CAIRNCROSS WASTE MANAGEMENT FACILITY - RESPONSE TO SUBMISSIONS REPORT APPENDIX C

ADDENDUM SURFACE WATER AND GROUNDWATER QUALITY ASSESSMENT

06 DECEMBER 2018

Incorporating

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Response to Submissions Appendix C

Addendum Surface Water and Groundwater Quality Assessment

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Report No	001
Date	6/12/2018
Revision Text	2

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REVISIONS

Revision	Date	Description	Prepared by	Approved by
1	10/09/2018	Internal Draft	DJ/LD	CH
2	06/12/2018	Final	DJ/GH	CH

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1 BACKGROUND

1.1 Introduction

Port Macquarie Hastings Council (PMHC) is seeking development approval to extend the Cairncross Landfill to cover the remaining area identified for landfilling in the 1999 Environmental Impact Statement (1999 EIS). The Proposal is for the expansion of the existing landfill at the Cairncross Waste Management Facility (Cairncross WMF), and would involve the progressive construction, operation and rehabilitation of three landfill stages (Stages 1-3) over approximately 36 years. Stage 1 would commence construction/operation in approximately 2019/2020 respectively and Stage 3 would reach capacity in approximately 2056 with a landfill closure period to follow.

An Environmental Impact Statement (EIS) was prepared for the Proposal seeking approval under Part 4, Division 4.7 of the E*nvironmental Planning and Assessment Act 1979* (EP&A Act). In particular, the EIS was prepared to address, and be consistent with, the Secretary's Environmental Assessment Requirements (SEARs) (SSD 13_5792) for the Proposal, which were issued on 7 May 2015.

The EIS was publicly exhibited, in accordance with Clause 83 of the *Environmental Planning and Assessment Regulations 2000* (EP&A Regulations) between 15 February 2018 and 16 March 2018. During this exhibition period submissions were invited from all stakeholders, including members of the community and government agencies. The submissions received included:

- A total of five submissions from government agencies
- One submission from a member of the community.

The submissions received during public exhibition of the EIS form the subject of formal response to submissions (RtS) report. Amendments are now proposed to the Proposal (the Amended Proposal) based on submissions provided by government agencies and the community, as part of design progression, and to provide additional clarity where relevant. A number of submissions received identified potential concerns with the surface water quality and trigger values proposed in the EIS. This report presents an amended technical note to address the management of surface water and justification of the chosen trigger values.

1.2 Objectives

The objective of this technical addendum is to:

- Determine the water quality of the closest monitoring location within the receiving water catchment from existing studies
- Present all available baseline water quality data from the initial baseline Environmental Impact Statement (1999)
- Identify the appropriate water quality objectives (WQO) for the receiving water catchment
- Establish the appropriate trigger values for surface water and groundwater discharges to be protective of the identified WQO
- Identify the likely causes and potential impact of historically detected contaminants within surface water
- Outline the management practices to be adopted to reduce the potential for surface water to be contaminated with leachate during future landfilling activities.

1.3 Key Features of Landfill

Item	Description
Waste input	General solid waste, including putrescible and non-putrescible materials and asbestos from domestic, commercial and industrial source.
Landfilling lifetime	Stages 1 to 2 are expected to be filled within 36 years commencing 2019/2020. While stage 3 is expected to each capacity in approximately 2056.
Nearest Surface Water Features	The upper reaches of Rawdon and Tommy Owers Creek which are tributaries of Hastings River. Both Creeks run through mainly freshwater forested areas until they discharge into brackish estuaries of the Hasting River.
Surrounding topography	The Cairncross Landfill Site is located approximately 10 km northwest of Port Macquarie within the Cooperabung State Forest. The Landfill Site is located within the eastern foothills of the State Forest covering the elevated ridge and a sloping area to the east. The State Forest bounds the Landfill Site to the north and east, while the Rawdon Creek Nature Reserve lies to the south.
Geometry of void	The geometry of the void is trapezoidal in shape with the northern boundary abutting the existing closed landfill. The expansion area is split into three stages (1 through to 3). Each stage has the following areas and total landfill void volume: • Stage 1: 79,453 m^2 and 1,610,290 m^3 • Stage 2: 105,840 m^2 and 1,005,030 m^3 • Stage 3: 161,894 m^2 and 1,490,289 m^3

2 EXISTING ENVIRONMENT

A summary of the relevant surface water and hydrogeology is presented below. Chapter 8.4 of the EIS (2017) provides further details of the existing surface water environment and Appendix F provides a detailed hydrogeological assessment.

2.1 Surface Water

2.1.1 Drainage and topography

The Amended Proposal Site drains via two ephemeral watercourses; one flows directly to Rawdon Creek and the other flows into Tommy Owens Creek which is a tributary of Rawdon Creek. Rawdon Creek flows through mainly forested areas and forms part of the Hastings River catchment. Rawdon Creek is located approximately two kilometres (km) to the south of the Amended Proposal Site and the Hastings River is located approximately six km to the south-east of the Amended Proposal Site.

The overall drainage and topography of the Amended Proposal Site itself is shown in Figure 2-1. The existing capped and grassed landfill area (Stage E) generally drains to the west and north via ephemeral gullies C and D. Once completed, the eastern corner of Stage E would drain to the existing firefighting storage and then into ephemeral gully B (PMHC, 2016). The Stage E operational area drains to Sediment Basin A which in turn discharges to ephemeral gully A.

To the south are the future landfill areas which slope to the south and south-east and are drained by ephemeral gullies A and B. Gullies A and B both drain to Rawdon Creek via ephemeral watercourses and join approximately two kilometres to the south of the Cairncross WMF (PMHC, 2016). Site slopes are generally in the range of one per cent to ten per cent. The majority of the Amended Proposal Site is currently vegetated.

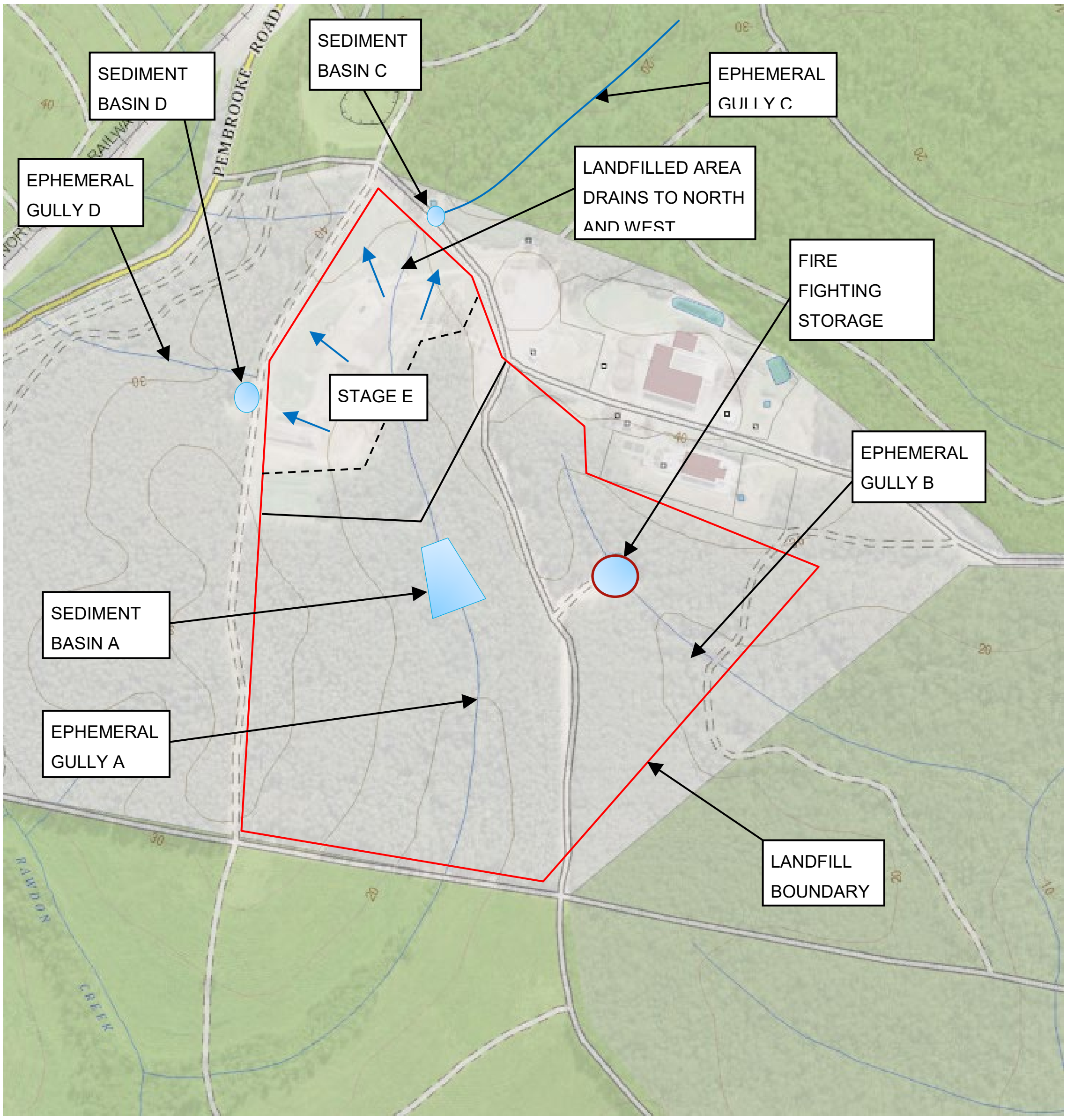


Figure 2-1 Site drainage and topography (Six Maps, 2016) (PMHC, 2016)

2.2 Local Climate

The *Hastings River Flood Study* (Patterson Britton & Partners, 2006) identifies the lower tributaries of Rawdon Creek as affected by flooding from the Hastings River during a 100 year average recurrence interval (ARI) flood event and Probable Maximum Flood (PMF). This flooding occurs approximately two km downstream of the Amended Proposal Site and as such the Amended Proposal Site is considered flood free from river flooding (PMHC, 2016).

