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RPS Australia West Pty Ltd ABN 42 107 962 872
A member of the RPS Group Plc

Date: 31/01/2018
Our Ref: EEL16056.003
Attn: Ashley Clements
South West Development Commission
Level 8, 61 Victoria Street
BUNBURY WA 6230

Dear Ashley

Proposed Koombana Marina Groundwater Monitoring Results and Potential Nutrient Loading

1 Introduction

The South West Development Commission is currently undertaking planning to implement a number of marine structures in Koombana Bay. One of the factors to consider in marina planning is the groundwater quality entering the marina. If groundwater quality is poor, particularly in relation to nutrients, there is an increased potential for algal blooms in the low energy marina water body.

The objective of this assessment is to estimate the nutrient load entering the marina water body from groundwater inflow. If required, this nutrient load will be included in hydrodynamic modelling of the marina water body and Koombana Bay, in order to determine whether marina construction represents an increased risk of algal bloom formation.

2 Sampling Methodology

The assessment included a desktop search of data available from Department of Water and Environmental Regulation (DWER) monitoring bores in the vicinity in order to determine local groundwater quality. An RPS scientist conducted two sampling events on 31 October 2016 and 30 January 2017. RPS obtained permission to access four DWER bores (AWRC numbers 61118027, 61111506, 61118001 and 61118002), which were the closest DWER bores to the site that were screened in the superficial aquifer and were accessible for sampling. Water levels were measured from the bores using an electronic dipper and water quality parameters were obtained in the field, including temperature (°C), pH, electrical conductivity (EC) (µS/cm), redox (mV) and dissolved oxygen (DO) (ppm). Once the field parameters had stabilised, water was collected and sent to a NATA accredited laboratory for nutrient suite analysis including total nitrogen (TN), ammonia (NH_4-N), nitrogen oxides (NO_x-N), total kjeldahl nitrogen (TKN), total phosphorus (TP) and filterable reactive phosphorus (FRP). In addition, on the second sampling event in January 2017, the samples were also analysed for a suite of metals including arsenic, cadmium, chromium, copper, nickel, lead, zinc and mercury.

For each of the monitoring events, a surface water sample was also collected from the outlet of the Leschenault Inlet to Koombana Bay. The surface water samples were analysed for the same parameters as the groundwater. The sampling locations and groundwater discharge locations are illustrated in Figure A. Results have been compared to ANZECC (2000) guidelines for in-shore marine waters in south-west Australia.

Figure A DoW Bore Locations and Groundwater Discharge Locations

3 Sampling Results

Groundwater levels and field physico-chemical results are presented as Appendix A, tabulated laboratory results are provided as Appendix B, QA/QC results are provided in Appendix C and the laboratory certificates are included as Appendix D.

Groundwater levels measured from the four DWER bores were generally less than two metres above Australian Height Datum (mAHD).

The pH ranged from slightly acidic (6.6 at 61118001 in October) to slightly alkaline (8.29 at 61118002 in October). The pH measured from 61118002 was considerably higher than for the other sites. This bore is located in the City's depot and site activities may have impacted the pH at this location.

Salinity (calculated from field measured EC) ranged from fresh to saline (~220 to 4,100 mg/L), with the surface water site being hypersaline (27,000 mg/L). As expected, the highest groundwater salinity values were measured from the bore closest to the coast (61118027) at ~4,100 mg/L, and the lowest salinity results were from the bore furthest from the coast (61118001) at 220 mg/L. Redox showed oxidising conditions for all sites.

TP concentrations were below the laboratory limit of reporting (LoR) from 61118001, 61118002 and the surface water site KWS1. TP concentrations were elevated (up to 0.29 mg/L) at the two bores closer to the coast (61118027, 61111506), with the results being above the marine guidelines.

The bioavailable phosphorus component FRP was generally low, but exceeded the guideline for Bore 61118027 (0.05 mg/L) and KWS1 (0.01 mg/L).

TN concentrations were typically above the marine water guideline of 0.23 mg/L, however groundwater quality was similar to existing surface water quality (KWS1), and all samples were <1.0 mg/L for TN.

The bioavailable nitrogen component referred to as Dissolved Inorganic Nitrogen (DIN), consists of NH_4-N plus NOx-N. These components generally exceeded the guidelines, with NH_4-N generally the highest proportion of DIN. The proportion TN that consists of DIN was variable, with DIN forming the largest component for two bores, and organic nitrogen forming the largest component of TN for two bores and the surface water sample.

Total metal concentrations for the January monitoring were mostly below the LoR. However, zinc concentrations were above the guidelines for all sites, with concentrations ranging from 0.016 mg/L (61118002) to 0.849 mg/L (61118027). The sample from 61111506 also had exceedances for copper (0.006 mg/L) and lead (0.005 mg/L).

In summary, groundwater quality is generally good and consistent with the surface water sample collected from the existing marina area. An exception is Bore 61118027 which has elevated zinc and nutrients compared to other sites.

Due to the low inland marine guideline values, the LoR is below the guideline for NH_4-N, NOx-N and FRP. QA/QC results are provided in Appendix C at the end of the report. All QA/QC results had a Relative Per cent Difference (RPD) <50% between the primary and duplicate sample.

