Alluvial Water Sources 2016 identifies Lake Wollumboola as a high-priority Lake GDE, and the SEPP 14 wetlands along the fringes of Lake Wollumboola as high priority Wetland GDEs. The WSP for the South Coast Groundwater Sources 2016 identifies Lake Wollumboola as a high-priority wetland GDE. The WSP for the Greater Metropolitan Region Groundwater Sources 2011 does not identify any high-priority GDEs within the study area. See Map 10 for a map of the high priority GDEs.

5.4.10 Groundwater System Productivity

The NSW Department of Primary Industries Office of Water NSW Aquifer Interference Policy (AIP, 2012) defines groundwater systems as 'high productivity' or 'low productivity', with high productivity groundwater systems characterised by:

(a) Groundwater quality – total dissolved solids (TDS) < 1,500 mg/L

(b) Groundwater supply – yield > 5 L/s.

The highest TDS measured was 14,000 mg/L in BH6, while the average across all bores and sample periods was 3,100 mg/L which is well over the limit for a highly productive aquifer in terms of groundwater quality.

In terms of groundwater supply, based on the measured hydraulic conductivities, 5 L/s abstraction from the aquifer is not assessed to be possible. Therefore, it is assessed that this aquifer should be classified as 'low productivity' according to the AIP.

5.5 Existing Conditions Groundwater Model

5.5.1 Conceptual Model

A conceptual hydrogeological section has been developed based on existing physical data across the model domain and is provided in Annexure L.

5.5.2 Hydraulic Conductivity and Confinement

As described in Section 3.1, there are two principle geologies and three principle soil landscapes across the West Culburra area. For modelling purposes, these have been grouped into four hydrogeological units: bedrock (Wandrawandian siltstone), Quarternary deposits / sands, alluvial sands, and residual soils. The following is observed:

(a) For all hydrogeological units, vertical hydraulic conductivity is assumed to be one third of the horizontal hydraulic conductivity due to layering of strata and the presence of relatively low permeability interbeds.

(b) Siltstone is expected to have the lowest hydraulic conductivity of all the geological units and be in the order of 10^{-4} to $5x10^{-2}$ m/day.[114]

(c) Sand deposits have the highest hydraulic conductivity of all the geological units in the model and would likely be in the order of 0.5 - 15 m/day.

(d) Residual soils will likely have lower hydraulic conductivity than sand, say in the order of 0.01-1.0 m/day, as per the field testing (Section 5.4.7).

(e) Groundwater likely occurs under unconfined and semi-confined conditions.

5.5.3 Groundwater Levels and Flow Directions

Groundwater gradients observed in monitoring wells indicate that groundwater generally flows from areas of high elevation to areas of low elevation. Over the model domain this means that groundwater generally flows from the ridgelines, down into gullies and valleys and towards either the Crookhaven River or Lake Wollumboola. The water table is generally deeper at areas of high elevations (up to 8 mbgl) and shallower at areas of low elevation (1 – 2 mbgl).

5.5.4 Sources and Sinks

Groundwater recharge is driven by rainfall infiltration which is typically low over the Concept Plan area due to topography and soil types. Evapotranspiration, which represents a primary sink for groundwater, is relatively high across the model domain due to the large areas of vegetation, observing that vegetation type varies across the model domain and includes grassed areas / pastures, forest, and mangroves.

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114 Bair, E. Scott, and Lahm T.D. (2006), *Practical Problems in Groundwater Hydrology*.

5.5.5 Software

The MODFLOW NWT Solver was utilised within the GMS 10.4.1 (2018) graphical user interface for this model.

5.5.6 Settings and Water Balance Error Criteria

The NWT solver options were taken as the recommended settings provided in the USGS Online Guide (2018).

A model water balance error threshold of 1% was used which represents the typically adopted industry threshold value. This water balance error is the percentage difference between the total water coming into the model and the total amount of water leaving the model and is a measure of the reliability of a groundwater model. If the error was above 1%, the model's convergence criteria (closure criterion) was reduced to ensure the model water balance error fell below 1%.

5.5.7 Model Extents

A model domain of approximately 4.14 km east-west by 3.86 km north-south was used (refer to Map 21). Of this area approximately 60% comprised the active model area with the remaining portion being inactive. The active model domain extents were assigned at topographic divides and the Crookhaven River and Lake Wollumboola.

5.5.8 Grid Cell Configuration

A 2.5 x 2.5 m grid cell size was used over a 1,660 m east-west, by 1137.5 m north-south area centred on the Proposal area. Over the remainder of the model domain, a progressively coarser resolution was used, from 5 x 5 m, 10 x10 m, to 20 x 20 m, up to 40 x 40 m cells. Grid cell configuration is provided at Map 21.

5.5.9 Model Layers

Model geology was represented using 2 layers. The top of layer 1 represents the existing topography and was defined using 10 m LIDAR data (NSW LPI,2010), 1m LIDAR data (NSW DFSI, 2011), and bathymetry data for the Crookhaven River (NSW Department of Natural Resources, 2008). The bottom of layer 2 was set to a constant value of -20 mAHD. This does not represent a geological boundary but was assessed to be acceptable for modelling given a minimum layer thickness of approximately 15 m.

The interface between layers 1 and 2 (bottom of layer 1, top of layer 2) was estimated using all borehole logs in the model domain which reached 'moderately weather siltstone'. The interface level was modelled in the following way:

(a) The entire model domain was classified into areas according to the assumed depth to rock (determined from borehole logs). This classification was converted into a raster in QGIS representing rock depth.

(b) The 'rock depth' raster was taken away from the surface elevation raster resulting in a 'top of rock' elevation raster.

(c) This 'top of rock' elevation raster was then processed using a 50-cell filter in QGIS to smooth the transition between classification zones and remove meaningless noise from the original surface elevation raster.

Layer 2 was taken to be all the same material (Wandrawandian siltstone), while layer 1 was divided into three material types based on the soil landscape map. Material / hydraulic conductivity zonation for layer 1 is shown in Map 22.

5.5.10 Constant Head Boundaries

Constant head boundaries were applied to all layers of the model along Crookhaven River and Lake Wollumboola. The constant head of Crookhaven River was set to 0.03 mAHD and 0.33 mAHD for Lake Wollumboola (refer to Section 5.4.5). Refer to Map 21 for the location of model boundary conditions.

5.5.11 Evapotranspiration

An average annual evapotranspiration rate was applied uniformly across the model domain. Evapotranspiration extinction depths of 3 m were applied to forested areas, 1 m to urban areas, and 2m to grass, scrub and mangrove areas. Extinction depth zonation is shown in Map 24.

5.5.12 Pre-Calibration Model Parameters

Horizontal hydraulic conductivities were adjusted within the upper and lower bounds in Table 36 to achieve calibration. A vertical anisotropy ratio of 3 was used for all geological units. Recharge rates were adjusted within the upper and lower bounds in Table 37 to achieve calibration with recharge zonation shown in Map 23.

Table 36: Horizontal hydraulic conductivity calibration ranges.

Calibration Zone	Investigation Range (m/day)
Greenwell Point (residual soils)	0.01 – 0.4
Seven Mile (Quaternary sands)	1.0 – 5.0
Mangrove Creek (alluvial sands)	2.0 – 15.0
Wandrawandian siltstone	0.002 – 0.100

Table 37: Recharge rate calibration ranges.

Calibration Zone	Investigation Range (mm/year)
Forest	30 - 75
Grassed	50 - 150
Industrial	0 - 25
Mangroves	30 - 100
Road	0 - 10
Swamp	40 - 120
Urban	10 - 30
Wastewater Treatment Facility	40 - 80

5.5.13 Calibration

5.5.13.1 Period and Targets

The existing conditions MODFLOW model was calibrated to the mean of all long-term groundwater level monitoring within the model domain. No reliable water level data were available for calibration purposes from existing registered bores in the model domain.

5.5.13.2 Final Parameterisation

Hydraulic conductivity values and recharge values were adjusted within the ranges identified in Section 5.5.12 to achieve calibration. Final calibrated model parameters are presented in Table 38.

Table 38: Calibrated model parameters.

Calibration Parameter	Units	Calibrated Value
Hydraulic Conductivities		
Greenwell Point (residual soils)	m/day	0.10
Seven Mile (Quaternary sands)	m/day	4.0
Mangrove Creek (alluvial sands)	m/day	10.0
Wandrawandian siltstone	m/day	0.035
Recharge Rates		
Forest	mm/year	54
Grassed	mm/year	120
Industrial	mm/year	12
Mangroves	mm/year	60
Road	mm/year	0
Swamp	mm/year	90
Urban	mm/year	24
Wastewater Treatment Facility	mm/year	60

5.5.13.3 Outcome Statistics

A calibration scatter plot of modelled and observed heads is provided in Annexure C, Figure 13, and a summary of the key calibration statistics is provided in Table 39. The model's normalised RMS was 9.99% with an absolute residual mean of 1.95 m and a residual mean of 0.91 m which indicates a bias towards a slight over-prediction of head. The mass balance discrepancy was -0.001% and therefore acceptable being below the adopted threshold of 1.0%.

Overall, the predicted existing conditions model closely replicated the observed groundwater level data and the model was considered satisfactory for predictive purposes.

Table 39: Summary of key calibration statistics.

Parameter	Result	Parameter	Result
No. of Data Points	24	Min Abs. Residual	0.0025
Mean Residual	0.907	Max Computed	23.96
Mean Absolute Residual	1.95	Min Computed	0.16
Root Mean Squared Residual	2.77	Min Observed	0.24
Normalised RMS	9.99%	Max Observed	27.95
Max Abs. Residual	6.37	Observed Range =	27.71

5.5.14 Results

The predicted heads for Layer 1 over the site for the existing conditions model are provided in Map 25 with existing conditions depths to groundwater provided at Map 26. A cross-section of the groundwater level through the model at the proposed development site is provided in Map 27.

5.5.15 Model Confidence Level Classification

In accordance with the Australian Groundwater Modelling Guidelines (2012), the model is considered to generally represent a 'Class 2' model confidence level classification, suitable for impact assessment. A 'Class 2' classification is justified on the basis of the following:

(a) Calibration statistics are generally reasonable.

(b) Mass balance error is less than 1.0%.

(c) Geotechnical data coverage is reasonable in the vicinity of the proposed development.

(d) Model parameters are generally consistent with conceptualisation.

5.6 Performance Assessment

5.6.1 Overview

A post-developed groundwater model was created from the existing conditions model to quantify potential changes to the local groundwater regime. Model parameters from the existing conditions model were kept constant except for those that would be impacted by changes caused by the proposed development.

The Concept Plan was assessed by completing three post-development models which are summarised in Table 40.

Table 40: Post-development groundwater models.