2.3 Local Climate

The Port Macquarie-Hastings area has a warm temperate climate with warm wet summers and mild dry winters. The closest historical rainfall gauge is located at Farawells Road, Telegraph Point (Bureau of Meteorology (BOM) Station 60031). The average annual rainfall for this gauge is 1,317 millimetres (mm). Mean monthly rainfall graphs are available in Section 8.4.1 of the EIS.

2.4 Geology

According to the current 1:250 000 Hastings geology map, the Landfill Site is underlain by Lower Permian Beechwood Beds comprising sandstone, siltstone, and mudstone (NSW Geological Survey, 1966). The Beechwood Beds are described as fissile blue grey mudstone and quartz-mica sandstone

The Port Macquarie Area coastal quaternary geology map 1:100 000 (Troedson and Hashimoto, 2005) identifies Carboniferous and Permian rock in the Project area.

Several boreholes have been completed across the Amended Proposal site and surrounding area. Three main geological units are identified within the Amended Proposal Site, generally:

- **Clay:** Clay/colluvium comprising silty medium to high plasticity clay:
  - The clay layer is discontinuous across the site with greater thickness in the valleys and lesser thickness at the ridges
  - The clay layer is reported to extend in several metre-wide strips in the northwest-southeast direction, varying in thickness from 1 to 5 m, or is absent.
- **Weathered Siltstone**:
  - The boundary between the weathered unit and underlying Fractured Shale depends on the depth and thickness of the overlying cover sediments.
- **Shale:** Fractured rock represented by shale:
  - The Shale unit occurs predominately as fresh rock, but is less competent in the upper section
  - The fractured rock is likely to be jointed and the presence of these joints may enhance permeability.

There are also minor areas of alluvium onsite. The alluvium is reported to be of very limited spatial extent and is associated with Rawdon Creek (which is oriented north-south to the west of the current landfill area).

2.5 Hydrogeology

A summary of the relevant site hydrogeology as presented below and a detailed hydrogeological assessment report within Appendix F of the EIS.

2.5.1 Local Hydrogeology

The Amended Proposal site has been defined by two distinct hydrogeological units:

- **Clay/colluvium:** spatially discontinuous comprising silty medium to high plasticity clay:
  - Reported as a discontinuous clay sequence 2-5 m thick, varying in thickness from 2 m at the ridges to 5 m in the valleys
  - There are no bores installed in the overlaying clay layer as its thickness is not consistent and its spatial extent does not extend across the site
  - Constant head permeability test reported an average permeability of 4×10^{-10} m/s This low permeability may indicated the clay is not an aquifer and is only influenced by groundwater from the deeper geological units.
  - Its major characteristic is the retardation of recharge to the underlying aquifer.

- **Weathered and fractured rock:** associated with siltstone and shale:
  - The overlying clay is underlain by a 4-5 m thick weathered siltstone, which is sequentially underlain by fractured shale bedrock.
  - The hydrographs of groundwater elevations from coupled bores screened in weathered rock and fractured rock generally show very similar response to climate events and negligible difference in groundwater head. Furthermore, the geochemical composition of the two water bearing zones are generally similar, being sodium chloride dominant. These findings suggest that shallower weathered rock and deeper fractured rock are highly connected and therefore have been treated as a single hydrostratigraphic unit
  - Site specific testing reported an average hydraulic conductivity $3x10^{-7}$ m/s
  - Reported to be unconfined in the crests/ridges and confined in the slopes/valley floors (as a result of topography with the generally increasing clay overburden occurrence).

Groundwater recharge occurs via minor seepage through the clay or lateral flow through the shale/siltstone unit.

2.5.2 Regional Hydrogeology

Appendix F of the EIS reported that there are ten registered groundwater bores within three km from the Amended Proposal Site, all of which are located at distances greater than approximately two km from the Amended Proposal Site.

The bores are installed to depths ranging from 23 to 67 m and their purpose is mainly water supply. All bores are installed in hard rock aquifers either shale or basalt, with the yield ranging from 0.5 to 2.5 L/s. The water quality is fresh to slightly saline to brackish, ranging from 700 to 2500 mg/L

2.6 Piezometric Surface and Flow Direction

The groundwater monitoring network comprises nine monitoring points across the existing landfill site and within the Amended proposal site. The monitoring network includes standpipe monitoring bores installed in the upper weathered and lower fractured rock horizon of a fractured rock hydrostratigraphic unit.

Table 2-1: Summary of Monitoring Bore Construction Details (Trace Environmental 2016)

Monitoring Bore	Depth (mbgl)	Hydrostratigraphic Unit	Groundwater Head (mbgl) Sept 2015	Comment
CG102	21.41	Fractured rock	7.78	
CG103	11.56	Weathered horizon	10.11	
CG104	24.15	Fractured rock	3.26	Nested/Coupled Wells
CG105	9.85	Weathered horizon	3.31	
CG106	26.49	Fractured rock	4.05	
CG107	30+	Fractured rock	3.34	
CG108	30+	Fractured rock	2.78	
CG109	26.19	Fractured rock	7.93	Nested/Coupled Wells
CG110	12.44	Weathered horizon	6.57	

Historically, groundwater heads/pressures ranged from 2.8 mbgl in CG108 to just over 10 mbgl in CG103.

Deepest piezometric heads are found at the ridges and the shallowest in the low lying areas. Therefore, at the ridges the fractured rock hydrostratigraphic unit is unconfined and within the low lying areas it is confined with groundwater head above the top of the hydro-stratigraphic unit. The confinement is a result of topography with the generally increasing clay overburden occurrence in the valleys.

The flow in the fractured rock unit appears to follow the topography, with flow from elevated areas in the north and west to low lying areas in the south, southwest and southeast towards the Hastings River.

The hydraulic gradient is relatively steep (1 m fall over 50 m). Based on the hydraulic conductivity, gradient and estimated shale porosity of 10 per cent; the average groundwater velocity is approximately 0.0008 m/day.

3 EXISTING WATER QUALITY

This section provides a summary of the surface and groundwater quality for the Amended Proposal Sites' receiving catchments as well the localised water quality at the Amended Proposal site.

3.1 Surface Water Quality

Surface water quality has been considered for the receiving catchments; the Hastings and Camden Haven Catchments, as well as the localised surface water quality at the Amended Proposal Site. Water quality has been determined based on the following key information sources:

- Catchment wide water quality (summarised in Section 3.1.1) has been determined based on the *Hastings – Camden Haven Ecohealth Project 2015: Assessment of River and Estuarine Condition. Final Technical Report* (Ryder et al. 2015).
- Water quality at the Amended Proposal Site has been determined based on available data sourced from the:
  - The 1999 Environmental Impact Statement (1999 EIS) (refer Section 3.1.2 and Section 3.2.1)
  - The Environment Impact Statement (2017) (the EIS) prepared for the Proposal (refer Section 3.1.3 and Section 3.2.2)
  - Subsequent water quality monitoring conducted by PMHC.

This section also summarises the findings of an investigations into historic detection of leachate within surface waters (Section 3.1.4). The purpose of this investigation was to determine the likely cause of the detected contaminants, the potential risk of harm to the environment as a result of the detected contaminants, and to ascertain potential for similar future occurrences.

3.1.1 Hastings and Camden Haven Catchments water quality

PMHC commissioned an Assessment of River and Estuarine Conditions of the Hastings and Camden Haven Catchments, referred to as the *Hastings – Camden Haven Ecohealth Project 2015: Assessment of River and Estuarine Condition*, dated 2017. A full citation of this report is provided in Section 6 of this report.

The Ecohealth (2017) report was prepared in response to the NSW Government Natural Resource Commission standard and targets that were adopted in August 2006. These studies form part of the NSW Natural Resources Monitoring Evaluation and Reporting (MER) program currently monitoring NSW estuaries and coastal rivers on either a bi- or triannual basis. The purpose of the MER framework is to allow local authorities, government agencies and private industry to establish a system of monitoring, evaluation and reporting of natural resource (waterways) conditions.