4 Estimation of Groundwater Discharge and Nutrient Loading

4.1 Assumptions

The water monitoring information was used to inform groundwater and nutrient discharge into the marina. Information on the local hydrogeological conditions in the vicinity of site is limited, as such the following assumptions have been made:

- Groundwater discharge from the beach at the proposed Casuarina Harbour and Koombana Sailing Club Marina has been calculated from the October 2016 sampling event using Darcy's Law, and adjusted to average monthly rainfall volumes (BoM station No. 009965) to account for seasonal variations in groundwater discharge volumes.
- For Casuarina Point, it was assumed that groundwater flow to the marina is equal to 50% the volume of infiltrated rainfall over the point (Fetter 1994); the monthly average rainfall was adopted for the estimation calculations. A recharge rate of 80% was adopted over the Point.
- Superficial aquifer saturated thickness at the coast is 5 m. This information has been obtained from the geological logs from DoW Bore 61118027, which indicates basalt at approximately six metres below ground level (mbgl). The exact depth to basalt near the proposed marina is unknown.
- A mean sea level of 0 mAHD.
- Both the maximum and average nutrient concentrations recorded from the RPS groundwater sampling were adopted as the source groundwater concentration
  - TN – 0.9 mg/L (average 0.4 mg/L)
  - TP – 0.29 mg/L (average 0.15 mg/L)
  - DIN – 0.63 mg/L (average 0.19 mg/L)
  - FRP – 0.05 mg/L (average 0.025 mg/L).
- The nutrient concentrations of the groundwater outflow from Casuarina Point were assumed to be the same as the groundwater outflow from the beach.

4.2 Groundwater Discharge Calculation

Groundwater discharge from the beach at the proposed marina was estimated using Darcy's Law (refer Equation 1)(Fetter 1994).

4.2.1 Equation 1

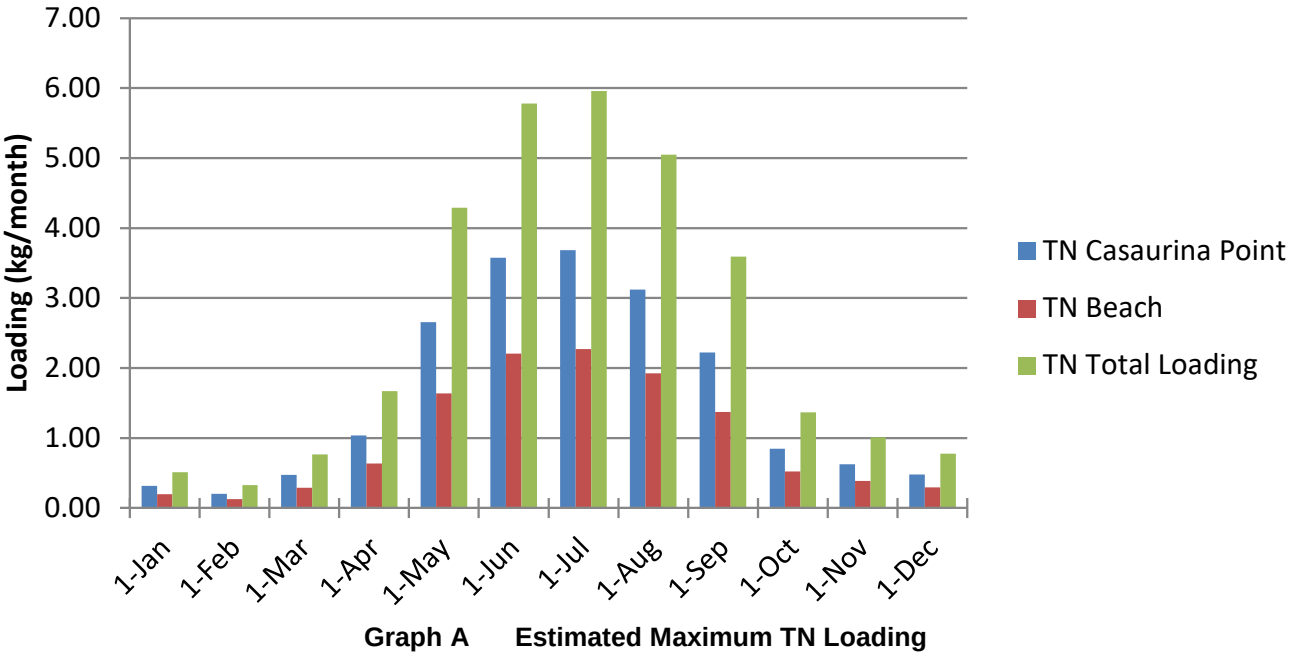
$$Q = KiA$$

Where:
Q is discharge in m³/day
K is the hydraulic conductivity – a value of 15m/day was adopted for the Safety Bay Sands (Davidson 1995).
i is the hydraulic gradient – a value of 7.6×10^{-4} was adopted based on groundwater measurements conducted by RPS in October 2016.
A is the area of discharge, i.e. thickness of aquifer (5 m) × width of discharge area (the beach adjacent to Casuarina Point (≈632 m)

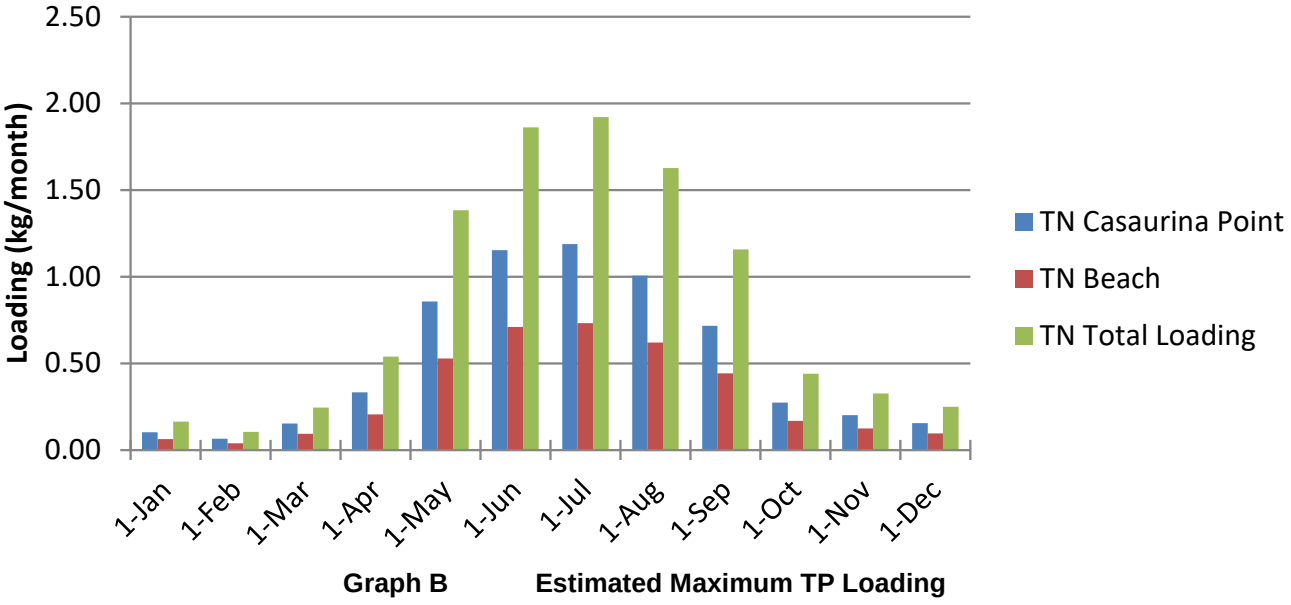
Estimated groundwater discharge is ~21,000 m³/yr from Casuarina Point, ~13,000 m³/yr from the Casuarina Harbour Beach and ~ 4,000 m³/yr from the Koombana Sailing Club Marina Beach (~38,000 m³/yr total). The groundwater discharge volumes are presented in Appendix E.