Model ID	Description	Purpose
GWD-T1	Developed – treated (no exfiltration)	To determine the effect of urbanisation assuming that no additional groundwater recharge would occur from the stormwater management measures such as biobasins and ponds.
GWD-T2	Developed – treated (with exfiltration)	To determine the effect of urbanisation assuming that groundwater recharge would occur from stormwater management measures such as biobasins and ponds at an exfiltration rate of 0.25 mm/hr.
GWD-T2WQ	Developed – treated water quality (with exfiltration)	To determine the effect on groundwater quality of groundwater recharge at stormwater management measures such as biobasins and ponds at an exfiltration rate of 0.25 mm/hr.

5.6.2 Adjustments to Existing Conditions Model

The post-development model was built from the existing conditions model by modifying the recharge rates and the evapotranspiration extinction depths over the developed area to account for the change to the landform and land-use. The following is noted:

(a) Recharge rates over the Concept Plan area were changed in line with the previously adopted and calibrated rates for urban, industrial, and grassed areas.

(b) Stormwater treatment device layout was taken from the designed sizes from MUSIC.

(c) Recharge rates for the bioswales, biobasins and ponds were taken from MUSIC modelling by taking the total yearly infiltration for each structure and dividing by the area of the structure resulting in a constant average infiltration rate from the structure to groundwater. The areas of the structures were modelled as 'effective areas.' This means that the large ponds were modelled as being 1.5 times as big to account for batters, and that the smaller swales were taken as the whole, uninterrupted length of the swale.

(d) Evapotranspiration extinction depths over the site were changed in line with the previously adopted and calibrated depths for urban, industrial, and grassed areas. Extinction depths for the water treatment swales and basins were taken as the same as grass (2.0 m).

(e) Evapotranspiration rates over the biobasins and ponds were increased to open water evaporation rates by dividing by a pan factor of 0.770[115] to account for the ponded water which will occur in these areas from time to time.

(f) All other parameters such as hydraulic conductivities, constant head boundaries were kept constant from the existing conditions model.

[115] McMahon T. A. et al (2013), '*Supplementary Material to paper: 'Estimating actual, potential, reference crop and pan evaporation using standard meteorological data: a pragmatic synthesis*''.

5.6.3 Groundwater Levels

5.6.3.1 Model GWD-T1 - No Losses from Stormwater Structures

Groundwater heads, depths to groundwater, and sections for this post-development model scenario are shown in Map 30, Map 31 and Map 32 respectively. Areal changes to groundwater levels from the existing model scenario are shown in the drawdown plot at Map 33. The drawdown plot is calculated by taking the post-development groundwater levels from the existing groundwater levels. Therefore, a positive value indicates a lowering of the groundwater level while a negative value indicates a raising of the groundwater level. The following is observed:

(a) In general, urbanisation results in a reduction in groundwater levels as a result of reduced direct rainfall recharge.

(b) Off-site impact in terms of groundwater are minor and meet the groundwater management performance targets.

5.6.3.2 Model GWD-T2 - With Exfiltration from Stormwater Structures

Groundwater heads, depths to groundwater, and sections for the post-development model scenario are shown in Map 34, Map 35 and Map 36 respectively. Areal changes to groundwater levels from the existing model scenario are shown in the drawdown plot at Map 37. The drawdown plot is calculated by taking the post-development groundwater levels from the existing groundwater levels. Therefore, a positive value indicates a lowering of the groundwater level while a negative value indicates a raising of the groundwater level. The following is observed:

(a) Enabling recharge causes groundwater levels to marginally rise in areas close to and downslope of the recharge structures. This to some degree compensates for the reduced flow rates experienced in upper portions of the Concept Plan where recharge on balance is reduced due to urbanisation.

(b) Drawdown does not extend past the edges of the model near the Culburra Beach township and therefore does not come close to any of the three old or abandoned water supply bores (see section 5.4.4 and Map 19).

(c) There is no drawdown at the edges of the Crookhaven River however there is an increase in groundwater levels in these areas due to being downslope of the proposed development. 30 m downstream from the edge of the basin, these increases are less than 1.0 m. It is therefore assessed that these changes are moderate and are acceptable.

5.6.4 Groundwater Flow Budgets

Groundwater flow zone budgets for the Crookhaven River and Lake Wollumboola were setup for both existing and post-development models as described in Map 25). From these areas, the flows into and out of the main aquifer could be quantified and then compared. These results are summarised in Table 41 for post-development model GWD-T1 with no recharge at stormwater management measures, and in Table 42 for post-development model GWD-T2 which includes an exfiltration rate of 0.25 mm/hr from stormwater management measures. Results indicate:

(a) Where no recharge at stormwater management measures occurs, recharge rates are reduced in the order of 30 % to the Crookhaven River and < 1 % to Lake Wollumboola.

(b) Where recharge at stormwater management measures occurs, recharge rates to the Crookhaven River and to Lake Wollumboola are close to existing conditions, demonstrating the benefit of undertaking stormwater recharge to groundwater.

Table 41: Groundwater flow budgets for Model GWD-T1 (no stormwater recharge).

	Existing Flow (ML/year)	Post-Development Flow (ML/year)	Difference (ML/year) [2]	% Difference [2]
Aquifer to Crookhaven River	20.604	20.163	-0.440	-2.14 %
Crookhaven River to Aquifer	54.616	65.128	10.512	19.25 %
Net Flow	- 34.012 [1]	-44.964 [1]	-10.952	-32.20 %
Aquifer to Lake Wollumboola	39.017	38.803	-0.215	-0.55 %
Lake Wollumboola to Aquifer	0.999	1.014	0.015	1.49 %
Net Flow	38.018 [1]	37.788 [1]	-0.230	-0.60 %

1. A positive indicates flow from the aquifer while a negative flow indicates flow into the aquifer.
2. A positive difference indicates an increase in the magnitude of that flow component while a negative difference indicates a reduction in the magnitude.

Table 42: Groundwater flow budgets for Model GWD-T2 (with stormwater exfiltration).

	Existing Flow (ML/year)	Post-Development Flow (ML/year)	Difference (ML/year) [2]	% Difference [2]
Aquifer to Crookhaven River	20.604	20.811	0.207	1.01 %
Crookhaven River to Aquifer	54.616	57.407	2.791	5.11 %
Net Flow	- 34.012 [1]	- 36.596 [1]	- 2.584	- 7.60 %
Aquifer to Lake Wollumboola	39.017	38.753	- 0.264	- 0.68 %
Lake Wollumboola to Aquifer	0.999	1.009	0.009	0.92 %
Net Flow	38.018 [1]	37.745 [1]	- 0.274	- 0.72 %

1. A positive indicates flow from the aquifer while a negative flow indicates flow into the aquifer.
2. A positive difference indicates an increase in the magnitude of that flow component while a negative difference indicates a reduction in the magnitude.

5.6.5 Groundwater Quality

5.6.5.1 Pollutant Transport Model GWD-T2WQ Setup

MT3DMS was used to model the behaviour of pollutants contained in stormwater recharged to the groundwater system at stormwater management structures. To do this:

(a) Background groundwater concentrations as well as recharge concentrations were assumed to be zero.

(b) Exfiltration concentrations from each of the stormwater management structures obtained from the MUSIC model[116] were reduced subtracting the median of the observed groundwater concentration levels (see Table 35) and defined as 'specified concentration' continuously recharged at these locations.[117]

(c) In order to model Faecal Coliforms, it was conservatively assumed that each stormwater management structure would deliver a constant concentration of 7,000 CFU/100mL. This is particularly conservative, or indeed unrealistic, for the pond structures which provide significant hydraulic retention and treatment of pathogens as documented in Section 4.5.4. However, the approach is useful in that it provides a potential upper bound analysis.

(d) Model inputs for MT3DMS are summarised in Table 43.

Table 43: MT3DMS model 'specific concentration' inputs.

	TN Specified Concentration (mg/L)	TP Specified Concentration (mg/L)	FC Specified Concentration (CFU/100mL)
Biobasin A East	0.6049	0.0583	8,000
Biobasin A West	0.6049	0.0583	8,000
Biobasin B	0.6015	0.0827	8,000
Biobasin C	0.6030	0.0710	8,000
Pond 1	1.1003	0.0923	8,000
Pond 2	1.1960	0.0953	8,000
Pond 3	0.6049	0.0583	8,000

In terms of the MT3DMS model set-up:

(a) The advection, dispersion, source / sink mixing, and chemical reaction packages were used.

(b) The chemical reaction package was set to run with linear isotherm sorption and first-order irreversible kinetic reaction.

(c) Other parameters used in the MT3DMS model are summarised in Table 44.

(d) We note that the effect of vegetative uptake, which would be considerable, has not been included in the analysis.

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116 Determined by dividing annual forecast infiltrated load by annual forecast infiltration volume.

117 *Specific Concentration* is the concentration above background concentration levels.

Table 44: Summary of parameters used in MT3DMS.

Parameter	Value	Comment
Greenwell Point Porosity	0.3	Assumed
Seven Mile Porosity	0.35	Assumed
Mangrove Creek Porosity	0.40	Assumed
Silt Stone Porosity	0.30	Assumed
Greenwell Point Specific Yield	0.03	Bair and Lahm (2006)[118]
Seven Mile Specific Yield	0.25	Bair and Lahm (2006)
Mangrove Creek Specific Yield	0.27	Bair and Lahm (2006)
Silt Stone Specific Yield	0.12	Bair and Lahm (2006)
Greenwell Point Longitudinal Dispersivity	14.29	Calculated[119]
Seven Mile Longitudinal Dispersivity	11.53	Calculated
Mangrove Creek Longitudinal Dispersivity	2.23	Calculated
Silt Stone Longitudinal Dispersivity	15.22	Calculated
Transverse / Longitudinal Dispersivity	0.1	Assumed, standard value
Vertical / Longitudinal Dispersivity	0.01	Assumed, standard value
Effective Molecular Diffusion Coefficient	0	N/A
Soil Bulk Density	1,600 kg/m^3	Look (2008)[120]
Siltstone Bulk Density	2,100 kg/m^3	Assumed
TN Sorption Coefficient	0.00933	Remya *et al.* (2010)[121]
TP Sorption Coefficient	0.713	GeoLINK (1996) [122]
FC Sorption Coefficient	0	N/A
TN Decay Rate	0.001386	Calculated. Equivalent to 500 d half life
TP Decay Rate	0	N/A
FC Decay Rate	0.578	Equivalent to a 1.2 d half-life

5.6.5.2 Contaminant Transport Outcomes

MT3DMS was used to simulate 10 years of pollutant transport in the groundwater system with resultant pollutant transport extents for TN, TP, and FC shown in Map 38, Map 39 and Map 40 respectively. The following is noted:

(a) Over time contaminant transport distances from the stormwater recharge location reaches a point of equilibrium, where any further transport is nullified by reaction of the pollutant with the environment (i.e. adsorption and decay).

