Report

Karaaf Wetlands Catchment – Ecological and Stormwater Assessment

The Sands Owners Corporation

15 October 2021

Document Status

Version	Doc type	Reviewed by	Approved by	Date issued
V01	DRAFT	J Theilemann	J Theilemann	29/08/2021
V02	DRAFT	J Theilemann	J Theilemann	30/09/2021
V03	FINAL	W Bishop	W Bishop	14/10/2021

Project Details

Project Name	Karaaf Wetlands Catchment – Ecological and Stormwater Assessment
Client	The Sands Owners Corporation
Client Project Manager	Andrew McCauley
Water Technology Project Manager	Johanna Theilemann
Water Technology Project Director	Ben Hughes
Authors	Johanna Theilemann, Jamie Kaye
Document Number	21010450_R01

Cover Photo: Saltmarsh inundation and dieback, western end of Karaaf Wetland.

51 Little Fyans Street
Geelong VIC 3220
Telephone (03) 8526 0800
ACN 093 377 283
ABN 60 093 377 283

EXECUTIVE SUMMARY

Water Technology was engaged by the Sands Owners Corporation to prepare a water balance and water quality assessment of the Karaaf Wetlands catchment. The assessment evaluated the impacts associated with urbanisation of the catchment on the ecological values of the downstream environment.

The investigation sought to quantify:

- the change in peak stormwater flows and volumes due to urbanisation within the catchment
- the effectiveness of water quality treatment measures installed within the catchment
- the cumulative impact of changed water quality and quantity discharging from the catchment into the Karaaf Wetlands.

Uncontrolled stormwater volumes within this catchment pose a high risk to the existing value of the Karaaf wetland. The Karaaf Wetlands is part of the Thompson Creek estuary which relies on a balance of salt and freshwater flows for ecological health.

An average monthly flow assessment enables comparison of pre-development and fully developed catchment runoff volumes. The assessment indicates there is an increase in annual freshwater inflow volume of 193% in the fully developed condition. The table below shows the changes in monthly average inflows pre and post development. The assessment indicated significant increases in estimated flow volumes across the entire year, particularly across the summer months when, under pre-development conditions, typical water levels and freshwater flows within the Karaaf Wetlands would be at their lowest.

TABLE 1-1 WATER BALANCE – MONTHLY CATCHMENT INFLOW VOLUME

Month	Average Catchment Inflow Pre-Development (ML/month)	Average Catchment Inflow Post-Development with reuse (ML/month)	Change in Average Monthly Catchment Inflow Volume
January	25	89	256%
February	36	99	175%
March	21	70	233%
April	18	82	355%
May	36	138	283%
June	50	123	146%
July	69	142	106%
August	61	140	129%
September	44	138	214%
October	46	167	263%
November	36	115	219%
December	33	90	173%
TOTAL	**475**	**1,393**	**193%**

The increase in freshwater flow volumes discharging to the Karaaf Wetlands over the year impacts on the natural water cycle and salinity balance within the wetlands. Additional runoff from the urban catchment contributes significantly more freshwater to the system than would have occurred prior to development, due to the increase in impervious area (roads, roofs, paths etc). The seasonality of flows is also impacted with greater increases in volume over the summer months. This additional freshwater volume contributes to sustained inundation of the downstream wetlands, preventing the system from experiencing natural wetting and drying regimes. This also impacts the salt balance within the system (reduction in salinity) which leads to vegetation dieback and loss of ecological communities. A systems approach, which uses integrated water management and sustainable water strategies, is needed to manage excess stormwater volumes and the impacts of seasonal freshwater flows entering the Karaaf Wetlands. This is essential in preventing any further decline in wetland health and preserving the existing sensitive values of this system.

An assessment of existing stormwater quality treatment wetlands within the upstream catchment indicates that many of the wetlands which drain to the Karaaf Wetlands have been undersized or are not performing to the necessary standards. The undersized wetlands are unable to adequately treat stormwater runoff to current industry standards (BPEM, 1999). These standards require that stormwater pollutant loads including Total Nitrogen, Total Phosphorus, Total Suspended Solids and Gross Pollutants are reduced in line with specified thresholds. The assessed compliance of these wetlands with industry benchmarks is shown in **TABLE 7-2**.

Wetlands are able to remove gross pollutants (litter) by trapping them within the dense coverage of emergent vegetation. This situation can translate to additional wetland maintenance obligations, requiring manual removal of accumulated gross pollutants within the sediment basins and wetlands. This can become increasingly difficult and labour intensive as wetlands become established with vegetation and access becomes limited. This issue can be addressed with the installation of Gross Pollutant Traps (GPTs) at the inlets of all wetlands, which can be regularly cleaned without needing to disturb the wetland.

TABLE 7-2 WETLAND POLLUTANT LOAD REDUCTION

Contributing Catchment	Wetland/Lake	TSS % Load Reduction	TP % Load Reduction	TN % Load Reduction	Gross Pollutant % Load Reduction
BEPM Targets (IDM, 2020)		**80**	**45**	**45**	**70**
Stretton	Catch3 Wetland	70	60	40	99
	Catch4 Wetland	62	53	35	96
	Catch7 Wetland	63	53	35	96
The Dunes Development	Dunes Wetland 1&2[3]	54	46	32	96
Horseshoe Bend Development – Zeally Sands	TN-Catch1 Wetland	69	59	39	98
	TN-Catch6 Wetland	37	30	19	88
The Quay Development[4]	Quay North Wetland	23	18	10	94
	Quay South Wetland	28	22	12	93
The Quay -Esplanade	Foreshore Wetland/Esplanade Wetland	57	46	27	94
The Sands Development	WL 4	69	59	40	99
	WL 5	70	59	40	99
	WL6	69	59	40	99
	WL7	70	59	40	99
	WL 9	69	59	40	99
	WL X	69	58	40	99

Contributing Catchment	Wetland/Lake	TSS % Load Reduction	TP % Load Reduction	TN % Load Reduction	Gross Pollutant % Load Reduction
	WL Z	70	59	40	99
	Amenity Lakes 1-3[2]	55	40	18	100
	Amenity Lakes 4-5[2]	36	17	6	100
	Irrigation Lakes 3-6[2,3]	85	67	62	100

In addition to assessing the performance and sizing of the existing stormwater treatment wetlands against current industry standards, a condition assessment of the current state of the wetlands was undertaken. This assessment indicated that the water quality wetlands within the catchment are in urgent need of significant maintenance and remediation. The sediment basins of the inspected wetlands were significantly compromised with accumulated sediment. Due to the filling of these sediment basins, shallowing of the remainder of the wetlands had occurred and this has compromised the effective performance of these treatment wetlands. It is notable that emergent aquatic vegetation within the wetlands was sparce, with low plant diversity. In many instances the wetlands had shallowed to the point where vegetation was encroaching within necessary deep water areas in the wetlands.

The effectiveness of existing water quality treatment within the urban catchment is critical to preserving the health of the downstream environment. The compounding impact of both the poor condition and the under sizing of these wetlands is a significant risk to the Karaaf Wetlands.

The amenity lakes and irrigation lakes of the Sands estate are recognised to act as additional defacto treatment ponds in this system. This does mean, as a whole, the constructed wetlands in series are able to meet water quality treatment requirements. It is noted however, that even in meeting these requirements that the Karaaf Wetlands is receiving a high residual load of pollutants from this system. Table 7-3 shows the annual passing pollutant load discharging to the wetlands (greyed column). It is estimated through water quality modelling that, over the past 5 years, more than 370 tonnes of passing sediment have discharged towards the Karaaf Wetlands and Thompson Creek, although it is likely that a portion of this has deposited within the Sands amenity lakes.

TABLE 7-3 PREDICTED CATCHMENT RESIDUAL PASSING POLLUTANT LOADS

Pollutant	Pre-Development (kg/year)	Post-Development without treatment (kg/year)	Post-Development with treatment (passing load) (kg/year)	Potential 5 Year (Passing Load) (kg)
TSS	23,600	292,000	74,200	371,000
TP	30	620	240	1200
TN	414	4,410	2,700	13,500
Gross Pollutants	8,820	65,100	3,740	18,700

This assessment assumes that the wetlands are functioning as designed which we also understand is unlikely, as indicated by the condition assessment. The observed issues associated with sedimentation within the existing wetlands are likely to be a result of more than just the indicated under sizing of these assets.

Construction sediment loads are a significant risk to constructed stormwater wetlands during development of urban areas. With development occurring within this catchment from east to west, the burden of high passing sediment loads is realised within the downstream wetlands and lakes. Observations of the developing areas within this catchment indicate an absence of appropriate sediment management both on major estate works and across domestic build sites. Failure to enforce compliance of appropriate mitigation measures will continue to result in high sediment loads and poor water quality within new wetlands. This will inevitably contribute to the existing issues within downstream constructed wetlands and the Karaaf.

Saltmarsh dieback has been identified in a number of reports over the past two decades. Dieback of saltmarsh vegetation has continued despite the upgrade and enlargement of culverts connecting Thompson Creek to the Karaaf Wetlands in 2004. The effects of ongoing and increasing freshwater discharge to the western end of the Karaaf Wetlands is clear. Saltmarsh vegetation is dying back or has been displaced by brackish-freshwater vegetation species. The recently observed presence of reeds and rushes (e.g. Common Reed and Cumbungi) at the western end of the wetland is evidence of altered hydrology and salinity, and these species have the potential to displace this temperate coastal saltmarsh (an EPBC listed ecological community). If freshwater inputs continue to increase, and if a more natural wetting and drying regime is not restored, it is likely that more coastal saltmarsh will be displaced and the unique habitats that support a number of threatened species (e.g. the Critically Endangered Orange-bellied Parrot) will be diminished.

The catchment analysis suggests peak flows during major storm events are adequately controlled within the stormwater management system. However, urbanisation of the catchment has significantly impacted on the total volume of stormwater runoff discharging to the Karaaf wetland.

The catchment assessment indicates there are some key actions which are essential in mitigating further damage to the Karaaf wetlands. These include:

1. Undertake an Integrated Water Management (IWM) plan for the Karaaf Wetlands catchment, focusing on volume management, water quality and environmental protection. The development of the plan should be led by Surf Coast Shire in conjunction with City of Greater Geelong, Corangamite CMA, Barwon Water, Parks Victoria, Southern Rural Water, EPA and DELWP. This plan may be complementary to an estuary management plan for the catchment which must also consider how increased stormwater volume and flow within this system impacts on estuary entrance management.

2. Improved enforcement of the performance of maintenance and operations for water quality treatment assets including:

    a. Install sediment protection measures within the Stretton Estate and developing land within other sites of the contributing catchment. This should include compliance auditing of developers and private builders within these estates. Regular street sweeping of these areas should also be implemented to ensure longevity of the installed measures.

    b. Immediate servicing of existing GPTs within the Dunes Wetlands, initiate inspection program of these assets at frequency intervals of no less than 3 months, until such time as the wetlands and developing catchment is considered stable. This inspection program should also include, as required, maintenance and cleaning of these structures. Undertake immediate works to reinstate catchment wetlands to “as designed” condition including verification of operational levels, sediment basin remediation, control structure inspections and vegetation planting (pipe connections, outlets weirs etc.). Consideration should also be given to the need for installation of litter traps as pre-treatment for existing and future wetlands which otherwise solely rely on the wetlands managing gross pollutant loads from the system.

    c. Develop clear and specific council standards and guidelines for developers in relation to design, maintenance and operation of water quality assets and construction sediment management. Asset management plans should be completed with clear guidelines on maintenance frequency, monitoring and triggers for works.

3. Develop and implement a monitoring program to survey sediment levels and vegetation within all catchment wetlands including the Sands amenity lakes. The surveys should be used to inform a works program to reinstate design levels and function of sediment basins, wetlands and the amenity lakes of the Sands.
4. Develop and implement a monitoring program for the Karaaf wetlands. Consideration should be given to the installation of a telemetered system which is able to monitor Water Level, Depth, Electrical Conductivity, PH, Temperature and Turbidity. (Similar to other programs currently being implemented on the Lower Barwon Wetlands).

   Further to this, ecological monitoring should also be implemented with regular vegetation surveys to best understand seasonal plant die off, structure and species cover/abundance change, including freshwater species invasion, and to record images from repeatable photo points.
5. Develop and implement a monitoring program for the constructed wetlands within the catchment. It is understood that some monitoring does occur, although the breadth and frequency of this monitoring should be increased to understand the performance of the system in terms of flow and pollutant generation and treatment.
6. Initiate procedure to formally extend the boundaries of the Ramsar listing of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar area to encompass the Thompson Creek Estuary inclusive of the Breamlea Flora and Fauna reserve and the Karaaf wetlands. Without changes to specifically address the functionality of the existing constructed wetlands and the impacts of urbanisation within the catchment, the degradation of the Karaaf Wetlands and downstream receiving waters will continue. This requires the consideration of construction sediment generated within the currently developing catchment and the development of a plan to manage stormwater volume generated within this catchment. Without intervention, the cumulative impact of existing and future development will potentially result in the ultimate loss of an important and valuable environmental/ cultural and community asset.

It is important to acknowledge that these assessments have been based on the Torquay North catchment being fully developed in line with the current precinct structure plan. Considering this, there is still time and opportunity to revisit proposed drainage assets which are yet to be constructed, improve construction sediment management within the undeveloped land and look at opportunities which may rely on the need to construct new assets within land that is currently undeveloped, or contemplate alternative impervious area runoff management measures, to address excess stormwater volume.

CONTENTS

APPENDICES

LIST OF FIGURES

LIST OF TABLES

GLOSSARY & ABBREVIATIONS

Term	Definition
Annual Exceedance Probability (AEP)	The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year.
Attenuation	The difference in peak discharge between two hydrographs. This is represented by a difference between two curves (flow and volume).
Average Recurrence Interval	The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration.
Catchment	That area of land from which stormwater runoff contributes to stream flow at the most downstream point of the catchment.
Estuary	The tidal part of a river system, where the mouth of the waterway meets the oceans tide.
Environment Protection and Conservation Act (EPBC)	EPBC refers to federal legislation which refers to the protection of environment and the conservation of biodiversity. The Act was introduced to protect and promote the recovery of threatened species and ecological communities.
Fraction Impervious	The part of the catchment represented as a fraction that is impervious and does not allow for runoff (rainfall) to pass into the soil.
Gross Pollution	Solid matter pollution, generally litter, debris or coarse sediment
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs.
Hydraulics	The physical behaviour of fluid by way of volume and flow through an environment. (constructed or natural)
Impervious Area	A surface or area within a drainage catchment that significantly restricts the infiltration of water, even though some minor infiltration may occur through minor pores and cracks, e.g. the initial 'wetting' of concrete surfaces. Impervious surfaces can include concrete, road surfaces, roofs and saturated ground such as a lake or pond.
Inflow	The water flowing into a structure or location such as a stream, wetland or catchment.
Initial Loss (IL)	An assumed stormwater loss, measured as a depth of rainfall over a given portion of a catchment, that occurs during the initial stages of a storm, and continues to occur until the total rainfall equals the assumed initial loss.
Integrated Catchment Management (ICM)	A system for managing natural resources within a 'whole of system' approach. In a stormwater context, this requires a whole of catchment approach incorporating the total water cycle. Consideration is given to all associated land and water processes and values
Intermittently Closed and Open Lake and Lagoon (ICOLL)	An estuary or river systems where the entrance of the river (river mouth) is intermittently separated from the ocean by a sand barrier or berm. The closure of the river is influenced by sand movement, waves, tides and river flows.

Littler Trap	A devise that is designed to catch/ intercept litter and gross pollution within a system.
Mitigation	The action of reducing the severity, seriousness or impact of a particular outcome.
Model for Urban Stormwater Improvement Conceptualisation (MUSIC)	MUSIC is an industry accepted software package used to model water quality treatment devices for capture, reuse and contaminate removal.
Peak Flow	The maximum discharge occurring during a flood event.
Ramsar Convention	Ramsar refers to the wetland convention. Named after the city in which it was developed, the Ramsar convention recognises wetlands of international importance and sets out an international treaty for the agreed protection, conservation and sustainable use of the recognised wetlands.
RORB	RORB is a runoff and streamflow routing software package used to calculate flood hydrographs from design rainfall.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Salt Wedge Estuary	An estuary which is intermittently or permanently open to saltwater inflows (ocean) where freshwater river flows are discharging to the ocean whilst tidal inflows are entering the lower reaches of the waterway. The saltwater intrusion into the estuary occurs as wedge on the bottom of the waterway as a consequence of the higher density of saltwater compared to freshwater.
Temporal Pattern	The pattern involving the depth of rainfall over time.
Total Suspended Solids (TSS)	The total dry weight of suspended matter, that are not dissolved into the water.
Water Balance	The quantified inflows and outflows of a catchment or watershed system over a defined period of time.
Wetland	Areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated or semi saturated soil conditions
Water Sensitive Urban Design (WSUD)	The land planning and engineering design approach which integrates the urban water cycle, including stormwater, groundwater and wastewater management and water supply, into urban design to minimise environmental degradation to rivers and creeks and improve aesthetic and recreational appeal.

1 INTRODUCTION

The Karaaf Wetlands are located within the Thompson Creek Catchment between Torquay and Breamlea. The wetlands form part of the Breamlea Flora and Fauna Reserve (Figure 1).

Understanding the value and importance of the wetlands has formed the basis of a number important monitoring and research projects including the works of Craig A Billows, Parks Victoria, Angair, Corangamite CMA, Surf Coast Shire and DELWP. The wetlands cover an area of around 100 hectares and are characterised by seasonally inundated coastal saltmarsh EVCs.

The saltmarsh species of the Karaaf are recognised for their ecological value with previous assessments identifying flora and fauna of both State and National Significance (Ecology Australia, 2001). During the fauna survey of the area in 2001, 19 native mammals were identified including the smokey mouse alongside 168 bird species. The wetland is uniquely positioned in proximity to the Ramsar listed wetlands of Lake Connewarre and shares many similar environmental characteristics.

The wetland is fed by water from both:

- tidal or overbank flows from Thompson Creek; and
- the catchment to the west, incorporating the Torquay North urban area, some rural residential and farming land.

The total Karaaf Wetlands catchment to the confluence with the Thompson River is estimated to be 1200 Ha. Of this, approximately 500 Ha is residential landuse, with the remainder of the catchment made up of low density rural residential and rural landuse, alongside the wetlands and adjoining reserves.

The Torquay North residential area makes up approximately 40% of the contributing catchment to the Karaaf wetlands. Prior to this residential development within the catchment, the Karaaf Wetlands were naturally tidally inundated and likely experienced seasonal wetting and drying. Significant urban expansion of Torquay into this area over the past 15 years has dramatically changed both the quantity and quality of runoff discharging to the Karaaf wetlands.

In recent years, negative outcomes of continued urban development in Torquay North have been observed within the constructed wetlands of the residential estates and within the Karaaf wetlands. These observations have resulted in further analysis of the existing constructed wetlands and their operations alongside further analysis of the changing flow regime.

It is understood that, at the time of development, the upstream estates which drain to the Karaaf Wetlands were required to design appropriate stormwater retardation and treatment measures to meet Urban Stormwater Best Practice Environmental Management Guidelines (CSIRO, 1999). These guidelines establish benchmark removal targets for Nitrogen, Phosphorus, Total Suspended Solids and Gross Pollutants. Further to this, current planning requirements provided under Clause 56.07-04 require that stormwater for events from the 20% up to the 1% AEP be appropriately management.

In more recent times an increased awareness of the need for volume management within urban environments has emerged. This need arises from the observed impacts of changed hydrologic and hydraulic regimes on natural downstream environments including waterways, wetlands, floodplains and estuaries. This is particularly important within coastal areas (including coastal wetlands) which rely on wetting and drying regimes, and which are dependent on estuary and catchment flows in relation to salinity.

The following investigation seeks to quantify the likely changes in quality and quantity of runoff from the Torquay North Catchment resulting from urban development. This can in turn identify potential magnitude of mitigation measures that may be required to restore the ecological values of the environmentally significant

Karaaf Wetlands, which form an important part of the Thompson Creek estuary system. The assessment will also seek to understand the efficacy of existing stormwater treatment assets within the catchment based on the current conditions and compliance with current industry standards.

FIGURE 1-1 KARAAF WETLANDS CATCHMENT

1.1 Project Objectives

The objective of this project is to assess the changes to the hydrological regime and environmental condition of the Karaaf Wetlands as a result of the stormwater runoff from the upstream urban catchments.

This consists of a desktop assessment, supported by two site inspections which were completed on 17 June 2021 and 13 September 2021. During these inspections Thompson Creek and Estuary, including the Karaaf wetlands, were observed. The wetlands and amenity lakes of the Torquay Sands estate and all residential estates within the Torquay North precinct were also inspected.

This report provides a comparison of predevelopment and full development conditions of the upstream urban catchment feeding the Karaaf wetlands. The completed assessment relied on information from the provided background report.

1.2 Background Documents

Information used in this report was gathered from various sources including the Sands Owners Corporation, Surf Coast Shire Council and documents freely available online. Key documents included:

- Flora and Fauna assessment and Environmental Management Plan for Torquay Sands Residential Lakes and Golf Course Development, Torquay (Ecology Australia, 2001)
- Torquay Sands Development – Surface Water Management System (Craigie, 2001)
- Report for Stormwater Master Plan - Torquay North (GHD, 2010)
- Report for Stormwater Master Plan - Torquay North, Master Plan Maintenance Guidelines (GHD, 2010)
- The Sands Torquay Resort - Operational Environmental Management Plan (GHD, 2011)
- The Sands Owners Corporation - Report on the environmental impact of offsite water entering The Sands System (GHD, 2017)

It is noted that no detailed information was available in relation to the Quay Estate and any changes associated with surface water management plans of the Stretton development.

1.3 Site and Catchment Characteristics

1.3.1 Development Catchments

The investigation area is focused on the developing urban catchment upstream of the Karaaf wetlands. The area includes a number to different estates which have been developed with water quality treatment and flow retardation assets designed to treat their respective areas.

For the purposes of this assessment the catchment areas will be referred to as the specific estate names where possible. These are shown in Figure 1--2 and include the following:

- Stretton which refers to the South Beach Road Development/Northern Catchment within the Torquay North Precinct Structure Plan (PSP).
- Quay Development – also referred to as the Austland Quay Development
- The Sands – which refers to the residential development area within the golf course development
- Dunes – which refers to the Southern Development within the Torquay North PSP
- Zeally Sands (Horseshoe Bend) – which refers to the Horseshoe Bend Road Development within the Torquay North PSP

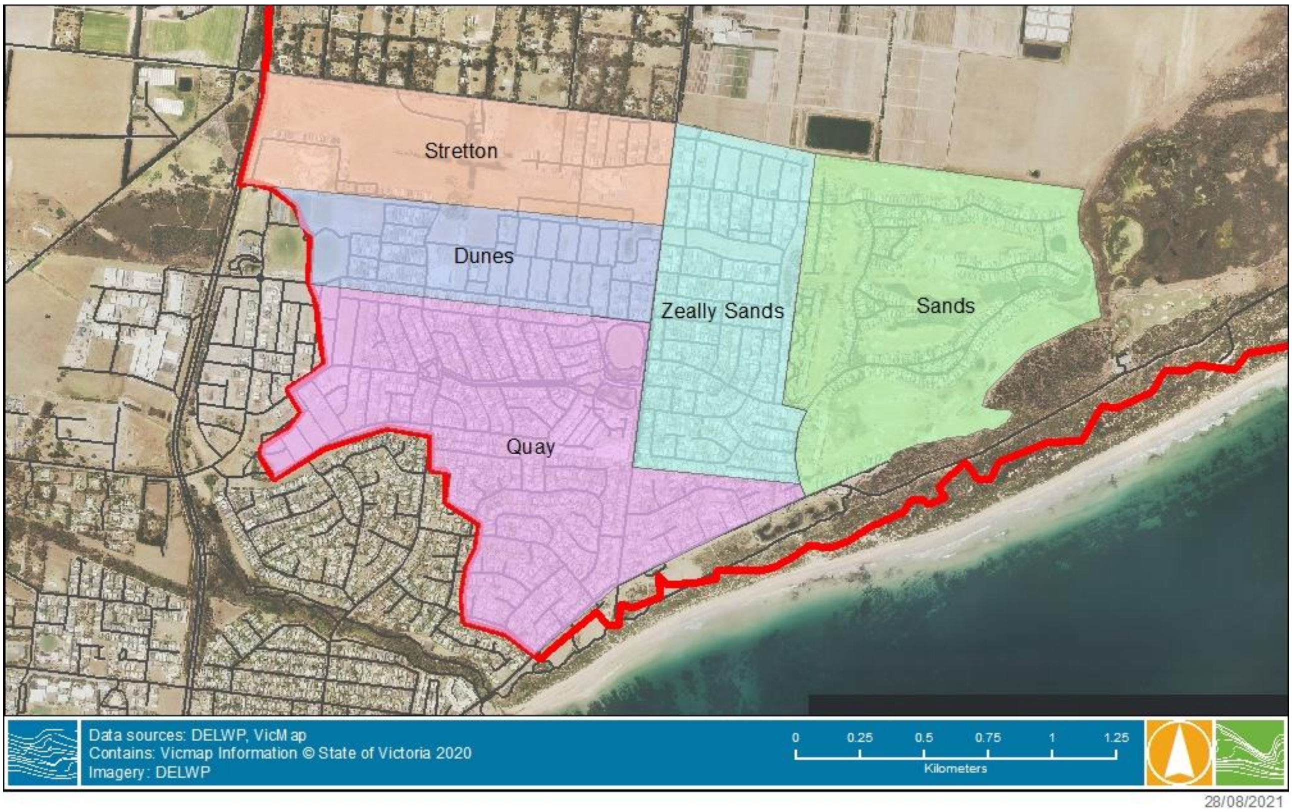


FIGURE 1-2 DEVELOPMENT AREAS

Figure Figure 1--3 provides a schematic diagram of the constructed wetlands that feed stormwater through The Sands development into the Karaaf Wetlands.