4.3 Estimated Nutrient Loading to the Proposed Koombana Marina

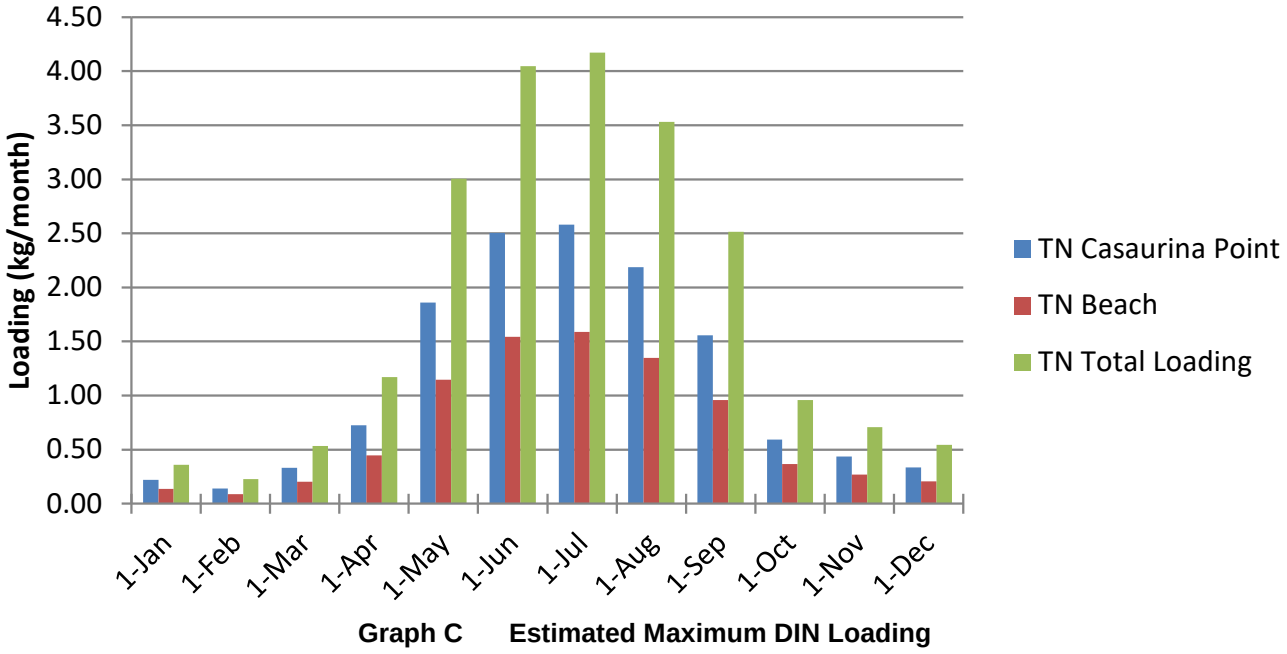
Nutrient loads to the proposed marina are calculated by multiplying groundwater discharge by the nutrient concentration in groundwater. The estimated nutrient loading based on both maximum and average recorded groundwater concentrations is presented in Appendix E. The nutrient loading (kg/month) based on the maximum-recorded groundwater concentrations is presented in Graphs A to D.