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118 Bair E. & Lahm, T. (2006), '*Practical Problems in Groundwater Hydrology*'.
119 Fetter C.W. (2001). '*Applied Hydrogeology 4th ed.*', equation 10.9.
120 Look, B. (2007) '*Handbook of Geotechnical Investigation and Design Tables (2007)*'.
121 Remya, N., Kumar, M. & Azzam, R. (2010), '*Influence of organic matter and solute concentration on nitrate sorption in batch and diffusion-cell experiments*'.
122 GeoLINK (1996) '*Clunes Wastewater Management Study Volume 1 and Volume 2*'.

(b) In respect of each contaminant modelled, the maximum 'plume' length and time to reach equilibrium conditions was observed.

A summary of distances the contaminants were transported downslope of the stormwater management structures, as well as the time taken to reach equilibrium conditions for each pollutant for the normal model run and the sensitivity model run is provided in Table 45. The following is observed from these outcomes:

(a) Contaminant transport distances are relatively short and are readily contained within the 100 m buffer to the Crookhaven River.

(b) Pathogen times to equilibrium concentration are a function of pathogen half lives and therefore do not require much time before equilibrating.

Table 45: Pollutant transport model results.

	Plume Extent Cut-off Concentration	Pollutant Plume Spread Range (m)	Time to Equilibrium Conditions
Total Nitrogen	0.01 mg/L	12 – 24	8 years
Total Phosphorous	0.001 mg/L	5 – 12	11 years
Faecal Coliforms	1 CFU/100mL	8 – 18	2 months

Further to the above, it is worth noting that the contaminant transport analysis was undertaken on the basis of median groundwater concentrations, which therefore discounts the spread of water quality data observed in the groundwater monitoring. At Table 46, the statistical TN and TP distributions modelled by MUSIC for net exfiltration from the entire stormwater management scheme is compared to the observed groundwater quality data distributions (see Table 35). The following is noted:

(a) Mean MUSIC model exfiltration TN concentrations are approximately 50% of the observed groundwater concentrations. Similarly mean MUSIC exfiltration TP concentrations are approximately 33% of the observed groundwater concentrations.

(b) 75th percentile MUSIC model exfiltration TN and TP concentrations are both lower than 75th percentile concentrations observed in groundwater.

(c) Maximum MUSIC model exfiltration TN and TP concentrations are significantly lower than maximum concentrations observed in groundwater.

(d) These above comparisons illustrate that stormwater contaminant concentrations exfiltrated from stormwater treatment measures are indeed very similar to, and at times at lower concentration, than the levels of contaminants found in the existing groundwater system. This concept is further illustrated by comparing the box and whisker plots for MUSIC exfiltration concentrations and groundwater monitoring data provided in Figure 14.

Table 46: Comparison of net MUSIC exfiltration and groundwater concentrations.

	MUSIC TN Concentrations (mg/L)	Groundwater Sampling TN Concentrations (mg/L)	MUSIC TP Concentrations (mg/L)	Groundwater Sampling TP Concentrations (mg/L)
Minimum	0.60	0.10	0.06	0.01
25th Percentile	0.60	0.21	0.06	0.05
Median	0.60	0.41	0.08	0.10
Mean	0.83	1.28	0.08	0.36
75th Percentile	1.10	0.91	0.09	0.32
Maximum	1.20	31.10	0.09	3.05

1. MUSIC summaries represent concentrations based on all treatment devices.
2. Groundwater summaries represent all available data.

It follows from the modelling undertaken, as well as the comparison between predicted MUSIC exfiltration contaminant concentrations and current groundwater contaminant concentrations, that recharge of groundwater at a rate of 0.25 mm/hr from stormwater management measures is ecologically sustainable and will not result in any detrimental harm to the existing groundwater system or downstream receiving environments.

5.6.6 Aquifer Interference Policy

The Aquifer Interference Policy (AIP) details the role and requirements of the Minister administering the *Water Management Act 2000* (NSW) in regards to water licensing and assessment processes for aquifer interference activities under the Act.

The AIP applies to all activities that penetrate, interfere with, obstruct, abstract water from, or dispose of water to, an aquifer. The AIP requires that proponents demonstrate that the minimal impact considerations specified under the AIP can be met. An assessment of the proposal's compliance with the AIP is provided in Annexure J and is based on physical hydrogeological investigations and the groundwater modelling reported in the previous sections.

The groundwater source category at the site is defined as being a 'Less Productive Porous and Fractured Rock Water Sources' due to a likely water yield rate of less than 5 L/s, as specified by the AIP.

The assessment has found that the groundwater impacts of the proposed development comply with the requirements of the AIP.

5.7 Summary Observations and Comments

The following summary observations and comments are made in respect of the groundwater management system and associated investigations documented herein:

(a) Groundwater flow modelling has demonstrated that groundwater flow regimes and directions are effectively maintained by the Proposal. The predicted groundwater levels, whilst modified somewhat from current conditions due to changes in the distribution in groundwater recharge arising from modifications to vegetation cover and the extent of impervious areas, are not likely to result in any adverse environmental outcomes.

(b) Groundwater modelling investigated the potential benefits and risks associated with enabling some recharge of groundwater via a nominal 0.25 mm/hr exfiltration rate at the proposed stormwater treatment measures. Results of those investigations found that some 15 ML/year of stormwater recharge[123] to groundwater can be achieved without any material adverse impact on the groundwater flow regime. Groundwater flow budgets to the Crookhaven River and Lake Wollumboola with a recharge system in place are closely matched to current conditions.

(c) On the basis of groundwater contaminant transport modelling undertaken, as well as the comparison between predicted MUSIC exfiltration contaminant concentrations and current groundwater contaminant concentrations, an exfiltration rate of 0.25 mm/hr from stormwater management measures is ecologically sustainable and will not result in any detrimental harm to the existing groundwater system or downstream receiving environments.

(d) The impact assessment undertaken herein has demonstrated compliance with the NSW Aquifer Interference Policy.

[123] Refer to Section 4.5.3.

6 Water Supply

6.1 Overview

The water supply scheme proposed for the Concept Plan uses a combination of 'at-source' and 'reticulated' services to ensure that an appropriate and sustainable water supply is provided. These include:

(a) Reticulated town mains provided by Shoalhaven Water.

(b) Rainwater tanks attached to individual dwellings and other commercial or industrial structures.

(c) Irrigation water supplied by stormwater harvested from urban runoff.

The following sections briefly outline each of these sources.

6.2 Preliminary Demand Analysis

A preliminary water demand analysis for the Concept Plan area has been prepared in Table 47. These daily demand rates do not include irrigation demands which have for the purposes of this report been adopted at 43 ML/year (refer to Section 4.4.3.6, Table 18). Ultimately these demand rates for urban release areas will be the subject of more detailed analysis and design requirements as directed by Shoalhaven Water as future development applications for the Proposal are lodged.

Table 47: Preliminary net water demand rate estimates.[124]

	Units	EP/Unit	Average Daily Demand (KL/d)	Peak Day Demand (KL/d)
Western Portion				
Residential Lots	244	3	146.4	366.0
Industrial	12	5	12.0	30.0
Eastern Portion				
Industrial	1	5	1.0	2.5
Medium Density	167	3	100.2	250.4
Integrated Housing	45	3	27.0	67.5
Mixed Residential/Commercial	3	5	3.0	7.5
Totals			289.6	723.9

124 Based on based demand rate of 0.2 KL/ep/day and methods derived from the Water Services Association of Australia (2011) *Water Supply Code of Australia*, 3rd ed.

6.3 Water Supply Sources

6.3.1 Reticulated Mains

Reticulated mains supply will be made available to the entire Concept Plan area. The reticulated supply will be owned and operated by Shoalhaven Water in accordance with their current water service provider obligations.

We understand that in order to service the Concept Plan, a single DN300 spur main from the existing trunk main in Culburra Road will be constructed by Shoalhaven Water to service the Proposal.

6.3.2 Rainwater Tanks

As outlined in Section 4.2.1, rainwater tanks for roof water capture and re-use have been incorporated into Concept Plan. Table 48 provides preliminary bulk rainwater storage volumes held within the Concept Plan area. With the provision of the storage across the site, approximately some 40 ML/year of stormwater is supplied for beneficial reuse.

Table 48: Preliminary bulk rainwater tank storages and rainwater demands.

	Units	Rainwater Tank Volume (KL)
Western Portion		
Residential Lots	244	1220
Industrial	12	180
Eastern Portion		
Industrial	1	15
Medium Density	95	475
Integrated Housing	45	225
Mixed Residential/Commercial	3	45
Total		2,160

6.3.3 Stormwater Harvesting

Harvesting of urban runoff and re-use for irrigation over parkland and sports fields proposed as part of the Concept Plan forms an important component of the WSUD strategy. Details of the harvesting system are summarised at Section 4.2.5.

For modelling purposes, total Concept Plan area irrigation demand was taken as 21 ML/year. However, based on Shoalhaven City Council estimates, required volumes may range between say 27 ML in a wet year to 39 ML in a dry year.

7 Sewage Management

7.1 Overview

The Concept Plan area will be serviced by a reticulated sewage management scheme owned and operated by Shoalhaven Water. Our understanding of the scheme is that it will broadly encompass the following:

(a) Reticulated sewer connection will be provided to all urban development areas.

(b) The western portion of the Proposal will require a new sewage pumping station (SPS) to be constructed.

(c) The eastern portion of the Concept Plan will be configured to drain into the existing Culburra Beach sewer network.

7.2 Scheme Description

7.2.1 Sewage Generation

Based on the layout, lot types and areas shown on the Concept Plan, preliminary sewage generation estimates are provided in Table 49 for average dry weather flow (ADWF), peak dry weather flow (PDWF), and anticipated peak wet weather flow (WWF) conditions. Flow estimates have been separated into sewer catchments draining west to the proposed sewage pumping station and draining east into the existing Culburra Beach sewer network.

We note that the WWF component are expected to be lower than forecast given the sewer system will be built to modern standards and tested for stormwater cross-connections as part of the commissioning process.

Table 49: Preliminary sewage generation rate estimates.[125]

	ADWF (L/s)	PDWF (L/s)	WWF (L/s)
Western Portion			
Residential Lots	1.54	5.38	23.81
Industrial	0.13	0.44	6.16
Eastern Portion			
Industrial	0.01	0.04	1.56
Medium Density	1.05	3.68	3.87
Integrated Housing	0.28	0.99	4.50
Mixed Residential/Commercial	0.03	0.11	0.91

[125] Based on estimates derived from the Water Services Association of Australia (2014) *Gravity Sewerage Code of Australia*.

7.2.2 Shoalhaven Water

We understand that Shoalhaven Water will own and operate the sewage management scheme under its current operating Licence obligations.