A summary of the Riparian Condition and Water Quality of the Hastings and Camden Haven Catchments as assessed in the Ecohealth (2017) report relevant to the subject site are provided below:

- *The 2015 Ecohealth score for riparian condition in the Hastings-Camden Haven Catchment was 65.9, a grade of C. The majority of Ecohealth sites contributing to this riparian condition grade were representative of the area of the Catchment that has been subjected to broadscale landuse and anthropogenic impact. The Hastings-Camden Haven Catchment was therefore assessed as moderately disturbed.*

- *Areas of moderate riparian condition were generally those areas of the Catchment that had been partially cleared of vegetation and subjected to long-term landuse yet retained remnant riparian vegetation, such as upland freshwater reaches and estuaries surrounded by low lying floodplains.*
- *The main stressors to riparian condition included historic clearing of vegetation resulting in isolation from larger patches of remnant vegetation and promotion of weed establishment due to site disturbance, the dominance and regeneration of invasive weed species particularly in the mid-storey and understory structural layers, trampling and grazing of riparian vegetation by livestock and a reduction in large woody debris.*
- *Water quality generally declined in freshwater and estuarine reaches of the Hastings and Camden Haven Rivers from an average grade of C+ in 2011, to C- in 2014-15.*
- *The poorest water quality in both river systems was recorded from the sites closest to the tidal limit, highlighting their role as depositional environments for both freshwater and estuarine contaminants.*
- *Water quality scores declined due to persistently elevated nutrient levels, especially TN and NOx, with exceedances of TN in the estuaries more than 50% of the time and exceedances of NOx in the estuaries more than 75% of the time. There was no consistent longitudinal pattern throughout systems of increasing nutrient concentrations with distance downstream.*
- *Observed increases in nutrient concentrations and pH, and reduced dissolved oxygen, which contributed to a change in condition and subsequent decline in water quality from 2011 to 2014-2015, may have been due to prolonged periods of low flow. This suggests that localised sources of nitrogen and phosphorus are regulating nutrient processes, as low flow conditions were experienced throughout the Catchment during much of the 2014-15 study period.*

3.1.2 Baseline Surface Water EIS (1999)

Baseline surface water monitoring, summarised in the 1999 EIS, was conducted at seven (7) locations throughout the receiving water catchment. Figure 3-1 presents the approximate locations of the samplings points. Following review of the water quality data (1999 EIS) it is apparent that the monitoring occurred across two different receiving water types. Sampling locations 1 through to 4 (inclusive) are classified as a marine/brackish ecosystem while sites 5 through to 7 (inclusive) are classified as freshwater streams. The marine water sampling sites are also within the tidal limits of the Hastings River and therefore, to avoid biases in the data, the two systems has been presented separately. This data is presented in Table 3-1 and Table 3-2.

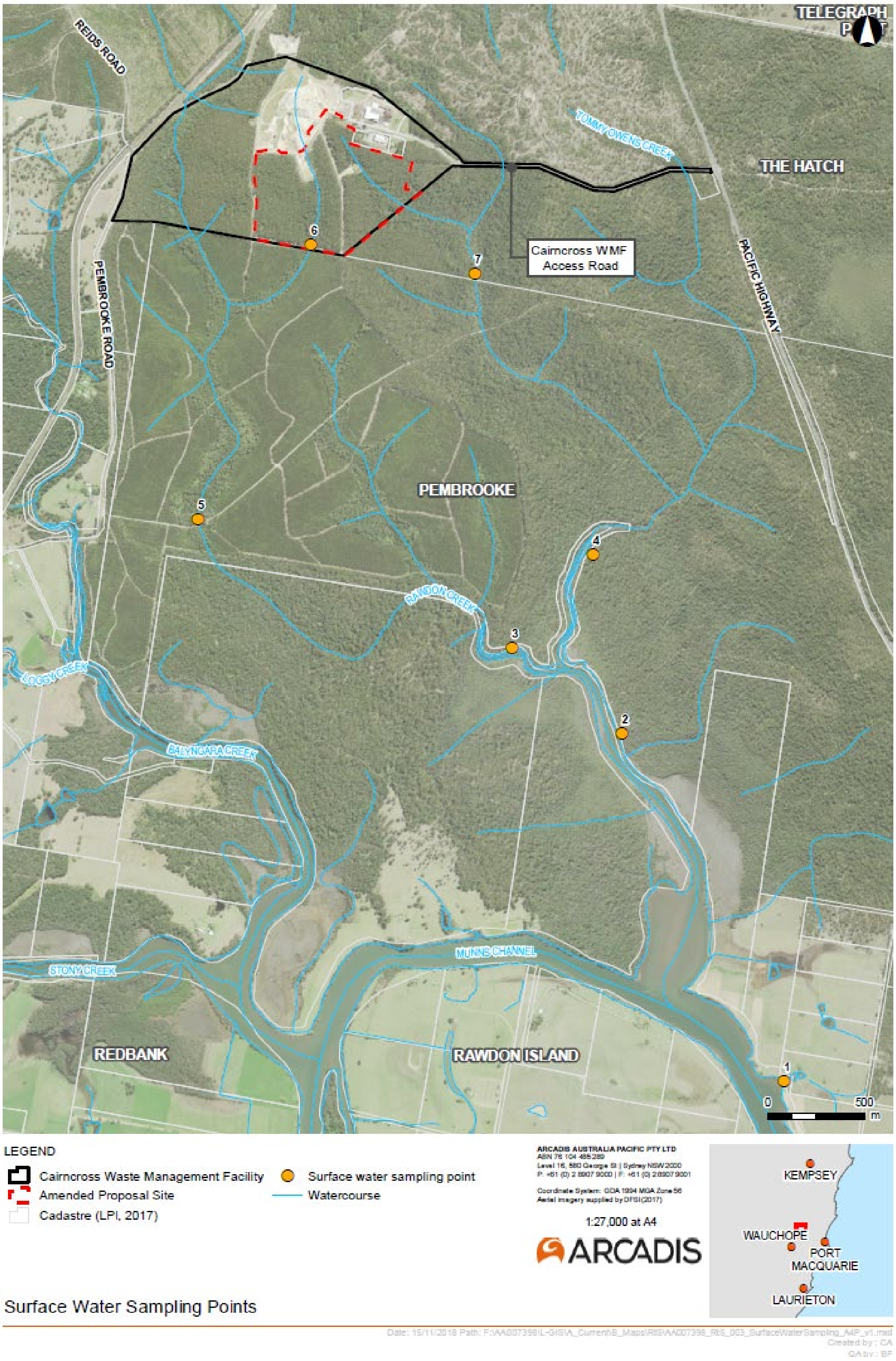


Figure 3-1 Surface water monitoring locations

Table 3-1 Summary of Marine Water Baseline Data EIS (1999)

Parameter	Units	Rounds of Sampling	Average	Minimum*	Maximum	Median
pH	-	3	7.4	6.93	7.95	7.43
Electrical conductivity	uS/cm	3	22720	10120	35500	23050
Turbidity	N.T.U	1	6.325	2.4	13.7	4.6
Temp	C	1	18.0	16.81	19.46	17.83
Salinity	ppt	1	16.98	14.04	22.38	15.75
ORP	mV	1	125.25	58	176	133.5
TDS	mg/L	3	12844	4260	26500	12400
TSS	mg/L	3	66.8	35	114	67
Calcium	mg/L	3	133.1	49	269	128.5
Magnesium	mg/L	3	404.4	142	809	390
Sodium	mg/L	3	3557.5	1290	7800	3505
Potassium	mg/L	3	136	50	298	135.5
Alkalinity (CaCO3)	mg/L	3	58.1	32	90	53
Sulphate	mg/L	3	116601	6	1390983	679
Chloride	mg/L	3	6347	2290	13500	6285
Iron	mg/L	3	0.45	0.2	0.7	0.45
Manganese	mg/L	2	0.0815	0.051	0.113	0.0775
Fluoride	mg/L	3	0.43	0.2	1	0.4
Ammonia as N	mg/L	3	0.046	0.02	0.07	0.04
Nitrate as N	mg/L	3	0.081	0.03	0.26	0.06
TOC	mg/L	3	15.1	6	34	12.5
BOD	mg/L	3	8.0	2	16	6
Phenols	mg/L	3	2.0	1	3.6	1.6
Absorbable Organic Halogens	ug/L	3	126.3	56	240	105

* Minimum detection, refer to Appendix A for Non-detect results

Table 3-2 Summary of Freshwater Baseline Data EIS (1999)

Parameter	Units	Rounds of Sampling	Average	Minimum	Maximum	Median
pH	-	3	6.5	5.1	8.3	6.3
Electrical conductivity	uS/cm	3	122.7	33.2	253	93.1
Turbidity	N.T.U	1	40	12.1	54	53.9
Temp	^{0}C	1	13.32	12.33	13.84	13.79
Salinity	ppt	1	0.25	0.15	0.3	0.3
ORP	mV	1	203.7	172	225	214
TDS	mg/L	3	561.1	108	3350	198
TSS	mg/L	3	47.6	15	100	40
Calcium	mg/L	3	2	1	3	2
Magnesium	mg/L	3	2.375	1	4	2.5
Sodium	mg/L	3	15.7	12	22	14
Potassium	mg/L	3	1.9	1	4	2
Alkalinity (CaCO3)	mg/L	3	7.4	3	17	6
Sulphate	mg/L	3	4.3	3	8	3.5
Chloride	mg/L	3	25.3	15	46	18
Iron	mg/L	3	1.03	0.5	3.4	0.8
Manganese	mg/L	2	0.036	0.021	0.057	0.0345
Fluoride	mg/L	3	0.10	0.1	0.1	0.1
Ammonia as N	mg/L	3	0.020	0.01	0.03	0.02
Nitrate as N	mg/L	3	0.064	0.02	0.14	0.06
TOC	mg/L	3	29.2	19	40	29
BOD	mg/L	3	8.9	2	18	6
Phenols	mg/L	3	3.0	3	3	3
Absorbable Organic Halogens	ug/L	3	121.4	68	197	110

Note: Due to the ephemeral nature of some sampling locations not all parameters were able to be tested

Refer to Appendix A for a summary results table of individual sites monitoring during the initial EIS (1999).