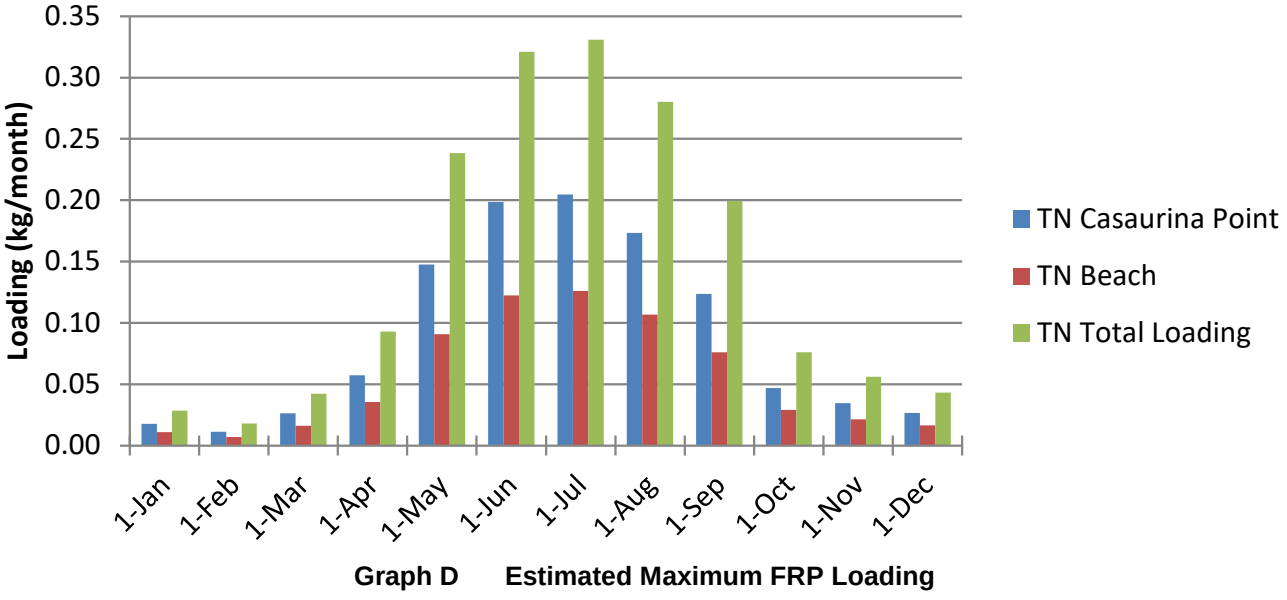
Graph A Estimated Maximum TN Loading



Graph B Estimated Maximum TP Loading



Graph C Estimated Maximum DIN Loading



Graph D Estimated Maximum FRP Loading

The nutrient loading estimations vary throughout the year with rainfall. Utilising maximum measured groundwater concentrations, monthly DIN loading ranges from ~0.8 to 3.3 kg (24 kg/year) while monthly FRP loading ranges from ~0.06 to 0.26 kg (1.7 kg/year). Based on average measured groundwater concentrations, monthly DIN loading ranges from ~0.07 to 1.26 kg (6.6 kg/year) while monthly FRP loading ranges from ~0.01 to 0.17 kg (0.86 kg per year) (Table A).

Table A Nutrient Loading Estimation Summary

Nutrient	Casuarina Harbour Beach		Casuarina Point		Koombana Sailing Club Marina Beach		Total	
	Average loading (kg/yr)	Maximum Loading (kg/yr)	Average loading (kg/yr)	Maximum Loading (kg/yr)	Average loading (kg/yr)	Maximum Loading (kg/yr)	Average loading (kg/yr)	Maximum Loading (kg/yr)
TN	5.26	11.85	8.55	19.24	1.63	3.67	15.45	34.75
TP	1.97	3.81	3.21	6.2	0.61	1.2	5.79	11.2
DIN	2.5	8.29	4.06	13.47	0.77	2.57	7.34	24.32
FRP	0.32	0.65	0.53	1.07	0.1	0.2	0.97	1.93

4.4 Comparison to Previous Rockwater Estimations on Groundwater Flows and Nutrient Loads

Rockwater (2015) previously estimated groundwater flows and nutrient loads to Casuarina Harbour. In their report, Rockwater used the same assumptions for hydraulic conductivity (K) as RPS, with the Superficial sands having a K of 15 m/d. Rockwater calculated the groundwater discharge to Casuarina Harbour to range between 20 m³/d and 40 m³/d (7,300 m³/yr and 14,600 m³/yr).

Rockwater then used a single water sample from DWER bore BY3B (AWRC No. 61118027) and the groundwater discharge calculated above to estimate nutrient loadings to the Harbour. Rockwater estimated TN loadings ranging from 7.3-18.25 kg/yr and TP loadings to range from 0.73-1.83 kg/yr. The TN loadings presented in this report are comparable to those previously provided by Rockwater, while the TP loadings in this report are higher than those calculated by Rockwater. This variability could be attributed to RPS using more than one water quality sample in their nutrient loading calculations.

5 Conclusions and Limitations

This assessment has been undertaken to estimate nutrient loading into the proposed Koombana Bay marine structures. The monitoring program showed that groundwater quality in the closest DoW monitoring bores is generally good and consistent with the surface water sample collected from the existing marina area. An exception is Bore 61118027 which has elevated zinc and nutrients compared to other sites.

The nutrient loading estimations vary throughout the year with rainfall. Based on average and maximum nutrient concentrations measured in groundwater, annual DIN loading rates are estimated to range from 7.3 to 24.3 kg/year) while FRP loading rates are estimated to range from 0.97 to 1.793 kg/year) monthly FRP loading ranges from ~0.06 to 0.26 kg (1.93 kg/year). These loading rates can be used in hydrodynamic modelling to inform the potential impact of groundwater on algal bloom formation.

Due to the paucity of detailed hydrogeological information for the area in the immediate vicinity of the proposed marina, a number of assumptions had to be made to estimate the nutrient loading to the marina. As such there is a degree of uncertainty in the estimated nutrient loading values and the values referenced in this letter should be adopted as an approximation only.

6 References

Rockwater. 2015. Groundwater flows to Casuarina Harbour, Bunbury. Prepared for MP Rodgers

Yours sincerely
RPS

Carl Davies
Principal Hydrogeologist

enc:
- Appendix A: GW Levels and Field Physico-Chemical Results
- Appendix B: Laboratory Results
- Appendix C: GW Quality Control Analysis GW Levels and Field Physico-Chemical Results
- Appendix D: Laboratory Certificates
- Appendix E: Estimated Nutrient Loading

Figures

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LEGEND

- Koombana Bay Marine Structures Proposal Project Area
- Koombana Bay Marine Structures Proposal
- Approved Development

CASUARINA HARBOUR DEVELOPMENT

CASUARINA HARBOUR

KOOMBANA BAY

MARLSTON NORTH MIXED USE PRECICT BY LANDCORP

KOOMBANA BAY SAILING CLUB MARINA

DOLPHIN DISCOVERY CENTRE REDEVELOPMENT

FINGER JETTY

KOOMBANA NORTH MIXED USE PRECICT BY LANDCORP

OPERATIONAL SHIPPING CHANNEL

INNER HARBOUR BASIN

RPS

Job Number: L16056.003
Doc Number: 001
Date: 14.03.17
Scale: 1:10,000 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2016