FIGURE 1-3 CONSTRUCTED WETLAND LOCATIONS AND FOW PATHS

21010450_R01v03_Torquay_Sands_Final

1.3.2 Fraction Impervious

Fraction impervious values represent the proportion of each sub-catchment where the land is covered my impervious surfaces. Impervious surfaces include roads, roof areas, paved areas and structures that do not allow rainfall or surface flow to infiltrate into the ground.

The fraction impervious (FI) values adopted for the flow (RORB), quality (MUSIC) and water balance model (MUSIC) were calculated using the ultimate development scenario in line with the Torquay North PSP and existing land zoning. The fraction impervious was determined for each of the sub-catchment areas within the respective models.

The adopted FI values were based on current Melbourne Water MUSIC modelling guidelines which provide industry standards for these parameters (Table Table 1-1). These guidelines are accepted across Victoria and form the basis of many council standards, including the City of Greater Geelong. In accordance with available information on their website, the Surf Coast Shire do not have MUSIC guidelines specifically related to their municipality.

TABLE 1-1 MUSIC GUIDELINES (MELBOURNE WATER, 2018, PAGE 7) – RECOMMENDED EFFECTIVE IMPERVIOUS VALUES

Zone - Landuse	Description	FI - Normal Range	FI - Typical Value
Residential (General Residential, Residential Growth Zone, Neighbourhood Zone)	Large Residential (Allotment size 601 m^2 – 1000 m^2)	0.50 – 0.80	0.60
	Standard Densities (Allotment size 300 m^2 – 600 m^2)	0.70 – 0.80	0.75
	High Densities (Allotment size <300 m^2	0.80 – 0.95	0.85
Low Density Residential	Allotments size > 1001 m^2	0.10 – 0.30	0.20
Education	Schools and Universities	0.60 – 0.80	0.70
Commercial Area	Activity Centres, Shots, retail	0.70 – 0.95	0.90
Rural	Rural and Agricultural	0.05 – 0.20.	0.10
Public Parks and Recreation	Reserves, Parks, Golf Courses	0.00 – 0.20	0.10

The adopted landuse and applicable fraction impervious layout within the overall catchment is shown in Figure 1-4 below. The landuse zones are in accordance with the Surf Coast Shire Council Planning Scheme and the recommended fraction impervious values outlined in the MUSIC Guideline recommendations above. Variability within catchments has taken into consideration lot sizes, road reserves and parkland areas.

21010450_R01v03_Torquay_Sands_Final

Conservative parameters have been adopted for this assessment which sit within the acceptable range of recommended fraction impervious values.

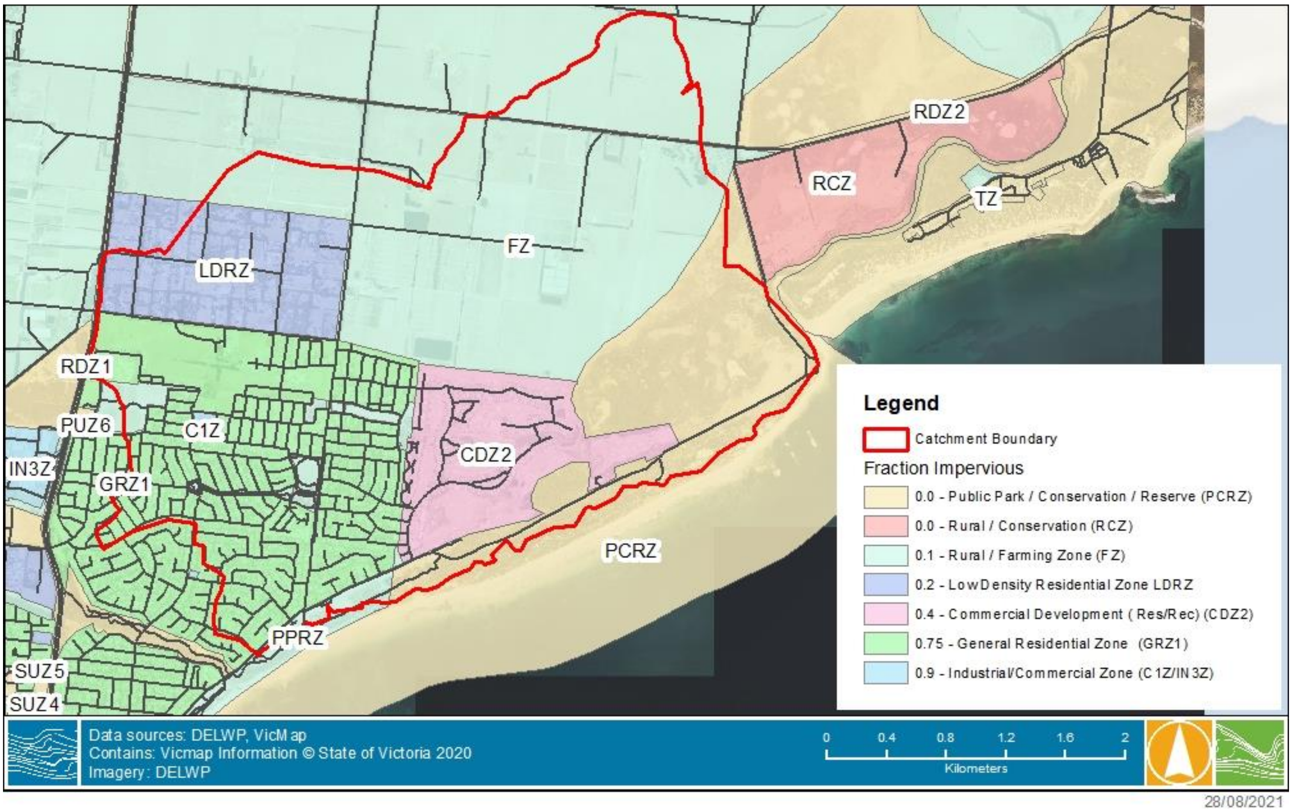


FIGURE 1-4 FRACTION IMPERVIOUS

2 PEAK STORM FLOW ASSESSMENT

2.1 Overview

An assessment of the flow (quality and quantity) entering the Karaaf Wetlands has been undertaken through the use of RORB and MUSIC models. The RORB model assesses peak storm flows, whereas the MUSIC model is used to assess longer term water volumes and water quality.

RORB is an industry accepted runoff and streamflow routing program used to calculate flood hydrographs from rainfall and other catchment inputs. It is used to determine peak flows based on assumptions around catchment characteristics, storm duration, rainfall depth, intensity and frequency.

The following section outlines the assessment of estimated peak flows within the catchment. Peak flows are the maximum rate of flow generated during prolonged and significant storms. In line with industry standards from Australian Rainfall and Runoff – Guide to Flood Estimation (ARR, 2019) the 1% AEP flood event (or the 1 in 100 year AEP) has been used as the focus of this assessment. In accordance with current planning requirements, new developments must manage the peak flows generated within the development to match pre-development conditions. This is typically achieved with the use of retarding basins and other flood storage within wetland areas. As a result, this assessment will look at pre-development peak flows in comparison with peak flows in a fully developed Torquay North catchment entering the Karaaf wetlands.

2.2 Hydrologic Model Setup

2.2.1 Overview

Two RORB models have been developed for the catchment to assess both pre-developed (pre-2002) and fully developed hydrological scenarios. An additional sensitivity test model was also developed to assess the impact of changed catchment boundaries which are associated with flows from the Esplanade Wetland (Quay catchment) drainage to the Karaaf wetlands. Topographic contours indicate that prior to development these catchments would have naturally drained towards Deep Creek and/or through low relief points in the dunes.

The RORB models utilise regional estimation parameters from both the Bureau of Meteorology (IFD) and the Australian Rainfall and Runoff Datahub (losses, ARFs, pre-burst depths). These parameter recommendations are validated against empirical equations and local estimations.

2.2.2 Fraction Impervious

The pre-developed RORB model fraction impervious values are based on imagery of the catchment from 2002 when there had been minimal development. The fraction impervious values for the pre-developed and developed models are shown in Figure 2-1 and Figure 2-2 respectively.

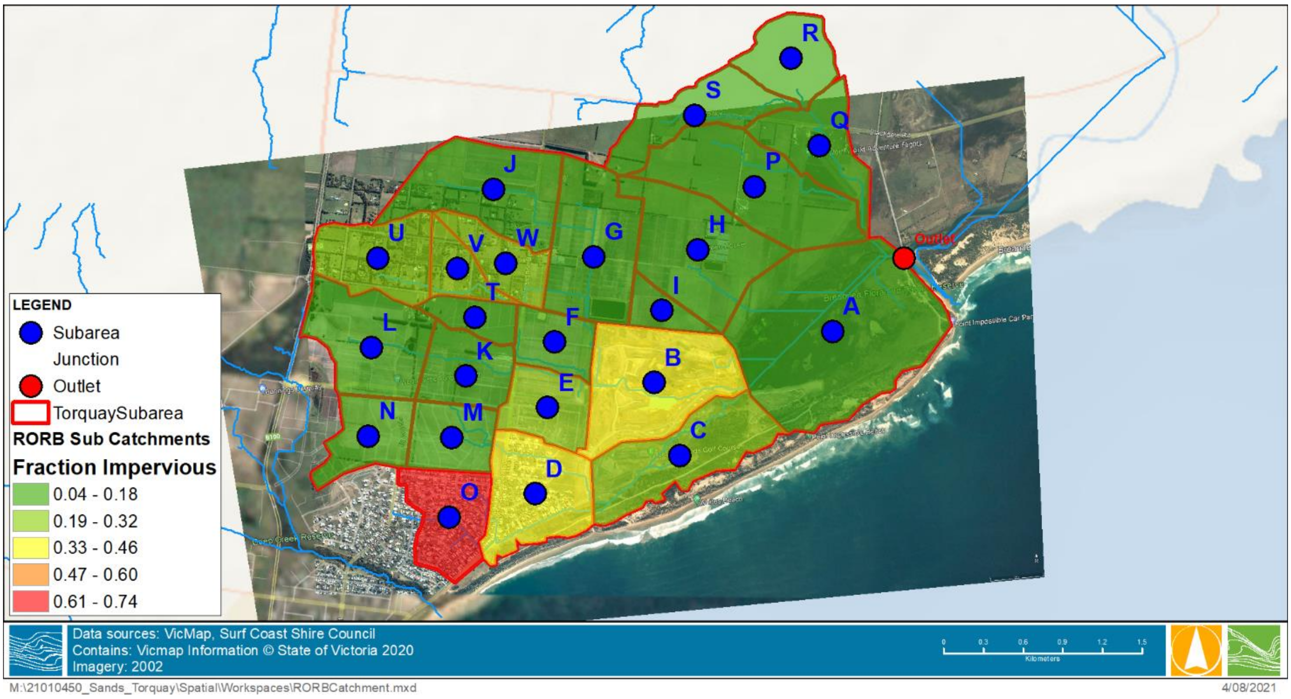


FIGURE 2-1 RORB PRE-DEVELOPMENT FRACTION IMPERVIOUS

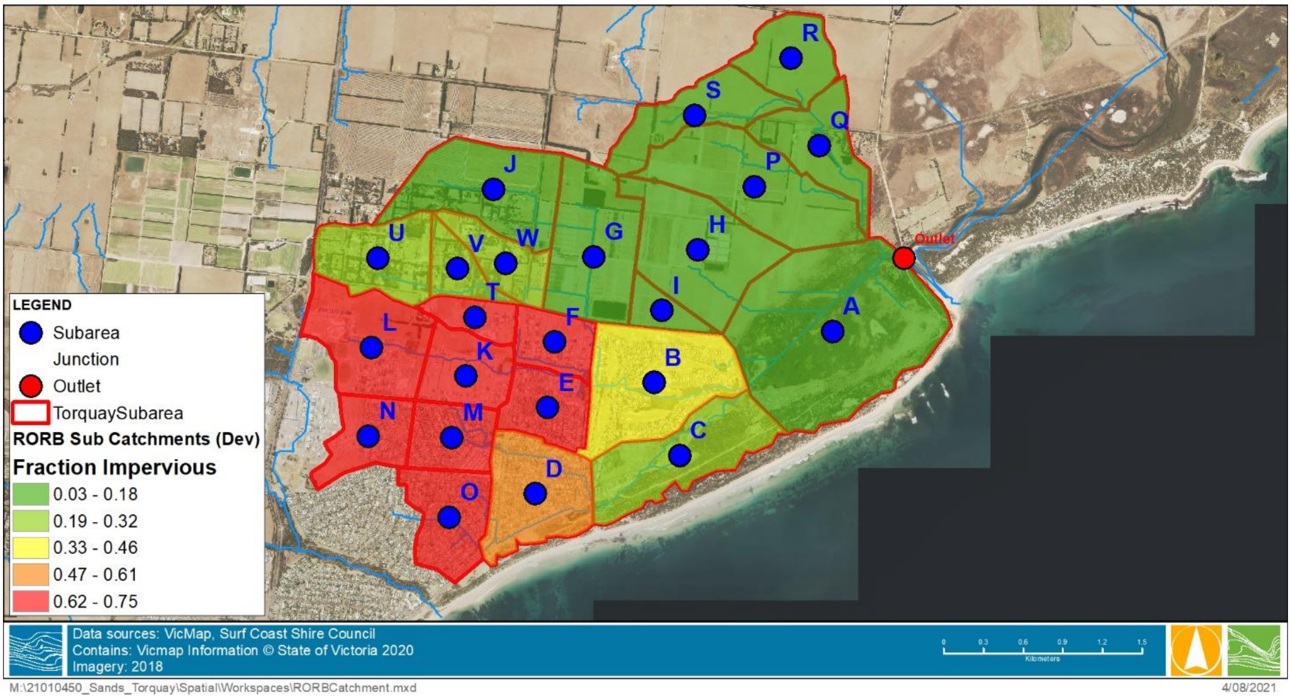


FIGURE 2-2 RORB DEVELOPMENT FRACTION IMPERVIOUS

2.2.3 Losses

Table 2-1 presents the initial and continuing loss assumptions extracted from the Australian Rainfall and Runoff Data Hub using the centroid of the catchment to extract the Bureau of Meteorology IFD (Intensity Frequency Duration) rainfall depths, storm losses, temporal patterns and median pre-burst depths.

The loss values are validated against various estimation equations and are considered fit-for-purpose across this catchment. As no calibrated RORB model exists within this region, the ARR Data hub values are considered the best available information, although the losses are generally recognised to be conservatively high.

TABLE 2-1 INITIAL AND CONTINUING LOSSES (ARR DATA HUB)

Initial Loss (mm)	Continuing Loss (mm/hr)
24.0	4.4

2.2.4 K_C

K_c is a RORB model routing parameter that influences peak flow attenuation and travel time along the model reaches. In gauged catchments the K_C value is one of the main parameters used to calibrate a RORB model, varying peak flow and timing. In ungauged catchments there are several ways to estimate the K_C value, these include empirical equation based estimates of K_C and the adoption of a K_C value scaled from nearby calibrated RORB models.

Regional equations and locational applicability for the RORB routing parameter K_C are shown in Table 2-2. Only 2 of these equations are appropriate for the Torquay region, being equations 2 and 4. As equation 4 is Victoria specific, this regional equation was determined to be the most appropriate.

TABLE 2-2 REGIONAL K_C ESTIMATIONS

No.	Regional Equation	Application	Source
1	$k_c = 0.49 \times A^{0.65}$	Areas with annual rainfall <800 mm	ARR16 Book 7, Chapter 6.2.1.3
2	$k_c = 2.57 \times A^{0.45}$	Areas with annual rainfall > 800 mm	ARR16 Book 7, Chapter 6.2.1.3
3	$k_c = 2.2 \times A^{0.5}$	General	RORB V6 User Manual Equation 2-5
4	$k_c = 1.25 \times d_{av}$	Victoria	Pearse et al. (2002)
5	$k_c = 2.2 \times A^{0.5}$	Yarra and Maribyrnong	Melbourne Water
6	$k_c = 1.53 \times A^{0.55}$	South East area. The area that was formerly managed by the Dandenong Valley Authority	Melbourne Water

TABLE 2-3 K_C COMPARISON

No.	Regional equation	k_C
2	$K_C = 2.57 \times A0.45$	7.86
4	$K_C = 1.25 \times d_{av}$	**2.13**

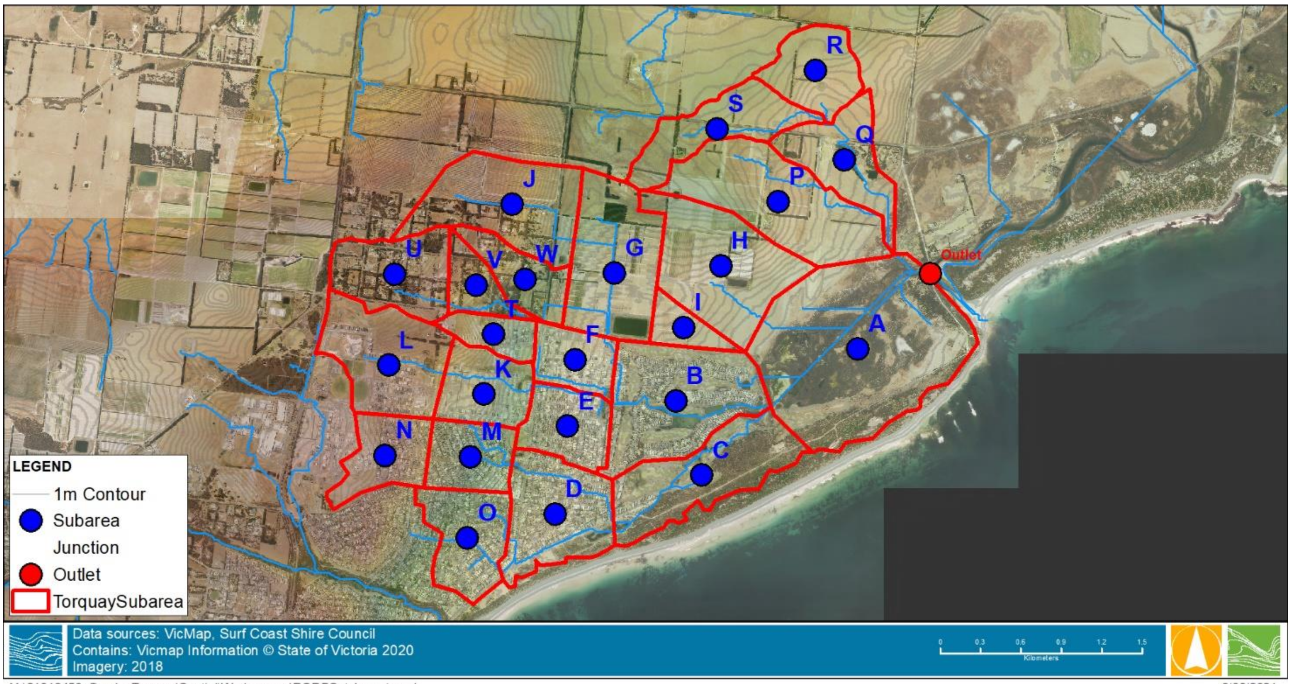
2.2.5 RORB Model Schematisation

The RORB model was established through the use of software packages ArcHydro to generate the sub-catchments and reach locations, and ArcRORB for the remaining model build.

Figure 2-3 shows the sub-catchment layout with Figure 2-4 showing the RORB model build for the pre-developed site conditions. Figure 2-6 shows the RORB model build for the developed conditions. Differences between these models include

- Increased fraction impervious area between pre and full development.
- Change in reach types from type 1 (natural) to 2 (excavated unlined) where drainage networks or roads have been constructed.
- Where available information existed proposed/constructed retardation storages including the Sands amenity lakes have been included in the developed conditions modelling.

For the purposes of this assessment, it has been assumed that catchment drainage to the Esplanade wetland is part of the pre-development catchment, although it is acknowledged that part of this catchment likely drained to the ocean (through Whites Gap) and/or Deep Creek prior to development. As such, our assumptions substantially increased the pre-development flows. A sensitivity test of the smaller pre-development conditions catchment was also undertaken excluding this area.



M:\21010450_Sands_Torquay\Spatial\Workspaces\RORBCatchment.mxd 3/08/2021

FIGURE 2-3 RORB SUBCATCHMENT SETUP

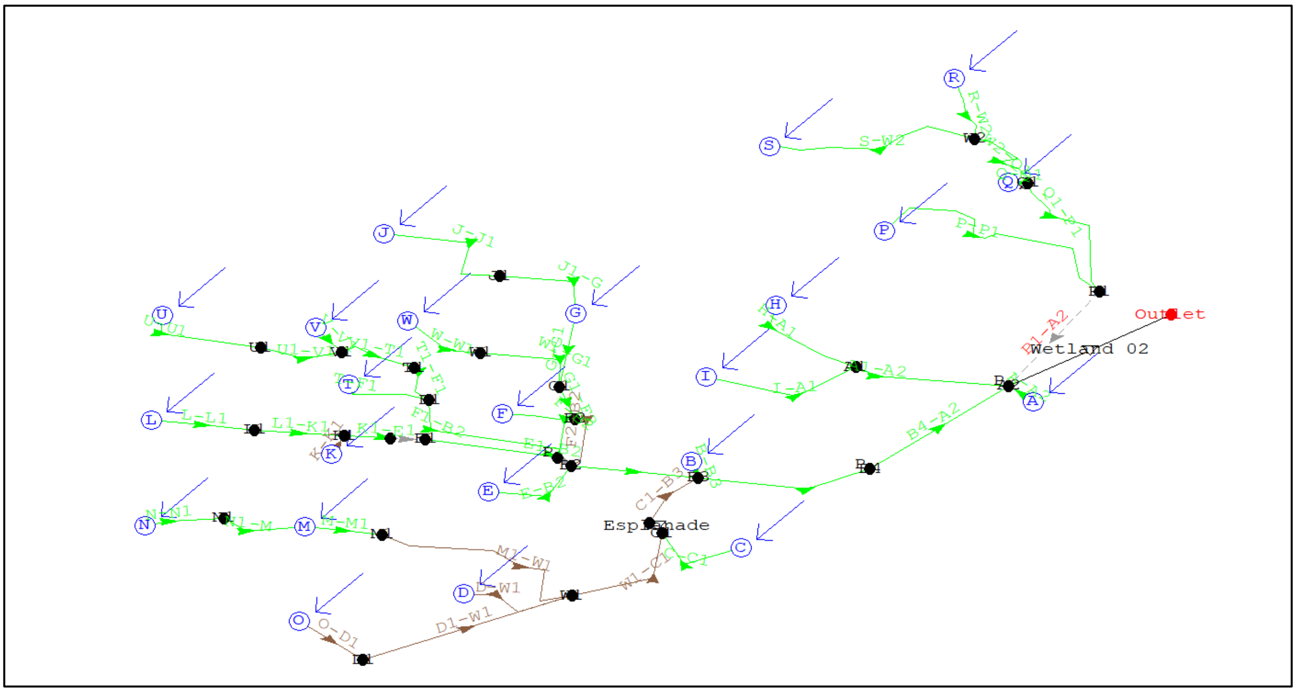


FIGURE 2-4 PRE-DEVELOPED (PRE 2002) RORB MODEL

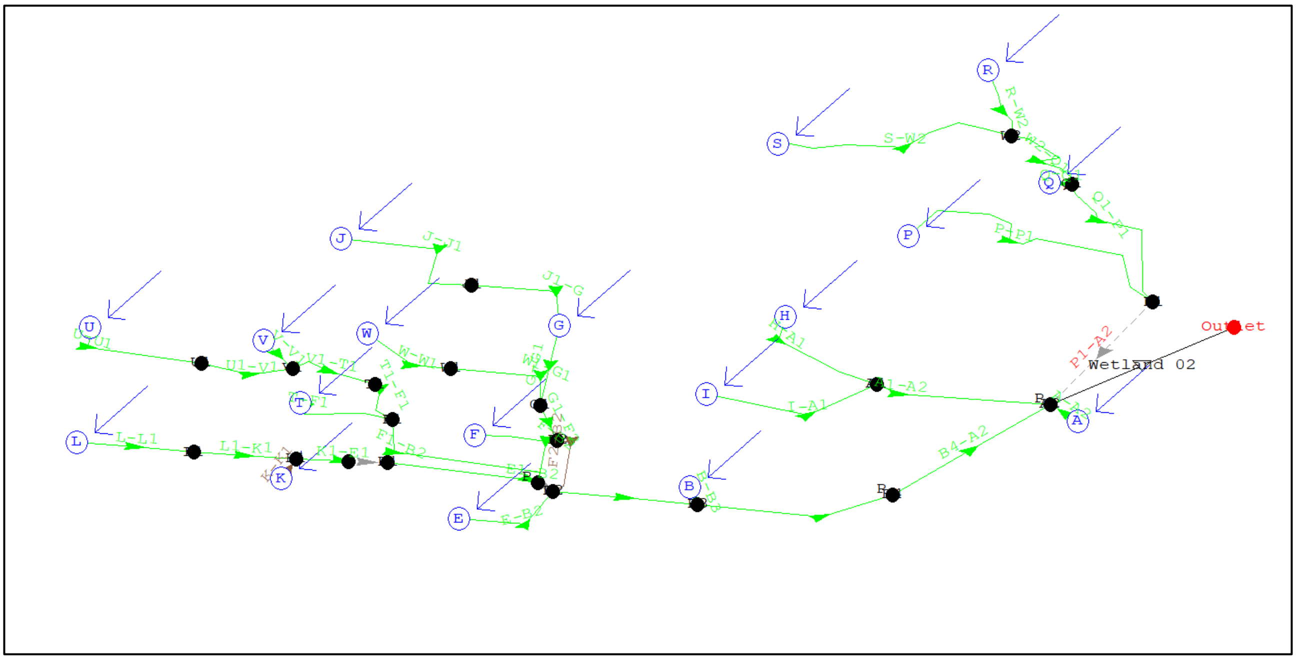


FIGURE 2-5 PRE-DEVELOPED EXC. ESPLANADE CATCHMENT RORB MODEL

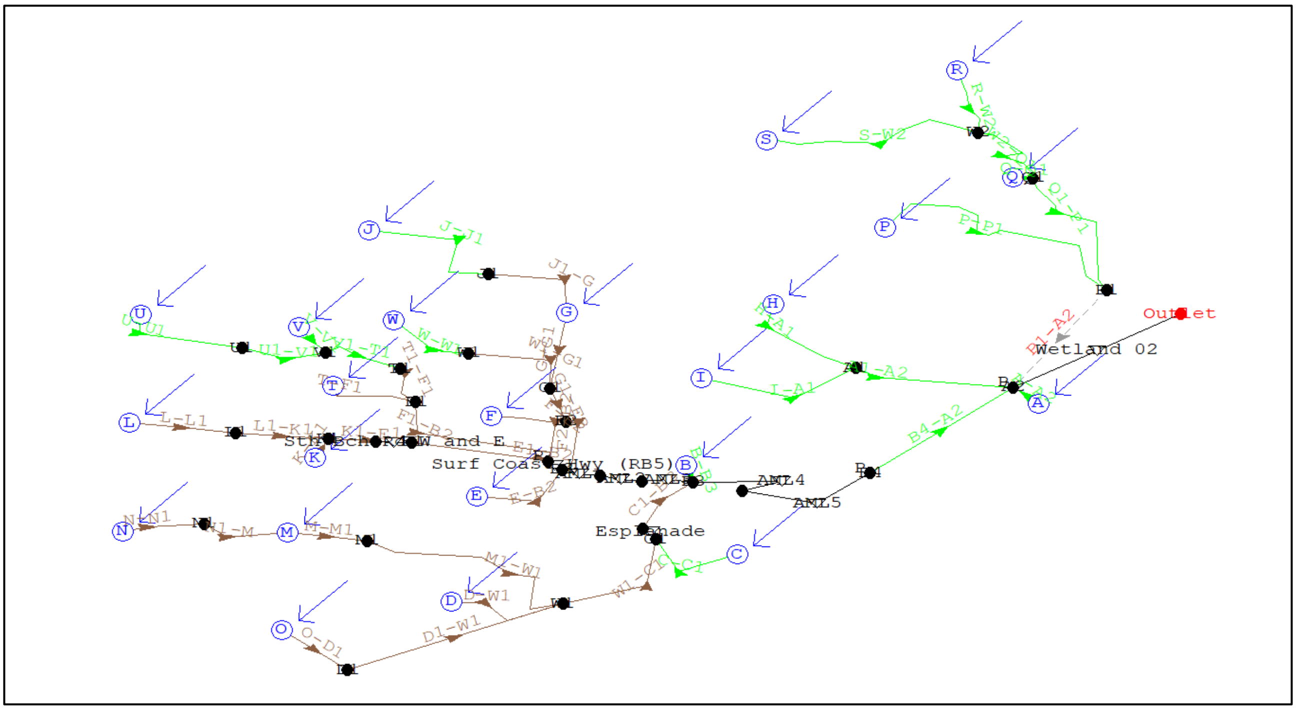


FIGURE 2-6 FULLY DEVELOPED RORB MODEL

2.3 Peak Storm Results

The peak flow results of the RORB modelling are displayed in Table 2-446. To ensure an accurate comparison, the temporal pattern for the median peak flow (within the ensemble) has been compared to the same event for both the developed and existing conditions. In all cases, the temporal pattern that produced the median flow for the existing condition did not produce the median flow for the developed conditions. The peak inflow volume (event based) has also been presented in Table 2-446.