7.2.3 Infrastructure

We understand that the following infrastructure will be required to service the Concept Plan:

(a) A reticulated gravity sewer system servicing the Proposal area.

(b) A new SPS to service the western portion of the Proposal area.

(c) Connection to the Culburra Sewage Treatment Plant (STP) which we understand, based on discussions with Shoalhaven Water, will be able to accommodate wastewater generated from the Concept Plan area.

Sewer infrastructure will where possible, be staged so that each development stage can be appropriately serviced. The SPS servicing the western portion of the Proposal area will need to be constructed at Stage 1.

7.3 Environmental Protection and Contingency Measures

7.3.1 Design Objectives

In accordance with the recommendations provided in The Healthy Estuaries Guideline, design objectives for the sewage management scheme are:

(a) Avoid dry weather overflows.[126]

(b) Minimise wet-weather overflows. [127]

(c) Reduce overflow volumes where these occur.[128]

(d) Incorporate 'best practice' risk management measures.

7.3.2 Risk Management Measures

The following risk management measures are recommended to be implemented as part of the sewage management scheme servicing the Concept Plan. These will ensure that maximum protection against overflows reaching and impacting the Crookhaven River Estuary is provided.

1. Implement Best Practice Design and Construction Methods: The sewer would be designed and constructed to current industry standards and in accordance with Shoalhaven Water criteria and obligations.

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126 Healthy Estuaries Guideline, section 2.4 p 10.
127 Healthy Estuaries Guideline, section 2.4 p 10.
128 Healthy Estuaries Guideline, section 3.3 p 27.

2. Undertake Integrity Testing During Commissioning: As part of the commissioning process, new sewer lines should be tested for leaks or potential stormwater ingress so as to minimise the potential for future wet-weather ingress.

3. Certification of Construction Works: Certification from appropriate professionals such as engineers, plumbing contractors and surveyors should be provided at each construction stage to confirm that any newly constructed sewer system is free from stormwater cross-connections and has been built in accordance with the relevant plans, standards and codes.

4. 24 Hour Emergency Response Plan: It is recommended that a site-specific emergency response plan is prepared for any new pumping stations within the Concept Plan area. The response plan would need to be prepared in consultation with Shoalhaven Water who will own and operate the sewer network.

5. Incorporate System Monitoring: The sewer system should be designed to incorporate appropriate alarms and back-to-base telemetry. At a minimum, the following should be provided:

   (i) Live monitoring of SPS water levels and alarms

   (ii) Live monitoring of SPS pump flow metering

   (iii) Live water level monitoring at key manholes in the eastern Proposal area that will drain directly to the existing Culburra Beach sewer system.

6. Backup Systems: The reticulation system would be designed to incorporate where possible various back-up systems and parts so as to reduce maintenance times required to return any system failures to operating conditions. The following should be provided where possible:

   (i) Alternative power supply to operate sewage pumping station(s) in the event of a local area power failure.

   (ii) Duty and stand-by pumping arrangements with capacity to accommodate expected wet-weather flows or pump failure.

   (iii) Key spare parts, such as replacement pumps and valves, located at the sewage pumping station site so that these can be readily exchanged in the event of a component failure, with the aim of preventing an overflow event occurring.

   (iv) Minimum 24 hour dry-weather flow detention storage to be provided at the sewage pumping to ensure that sufficient time is provided to repair any breakdowns prior to overflow occurring.

7. No Direct Overflow Point to Estuary: The reticulation system should be designed so that no infrastructure or overflow points are located within the 100 m forested buffer provided as part of the Concept Plan. This will provide an appropriate level of separation between the sewer scheme and the Estuary, and will ensure compliance with The Healthy Estuaries Guideline.

8. Direct Overflows to Stormwater Ponds: The sewer reticulation system will be designed so that any potential overflows are capable of being directed to the stormwater bioretention basins / ponds for containment and pathogen treatment and removal in the event of an overflow emergency. In the western portion of the Proposal, the SPS overflow will be configured to be directed to the western pond. In the eastern portion of the Proposal, the sewer will be configured so that redirection from a suitably located manhole can occur.

7.3.3 Stormwater Pond Containment

As outlined above under item (8) of the recommended Risk Management Measures, sewer system overflows will be directed to one of the terminal stormwater ponds as an additional risk management measure for protection of water quality in the Estuary.

The ponds will provide significant attenuation of any potential sewer overflow. To illustrate this, the following example is given:

(a) If the western SPS overflowed for around 6 hrs during full wet-weather flow conditions, a peak flow rate of approximately 30 L/s may occur. If the event duration was say 6 hours, then some 650 m^3 of diluted sewage could escape.

(b) Assuming a conservative dilution ratio of 15 and a dry weather FC concentration of say 10^6 CFU/100 mls, overflow concentrations would be say around $7x10^4$ CFU/100 mls. This would be directed to the western pond.

(c) If urban stormwater flow into the pond was say around the 95^{th} percentile flow given it was wet-weather, then some 721 KL/day of water would potentially flow into the pond at a concentration of $7x10^3$ CFU/100 mls. The combined inflow would therefore be 1,391 KL/d at an approximate average concentration of $3.7x10^4$ CFU/100mls.

(d) The hydraulic residence time (HRT) of the combined inflow would therefore be around 7.5 days assuming the pond was full at the start of the event.

(e) Based on the methodology outlined in Section 4.5.4 of this report, pond 1 would treat pathogens to around 500 CFU/100 mL prior to release to the 100 m forest buffer. This is within the range expected from existing forested catchments.

(f) During a dry weather overflow emergency, the ponds would provide a higher level of protection of the downstream environment. This is because: the ponds would not likely be at full capacity; the overflow rate would be much lower at < 10% of the forecast wet weather flow rate; there would be a much higher dilution effect with stormwater contained in the pond, and the pond HRT would consequently be much longer at say > 20 days.

Further to the above, it is reasonable to expect that in the event of an overflow that was contained by the terminal pond, Shoalhaven Water would pump overflows from the pond back into the sewer to prevent losses to the environment.

In conclusion, the terminal stormwater ponds provide a significant and effective risk mitigation measure, during both dry and wet weather overflow risk scenarios.

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8 Construction Staging and Management

8.1 Construction Staging

Given the size of the urban land release area proposed, we understand that the Concept Plan will be developed in a series of discrete stages. The current development staging plan for the Proposal is provided at Annexure P. The following is observed:

(a) Residential land in the western portion of the Proposal is anticipated to be developed in 9 stages. Stage 1 will include the western stormwater pond park area as well as the SPS, bioretention basins servicing residential lots, as well as the bioretention basin servicing the new roundabout and link road to the Concept Plan area.

(b) Industrial land in the central portion of the Proposal is anticipated to be developed in 2 stages.

(c) The Town Centre portion of the Proposal is anticipated to be developed in 5 stages. Stage 1 will include the eastern stormwater pond, bioretention basins and sports field.

(d) Each stage, once completed, will be provided with suitable stormwater management measures to ensure that downstream receiving environments are protected.

8.2 Soil and Water Management Principles

In accordance with the Healthy Estuaries Guideline[129] and recommendations within SDCP,[130] erosion and sediment control will be undertaken in accordance with The Blue Book (see Section 8.3). The Blue Book provides a long accepted state-wide standard for managing soils and stormwater during the construction phase of a project.

It is anticipated that any consent would likely require by way of conditions, compliance with The Blue Book. Compliance with any such conditions is naturally accepted. It is worth noting the following:

(a) Development is likely to be undertaken over a number of construction phases and extending over a number of years. This is not unusual for a large residential land release in an area where the residential market is relatively slow compared to larger urban areas such as Sydney.

(b) Sediment and erosion control measures would be in place and managed for the duration of each construction phase, only to be removed once construction work had been completed and land was sufficiently stable or revegetated to ensure that erosion and sediment generation would not occur.

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129 Healthy Estuaries Guideline, section 2.9 p 17.

130 SDCP, section 5.3.1 p 9.

(c) It follows that even though construction may ultimately occur over many years, it will be staged such that the construction risks presented at each stage are managed and mitigated.

8.3 Erosion and Sediment Control Plan

A preliminary plan, showing the location of all erosion and sedimentation control measures to be utilised for the Proposal is provided at Annexure Q. The details of this plan will be further developed and refined during the development application documentation process as part of future development applications lodged for land within the Concept Plan area.

Generally, we recommend that all sediment and erosion control measures should be audited for compliance during their operational phase. This should at a minimum include the following:

(a) Certification by a suitably qualified engineer that sediment and erosion control structures have been installed in accordance with relevant guidelines such as the Blue Book and any development consent condition requirements.

(b) During construction, outflows from all operational sediment ponds should be monitored to ensure compliance with the Blue Book.

(c) Following heavy or prolonged rainfall, all sediment and erosion control structures should be inspected, cleaned and repaired as required to ensure on-going performance compliance.

(d) In the event that rainfall has not occurred, all sediment and erosion control structures should be inspected, cleaned and repaired on a 3 monthly basis to ensure on-going performance compliance.

(e) A log-book should be kept during the operational phase of all sediment and erosion control measures. The log book should document the date and time of inspection, observations made during the inspection, recommendations for remedial works, and a sign-off for when such works were completed and who completed the works.

9 Water Quality Monitoring Program

9.1 Overview

9.1.1 Purpose

This Water Quality Monitoring Program (WQMP) is intended to provide a framework through which long-term water quality objectives for the Concept Plan are maintained. This WQMP supersedes previous plans prepared for the Proposal given the significant amendment in the footprint in the most recent iteration of the Concept Plan.

9.1.2 Consultation

This WQMP has been prepared with the benefit of an extended period of consultation over the past few years which considered the much larger Concept Plan footprint. This process was useful in identifying key elements and requirements of the monitoring plan. Consultation included a meeting held on 13 August 2013 attended by:

(a) Local oyster farmers

(b) Australia's Oyster Coast Inc

(c) NSW Food Authority

(d) Southern Rivers Catchment Management Authority

(e) Shoalhaven Water

(f) Shoalhaven City Council

(g) NSW OEH

(h) NSW Fisheries

Other historical consultation has included:

(a) A meeting held on 12 September 2013 with additional stakeholders

(b) Submissions provided by NSW OEH (9 May 2014) and NSW DoPE (6 March 2014)

(c) Meetings held with local Oyster farmer representatives on 27 August 2019 and 6 November 2019.

9.2 Risk Assessment

9.2.1 Environmental Receptors

The following sensitive environmental receptors were identified as part of this assessment:

(a) SEPP 14 wetlands

(b) Oyster lease areas

(c) Lake Wollumboola riparian and aquatic areas

(d) Crookhaven River riparian and aquatic areas

(e) Groundwater below the Concept Plan area

9.2.2 Risk Assessment Methodology

The following steps have been completed in undertaking this risk assessment:

(a) Identify hazards by consideration of each sensitive environmental receptor.