GDA 1994 MGA Zone 50

0 62.5 125 250 375 500 m

Figure 1

Koombana Bay Marine Structures Proposal

LEGEND

Koombana Bay Marine Structures Proposal Project Area

Koombana Bay Marine Structures Proposal

CASUARINA HARBOUR

KOOMBANA BAY

OPERATIONAL SHIPPING CHANNEL

VITTORIA BAY

INNER HARBOUR BASIN

GEOGRAPHE BAY

LESCHENAULT INLET

61118027

61111506

61118001

61118002

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RPS

Job Number: L16056.003
Doc Number: 002
Date: 14.03.17
Scale: 1:24,000 @ A3
Created by: MA
Source: Orthophoto - Landgate, 2016

GDA 1994 MGA Zone 50

0 125 250 500 750 1,000 m

Figure 2

DoW Bore Locations

Appendix A

GW Levels and Field Physico-chemical Results

Appendix 1

Table 1-1: Groundwater Levels and Field Physio-Chemical Results

Bore ID	Date	DTW (mbtoc)	DTW (mbgl)	GWL (mAHD)	Temp (°C)	pH	EC (µS/cm)	Salinity (mg/L) (Calculated)	Redox (mV-SHE)	DO (ppm)
61118027	31/10/2016	2.59	2.305	-1.242	19.6	7.53	6,910	4,146	218	1.02
	30/01/2017	2.66	2.375	-1.312	21.1	7.3	1,602	961	170	0.98
61111506	31/10/2016	2.38	1.791	0.943	18.4	7.13	1,772	1,063	208	3.2
	30/01/2017	2.74	2.151	0.583	23.8	7.55	2,150	1,290	196	0.02
61118001	31/10/2016	2.97		1.985	19.4	6.6	377	226	116	0.84
	30/01/2017	5.01		-0.055	20.1	7.06	366	220	65	2.09
61118002	31/10/2016	2.91		2.029	20	8.29	871	523	235	0.4
	30/01/2017	5.075		-0.136	21.6	9.1	554	332	89	1.17
KBSW1	31/10/2016	na			18.7	7.73	45,600	27,360	225	7.12
	30/01/2017	na			22.5	7.96	45,100	27,060	191	5.38

Appendix B

Laboratory Results

Appendix 2

Table 2-1: Tabulated Laboratory Analysis Results

Sample ID	Date Sampled	Trigger	Nutrients				
			Ammonia	Nitrogen Oxides	Total Nitrogen	Total Phosphorus	Filtered Reactive Phosphorus
		Marine	0.005	0.005	0.23	0.02	0.005
		LOR	0.01	0.01	0.1	0.01	0.01
		Units	mg/L	mg/L	mg/L	mg/L	mg/L
61118027	31/10/2016		0.63	<0.01	0.9	0.29	0.05
	30/01/2017		0.33	0.02	0.7	0.09	0.05
61111506	31/10/2016		0.03	0.01	0.3	0.16	<0.01
	30/01/2017		<0.01	0.06	0.4	0.07	<0.01
61118001	31/10/2016		0.11	<0.01	0.3	<0.01	<0.01
	30/01/2017		0.06	<0.01	0.3	<0.01	<0.01
61118002	31/10/2016		0.23	<0.01	0.3	<0.01	<0.01
	30/01/2017		0.09	0.02	0.2	<0.01	<0.01
KWS1	31/10/2016		0.12	0.05	<1.0	<0.10	<0.01
	30/01/2017		0.03	<0.01	0.7	<0.01	0.01

Notes:

Marine	Marine Inshore guidelines for South-west Australia (ANZECC 2000)
FWG	Lowland River guidelines for South-west Australia (ANZECC 2000)
LOR	Laboratory Limit of Reporting

Total Metals							
Arsenic	Cadmium	Chromium	Copper	Nickel	Lead	Zinc	Mercury
NG	0.0007	NG	0.0013	0.007	0.0044	0.015	0.0001
0.001	0.0001	0.001	0.001	0.001	0.001	0.005	0.0001
mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
<0.001	<0.0001	<0.001	<0.001	<0.001	0.004	0.849	<0.0001
0.006	<0.0001	0.01	0.006	0.005	0.005	0.017	<0.0001
<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	0.146	<0.0001
<0.001	<0.0001	<0.001	<0.001	<0.001	<0.001	0.016	<0.0001
<0.005	<0.0005	<0.005	<0.005	<0.005	<0.005	0.036	<0.0001

Appendix C

GW Quality Control Analysis GW Levels and Field Physico-chemical Results

Appendix 3

Table 3-1: Groundwater QA/QC Analysis

denotes at or below Limit of Reporting (LoR)

Sample ID	Date	Nutrients					Metal (Dissolved)							
		TP	FRP	TN	NH_4-N	NOx-N	Arsenic (non-speciated)	Cadmium	Chromium (non-speciated)	Copper	Lead	Mercury	Nickel	Zinc
LOR		0.05	0.1	0.005	0.005	0.005	0.001	0.0001	0.001	0.001	0.001	0.00005	0.001	0.001
Duplicates														
61118002	31/10/2016	<0.01	<0.01	0.3	0.23	<0.01								
MBZ		<0.01	<0.01	0.3	0.22	<0.01								
RPD (%)		na	na	0	4	na								
61118001	30/01/2017	<0.01	<0.01	0.3	0.06	<0.01	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.146
MBZ		<0.01	<0.01	0.2	0.06	<0.01	<0.001	<0.0001	<0.001	<0.001	<0.001	<0.0001	<0.001	0.112
RPD (%)		na	na	40	0	na	na	na	na	na	na	na	na	26