The results suggest that peak flows decrease from the pre-development to the fully developed case. However, the peak volume increases when comparing the two cases. This indicates that the attenuation within the catchment and upstream storages has reduced the peak flow but development has increased the volume entering the Karaaf wetlands. The assumptions around available flood storage were based on the Torquay North PSP and Sands SWMP which provide storage volumes (m³) above wetland normal water level. These references were also used to specify basin outlet sizes.

TABLE 2-4 RORB RESULTS AT KARAAF WETLAND

Karaaf Wetland - Inflow	Event	Duration	Temporal Pattern	Peak Flow (m^3/s)	Peak Volume Inflow (m^3)
Fully Developed	1% AEP	9hr	TP27	18.8*	3.7E+05
Pre-developed	1% AEP	9hr	TP27	20.9	3.4E+05
Pre-developed (Excl. Esplanade)	1% AEP	9hr	TP27	19.1	2.7E+05
Fully Developed	1% AEP	9hr	TP25	20.1	4.6E+05
Pre-developed	1% AEP	9hr	TP25	21.0*	4.3E+05
Pre-developed (Excl. Esplanade)	1% AEP	9hr	TP25	18.7	3.5E+05
Fully Developed	20% AEP	9hr	TP4	3.5*	8.3E+04
Pre-developed	20% AEP	9hr	TP4	4.7	8.0E+04
Pre-developed (Excl. Esplanade)	20% AEP	9hr	TP4	4.5	6.3E+04
Fully Developed	20% AEP	9hr	TP3	2.3	8.6E+04
Pre-developed	20% AEP	9hr	TP3	4.5*	8.1E+04
Pre-developed (Excl. Esplanade)	20% AEP	9hr	TP3	4.4	6.4E+04

*Indicates median temporal pattern

** In accordance with industry standards the temporal pattern which yields the median peak flow should be adopted as the basis of design flood event. The applicable temporal pattern can vary across the catchment depending on catchment characteristic and the critical timing of the event.

A summary of the changes from the pre-developed to fully developed cases can be seen in Table 2-557.

TABLE 2-5 RORB RESULTS CHANGE SUMMARY

Event	Duration	Temporal Pattern	Peak Flow Change (Pre-developed to Fully Developed)	Volume Change * (Pre-developed to Fully Developed)
1% AEP	9hr	TP27	-10% -2% (Excl Esp)	8% 38% (Excl Esp)
1% AEP	9hr	TP25	-4% 8% (Excl Esp)	7% 32% (Excl Esp)
20% AEP	9hr	TP4	-25% -21% (Excl Esp)	3% 32% (Excl Esp)
20% AEP	9hr	TP3	-48% -47% (Excl Esp)	6% 34% (Excl Esp)

* The volume change displayed in this assessment relates to an individual design storm which occurs over a short period of time. RORB does not consider total catchment volumes in the same way that water balance assessments like MUSIC consider volume. Water Balance modelling uses real rainfall data and catchment characteristics to assess total volumes of runoff over long periods. Water Balance models provide a better representation of seasonal or annual flow volume variations.

Figure 2-7 to Figure 2-9 show the hydrographs for the 1% AEP critical duration, 1% AEP 1.5 hr duration and 20% critical duration design storms. It is evident that, generally, the existing flows are higher than the developed flows throughout the event on the rising limb. However, on the falling limb the developed flows are higher, resulting in an overall increase in volume of inflow as shown in Table 2-446.

The greater variation shown in the 'Excl Esp' scenario is a result of the comparison of the current catchment and flow conditions with a smaller pre-development catchment, where the current catchment which drains through the Esplanade wetland is excluded. This scenario has been provided to simulate catchment conditions before diversion of the Quay development occurred.

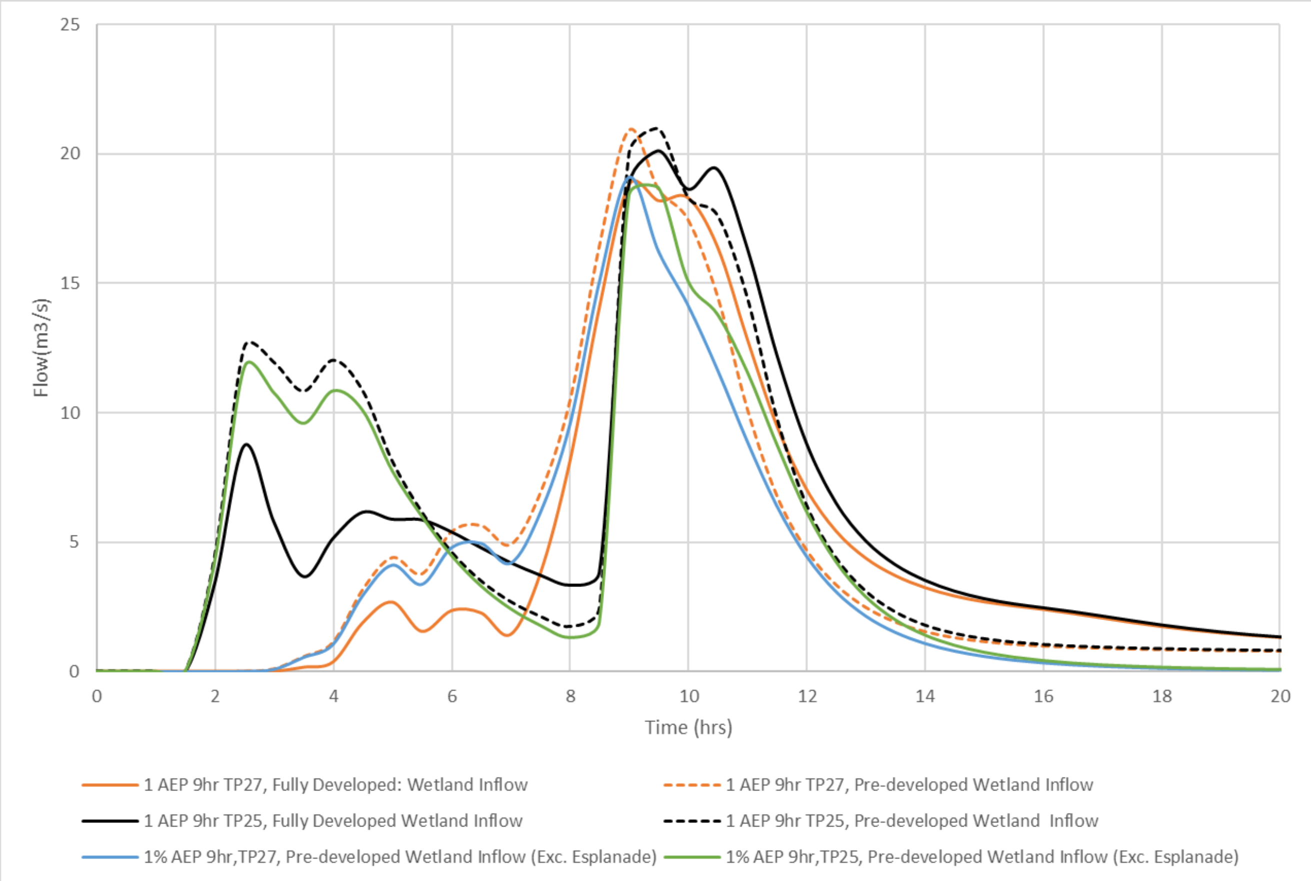


FIGURE 2-7 SANDS TORQUAY - KARAAF WETLANDS INFLOW (1% AEP, CRITICAL DURATION)

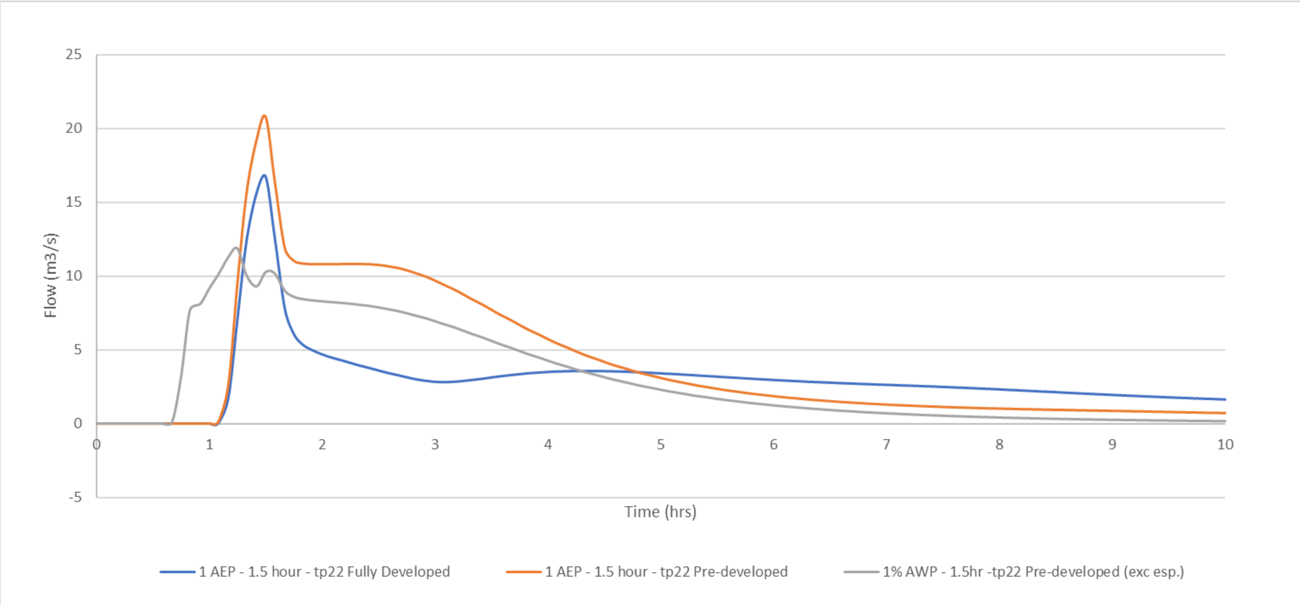


FIGURE 2-8 SANDS TORQUAY - KARAAF WETLAND INFLOW (1% AEP, 1.5 HR DURATION)

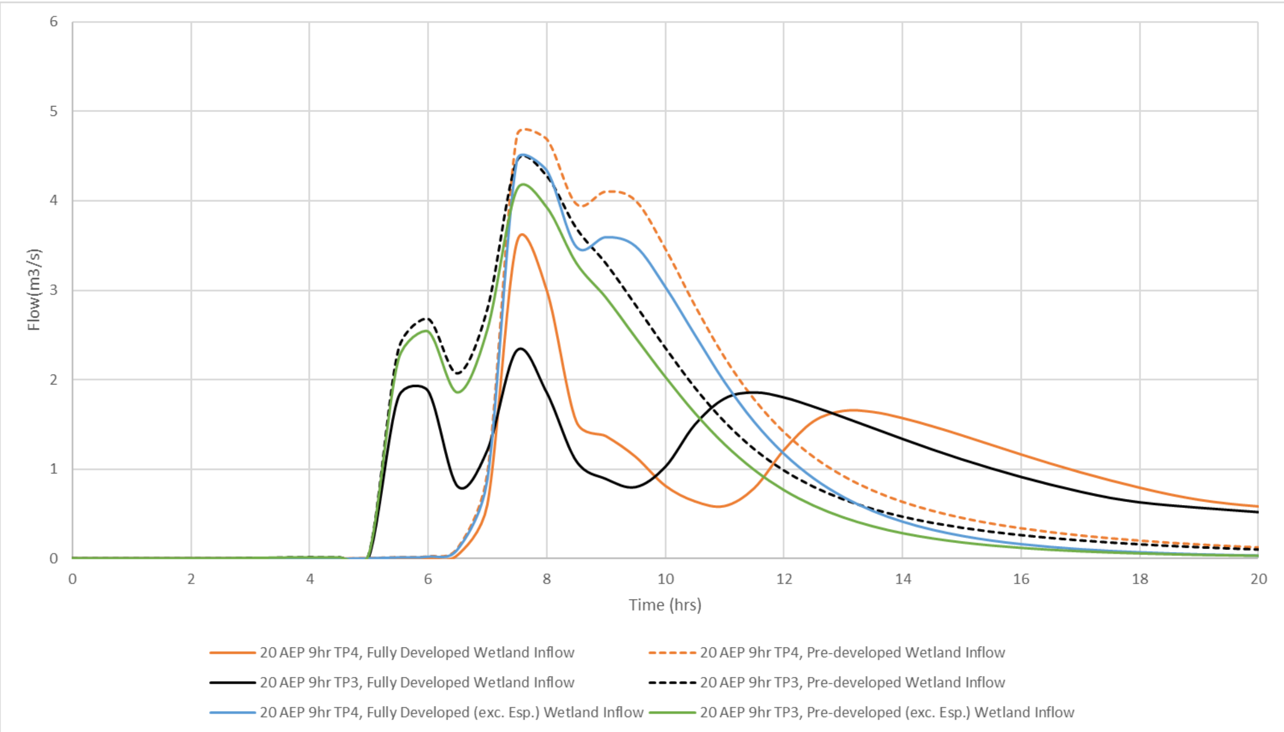


FIGURE 2-9 SANDS TORQUAY - KARAAF WETLAND INFLOW (20% AEP, CRITICAL DURATION)

2.4 Discussion

The RORB model results suggest that for the 1% AEP design flood the development of the catchment has resulted in a reduction in peak flows due to the active storage and controlled outlets provided in the wetland-retarding basins. This occurs when comparing both the pre-development and pre-development excluding the Esplanade wetland catchment connection with developed conditions. Whilst the diversion of the Esplanade catchment does contribute to a minor increase in overall peak flows, the timing of the peak of these flows is not at the same time as the Torquay North catchment. Subsequently the impact of the increase in catchment area draining to the Karaaf Wetlands is not predicted to be significant.

The development has resulted in an overall increase in flood event flow volume into the Karaaf wetland. A comparison of these results shows that the volume for the 1% AEP fully developed conditions design flood, when compared to the pre-development and pre-development excluding the Esplanade catchment, is increased by 8% and 38% respectively.

This result is not unexpected. Urban development will result in an increase to impervious areas. Although the peak flows are mitigated through the installation of retarding basins and wetlands, the overall volume increase from the reduction of natural catchment losses (via interception, infiltration, evapotranspiration and ponding) is evident by the increased flood volumes. This increase in volume is exacerbated by the diversion of additional catchment area which naturally would not have drained to the Karaaf wetlands.

Increased attenuation throughout the catchment results in a lower peak flow rate but a longer period after the completion of the storm. Importantly the system is not as effective at retarding flows to pre-development levels for storms smaller than the 1% AEP. This is likely due to the size and configuration of the outlets from the retarding basins. For these outfalls to successfully retard flows from both minor and major storms, changes to the outfall structures would be required. It is likely that, as a result of sedimentation within the wetlands/basins, the available flood storage has been reduced compared to the original designs. However, without detailed level assessments and sediment survey the degree to which this may impact flood retardation is difficult to assess.

Further analysis of the changes to the long-term annual flow regime is shown in Section 3 of this report.

3 EXISTING URBAN WATER QUALITY MANAGEMENT

3.1 Overview

The urban catchments which ultimately discharge to the Karaaf Wetlands and Thompson Creek are subject to planning and regulatory controls which require that water quality and flows be appropriately managed in line with industry standards and regulations including Clause 56.07 of the Victorian Planning Policy and the Urban Stormwater Best Practice Environmental Management Guidelines (1999). The State Environment Protection Policy (SEPP; EPA 1970) requires stormwater quality treatment from all urban developments be undertaken. The SEPP is binding on all government agencies, private individuals and businesses conducting activities on private and public land. Importantly these guidelines have recently been updated in the hope of strengthening controls around protection of beneficial uses of Victorian waterways, including the impacts of urban stormwater and defined pollutant thresholds.

At the time of planning and designing both the Sands and Torquay North development areas, surface water management plans were completed. The intent of the surface water planning being primarily focused on:

- Ensuring peak flows were maintained to pre-development 1% AEP storm levels, and
- Stormwater Runoff from the development areas was treated in line with best practice water quality requirements.

At the time of completing this report not all detailed surface water management plans were available for review. Having regard to this, the basis of the assessment has been made on assumptions and documentation from the following key documents:

- Torquay Sands Development – Surface Water Management System (Craigie, 2001)
- Report for Stormwater Master Plan - Torquay North (GHD, 2010)

These reports identify the type, size and location of recommended water quality treatment assets within the respective development areas. It is noted that a number of alterations are likely to have occurred during the detailed design phase of estate planning which have been noted below, where this was able to be confirmed. Further to the design of these assets the management plans identify maintenance requirements and clean-out frequencies of key assets.

Water Technology has identified the following key Water Quality and retardation basins as noted in the stormwater management plans:

- Torquay North
  - Horseshoe Bend Development (Zeally Sands)
  - Dunes Development (Dunes)
  - Stretton Development (Stretton)
- Austland The Quay Development (Quay)
  - North Quay Boulevard
  - South Quay Boulevard
  - Torquay Esplanade Wetland
- The Sands
  - Amenity Lakes (1-5)
  - Irrigation Lakes (7)
  - Water Quality Wetlands (1-9)

As part of the catchment assessment, the key constructed wetlands within the Karaaf Wetlands catchment were inspected. The condition assessment undertaken included a visual inspection of the wetlands focussed on the following aspects:

- Visual gross pollution and litter
- Sedimentation
- Vegetation establishment, uniformity and abundance
- Inlet and outlet integrity and blockage
- Visual water colour

Further to the above, where plans were available, validation of asset sizes including surface area, inlet ponds, inlet and outlet culvert sizes were completed.

The sites were inspected on the 17th of June 2021, the catchment conditions for the week leading up to the inspection included up to 8mm of rainfall (3.5mm 10/6, 0.75mm 11/6, 0.25mm 12/6, 1.25mm 16/6) with an additional 8.5mm falling on the 8/6.

3.2 Zeally Sands Drainage Reserve – Horseshoe Bend

Plans available of this drainage reserve show three main wetland areas. Each of the respective areas has a sediment basin and separated wetland area connected with bunds and outflow pipes through to The Sands amenity lakes.

At the time of inspection, it appeared that recent works had occurred to remove excess vegetation within the inlet ponds. We are advised that 2 of the 4 sediment ponds had recently been cleared of some sediment. It has been reported that during this recent clearing, the sediment ponds were not drained and hence full removal of accumulated sediment from the basins did not occur.

The following observations were made:

- Significant encroachment of vegetation had occurred within the sediment basins and deep water zones of the wetland areas.
- Lack of aquatic vegetation.
- Minor gross pollutants were visible within the wetland
- Significant sedimentation and shallowing has occurred within the respective sediment basins of each of the wetland areas (3).
- Deep Water zones appear to have been diminished with a high degree of sediment contributing to vegetation encroachment across the extent of the wetlands.
- The inlet pipes were visible and vegetation overgrowth was beginning to encroach on the northern inlet. This inlet was drowned to 60-80% at the time of inspection.
- Due to sedimentation and vegetation growth, it is likely that any low flow/balance pipes between the wetlands pool are blocked. This is likely to compromise the functionality of the wetland.
- Plant diversity within the wetland appeared to be limited. This was also evident within the fringing and adjoining landscaping.

FIGURE 3-1 ZEALLY SAND WETLAND PHOTOGRAPHS

3.3 Dunes Wetlands

At the time of inspection, the following observations were made:

- A signification amount of gross pollution was present within the wetland
- The water level in the sediment pond was above Normal Water Level (NWL)
- The southern sediment pond appeared to have exceeded its capacity with inflows scouring a path through the accumulated sediment.
- Some sediment pond inlets were not visible and likely not functional due to accumulated sediment and vegetation overgrowth. At the time of inspection the two northern inlets were discharging to a single water body.
- Water within the wetland was notably turbid, although no water quality sampling was undertaken at this time to confirm levels.

- The north-western pipe inlet was severely obstructed with vegetation, debris and sediment.
- 3 Gross Pollutant Trap (GPT) devises were identified at the inlet locations to the wetland. No inspection of these devices was possible. It is also noted that an additional GPT was identified within the eastern access driveway. This GPT does not appear to align with the inlet of the wetland in accordance with available plans and councils pipe network database.
- It appeared that some management of vegetation at the southern sediment basin had occurred as visible by the vegetation debris at this location.
- All three inlet pipes were partially drowned at the time of inspection.
- There was a visible lack of aquatic vegetation within the wetland.

FIGURE 3-2 DUNES WETLAND PHOTOGRAPHS

3.4 Stretton Wetland

At the time of inspection, it was noted that the Stretton Estate wetland was not complete, although it appeared to be receiving flows from some connected catchments. The following observations were made at the time of inspection:

- Water levels within the wetland appeared high with no visible separation between sediment areas, deep water and macrophyte zones. The constructed berms visible in the aerial image below were below water level at the time of inspection. The aerial image appears to have been taken during construction phase. It appears that since this time the wetland is retaining higher than design water levels with water levels lower than the apparent wetland outlet located in the south eastern corner of the wetland.

- Water was visibly turbid.
- Whilst some vegetation appeared to have established within the northern part of the wetland, it did not appear that aquatic vegetation planting had occurred and or that landscaping of the banks and riparian area had occurred.
- A high degree of disturbed soil was present around the wetland with limited visible sediment control in place.
- A large area of sediment and sand appeared to have deposited immediately downstream of the inlet within the southwest corner of the wetland.
- No sediment control was visible within the estate related to stormwater pit entries.

FIGURE 3-3 STRETTON WETLAND PHOTOGRAPHS

3.5 Esplanade Wetland (Quay)

At the time of inspection following observations were made:

- No visible gross pollution was present within the wetlands

- Water levels within the wetland were relatively high with inundation extending out of bank to the north of the outlet at the time of inspection.
- The wetland outlet was not visible and appeared significantly obstructed by vegetation overgrowth.
- Water was audibly flowing from the wetland at the time of inspection.
- Whilst vegetation health within the wetland appeared good, Typha, a designated weed of the Surf Coast Shire was identified within the wetland.

FIGURE 3-4 ESPLANADE WETLAND PHOTOGRAPHS

3.6 Quay Wetlands

At the time of inspection the following observations were made:

- Minor gross pollution was present within the wetland

- No visible sediment pond or separated treatment areas.
- Vegetation overgrowth was present around the wetland inlets, although they did not appear blocked by vegetation.
- There appeared to be significant shallowing of some parts of the wetland with identifiable sediment deposition within the wetland.
- Typha, a designated weed of the Surf Coast Shire, was present within the wetland.
- Whilst there was good vegetation coverage within the wetland it appeared that some non-native species had established.