(b) Assess consequence of each hazard (Table 50).

(c) Determine likelihood of each hazard occurring (Table 51) with risk management measures in place.

(d) Classify risk as a combination of consequence and likelihood (Table 52).

For each identified hazard the following was assessed:

(a) Pathways by which the hazard could arise.

(b) The types of consequences that may occur if the hazard eventuated and was not suitably mitigated.

(c) The required risk mitigation measures to appropriately mitigate hazard consequences. The measures are aimed at achieving both a reduction in consequence but also a reduction in likelihood.

Table 50: Adopted hazard consequence [Con] definitions.

Descriptor	Definition
Catastrophic (E)	Severe, permanent environmental impact or human health impacts.
Major (D)	Severe, long term environmental impact or possible human health impacts.
Moderate (C)	Localised, medium term environmental impact.
Minor (B)	Localised, short term environmental impact.
Insignificant (A)	No detectable or material environmental impact.

Table 51: Adopted hazard likelihood [Prob]definitions.

Descriptor	Definition
Almost certain (1)	Event is expected to occur often (several times per year).
Likely (2)	Event will probably occur often (once every 1 to 3 years).
Possible (3)	Event might occur (once every 3-10 years).
Unlikely (4)	Event could occur (once every 20 years).
Rare (5)	Event will occur only in rare circumstances (once every 100 years).

Table 52: Adopted risk [risk] definitions.

		Consequence				
		Insignificant (A)	Minor (B)	Moderate (C)	Major (D)	Catastrophic (E)
Likelihood	Almost certain (1)	Low	Medium	High	Very High	Very High
	Likely (2)	Low	Medium	High	Very High	Very High
	Possible (3)	Low	Low	Medium	High	Very High
	Unlikely (4)	Very Low	Low	Low	High	High
	Rare (5)	Very Low	Very Low	Low	Medium	High

9.2.3 Hazards and Risk Management Measures

Identified hazards, hazard pathways and a description of potential consequences of an unmitigated hazard occurring, that being without risk management measures in place, are documented in Table 53.

Table 53: Unmitigated hazards pathways and potential consequences.

Hazard and Pathways	Description of Potential Consequences of Unmitigated Hazard
SPS Overflow to Estuary • SPS component failure • Excessive flow • Rising main failure • SPS power failure	• Temporary degradation in Estuary water quality (typically < 1 day). • Temporary degradation in ecological systems located in riparian zones or SEPP14 wetland areas (typically < 1 day). • Reduced productivity of Oyster lease areas during and after the incident.
Sewer Network Overflow to Estuary • Collapsed sewer • Sewer blockage • Component failure	• Temporary degradation in Estuary water quality (typically < 1 day). • Temporary degradation in ecological systems located in riparian zones or SEPP14 wetland areas (typically < 1 day). • Reduced productivity of Oyster lease areas during and after the incident.
Untreated Stormwater to Estuary • Long-term gross failure of stormwater treatment infrastructure	• Very low-level changes in Estuary water quality.

• Long-term failure in terminal pond embankments	• Possible changes in ecological systems located in riparian zones or SEPP14 wetland areas. • Possibility of reduced productivity of Oyster lease areas during and after the incident.
Untreated Stormwater to Lake • Long-term gross failure of stormwater treatment infrastructure	• Very low-level changes in Lake water quality. • Possible changes in ecological systems located in riparian zones or SEPP14 wetland areas.
Untreated Stormwater to Groundwater • Long-term gross failure of stormwater treatment infrastructure	• Very low-level changes in groundwater water quality.
Irrigation Scheme Failure • Long-term gross failure of stormwater treatment infrastructure	• Increased stormwater runoff volume to Estuary. • Very low-level changes in Estuary water quality. • Possible changes in ecological systems located in riparian zones or SEPP14 wetland areas.
Sediment & Erosion Control Systems Failure • Poor construction and establishment procedures. • Inadequate maintenance during operational phase	• Increased sediment runoff to Estuary or Lake during failure period. • Possible short-term changes in ecological systems located in riparian zones or SEPP14 wetland areas. • Possibility of reduced productivity of Oyster lease areas near the stormwater discharge locations during construction.

9.2.4 Risk Management and Assessment

Risk mitigation / management measures are provided at Table 54, which also provides an assessment of the risk following implementation of risk mitigation measures incorporated into the Concept Plan. Hazard consequence [Cons] and likelihood [Prob] are rated on the assumption that risk mitigation measures are adopted.

Table 54: Hazards, risk management measures and risk assessment.

Hazard	Risk Mitigation Measures Included in Concept Plan	Cons	Prob	Risk
SPS Overflow to Estuary	1. Operated by local water authority under Environment Protection License obligations 2. Best practice design and construction 3. Construction inspection & certification on completion 4. 24 hr dry-weather holding capacity 5. Alarms & back-to-base live monitoring 6. Routine inspections and maintenance 7. 24 hr emergency response plan 8. Incident reporting hotline 9. Include design redundancy (e.g. duty-standby pumps) 10. Back-up parts on-site 11. Alternative power source in event of power failure	A	3	L

	12. No direct overflow connection to Estuary 13. 100 m buffer to Estuary 14. Overflows directed to bioretention basins / ponds for containment and treatment 15. Overflows dispersed across stormwater dispersal swale upslope 100 m buffer			
Sewer Network Overflow to Estuary	1. Operated by local water authority under Environment Protection License obligations 2. Best practice design and construction 3. Construction inspections, leak and cross-connection testing & certification on completion 4. Alarms & back-to-base live monitoring 5. Routine inspections and maintenance 6. 24 hr emergency response plan 7. Incident reporting hotline 8. No direct overflow connection to Estuary 9. 100 m buffer to Estuary 10. Overflows directed to terminal bioretention basins / ponds for containment and treatment 11. Overflows dispersed across stormwater dispersal swale upslope of 100 m buffer	A	3	L
Untreated Stormwater to Estuary	1. Operated by local Council 2. Signage around structures for community awareness 3. Best practice design and construction 4. Independent auditing including construction inspections & certification on completion 5. Routine inspections and maintenance 6. No direct overflow connection to Estuary 7. 100 m buffer to Estuary 8. Overflows dispersed using dispersal system upslope of 100 m buffer 9. On-going water quality monitoring of treatment structures and environmental water (see Section 9.3)	A	4	VL
Untreated Stormwater to Lake	1. Operated by local Council 2. Signage around structures for community awareness 3. Best practice design and construction 4. Construction inspections & certification on completion 5. Routine inspections and maintenance 6. No direct overflow connection to Lake 7. >1,000 m buffer to Lake 8. On-going water quality monitoring of treatment structures and environmental water (see Section 9.3)	A	5	VL
Untreated Stormwater to Groundwater	1. Operated by local Council 2. Best practice design and construction 3. Construction inspections & certification on completion 4. Routine inspections and maintenance	A	4	VL

	5. On-going water quality monitoring of treatment structures and environmental water (see Section 9.3)			
Irrigation Scheme Failure	1. Operated by local Council 2. Best practice design and construction 3. Construction inspections & certification on completion 4. Routine inspections and maintenance	A	4	VL
Sediment & Erosion Control Systems Failure	1. Best practice design and construction 2. Routine auditing, inspection and maintenance during operation including for example structural integrity checks, removal of accumulated sediment and repairs 3. On-going water quality monitoring of treatment structures and environmental water (see Section 9.3)	A	3	L

9.3 On-going Monitoring Plan

9.3.1 Overview

The water quality monitoring plan covers the following environmental water systems:

(a) Surface waters

(b) Stormwater infrastructure

(c) Groundwater

For each environmental water system, the following is described:

(a) Monitoring locations

(b) Monitored parameters

(c) Monitoring frequency

(d) Interim trigger values

(e) Contingency measures

We recommend that the interim trigger values be revised as part of the documentation prepared for the Stage 1 development application in the event that additional environmental data become available.

9.3.2 Surface Water Monitoring

Surface water monitoring locations are provided in Map 41. Parameters to be monitored and associated interim trigger values are provided in Table 55. Recommended monitoring frequency is as follows:

(a) Prior to Stage 1: Monthly for 1 year prior to construction.
2 wet-weather events prior to construction.

(b) On start of Stage 1 build: 3 monthly for 2 years and then review frequency. Following any sewage overflow event.

All sampling is to be undertaken by suitably qualified consultant experienced in fresh and saltwater chemistry including natural, stormwater and groundwater systems and undertaken in accordance with NSW OEH (2013) '*Assessing Estuary Ecosystem Health: Sampling, data analysis and reporting protocols*' and any Shoalhaven City Council requirements.

A trigger event is considered to have occurred if interim trigger values have been exceeded for 2 out of 3 consecutive sampling periods. If a trigger event has occurred, a suitably qualified consultant experienced in fresh and saltwater chemistry including natural, stormwater and groundwater systems should review the water quality data and:

(a) Determine if the changes in water quality are attributable to development in the Concept Plan area.

(b) If the water quality observations are deemed to be attributable to development in the Concept Plan area, then make recommendations to Council or Shoalhaven Water for any necessary remediation works or improvement works to the water cycle management system.

Table 55: Surface water monitoring parameters and interim trigger values.

Parameter	Interim Trigger Value
pH	< 6.75 or > 8.75
Temperature	-
Electrical Conductivity	-
Salinity	< 20 or > 35 g/L
Turbidity	-
Faecal Coliforms	90^{th} percentile > 43 CFU/100mls
Suspended Solids	> 75 mg/L
Total Nitrogen	> 0.60 mg/L
Orthophasphate	-
Total Phosphorus	> 0.06 mg/L
Polycyclic Aromatic Hydrocarbons (PAH)	> Practical Quantification Limit (PQL)
Chlorophyll a	> 4 ug/L
Dissolved Oxygen	< 5 mg/L
Heavy Metals	Aluminium or Iron > 0.01 mg/L

9.3.3 Stormwater Infrastructure Monitoring

Stormwater monitoring locations are provided in Map 41. Parameters to be monitored and associated interim trigger values are provided in Table 56. Suitable monitoring structures will need to be incorporated into the final design of any stormwater infrastructure to be monitored (documented at the stage development application phase). Recommended monitoring frequency is as follows:

(a) Completion of each stage: 3 monthly for 2 years and then review frequency.
Following any sewage overflow event.
2 wet-weather events per year for 2 years and then review frequency.

All sampling is to be undertaken by a suitably qualified consultant experienced in fresh and saltwater chemistry including natural, stormwater and groundwater systems and any Shoalhaven City Council requirements.

A trigger event is considered to have occurred if interim trigger values have been exceeded for 2 out of 3 consecutive sampling periods. If a trigger event has occurred, a suitably qualified consultant experienced in fresh and saltwater chemistry including natural, stormwater and groundwater systems should review the water quality data and:

(a) Determine if the changes in water quality are out of the ordinary or expected performance range or cannot be readily explained by an obvious incident.