Appendix D

Laboratory Certificates

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EP1610350**	Page	: 1 of 5
Client	: **RPS ENVIRONMENTAL BUSSELTON**	Laboratory	: Environmental Division Perth
Contact	: ANGELA FILARDI	Contact	: Luke Jones
Address	: UNIT 1, 8 PRINCE STREET BUSSELTON WESTERN AUSTALIA 6280	Address	: 10 Hod Way Malaga WA Australia 6090
Telephone	: 08 9754 2898	Telephone	: 08 9209 7631
Project	: L1605601	Date Samples Received	: 01-Nov-2016 11:15
Order number	: ----	Date Analysis Commenced	: 04-Nov-2016
C-O-C number	: ----	Issue Date	: 08-Nov-2016 14:32
Sampler	: ANGELA FILARDI		
Site	: Koombana Bay		
Quote number	: ----		
No. of samples received	: 12		
No. of samples analysed	: 12		

Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Greg Vogel	Laboratory Manager	Brisbane Inorganics, Stafford, QLD
Jeremy Truong	Laboratory Manager	Perth Inorganics, Malaga, WA

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When sampling time information is not provided by the client, sampling dates are shown without a time component. In these instances, the time component has been assumed by the laboratory for processing purposes.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EK061G (Total Kjeldahl Nitrogen as N) / EK067G (Total Phosphorus as P): Sample EP1610350-006 (KBSW1) was diluted due to matrix interference. LOR adjusted accordingly.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	61118027	61111506	61118001	61118002	MBZ
				Client sampling date / time	[31-Oct-2016]	[31-Oct-2016]	[31-Oct-2016]	[31-Oct-2016]	[31-Oct-2016]
Compound	CAS Number	LOR	Unit		EP1610350-001	EP1610350-002	EP1610350-003	EP1610350-004	EP1610350-005
					Result	Result	Result	Result	Result
EK055G-NH4: Ammonium as N by DA									
Ammonium as N	14798-03-9_N	0.01	mg/L		**0.63**	**0.03**	**0.11**	**0.23**	**0.22**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	**0.01**	<0.01	<0.01	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**0.9**	**0.3**	**0.3**	**0.3**	**0.3**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ **Total Nitrogen as N**	----	0.1	mg/L		**0.9**	**0.3**	**0.3**	**0.3**	**0.3**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.29**	**0.16**	<0.01	<0.01	<0.01
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		**----**	**----**	**----**	**----**	**----**

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)			Client sample ID	KBSW1	61118027	6111506	61118001	61118002
			Client sampling date / time	[31-Oct-2016]	[03-Nov-2016]	[03-Nov-2016]	[03-Nov-2016]	[03-Nov-2016]
Compound	CAS Number	LOR	Unit	EP1610350-006	EP1610350-007	EP1610350-008	EP1610350-009	EP1610350-010
				Result	Result	Result	Result	Result
EK055G-NH4: Ammonium as N by DA								
Ammonium as N	14798-03-9_N	0.01	mg/L	**0.12**	----	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser								
Nitrite + Nitrate as N	----	0.01	mg/L	**0.05**	----	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser								
Total Kjeldahl Nitrogen as N	----	0.1	mg/L	<1.0	----	----	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser								
^ **Total Nitrogen as N**	----	0.1	mg/L	<1.0	----	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser								
Total Phosphorus as P	----	0.01	mg/L	<0.10	----	----	----	----
EK071G: Reactive Phosphorus as P by discrete analyser								
Reactive Phosphorus as P	14265-44-2	0.01	mg/L	----	**0.05**	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	MBz	KBSW1	----	----	----
				Client sampling date / time	[03-Nov-2016]	[03-Nov-2016]	----	----	----
Compound	CAS Number	LOR	Unit		EP1610350-011	EP1610350-012	--------	--------	--------
					Result	Result	----	----	----
EK055G-NH4: Ammonium as N by DA									
Ammonium as N	14798-03-9_N	0.01	mg/L		----	----	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		----	----	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		----	----	----	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ **Total Nitrogen as N**	----	0.1	mg/L		----	----	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		----	----	----	----	----
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		<0.01	<0.01	----	----	----

ALS Environmental

CERTIFICATE OF ANALYSIS

Work Order	: **EP1700931**	Page	: 1 of 4
Client	: **RPS ENVIRONMENT PTY LTD**	Laboratory	: Environmental Division Perth
Contact	: ANGELA FILARDI	Contact	: Luke Jones
Address	: 38 STATION STREET SUBIACO WA, AUSTRALIA 6008	Address	: 10 Hod Way Malaga WA Australia 6090
Telephone	: +61 08 9754 2898	Telephone	: 08 9209 7631
Project	: L16056.003	Date Samples Received	: 31-Jan-2017 10:58
Order number	: ----	Date Analysis Commenced	: 01-Feb-2017
C-O-C number	: ----	Issue Date	: 07-Feb-2017 16:08
Sampler	: ----		
Site	: Koombana Bay		
Quote number	: EN/064/16		
No. of samples received	: 6		
No. of samples analysed	: 6		

ilac-MRA NATA
Accreditation No. 825
Accredited for compliance with
ISO/IEC 17025 - Testing

This report supersedes any previous report(s) with this reference. Results apply to the sample(s) as submitted. This document shall not be reproduced, except in full.

This Certificate of Analysis contains the following information:

- General Comments
- Analytical Results

Additional information pertinent to this report will be found in the following separate attachments: Quality Control Report, QA/QC Compliance Assessment to assist with Quality Review and Sample Receipt Notification.

Signatories

This document has been electronically signed by the authorized signatories below. Electronic signing is carried out in compliance with procedures specified in 21 CFR Part 11.

Signatories	*Position*	*Accreditation Category*
Canhuang Ke	Metals Instrument Chemist	Perth Inorganics, Malaga, WA
Jeremy Truong	Laboratory Manager	Perth Inorganics, Malaga, WA

General Comments

The analytical procedures used by the Environmental Division have been developed from established internationally recognized procedures such as those published by the USEPA, APHA, AS and NEPM. In house developed procedures are employed in the absence of documented standards or by client request.