3.1.3 Surface Water Quality EIS (2017)

Baseline surface water quality from two locations CS8A and CS9 were collected by PMHC generally on a quarterly basis over a period between September 2001 and March 2017. The location of the surface water sampling points are provided in Figure 3-2 and a summary of the data is provided in Table 3-3.

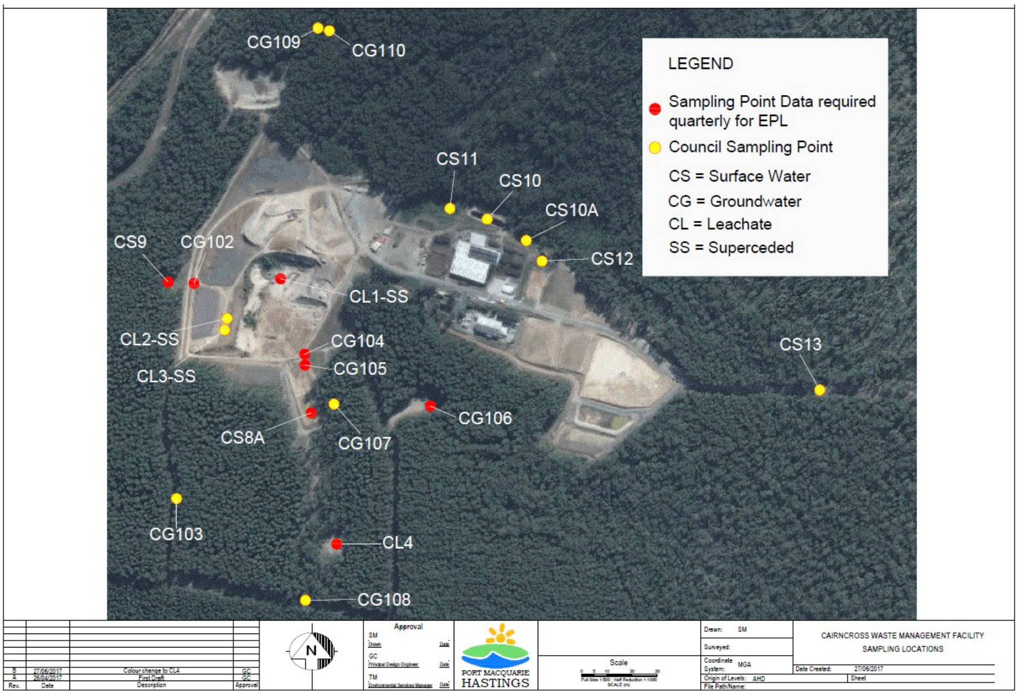


Figure 3-2 PMHC Water Sampling Locations EIS 2017

Compared to the locations sampled in the 1999 EIS this data set has greater temporal coverage but less spatial coverage of the catchment. Direct comparison to the 1999 EIS data set would therefore not be appropriate. A more appropriate comparison has therefore been provided against *The Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ, 2000) (ANZECC Guideline) values for 95 per cent protection of freshwater species (ANZECC limits). Further justification for direct assessment against the ANZECC limits is provided in the subsequent sections of this report.

Table 3-3 Summary of Surface Water Results between 2001 and 2017 EIS (2017)

Parameter	Units	ANZECC Freshwater 95%	min	max	average	median
pH	pH Units	**6 - 8.5**	4.55	8.53	6.90	7.0
Electrical Conductivity	uS/cm		55	6900	1031.07	609.0
Suspended Solids	mg/L		5	11100	531.16	154.5
Calcium (dissolved)	mg/L		1	288	31.59	15.5
Magnesium (dissolved)	mg/L		1	120	13.80	6.0
Sodium (dissolved)	mg/L		9	1880	175.64	56.5
Potassium (dissolved)	mg/L		1	656	59.00	20.0
Alkalinity ($CaCO_3$)	mg/L		1	889	92.18	10.5
Sulfate as SO_4	mg/L		3	124	41.74	33.3
Chloride	mg/L		11	1910	219.58	90.1
Iron (dissolved)	mg/L		0.01	11.8	1.45	0.6
Manganese (dissolved)	mg/L	**1.9**	0.008	0.929	0.15	0.1
Fluoride	mg/L		0.03	1.31	0.16	0.1
Ammonia as N	mg/L	**0.9**	0.01	146	5.80	0.2
Nitrite as N	mg/L		0.01	0.07	0.03	0.02
Nitrate as N	mg/L	**0.7**	0.01	228	7.73	0.2
Nitrite and Nitrate as N	mg/L		0.73	1.43	1.20	1.3
Total Anions	mg/L		1.83	4.84	2.97	2.6
Total Cations	mg/L		1.75	5.19	3.14	2.8
Ionic Balance	unitless		3.5	3.5	3.50	3.5
Total Organic Carbon	mg/L		1	660	87.82	17.5
Phenols	mg/L	**0.32**	0.05	2.29	0.32	0.1
Absorbable Organic Halogens (ug/L)*	ug/L		1.16	50.00	31.52	32.00

* CS9 was monitored on 14 occasions only between 2001 and 2004.

In addition to the data provided above analysis for total fumigants, total halogenated aliphatic hydrocarbons, total halogenated aromatic hydrocarbons and total trihalomethanes was conducted for a period between 2004 and 2015. All results collected during this period were reported at non-detect.

3.1.4 Previous Leachate Outflow Event

Between June 2009 and February 2010 there were spikes in the ammonia, nitrate and phenols within the site surface water dams, indicating leachate may have entered the dams. Following discussion with PMHC it was concluded the likely cause of the spike in nitrate, ammonia and phenols was previous site management practices which may have resulted in the surface water sampling locations inadvertently receiving leachate. The specific cause is un-known however it was likely to be related to the management of the leachate recirculation system at the time. This caused leachate to pond around the infiltration wells and potentially run-off into the site stormwater dams.

Between September 2010 and December 2011 site management practices were reviewed and improved to prevent leachate from entering the surface water system. This included improvement in the monitoring and operation of the existing leachate extraction and re-circulation system. The improvements included the pump-out of excess leachate by a liquid waste contractor and lawful offsite disposal to ensure the re-circulation system does not pool leachate. In addition to these improvements further modifications to the existing leachate collection system will connect the existing landfill stage (E) directly to the STP.

Following implementation of the management improvements concentrations of ammonia, nitrate and phenols at CS8A and CS9 all reduced to levels within the ranges reported prior to the identified elevated levels. The concentrations have remained at background (pre-event) levels since November 2011. This suggests the management improvements were successful at preventing the leachate entering the surface water dams.

Risk of Harm to the Environment

The overall risk of harm to the environment based on the historical leachate event is considered low. Note that the leakage event occurred some years ago and therefore the following points are based on anecdotal evidence and most likely case:

- The receiving environment of the leaked leachate was most likely limited to the onsite sediment dams. If there was a discharge from the dams then the receiving environment would have included the ephemeral creeks and gullys (Rawdon and Tommy Owers Creek) immediately down gradient of the site.
- There is no evidence within the monitoring record to suggest the dams were discharged through the period of September 2010 and December 2011. The leachate was therefore contained onsite within the dams. Therefore it is unlikely there was a significant contaminant load discharged from the site.
- Dam water was re-used onsite for dust suppression and operational uses and therefore was unlikely to have been discharged offsite to the ephemeral creeks.
- If the dams did overtop the discharge would have significant flow path before reaching a surface water body. It is estimated that the ephemeral flowpath is likely to be greater than one km in length. This distance would provide a large area that would allow the water and, if present, leachate to infiltrate into the soils where it is likely to attenuate (though plant uptake) or naturally degrade within the shallow aerobic soils.
- The risk to human health is considered low. The site is an operational landfill and access is restricted that will prevent the public entering the dams. The water is not re-used for potable or grey-water purposes. Given the low flow rates associated with the ephemeral gullies, these areas are not expected to be directly used for recreational swimming, however they may be used as recreational walking tracks during dry spells.