FIGURE 3-5 QUAY WETLAND PHOTOGRAPHS

21010450_R01v03_Torquay_Sands_Final

3.7 Torquay Sands

The following observations were made at the time of inspection:

- No gross pollution was present within the amenity lakes or treatment wetlands.
- A pollution bund was present within the first amenity lake adjacent to the Zeally Sands wetland.
- The wetlands had a good distribution of aquatic vegetation species
- It appeared that recent weed control had occurred.
- Turbidity within the lakes appeared to progressively decrease through the amenity lakes.
- Minor flows were discharging to the Karaaf Wetlands at the time of inspection via the concrete spillway along the eastern boundary of the estate.
- A number of the amenity lakes were observed to have a filamentous algae growth.

FIGURE 3-6 THE SANDS WETLAND PHOTOGRAPHS

4 MUSIC MODELLING

MUSIC modelling was undertaken to assess freshwater volumes entering the Karaaf Wetlands under pre-development and future full development of the Torquay North Precinct. Refer to Appendix A for MUSIC model parameters. A summary of modelling and key outcomes are presented below.

4.1 Model Schematisation

A schematic of the model is shown in Figure 4-1. The overall catchment area, including both urban and rural areas, draining to the Karaaf Wetlands was estimated to be 1,202 Ha, with an estimated fraction impervious (FI) of 29% at full development[1]. Freshwater inflows entering the Karaaf Wetlands through the Sands development and the golf course were the focus of the current assessment. Therefore, stormwater runoff generated through agricultural catchments are not reported. Furthermore, for reporting purposes, the pre-development FI was assumed to be 10%. Existing and proposed WSUD assets such as gross pollutant traps (GPTs), sediment ponds, wetlands and lakes are included in the MUSIC model. Additionally, the existing stormwater harvesting scheme for golf course irrigation and the proposed 12 ML/year stormwater diversion at the Dunes development were captured in the current MUSIC model.

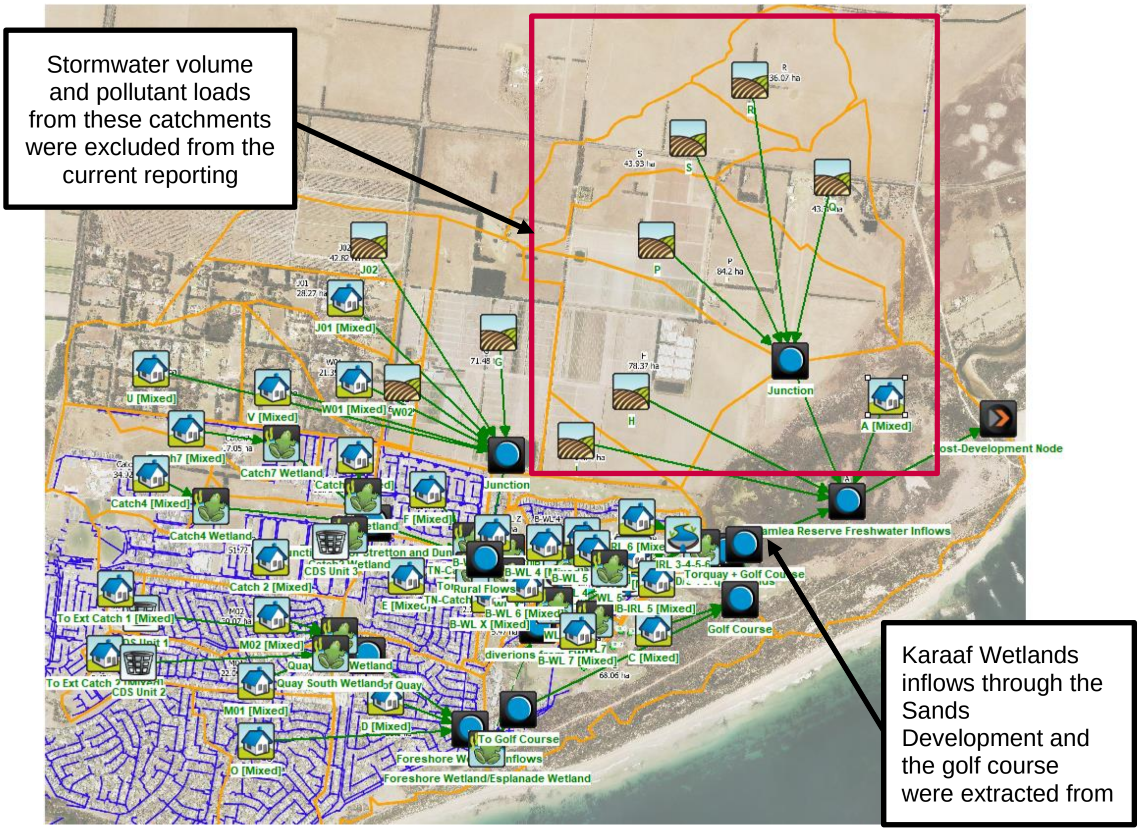


FIGURE 4-1 MUSIC MODEL SCHEMATIC

[1] It should be noted that the previous surface water management study (GHD, 2010) had adopted a relatively low FI (45%) for the proposed Torquay North Precinct area. A preliminary review of residential lots in the area revealed that the average lot size in new sub-divisions is ~ 540 m^2. The typical FI values for residential zones with lot sizes 300 - 600 m^2 vary between 70 – 80%. The current study adopts an average 70% FI for residential subdivision which is considered conservatively low.

4.1.1 Model limitations

All efforts were made to represent the future development scenario with the proposed WSUD assets as accurately as possible. However, it should be noted that the MUSIC model has some limitations listed below. Therefore, model results should be interpreted taking these limitations into consideration.

- It should be noted that the MUSIC model does not include Pintail Dam and small farm dams within the rural residential/agricultural catchments.
  - It is understood that the Pintail dam is used to store excess water from the golf club and receives Class C water from Black Rock Sewage Treatment Plant (BRSTP) to mix with stormwater. However, this operation arrangement has been cancelled, and the future of dam operation is uncertain at the time of reporting. We understand Southern Rural Water has indicated a licence is needed for its operation (information received from the client). Furthermore, it was evident from LiDAR surface data that Pintail dam is constructed as a turkey nest dam, therefore it does not receive surface runoff from upstream catchment.
  - As a conservative approach, the Pintail dam was excluded from the assessment.
- Treatment asset parameters were based on initial concept design reports (Craige & Condina, 2001; GHD, 2010) and may not match the actual on-ground asset specifications (either what was constructed or what exists now).
- A constant annual irrigation demand was adopted. In reality the irrigation demand will vary between years depending on prevailing weather conditions (rainfall, temperature, wind, humidity etc).
- Any existing/proposed rainwater harvesting associated with the Dunes development is not represented in the model.
  - However, the proposed 12 ML/y stormwater diversion to the pintail dam in represented as an annual reuse demand in the MUSIC model.

4.2 Asset Design and Performance

Existing and proposed Water Sensitive Urban Design (WSUD) assets (wetlands, lakes and gross pollutant traps) design information were primarily extracted from the previous reports (Craige & Condina, 2001; GHD, 2010). Where sufficient information was not available, design parameters were estimated using the aerial imagery (surface area of assets) and WUSD standards. Refer to Appendix A for asset model parameters.

A summary of WSUD asset pollutant removal performance is presented in **TABLE 4-1**. In this table red values indicate a target is met, whilst green numbers show the target is met. The modelling suggests the wetlands consistently do not meet Total Suspended Solids (TSS) and Total Nitrogen (TN) load reduction targets. Modelling results are supported by site visit observations where the existing sediment ponds of wetlands within the Dunes, Quay and Zeally Sands developments appear substantially filled with sediment. Whilst the pollutant removal performance of the amenity lakes is low due to the limited emergent macrophyte coverage and depth profile, this is acceptable and as designed, with the primary function of these assets being flood conveyance and storage, rather than water quality treatment. Nevertheless, the MUSIC model indicates there is significant pollutant removal occurring at the irrigation lakes. This high pollutant removal performance is partly due to the treatment node, where stormwater is extracted for irrigation in the MUSIC model.

It is important to recognise that at Amenity Lakes 1-3 the system is receiving flows from both the estate wetlands and the Zeally Sands. Immediately downstream of this, at Amenity Lakes 4-5 the system is receiving flows from The Esplanade wetlands. This means the Sands system is receiving a cumulative and compounding sediment load from upstream, which is evidenced by the degraded state of the amenity lakes. This is supported by regular water sampling within the lakes which shows reducing turbidity progressively through the lakes as sediment deposits within the system.

TABLE 4-1 MODELLED WETLAND AND LAKE MEAN ANNUAL POLLUTANT LOAD REDUCTION PERFORMANCE1

Contributing Catchment	Wetland/Lake	TSS % Load Reduction	TP % Load Reduction	TN % Load Reduction	Gross Pollutant %Load Reduction
BEPM Targets (IDM, 2020)		**80**	**45**	**45**	**70**
Stretton Development	Catch3 Wetland	70	60	40	99
	Catch4 Wetland	62	53	35	96
	Catch7 Wetland	63	53	35	96
The Dunes Development	Dunes Wetland 1&2[3]	54	46	32	96
Horseshoe Bend Development – Zeally Sands	TN-Catch1 Wetland	69	59	39	98
	TN-Catch6 Wetland	37	30	19	88
The Quay Development[4]	Quay North Wetland	23	18	10	94
	Quay South Wetland	28	22	12	93
The Quay - Esplanade	Foreshore Wetland/Esplanade Wetland	57	46	27	94
The Sands Development	WL 4	69	59	40	99
	WL 5	70	59	40	99
	WL6	69	59	40	99
	WL7	70	59	40	99
	WL 9	69	59	40	99
	WL X	69	58	40	99
	WL Z	70	59	40	99
	Amenity Lakes 1-3[2]	55	40	18	100
	Amenity Lakes 4-5[2]	36	17	6	100
	Irrigation Lakes 3-6[2,3]	85	67	62	100

Notes: -

1. Reported performance summary is the individual asset performance and does not represent total treatment train effectiveness including any upstream WSUD assets such as GPTs and other wetlands.
2. Lakes are not proposed as water quality assets. They are designed to be flood conveyance and storage assets. Water quality treatment is primarily achieved through GPTs, sediment ponds and wetlands.
3. Increased load reduction due to stormwater reuse applied at this node
4. Wetland parameters could not be found in previous assessments. Surface area was extracted from VicMap database (hy_water_area_polygon.shp) to be consistent with other wetlands/lakes for which parameters cannot be extracted from the previous reports. Actual wetland size is likely to be larger than the modelled parameters.

A key assumption in relation to treatment performance is that the treatment system, whether by wetlands or otherwise, will remove 100% of gross pollutants from stormwater (excluding bypass flows). Gross pollutants are described as any solid waste greater than 5 mm in diameter. Inspection of the wetlands within the catchment showed that this appears to be occurring by way of trapped litter amongst aquatic vegetation. However, it is something that is often overlooked in management of wetlands which do not have any pre-treatment. This is because, without specific gross pollutant removal, the wetlands effectively act as a litter trap. This situation can translate to an additional maintenance obligation which requires manual removal of accumulated gross pollutants from within the wetlands. This is increasingly difficult as wetlands establish with vegetation. It is best addressed with the installation of GPTs at the inlet of all wetlands which can regularly be cleaned without needing to disturb the wetland.

A further investigation of wetland sizing was undertaken to understand the overall low pollutant load reduction performance. Table 4-3 presents a summary of wetland catchment comparison between the previous assessment and the current model. It is evident that catchment imperviousness in the current MUSIC model is generally higher than the original assessments (Craige & Condina, 2001; GHD, 2010). This is understandable as development densities have increased over the past 20 years with average lot sizes generally reducing. Furthermore, in the case of 'TN-Catch6 Wetland', it was noticed that there was a significant increase in contributing catchment area, which will subsequently exacerbate the poor wetland pollutant removal performance. It is also apparent that, in general, wetlands were sized as 1 to 1.5% of their contributing catchment. Wetland design has evolved over the past 20 years. Current practice suggests wetlands are typically sized to around 3% of their catchment area to achieve best practice targets[2].

An additional sensitivity analysis was conducted to test the efficacy of the treatment train by removing sediment ponds (i.e. by setting wetland inlet pond volume to 0 m^3). Noting that previously modelled inlet pond sizes were based on information available from the Torquay North Stormwater Plan and/or based on estimated geometry from aerial images.

Model results indicated that the removal of wetland inlet ponds/sediment ponds resulted in an overall lowering in pollutant reduction performance (average 9%, 6% and 3% reduction in TSS, TP and TN removal performance, refer to Table 4-2) and as a result an additional sediment load of 1,800 kg/year will pass through the system if all sediment basins in all wetlands upstream of Sands development (including the Foreshore wetland) are not operational. This demonstrated it is critical to maintain WSUD assets regularly, as well as protecting these assets from excessive sediment loads generated from catchment development activities.

[2] Melbourne Water Wetland Analyser Tool, available at https://musicauditor.com.au/

TABLE 4-2 SEDIMENT POND EFFICACY SENSITIVITY TEST RESULTS

Contributing Catchment	Wetland	Inlet Pond Volume (m^3)	TSS % Load Reduction	TP % Load Reduction	TN % Load Reduction	Gross Pollutant %Load Reduction
BEPM Targets (IDM, 2020)			**80**	**45**	**45**	**70**
Stretton Development	Catch3 Wetland	289	70	60	40	99
		0	61	53	36	99
	Catch4 Wetland	333	62	53	35	96
		0	56	49	32	96
	Catch7 Wetland	238	63	53	35	96
		0	52	46	31	96
The Dunes Development	Dunes Wetland 1&2	500	54	46	32	96
		0	47	41	29	96
Horseshoe Bend Development – Zeally Sands	TN-Catch1 Wetland	406	69	59	39	98
		0	60	52	35	98
	TN-Catch6 Wetland	103	37	30	19	88
		0	29	25	15	88
The Quay Development	Quay North Wetland	95	23	18	10	94
		0	14	12	7	94
	Quay South Wetland	109	28	22	12	93
		0	18	15	9	93
The Quay - Esplanade	Foreshore Wetland	2100	57	46	27	94
		0	48	40	25	94

TABLE 4-3 WETLAND CATCHMENT COMPARISON

Contributing Catchment	Wetland	Wetland Area (m^2)	Current Assessment		Previous Assessments		Reference
			Catchment Area (ha) and FI	Wetland/Catchment area ratio	Catchment Area (ha) and FI	Wetland/Catchment area ratio	
Stretton	Catch3 Wetland	1,735	16.7 (70%)	1.0%	17.1 (45%)	1.0%	(GHD, 2010)
	Catch4 Wetland	3,000	34.9 (70%)	0.8%	35.7 (45%)	0.9%	
	Catch7 Wetland	1,429	17.1 (70%)	1.0%	14.1 (45%)	0.8%	
Horseshoe Bend Development – Zeally Sands	TN-Catch1 Wetland	2,435	25.4 (67%)	1.0%	24.1 (45%)	1.0%	
	TN-Catch6 Wetland	1,200	34.1 (67%)	0.8%	14.7 (45%)	0.4%	
The Dunes Development	Dunes Wetland 1&2	3133	52.7 (70%)	0.6%	48.3 (45%)[3]	0.6%	(WBCM Group, 2015)
The Sands Development	WL4 – Z	4,135[1]	27.6 (70%)	1.5%	45 (60%)	1.5%[1]	(Craige & Condina, 2001)
The Quay Development	Quay North Wetland	635[2]	42.4 (73%)	0.1%	-	-	
	Quay South Wetland	725[2]	31.5 (73%)	0.2%	-	-	
The Quay - Esplanade	Foreshore Wetland/Esplanade Wetland	14,000	169.5 (67%)	0.8%	180 (43%)	0.7%	(Craige & Condina, 2001)

Notes:

1. Surface areas of proposed stormwater wetlands is not available in the previous report. Instead, it is mentioned that the wetlands are sized to 1.5 % of the contributing catchment (residential and commercial areas of the resort and form non irrigated golf areas). Wetland surface area reported in the Table above is the 1.5% of residential catchment estimated using council stormwater drainage network layout.
2. Surface area extracted from VicMap database (hy_water_area_polygon.shp). Actual wetland surface area is likely to be higher than the area reported in VicMap database based on the extent observed in the latest aerial image. Surface are reported in VicMap databased was adopted to be consistent with other wetlands where no data was available in previous reports
3. Catchment FI estimates vary marginally between catchment associated with average lot sizes and estate layout.
4. MUSIC Catchments FI was not reported in the previous study (WBCM Group, 2015). 45% FI generated similar wetland inflow volumes and pollutant loads reported in the previous study (WBCM Group, 2015). Furthermore 45% FI is consistent with the FI used in overall Torquay North Precinct MUSIC modelling (GHD, 2010) .

In addition to individual wetland pollutant removal performance, the overall treatment train effectiveness was also evaluated at selected assessment locations (Table 4-4). Modelling results indicate that in general, industry standard BPEM targets are only met for TP and gross pollutants (GP).

Since WUSD assets were designed to only treat post-development runoff from their contributing residential subdivisions, the pollutant load reductions were also reported as a percentage of the developed catchment (excluding agricultural and rural residential catchment north of South Beach Road) loads. Since all assessment locations, except downstream of the Sands development, only had urban catchments, there was no difference in the pollutant load reductions with respect to the total catchment load and WSUD catchment load at those locations. Modelling results indicated that the proposed treatment train exceeds industry standard BPEM targets when assessing the pollutant load reduction with respect to urban catchment loads at the Sands development.

TABLE 4-4 OVERALL WATER QUALITY TREATMENT PERFORMANCE

Location	Pollutant	Total Catchment Runoff Load (kg/year)	WSUD Catchment Load[1] (kg/year)	Passing Pollutant Load (kg/year)	Load Removed (kg/year)	Load Reduction as % of Total Catchment Load	Load Reduction as % of WSUD Catchment Load
Downstream of Stretton Development	TSS	21,300	21,300	7,120	14,180	67%	67%
	TP	43.1	43	19	24	57%	57%
	TN	303	303	190	113	37%	37%
	GP	4,700	4,700	122	4,578	97%	97%
Downstream of Dunes Development	TSS	32,200	32,200	7,160	25,040	78%	78%
	TP	66	66	30	36	55%	55%
	TN	464	464	316	148	32%	32%
	GP	7,200	7,200	6	7,194	100%	100%
Downstream of Horseshoe Bend Development (Zeally Sands)	TSS	111,000	111,000	40,100	70,900	64%	64%
	TP	228	228	112	116	51%	51%
	TN	1,590	1,590	1,080	510	32%	32%
	GP	24,800	24,800	907	23,893	96%	96%
Downstream of Quay Development	TSS	43,900	43,900	29,100	14,800	34%	34%
	TP	89	89	68	20	23%	23%
	TN	623	623	556	67	11%	11%
	GP	9,580	9,580	487	9,093	95%	95%
Downstream of Esplanade Wetland (Quay Development)	TSS	101,000	101,000	36,400	64,600	64%	64%
	TP	208	208	91	118	56%	56%
	TN	1,460	1,460	819	641	44%	44%
	GP	22,900	22,900	791	22,109	97%	97%
Downstream of Sand Development and Golf Course	TSS	292,000	252,607	74,200	217,800	75%	86%
	TP	620	521	240	380	61%	73%
	TN	4,410	3,701	2,700	1,710	39%	46%
	GP	65,100	57,533	3,740	61,360	94%	107%

Notes: WSUD catchments are the existing and proposed residential developments area south of South Beach Road. This assessment considers the downstream combined loads of the wetlands in series.

4.3 Water Quality Assessment

A preliminary assessment of pollutant loads entering under pre-development and post-development conditions was also undertaken using the MUSIC model results (Table 4-5). Pollutant loads entering the Reserve significantly increased under the post-development scenario. Pollutant loads were reduced when WSUD stormwater treatment and stormwater harvesting was implemented, but the overall pollutant loads are still higher than the pre-development scenario except for gross pollutants.

TABLE 4-5 FRESHWATER POLLUTANT LOADS UNDER PRE-DEVELOPMENT AND POST-DEVELOPMENT SCENARIOS

Pollutant	Pre-Development (kg/year)	Fully Developed without treatment (kg/year)	Fully Developed with treatment (kg/year)
TSS	23,600	292,000	74,200
TP	30	620	240
TN	414	4,410	2,700
Gross Pollutants	8,820	65,100	3,740

4.4 Water Reuse

An average annual irrigation demand of 102 ML was applied in the MUSIC model with a seasonal distribution corresponding to the rainfall and PET deficit (Refer to Table 4-6 for more detail). MUSIC model results indicated a 79% reliability for the stormwater harvesting scheme (Table 4-6) and therefore within the current best practice design for stormwater harvesting systems[3]. Generally, the harvested stormwater could meet almost all irrigation demand except in the Summer and early Autumn months. The water reuse assumptions is this assessment are based on recorded usage requirements provided by the Sands grounds staff and in line with the usage values presented in the Dune Stormwater Management Plan.

TABLE 4-6 MODELLED STORMWATER HARVESTING SCHEME RELIABILITY

Month	Reuse Demand (ML/month)	Volume Supplied (ML/month)	% Reliability
September	3.1	3.1	100%
October	9.2	9.2	100%
November	16.3	16.0	98%
December	18.4	16.2	88%
January	21.4	14.1	66%
February	16.3	8.6	53%
March	12.2	8.8	72%
April	5.1	4.8	94%
Annual Average (ML/year)	**102**	**81**	**79%**

[3] Typically, stormwater harvesting systems are designed to achieve 80-90% reliability. In order to achieve reliability higher than this would require significant increase in storage, which will not be economically feasible.

4.5 Volume Assessment

A summary of pre and post-development runoff volume at a selected set of locations are presented in Table 4-7. It is evident that post-development stormwater volumes (combined total of surface runoff and baseflow) have increased consistently across the catchment by more than 200%. Post-development flows after inclusion of WSUD (wetlands) reduced on average by 5%.

TABLE 4-7 ANNUAL PRE-DEVELOPMENT AND FULLY DEVELOPED SCENARIO STORMWATER VOLUMES (SURFACE RUNOFF + BASEFLOW) AT SELECTED LOCATIONS

Month	Average Total Flow Pre-Development (ML/year)	Average Flow Fully Developed without mitigation (ML/year)	Average Flow Fully Developed with mitigation (ML/year)
Downstream of Stretton Development	57	216	207
Downstream of Dunes Development	44	162	146
Downstream of Zeally Sands Development	152	558	528
Downstream of Quay Development	56	218	216
Esplanade Wetland Inlet	143	512	512
Downstream of Sands Development and Golf Course	475	1,560	1,390

A further analysis of freshwater inflows (combined total of surface runoff and baseflow) entering to the Karaaf Wetlands through the Sands development and the golf course is presented in Table 4-8. It should be noted that these volumes exclude runoff from the agricultural catchments to the north of the reserve as well as the reserve footprint area. MUSIC modelling results indicate that the post development flows increase by 228%. The increase in freshwater inflows was due to two main factors:

- Increase in overall catchment area
  - An additional catchment area of 169 ha is currently entering the Karaaf Wetlands through the golf course in comparison to the pre-development scenario. These are the Quay development and other existing residential developments that drain to the foreshore wetland. Runoff from these catchments previously discharged into an ocean outfall or were pumped to Deep Creek.
- Increase in catchment impervious area due to subdivisions
  - Overall catchment impervious fraction increased from 10% to 43%.

The impact of proposed stormwater harvesting is evident in the irrigation season (Figure 4-2), but the volume reduction is insignificant (~11% reduction of post development flows). It should be noted that a conservative modelling approach was undertaken by excluding the Pintail dam. It is expected that the Pintail dam storage will be able to reduce stormwater runoff entering the Karaaf Wetlands by storing excess stormwater in winter months, but without a significant irrigation demand, it is unlikely to make a noticeable impact on runoff volume reduction.

TABLE 4-8 TOTAL FRESHWATER MONTHLY INFLOWS (SURFACE RUNOFF + BASEFLOW) AT PRE-DEVELOPMENT AND POST-DEVELOPMENT SCENARIOS

Month	Average Total Flow Pre-Development (ML/month)	Average Flow Fully Developed without mitigation (ML/month)	Average Flow Post-Development with mitigation (ML/month)
January	25	113	89
February	36	116	99
March	21	93	70
April	18	96	82
May	36	148	138
June	50	124	123
July	69	146	142
August	61	145	140
September	44	147	138
October	46	182	167
November	36	141	115
December	33	111	90
TOTAL	**475**	**1560**	**1393**

Sensitivity analysis was conducted by separating baseflow from the surface runoff (Figure 4-2 and Table 4-9). As expected, baseflow volume was decreased under post-development conditions. On average, ~19% reduction in annual baseflow volume was observed. On the other hand, model results indicated that the surface runoff would increase by 355% under post-development without mitigation scenario. These results reinforce the need for significant runoff volume reduction. The evaporation losses through proposed WSUD assets, 12 ML/y stormwater diversion at the Dunes development and the stormwater harvesting at the golf course was only able to reduce 12% of the post-development surface runoff volume.