(b) If the water quality observations are deemed out of the ordinary, then make recommendations to Council or Shoalhaven Water for any necessary remediation works or improvement works to the water cycle management system.

Table 56: Stormwater monitoring parameters and interim trigger values.

Parameter	Interim Trigger Value
pH	< 5.5 or > 8.5
Temperature	-
Electrical Conductivity	-
Salinity	> 1,500 mg/L
Turbidity	-
Faecal Coliforms	90th percentile > 250 CFU/100mls
Suspended Solids	> 50 mg/L
Total Nitrogen	> 0.70 mg/L
Orthophasphate	-
Total Phosphorus	> 0.15 mg/L
Polycyclic Aromatic Hydrocarbons (PAH)	> Practical Quantification Limit (PQL)
Heavy Metals	Aluminium > 0.6mg/L, Iron > 1.2 mg/L

In addition to the stormwater quality monitoring, visual inspection and documentation of the stormwater system is required on an equivalent frequency to water sampling. Table 57 lists inspection requirements and trigger indicators

Table 57: Additional stormwater quality monitoring requirements.

Stormwater Structure	Trigger Indicator
Biobasins	• Embankment destabilised • Soil erosion • Vegetation dieback • Excessive vegetation growth • Excessive sediment accumulation
Stormwater Ponds	• Embankment destabilised or leak evident • Soil erosion • Vegetation dieback • Excessive vegetation growth • Excessive sediment accumulation
Irrigation Scheme	• Pumps not working • Broken or leaking pipe • Saturated soils in irrigation field

A trigger event is considered to have occurred if one of the trigger indicators has occurred. If a trigger indicator has occurred, a suitably qualified engineer should document the requirements for rectification and notify Council of the required works.

9.3.4 Groundwater Systems

Groundwater monitoring locations are provided in Map 41. Parameters to be monitored and associated interim trigger values are provided in Table 58. Recommended monitoring frequency is as follows:

(a) Prior to Stage 1: Monthly for 1 year prior to construction.

(b) On build of any stage: 3 monthly for 2 years and then review frequency.

All sampling is to be undertaken by a suitably qualified consultant experienced in fresh and saltwater chemistry including natural, stormwater and groundwater systems and any Shoalhaven City Council requirements.

A trigger event is considered to have occurred if interim trigger values have been exceeded for 2 out of 3 consecutive sampling periods. If a trigger event has occurred, a suitably qualified consultant experienced in fresh and saltwater chemistry including natural, stormwater and groundwater systems should review the water quality data and:

(a) Determine if the changes in groundwater level or water quality are attributable to development in the Concept Plan area.

(b) If the groundwater level or water quality observations are deemed to be attributable to development in the Concept Plan area, then make recommendations to Council or Shoalhaven Water for any necessary remediation works or improvement works to the water cycle management system.

Table 58: Groundwater monitoring parameters and interim trigger values.

Parameter	Interim Trigger Value
Groundwater Level	< 0.5 m below surface
pH	< 5.5 or > 7.5
Temperature	-
Electrical Conductivity	-
Salinity	> 5,000 mg/L
Faecal Coliforms	> 100 CFU/100mls
Total Nitrogen	> 1.50 mg/L
Orthophasphate	-
Total Phosphorus	> 0.30 mg/L

9.3.5 Shell Fish Site Monitoring

Shell fish site monitoring locations are provided in Map 41. Parameters to be monitored and associated interim trigger values are provided in Table 59. Recommended monitoring frequency is as follows:

(a) Prior to Stage 1: Monthly for 1 year prior to construction.
2 wet-weather events prior to construction.

(b) On build of any stage: 3 monthly for 2 years and then review frequency.
Following any sewage overflow event

All sampling is to be undertaken by suitably qualified consultant experienced in fresh and saltwater chemistry including natural, stormwater and groundwater systems and undertaken in accordance with NSW OEH (2013) '*Assessing Estuary Ecosystem Health: Sampling, data analysis and reporting protocols*' and any Shoalhaven City Council requirements.

A trigger event is considered to have occurred if interim trigger values have been exceeded for 2 out of 3 sampling periods. If a trigger event has occurred, a suitably qualified consultant experienced in fresh and saltwater chemistry including natural, stormwater and groundwater systems should review the water quality data and:

(a) Determine if the changes in water quality are attributable to development in the Concept Plan area.

(b) If the water quality observations are deemed to be attributable to development in the Concept Plan area, then make recommendations to Council or Shoalhaven Water for any necessary remediation works or improvement works to the water cycle management system.

Table 59: Shell fish sites monitoring parameters and interim trigger values.

Parameter	Interim Trigger Value
Organochlorine / Organophosphorus Pesticides (OCP/OPP)	> Practical Quantification Limit (PQL)
E. coli	90th percentile > 35 enterococci/100 mls
Polycyclic Aromatic Hydrocarbons (PAH)	> Practical Quantification Limit (PQL)
Polychlorinated Biphenyls (PCB)	> 2ug/L
Heavy Metals	Aluminium > 0.01mg/L, Iron > 0.01 mg/L

9.3.6 Photo Monitoring Points

In addition to the water sampling regime, a number of photo point monitoring sites are recommended. These will provide a visual record of the receiving environment during the staged release of land within the Concept Plan area. Photo monitoring locations are provided in Map 41. Environmental assets to be monitored and associated interim trigger indicators are provided in Table 60. Recommended monitoring frequency is as follows:

(a) Prior to Stage 1: Monthly for 1 year prior to construction.
2 wet-weather events prior to construction.

(b) On build of any stage: 3 monthly for 2 years and then review frequency.
Following any sewage overflow event

All monitoring is to be undertaken by suitably qualified consultant and any Shoalhaven City Council requirements.

A trigger event is considered to have occurred if a trigger indicator has occurred. If a trigger event has occurred, a suitably qualified consultant should review the information and:

(a) Determine if the observed changes are attributable to development in the Concept Plan area.

(b) If the changes are deemed to be attributable to development in the Concept Plan area, then make recommendations to Council or Shoalhaven Water for any necessary remediation works or improvement works.

Table 60: Photo monitoring point requirements and trigger indicators.

Environmental Asset	Trigger Indicator
SEPP14 Wetlands	• Excessive sediment accumulated • Significant vegetation dieback of change in species composition • Major gross pollutant deposition
Mangroves	• Excessive sediment accumulated • Significant vegetation dieback of change in species composition • Major gross pollutant deposition
Riparian Vegetation	• Excessive sediment accumulated • Significant vegetation dieback of change in species composition • Major gross pollutant deposition

9.4 Annual Reporting

All results of the on-going water quality and other monitoring should be collated and reviewed in an annual report prepared by a suitably qualified consultant experienced in fresh and saltwater chemistry including natural, stormwater and groundwater systems. The annual report shall include at a minimum:

(a) Data summaries and analysis of all water quality information collected.

(b) An analysis of photographs collected at each photo point.

(c) Details, including a log, of any environmental pollution incidents and the response to those incidents.

(d) Details of any significant maintenance or remedial works undertaken in respect of the stormwater management system or sewage management scheme.

(e) Any recommendations for improvements to existing stormwater management infrastructure that are seen as necessary in continuing to achieve the aims and objectives of this WCMS.

9.5 Periodic Review of WQMP

As part of the first stage development application for land within the Concept Plan area, a final stand-alone version of this WQMP should be prepared.

This WQMP should be reviewed and updated following 2 years of operation once the first stage of construction has commenced. On-going reviews should then be prepared on a 5-yearly cycle.

Each time the WQMP is amended, this should be issued as a stand-alone document and issued to Shoalhaven Council and the NSW Department of Planning.

10 Conclusions

10.1 Stormwater Impacts

The proposed stormwater management system has been designed to include a raft of WSUD elements including at source treatment, large scale re-use and groundwater recharge. Modelling of the stormwater scheme has demonstrated that there will be no material impacts on the downstream environment including the Crookhaven River and Estuary, or Lake Wollumboola. The following is noted:

(a) The inclusion of various WSUD elements within the Concept Plan, including stormwater ponds, primary and secondary bioretention basins, stormwater dispersal systems and no new stormwater connections to the Estuary or Lake, large scale stormwater re-use and opportunities for groundwater recharge with stormwater, have contributed to the overall approach to stormwater management representing industry best practice.

(b) The proposed stormwater treatment measures have been demonstrated to be effective in removing or reducing water borne contaminants to acceptable levels. Pollutant load reduction targets are achieved, the potential for pathogen impacts is mitigated, and the NorBE water quality criteria are satisfied because the development will have no identifiable impact on water quality.[131]

(c) A comprehensive monitoring program has been included as a part of the WSUD to ensure that the proposed stormwater treatment measures achieve design criteria.

10.2 Groundwater Impacts

The impact of the Proposal on local groundwater systems was investigated through the collection and review of extensive physical data and undertaking numerical modelling to simulate developed conditions. Included in the assessment process was an investigation of the benefits and risks associated with recharging stormwater to the groundwater system. The investigation found that development of the Concept Plan would not result in any material groundwater related impacts, and that enabling some groundwater recharge from stormwater treatment measures would reduce overall stormwater flows and not unacceptably impact groundwater. The following is noted:

(a) Groundwater flow modelling has demonstrated that groundwater flow regimes and directions are effectively maintained by the Proposal. The predicted groundwater levels, whilst modified somewhat from current conditions due to changes in the distribution in groundwater recharge arising from modifications to vegetation cover and the extent of impervious areas, are not likely to result in any adverse environmental outcomes.

(b) Groundwater modelling investigated the potential benefits and risks associated with enabling some recharge of groundwater via a nominal 0.25 mm/hr exfiltration rate at the proposed stormwater treatment measures. Results of those

131 In accordance with the NorBE definition provided in the NorBE Guideline, Section 3.1 p 6.

investigations found that some 15 ML/year of stormwater recharge[132] to groundwater can be achieved without any material adverse impact on the groundwater flow regime. Groundwater flow budgets to the Crookhaven River and Lake Wollumboola with a recharge system in place are closely matched to current conditions.

(c) On the basis of groundwater contaminant transport modelling undertaken, as well as the comparison between predicted MUSIC exfiltration contaminant concentrations and current groundwater contaminant concentrations, an exfiltration rate of 0.25 mm/hr from stormwater management measures is ecologically sustainable and will not result in any detrimental harm to the existing groundwater system or downstream receiving environments. On that basis a recharge scheme is recommended.

(d) The impact assessment undertaken herein has demonstrated compliance with the NSW Aquifer Interference Policy.

10.3 Oyster Lease Impacts

The Crookhaven River Estuary contains several Oyster leases, some of which are located within Curleys Bay to the north east of the Proposal, and some located within the main Crookhaven River channel to the north of the Proposal. Current locations for known Oyster leases are provided at Map 6.