3.2 Groundwater

Baseline groundwater quality data was collected and reported in the 1999 EIS and the EIS (23017) for the Proposal. A summary of groundwater quality is presented below.

3.2.1 Baseline Groundwater EIS (1999)

Baseline groundwater monitoring was conducted at three (3) locations within the Amended Proposal Site across one sampling event. Figure 3-3 presents the approximate locations of the samplings points. Review of data indicates background concentrations of dissolved metal species, absorbable organic halogens (AOX), fluoride and ammonia are present. The concentrations are typical of a shale bedrock system. The presence of ammonia in background groundwater samples is likely due to the deposition of organic matter within the shale which decomposes under anaerobic conditions creating ammonia. A by-product of this decomposition can include, AOX compounds and ammonia.

Since only one round of groundwater monitoring was completed prior to operation of the landfill a true baseline data-set is not available. Table 3-4 presents all available baseline (1999 EIS) groundwater data.

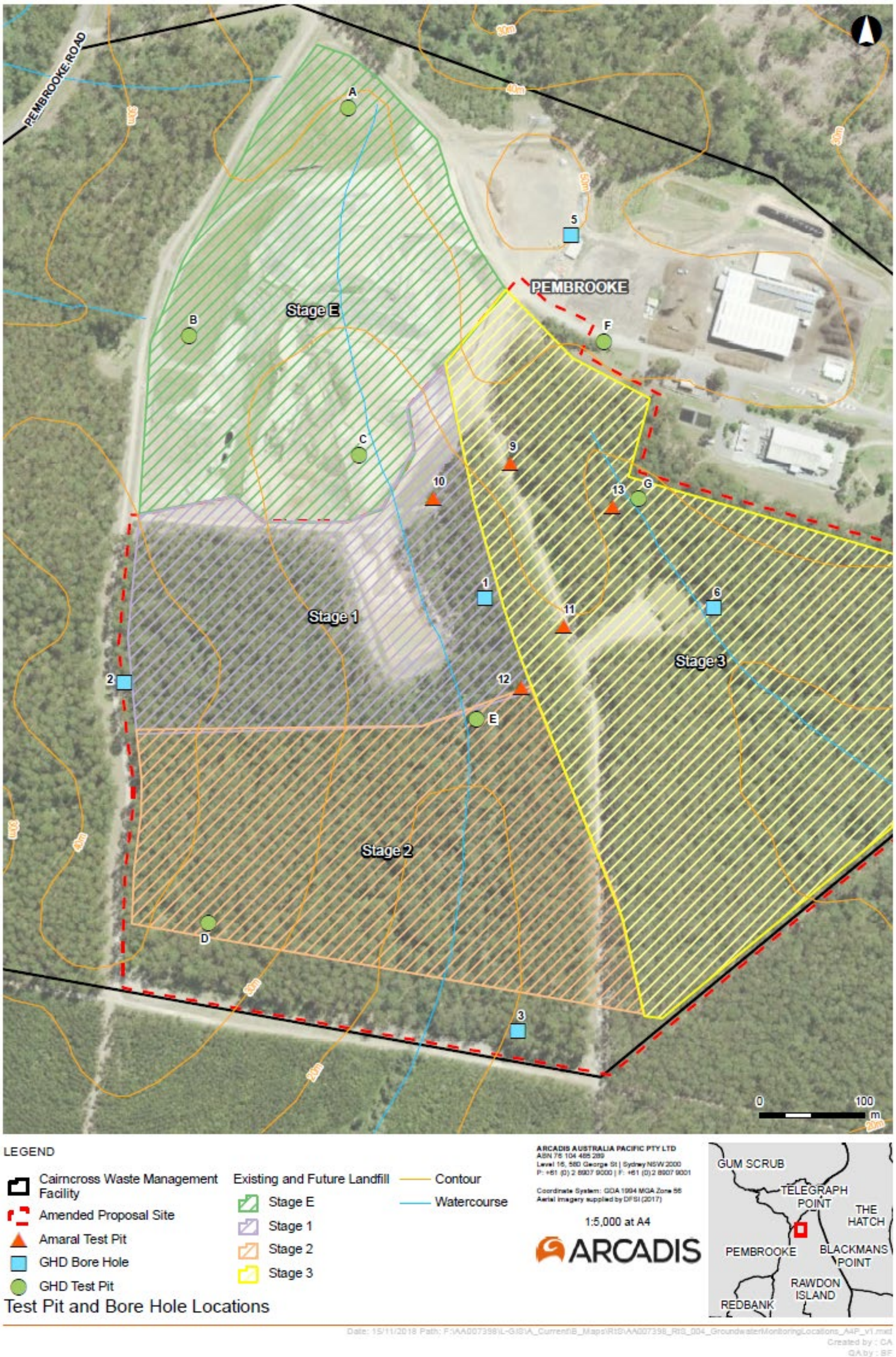


Figure 3-3 Groundwater monitoring locations 1999 EIS

Table 3-4 Summary of Baseline EIS (1999) Groundwater Results

		ANZECC 2000 95% Freshwater	BH1	BH3	BH6 Sample A	BH6 Sample B	Average	Min	Max	Median
pH	pH units		7	7.1	6.6	6.6	6.83	6.60	7.10	6.80
Total Phenols	mg/L	**0.32**	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Iron	mg/L		1.6	34	3.8	3.7	10.78	1.60	34.00	3.75
Manganese	mg/L	**1.9**	0.79	1.4	0.54	0.53	0.82	0.53	1.40	0.67
Sodium	mg/L		420	390	260	265	333.75	260.00	420.00	327.50
Potassium	mg/L		4.5	1.9	1.8	2.9	2.78	1.80	4.50	2.40
Calcium	mg/L		200	80	80	0.2	90.05	0.20	200.00	80.00
Magnesium	mg/L		150	46	46	0.4	60.60	0.40	150.00	46.00
Ammonia	mg/L	**0.9**	0.9	1.6	<0.1	<0.1	1.25	0.90	1.60	1.25
Chloride	mg/L		770	1020	480	490	690.00	480.00	1020.00	630.00
Alkalinity	mg/L		330	210	200	2	185.50	2.00	330.00	205.00
Sulphate	mg/L		150	170	55	60	108.75	55.00	170.00	105.00
Nitrate	mg/L	**0.7**	<0.1	<0.1	<0.1	<0.1	ND	ND	ND	ND
Fluoride	mg/L		0.2	<0.1	0.4	0.3	0.30	0.20	0.40	0.30
AOX	ug/L		6	4	7	N/T	5.67	4.00	7.00	6.00
TOC	mg/L		48	6.8	3.9	N/T	19.57	3.90	48.00	6.80

3.2.2 Groundwater Quality Post Stage E

Groundwater monitoring was conducted at four (4) locations within the Amended Proposal Site between 2001 and 2017. Figure 3-2 presents the approximate locations of the sampling points inclusive of CG102, CG104, CG105 and CG106. Review of data indicates background concentrations of dissolved metal species, absorbable organic halogens (AOX), fluoride and ammonia are present. The concentrations are typical of a shale bedrock system. The presence of ammonia in background groundwater samples is likely due to the deposition of organic matter within the shale which decomposes under anaerobic conditions creating ammonia. A by-product of this decomposition can include, AOX compounds and ammonia.

A summary of the groundwater quality results from the four sampling locations, is provided in Table 3-5. Note that the dataset has been presented as a whole and not split into differing sampling methods (described below) as was provided in the EIS (2017).

Table 3-5: Ranges of Groundwater Contaminant Quality Measurements

Parameter	Units	ANZECC Freshwater 95%	min	max	average	median
pH	**pH units**	**6 - 8.5**	5.92	7.8	6.7	6.7
Electrical Couctivity	**uS/cm**		314	4140	2412.9	2400
Calcium	**mg/L**		12	80	49.9	54
Magnesium	**mg/L**	**1.9**	8	92	51.0	51
Sodium	**mg/L**		32	650	388.7	394
Potassium	**mg/L**		1	24	3.7	2
Alkalinity	**mg/L**		27	383	243.4	232
Sulfate as SO_4	**mg/L**		15	90	54.5	54
Chloride	**mg/L**		48	1180	615.2	594
Iron (dissolved)	**mg/L**		0.02	16.2	0.9	0.06
Manganese (dissolved)	**mg/L**		0.001	4.32	0.6	0.364
Fluoride	**mg/L**		0.02	1.7	0.6	0.6
Ammonia as N	**mg/L**	**0.9**	0.01	3.08	0.1	0.04
Nitrite as N	**mg/L**		0.01	0.01	0.0	0.01
Nitrate as N	**mg/L**	**0.7**	0.01	1.22	0.2	0.115
Nitrite a Nitrate as N	**mg/L**		0.01	0.9	0.2	0.12
Total Anions	**mg/L**		18	37.8	25.5	25
Total Cations	**mg/L**		19.2	39.3	26.0	25.4
Ionic balance	**unitless**		0.02	11.8	2.5	2.29
Total Organic Carbon	**mg/L**		1	122	5.4	2
Phenols	**mg/L**	**0.32**	0.05	0.42	0.1	0.05