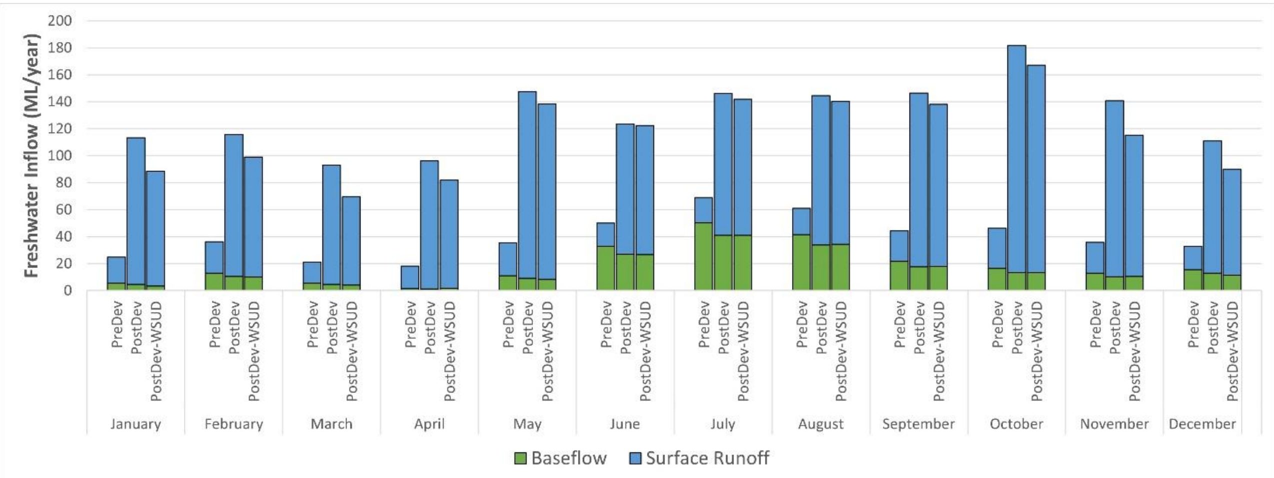


FIGURE 4-2 FRESHWATER INFLOWS UNDER PRE-DEVELOPMENT AND POST-DEVELOPMENT SCENARIOS

TABLE 4-9 AVERAGE ANNUAL SURFACE RUNOFF AND BASEFLOW VOLUMES UNDER PRE-DEVELOPMENT AND POST-DEVELOPMENT SCENARIOS

Flow Component	Average Total Flow Pre-Development (ML/year)	Average Flow Fully Developed without mitigation (ML/year)	Average Flow Fully Developed with mitigation (ML/year)
Baseflow	228 (48%)	186 (12%)	183 (13%)
Surface Runoff	248 (52%)	1,374 (88%)	1,210 (87%)
Total Inflow	475	1,560	1,393

4.6 Discussion

It is evident from MUSIC model results that significant efforts, beyond current stormwater harvesting, are needed to substantially reduce freshwater inflows entering the Karaaf Wetlands and restore a hydrologic regime closer to the pre- development situation. It is considered unlikely that the volume reduction could be achieved through open space irrigation alone. Other opportunities for non-potable reuse such as toilet flushing, hot water (applicable for rainwater harvesting only) and stormwater infiltration needs to be explored. It is worth investigating the possibility of mandating rainwater harvesting for future residential developments. The investigation has indicated total annual inflows to the Karaaf Wetlands have increased from approximately 475ML/year to 1393ML/year, an increase of approximately 193%.

The latest stormwater best management guidance (EPA Victoria, 2021) recommends harvesting at least 31% of impervious runoff and infiltrating at least 4% of impervious runoff in areas with 500 mm mean annual rainfall, to protect the downstream receiving waters from adverse impacts of urban stormwater runoff.

Another key finding of the MUSIC modelling is that the wetlands do not currently meet the best practice stormwater treatment targets, particularly for sediment and nitrogen. It is worth investigating the actual contributing catchment characteristics (area and imperviousness), and that design flows match with the original design estimates. Our analysis has indicated that the assets within this catchment have been under designed through adopting a fraction impervious of 45%. Current best practice guidelines indicate the need to adopt a much higher 70-80% fraction impervious based on land use and lot sizes within this area. As a result of this under sizing, it is likely that the existing assets have been overwhelmed with sediment leading to significant underperformance and a need to reduce maintenance intervals and or consideration of supplementary treatment and remediation.

The completed assessment has been based on available information, it is also recommended to confirm that the wetland parameters in the MUSIC model match with the actual asset on-ground (if constructed) or the latest design (if the design has progressed beyond the initial concept). Depending on the outcomes of this investigation, some asset designs may need to be revisited prior to council taking them over.

The water quality modelling undertaken as part of this assessment assumes that the wetlands have been constructed, planted and maintained as designed. The treatment mechanisms which reduce pollutants loads within these stormwater treatment assets rely on the presence of aquatic plants. The presence of appropriate aquatic vegetation is essential to the optimal performance of the wetland as plants play a key role in uptake of nutrients. In continuing to assess the condition and performance of the existing wetlands within the catchment a survey or vegetation within the wetlands is important. Melbourne Water guidelines provide recommendations regarding core plant species required to maintain long term treatment performance.

Furthermore, at least 80% of the wetland area needs to be covered by vegetation (macrophytes) in order for it to be efficient in nutrient removal. Selecting the correct plant species and keeping the water level regime within acceptable limits is the key to maintaining a healthy vegetation cover in wetlands.

5 ECOLOGICAL ASSESSMENT

5.1 Background to saltmarsh ecosystems

Coastal saltmarshes (saltmarsh) are ecologically important ecosystems located between the land and the sea. Saltmarshes have been described as intertidal soft sediment occupied by a range of plants such as low shrubs, reeds, rushes, succulent herbs and grasses, that can tolerate high soil salinity levels. These areas are usually waterlogged and frequently flooded by tidal salt water (Billows 2006, DPI 2013). Saltmarshes have low vegetation, often interspersed with clear areas of open water or bare mud in drier periods.

The periodic and predictable rise and fall of tidal movements across a saltmarsh is the most important environmental factor that influences the life and structure of these areas (Billows 2006). Periodic flooding of the saltmarsh, with periods of drying, is important in maintaining ecological processes related to plant growth and recruitment, and the maintenance or fish nurseries and food chains (Billows 2006). Invertebrates including crabs, molluscs, prawns, insects and spiders are abundant in healthy tidal saltmarshes and attract other important fauna, including fish and birds that come into the saltmarsh to feed, roost and breed (DEE 2016).

Plant vigour, survival and recruitment is influenced, if not controlled, by the magnitude, duration and frequency of tidal movement. In conjunction with other factors, tides control salinity, soil chemistry and the degree of waterlogging and aeration (Adam 1990, as cited in Billows 2006). Saltmarsh plants must have the ability to tolerate anoxic (an absence of oxygen) waterlogged soils, extreme salinity changes and inundation by tidal waters (Underwood & Chapman 1993, Morrisey 1995a, Edgar 200, as cited in Billows 2006). Plants within a saltmarsh have differing tolerances to such environmental factors and this determines the distribution of and positioning of plants across and throughout the marsh.

Within a saline environment, plants that have the ability to tolerate salinity (halophytes) have a competitive advantage over plants that are not adapted to tolerate salinity (glycophytes). Many halophytes are considered facultative halophytes, indicating that they can grow in saline and nonsaline habitats. Others are obligate halophytes which can survive only in a saline environment and complete their life cycles in soils or waters containing high salt concentrations (Silvestri and Marani 2004, Plant Life 2021).

If salinity levels remain high, particularly in soils as saltmarshes dry, glycophytes cannot establish and compete with the halophytes. However, if salinity levels reduce to low (e.g. fresh <3000 mg/L), or even moderate levels (e.g. hyposaline salinity <10,000 mg/L), glycophytes and other plants that tolerate slightly saline conditions, can invade the saltmarsh and outcompete existing halophyte vegetation (Silvestri and Marani 2004).

5.2 Causes of saltmarsh dieback

The specific cause of saltmarsh dieback can be difficult to determine. The dieback of halophytic shrubs can happen slowly and may be caused by a combination of factors that reduce the plants vitality. The following sections identifies a number of known causes of saltmarsh dieback.

5.2.1 Waterlogging

Waterlogging can occur due to several factors including:

- Sea level rise – a rise in mean sea water level will slowly cause the migration of saltmarsh plant species, unless sediment accumulation can elevate the marsh surface at the same rate as the sea level. If the lower saltmarsh areas remain permanently inundated, the saltmarsh vegetation will die off.
- Creek mouth closures – the closing of creek mouths can elevate the water level within the saltmarsh, leaving the soil waterlogged until the mouth is breached or the water evaporates.

- Increased stormwater discharge – the delivery of increased runoff from a catchment due to urban development and subsequent increase in impervious surfaces, can cause prolonged inundation or at least water logging.

Waterlogging can cause saltmarsh vegetation to 'drown', as plants need oxygen at their roots to allow the plant to breath and respire aerobically. Waterlogging causes the plant to respire anaerobically, which in turn depletes the plants energy reserves causing dieback and ultimately death of the plant unless the water recedes, at least periodically.

Another product of waterlogging is the increase of sulphide in soil caused by anaerobic and aerobic bacteria. Increased sulphide has been shown to substantially reduce nitrification in sediments (Joye and Hollibaugh 1995), thereby inhibiting plant nutrient availability.

5.2.2 Water Freshening

Freshening of water within a saltmarsh can occur in the following ways:

- Tidal disconnection – Creek mouth closures and obstructions such as roads, culverts and regulators can hinder or restrict tidal flow into a saltmarsh.
- Altered hydrology / increase in stormwater discharge to the saltmarsh – increased freshwater discharge

Obligate halophytes, which can survive only in a saline environment and complete their life cycles in soils or waters containing high salt concentrations, will be threatened by constant freshwater inputs. Water freshening also allows glycophytes and other plants that tolerate slightly saline conditions to invade the saltmarsh and outcompete existing halophyte vegetation. Plants such as Common Reed (*Phragmites australis*) can invade and spread, forming monotypic stands that alter the ecology and function of a saltmarsh (Laegdsgaard et al., as cited in DSEWPC 2013).

5.3 Desktop review of existing reports in the context of freshwater discharge to Karaaf Wetlands

The following review of reports has been undertaken with specific reference to freshwater discharge through The Sands (also referred to as Torquay Sands) constructed wetland system to the western end of the Karaaf Wetlands.

5.3.1 Flora and Fauna Assessment and Environmental Management Plan for Torquay Sands Residential Lakes and Golf Course Development, Torquay (Ecology Australia 2001)

This report states the following key points relating to the freshwater discharge and protection of the Karaaf Wetlands system:

- *"A 173 Agreement specifically addresses a range of issues relating to the Torquay Sands development and its implementation and operation which are intended to protect the saltmarsh from direct and indirect impacts."*
- *"There have been massive alterations to the pre-European hydrological regime of the Saltmarsh Complexes which have set in train serious degradation processes. If these are not reversed or appropriately addressed, they will cause long-term destruction of the flora and fauna values of national significance with or without development (residential or otherwise) of the hinterland. These changes are:*
  - *Construction of Point Impossible Road on the west side of Thompson Creek which has, except for a small culvert with a pipe, closed off the tidal Mullet Creek which allows the flooding of the Saltmarsh Complex* (note: this culvert was replaced with larger capacity box culverts in June 2004).

  - *Clearing of most native vegetation in the catchment to the west of the saltmarsh, resulting in greatly increased runoff into the saltmarsh. Craigie and Condina (1999) estimated that under existing conditions there is an average annual 60ML input of freshwater into the saltmarsh from the catchment draining through the development site."*

- *"Serious degradation of the saltmarsh is predictable on theoretical grounds (i.e. maintenance of the dominant, obligate, slat-loving plants – halophytes) and this degradation is probably now evident in the vegetation, with widespread decline and death of the most important saltmarsh dominant, Shrubby Glasswort (Sclerostegia arbuscula)* (now *Tecticornia arbuscula*). *This may be related to reduced salinity, as well as invasion of the saltmarsh by weeds, especially annual grasses."*
- *"Reinstating the tidal regime will assist in mitigating the impacts of freshwater input to the saltmarsh from the cleared catchment. It will also be important to ensure that surface runoff regimes associated with proposed urban development in the catchment (including Torquay Sands) are maintained as close as possible to existing rural runoff levels and, wherever practical, that opportunities to reduce runoff are grasped. In regard to the Torquay Sands development, Craigie and Condina (1999) estimated that a variation of +/-15-20% from "natural" conditions would be a practical expectation in respect to post-development runoff volumes."*

5.3.2 Ecological Responses to Improved Tidal Flows into the Karaaf Wetlands, Breamlea, Victoria (Craig A. Billows 2006)

The focus of this study was to identify selected ecological responses of the Karaaf Wetlands to the de-restriction of tidal flows via the installation of an improved culvert system. The primary aim was to identify changes to saltmarsh vegetation growth and patterns by comparing areas of saltmarsh before and after the culvert upgrade (Billows 2006).

The report makes the following key points relating to the freshwater discharge affecting salinity levels, and eutrophication within the Karaaf Wetlands system:

- *"Salinity varied widely throughout the wetlands, with 3.41 ppt recorded at the golf course discharge point at K4 on 26/8/2005 and 48.08 ppt recorded from the old ford (K3) on 15/2/2006, indicating hypersaline conditions. Consistently low salinity levels below 5 ppt were observed at K4 indicating predominantly freshwater conditions. Salinity within the main channel of the Thompson Creek estuary varied from 8.9 ppt to 44.74 ppt, indicating a potential for hypersaline conditions."*

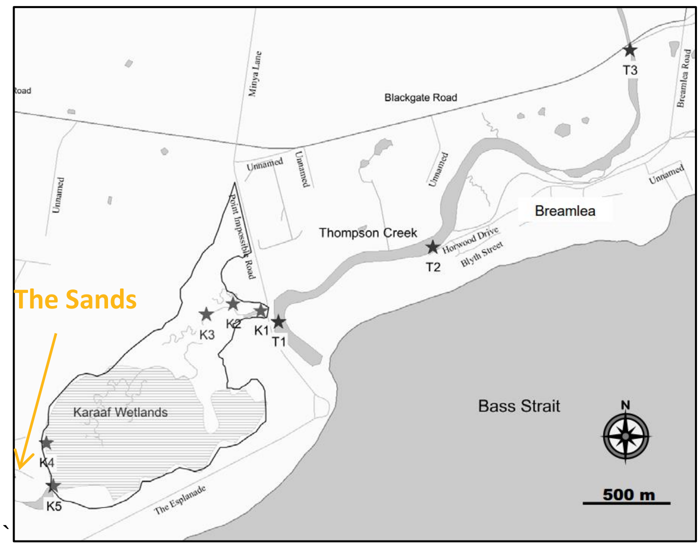


FIGURE 5-1 WATER MONITORING AND SAMPLING SITES IN THOMPSON CREEK AND KARAAF WETLANDS (FROM BILLOWS 2006)

- *"Salinity levels in Mullet Creek (K1, K2, K3) were similar to those in the main channel. This may be a result of the improved tidal flushing created by the culvert upgrade. Increased tidal exchange between the two channels would improve the mixing of salts, nutrients, and contaminants, as long as the mouth of the estuary remained open to the sea to maintain circulation."*
- *"Low salinities at K4 and K5 can be explained by the degree of confinement of local catchment-derived waters discharged from the adjoining golf course and residential development. K4 was sampled from a small, discrete pool directly below a pipe outlet on the fringe of the saltmarsh, so there was negligible influence from saltmarsh waters or sediments. The K5 sampling point was situated where stormwater enters a saline wetland before passing into the upper saltmarsh within the Karaaf Wetlands. Depending on the volume of stormwater discharged and the effects of local runoff, evaporation and tidal flooding on the amount of overlying water in the immediate area, salinity at K5 has the capacity to fluctuate from fresh to hypersaline."*
- *"The frequency of high macronutrient (N and P) levels, wide fluctuations of DO and the frequent occurrence of nuisance macroalgal mats (e.g. Lyngbya sp. and Enteromorpha sp.) provides evidence to suggest that the Thompson Creek estuary and the Karaaf Wetlands are potentially in a state of eutrophication for extended periods throughout the year. Historical Waterwatch records indicate a high frequency of elevated phosphorus levels within upper and middle reaches of Thompson Creek (Billows 1997, as cited in Billows 2006) and elevated levels of both total N and total P recorded in 2002 (Mondon 2003, as cited in Billows 2006), suggest a sustained input of phosphorus from further up the catchment is a significant contributor to nutrient loading in the estuarine reaches."*
- *"High levels of phosphorus and nitrogen in these waters may be a symptom of internal loading as nutrients are released from estuarine and saltmarsh sediments into overlying waters. Many estuaries are known to act as nutrient sinks, due to their depositional characteristics (Elliot and de Jonge 2002, as cited in Billows 2006), as nutrient-laden, suspended organic and inorganic particles settle out to form the muddy sediments. Nutrient fluxes between sediments and the overlying water column can occur under favourable conditions. Release of phosphates from sediments into the water column may be a regular occurrence as oxygen levels in overlying waters continually fluctuate between oxic and hypoxic conditions."*

Billows warned of the potential threat of eutrophication of the Karaaf wetland and Thompson Creek form urban and rural runoff. Algal blooms are now being seen regularly within the Karaaf wetland system.

5.3.3 Expert advice regarding the Armstrong Creek residential development near Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar wetland, Victoria (Lloyd 2016)

The main objectives of this report were to assess the extent and distribution of impacts from the developments at Armstrong Creek East and Horseshoe Bend Precincts to the ecological character of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site. Although this area is outside and adjacent to the Breamlea Wetland system, this report is of relevance as it specifically discusses how the ecological character of the Ramsar Site may be affected by the likely changes in flow and water quality. Key relevant issues addressed in this report include the following:

- *"The State Environment Protection Policy (SEPP, EPA 1970) requires stormwater quality treatment from all urban developments be undertaken. The SEPP is binding on all government agencies, private individuals and businesses conducting activities on private and public land and the City of Geelong is committed to this policy (City of Geelong 2012)."*
- *"Hydrology and Sedimentation – With the changed hydrology and increased sediment run off from Armstrong Creek, it is likely that Hospital Swamps will be subjected to much higher rates of sedimentation.*

This will change the nature of the wetland basins, affect the vegetation and alter water quality, affecting aquatic plants, fish and macro-invertebrates."

- *"Vegetation biodiversity – Vegetation distribution and diversity is dependent upon the hydrology of the system. More freshwater species are found when the water is fresher in early spring, and more salt tolerant species as the system dries out. Low water levels in November and December are required for these* (halophytic) *species to flower and set seed before excessive temperatures, high salinities, or dry conditions in January and February inhibit further growth. The suite of species present at Hospital Swamps indicates that a late spring drawdown of the wetland creates this vegetation structure (Lloyd et al. 2012)."*
- *"Likely Changes to Hydrology – the late spring drawdown creates this vegetation structure therefore maintenance of this water management regime will, importantly, prevent changes and potential threats to the ecological character into the future. The changes to water regime from stormwater flows from the Armstrong Creek developments are likely to produce inflows over summer and autumn when low or no flows are required in this period."* A 45 mm rain event over the Warralily precinct in January 2016 flowed into the swamp peaking at the Baenschs Lane wetland gauge at 0.91 m about 48-72 hours later. "*The water levels only slowly dropped to about a half a metre depth after two weeks, but the remaining water is unlikely to evaporate quickly, potentially affecting the wetland vegetation. The water quality (e.g. silt load) worsened as time went on, presumably as the water from the construction areas upstream of the development areas arrived towards the end of the event. It is expected that these run-off events will be frequent during each summer/autumn period disrupting the current water regime, which is seen to be vital to maintaining the ecological character of the Site."*
- *"Likely Changes to Water Quality – The stormwater run-off will not only change the amount and patterns of run-off to the swamps, but also alter its water quality. Stormwater is known to have high loads of organic matter sediments, toxicants (such as oils, detergents, herbicides, and pesticides) and heavy metals, as well as gross pollutants such as litter and debris, (CSIRO 1999, Australian Government 2000). The State Environment Protection Policy (SEPP; EPA 1970) requires stormwater quality treatment from all urban developments be undertaken. The SEPP is binding on all government agencies, private individuals and businesses conducting activities on private and public land and the City of Geelong is committed to this policy (City of Geelong 2012). They state that if run-off water from the land surface is causing, or is likely to cause, non-compliance, then control measures are required. The intention of the policies is to eliminate or treat the sources of contaminated run-off from the changes to land use."*
- *"Likely Changes to Ecosystems, Ecological Processes and Ecological Character"*
  - *"Ecosystem Processes - The ecosystem processes and, ultimately, ecological character, of the Hospital Swamps will be altered by increases of inflows over summer and autumn, as the system relies upon the normally low flows, or no flows, in this period to create saline conditions in the wetland bed. These conditions exclude emergent macrophytes and maintains a diverse community of plants. Further, summer inflows will suppress groundwater discharge to the wetland and dilute surface water salinities. This is likely to lead an increase in the extent of reeds and a loss of a variety of salt tolerant herbs, sedges and shrubs. Further, sediment and nutrient run-off from urban stormwater is also likely to change the nutrient status of the Hospital Swamps, and therefore, the vegetation community and the rest of the ecosystem through trophic cascades"* (i.e. powerful indirect interactions that can control entire ecosystems).
  - *"Waterbirds - Waterbirds are also dependent upon the wetland hydrology and, in particular, the depth of inundation and the wetting and drying regime. If summer stormwater inflows prevent the annual drying and salinisation of the swamps, then marked changes, and probably simplification, of the vegetation communities across the wetlands is likely, with significant reductions in waterbird community diversity."*
  - *"Fish and aquatic fauna - Rising water levels in the Hospital Swamps in spring are critical to create new habitat and boost invertebrate populations for food, triggering fish spawning and then allowing*

sustained food resources to enhance recruitment of juveniles. Deeper water in late spring allows creation of open water habitat required for some species and provides time for growth and maturation. Recession of water level to expose the entire wetland bed will restart wetland processes, allow eggbanks to be produced and laid, and control carp populations. The increase in stormwater inflow during the summer will not allow the wetland to dry out, which will prevent the system resetting and prevent the spring response which is critical to the fish abundance and diversity. The increased summer flows will also freshen the wetland and this will reduce the habitat for the estuarine species, reducing the biodiversity of fish"

- *"Potential Mitigation – The mitigation and treatment concept involves the diversion of Armstrong Creek to large constructed wetlands situated on Cold Winds and Sparrovale Farms. These wetlands would store and treat water quality before discharge either directly into the Barwon River or the Hospital Swamps in a manner to mimic natural/current flows."*

The likely changes in hydrology, water quality and ecosystems resulting from the Armstrong Creek residential development identified by Lloyd are similar to what is already happening or is predicted for the Karaaf. Restorative actions need to be implemented to reduce existing impacts, and further actions will be required to ensure ongoing developments do not exacerbate the impacts

5.3.4 Opportunities and Constraints Assessment: Torquay North East Future Residential Investigation Area (EHP 2020)

This report included an ecological assessment to identify and assess the potential ecological values and constraints associated with the development of the Torquay North East Future Residential Investigation Area, with consideration of the surrounding ecological context. Based on this assessment, recommendations were provided regarding the suitability of the land for development, and requirements to mitigate impacts on ecological values including stormwater management were identified.

This report states the following key points relating to the stormwater management within Torquay North East Future Residential Investigation Area in order to protect the Karaaf/Breamlea Wetland system:

- *"Whilst the current stormwater management techniques were considered adequate to mitigate impacts from The Sands, future development upstream will require additional retarding storage to be provided as the Sands Development has no control over discharges emanating from lands external to its boundaries (Neil M. Craig Pty Ltd 2001)."*
- *"The Torquay North Stormwater Masterplan (Flood Flow Updates) (2020) observed that drainage arrangements resulting from the Torquay North development has led to an increase in the peak flow entering The Sands site. As such, whilst there were adequate stormwater management techniques to capture and reuse stormwater generated on-site, these measures were unable to account for the increase in stormwater flowing into The Sands from surrounding developments. With nowhere else to go, this additional influx of stormwater ultimately discharges into the adjacent Breamlea Flora and Fauna Reserve."*
- *"It is understood that a retarding basin has been established in the south-east corner of the Torquay North East Future Residential Investigation Area in an attempt to capture the additional overflow from the Sands. However, an influx of freshwater was still observed to be flowing into the Reserve from the adjacent Sands development. This increase in run-off flow to the Breamlea Flora and Fauna Reserve has ultimately changed the ecological character of the area with large expanses of freshwater now covering previously exposed areas of Beaded Glasswort and the encroachment of freshwater plant species is also apparent."*
- *Field Assessment – "noted an influx of freshwater into the Karaaf Wetlands, emanating from the adjacent Sands development. The water was observed to be flowing into the reserve area from two points; a pipeline and a floodway. Large expanses of freshwater covered previously exposed areas of Beaded*

Glasswort and freshwater species (e.g. Senecio spp.) were already established around these areas (Plate 9). In areas where freshwater had previously retreated, saltmarsh groundcover species were also noted to be experiencing dieback, with very little regeneration observed. This reduction in the quality and extent of saltmarsh has severe implications for a number of fauna species which rely on the saltmarsh for foraging and breeding habitat."