Where moisture determination has been performed, results are reported on a dry weight basis.

Where a reported less than (<) result is higher than the LOR, this may be due to primary sample extract/digestate dilution and/or insufficient sample for analysis.

Where the LOR of a reported result differs from standard LOR, this may be due to high moisture content, insufficient sample (reduced weight employed) or matrix interference.

When no sampling time is provided, the sampling time will default 00:00 on the date of sampling. If no sampling date is provided, the sampling date will be assumed by the laboratory and displayed in brackets without a time component.

Where a result is required to meet compliance limits the associated uncertainty must be considered. Refer to the ALS Contact for details.

Key : CAS Number = CAS registry number from database maintained by Chemical Abstracts Services. The Chemical Abstracts Service is a division of the American Chemical Society.
LOR = Limit of reporting
^ = This result is computed from individual analyte detections at or above the level of reporting
ø = ALS is not NATA accredited for these tests.
~ = Indicates an estimated value.

- EG020: LOR raised for sample 'KBSW1' due to possible sample matrix interference.

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	61118027	61111506	61118001	61118002	MBZ
				Client sampling date / time	30-Jan-2017 00:00	30-Jan-2017 00:00	30-Jan-2017 00:00	30-Jan-2017 00:00	30-Jan-2017 00:00
Compound	CAS Number	LOR	Unit		EP1700931-001	EP1700931-002	EP1700931-003	EP1700931-004	EP1700931-005
					Result	Result	Result	Result	Result
EG020T: Total Metals by ICP-MS									
Arsenic	7440-38-2	0.001	mg/L		<0.001	**0.006**	<0.001	<0.001	<0.001
Cadmium	7440-43-9	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Chromium	7440-47-3	0.001	mg/L		<0.001	**0.010**	<0.001	<0.001	<0.001
Copper	7440-50-8	0.001	mg/L		<0.001	**0.006**	<0.001	<0.001	<0.001
Nickel	7440-02-0	0.001	mg/L		<0.001	**0.005**	<0.001	<0.001	<0.001
Lead	7439-92-1	0.001	mg/L		**0.004**	**0.005**	<0.001	<0.001	<0.001
Zinc	7440-66-6	0.005	mg/L		**0.849**	**0.017**	**0.146**	**0.016**	**0.112**
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
EK055G-NH4: Ammonium as N by DA									
Ammonium as N	14798-03-9_N	0.01	mg/L		**0.33**	<0.01	**0.06**	**0.09**	**0.05**
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		**0.02**	**0.06**	<0.01	**0.02**	<0.01
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**0.7**	**0.3**	**0.3**	**0.2**	**0.2**
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ Total Nitrogen as N	----	0.1	mg/L		**0.7**	**0.4**	**0.3**	**0.2**	**0.2**
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		**0.09**	**0.07**	<0.01	<0.01	<0.01
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		**0.05**	<0.01	<0.01	<0.01	<0.01

Analytical Results

Sub-Matrix: WATER (Matrix: WATER)				Client sample ID	KBSW1	----	----	----	----
				Client sampling date / time	30-Jan-2017 00:00	----	----	----	----
Compound	CAS Number	LOR	Unit		EP1700931-006	--------	--------	--------	--------
					Result	----	----	----	----
EG020T: Total Metals by ICP-MS									
Arsenic	7440-38-2	0.001	mg/L		<0.005	----	----	----	----
Cadmium	7440-43-9	0.0001	mg/L		<0.0005	----	----	----	----
Chromium	7440-47-3	0.001	mg/L		<0.005	----	----	----	----
Copper	7440-50-8	0.001	mg/L		<0.005	----	----	----	----
Nickel	7440-02-0	0.001	mg/L		<0.005	----	----	----	----
Lead	7439-92-1	0.001	mg/L		<0.005	----	----	----	----
Zinc	7440-66-6	0.005	mg/L		**0.036**	----	----	----	----
EG035T: Total Recoverable Mercury by FIMS									
Mercury	7439-97-6	0.0001	mg/L		<0.0001	----	----	----	----
EK055G-NH4: Ammonium as N by DA									
Ammonium as N	14798-03-9_N	0.01	mg/L		**0.03**	----	----	----	----
EK059G: Nitrite plus Nitrate as N (NOx) by Discrete Analyser									
Nitrite + Nitrate as N	----	0.01	mg/L		<0.01	----	----	----	----
EK061G: Total Kjeldahl Nitrogen By Discrete Analyser									
Total Kjeldahl Nitrogen as N	----	0.1	mg/L		**0.7**	----	----	----	----
EK062G: Total Nitrogen as N (TKN + NOx) by Discrete Analyser									
^ **Total Nitrogen as N**	----	0.1	mg/L		**0.7**	----	----	----	----
EK067G: Total Phosphorus as P by Discrete Analyser									
Total Phosphorus as P	----	0.01	mg/L		<0.01	----	----	----	----
EK071G: Reactive Phosphorus as P by discrete analyser									
Reactive Phosphorus as P	14265-44-2	0.01	mg/L		**0.01**	----	----	----	----