The Hydrogeological Assessment (Trace Environmental, 2016) (Appendix F of the EIS) found that:

> *The groundwater chemistry indicates that a single groundwater type heavy metal and nutrient concentrations below the ANZECC (2000) guideline values for 95% protection of freshwater species. Geochemical characteristics of the clay layer have not been investigated as this layer is spatially discontinuous.*
>
> *The Stage E landfill leachate has an entirely different chemical composition to groundwater with high salinity, high nutrient load and measurable phenol concentrations. Pre-operational baseline data has similar geochemical composition to groundwater collected over the past 15 years. Based on the chemistry of leachate and baseline groundwater data, it is concluded that there is presently no mixing of leachate with groundwater occurring at the site.*

In November 2015, Trace Environmental undertook groundwater monitoring at the Amended Proposal Site for a two-month period. Prior to this the sampling was conducted by PMHC Environmental Laboratory. PMHC identified a change in sampling method from November 2015. Groundwater monitoring data collected at the Amended Proposal site prior to November 2015 had been collected using bailers and with limited or no purging of wells. Data collected by Trace Environmental was obtained using low flow methods, including monitored purging. Sampling of water without purging can result in collection of non-representative samples due to exposure to oxygen within the well resulting in water chemistry changes (pH and dissolved oxygen in particular). This chemistry change directly affects the dissolved contaminants in the water including ammonia and dissolved metals. The use of a bailer to sample can also result in entrainment of colloidal material and the disturbance and oxygenation of the water. Metals and organic compounds bind to colloidal clays and can then be detected in the water analysis giving falsely high concentrations. Volatile contaminants can be lost through the disturbance and oxygenation.

In the majority of wells there is no appreciable difference in reported concentrations obtained using the two methods. In CG107 and CG108 there is a clear increase in the reported ammonia concentration and the salinity corresponding with the sampling method change. In CG108, the salinity measurements went from a consistent 200 μS/cm to around 4,000 μS/cm and the ammonia concentration from 0.1 mg/L or less to approximately 1.4 mg/L. In CG107 the ammonia concentration went from <0.05 mg/L prior to November 2015 to approximately 1 mg/L after, although no change in salinity was reported.

It is considered likely that these two wells may be prone to infiltration from surface water or precipitation and that the historical sampling was not representative of the formation water chemistry. Therefore the more recent measurements should be taken as representative. Note that leachate is discussed in Section 8.5 of Appendix F of the EIS, representative leachate measurements at CL1 indicate ammonia in the leachate (used here as a tracer compound) is typically 1,000 – 1,300 mg/L. Concentrations of ammonia in groundwater in the order of 1 mg/L are not considered indicative of leachate leakage as they represent less than 0.1 per cent of the leachate concentration.

It is further noted that whilst ammonia, albeit at low concentrations, was reported in CG107 and CG108 downgradient of the existing cell, it was not reported at concentrations above 0.1 mg/L in the boundary wells at the cell edge (CG104 and CG105, monitoring data post November 2015). These wells are hydraulically aligned with CG107 and CG108 and would be expected to report similar or higher ammonia concentrations to those observed in downgradient wells if there were a breach of containment. This has not been observed.

4 DISCHARGE WATER TRIGGER VALUES

The following sections outlines the justification and rationale for selection of the default *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ, 2000) (ANZECC Guideline) values for 95 per cent protection of freshwater species (ANZECC limits) trigger values.

4.1 NSW Water Quality Objectives

The NSW Government Water Quality Objectives website is accessible at https://www.environment.nsw.gov.au/ieo/ and describes them as follows.

The NSW Water Quality Objectives are the agreed environmental values and long-term goals for NSW's surface waters. They set out:

- *the community's values and uses for our rivers, creeks, estuaries and lakes (i.e. healthy aquatic life, water suitable for recreational activities like swimming and boating, and drinking water); and*
- *a range of water quality indicators to help us assess whether the current condition of our waterways supports those values and uses.*

Water Quality Objectives have been agreed for Fresh and Estuarine surface waters (follow the catchment links above) and Marine Water Quality Objectives.

The Objectives are consistent with the agreed national framework for assessing water quality set out in the ANZECC 2000 Guidelines. These guidelines provide an agreed framework to assess water quality in terms of whether the water is suitable for a range of environmental values (including human uses). The Water Quality Objectives provide environmental values for NSW waters and the ANZECC 2000 Guidelines provide the technical guidance to assess the water quality needed to protect those values.

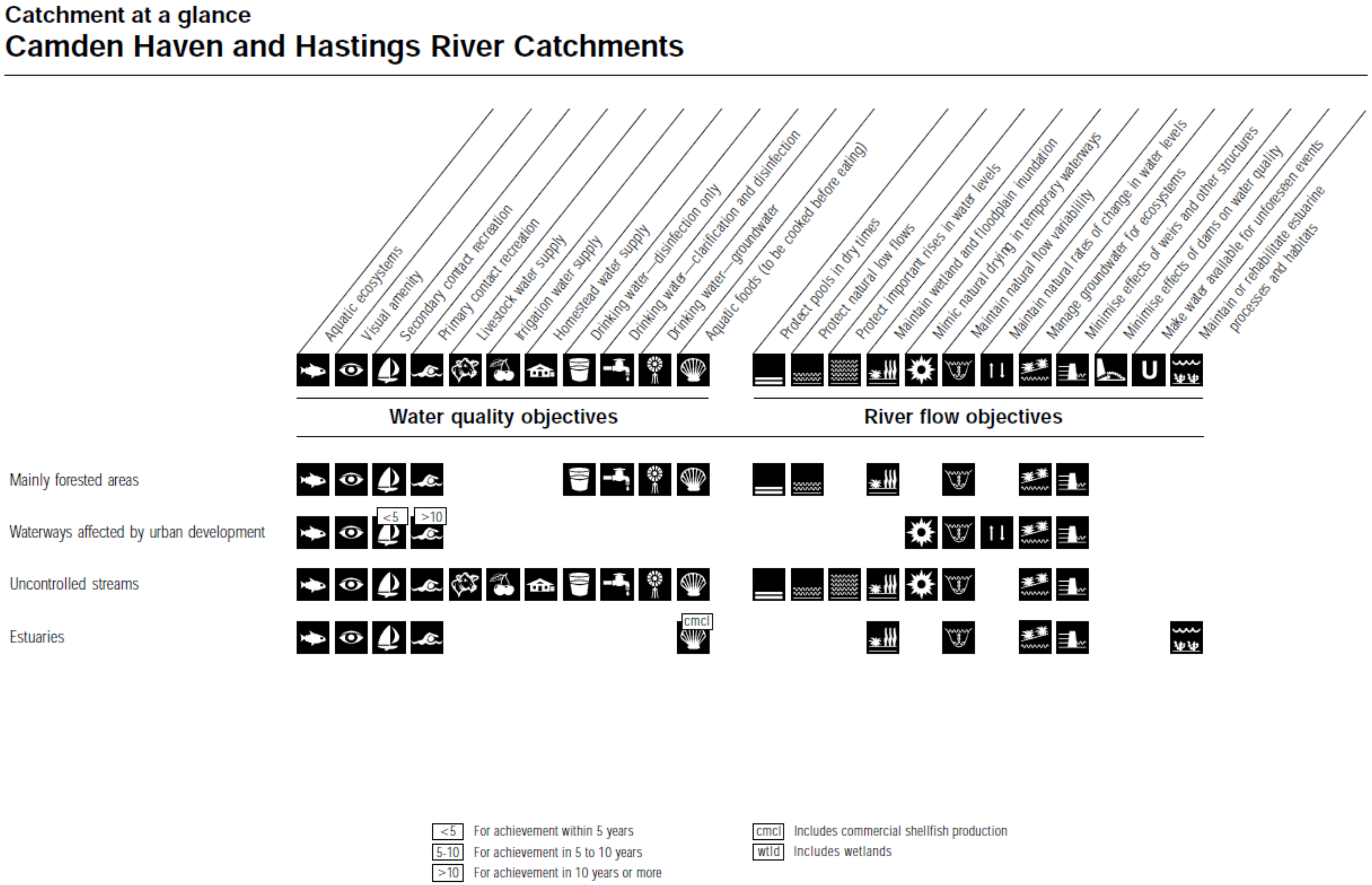
The River Flow Objectives are the agreed high-level goals for surface water flow management. They identify the key elements of the flow regime that protect river health and water quality for ecosystems and human uses.

Based on the review of the catchment mapping available at the website (https://www.environment.nsw.gov.au/ieo/) the Amended Proposal Site falls within the Camden Haven and Hastings River Catchment. The receiving waters are mainly forested areas and nature reserves and the estuarine reaches of the Hasting River.