- *Known and Likely Impacts – "Of particular concern, is the off-site ecological impacts to the Breamlea Flora and Fauna Reserve as a result of stormwater run-off from any future urban development within the Torquay North East Future Residential Investigation Area. The existing urban development has already altered the natural hydrological cycle of the area. As urban structures such as rooftops, roads, driveways and buildings have been built, the amount of area impervious to rainfall has increased. This, in turn, increased the peak run-off flow rate during rainfall events and increased the total run-off volume (Venant Solutions 2015, 2018). As a result, due to the topography of the area, any stormwater run-off ultimately flows into the Breamlea Flora and Fauna Reserve. The increase in run-off flow to the Breamlea Flora and Fauna Reserve has already changed the ecological character of the area in terms of an influx of freshwater into the saltwater wetland and the encroachment of freshwater plant species as a result of the existing developments within the immediate area. A further increase in stormwater run-off from any future residential development will only serve to exacerbate these negative impacts, which include but are not limited to the loss of native vegetation and critical habitat for migratory bird species."*
- *Stormwater Management Techniques – "The construction of retarding basins and wetland systems would assist to capture water flows from local stormwater drainage networks and overland flows from roads. Such methods would allow the captured surface water to be reused or repurposed to irrigate any park lands or recreation reserves within a future development. However, as seen with the Sands development, these stormwater management techniques may be considered adequate to mitigate impacts from the development itself, however, cannot account for discharges emanating from lands external to its boundaries. As such, as future developments are created, it is likely that any future stormwater catchments within the Torquay North East Investigation Area will be insufficient to capture all surrounding runoff and stormwater will still be discharged into the Breamlea Flora and Fauna Reserve. An alternative solution is the construction of a stormwater bypass channel to connect the proposed future development to the ocean, in order to allow stormwaters to bypass the Breamlea Flora and Fauna Reserve. However, the construction of a channel into the ocean may still have the potential for ecological impacts on the Coastal Dune areas. Where feasible, alternative diversion routes should be considered, such as to the adjoining Flower Farm or adjacent farmland, where there is potential reuse for the water to increase farm productivity."*
- *Conclusions - The future development of the Torquay North East Investigation Area is highly likely to exacerbate the ecological impacts to the Breamlea Flora and Fauna Reserve that have been observed to date if appropriate prevention measures are not put in place. A hydrological assessment is required before any future development of the Investigation Area can be progressed. This assessment will confirm if no direct/indirect storm water runoff into the Breamlea Flora and Fauna Reserve can be achieved and draw conclusions about the appropriate stormwater prevention measure (if any) to be implemented.*

5.3.5 Report on the environmental impact of offsite water entering The Sands system (GHD 2017)

This report reviewed the change in water quality (turbidity and nutrients, 2010-2017), and investigated the condition of vegetation within the five Amenity Lakes within The Sands. Analysis concluded that the increased volume of stormwater generated from upstream developments was compromising the health of these water bodies and the Karaaf Wetlands. This was evidenced by the following observations:

- Turbidity levels between 2010 and 2014 averaged 13 NTU, while the average increased to 153 NTU between 2014 and 2017. The turbidity increases over time correspond with urban development occurring in the upstream catchment where soil surfaces are stripped and exposed to erosion. Increased turbidity threatens wetland vegetation, particularly fully aquatic submerged vegetation, by reducing light penetration and plant photosynthesis.

- Nutrient levels were elevated in the Amenity and Storage Lakes above acceptable water quality criteria (ANZECC 2000 trigger values, and SEPP objectives). Elevated nutrient levels can favour invasive exotic vegetation and cause eutrophication and algal blooms.
- Field observations indicated that turbidity decreased towards the east / downstream through the Amenity Lakes, suggesting that the poor water quality was generated upstream of The Sands, and that the system of five lakes was helping to improve water quality. Onsite water bodies that are isolated from the Amenity Lake system showed signs of good health.
- Vegetation is being affected adversely by reduced water quality and increases in water volume, evidenced by patches of dead vegetation where water quality was reduced.
- The impact of increased freshwater volumes, nutrient and turbidity on the Karaaf Wetlands was also evident with the observed invasion of exotic salt-intolerant species altering the floristic composition.
- To protect the Amenity and Storage Lakes, it is recommended that water be controlled to alleviate pulses of contaminated stormwater prior to entering The Sands system. Water quality issues should be rectified at the source well before entering The Sands. “The Sands should not be accountable for poor water quality generated offsite”.

5.4 Index of Estuary Condition (IEC)

The Index of Estuary Condition (IEC) was developed by the Victorian Government to help improve estuary management (Sinclair et al. 2020). The Index of Estuary Condition (IEC) provides a consistent condition assessment method that can be applied state-wide (DELWP 2017). There are five themes that make up the Index: fauna, flora, water quality, physical form and hydrology. Each of these sub-indices contains multiple measures and standard methods have been developed to assess these. The IEC assessment program aims to:

- report on the condition of estuaries across Victoria
- assist the prioritisation of management investment among estuaries
- provide a baseline for assessing long-term and large-magnitude changes in resource condition (DELWP 2017).

The results of a state-wide assessment of Victoria’s estuaries using the IEC were released in 2021, with the results published in the document “Assessment of Victoria’s estuaries using the Index of Estuary Condition: Results 2021 (DELWP 2021). The condition of the Thompson Creek estuary, which includes the Breamlea / Karaaf Wetlands system, was reported within this state-wide assessment and some key results are summarised as follows:

- Overall condition is classed as either Excellent, Good, Moderate, Poor or Very Poor. The Thompson Creek estuary was assessed as being in **Moderate condition** (scoring 31/50).
- State-wide the IEC assessed 101 estuaries. 13% of estuaries were assessed as being in Excellent condition, 25% Good, 32% Moderate, 25% Poor and 5% Very Poor.
- The IEC assessed 17 estuaries in the Corangamite Region, including the Thompson Creek. 29% of estuaries were in Good condition, 59% Moderate and 12% were in Poor condition (no estuaries were assessed as Excellent or Very Poor).
- There are 5 sub-indices that make up the total index. The results of each sub-index for the Thompson Creek are as follows:
  - Physical Form – 7/10 moderately modified

- Hydrology – 4/10 considerably modified
- Water Quality – 8/10 good
- Flora – 8/10 good
- Fish – 7/10 good

- It should be noted that the Hydrology sub-index score (4/10) has heavily impacted the overall index score for the Thompson Creek. This relatively poor score has been directly impacted by the input of fresh stormwater inputs from North Torquay.
- The Thompson Creek estuary was assessed as having the same total IEC score (31/50) and condition class (Moderate) as the adjacent Barwon River estuary.

5.4.1 State-wide assessment of fringing vegetation for the index of estuary condition (Sinclair et al. 2020)

The state-wide assessment and mapping of estuarine fringing vegetation was undertaken to derive condition indicator scores that are combined to calculate the Flora sub-index score of the IEC. The three indicators are:

- Percent of fringe covered by built structures
- Nativeness of the fringing vegetation
- Structural complexity of the fringing vegetation.

In order to calculate condition scores for each estuary, the full extent of fringing vegetation was mapped by Ecological Vegetation Class (EVC), and further divided into zones of consistent condition state. Within each EVC condition zone/polygon, the cover of defined native plant lifeforms was assessed, and the cover of weeds was estimated.

The fringing vegetation mapping shapefile provided by DELWP has been used to generate a map of EVCs within the Karaaf Wetlands (Figure 5-2).

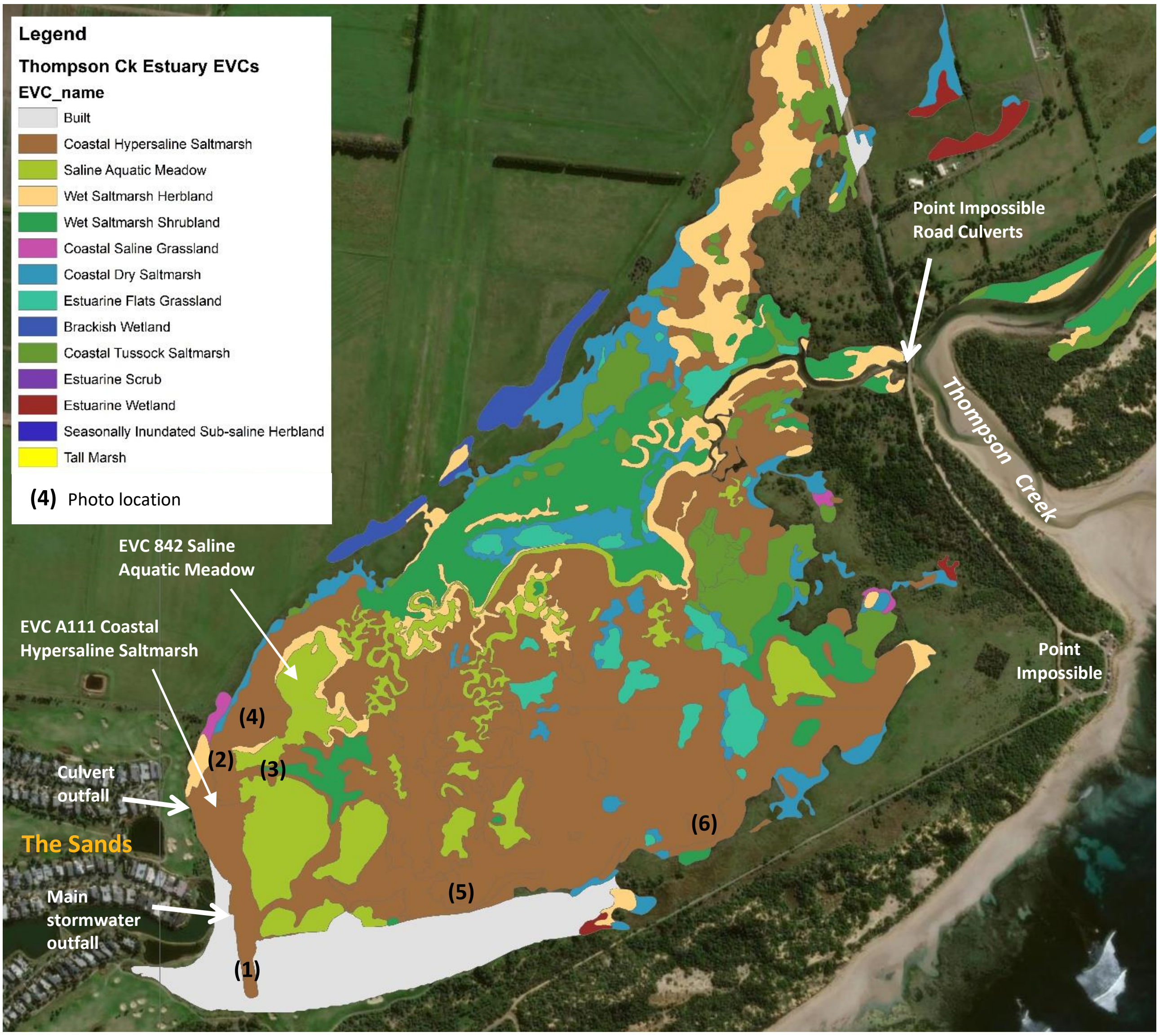


FIGURE 5-2 KARAAF WETLANDSEVC MAPPING

Figure 5-2 indicates that the vegetation adjacent to the main stormwater outfall is EVC A111 Coastal Hypersaline Saltmarsh. This EVC is the dominant EVC within the Karaaf Wetlands. The characteristics and salinity tolerances/requirements of this EVC is discussed in Section 5.5. EVC 842 Saline Aquatic Meadow is another dominant EVC in the vicinity of the outlets. This Saline Aquatic Meadow occurs in the areas of open water (when the wetland is inundated) that are too deep/waterlogged to accommodate the Coastal Hypersaline Saltmarsh.

It should be noted that there is no EVC 821 Tall Marsh (nor EVC 952 Estuarine Reedbed) mapped within the Karaaf Wetlands at the time of survey, 2017. However, a patch of Reeds (Common Reed and Cumbungi) was observed at the western end of the wetland during field assessment in September 2021 (around photo locations (2) and (3) in Figure 5-2). The recent appearance of Tall Marsh vegetation is discussed further in Section 5.6.2.

5.5 A guide to water regime, salinity ranges and bioregional conservation status of Victorian Ecological Vegetation Classes (Frood and Papas 2016)

This guide documents the water regime and salinity ranges for wetland Ecological Vegetation Classes (EVCs) that are presently described in Victoria (Frood and Papas 2016). Water regime information includes the frequency of inundation, maximum range of duration of waterlogging and inundation, and the maximum depth usually experienced by the EVC.

This document was referenced to help understand the likely water regime requirements across the Karaaf Wetlands. The Karaaf Wetlands EVC mapping, as shown in Figure 5-2, indicates that EVC A111 Coastal Hypersaline Saltmarsh is the dominant vegetation class across the wetland and is located adjacent to the main stormwater input location. It is therefore most relevant to understand this EVCs water regime requirements that help to maintain plant vigour and survival.

TABLE 5-1 EVC A111 COASTAL HYPERSALINE SALTMARSH – WATER REGIME, SALINITY RANGES AND DETAILS (FROM FROOD AND PAPAS 2016)

EVC description		
Defining characteristics: Low shrubland dominated by succulent chenopods (or rarely Salt Lawrencia), occurring in highly hypersaline coastal saltmarsh habitat above the zone of regular tides. Extremely localised in Western Port Phillip Bay and on the Bellarine Peninsula, with a community dominated by *Tecticornia pergranulata* also occurring at Lake Reeve in Gippsland. **Indicator species:** Dominated by *Tecticornia pergranulata*, *T. halocnemoides*, or very locally *Lawrencia squamata*. Can be very species poor, with most consistent associated species including *Sarcocornia quinqueflora* and to a lesser extent *Frankenia pauciflora*, and less frequently *Disphyma crassifolium* subsp. *clavellatum*, *Samolus repens* and *Suaeda australis*. A range of indigenous annuals can be present in relatively intact sites (e.g. on low mounds associated with *T. halocnemoides*).		
Ecological overview		
Hypersaline conditions occur when habitat is dry or nearly so rather than during inundation events. This vegetation can also be influenced by groundwater discharge. See also notes under Coastal Saltmarsh Aggregate (EVC 9).		
Phase context of EVC representation		
Continuous		
Frequency of inundation		
Category	**Description**	**EVC preference**
King tide	Several times per year	Common
Fringing	Inundation periodic but brief	Common
Maximum event duration		
Duration of waterlogging	**Duration of inundation**	**EVC preference**
Variable (fringing wetland)	Variable, usually brief	Common
1–6 months	<1 month	Common
Water depth		
Category	**Range (cm)**	**EVC preference**
Very shallow	<30	Common
Salinity		
Category	**Range (mg/L)**	**EVC preference**
Hypersaline	>50,000–350,000	Common
Management considerations		
Environmental watering is not relevant to this EVC. Removing barriers to natural tidal inputs may be relevant in some wetlands that support this EVC. This EVC is potentially vulnerable to freshwater inputs and run-off from adjacent land uses.		

The pertinent information to be drawn from Table 5-1 includes:

- This EVC is a low shrubland dominated by succulent chenopods, most often dominated by *Tecticornia* spp.
- The hypersaline conditions occur when this habitat is dry or nearly dry. As previously referenced (Lloyd 2016), these saltmarsh systems rely upon normal low flows, or no flows, to create saline conditions in the wetland bed, which excludes emergent macrophytes and maintains the diverse community of saltmarsh plants.
- Tidally influenced inundation of fringing vegetation is expected regularly but only for brief periods. Deeper inundation during king tides can be expected several times a year.

- The water depth in this EVC should be less than 30 cm.
- This EVC is potentially vulnerable to freshwater inputs and run-off from adjacent land.

5.6 Field inspection

Field inspections of constructed and natural wetlands was undertaken on 17th June and again on the 13th September 2021. The June inspection provided an opportunity to view all wetlands in the system, from the constructed wetlands in the new estates upstream of The Sands, to the lakes and wetlands within The Sands, to the Karaaf Wetlands, and finally through the Breamlea Flora and Fauna Reserve to Breamlea village.

The subsequent visit in September concentrated on the western end of the Karaaf Wetlands where the stormwater discharges to the saltmarsh.

5.6.1 Constructed Wetlands

The constructed wetlands within Torquay that direct stormwater to the Karaaf Wetlands (as shown in Figure Figure 1--3) were inspected on the 17th June 2021. Notes regarding the condition of vegetation and habitats is provided in Section 3. The common issues observed within the established constructed wetlands upstream of The Sands include:

- Sediment ponds are not being cleaned out frequently enough to prevent significant sediment build-up and resulting reduction in performance.
- Sediment ponds are not capturing sediment but passing it into the downstream amenity and treatment sections of the individual wetland.
- As wetlands fill with sediment, areas that were designed to be deep open water are shallowing, and plants are colonising large proportions of wetlands.
- Cumbungi (*Typha* spp.) is invading the deeper areas of wetlands and has colonised a large proportion of the Esplanade Wetland.
- This reduces the habitat opportunity, amenity and overall function of the wetland. Wetlands without open water limit habitat opportunities for a number of fauna species.
- In higher flow rain events, sediment and associated nutrient will be carried out of the wetland entirely and passed to the downstream wetlands. Turbid water emanating from exposed soils in the catchment is not having the time (nor opportunity if sediment ponds are full) to settle out in sediment ponds. This is leading to further sedimentation of downstream wetlands.
- All constructed wetlands (i.e. Quay, Esplanade, Dunes, Stretton and Zeally) discharge into The Sands Amenity Lakes which in turn discharge into the Karaaf Wetlands. All wetlands must be maintained and function, at least as designed, to limit additional impacts to downstream constructed and natural wetlands.
- Sedimentation will also be reducing retardation of flows and resident time, thereby increasing the volume and likely nutrient content of stormwater leaving the wetland.

5.6.2 Karaaf Wetlands

The Karaaf Wetlands was visited on two occasions, June and September 2021. The wetland was viewed from a number of locations, however the main area of interest was at the western end where stormwater is discharged into the wetland from the main spillway outlet (end of Amenity Lake 5) and from a culvert approximately 250 m to the north (see locations shown in Figure 5-2).

Dieback within the Karaaf Wetlands has been reported over the past two decades (e.g. within Ecology Australia 2001, Billows 2006, GHD 2017, EHP 2020) however the extent and severity was not recorded to allow empirical comparisons with current day. It has been repeatedly reported that saltmash dieback and freshwater plant invasion has occurred at the western end of the wetland. If dieback were to be anticipated anywhere within the wetland it would be at this western end, where freshwater enters from historic and current drainage lines, and being the area furthest from the saltwater entry point off Thompson Creek. Salinity levels would be expected to be lower at this far western end where saltwater intrusion and mixing would occur least.

Dieback of the dominant shrubs, Shrubby Glasswort (*Tecticornia arbuscula*), was apparent during field inspections. The reported displacement of saltmarsh vegetation along the western fringe of the wetland was evident, with freshwater species dominating the margin adjacent to The Sands (see Photo 1 in Figure 5-3). Photo 2 was taken approximately 75 m in from the north-eastern wetland margin, looking centrally showing severe shrub dieback and the emergence of Cumbungi (*Typha* sp.) and Common Reed (*Phragmites australis*).

FIGURE 5-3 PHOTO 1 – FRESHWATER SPECIES, PHOTO 2 – SHRUB DIEBACK AND TALL MARSH EMERGING

The lack of saltmarsh shrubs along the western margins of the wetland suggests the combination of previous disturbance, and freshwater inputs are having a tangible impact on the vegetation structure and community.

The incursion of plants that tolerate or prefer freshwater but can tolerate up to hyposaline conditions (i.e. salinity <10,000 mg/L) is an indication that these soils are not drying out and becoming hyposaline for sufficient time to kill off these species (see Figure 5-3). Under the current hydrological regime, control of these invasive plants may require an extended dry spell or drought. The Cumbungi and Common Reed have only entered the Karaaf Wetlands in the past two years (Glenda Shomaly pers. comm.), despite both species being in the vicinity (e.g. The Sands and Dunes wetlands) to potentially deliver airborne seed.

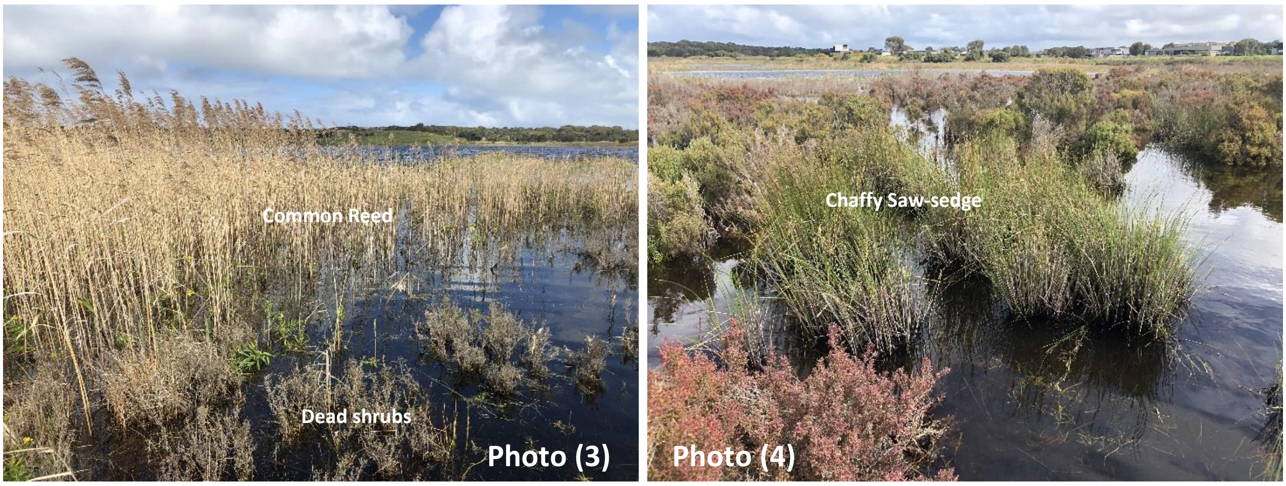


FIGURE 5-4 PHOTO 3 – PHRAGMITES PATCH ESTABLISHED, PHOTO 4 – SHRUB DIEBACK AND SEDGE INVASION

Shrubby Glasswort dieback was observed throughout the Karaaf Wetlands, although the severity and displacement/competition were much higher at the western end. The southern edge of the wetland was viewed at 450 m and 900 m away from the stormwater outlets (Figure 5-5).

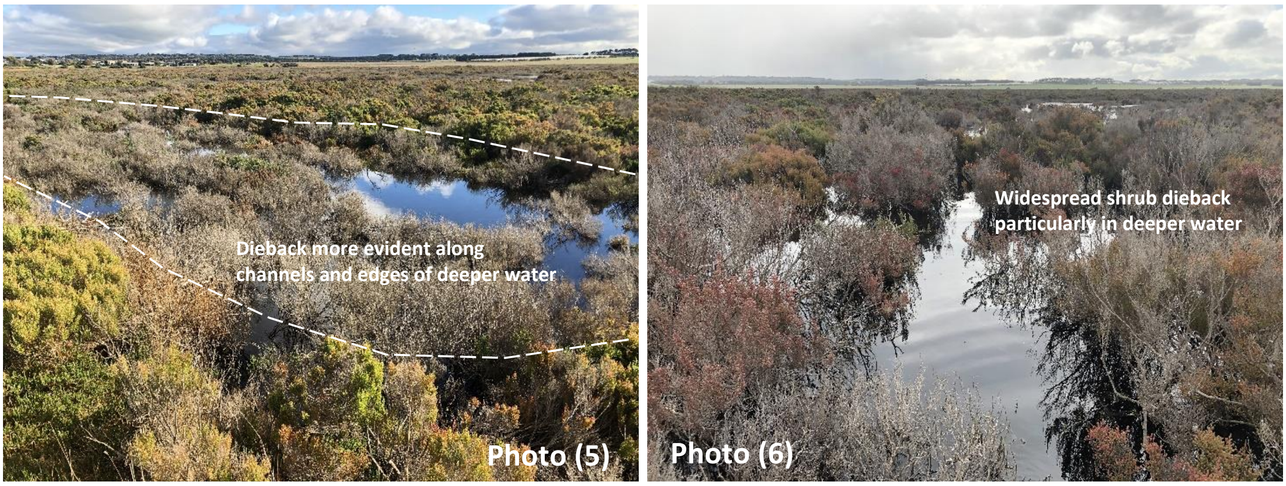


FIGURE 5-5 SOUTHERN EDGE OF KARAAF WETLAND, PHOTO 5 – 450 M FROM OUTLET, PHOTO 6 – 900 M FROM STROMWATER OUTLET

Although dieback was present, it was clearly more sever along the edges of channels and open water areas, presumably where plants are growing from slightly lower elevations. Due to these observations, it is speculated that the dieback is occurring more where the soils dry last and are more likely to remain waterlogged. As discussed in Section 5.2.1, waterlogging forces the plant to respire anaerobically, depleting the plants energy stores, leading to dieback or death. The lack of drying and development of hypersaline soil conditions can also interrupt the recruitment processes of some saltmarsh species.

While there is a lack of flora cover/abundance and condition assessments from the past 20 years, every report since (e.g. Ecology Australia 2001, Billows 2006, GHD 2017, EHP 2020) has indicated the presence of dieback and freshwater species invasion at the western end of the Karaaf Wetlands. All these reports identify the threat that increased freshwater inputs pose to the saltmarsh and have a common theme of the urgent requirement to mitigate the impacts of freshwater input. It is apparent that the current level of stormwater discharge to the Karaaf Wetlands is changing the character of the saltmarsh, particularly at the western end. The emergence of reeds and rushes (e.g. Common Reed and Cumbungi) in the past two years is evidence of altered hydrology and salinity levels, and these species have the potential to displace this temperate coastal saltmarsh (an EPBC listed ecological community). If a more natural wetting and drying regime is not restored, the coastal saltmarsh will be displaced and the unique habitats that support a number of threatened species (e.g. the Critically Endangered, Orange-bellied Parrot) will be lost.

It is likely that this decline in condition and change in character will occur under the current levels of stormwater input. To allow the existing saltmarsh to recover, and maintain vigour, a reduction in existing stormwater volumes entering the Karaaf Wetlands is required.

6 DISCUSSION AND RECOMMENDATIONS

6.1 Overview

The following discussion highlights the analysis and findings of this investigation. Six (6) key recommendations have been put forward as a result, as detailed in Section 6.5.

While the analysis was completed based on the proposed full development to the catchment, a significant area is yet to be developed. As development continues within the catchment there is still time for solutions to be implemented to manage the stormwater issues created by urbanisation and prevent further impacts to the Karaaf Wetlands and Thompson Creek Estuary.

The recommendations listed below relate to key issues identified, and seek to address inadequacies in current surface water management within the catchment, with the intent of ensuring the ongoing protection and preservation of the downstream natural environment. The recommendations relate to the following key areas:

- Water volume management (Annual Water Cycle)
- Sediment and water quality management
- Water quality asset performance, maintenance and remediation
- Ongoing catchment monitoring
- Formal recognition and protection of Karaaf Wetlands and Thompson Creek Estuary

6.2 Volume Management

Risks associated with urban runoff were identified through the planning processes of both the Sands Development and Torquay North Precinct. These risks formed the basis of environmental management and surface water management plans for this area.