In terms of the oyster aquaculture leases operated within the Crookhaven River Estuary, detrimental impacts are not expected or likely to occur because the Proposal has been designed in compliance with the Healthy Estuaries Guideline and has incorporated stormwater and sewage management infrastructure that is best practice and appropriately mitigates any risk to the Estuary. The following is noted and observed:

(a) Nutrient and sediment loads released from the Proposal will be treated by a best practice WSUD stormwater management scheme so that levels are below existing conditions. The proposed stormwater and sewage management systems sufficiently mitigate any potential risk of water pollution arising within the Estuary in association with the Proposal.

(b) The Stormwater Proposal, which will include a 100 m riparian setback, as recommended by the Healthy Estuaries Guideline, as well as major stormwater treatment infrastructure, cannot be compared to existing urban development discharging into the Estuary as that existing development does not provide any setback to the Estuary or any material measures for stormwater treatment and water quantity and quality control.

(c) The potential for pathogen production through urban stormwater and release to the Estuary from the Concept Plan area has been mitigated through the incorporation of a range of measures including: stormwater treatment; stormwater retention to enable natural pathogen decay to take place; stormwater volume reduction through large scale stormwater re-use and recharge to local groundwater; and provision of a 100 m buffer to the Estuary.

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132 Refer to Section 4.5.3.

It is also worth observing that pathogen concentrations in urban runoff monitored during the investigation period were in the same order of magnitude as runoff currently experienced in forested and agricultural catchments. A reduction in pathogen levels at the Estuary due to the proposed stormwater system is therefore anticipated.

(d) In respect of sewage generated by the Proposal, this will be collected by a reticulated sewerage system as recommended by the Healthy Estuaries Guideline. Wet-weather overflows will be managed by incorporating maximum wet-well storage capacities in accordance with Shoalhaven Water's current catchment wide approach to sewage pumping stations for reducing wet-weather discharges to the Shoalhaven River system.

Sewage pumping stations, including key manhole structures, will be fitted with multiple alarms and on-line back-to-base monitoring as is current standard practice for Shoalhaven Water. Spare parts will be retained locally, including an alternative power supply to ensure rapid maintenance and quick return to fully operational conditions. In the unlikely event of a sewer overflow, all overflows from the sewer system within the Concept Plan area will be directed to the stormwater infrastructure for further detention and pathogen removal. These risk management measures ensure that the risk to Estuary water quality is appropriately managed.

(e) The potential for sediment production from urban areas impacting oyster aquaculture leases has been appropriately managed by including best practice WSUD stormwater management measures into the Proposal. The 100 m riparian buffer together with an extensive stormwater dispersal system provide a comprehensive method of further reducing the risk of any sediment related impacts on the Estuary arising out of the Proposal.

(f) There is no material risk of lowering salinity in the Estuary such that there would be any effect on oyster aquaculture. The following is observed:

(i) Local catchment water quality monitoring has found that urban runoff salinity levels are higher than present runoff concentration conditions. This indicates that reductions in salinity within the Estuary are not expected due to urban runoff.

(ii) The Proposal site represents approximately 1 % of the total catchment area draining to the Crookhaven River Estuary. It is inconceivable that any modification to the Site's drainage regime would materially and detrimentally alter the salinity regime within the Crookhaven River Estuary.

(iii) The Crookhaven River Estuary generally maintains a salinity range well within what is recommended by the Healthy Estuaries Guideline. When salinity levels fall below the recommended levels, this is associated with catchment wide rainfall-runoff events that are a natural part of the ecological regime of the Crookhaven River Estuary.

(g) In respect of Iron and Aluminium, the Proposal does not contain any significant sources of these elements and it follows that stormwater generated by the proposal could not lead to an increase in the concentration of these contaminants. Surface water sampling undertaken during this investigation has demonstrated that urban runoff concentrations of aluminium and iron are similar to or lower than runoff under the current land-use. This is not unexpected because one by-product of the urbanisation process is that there is reduced contact between surface water and catchment soils.

10.4 Ecologically Sustainable Development (ESD)

The OISAS says that Ecologically Sustainable Development (ESD) constitutes:

"using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be increased".[133]

The principles of ESD are further defined by the following principles:[134]

(a) *"The Precautionary Principle, namely, that if there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation"*.

In application this means that decisions should be guided by:

"(i) careful evaluation to avoid, wherever practicable, serious or irreversible damage to the environment, and
(ii) an assessment of the risk-weighted consequences of various options",

(a) The principle of "*inter-generational equity*, namely, that the present generation should ensure that the health, diversity and productivity of the environment are maintained or enhanced for the benefit of future generations".

(b) The principle of "*conservation of biological diversity and ecological integrity*, namely, that conservation of biological diversity and ecological integrity should be a fundamental consideration".

In respect of the overarching goal of ESD, the Proposal has been developed based on best practice WSUD stormwater management principles. There are no anticipated material impacts on the heath of the Crookhaven River Estuary or Lake Wollumboola. The modelling and assessments undertaken demonstrate that there are no impacts of consequence to local water resources or any industry depending on those water resources. It follows therefore that the overarching goal of ESD is met.

In respect of the Precautionary Principle, the Stormwater Proposal does not represent a threat of serious or irreversible environmental damage in that it will not result in any significant harm to water quality in the Crookhaven River Estuary or in Lake Wollumboola. This principle is therefore achieved.

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133 OISAS p 2.
134 *EPAR* sch 2 pt 3 cl 7(4).

In respect of the principle of inter-generational equity, the Stormwater Proposal ensures that the health, diversity and productivity of the environment will be maintained for the benefit of future generations. This principle is therefore achieved.

In respect of principle of conservation of biological diversity and ecological integrity, the Stormwater Proposal ensures that biological diversity and ecological integrity will not be impacted by the Proposal. This principle is therefore achieved.

10.5 SLEP 1985

We have considered the Proposal in respect of the SLEP 1985 and are of the view that there the Proposal demonstrates that it clearly meets the objectives pursuant to cl(2). The following is specifically noted:

(a) In respect of cl(2)(o), the WCMS has been designed to ensure the protection of important natural and cultural aquatic environments in that it will not result in any material harm to the environment.

(b) In respect of cl(2)(p), The WCMS has been designed so that it does not compromise aquatic scenic and landscape qualities.

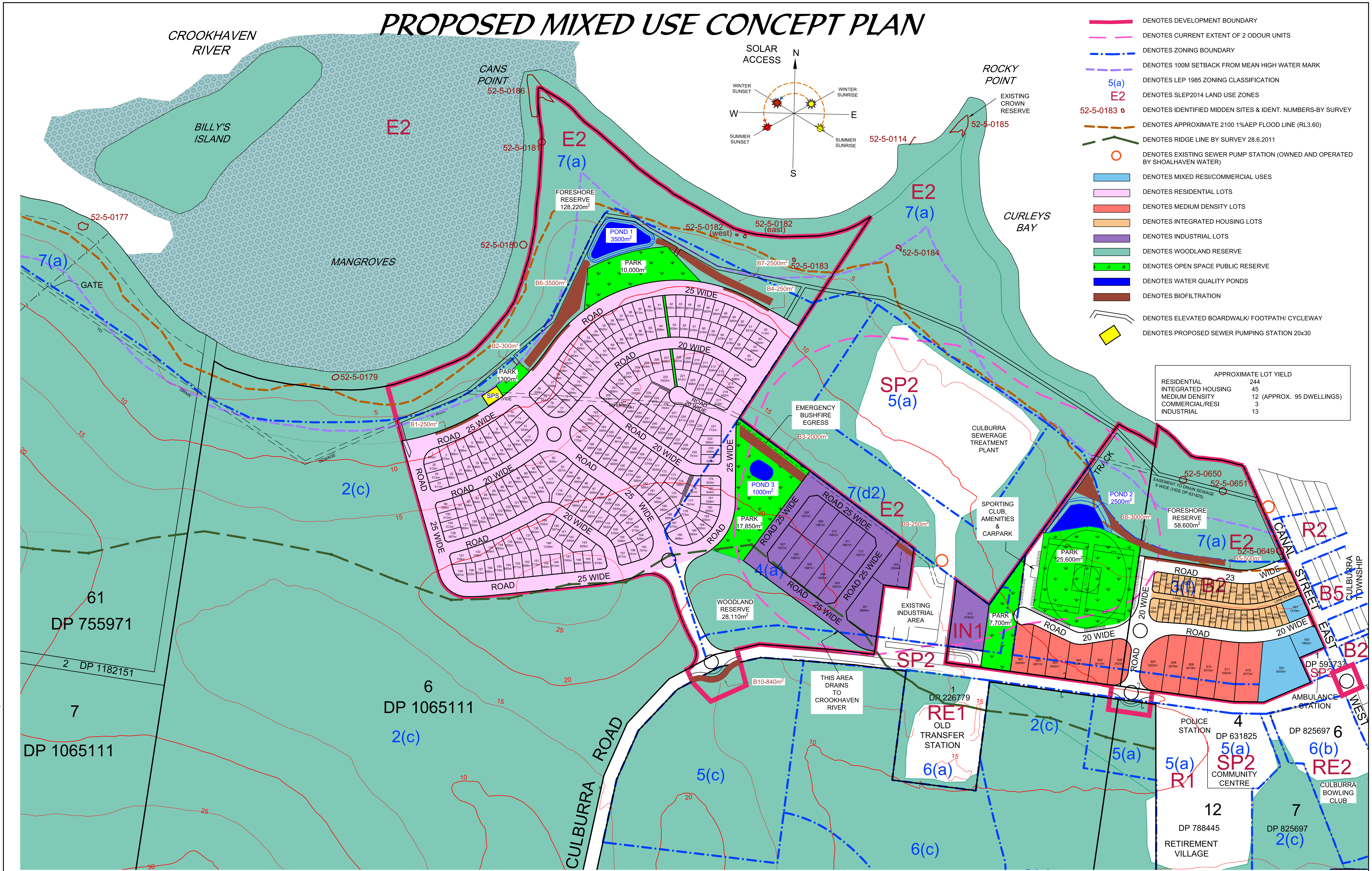
(c) In respect of cl(2)(r), the WCMS has been designed to ensure that development does not compromise the water quality or river flow objectives of ground water, rivers, estuaries, wetlands and other water bodies.

(d) In respect of cl(2)(s), the WCMS has been designed to avoid and mitigate against any potential adverse effects of the Proposal on the receiving waters and the environment.

(e) In respect of cl(2)(u), the WCMS has been designed to minimise potable water consumption by including domestic and public stormwater re-use.