Appendix E

Estimated Nutrient Loading

Attachment 5: Estimated Nutrient Loading to Proposed Marina

Loading Estimates Based on Maximum Nutrient Concentrations

Casuarina Point	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Groundwater Discharge (m^3/month)	352	223	524	1,149	2,951	3,973	4,096	3,469	2,470	941	694	533	21,374
TN Loading (kg/month)	0.32	0.20	0.47	1.03	2.66	3.58	3.69	3.12	2.22	0.85	0.62	0.48	19.24
TP Loading (kg/month)	0.10	0.06	0.15	0.33	0.86	1.15	1.19	1.01	0.72	0.27	0.20	0.15	6.20
DIN Loading (kg/month)	0.22	0.14	0.33	0.72	1.86	2.50	2.58	2.19	1.56	0.59	0.44	0.34	13.47
FRP Loading (kg/month)	0.02	0.01	0.03	0.06	0.15	0.20	0.20	0.17	0.12	0.05	0.03	0.03	1.07
Casuarina Harbour Beach													
Groundwater Discharge (m^3/month)	217	137	323	708	1,818	2,448	2,524	2,138	1,522	580	428	329	13,170
TN Loading (kg/month)	1.01	0.91	1.01	0.97	1.01	0.97	1.01	1.01	0.97	1.01	0.97	1.01	11.83
TP Loading (kg/month)	0.32	0.29	0.32	0.31	0.32	0.31	0.32	0.32	0.31	0.32	0.31	0.32	3.81
DIN Loading (kg/month)	0.70	0.64	0.70	0.68	0.70	0.68	0.70	0.70	0.68	0.70	0.68	0.70	8.28
FRP Loading (kg/month)	0.06	0.05	0.06	0.05	0.06	0.05	0.06	0.06	0.05	0.06	0.05	0.06	0.66
Koombana Bay Sailing Club Marina													
Sailing Club Marina Outflow per month(m^3)	67.2	42.6	100.2	219.5	563.8	759.2	782.7	662.9	472.0	179.7	132.7	101.9	4084.5
TN Loading (kg/month)	0.060	0.038	0.090	0.198	0.507	0.683	0.704	0.597	0.425	0.162	0.119	0.092	3.676
TP Loading (kg/month)	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.0	0.0	1.2
DIN Loading (kg/month)	0.042	0.027	0.063	0.138	0.355	0.478	0.493	0.418	0.297	0.113	0.084	0.064	2.573
FRP Loading (mg/month)	0.003	0.002	0.005	0.011	0.028	0.038	0.039	0.033	0.024	0.009	0.007	0.005	0.204
Total													
Groundwater Discharge (m^3/month)	568	360	848	1,856	4,769	6,421	6,620	5,607	3,992	1,520	1,122	862	38,629
TN Loading (kg/month)	1.32	1.11	1.48	2.01	3.66	4.55	4.69	4.13	3.20	1.85	1.60	1.49	34.75
TP Loading (kg/month)	0.43	0.36	0.48	0.65	1.18	1.47	1.51	1.33	1.03	0.60	0.51	0.48	11.20
DIN Loading (kg/month)	0.93	0.78	1.03	1.40	2.56	3.18	3.28	2.89	2.24	1.30	1.12	1.04	24.32
FRP Loading (kg/month)	0.07	0.06	0.08	0.11	0.20	0.25	0.26	0.23	0.18	0.10	0.09	0.08	1.93

Loading Estimates Based on Average Nutrient Concentrations

Casuarina Point	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Groundwater Discharge (m^3/month)	352	223	524	1,149	2,951	3,973	4,096	3,469	2,470	941	694	533	21,374
TN Loading (kg/month)	0.14	0.09	0.21	0.46	1.18	1.59	1.64	1.39	0.99	0.38	0.28	0.21	8.55
TP Loading (kg/month)	0.05	0.03	0.08	0.17	0.44	0.60	0.61	0.52	0.37	0.14	0.10	0.08	3.21
DIN Loading (kg/month)	0.07	0.04	0.10	0.22	0.56	0.75	0.78	0.66	0.47	0.18	0.13	0.10	4.06
FRP Loading (kg/month)	0.01	0.01	0.01	0.03	0.07	0.10	0.10	0.09	0.06	0.02	0.02	0.01	0.53
Casuarina Harbour Beach													
Groundwater Discharge (m^3/month)	217	137	323	708	1,818	2,448	2,524	2,138	1,522	580	428	329	13,170
TN Loading (kg/month)	0.09	0.05	0.13	0.28	0.73	0.98	1.01	0.86	0.61	0.23	0.17	0.13	5.27
TP Loading (kg/month)	0.03	0.02	0.05	0.11	0.27	0.37	0.38	0.32	0.23	0.09	0.06	0.05	1.98
DIN Loading (kg/month)	0.04	0.03	0.06	0.13	0.35	0.47	0.48	0.41	0.29	0.11	0.08	0.06	2.50
FRP Loading (kg/month)	0.01	0.00	0.01	0.02	0.05	0.06	0.06	0.05	0.04	0.01	0.01	0.01	0.33
Koombana Bay Sailing Club Marina													
Sailing Club Marina Outflow per month(m^3)	67.2	42.6	100.2	219.5	563.8	759.2	782.7	662.9	472.0	179.7	132.7	101.9	4084.5
TN Loading (kg/month)	0.027	0.017	0.040	0.088	0.226	0.304	0.313	0.265	0.189	0.072	0.053	0.041	1.634
TP Loading (kg/month)	0.010	0.006	0.015	0.033	0.085	0.114	0.117	0.099	0.071	0.027	0.020	0.015	0.613
DIN Loading (kg/month)	0.013	0.008	0.019	0.042	0.107	0.144	0.149	0.126	0.090	0.034	0.025	0.019	0.776
FRP Loading (mg/month)	0.002	0.001	0.003	0.005	0.014	0.019	0.020	0.017	0.012	0.004	0.003	0.003	0.102
Total													
Groundwater Discharge (m^3/month)	568	360	848	1,856	4,769	6,421	6,620	5,607	3,992	1,520	1,122	862	38,629
TN Loading (kg/month)	0.23	0.14	0.34	0.74	1.91	2.57	2.65	2.24	1.60	0.61	0.45	0.34	15.45
TP Loading (kg/month)	0.09	0.05	0.13	0.28	0.72	0.96	0.99	0.84	0.60	0.23	0.17	0.13	5.79
DIN Loading (kg/month)	0.11	0.07	0.16	0.35	0.91	1.22	1.26	1.07	0.76	0.29	0.21	0.16	7.34
FRP Loading (kg/month)	0.01	0.01	0.02	0.05	0.12	0.16	0.17	0.14	0.10	0.04	0.03	0.02	0.97