Whilst the Sands site did undertake a water balance as part of a surface water management assessment at the time, the focus of the assessment was on management of volume to enable irrigation of the site as part of an integrated water strategy. Although limited in its analysis, the strategy also looked to minimise the impact of freshwater flows from the development into the Karaaf Wetlands during the dry season.

During development, construction in Torquay North, regulatory controls did not require that volume management (in terms of annualised quantity) be included as part of the surface water assessment. There is also no evidence that any water balance assessment of the downstream receiving waters was undertaken or that any update to existing annualised volumes assessment completed.

It is important to distinguish annualised water volume management from stormwater retardation management, which is used to control peak flows within a catchment during significant storm events. Flood management/retardation does not remove volume from the system. As development occurs within a catchment, the increase in impervious area causes increases in peak flow and total surface water runoff volume. The greater total volume of runoff, by way of the formal stormwater networks, makes its way to natural receiving waterways. In the case the Karaaf Wetlands and Thompson Creek, changing the natural hydrologic regimes of the natural waterways. Stormwater management is a treatment method used to temporarily store water to manage peak flows, which is used within this system; however, this water still ultimately drains through the system after the peak of the storm event has subsided.

The MUSIC modelling presented in Section 4 of this report quantified the impact of the increase in impervious surfaces within the developed catchment at the point where the developed catchment discharges into the Karaaf Wetlands. This assessment used information regarding existing and proposed wetlands, lakes and development to quantify the likely volume of water discharging at an average monthly and yearly basis to the

Karaaf Wetlands. The assessment highlighted the significance of the increase in total annual flow volumes from the developed upstream catchment of the Karaaf Wetlands. With the catchment fully developed (in line with the Torquay North development plans), volumes are expected to increase by close to 228%. This change in volume occurs throughout the year as shown in Figure 6-1 below. The annual discharge from this catchment prior to development was estimated to be 475 ML/Yr, ignoring any reuse or diversion of runoff which might occur this increases to 1560 ML/Yr. The estimated increase is slightly reduced when including the associated use and diversion of water from both the Dunes and Sands development sites. The total annual volume decreases from 1560ML/Yr to 1360ML/Yr, which subsequently attributed to an increase in volume of around 193%.

TABLE 6-1 DISCHARGING VOLUME BREAKDOWN

Flow Component	Average Total Flow Pre-Development (ML/year)	Average Flow Post-Development without Reuse (ML/year)	Average Flow Post-Development with Current Reuse (ML/year)
Baseflow	228 (48%)	186 (12%)	183 (13%)
Surface Runoff	248 (52%)	1,374 (88%)	1,210 (87%)
Total Inflow	475	1,560	1,393

Concerns have been raised in relation to the ongoing reuse and diversion operation activities within this catchment with both the Dunes and Sands development relying on diversion of flow to and from Pintail dam, which may no longer be possible. The measurable reuse within the system, associated with the Golf Course remains the primary volume reduction mitigation measure within the catchment.

The impacts associated with increases in volume discharging to the downstream receiving wetland include:

- Contributing to high inundation depths within the downstream wetlands.
- Contributing to longer periods of inundation (with and without impacts to the downstream intermittently closed and open estuary).
- Increased freshwater flows into a historically saltwater system.
- Changes to the natural wetting and drying regime of the saltmarsh wetlands.

These impacts are leading to increased stress on the downstream system including vegetation dieback and encroachment of freshwater vegetation and weeds.

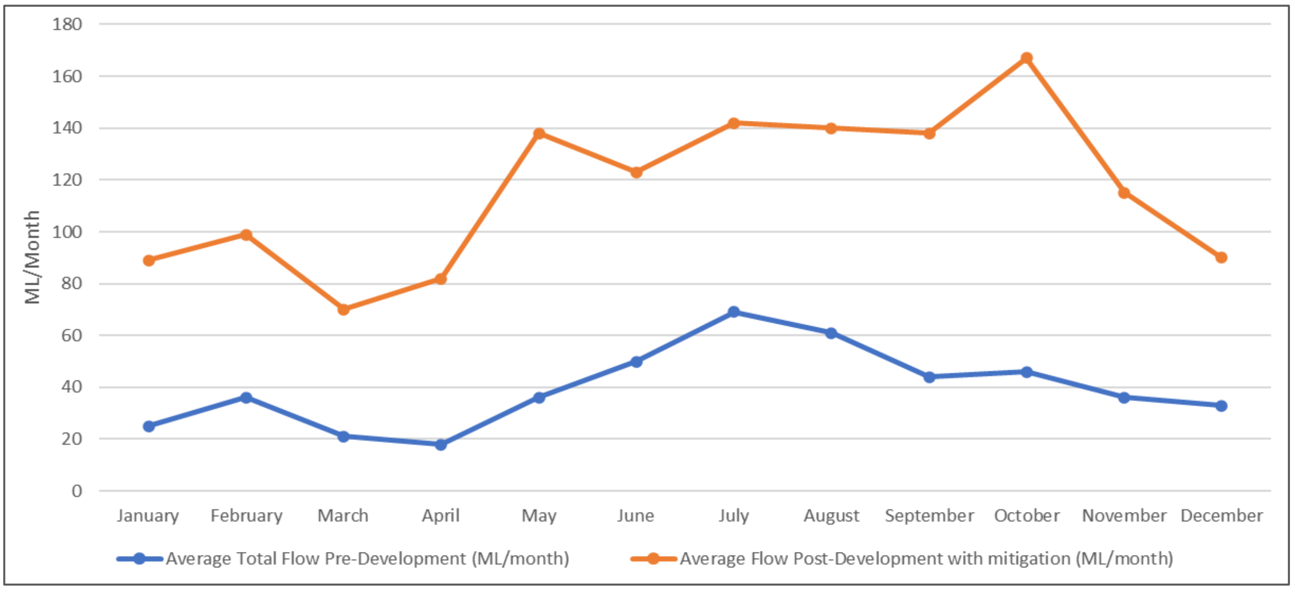


FIGURE 6-1 DEVELOPED CATCHMENT VOLUME DIFFERENCES

The downstream saltmarsh areas of the Karaaf Wetlands are considered particularly sensitive to the receiving waters of the upstream catchment flows. This is more recently recognised in the June 2021 release of the EPA Urban Stormwater Management Guidance (EPA, 2021). The new guidance now recognises volume management as a performance measure of effective stormwater control, and one of the performance measures which must be considered in mitigating harm to receiving waters. The guidance note provides specific Melbourne priority areas and recommended performance objectives in relation to reduction % for mean annual impervious runoff. Whilst this is not directly applicable to Surf Coast Shire Council at this time, the guidance note does acknowledge the requirements of assessment of volume risk and states that ‘A transparent process is required to identify priority areas for enhanced stormwater management outside the greater Melbourne area’.

Based on the information presented above and the identified risks to the sensitive Karaaf Wetlands and Thompson Creek Estuary, progressing with efforts to reduce volumes discharging from the developed catchment is increasingly important.

Whilst the other parts of the Stretton and Dunes development are still undergoing construction, in order to mitigate the ongoing stress of these significant freshwater inflows to the Karaaf Wetlands, an integrated water plan and mitigation strategy is required.

The strategy should consider where storage and reuse within the existing catchment could be achieved, with the construction and expansion of existing stormwater assets. This might include:

- Expansion of the Esplanade wetlands to create a larger retention system (allowing storage and evaporation)
- Creation of an open water storage body or chain of ponds within the Horseshoe Bend development area linear park.
- Construction of a large storage retention system within the remainder of the undeveloped Stretton estate or neighbouring rural land holdings with connection through to other wetlands.
- Where storage and reuse within the catchment cannot be feasibly achieved diversion of catchment stormwater to Deep Creek or alternative direct ocean outfall should also be considered (Esplanade Catchment).

- Investigate opportunities for mixing of reclaimed wastewater (Barwon Water) with stormwater to service existing commercial and agricultural demand within the catchment, a service previously offered by the Pintail Dam.
- Investigation of diversion systems

Any reuse scheme must consider the seasonal requirements of the wetlands including the annual wetting and drying regimes of the saltmarsh areas. Furthermore, flexibility within the system should be enabled such that the system is not starved of flow during drought or low rainfall periods should vegetation stress be identified. The watering plan should consider a whole of system, integrated water plan which can closely examine a holistic water balance.

Making the most of existing partnerships with local industry and Barwon Water, who currently operate a wastewater reuse system which services many of the estates and local agricultural land, is encouraged.

6.3 Maintenance and Remediation of Existing Constructed Wetlands

The assessment provided in Section 4 indicates a number of issues associated with the sediment basins and wetlands within this catchment are attributed to maintenance deficiencies, undersized assets and likely significant construction sediment loading. The assessment used MUSIC which is an industry standard tool to test and confirm treatment performance within the catchment based on an assessment of assumptions around fraction impervious and constructed assets within the catchment.

Key to this assessment was available information regarding the developed outcomes of areas within Torquay North and The Sands alongside visual condition assessment of the existing stormwater treatment assets.

Constructed stormwater assets within the Torquay North precinct plan utilised a fraction impervious percentage of 45% for the purposes of sizing required stormwater treatment. Melbourne Water MUSIC guidelines suggest a FI of 70% would be more appropriate for the type and density of development in the catchment.

An assessment of developed lot sizes using VicMap datasets within the respective catchment indicates that in general, lot sizes range between 300-600 m^2, trending towards the smaller end of this range. Current Melbourne Water MUSIC guidelines, which outline the accepted industry standard, indicate that for residential developments where lot sizes range between 300-600 m^2 that a fraction impervious ranging between 0.7 - 0.8 is considered appropriate (Melbourne Water, 2018). In consideration of other associated land uses within the catchments, fraction impervious values of between 67% and 73% were adopted for this assessment, which is considered conservative. The difference in the fraction impervious values resulted in changes to both stormwater quality and quantity results for the catchment. The results at a site level are presented in Table 4-1 of this report and suggest a number of the constructed wetlands do not meet current TSS and TN load reduction targets (BPEM, 1999). This is due to these wetlands being sized to accommodate less intense development (and hence less impervious surface area) than has actually occured. This results in more stormwater runoff than anticipated in the design process and subsequently higher pollutant loads.

Sediment basins are generally designed such that their sediment storage capacity is sufficient to require cleaning out once every 3-5 years. This does not consider the high sediment loading that can result from construction. The higher than anticipated development intensity is also expected to fill the sediment ponds more quickly than estimated at the original investigation stage. These aspects are consistent with the observed condition of the sediment basins, which suggests current maintenance frequency is not adequate to ensure adequate treatment performance..

TABLE 6-2 SEDIMENT LOADING AND DESIGN EFFICACY

Location	Pollutant	Total Catchment Runoff Load (kg/year)	WSUD Catchment Load[1] (kg/year)	Passing Load (kg/year)	Load Removed (kg/year)	Load Reduction as % of Total Catchment Load	BPEM Standard
Downstream of Stretton	TSS	21,300	21,300	7,120	14,180	67%	67%
Downstream of the Dunes Development	TSS	32,200	32,200	7,160	25,040	78%	78%
Downstream of Zeally Sands Development	TSS	111,000	111,000	40,100	70,900	64%	80%
Downstream of Quay Development	TSS	43,900	43,900	29,100	14,800	34%	80%
Downstream of Esplanade (Quay) Wetland	TSS	101,000	101,000	36,400	64,600	64%	80%
Downstream of Sand Development and Golf Course	TSS	292,000	252,607	74,200	217,800	75%	80%

Whilst MUSIC modelling suggests the overall water quality treatment load reduction targets are being achieved at the Karaaf Wetlands inlet, this is dependent on the additional treatment occurring within the amenity and irrigation lakes of the Sands site. This is due to the large surface area and storage volume which contribute to extended detention within the Sands system. This is expected to have a negative impact on the Sands lakes due to excessive sediment loads being retained.

Under sized sediment basins and wetlands places increasing stress on the stormwater treatment assets. This means that the sediment basins fill more frequently which has a flow on impact with excess sediment then also accumulating in the downstream wetland areas, diminishing the capacity of deep-water zones. This consequently impacts on design detention depths, effectiveness of outlet controls and overall shallowing of wetland profiles, leading to encroachment of vegetation. These issues have been observed within this system with inspection of the existing constructed wetlands within this catchment indicating shallowing of sediment basins and wetlands areas and encroachment of vegetation.

Sediment basins are typically sized in consideration of a 3 to 5 year maintenance cycle; however, smaller assets will likely require cleanout frequencies of less than 3 years and should be monitored and works undertaken as necessary. This cleanout frequency may need to be further reduced if assets are undersized due to likely load thresholds being met more quickly. During the construction phase it is possible that inspection and clean out frequency could reduce to as little at 3 months, with construction within larger development area often extending beyond 5 years.

Poor construction sediment management within this catchment has also contributed to high construction sediment loads to a number of these wetlands and the downstream Sands amenity lakes. As a result, it is likely that many of the existing sediment basins and wetlands within the catchment will now require major works to bring them back to full functionality. Typically, the basins and wetlands are constructed as part of the initial subdivision infrastructure. When these are allowed to come online prior to works being complete and without appropriate protection within the catchment they are severely impacted by construction sediment which impacts the geometry of the wetlands along with the vegetation health and performance of water quality treatment mechanisms. Construction within the catchment can continue for some time (5-10 years) after infrastructure works are complete. During this time, with the wetlands connected to the drainage network, construction at a lot level creates a steady sediment load within the system. The design on which wetlands are based does not consider this loading which means that sediment management becomes one of the most important mitigation measures in preserving these wetlands in the early stages of any development. Because these wetlands function as a system, failure within the upper parts of the network will cascade through the system resulting in a cumulative impact over the time the construction continues.

Whilst the wetlands, basins and lakes carry the burden of high sediment loads, this also impacts the performance of the pipe drainage network, leading to blockages and reduced system capacity. These blockages are also likely to be observed within the wetlands themselves (inlet pipes, balance pipes and outlets).

Poor turbidity and high sediment load within The Sands wetlands and amenity lakes was identified in the 2017 GHD report, regarding the impact on the environment of the offsite water entering The Sands system. This report investigated available water quality monitoring which identified continually increasing turbidity and nutrient levels above acceptable thresholds. It is likely that the cumulative impact of both the construction sediment load and wetland performance has resulted in a significant volume of sediment being deposited within the wetlands as has been reported.

The MUSIC water quality modelling completed as part of this assessment indicated the existing wetlands in series alongside the amenity lakes and irrigation wetlands assists to maintain water quality discharging to the Karaaf Wetlands. The efficacy of this system if the waterbodies within The Sands estate are unable to be properly restored is uncertain. Further to this, it should be noted these current comparisons are made to BPEM standards (CSIRO, 1999) and do not recognise the higher water quality standards/thresholds which are likely required to ensure protection of the sensitive downstream natural environment.

The modelling and anecdotal evidence indicates that these private assets have contributed to the protection of the Karaaf Wetlands from higher sediment and nutrient loads from the developing catchment and as such the cost associated with remediating these waterbodies should be shared amongst the beneficiaries. To understand the necessary works required within both the Sands and upstream wetlands a detailed survey of the extent and depth of sedimentation is required.

With a number of outstanding development stages still to be constructed within the upper catchment, tightening of sediment management compliance should be a focus. Appropriate sediment management during construction of future stages within this development will ensure that maintenance and remediation works to downstream wetlands can be controlled. Sediment management control and compliance should also be extended to any dewatering activities which are likely to be required within the catchment to facilitate maintenance and remediation works.

In line with the current guidelines, minimum standards of sediment management within the estate and domestic development sites should include:

- Sediment fencing
- Coir logs
- Temporary sediment basins
- Appropriate remediation of wetlands and basins prior to asset handover
- Controlled dewatering of wetlands prior to works

- Regular street sweeping
- Environmental Management Plan compliance and auditing
- Domestic builder site management spot checks

High gross pollutant loads within the Dunes and Zeally Sands wetlands were observed. The Dunes Wetlands receive surface runoff drainage from the Neighbourhood Activity Centre. High gross pollutant loads (general rubbish) are typically associated within retail and hospitality areas as was evident by the type of litter visible within the wetlands, dominated by drink bottles, snack food and take away containers. Based on this high load and the evident exceeded capacity of the gross pollutant traps, the clean out frequency on these assets needs to be increased. Whilst there are a number of further wetlands in series from the point to the Karaaf Wetlands, even small quantities within the Karaaf Wetlands could cause significant hardship and or death of valuable and threatened mammal and bird species. Plastic within this system is of increasing concern with microplastics pollution having been recently reported in the Thompson Creek.

Careful consideration should be given by council to the development and endorsement of specific municipal guidelines for development, which outline the accepted assumptions and industry standards around design of water sensitive urban design assets within with catchment, alongside management and maintenance obligations. This would enable council to have greater proactive involvement in mitigating poor construction management practices which impact catchment health and ensure future wetlands are designed in line with current accepted industry standards. With industry standards around water management rapidly evolving frequent review and update is critical.

6.4 Ongoing Monitoring

As part of this assessment, it was recognised that limited available data on which to base modelling assumptions and environmental trends analysis was available. No detailed level or flow information within the Karaaf Wetlands was available on which to understand existing and or pre-development hydrological regimes. An active 'estuary watch' program does exist within the highly engaged local community of Breamlea who have recorded and observed changes to the downstream system over the period of record. This citizen science contributes significantly to the broader understanding of catchment response to increasing urbanisation, however a formal permanent monitoring system within other parts of the catchment is required and would complement this ongoing monitoring.

Whilst it is noted that some infrequent water quality testing takes place by Surf Coast Shire and within the Sands, there is a lack of long-term records regarding flows, water levels and quality within the Karaaf Wetlands. The frequency and timing of monitoring, especially if this is only occurring monthly, can limit meaningful information being collected about effectiveness of treatment and flow managment within the catchment, as is currently occurring. A permanent telemetry system would be beneficial, so that changing flow and quality trends can be recorded and inform appropriate management response activities. Instantaneous data would also enable more comprehensive and ongoing monitoring of the system and changes to hydrologic flow conditions as part of longitudinal studies, such as is occurring in similar settings (Lower Barwon Wetlands and Sparrovale Wetlands). Significant increases in freshwater flows will and have impacted the natural wetting and drying regime of the salt marsh putting ecological stress on existing vulnerable vegetation species.

In light of the above, a monitoring plan in partnership with Surf Coast Shire, CCMA and Parks Victoria should be established with suggested emphasis on monitoring:

- Water level, quality and flow entering and within Karaaf Wetlands
- Ecological monitoring of Karaaf Wetlands– regular flora condition assessment and fauna survey.
- Frequent and ongoing monitoring of constructed wetlands water quality, vegetation health and performance

Consideration should be given to permanent telemetered gauges which could form part the Victorian Water Quality Monitoring Network.

6.5 Formal Protection and Recognition of the Karaaf Wetlands

The Karaaf Wetlands are part of a sensitive wetlands complex which makes up the Thompson Creek Estuary. A number of key environmental studies have identified important flora and fauna within this area, including species of state and national significance. The wetlands themselves and the adjoining catchment share similarities to the Lake Connewarre wetlands complex and require management interventions. The modelled changes to the hydrologic regime of the wetlands are continuing to impact on the health of this natural system. The wetlands and the management of the upstream catchment require urgent attention from responsible agencies to ensure appropriate management actions are taken to mitigate the impacts of intensifying development which has significantly changed the watering regime of the saltmarsh areas.

The Convention of Wetlands of International Importance holds an important recognition in conserving natural resources. The Ramsar convention seeks to protect against the loss of unique wetlands. The Karaaf Wetlands and the greater estuary of Thompson Creek does not currently fall within the already identified Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar Site, although it shares many similarities to the wetlands identified within these areas. The Index of Estuary Condition (DELWP 2021) indicated that the overall condition score for the Thompson Creek estuary equalled that of the adjacent Barwon River estuary.

Formal recognition of this wetland's importance would help to ensure that key ongoing management and maintenance activities within the catchment are given appropriate importance and status.

Preservation of the wetlands falls to a number of key agencies within this area including the following:

- Parks Victoria (as the committee of management)
- Corangamite Catchment Management Authority
- Surf Coast Shire Council
- City of Greater Geelong
- Department of Environment Land Water and Planning

6.6 Recommendations

The following key priorities are recommended in order to address identified water management risks within the catchment:

1. Undertake an Integrated Water Management (IWM) plan for the Karaaf Wetlands catchment, focusing on volume management, water quality and environmental protection. The development of the plan should be led by Surf Coast Shire in conjunction with City of Greater Geelong, Corangamite CMA, Barwon Water, Parks Victoria, Southern Rural Water, EPA and DELWP. This plan may be complementary to an estuary management plan for the catchment which must also consider how increased volume and flow within this system impacts on estuary entrance management.
2. Improved maintenance, operation and enforcement of water quality treatment assets including;
   - A. Install sediment protection measures within the Stretton Estate and developing land within other sites of the contributing catchment. This should include compliance auditing of developers and private builders within these estates. Regular street sweeping of these areas should also be implemented to ensure longevity of the installed measures.

B. Immediately service existing GPTs within the Dunes Wetlands, initiate inspection program of these assets at frequency intervals of no less than 3 months, until such time as the wetlands and developing catchment is considered stable. This inspection program should also include as required maintenance and cleaning of these structures. Undertake immediate works to reinstate catchment wetlands to as design condition including verification of operational levels, sediment basin remediation, control structure inspections and vegetation planting (pipe connections, outlets weirs etc.). Consideration should also be given to the need for installation of litter traps as pre-treatment for existing and future wetlands which otherwise rely on the wetlands solely managing gross pollutant loads from the system.

C. Develop clear and specific council standards and guideline for developers in relation to design, maintenance and operation of water quality assets and construction sediment management. Asset management plans should be completed with clear guidelines on maintenance frequency, monitoring and triggers for major works.

3. Develop a monitoring program to survey sediment levels and vegetation within all catchment wetlands including the Sands amenity lakes. The surveys should be used to inform a works program to reinstate design levels and function of sediment basins, wetlands and the amenity lakes of the Sands.

4. Develop and commence monitoring program within the Karaaf wetlands. Consideration should be given to the installation of a telemetered system which is able to monitor:

   - Water Level
   - Depth
   - Electrical Conductivity
   - PH
   - Temperature
   - Turbidity
   - Pollutant Loads (TN and TP)

   Further to this, ecological monitoring should also be implemented with regular vegetation surveys to best understand seasonal plant die off, structure and species cover/abundance change, including freshwater species invasion, and to record images from repeatable photo points.

5. Develop and implement a monitoring program for the constructed wetlands within the catchment. It is understood that some monitoring does occur, although the breadth and frequency of this monitoring should be increased to understand the performance of the system in terms of flow and pollutant generation and treatment.

6. Initiate procedure to formally extend the boundaries of the Ramsar listing of the Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar area to encompass the Thompson Creek Estuary inclusive of the Breamlea Flora and Fauna reserve and the Karaaf wetlands.

7 REFERENCES

P. Adam (1990), Saltmarsh Ecology, Cambridge University Press, Cambridge

Australian Government. 2000. Australian Guidelines for Urban Stormwater Management - National Water Quality Management Strategy. Agriculture and Resource Management Council of Australia and New Zealand and Australian and New Zealand Environment and Conservation Council.

Billows, C.A., (2006). Ecological Responses to Improved Tidal Flows into the Karaaf Wetlands, Breamlea, Victoria (Doctoral dissertation, Honours Thesis, School of Life and Environmental Sciences, Deakin University)

City of Greater Geelong. (n.d.). MUSIC - Modelling Approach and Parameters for use within the City of Greater Geelong. Retrieved 07 05, 2021, from https://geelongaustralia.com.au/idm/documents/item/8cf4f273fe1120f.aspx

City of Geelong. 2012. Armstrong Creek Urban Growth Plan, Volume 1, May 2010, Amended September 2012.

Craige, N. M., & Condina, P. (2001). Torquay Victoria, Surface Water Management System (Draft Final Report).

CSIRO. 1999. Urban stormwater: best practice environmental management guidelines. Victorian Stormwater Committee with assistance of Environment Protection Authority, Melbourne Water Corporation, Department of Natural Resources and Environment and Municipal Association of Victoria.

DEE (2016). Coastal wetlands - Mangroves and saltmarshes, Australian Government, Department of the Environment and Energy, Factsheet retrieved 14/09/2021, from https://www.environment.gov.au/system/files/resources/e013aa9d-4167-4709-8080-7732950dcc76/files/factsheet-wetlands-mangroves-saltmarshes.pdf

DELWP (2017). Index of Estuary Condition, Project overview - May 2017, Retrieved on 27/08/2021 from https://www.ari.vic.gov.au/__data/assets/pdf_file/0033/74769/Index-Estuary-Condition_fact-sheet_May2017.pdf

DELWP (2021). Assessment of Victoria's estuaries using the Index of Estuary Condition: Results 2021. The State of Victoria, Department of Environment, Land, Water and Planning, East Melbourne, Victoria.

DPI (2013). Coastal saltmarsh, Primefact 1256, First edition, NSW Government Department of Primary Industries, Retrieved 14/09/2021, from http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/459628/Coastal-Saltmarsh-Primefact.pdf

DSEWPC (2013), Conservation Advice for SUBTROPICAL AND TEMPERATE COASTAL SALTMARSH, Department of Sustainability, Environment, Water, Population and Communities. Retrieved on 13/08/2021 from http://www.environment.gov.au/biodiversity/threatened/communities/pubs/118-conservation-advice.pdf. In effect under the EPBC Act from 10-Aug-2013.

Ecology Australia (2001). Flora and fauna assessment and environmental management plan for Torquay Sands Residential Lakes and Golf Course development, Torquay. Unpublished report MHY Joint Venture Pty Ltd, Ecology Australia Pty Ltd, Fairfield, Victoria

EHP (2020). Opportunities and Constraints Assessment: Torquay North East Future Residential Investigation Area, Ecology and Heritage Partners, report prepared for the Department of Environment, Land, Water and Planning

EPA Victoria. (2021). Urban stormwater management guidance (Publication 1739.1).