Based on the location of the Amended Proposal Site and the WQO requiring consideration are presented in Figure 4-1 and include the following:

- Aquatic Ecosystems
- Visual amenity
- Secondary contact recreation
- Primary contact recreation
- Drinking water disinfection only (forested areas only)
- Drinking Water - Clarification and disinfection (forested areas only)
- Drinking Water - Groundwater (forested areas only)
- Aquatic foods to be cooked before eating.

Figure 4-1 Summary of WQO for Camden Haven and Hasting Catchment



4.2 Assessment of NSW WQO applicability

An assessment of the appropriateness of the WQO should be made to ensure trigger values are not overly conservative or under protective. For example, the drinking water objectives may not be suitable for areas outside of drinking water catchments, areas with commercial land-uses and ephemeral streams with low yields. Table 4-1 below presents a site-specific assessment of the WQO.

Table 4-1 Assessment of appropriateness of WQOs

WQO	Assessment	Suitability for Proposed Site
Aquatic Ecosystems and Visual Amenity	Receiving waters of both the forested streams and estuaries are considered aquatic ecosystems. Note that the upland reaches of Rawdon and Tommy Owers Creek are freshwater ephemeral creeks and have differing objectives to the Estuaries of the Hasting River.	Appropriate.
Primary and Secondary contact recreation	Receiving waters of Rawdon and Tommy Owers Creek are ephemeral in nature and therefore primary and secondary recreational contact is not considered an appropriate WQO in the upland forested areas. The estuaries of the Hasting River may be used for both primary and secondary contact – recreation.	Inappropriate for the upland reaches of Rawdon and Tommy Owers Creek. Appropriate for the Hasting River estuaries.
Drinking water: • Disinfection only • Clarification and disinfection; • Groundwater	Receiving waters of Rawdon and Tommy Owers Creek are ephemeral in nature. They are not located within a drinking water catchment, have only limited yield and are effected by the activities within the state forest hardwood plantation located between the site and the Hasting River. Furthermore, drinking water within the catchment is likely to be harvested from rainwater tanks. A search of private water bores within 3 km radius from the Landfill Site was undertaken using the Groundwater explorer (DPI Water and BOM database, 2015). The search yielded ten bores. The bores are installed to depths ranging from 23 to 67 m and their purpose is mainly water supply, with one bore installed for stock and domestic purpose. The DPI Water database does not specify the purpose of those bores, however based on the salinity levels, the water is not suitable for drinking purposes. Due to salinity levels the estuarine receiving waters are not considered suitable for drinking water.	Inappropriate for both the forested upland reaches of Rawdon and Tommy Owers Creek and the estuaries of the Hasting River.

WQO	Assessment	Suitability for Proposed Site
Aquatic foods, to be cooked before eating.	Receiving waters of Rawdon and Tommy Owers Creek are ephemeral in nature it is unlikely that edible aquatic foods would be harvested within the ephemeral creeks. The estuarine receiving waters of the Hasting River are likely to contain aquatic foods that may be cooked before eaten.	Appropriate.

4.3 Selection of Site Trigger Values

Both site surface water and groundwater should meet the default *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC and ARMCANZ, 2000) (ANZECC Guideline) values for 95 per cent protection of freshwater species (ANZECC limits) trigger values prior to discharge from the Amended Proposal Site. These are deemed to be appropriate given they will be protective of the moderately disturbed receiving waters and the site specific WQO.

ANZECC Guidelines recommend the use of site specific water quality trigger values. They recommend site specific values are formulated based on the 80th percentile of the site-specific monitoring data and compared to an up-gradient (un-effected) reference site. In the absence of a data-set that provides this information the 95 percentile freshwater species default trigger values have been adopted. In regards to the existing data set the following is noted:

- The baseline groundwater assessment completed as part of the 1999 EIS was only completed over one sampling event
- A baseline data-set of two years or more does not exist for either surface water or groundwater at the site prior to the Stage E cell being constructed. Therefore it is not possible to determine baseline conditions or accumulative effects from the Stage E landfill cell.
- The Amended Proposal Site is located at the top of a catchment and therefore there is no practical manner to collect a site specific surface water reference sample.

PMHC will undertake monitoring of surface water and groundwater prior to discharge (refer Section 5). Inclusion of additional sampling sites within the monitoring network will allow site specific values to be developed. In the interim both surface and groundwater waters will need to be assessed against the ANZECC (2000) guidelines for 95 per cent protection of freshwater ecosystems prior to discharge offsite. If determined to be within the trigger values, surface water and groundwater can safely be discharged from the site.

5 MANAGEMENT PRACTICES

This section details proposed and additional management measures for the management of surface water and groundwater. These measures will supplement the existing Leachate Management Strategy detailed in Section 5.6 of the EIS (2017) and recommendations within the Pacific Environment *Cairncross Landfill Leachate Generation Modelling* report dated August 2016.

5.1 Proposed Surface Water and Leachate Management

This document does not propose any changes to the management of surface waters than that detailed within the EIS (2017). A summary of the measures is provided below.

The proposed leachate collection and management system consists of gravel collection systems above the landfill liner that gravity feeds to sumps which are pumped into above ground bunded tanks and then piped to the sewerage treatment plant (STP) for treatment and disposal. The STP has been designed by PMHC Water and Sewer division and will be capable of accommodating the leachate characteristics of the landfill and estimated flow rates.

The proposed leachate collection system described above is essentially a closed loop system. It will collect leachate from the base of the landfill and convey it within a dedicated piping network through a storage and treatment system. The storage system has been sized to accommodate up to two days at the maximum predicted inflow rate. In addition, the STP has primary holding tanks that can accommodate additional leachate storage if required.

The existing leachate management system for Stage E of the landfill consists of a recirculation system that is manually pumped into a liquid waste truck and disposed of offsite as required. Once the additional leachate holdings tanks are constructed and connection with the local STP is setup then the leachate collection system of Stage E will also be connected to the STP. This is an improvement to the existing system and will prevent overflow of sumps and potential loss of leachate through manual truck transfers.

The proposed leachate collection layer within the landfill and the direct piping of the leachate to the nearby STP is considered to be best practice. In relation to the leachate collected via surface run-off during operation of the landfill good civil work management practices and house-keeping can prevent the cross contamination of clean surface waters from leachate, these should include:

- Diversion of all overland clean water around and away from the waste storage and tipping areas;
- Enclosure of all stockpiled wastes and waste sorting operations as much as practical to reduce the volume of leachate collected;
- Continual site contouring to ensure all overland leachate from the tipping face is collected within the leachate sumps. This may require the construction of temporary bunds, diversion walls and dams within the landfill cell;
- Marking and labelling of all permanent and temporary dams to prevent any inadvertent discharges;
- Maintenance of sufficient freeboard in all permanent and temporary surface leachate dams. All dams should have sediment and freeboard markers (stakes) clearly displaying the dam capacity to be maintained at all times;
- Ground truthing to confirm surface water dams are not receiving any run-off from waste storage areas;

- Implementation of surface water, groundwater and hydraulic trap (groundwater capture) monitoring program to confirm the effectiveness of the management strategies. Monitoring of the hydraulic trap within the sampling regime would allow it to be used as a potential early warning of the liner breach.

5.2 Proposed Groundwater Management

Groundwater ingress and hydro-static uplift will be managed through implementation of a base groundwater collection system as detailed within the Arcadis *Groundwater Collection System – Cairncross Landfill Conceptual Design* dated September 2018 (Appendix D of the RtS). The requirement for such a system was determined based on the potential maximum groundwater level being recorded above the proposed base of the landfill. The Hydrogeological Assessment is provided as Appendix F of the EIS (2017).

The management protocols employed to prevent unsuitable groundwater being discharged from site include:

- Collection of groundwater within sumps that will be tested and compared against the trigger values
- Groundwater that meets the trigger values protective of the receiving environments will be discharged as surface discharge into the catchment.
- Groundwater that is not suitable for discharge will be used onsite for dust suppression or piped to the STP prior to disposal offsite.

5.3 Water Management Plan

A detailed Water Management Plan will be developed to cover both construction and operation of the Amended Proposal, including:

- A surface and groundwater monitoring program will be developed in accordance with requirements outlined in the Concept Design Report (Appendix B of the EIS), the Hydrogeological Assessment (Appendix F of the EIS) and the Guidelines. The monitoring program will include:
  - Surface water and groundwater monitoring locations
  - Frequency of monitoring to be undertaken
- Measures to manage erosion and sediment control, in accordance with the Blue Book, including:
  - Installation of erosion and sediment controls prior to construction commencing
  - Separation of clean and dirty water
  - Minimisation of ground disturbance and areas of exposed soils, where possible
  - Stabilisation and revegetation of exposed soils as soon as practicable
  - Avoidance/minimisation of clearing and earthworks during periods of heavy rain
  - Measures to reduce the velocity and erodibility of surface water flows across the site
  - Measures for management of stockpiles and sediment basins
- Measures to manage impact to, and discharge of, surface water, including:
  - Surface water discharge should meet the default ANZECC trigger values for 95% protection of freshwater species, prior to discharge form the Amended Proposal site.