11 Annexure A: Concept Plan Layout

PROPOSED MIXED USE CONCEPT PLAN



SCALE:- 1:3000 (0 50 100 150)

REV	DESCRIPTION	BY	DATE
08	CANAL ST EAST AREA REDESIGNED	DS	28.09.2020

CONTOUR INTERVAL 5.0 METRES

PROFESSIONAL STANDARDS SCHEME
Liability limited by a scheme approved under Professional Standards Legislation

M:\Projects\20000\25000s\25405\Drawings\25405-210 - MIXED USE CONCEPT PLAN - SUBDIVISION.dwg

RATIO: 1:3000 (AT A1 ORIGINAL) (1:8000 AT A3)

DATUM: AUSTRALIAN HEIGHT DATUM
ORIGIN: SSM RL
DATE OF PLAN: 19.11.2019

SURVEY	AERIAL PHOTOGRAPHY
DESIGN	MP
DRAWN	DS
CHECK'D	MP

REV	DESCRIPTION	BY	DATE
01	MIDDEN SITES LOCATED BY SURVEY ADDED	DS	09.12.2019
02	FURTHER MODIFICATIONS	DS	20.12.2019
03	SOUTHERN DEVELOPMENT OMITTED	DS	15.01.2020
04	FOOTPATH LINKS TO DEVELOPMENT ADDED	DS	29.01.2020
05	TITLE CHANGED. MINOR LOT AMENDMENTS MIDDEN SITES CLARIFIED	DS	18.02.2020
06	MINOR STORMWATER QUALITY AMENDMENTS	DS	01.04.2020
07	INDUSTRIAL & COMMERCIAL AREAS MODIFIED	DS	17.09.2020

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consultants@allenprice.com.au www.allenprice.com.au

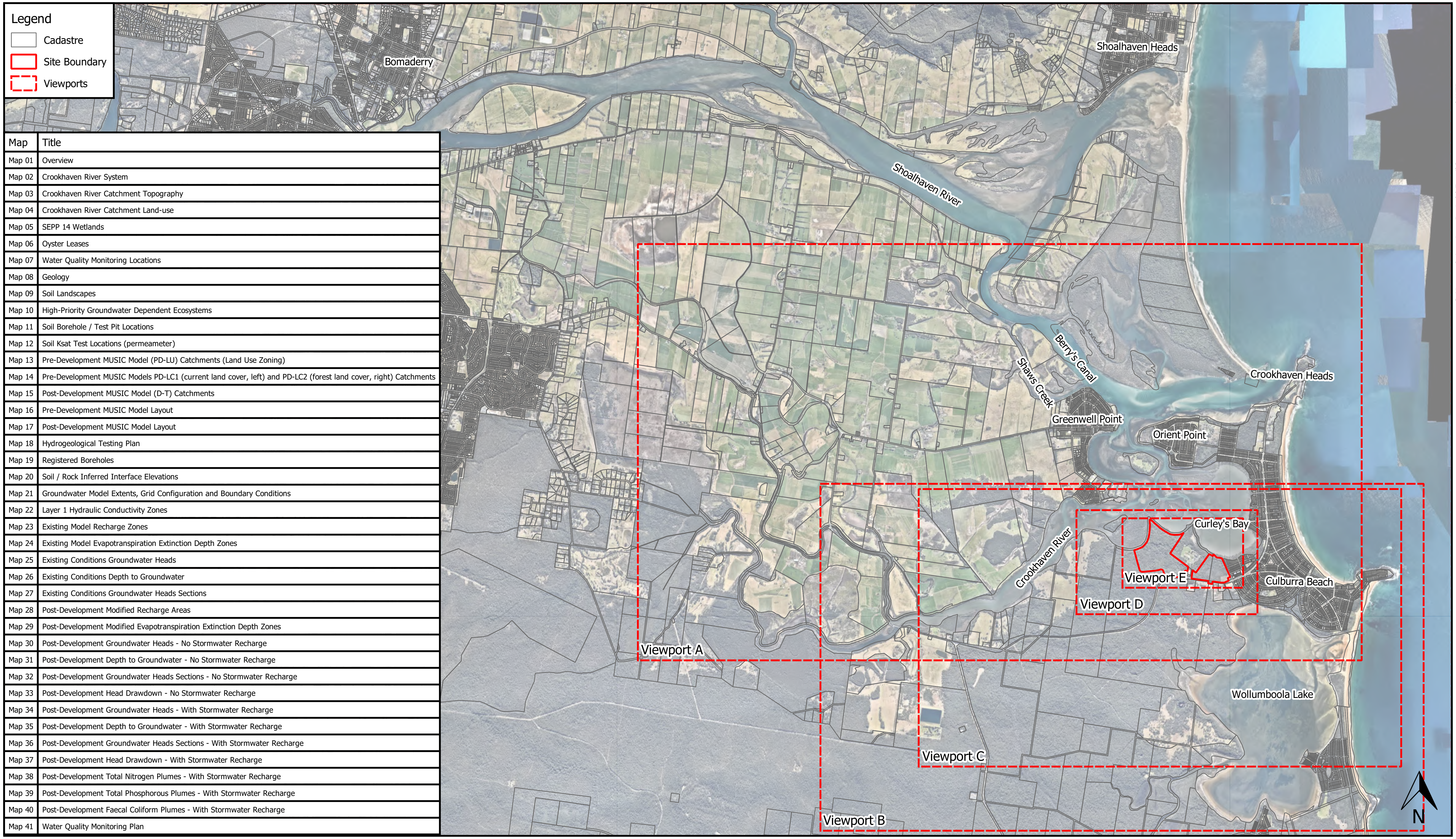
PROPOSED MIXED USE CONCEPT PLAN OVER PART OF LOTS 5 & 6 DP1065111

AT WEST CULBURRA FOR SEALARK PTY LTD

DRAWING STATUS: PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION PURPOSES

DRAWING NUMBER: 25405-210
SHEET 1 OF 1
REVISION 08

12 Annexure B: Maps



Map	Title
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Map 09	Soil Landscapes
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Map 41	Water Quality Monitoring Plan

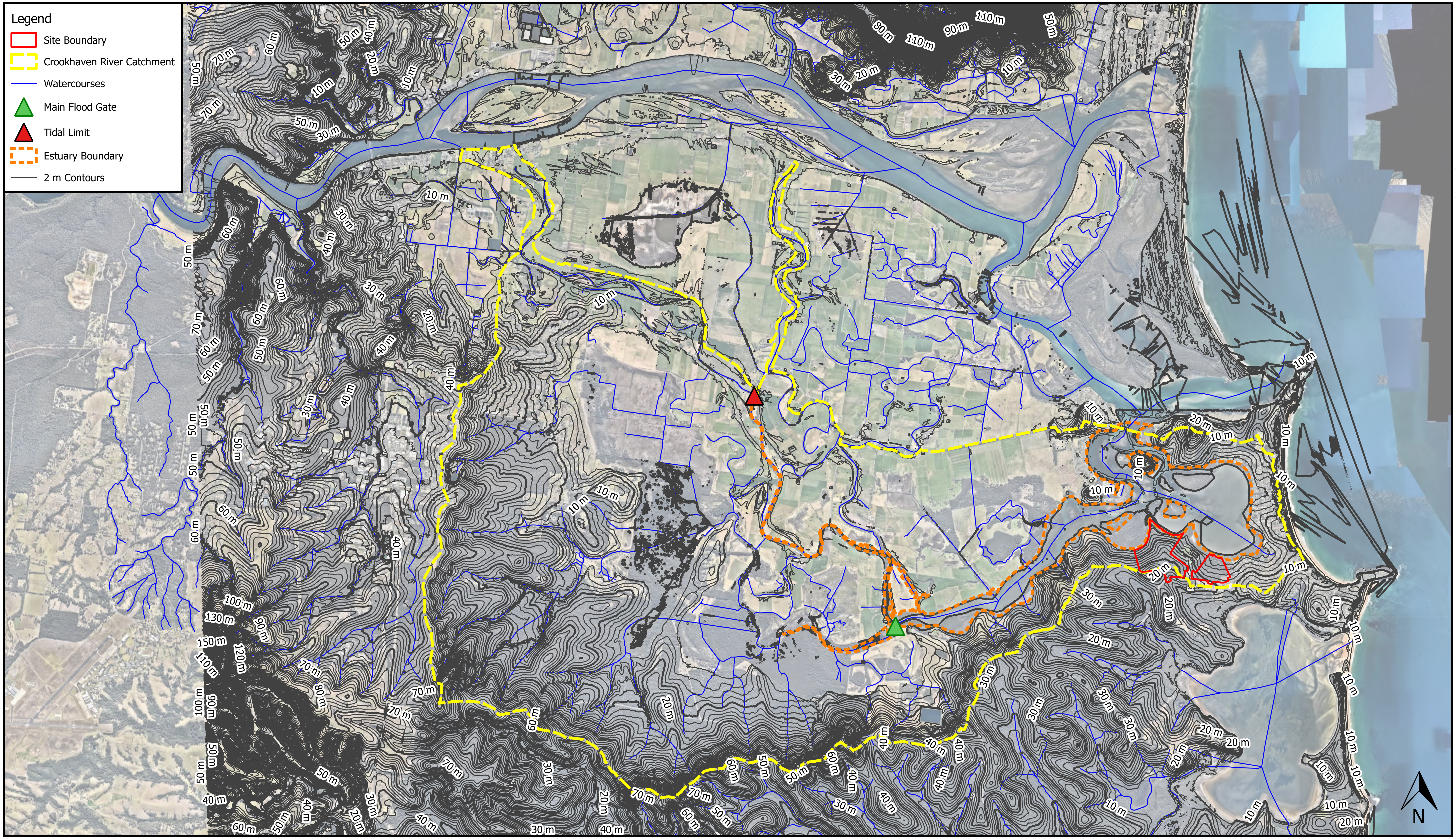
Notes:
- Aerial image from Nearmap (2019).
- Cadastre from NSW Department of Finance, Services and Innovation 'Clip and Ship' data.

Map Title / Figure:
Overview

Map 01	Map
West Culburra, NSW	Site
Proposed Mixed Use Subdivision	Project
Concept Water Cycle Management Strategy	Sub-Project
Sealark Pty Ltd	Client
04/11/2020	Date

martens
Environment | Water | Geotechnics | Civil | Projects

Project No: P1203365 Map Set: MS05-R02 Projection: MGA



0 700 1400 2100 2800 3500 m

1:60000 @ A3

Notes:
- Aerial image from Nearmap (2019).
- Watercourses from NSW DFSI 'Clip and Ship' website.
- Contours from NSW LPI 10 m LiDAR and NSW DFSI 1 m DEM over site.
- Bathymetry from NSW OEH (2012).

Map Title / Figure:

Crookhaven River System

Map 02	Map
West Culburra, NSW	Site
Proposed Mixed Use Subdivision	Project
Concept Water Cycle Management Strategy	Sub-Project
Sealark Pty Ltd	Client
04/11/2020	Date

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Project No: P1203365 Map Set: MS05-R02 Projection: MGA