GHD. (2010). Report for Stormwater Master Plan - Torquay North

GHD (2017). Report on the environmental impact of offsite water entering The Sands system, report for The Sands Owner Corporation

Government of Victoria. 1970. State Environment Protection Policy (Waters of Victoria) - Environment Protection Act 1970, Amended 23/2/1988, No. S13, Gazetted 26/2/1988; Update No. S 107 Wednesday 4 June 2003.

IDM. (2020). Local Government Infrastructure Design Manual (Version 5.30). State Government of Victoria.

S. Joye and J. Hollibaugh (1995), Influence of Sulphide Inhibition of Nitrification on Nitrogen Regeneration in Sediments, Science, Vol 270, Issue 5236, pp. 623-625

Lloyd Environmental, Fluvial Systems and Ecological Associates (2006). Environmental Flow Determination for the Barwon River: Final Report - Flow Recommendations. Lloyd Environmental Report to Corangamite Catchment Management Authority, Colac

Lloyd, L.N., Cooling, M.P, Kerr, G.K., Dahlhaus, P. and Gippel, C.J. (2012). Flow/ecology relationships and scenarios for the Lower Barwon Wetlands environmental entitlement: Draft Final Report. Lloyd Environmental Pty Ltd Report to the Corangamite CMA, Colac

Lloyd, L.N. (2016), Expert advice regarding the Armstrong Creek residential development near Port Phillip Bay (Western Shoreline) and Bellarine Peninsula Ramsar wetland, Victoria, Lloyd Environmental report to Department of the Environment (Government of Australia), Syndal, Victoria

Plant Life (2021), Halophytes, Retrieved on 27/08/2021 from http://lifeofplant.blogspot.com/2011/03/halophytes.html

S. Silvestri and M Marani (2004), Salt-marsh Vegetation and Morphology: Basic Physiology, Modelling and Remote Sensing Observations, published in 'Ecogeomorphology of Tidal Marshes', American Geophysical Union, Coastal and Estuarine Monograph Series

Sinclair, S.J., Kohout, M., Batpurev, K., Bryant, D., Bruce, M., Mujr, A. Downe, J., Macak, P., Leevers, D. and Brown, G. (2020). State-wide assessment of fringing vegetation for the index of estuary condition. Arthur Rylah Institute for Environmental Research Technical Report Series No. 319. Department of Environment, Land, Water and Planning, Heidelberg, Victoria.

WBCM Group. (2015). "The Dunes" Estate, Torquay, Stormwater Management Strategy.

WBM Oceanics Australia. (2002). City of Greater Geelong Stormwater Management Plan Volume I. WBM Oceanics Australia Report to City of Greater Geelong. Document no: R.W00234.001.02.COGGSWMP.VolI.doc.

Wikipedia (2021), Salt marsh dieback, Retrieved on 27/08/2021 from https://en.wikipedia.org/wiki/Salt_marsh_dieback

APPENDIX A
MUSIC MODEL PARAMETERS

A-1 Climate Template

Geelong North 20year (1971 – 1990) 6-minute MUSIC climate template available from City of Greater Geelong (COGG) MUSIC modelling guidelines (City of Greater Geelong) were adopted for the current study. Geelong North template is recommended for areas with a mean annual rainfall greater than 500 mm. Since the mean annual rainfall in Torquay is 552 mm (BOM station 87160 at Torquay Golf Course), the Geelong North climate template was adopted. It is noted that the previous assessment for Torquay North Stormwater Master Plan (GHD, 2010) also adopted the same rainfall station for MUSIC modelling assessment.

A-2 Source Nodes

A-2-1 Catchment Delineation

The catchment delineation and fraction impervious adopted for the RORB modelling was used for MUSIC modelling. The only exception is the further breakdown of MUSIC catchments within the proposed "South Beach Road Development' to match with the previous assessment (GHD, 2010) and 'The Sands' development to incorporate a chain of amenity lakes, irrigation lakes and wetlands. MUSIC catchments are shown in Table 7-1 and listed in Figure 7-1. A total of 1,202 ha (including the reserve footprint) was estimated to be draining to Breamlea Reserve under fully developed conditions. The estimated overall fraction imperviousness of the fully developed catchment is 29%. The full development scenario is when the proposed development in the Torquay North precinct is completed.

For comparison purposes, it was assumed the pre-developed catchment FI was 10%.

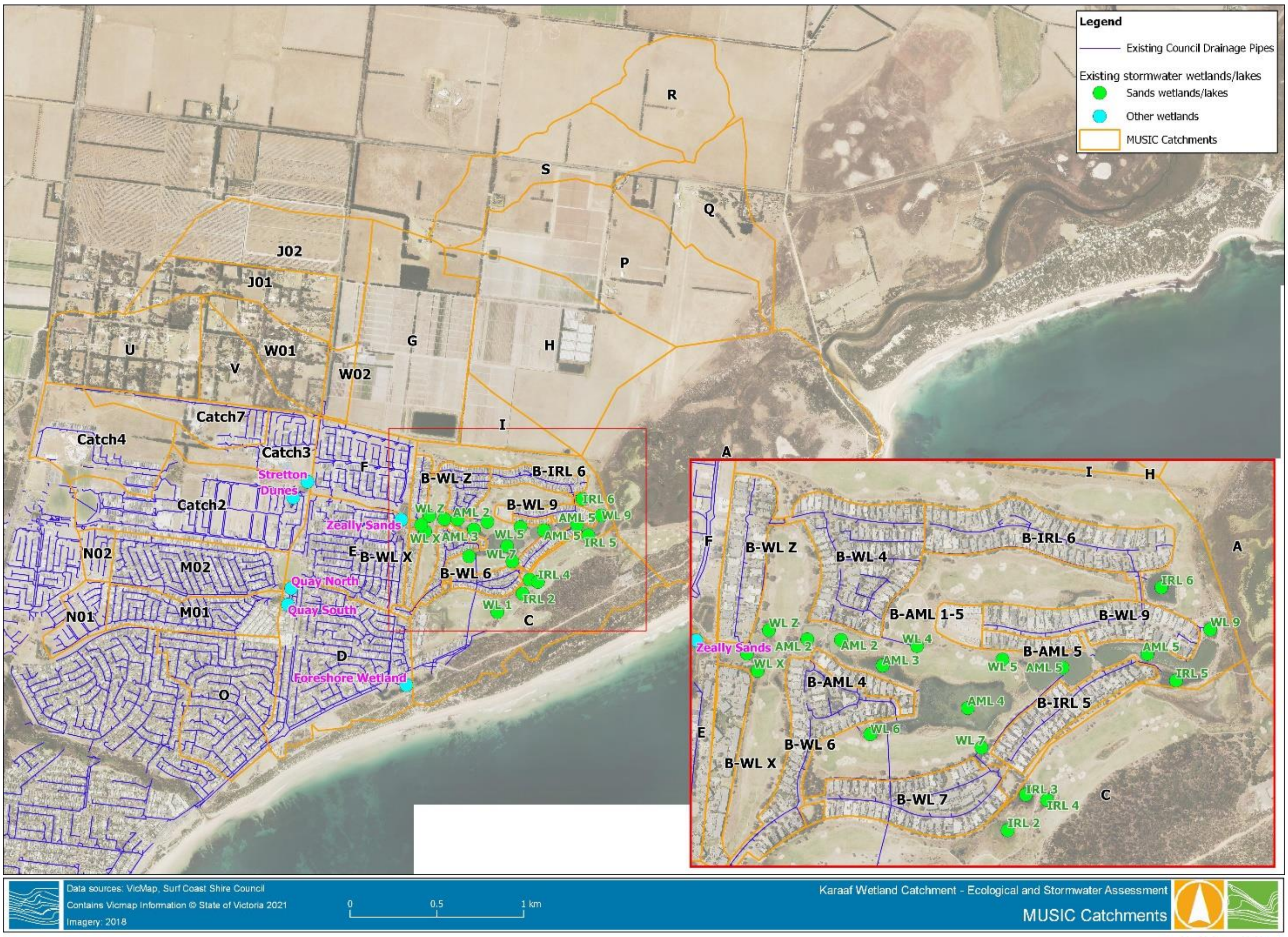


FIGURE 7-1 MUSIC MODEL CATCHMENTS

TABLE 7-1 MUSIC CATCHMENT SUMMARY

Source Node Type	Location	Total Area (ha)	Fraction Impervious Fully Developed Scenario
Urban	A	167.54	1%
Urban	B-AML 1-5	44.02	10%
Urban	B-IRL 5	2.96	70%
Urban	B-IRL 6	5.81	70%
Urban	B-WL 4	6.45	70%
Urban	B-WL 5	0.88	70%
Urban	B-WL 6	5.47	70%
Urban	B-WL 7	4.78	70%
Urban	B-WL X	2.72	70%
Urban	B-WL Z	3.6	70%
Urban	B-WL9	3.66	70%
Urban	C	68.06	20%

Source Node Type	Location	Total Area (ha)	Fraction Impervious Fully Developed Scenario
Urban	Catch 2	51.72	70%
Urban	Catch3	16.73	70%
Urban	Catch4	34.92	70%
Urban	Catch7	17.05	70%
Urban	D	59.9	56%
Urban	E	34.06	67%
Urban	F	25.44	67%
Agricultural	G	71.61	10%
Agricultural	H	78.37	10%
Agricultural	I	14.74	10%
Urban	J01	28.27	20%
Agricultural	J02	42.82	10%
Urban	M01	22.09	74%
Urban	M02	30.07	74%
Urban	O	42.72	74%
Agricultural	P	84.2	10%
Agricultural	Q	43.78	11%
Agricultural	R	36.07	10%
Agricultural	S	43.93	12%
Urban	To Ext Catch 1	5.28	69%
Urban	To Ext Catch 2	9.43	69%
Urban	U	45.78	27%
Urban	V	19.56	23%
Urban	W01	21.39	20%
Agricultural	W02	6.38	10%
	TOTAL	**1202.26**	**29%**

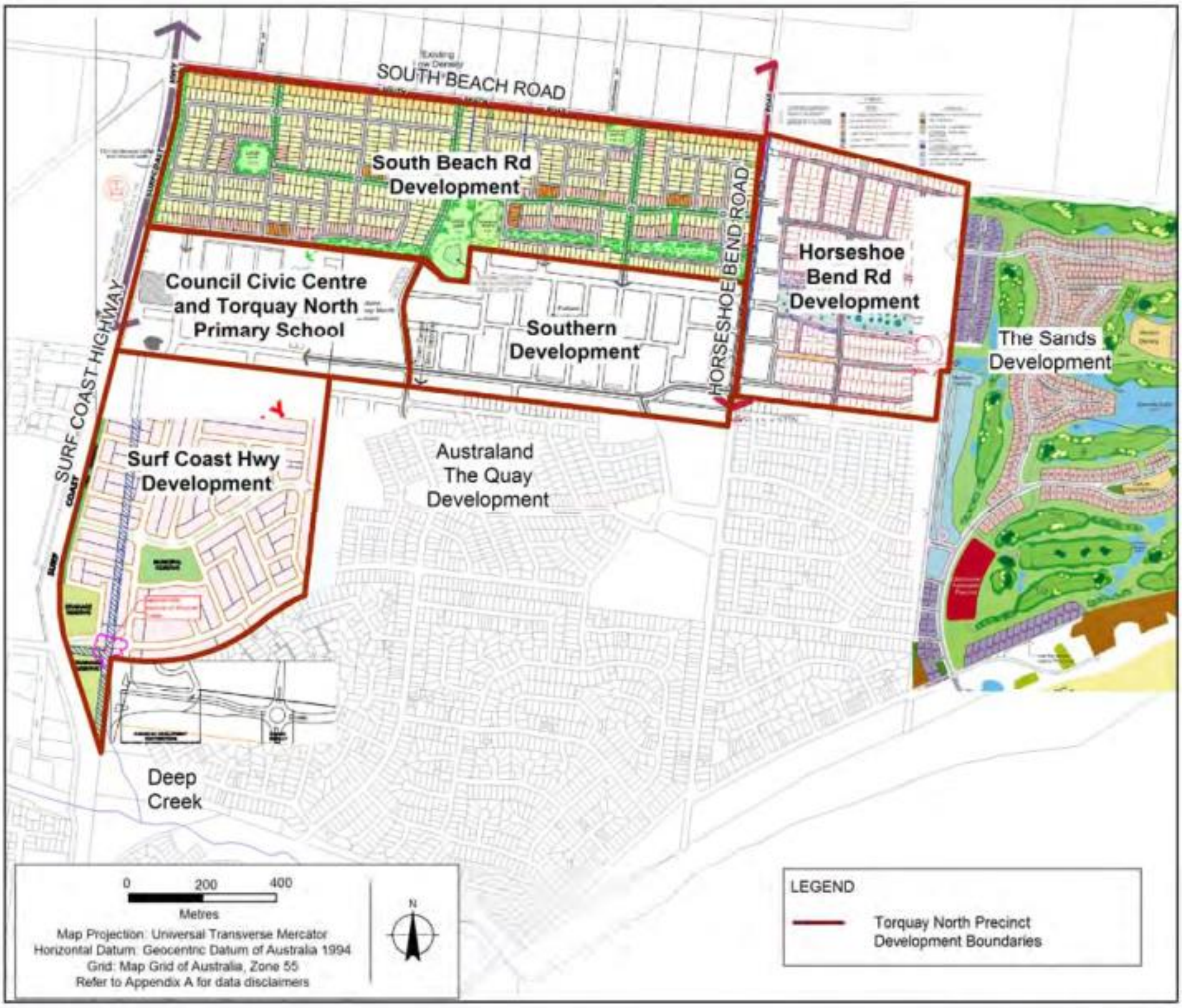


FIGURE 7-2 TORQUAY NORTH PRECINCT SITE PLAN (SOURCE: GHD (2010))

A-2-2 Source Node Types

Catchment areas within farming zones were modeled using the “Agricultural’ node while all the source nodes were modelled using the ‘Urban’ node with surface type set to ‘Mixed’ in the future scenario. The pre-development catchment was represented using the ‘Forest’ node.

Default rainfall-runoff parameters were used except where soil storage capacity was set to 120 mm and field capacity was set to 50 mm in all source nodes to be consistent with CoGG MUSIC modelling guidelines.

A-3 Treatment Assets

Previous assessment reports for The Sands development (Craige & Condina, 2001), Torquay North Growth Area (GHD, 2010) and the Dunes Development (WBCM Group, 2015) were used to extract treatment asset design parameters. Where no sufficient design information could be found, the waterbody footprint was extracted from VicMap database (hy_water_area_polygon.shp) to estimate design parameters using best judgement.

A total of 16 wetlands were included in the MUSIC model. These includes;

- 1 existing and 2 proposed wetlands at the South Beach Road Development
- 2 existing wetlands (lumped into 1 node in MUSIC) at the Dunes Development
- 2 existing wetlands within the Horseshoe Bend Road Development
- 2 existing wetlands within the Quay development
- 1 existing wetland within the Esplanade
- 8 existing wetlands within the Sands development

A summary of wetland key model parameters is listed in Table 7-2. For wetlands proposed within the South Beach Road Development, MUSIC model parameters adopted in the previous assessment (GHD, 2010) was used as it is. The proposed wetland within the Dunes development (Shown as Southern Development in Figure 7-2) GHD (2010) report has already been constructed as two wetlands in series (WBCM Group, 2015). These two wetlands were lumped into a single wetland node for simplicity. The previous assessment for the Sands development has sized wetland to 1.5% of the contributing area. Therefore, wetlands identified from the aerial imagery was sized to estimated contributing catchment (based on existing Council drainage pipes layout). The only exception was the Foreshore wetland, where the design information was extracted from the previous report (Craige & Condina, 2001). No information could be found for the existing wetlands at The Quay development. Therefore, it was assumed wetland design is similar to the other wetlands in the Torquay North precinct and similar parameters were adopted. For all wetlands, the macrophyte zone outlet was sized to achieve a detention time as close as to 72 hrs.

Surface water management assessment for the Sands development (Craige & Condina, 2001) recommended diverting water from the updated foreshore wetland to amenity lakes (AML). Therefore, treated stormwater was diverted from the foreshore wetland to the amenity lake node (AML 4-5) in the MUSIC model.

TABLE 7-2 WETLAND MODEL PARAMETER SUMMARY

Main Catchment	MUSIC ID	Hi-flow bypass rate (m^3/s)[1]	Inlet pond volume (m^3)[2]	Surface Area (m^2)	Extended detention depth (m)[3]	Permanent Pool Volume (m^3)[4]	Equivalent Pipe Diameter (mm)	Notional Detention Time (hrs)
South Beach Road Development	Catch3 Wetland	0.72	289	1735	0.5	833	45	72.2
	Catch4 Wetland	0.85	333	3000	0.5	1500	59	72.7
	Catch7 Wetland	0.41	238	1429	0.5	686	41	71.7
The Dunes Development	Dunes Wetland 1&2	1.13[5]	500[6]	3133[7]	0.5	1566.5[8]	60	73.4
The Quay Development	Quay North Wetland	0.63	95	630	0.5	315	27	72.9
	Quay South Wetland	0.51	109	725	0.5	363	29	72.7
Horseshoe Bend Road Development	TN-Catch1 Wetland	0.91	406	2435	0.5	1170	53	73.1
	TN-Catch6 Wetland	0.35	133	1200	0.5	600	38	70.1
Existing Residential Catchment including The Quay Development	Foreshore Wetland/Esplanade Wetland	3.35	2100	14000	0.3	9000	112	72.9
The Sands Development	WL 4	0.27	145	968	0.3	290	30	70.2
	WL 5	0.05	20	132	0.3	40	11	71.2
	WL 9	0.17	82	549	0.3	165	22	74.1
	WL X	0.13	61	408	0.3	122	19	73.8
	WL Z	0.17	81	540	0.3	162	22	72.9
	WL6	0.24	123	821	0.3	246	27	73.5
	WL7	0.21	108	717	0.3	215	25	74.9

Notes:

1. Set as 1-year ARI flow. 1 year ARI flow was either extracted from the previous report (GHD, 2010) for wetlands within South Beach Road and Horseshoe Bend Road developments. For all other wetlands, 1-year ARI flow was estimated using the rational method and ARR1987 IFD parameters reported in GHD (2010) report for Torquay
2. For all wetlands except for the ones within South Beach Road and Horseshoe Bend Road developments, inlet pond volume was taken as 15% of the wetland surface area (based on ration of inlet pond volume and surface area in GHD (2010) report)
3. Extended detention depth (EDD) for all wetlands within the Sands development was set to 0.3 m based on the extended detention used for Amenity Lakes. Foreshore Wetland EDD was taken from Neil Craige's report (Craige & Condina, 2001). All remaining wetland EDD was set to 0.5 m to be consistent with other wetlands within the Torquay North Precinct.
4. All wetlands within the Torquay North Precinct was assumed to have 0.5 m average depth to be consistent with GHD (2010) report. All wetlands within the Sands development was assumed to be have an average depth of 0.3 m.
5. High flow bypass rate cannot be found in WBCM Group (2015) report. Therefore, the high flow by pass rate set in GHD (2010) report was adopted.
6. WBCM Group (2015) report only provides sediment pond surface area. Corresponding volume for sediment pond surface area of 250 m^2 was estimated using the "Estimate Inlet Volume" calculator in MUSIC.
7. Combined total of two wetlands
8. Permanent pool volume was taken as 0.5 x surface area similar to other wetlands in Torquay North Precinct (GHD, 2010)

Additionally, existing amenity lakes and irrigation lakes with the Sands developments are also included in the MUSIC modelling. Three pond nodes were used to represent the lake system:

- Pond 1 - Amenity lakes 1, 2 and 3
  - Permanent pool volume, surface area and overflow weir length were extracted from the previous report (Craige & Condina, 2001)
  - These ponds don't provide storage for irrigation water. Therefore, EDD was set to minimum allowable (0.01 m)
- Pond 2 – Amenity lakes 4 and 5
  - Permanent pool volume, surface area and overflow weir length were extracted from the previous report (Craige & Condina, 2001)
  - EDD was set to 0.3 m as per the previous report.
  - Equivalent pipe diameter was set to achieve a notional detention time equivalent to what would have been achieved if the stage-storage-discharge relationship was provided in the previous report.
- Pond 3 – Irrigation Lakes 3, 4, 5 and 6
  - This node was used to represent irrigation water storage for the golf club.
  - The previous report did not specify pond volumes or storage details.
  - Therefore, the lake surface area was extracted from VicMap database (hy_water_area_polygon.shp).
  - Permanent pool volume was estimated, assuming an average depth of 1 m.
  - It was assumed, irrigation volume will be stored within the EDD of each lake.
  - EDD was set to achieve 39 h detention time which is equivalent to the pumping rate assumed in the previous report.

Irrigation Lakes extended detention sizing
Short term irrigation volume = 16.2 ML (Craige & Condina, 2001)
Storage within Amenity Lakes 4 -5 = 7.8 ML (Craige & Condina, 2001)
Therefore, remaining storage within irrigation takes = 8.4 ML
Surface area = 11,599 m^2 (VicMap data)
Estimated EDD = 0.72 m
Pumping rate = 50 – 60 L/s (Craige & Condina, 2001) 60 L/s was adopted
Estimated detention time = 39 h

A summary of key model parameters used for each lake system is listed in Table 7-3. Treated flows from AML 4-5 are diverted to IRL 3-4-5-6 node using a secondary link. Overflows from AML 4-5 are directed to Bremlea Reserve.

TABLE 7-3 AMENITY LAKES AND IRRIGATION LAKES MODEL PARAMETER

MUSIC model ID	Surface Area (m^2)	Extended detention depth (m)	Permanent Pool Volume (m^3)	Equivalent Pipe Diameter (mm)	Overflow Weir Length (m)	Detention Time (h)
AML 1-3	15,100	0.01	25,000	50	20	0.007
AML 4-5	4,600	0.3	98,000	80	20	46.9
IRL 3-4-5-6	11,599	0.75	11,599	175	2	39.1

Two gross pollutant traps (GPT) that were proposed to treat runoff from the Sur Coast Highway Development that drains to the existing residential catchment (The Quay development) was also included in the current MUSIC model. GPT removal performances were extracted from the previous report (GHD, 2010)

- TSS - 52% removal
- TP – 17% removal
- TN – 0% removal
- Gross pollutants - 98% removal

Additionally, three GPTs were observed upstream of Dunes wetlands. Therefore an additional GPT was included in the MUSIC model. In absence of specific GPT performance data, the same pollutant performance parameters the previous report (GHD, 2010) were adopted.

A-4 Water Reuse

It is understood that the excess stormwater harvested at from the Sands development and surrounding area was pumped to the Pintail dam for winter storage. Stormwater was then mixed with Class C recycled water from the Black Rock Sewage Treatment Plant (BRSTP) before being used for golf club irrigation. However, it is understood that his arrangement has now been cancelled. Therefore, in MUSIC modelling, it was assumed only stormwater would be reused for irrigation, and additional storage at the Pintail dam is unavailable.

The average irrigation demand was estimated as 102 ML/year based on 2017-2019 data shown in Table 7-4 below. Water usage in 2020 was excluded as it appears to be significantly lower than the previous year. The previous assessment estimated the golf course irrigation demand to be 160 ML/year on average, rising to 245 ML/year in severe drought years.

TABLE 7-4 ALTERATIVE WATER USAGE SUMMARY

Year	Stormwater Transfer Credits (ML/year)	Class C Water Usage (ML/year)	Total Reuse (ML/year)
2017	69.9	35.2	105.1
2018	28.4	51.1	79.5
2019	54.1	68.0	122.1
2020	19.4	28.4	47.8

For MUSIC modelling purpose, seasonal demand was adjusted to average monthly deficit, also shown in Table 7-5.

TABLE 7-5 INDICATIVE MEAN RAINFALL, PET AND SEASONAL DEFICIT AT GOLF COURSE

MONTH	RAINFALL[1] (mm)	EVAPORATION [1] (mm)	DEFICIT (mm)	SEASONAL DEMAND (%)
January	39.8	164.9	125.1	21%
February	35.8	134.4	98.6	16%
March	33.4	106.6	73.2	12%
April	36.6	68.4	31.8	5%
May	54.2	40.6	0	0%
June	40.5	30	0	0%
July	43.6	33.8	0	0%
August	46.9	47.1	0.2	0%
September	51.3	70.2	18.9	3%
October	62.8	119	56.2	9%
November	49.3	144.3	95	16%
December	37.1	146.9	109.8	18%
TOTAL	**531.3**	**1106.2**	**608.8**	**100%**

Notes:

Rainfall and PET was extracted from MUSIC model climate template

Proposed rainwater harvesting (RWH) at the Dunes development for toilet flushing and irrigation was not included in the current MUSIC model as there wasn't sufficient information. Furthermore, proposed RWH was not included in the Dunes SWMS MUSIC model (WBCM Group, 2015). Nevertheless, the proposed diversion of 12 ML/year from the Dunes wetlands to the Pintail Dam to reduce freshwater entering the Karaaf Wetlands was included in the current MUSIC model.

Melbourne

15 Business Park Drive
Notting Hill VIC 3168
Telephone (03) 8526 0800
Fax (03) 9558 9365

Brisbane

Level 3, 43 Peel Street
South Brisbane QLD 4101
Telephone (07) 3105 1460
Fax (07) 3846 5144

Adelaide

1/198 Greenhill Road
Eastwood SA 5063
Telephone (08) 8378 8000
Fax (08) 8357 8988

Perth

Ground Floor
430 Roberts Road
Subiaco WA 6008
Telephone 08 6555 0105

Geelong

PO Box 436
Geelong VIC 3220
Telephone 0458 015 664

Gippsland

154 Macleod Street
Bairnsdale VIC 3875
Telephone (03) 5152 5833

Wangaratta

First Floor, 40 Rowan Street
Wangaratta VIC 3677
Telephone (03) 5721 2650

Wimmera

PO Box 584
Stawell VIC 3380
Telephone 0438 510 240

www.watertech.com.au

info@watertech.com.au