  - Management measures for the treatment of water that doesn't meet the ANZECC guideline values. Such measures may include onsite use for dust suppression, or active treatment (via pipe) at the STP, prior to offsite disposal.
  - Contingency measures in the event of contamination detected in surface water
- Measures to manage impacts to, and discharge quality of, groundwater, including:
  - Measures for management of groundwater flows and discharge locations
  - Groundwater discharge water quality trigger values and management measures for water not suitable for discharge
  - Contingency measures in event of contamination detected in groundwater.

6 REFERENCES

NSW EPA (2016) ***Environmental Guidelines: Solid Waste Landfills*** Environmental Protection Authority, Chatswood

Trace Environmental ***Hydrogeological Assessment Cairncross Landfill Expansion***. 11 October 2016.

Arcadis ***Cairncross Landfill Expansion Environmental Impact Statement*** 11 November 2017.

ERM ***Environmental Impact Statement***. 1999. Note: The EIS was developed by ERM to support the development application, and subsequent approval, for the first stage of the Cairncross landfill.

Ryder, D., Mika, S., Vincent, B. and Schmidt, J. (2017). ***Hastings – Camden Haven Ecohealth Project 2015: Assessment of River and Estuarine Condition. Final Technical Report.*** University of New England, Armidale.

APPENDIX A

EIS Baseline Surface Water Data

Summary of Baseline Surface Water Monitoring data, Initial EIS (1999)

				Marine				Freshwater			Marine Sites				Freshwater Sites			
	Unit	ANZECC 95% Freshwater	Date	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	Site 7	Average	Min	Max	Median	Average	Min	Max	Median
pH	pH units		11/2/1998	7.42	7.59	7.44	7.38	6.32	5.68	5.14								
			19/5/98	7.1	7.07	6.94	6.93	6.83	5.67	5.4	7.4	6.9	8.0	7.4	6.5	5.1	8.3	6.3
			1/9/1998	7.84	7.67	7.95	7.64	7.85	8.32	7.54								
Electrical conductivitiy	uS/cm		11/2/1998	34,000	15,870	10,120	11,390	33.2	57.3	57.7								
			19/5/98	27,500	22,600	22,800	17,860	94.4	69.5	93.1	22720.0	10120.0	35500.0	23050.0	122.7	33.2	253.0	93.1
			1/9/1998	35,500	23,300	25,000	26,700	253	216	230								
Turbidity	N.T.U		11/2/1998	-	-	-	-	-	-	-								
			19/5/98	-	-	-	-	-	-	-	6.3	2.4	13.7	4.6	40.0	12.1	54.0	53.9
			1/9/1998	2.4	13.7	5.1	4.1	54	12.1	53.9								
Temp	0C		11/2/1998	-	-	-	-	-	-	-								
			19/5/98	-	-	-	-	-	-	-	18.0	16.8	19.5	17.8	13.3	12.3	13.8	13.8
			1/9/1998	19.46	17.84	17.82	16.81	13.79	12.33	13.84								
Salinity	ppt		11/2/1998	-	-	-	-	-	-	-								
			19/5/98	-	-	-	-	-	-	-	17.0	14.0	22.4	15.8	0.3	0.2	0.3	0.3
			1/9/1998	22.38	14.04	15.17	16.33	0.3	0.15	0.3								
ORP	mV		11/2/1998	-	-	-	-	-	-	-								
			19/5/98	-	-	-	-	-	-	-	125.3	58.0	176.0	133.5	203.7	172.0	225.0	214.0
			1/9/1998	176	151	116	58	225	172	214								
TDS	mg/L		11/2/1998	26,500	11,500	6,900	8,240	212	164	152								
			19/5/98	20,600	17,900	17,400	13,300	3,350	342	350	12844.2	4260.0	26500.0	12400.0	561.1	108.0	3350.0	198.0
			1/9/1998	13,300	6,560	7,670	4,260	108	198	174								
TSS	mg/L		11/2/1998	114	70	66	60	74	40	28								
			19/5/98	92	74	90	68	60	58	100	66.8	35.0	114.0	67.0	47.6	15.0	100.0	40.0
			1/9/1998	45	43	45	35	15	15	38								
Calcium	mg/L		11/2/1998	269	118	73	83	nd	1	nd								
			19/5/98	212	174	184	142	3	1	1	133.1	49.0	269.0	128.5	2.0	1.0	3.0	2.0
			1/9/1998	139	71	83	49	3	3	2								
Magnesium	mg/L		11/2/1998	809	358	212	239	nd	1	1								
			19/5/98	656	550	567	438	3	1	2	404.4	142.0	809.0	390.0	2.4	1.0	4.0	2.5
			1/9/1998	422	213	247	142	4	3	4								
Sodium	mg/L		11/2/1998	7,800	3,480	2,120	2,320	12	14	12								
			19/5/98	5,390	4,320	4,420	3,530	14	12	15	3557.5	1290.0	7800.0	3505.0	15.7	12.0	22.0	14.0
			1/9/1998	3,970	1,790	2,260	1,290	22	20	20								
Potassium	mg/L		11/2/1998	298	133	92	95	2	2	2								
			19/5/98	198	160	175	138	1	nd	nd	136.0	50.0	298.0	135.5	1.9	1.0	4.0	2.0
			1/9/1998	138	72	83	50	4	1	1								
Alkalinity (CaCO3)	mg/L		11/2/1998	90	51	32	42	6	3	3								
			19/5/98	73	73	64	52	17	3	7	58.1	32.0	90.0	53.0	7.4	3.0	17.0	6.0
			1/9/1998	80	47	54	39	nd	13	nd								
Sulphate	mg/L		11/2/1998	1,830	794	468	530	3	3	5								
			19/5/98	1,390,983	1,100	1,200	928	3	4	8	116600.9	6.0	1390983.0	678.5	4.3	3.0	8.0	3.5
			1/9/1998	485	563	324	6	3	5									
Chloride	mg/L		11/2/1998	13,500	6,090	3,780	4,140	15	18	17								
			19/5/98	9,590	7,920	8,170	6,480	18	17	23	6346.7	2290.0	13500.0	6285.0	25.3	15.0	46.0	18.0
			1/9/1998	7,020	3,140	4,040	2,290	46	33	41								
Iron	mg/L	0.3	11/2/1998	nd	nd	nd	nd	0.9	0.6	0.6								
			19/5/98	0.2	nd	nd	nd	3.4	0.9	0.8	0.5	0.2	0.7	0.5	1.0	0.5	3.4	0.8
			1/9/1998	nd	0.6	0.3	0.7	0.9	0.5	0.7								
Manganese	mg/L	1.7	11/2/1998	0.061	0.081	0.074	0.072	0.057	0.045	0.024								
			19/5/98	-	-	-	-	-	-	-	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.03
			1/9/1998	0.051	0.104	0.113	0.096	0.021	0.027	0.042								
Fluoride	mg/L		11/2/1998	1	0.4	0.3	0.3	nd	nd	nd								
			19/5/98	0.5	0.5	0.5	0.4	0.1	nd	nd	0.4	0.2	1.0	0.4	0.1	0.1	0.1	0.1
			1/9/1998	0.5	0.3	0.3	0.2	nd	nd	nd								
Ammonia as N	mg/L	0.9	11/2/1998	0.07	0.04	0.05	0.02	0.01	nd	nd								
			19/5/98	0.07	0.04	0.05	0.03	0.03	nd	nd	0.05	0.02	0.1	0.04	0.02	0.01	0.03	0.02
			1/9/1998	nd	nd	nd	0.04	nd	nd	nd								
Nitrate as N	mg/L	0.7	11/2/1998	0.04	0.03	0.05	0.03	0.07	0.08	0.07								
			19/5/98	0.26	0.06	0.08	0.05	0.05	0.14	0.04	0.1	0.03	0.3	0.1	0.1	0.02	0.1	0.1
			1/9/1998	0.11	nd	0.08	0.1	0.02	nd	0.04								
TOC	mg/L		11/2/1998	6	13	16	9	19	33	29								
			19/5/98	9	11	8	12	29	35	26	15.1	6.0	34.0	12.5	29.2	19.0	40.0	29.0
			1/9/1998	21	21	21	34	31	40	21								
BOD	mg/L		11/2/1998	14	15	15	16	17	17	18								
			19/5/98	4	2	nd	4	4	6	8	8.0	2.0	16.0	6.0	8.9	2.0	18.0	6.0
			1/9/1998	2	6	4	6	4	4	2								
Phenols	mg/L	0.32	11/2/1998	nd	nd	nd	nd	nd	nd	nd								
			19/5/98	1	2.4	3.6	1.2	3	nd	nd	2.0	1.0	3.6	1.6	3.0	3.0	3.0	3.0
			1/9/1998	nd	nd	nd	1.6	nd	nd	nd								
Absorbable Organic Halog	ug/L		11/2/1998	140	87	120	90	68	115	110								
			19/5/98	72	69	56	88	71	91	102	126.3	56.0	240.0	105.0	121.4	68.0	197.0	110.0
			1/9/1998	220	168	165	240	171	197	168								